PRACTICAL STEAM AND HOT WATER HEATING AND VENTILATION

ALFRED G. KING

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A MODERN PRACTICAL WORK ON
STEAM AND HOT WATER HEATING AND VENTILATION,
WITH DESCRIPTIONS AND DATA OF ALL MATERIALS
AND APPLIANCES USED IN THE CONSTRUCTION
OF SUCH APPARATUS; RULES, TABLES, ETC.

BY

ALFRED G. KING

AUTHOR OF "PRACTICAL HEATING ILLUSTRATED," ETC.

SECOND EDITION, REVISED

*CONTAINING OVER THREE HUNDRED SPECIALLY MADE ILLUSTRATIONS
SHOWING IN DETAIL ALL OF THE VARIOUS HEATING SYSTEMS,
WITH PIPE, RADIATOR AND BOILER CONNECTIONS*

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PREFACE

From a more or less experimental stage to one of an exact science has been the progress of the art of artificial heating and ventilation during the period covering the past twenty-five or thirty years. In the early days of this industry there were but few competent fitters located outside of the larger cities. However, of later years the above conditions have changed, due in a great measure to the constant advancement and education of the steam fitting trade. To-day it is not an uncommon thing to find in a small city or town one or more steam fitters entirely competent to install almost any kind of a steam or hot-water heating apparatus.

This education of the steam fitter has been accomplished largely by the frequent publication in the trade papers of much practical information, accompanied by drawings and data which could be readily understood by him.

The publication of a number of books on the subject of Steam and Hot-Water Heating and Ventilation has also been of great assistance to the steam fitter in his mental advancement. However, much of the matter contained in these books is too technical and of a nature too difficult to be clearly understood by a man of average education.

In presenting this work the author wishes to give a brief history of the science of steam and hot-water heating and ventilation and the early methods of constructing work, and to describe and illustrate the advancement and improvements over the earlier methods. By the illustrations, rules and explanations given, we shall aim to make plain to the steam fitter or apprentice the best methods of estimating and installing heating work by any one of the modern methods or systems now in use.

To keep pace with the means and methods employed we must be continually studying and actively interesting ourselves in the improvements as they are brought out. The methods of a score of years ago have given place to other and improved methods and further experimenting and study by the wide-awake American mechanics are bound to result in still further progress.

To those authors and authorities from whose works we have quoted and to the manufacturers of heating appliances who have so kindly assisted us, we extend our thanks.

Our effort is not to criticise but rather to comment upon the various heating and ventilating systems in vogue at the present time and to instruct the steam fitter in a practical way regarding their application and installation.

We have also added such tables, rules and general information as will make this valuable as a reference book for the contracting steam fitter.

A. G. King.

October, 1912.

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PRACTICAL HEATING AND VENTILATION

CHAPTER I

Introduction

It is well in beginning the study and consideration of the science of heating and ventilation to look back to the start of what has grown to be one of our most important industries.

We may properly term it Domestic Engineering, as on the work of the heating and ventilating engineer depends largely the health, and consequently the happiness, of the great body of civilized people of the world.

There is no doubt that the use of hot water for heating purposes antedates the use of steam. We have a more or less obscure record of the use of hot water in this respect by the Romans. In the beginning of the eighteenth century we have records of greenhouses (at that time called "hothouses") being successfully heated by hot water and later in the same century, about the year 1775, we find a Frenchman, Bonnemain, using hot water to heat a brooder on a chicken farm. This may be said to be the beginning of the practical application of hot water for heating purposes.

Steam was probably first used for heating purposes in the early part of the nineteenth century, when efforts were made to heat a factory by steam at a high pressure. The development of steam heating from that date to the present time has been both rapid and constant, although the last decade has seen this industry advanced to a state of perfection never dreamed of by the early heating engineers. From a loose and haphazard method of figuring and installing work of this character, it has reached a scientific stage, and as such is more or less understood by a large majority of those engaged in the business.

Heating and Ventilation are kindred trades and sciences, each, in a measure, dependent on the other. The early effort to ventilate the British House of Commons, in 1723, was probably the real beginning of artificial ventilation.

Dr. J. F. Desaguliers, a French boy, whose father removed to England when Desaguliers was but an infant, was, without doubt, the most distinguished student of physics and mechanics of that time. To him was intrusted the problem of ventilating the House of Commons. Previous to this date, however, other plans had been tried to provide a means of ventilation, but we believe the first scientific study and experiments were conducted by Dr. Desaguliers.

Efforts were put forth during the early part of the nineteenth century to improve on this ventilating apparatus by the providing of large fans or blowers, which were propelled by hand. The ventilation of other public buildings was then undertaken and the science had advanced to such a stage that in the year 1824 an English engineer, Tredgold by name, published a book entitled "Principles of Warming and Ventilating Public Buildings"—a standard work still referred to at this date.

While the history of the sciences of heating and ventilation and the endeavors of many engineers of eminence may be both interesting as well as instructive, we refer only to the beginning in order that our readers may realize, to the fullest extent, the evolution of the methods of heating by steam and hot water and ventilating by natural or mechanical means.

To such men as Tredgold, Dr. Reid, Charles Hood, E. Péclet, Robert Briggs and others of earlier date, and Mills, Billings, Baldwin, Carpenter and other engineers of these latter times, are we indebted for the advancement and perfecting of the various methods of estimating and constructing the warming and ventilating systems of to-day.

The remainder of the credit is justly due to those who manufacture and install the work and who have, by the use of modern machinery and up-to-date ideas, reduced the cost of steam and hot-water warming and ventilating apparatus to such an extent as to place it within the reach of those in moderate circumstances.

Our public schools are better warmed and ventilated than ever before, as are also the majority of our other public and semi-public buildings. Our architects now study and consider the subject of heating and ventilation and we firmly believe that the coming decade will witness far greater advancement in these sciences than we have known before.

An estimate made in the year 1906 shows that but a little over one tenth of our homes and public buildings are provided with steam or hot-water heating apparatus. Such an estimate further reveals the fact that less than two per cent of our homes are provided with even a partial ventilating apparatus.

As a nation we seem to have been satisfied to roast one side of our body while the other side was chilled, or, when fresh air was absolutely needed in the room, to open the door or window, regardless of the outside temperature or the condition of the weather. These sudden changes, of course, produced colds and bodily ills of like nature, which, no doubt, in many cases, proved fatal. We knew of no uniformity in either the temperature of the house or the purity of the atmosphere in the several rooms.

Becoming aware of our mistakes of the past, we now demand a uniform temperature within our homes; we are swiftly coming to the conclusion that we might better pay the coal dealer for the energy to produce heat, ventilation and comfort than to pay our physician for doctoring the ills resulting from our carelessness.

It will be readily noted what a tremendous field there is for study and work along these lines, and to the journeyman steam fitter or contractor who fits himself thoroughly for this work, we see an abundant reward in store.

CHAPTER II

Heat

HEAT is motion, or a form of energy. Scientists tell us that it is their belief that all matter is made up of small vibrating particles called molecules. The faster these particles move or vibrate, the more heat is produced, and the more the matter or body is expanded. This expansion may be carried to such an extent as to transform the body into another state. For example, note the formation of gas from coal or oil, or the formation of steam from water.

With a hammer we may pound upon a piece of iron until it becomes hot. The Indians started a fire by briskly rubbing together two pieces of wood, the energy of motion producing the necessary heat to ignite the dry moss, or other material used for kindling.

The nature of heat is peculiar and it is well that we become somewhat acquainted with these peculiarities.

Heat cannot be measured as to quantity, but the intensity of heat may be measured by a thermometer, and this measure we call temperature, and for registering this temperature we use the Fahrenheit scale. For example, water freezes at 32° F. and boils at 212° F. (Fahrenheit was a German, who in 1721 made the first mercurial thermometer.)

Heat may be transferred from one body to another by three distinct methods, namely, Conduction, Convection and Radiation. Lay a piece of hot iron upon another piece of iron, or a different object, and a certain proportion of the heat from the heated iron is transferred to the under object. This method is by Conduction.

Water which has been heated and transferred to a storage tank through pipes makes the tank hot. This is heating by Convection.

We may place a chair too near a heated stove and burn or blister the paint or finish upon same. The chair has not been against the stove, neither has there been any direct connection between it and the heat producer, yet it has received the heat from the stove to such an intensity as to damage it. This damage was caused by radiation of heat, the heat being carried to the chair upon waves of air usually imperceptible to the eye.

It is this latter method of heat transfer which is employed in the warming of buildings. The energy is developed at a boiler, or heater, placed usually in the basement of the building, the heat being transferred to the radiators, or radiating surfaces placed within or adjacent to the room to be heated and the heat again transferred to the room by radiation.

While we cannot properly measure heat itself, we may measure it by the effect it produces, and this is accomplished by the so-called Heat Unit. The Heat Unit as adopted for engineering and scientific purposes is of three measures: viz., British, French and German. In this country it is the former that has come into general use.

A British Thermal Heat Unit (B. T. U.) is the amount of heat required to raise the temperature of a pound of water one degree Fahrenheit, or one degree on the Fahrenheit scale of measuring. The British system of measuring heating work, or the effect produced by the action of heat, is by what is known as foot pounds. Professor Allen's definition of this term foot pounds is as simple as we have come across. He says: "Ten units of work or ten foot pounds would be the amount of work done in raising ten pounds one foot high, or one pound ten feet high." Professor Allen thus calls our attention to the definite relationship between heat and work, which was probably first determined by Joule in 1838 while conducting a series of experiments.

In measuring work the term horse power (H. P.) is frequently made use of. A horse power is 33,000 foot pounds per minute, or the amount of work required to raise 33,000 pounds one foot high per minute, and this is equivalent to 42.5 heat units per minute.

As in this country the capacity of all engines and machinery, and all tubular and power boilers, is expressed by horse power, it is well to remember that a horse power represents the energy developed by evaporating 2.655 pounds of water into steam, and which is sufficient to supply 100 square feet of radiation. Furthermore, a horse power represents the condensation from 100 square feet of direct cast-iron radiation, or approximately 90 square feet of pipe radiation or heating coils.

The steam is condensed by loss of heat or cooling, and we must know in what manner certain elements act upon the heating surface to cool it, and again in what manner the heat is given off from the radiator or heated body.

All building material is porous and there is a loss of heat through walls and window glass. Again, a ventilating register may be open in the room. There is a constant loss of heat through this aperture until such time as it is closed. Therefore, to determine upon the amount of heat necessary we must take into consideration all heat losses and this we shall discuss later on in this work.

Heat is radiated in straight lines or in waves from a heated body. If certain objects are placed in the line of these waves they will absorb the heat and transmit it again to some cooler body. On the contrary, such substances as magnesia, asbestos, hair felt, and the like, will prevent the radiation of the heat beyond their influence. For example, note the plastic covering on boilers, or the asbestos and hair-felt coverings placed on steam and hot-water pipes. Air and other gases are almost transparent to heat and, in fact, in many cases assist in conveying it from the source of energy to the body to be warmed.

The radiating power of bodies differs materially. Polished or enameled surfaces radiate less heat than rough or unfinished surfaces. Péclet gives the following table of the radiating power of bodies, the figures equaling heat units given off from a square foot of surface per hour for a difference of one degree Fahrenheit:

TABLE NO. I

Radiating Power of Bodies

Polished Copper	.0327
Sheet Iron	.0920
Glass	.5940
Cast Iron (rusted)	.6480
Stone, Wood or Brick	.7358
Woolen Material	.7522
Water	1.0850

A cast-iron radiator will radiate much less heat when enameled than when painted with bronze or a mineral paint.

Specific heat is the amount of heat necessary to raise the temperature of a solid or liquid body a certain number of degrees, taking water as a unit or standard of comparison.

Some bodies absorb heat more rapidly than others. According to Walter Jones, M.E., the heat necessary to raise one pound of water one degree will raise

	32	lbs. of Lead	one degree.
	31	lbs. of Mercury	
	9	lbs. of Iron	
	4½	lbs. of Air	
or	2	lbs. of Ice	

For the practical purposes of the steam fitter it is necessary only that he consider:

1. The energy necessary to produce a certain amount of heat, or number of heat units; how produced, and how measured.

2. How these heat units may be transferred, radiated or conducted from one body to another.

3. The effect of this heat upon the cooler body to which it is transferred, or the so-called cooling surfaces of a room or building.

4. The percentage of loss of energy by radiation, or otherwise, between the production of the heat and its delivery to the body to be warmed.

In the discussion of radiation, ventilation, etc., we shall give other peculiarities and facts regarding the loss of heat, the causes leading to the same and rules for providing against the amount of heat loss under varying conditions.

CHAPTER III

Evolution of Artificial Heating Apparatus

THE arrangement of some form or method of securing warmth within our homes or buildings is a matter to which our attention has grown in keeping with our advancement as a nation.

History relates that among the ancient Romans it was customary for the poorer class to build fires upon a stone or brick floor located at one side or end of a room, the smoke and soot passing out of the room through holes in the roof. The wealthier class used braziers in their living rooms, in which was burned carefully dried wood.

The heating apparatus of our forefathers was the open fireplace, and it is related of the old New England type of fireplace that it was six or eight feet in length and so deep that the children had blocks on which they sat far within, where they could see the stars up the chimney. Large logs of wood were used for fuel. Later, after coal could be purchased, the fireplace was built very much smaller.

In either case a very large proportion of the heat thus obtained escaped up the chimney, probably from seventy-five to ninety per cent being lost in this manner.

As the country grew in population, cities and towns sprang up and fuel became scarcer. Larger buildings were erected and the number of rooms increased until, as a matter of economy, it became necessary to provide some other form of heating apparatus.

To this end the old Franklin stove was designed, followed by later styles more improved, all in order to provide better combustion and save the lost heat.

Again was "necessity the mother of invention," as, to save labor of carrying fuel and ashes for many fires, the idea of centralizing the heating apparatus and of warming several rooms from one fire, led to the adoption of the inclosed stove. Tin or sheet-iron pipes were used to convey the heated air to each separate room and from this arrangement developed the modern furnace.

Experiments were next conducted with heated water and steam as means of conveying heat from a central point to various parts of a building, a form of heating which has been carried to such a state of perfection as to warrant the use of either system under almost any known condition, and the establishing of foundries and shops for the manufacture of heating apparatus. The development has been such that at the present time there are many millions of dollars invested in the business of manufacturing and installing apparatus for heating by steam and hot water.

The relative efficiency of the several methods of heating may be given as follows:

1. Open Fireplaces.
2. Stoves.
3. Hot-Air Furnaces.
4. Steam.
5. Hot Water.

In classifying them in this order, we consider not only efficiency, but healthfulness, durability, and cost of maintenance, i. e., cost for fuel.

Were healthfulness alone considered, we should prefer the open fireplace to either stoves or furnaces. The waste of fuel in fireplaces and stoves, largely also in hot-air furnaces, is too well known to need many comments.

Fireplaces radiate the heat from one side of the room only, and stoves warm but in spots.

Furnaces fail to produce the right results when placed in buildings not well protected from the wind; and there is no uniformity in temperature where any one of the three above-mentioned systems are used.

Furnaces as ordinarily installed are not much more satisfactory than stoves, and nine tenths of them are too small. They are used in preference to a steam or hot-water apparatus because of the apparent saving in cost. We say *apparent* saving in cost, as after all things are weighed, *there is no saving* in using a furnace in preference to steam or hot water, and it is well that the steam fitter or heating contractor has this fact clearly in mind. Therefore, we shall discuss this feature of furnace heating very freely and shall consider the matter, endeavoring to show a comparison between the furnace and steam or hot-water heat.

First: As to cost and average life of the apparatus.

Second: As to comfort and healthfulness.

Average Life and Cost

Where a furnace too small is installed, it is necessary, in extreme cold weather, to raise the heating surfaces to an exceedingly high temperature, often a red heat, in order to secure comfort. As a result, the expansion and contraction loosens the joints of the furnace and allows the sulphurous and carbonic-oxide gases and other poisonous products of combustion to escape through the hot-air pipes into the rooms above. This is true of both wrought-iron and cast-iron furnaces.

Again, heating the furnace to this extremely high temperature shortens the life of the apparatus, with the result that ten per cent of the first cost is needed for repairs during the first five years, while, as a rule, the next five years find the furnace entirely worn out.

A steam-heating apparatus has an average life of probably twenty-five years, the first ten years of this period without any repairs except of a trivial nature, such as the repacking of valves, etc.

A hot-water-heating apparatus will last an even greater length of time, without the expense of repairs, the system being practically indestructible. Thus it will be readily seen that while the cost of a furnace, as usually installed, is but one half that of a steam-heating apparatus, or probably two fifths that of a hot-water-heating apparatus, it is, as an investment, not counting healthfulness or the excess amount of fuel consumed, by far the more costly of the three systems.

In pondering the question of cost, we have not taken into consideration the long list of fires and damaged buildings resulting from the "defective flue," nor the damage to house furnishings, due to dust and dirt from the furnace. The housewife, more than anyone else, knows of the constant dusting and cleaning and the frequency with which it is necessary to renew carpets and draperies.

Healthfulness of Furnace Heating *vs.* Steam or Hot Water

We have mentioned some of the disadvantages of heating with a furnace. Let us now consider the healthfulness of the various systems, the quality of the heat produced and its effect on the human system.

A furnace must of necessity have an air supply. The source of this air supply is often very bad. Perhaps the air is admitted to the furnace direct from the basement or cellar in which it is located. This air may be contaminated with the odors from decaying vegetable matter, or gases from a sewer. The air is admitted to the furnace at its base, or from underneath the base, and when a fresh air supply is taken from outside the building, it is frequently conveyed to the furnace through an underground duct which is not air tight, with the result that it gathers impurities from the earth. The duct may run across the basement floor and if not air tight, will, owing to the draught produced by the furnace, suck in the impure air from the basement through the numerous cracks or crevices. With an impure air supply, it is impossible to serve the occupants of the building with pure air. Again, the air is devitalized by passing over metal, heated often to 1,200 or 1,500 degrees Fahr., which robs it of all its health-giving properties.

The advocate of the furnace will endeavor to tell of the pure air which is constantly admitted to the building, and its advantages—an exploded theory, as every heating and ventilating engineer knows.

What then with devitalized air, often charged with dust or poisoned by gases, can we say in favor of the healthfulness of heating with a hot-air furnace? Nothing, except possibly the apparent saving in first cost and the freedom of the house owner from participating in the "semiannual stovepipe performance," viz.—that of taking down or putting up a miscellaneous assortment of stovepipe loaded with soot, as would be the case where stoves were used.

Heating by either steam or hot water has none of the disadvantages mentioned and for this reason, since the large reduction in cost during the last decade, have in their several forms and variations, been generally adopted as the best methods of heating known.

There are many buildings more or less protected from the variable winds of winter, where a furnace *properly installed* will heat *all parts* of the building to a uniformly comfortable temperature. We emphasize " properly installed " and " all parts " for the reason that the average furnace has neither of these conditions to recommend it. As a rule, the contractor setting the furnace places it near to the center of the basement in order to shorten the hot-air supply pipes and thereby simplify or cheapen the work. It is impossible to force the heated air to the side of the building against which the wind is blowing, and for this reason the furnace should be set near to the side which most frequently receives the action of the wind. We think it safe to say that a furnace installed in this manner and built heavy enough to last a considerable term of years, with the tin work of first quality, will cost one third more than the average furnace job as regularly installed, or to within a very small amount of the price of a low-pressure steam-heating apparatus.

The Heart of the System

In a steam or hot-water heating apparatus, the boiler or heater is the real heart of the system and largely upon the character of the boiler or heater installed, depends the success of the apparatus as a whole.

It has become customary to refer to the heart of a steam-heating apparatus as a " boiler," and to the heart of a hot-water-heating apparatus as a " heater," probably from the fact that in a steam-heating apparatus it is necessary to boil the water to make steam, while in a hot-water-heating apparatus it is necessary only to heat or expand the water in the heater to produce a circulation in the system.

Early Types of Boilers

There seems to be no question but that the original type of boiler used for steam heating was the horizontal tubular, or the upright tubular wrought-iron boiler, or the same character of a boiler as was used for power, and very much the same in outward appearance as those in use to-day.

Fig. 1 shows a standard make of tubular boiler, with full-arch front and manner of bricking.

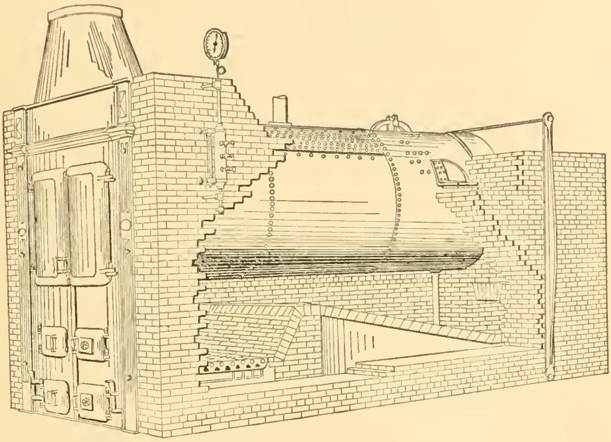

Fig. 1.—Standard type of tubular boiler with full-arch front.

Fig. 2 shows the same character of a boiler, with half-arch front and manner of bricking.

Under "Boiler Setting" will be found explanations and di-

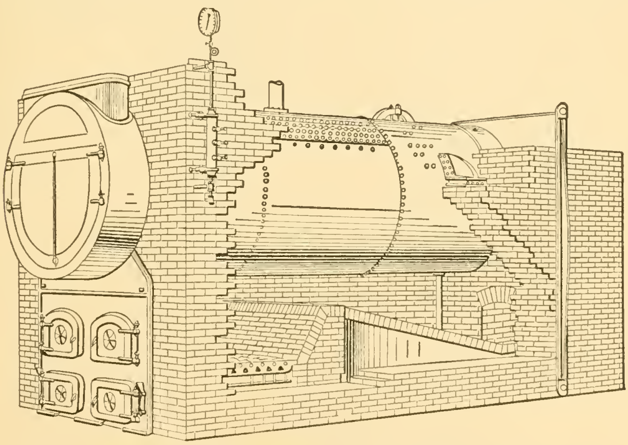

Fig. 2.—Standard type of tubular boiler with half-arch front.

rections for setting each of the above, with sketches showing ground plan, longitudinal section and cross section of brickwork, etc.

The original type of upright tubular was mounted on a brick and iron base, forming the ash pit and supporting the grate. Fig. 3 shows this boiler as it is now commonly used, with a cast-iron portable base and without brickwork.

One of the earliest types of wrought-iron boilers used exclusively for heating purposes was designed and patented by Mr. William B. Dunning, of Geneva, N. Y., and is yet manufactured as the Dunning Boiler in an improved form by the New York Central Iron Works Company.

Fig. 4 shows the shell of this boiler; Fig. 5, the boiler as it appears when bricked.

Another early type and somewhat similar character of a boiler

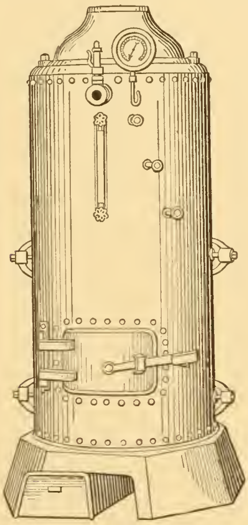

Fig. 3.—Common type of upright tubular boiler.

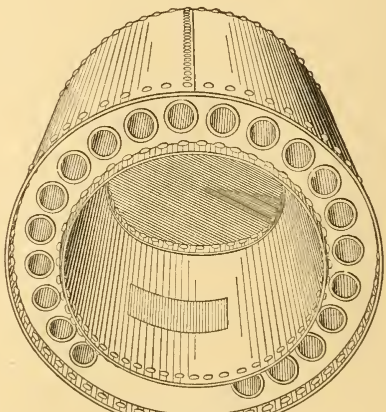

Fig. 4.—Shell of Dunning boiler.

is shown by Fig. 6. This is known as the " Haxtun " boiler, manufactured by the Kewanee Boiler Company, Kewanee, Ill.

Many other boilers of similar construction were built and sold, following the introduction of those illustrated, some of them having a local sale only, being used in the immediate vicinity where they were manufactured.

It is probable that the H. B. Smith Company, of Westfield, Mass., were the pioneers in the manufacture of the cast-iron boiler for steam heating, as the Gold Boiler (see Fig. 7), manufactured by this concern, was undoubtedly the first of the cast-iron steam boilers, and as such should receive more than a passing mention.

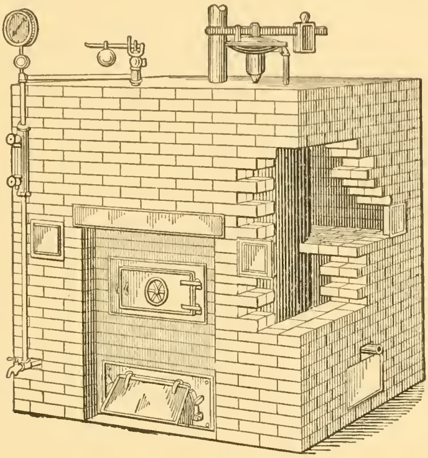

Fig. 5.—Dunning boiler set in brickwork.

Reference to the illustration (Fig. 8) will show the Mills Boiler and the manner in which this boiler is constructed. The

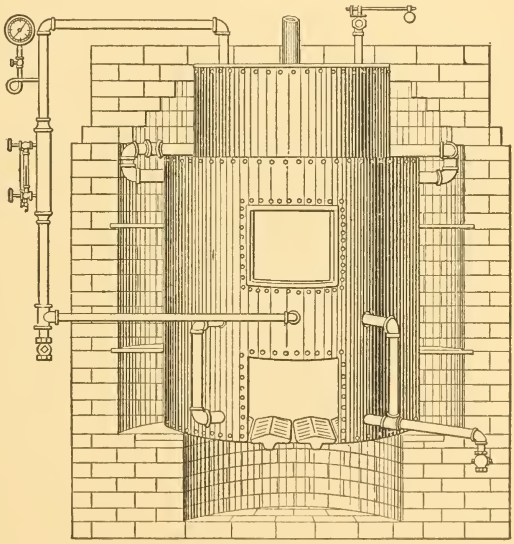

Fig. 6.—The Haxtun boiler.

sections are cast in halves, and on the square or rectangular base supporting the grate, these half sections are erected in pairs. The upper parts of the half sections are joined to a central dome or header, lock-nut nipples being used for this purpose. The upper part of each half section, as well as the header suspended between these half sections, form a steam chamber from which the supply

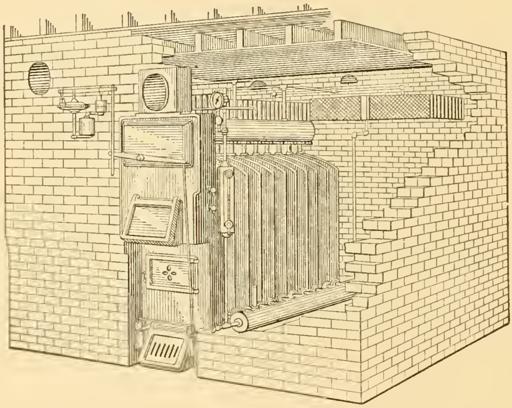

FIG. 7.—The Gold boiler.

pipes are taken. In depth these sections are about six inches, and they may be arranged to form a boiler of practically any size desired.

Along either side of the boiler is a cast-iron header into which

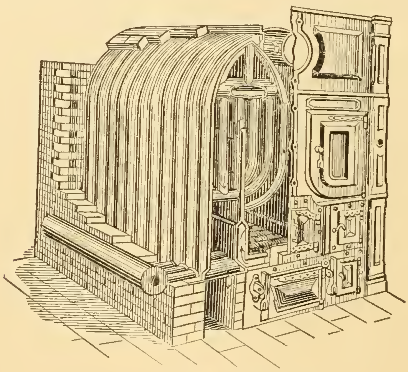

FIG. 8.—The Mills boiler.

the various return pipes are connected, the water being admitted to the boiler through nipples connecting each individual half section with the return header. This connection is made in the same manner as the connections to the steam header with lock-nut nipples. Each half section, therefore, is a unit or boiler by itself, contributing its quota of steam to the steam chamber above.

This proved to be a very strong type of boiler, able to withstand

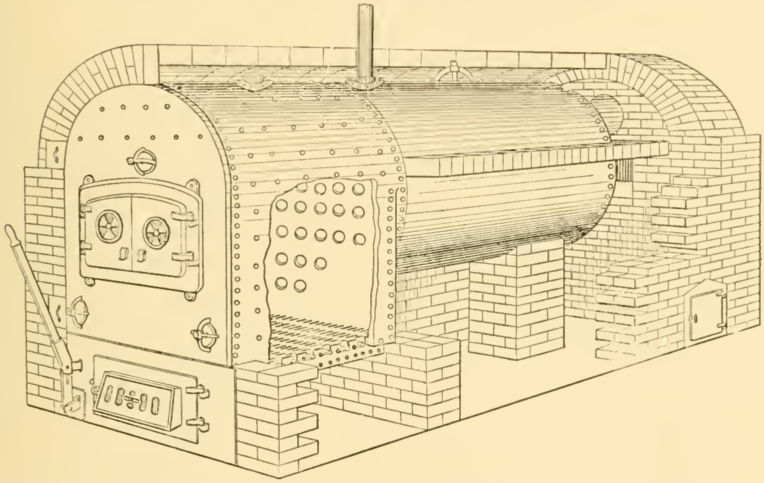

FIG. 9.—Locomotive fire-box boiler.

a considerable pressure and being also a quick and powerful steamer.

It is worthy of note that some of the more modern boilers are

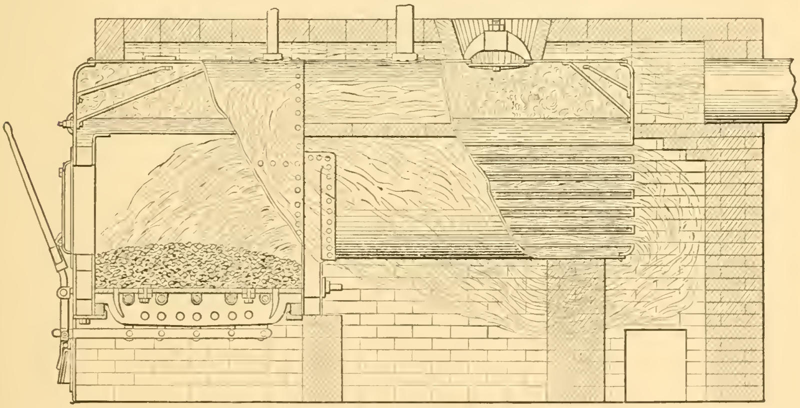

FIG. 10.—Locomotive fire-box boiler showing smoke travel.

built along the lines of the Mills Boiler, without the brick setting. We refer to the "divided-section" or "half-section" idea of boiler construction which we illustrate elsewhere.

Aside from those already mentioned, the most common type of wrought-iron boiler now used for heating is the locomotive fire-box boiler, as illustrated by Fig. 9 and Fig. 10. Fig. 9 shows a view of the boiler as it appears in the bricking, and Fig. 10 shows the smoke travel. In some localities these boilers are used largely

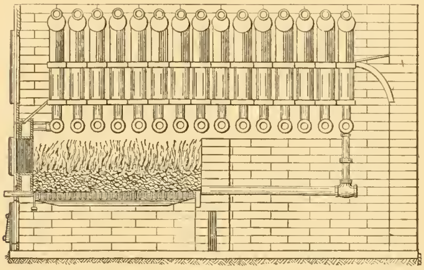

Fig. 11.—Page safety sectional boiler.

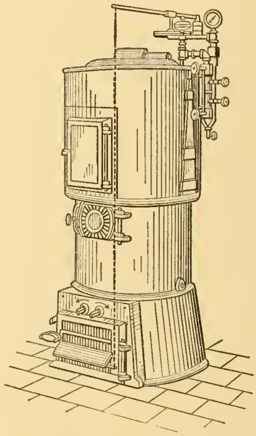

Fig. 13.—Original type of Volunteer boiler.

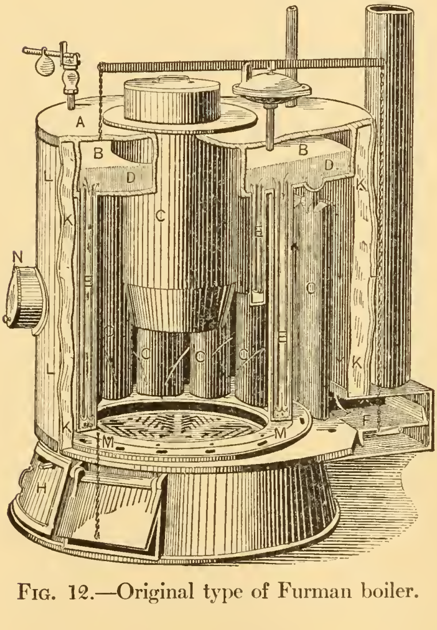

Fig. 12.—Original type of Furman boiler.

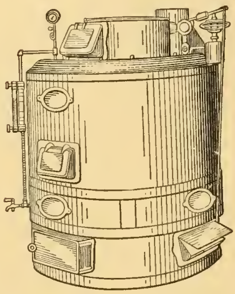

Fig. 14.—The Florida boiler.

in apartment houses and business blocks, and while there is considerable argument as to their longevity and economical qualities, it is an established fact that they are comparatively quick steamers and do the work required of them.

Still another of the early types of sectional brick-set boilers is shown by Fig. 11. It is the Page Safety Sectional Boiler and it also is capable of withstanding a heavy pressure for a cast-iron heater. A few of the earlier designs of heating boilers had maga-

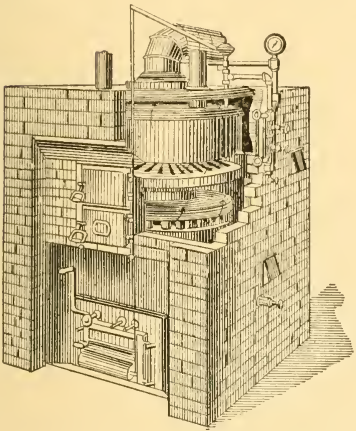

FIG. 15.—The All Right boiler.

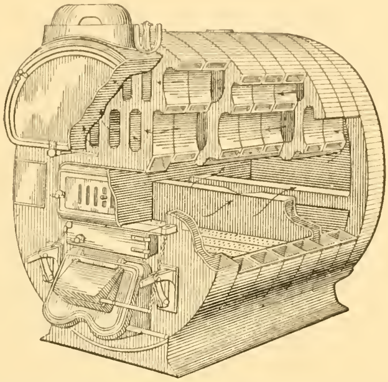

FIG. 16.—The Bundy cast-iron tubular boiler.

zine feeds similar to that of a parlor stove, although at the present time the number of boilers sold so equipped is very small.

The Furman Boiler, Fig. 12, the Volunteer Boiler, Fig. 13, the

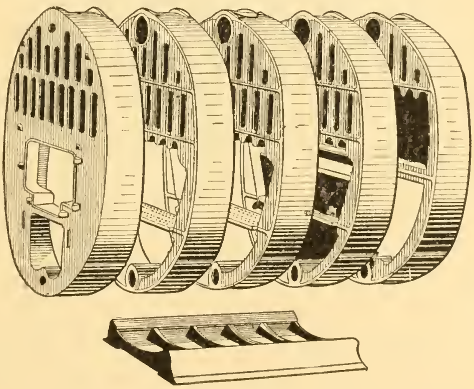

FIG. 17.—Sections of cast-iron tubular boiler.

Florida Boiler, Fig. 14, the All Right, Fig. 15, comprise some of the earlier round and sectional boilers.

Many of the early models of round boilers were cased with a jacket of black or galvanized iron, frequently lined with asbestos.

The latest method of boiler construction, however, dispenses with the brick setting and the sheet-iron casing, the sectional, as well as the round boilers, being portable, and, when covered, are coated to the depth of 1″, or more, with a plastic cement made of a mixture of magnesia and asbestos.

A departure from the regular style of cast-iron sectional boiler is shown by Figs. 16 and 17. It is the Bundy Tubular Boiler

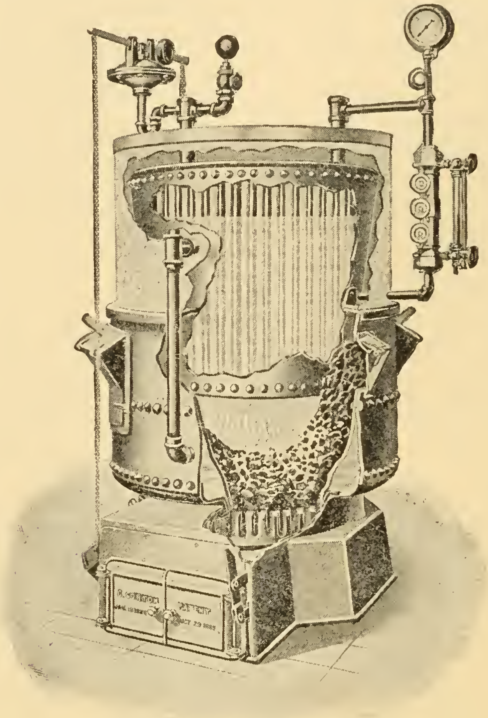

Fig. 18.—The Gorton boiler.

and is on the order of the Scotch Marine type of construction. The Gorton Side-feed Boiler, as shown by Fig. 18, is a peculiar type of wrought-iron boiler construction.

So rapid has been the advancement in methods of boiler construction during the past ten to twenty years that a large number of styles have been and are now being manufactured, approximating probably over one hundred varieties.

Among the round boilers may be found, in addition to those already mentioned, the Doric, Richardson, Boynton, Cambridge, Ideal, Richmond, Orbis, Winchester, Capitol Mascot, Arco and Radiant.

In the list of manufactured sectional boilers we find the Mercer, Richmond, American, Ideal, Thermo, Carton, Sunray, Sunshine,

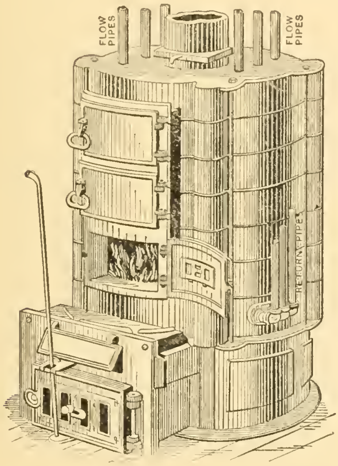

Fig. 19.—Early type of Gurney hot-water heater.

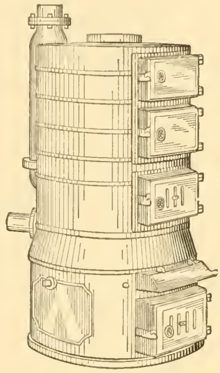
Fig. 20.—The Spence hot-water heater.

Boynton, Cornell, Monarch, Furman, Capitol, Gem, Model, Thatcher, Richardson, Royal and many others which lack of space prevents our mentioning.

Hot-Water Heaters

What has been said regarding the multiplicity of steam boilers is equally applicable to hot-water heaters.

One of the pioneer heaters was the Gurney, shown by Fig. 19. In the Spence Heater, Fig. 20, we have another early design of a hot-water heater. Each of these heaters was originally made in Canada, as was also the Champion, a heater of square construction manufactured at Montreal by Rogers & King.

The Spence Heater in Canada was known by the name "Daisy," and it was after being brought to this country that it was called the "Spence." This heater in this country was originally manufactured by The National Hot Water Heater Co., of Boston, Mass., long since out of business, and is now one of the productions of the Pierce, Butler & Pierce Mfg. Co., Syracuse, N. Y.

The firm of E. & C. Gurney Co., of Toronto, Canada, were the

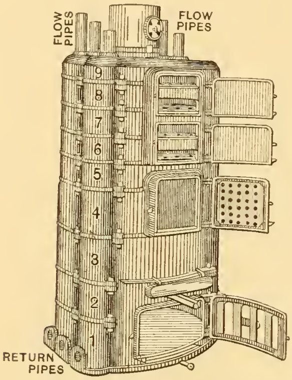

Fig. 21.—Improved Gurney heater.

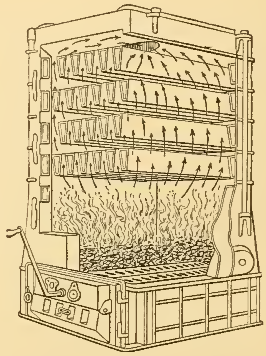

Fig. 22.—The Perfect hot-water heater.

original builders of the Gurney, which, when brought to this country in the year 1884, was manufactured under the same firm name, but now known as the Gurney Heater Mfg. Co. This boiler was

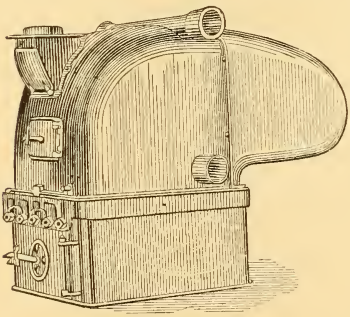

Fig. 23.—The Hitchings hot-water heater.

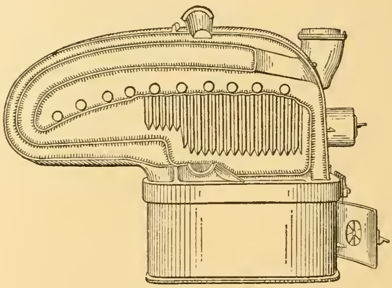

Fig. 24.—Sectional view of hot-water heater.

further improved as shown by Fig. 21, and later, still other improvements were made in its construction.

The Perfect Heater, Fig. 22, was another of the old-time heaters which helped to contribute to the success of hot-water heating in this country.

We have still another type in the Hitchings Boiler, Fig. 23 and Fig. 24. This was an old-time cast-iron heater of peculiar construction, originally intended for the heating of hothouses, and known as a Corrugated Fire-Box Boiler. It was first made about the year 1867. The concern who manufactured it was established in 1844, and their first production was a conical-shaped affair.

Fig. 25 shows the Carton, one of a number of later styles of sectional hot-water heaters.

The advancement in the manufacture of hot-water heaters has kept pace with the improvements in the steam boiler, and many

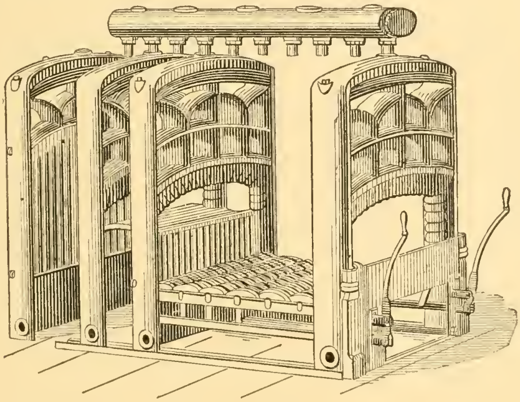

Fig. 25.—The Carton hot-water heater.

manufacturers make both steam and hot-water heaters under the same name and with the same general form of construction.

We have spoken of the half-section or divided-section type of boiler construction, as shown by the original Mills Boiler. This has, in a very great measure, come to be a favorite method of building sectional boilers. The Capitol, The Monarch Sunshine, and the Henderson Thermo are boilers of this type. Fig. 26 shows a line drawing of the Thermo, illustrating the style of sections and the manner of nippling them together.

Naturally it would seem that with such a large number of makes and types of boilers, the steam fitter or heating contractor would get confused in the selection of a suitable boiler or heater, but such should not be the case. Each individual fitter may have his own ideas of what constitutes a good boiler or heater, and select his favorite type of boiler construction. Again, his customer may have previously decided upon the make of heater he

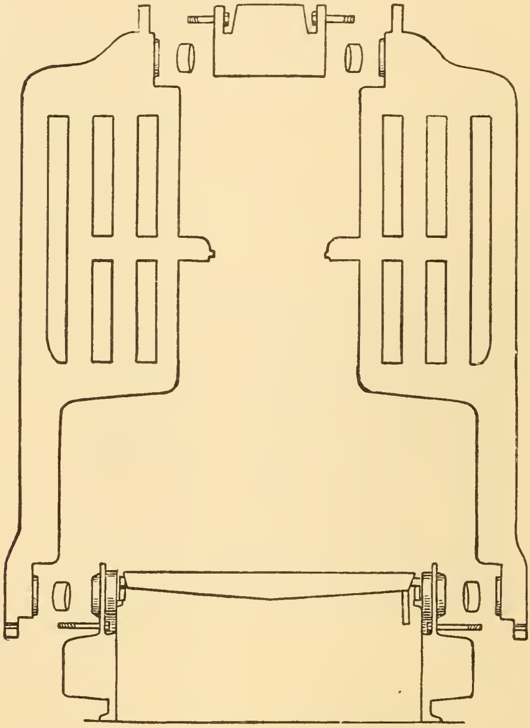

Fig. 26.—Line cut of the Thermo hot-water heater.

wishes installed,—a fact which the fitter cannot afford to overlook, as it is much easier to sell a prospective customer what he wants than what he does not desire, or thinks that he does not.

What Constitutes a Good Boiler

There are a number of features that should be considered when endeavoring to select a good boiler for steam heating, or a heater for hot-water heating. A few pointers:

1. Select a boiler manufactured by a Company or firm of unquestioned business standing—a reputable concern whose guarantee is good. Reliable manufacturers of first-class goods never

hesitate to make good any defect which may develop in their product.

2. Select a boiler which is so constructed as to permit of easy and perfect cleaning of all heating surfaces. Soot is one of the greatest of nonconductors and a boiler which cannot be thoroughly cleaned, while it is in operation, will be expensive to use and short-lived.

3. The fire box should be spacious and deep below the feed door, in order to provide for perfect combustion and a depth of fire that will last for hours without attention.

4. The boiler should have no packed joints to dry out and leak. Push or screw nipples should be the medium for connecting the various parts; and so far as is possible, no bolts should pass through the water ways.

5. The grate is a particular part of the apparatus. It should be of such a construction as to admit of easy cleaning and at the same time heavy enough to carry its load of coal without sagging. The grate should be so arranged as to be readily removable from the heater and replaced, in case repairs are necessary.

6. Select a boiler with a large amount of fire surface and so constructed as to have sufficient fire travel, or flue surface to utilize as many of the heat units from the coal consumed as is possible.

7. The height of the boiler should not be so great as to interfere with a giving of the proper pitch to the piping.

8. If a steam boiler, see that there is provision for a sufficient depth of water above the crown sheet, or prime heating surfaces, to allow the bubbles or globules of steam passing upward through the water to liberate without commotion. This means a steady water line in the boiler.

9. There should be a positive circulation of the water through all parts of the boiler.

10. Select a boiler full large for the work, in order to avoid straining the boiler or wasting fuel by forcing. The greatest economy in the consumption of fuel is attained when the fire burns freely and evenly under normal conditions of draught.

The ratings of house-heating boilers have, as a rule, been worked out from actual use and experience and they may generally be safely accepted by the steam fitter or house owner.

CHAPTER IV

Boiler Surfaces and Settings

The heating surfaces in all boilers, whether cast or wrought iron, are of two kinds, namely, direct surface and flue surface. Direct surface is that immediately above and surrounding the fire, or those parts of a boiler against which the light from the incandescent fuel shines. Flue surface is that which receives the heat from the burning gases while traversing from the combustion chamber to the smoke outlet of the boiler.

Direct surface is more effective than flue surface, the proportion being about three to one. It would seem, therefore, that the boiler presenting the most direct surface to the action of the fire would be the most effective. This is true only in a measure, as a boiler may have a large amount of direct surface and yet have so little flue surface, or distance of fire travel, that the heat from the gases of combustion is not thoroughly extracted before passing out into the chimney, and a large number of heat units from the fuel consumed are therefore wasted.

While it is desirable to have a large proportion of direct heating surface, there must be sufficient flue surface, or distance of fire travel, to consume the gases and render the direct surface effective. It is also desirable that the heating surface should be broken up in such shape that the heat from the fire and the hot gases should impinge at right angles against it and extract as much of the available heat as is possible.

In the manufacture of some of the earlier types of sectional boilers, the builders were imbued with the idea that the length of a boiler or size of it might be increased indefinitely by adding more sections, each having the same area or size of flues. Manifestly this is wrong, and most manufacturers have come to understand that if a certain area of flue opening through sections is right for a five-section heater, this same area is too small for a heater of ten sections, and the flue surfaces are now increased by making the heater in several widths. The proportion of direct and flue surfaces in any heater depends entirely upon the character of its construction.

Grate Surface

In all house-heating boilers there should be a low rate of combustion, and the grate surface should be so proportioned with the heating surface that this may be accomplished. The consumption of fuel should not exceed six or eight pounds of coal per square foot per hour, depending upon the quality of the fuel and the management of the apparatus.

Tests are usually made by evaporation and under perfect conditions of draught, a pound of the best anthracite coal will evaporate from twelve to fifteen pounds of water. However, we never reach perfect conditions of draught in a heating apparatus, as there is always a loss of from twenty-five to forty per cent of the heat up the chimney flue. Some manufacturers of boilers claim a rate of evaporation of ten pounds of water per pound of fuel. The average is much less, and a low-pressure boiler that will evaporate eight pounds of water per pound of fuel is considered as economical.

In the locomotive fire-box type of heating boiler, the ratio of grate to steam radiation capacity (gross) is from 1 to 190 in the smaller sizes, to 1 to 275 in the larger sizes; that is to say, for each square foot of grate, 190 to 275 sq. ft. of steam radiation capacity is figured.

In cast-iron sectional boilers, the ratio of grate surface and steam radiation capacity is from 1 to 175, to 1 to 220, while in round cast-iron heaters, the rating is quite a little less, the ratio being from 1 to 160, up to 1 to 180.

Where tubular boilers are used for heating, it is customary to allow one hundred feet of direct cast-iron radiation per horse power, considering 15 sq. ft. of heating surface as one horse power.

Water Surface

The water surface necessary in a low-pressure boiler depends largely upon the construction of the same. A boiler so constructed as to have a perfect circulation in all of its parts, requires less water than a boiler in which this circulation is not maintained. It is necessary to have sufficient water surface in order that the steam bubbles may liberate easily without disturbing the water line, or carrying water into the steam supply pipes of the heating system. A boiler constructed so that all of the water ways are small and the water consequently divided into small parts, should steam quicker and prove more economical than a boiler where the water is held in large bodies. The water divided into smaller parts is more easily and quickly heated and a circulation of the water within the boiler more readily established.

Boiler Setting

The large majority of boilers now used for heating have what is known as a "portable setting." The early types of heating boilers were bricked in. At the present time, aside from the tubular or fire-box boilers, but very few of the modern boilers are bricked. Many require no covering whatever, although it is customary to cover some of the heaters with a plastic covering of magnesia and asbestos, which, as its name indicates, is applied in the form of plaster and is dried or baked on the surfaces to be covered. This covering is usually put on about 2″ thick and is sufficient to prevent the radiation of heat in the cellar or boiler room, and also adds to the efficiency and appearance of the boiler. The castings should be heated before applying the covering.

Many boilers have a somewhat low or shallow base or ash pit, and when using a boiler of this nature, and the height of boiler cellar will allow, it is a good plan to set it on a raised foundation of brick two or three courses in height, leaving the center hollow. This provides a good, deep ash pit, reducing the probability of burning out the grate, which frequently happens when the ashes are packed underneath it.

Fig. 27 shows the manner of bricking a locomotive fire-box boiler, when it is desired to take the smoke out at the front end, and Fig. 28 shows the method of bricking the same boiler, where the smoke is taken out at the back end. As in this boiler the fire or flame does not come in contact with the brickwork, no fire brick are necessary.

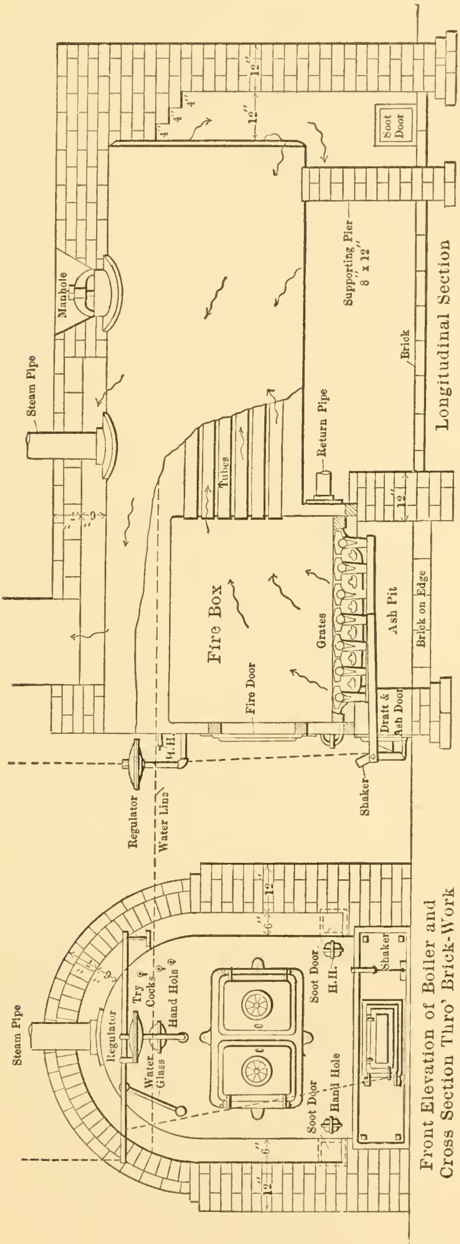

FIG. 27.—Manner of bricking locomotive fire-box boiler. Smoke taken out at front of boiler.

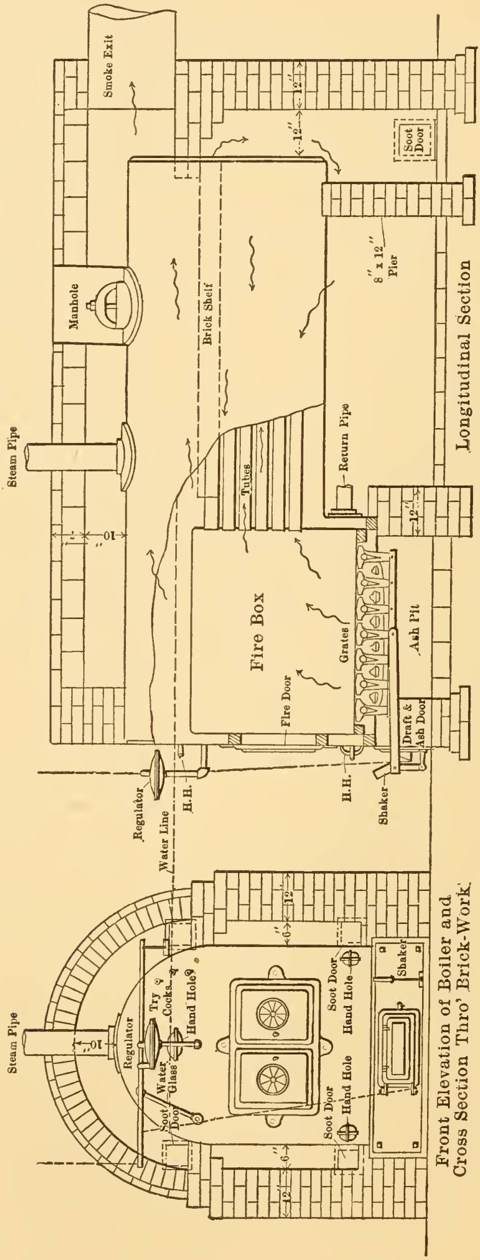

FIG. 28.—Manner of bricking locomotive fire-box boiler. Smoke taken out at rear of boiler.

TABLE II

Measurements for Setting Tubular Boilers with Full Fronts

Reference Letters on Diagram

A	B	C	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	Common Brick.	Fire Brick.
In.	Ft.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	Ft. In.	Ft. In.		
30	8	12½	14	30	44	80	18	18	18	8	18	13	35	16	36	5– 2	11–7½	5,200	320
30	10	12½	14	36	50	80	18	18	18	8	18	13	35	16	36	5– 2	13–7½	5,800	320
36	8	12½	14	36	50	80	18	18	18	8	18	13	35	16	42	5– 8	11–7½	6,200	480
36	10	12½	14	36	50	80	18	18	18	8	18	13	35	16	42	5– 8	13–7½	7,000	480
40	10	14¾	14	36	50	92	21	20	21	8	18	18	40	21	46	6–10	14–2¾	7,700	600
40	12	14¾	14	42	56	92	21	20	21	8	18	18	40	21	46	6–10	16–2¾	8,800	600
42	10	14¾	14	36	50	92	21	20	21	9	20	18	40	21	48	7– 0	14–4¾	10,000	720
42	12	14¾	14	42	56	92	21	20	21	9	20	18	40	21	48	7– 0	16–4¾	10,800	720
42	14	14¾	14	48	62	92	21	20	21	9	20	18	40	21	48	7– 0	18–4¾	11,600	720
48	12	14¾	16	42	58	100	22	21	24	9	20	18	42	21	54	7– 6	16–4¾	13,200	980
48	14	14¾	16	48	64	100	22	21	24	9	20	18	42	21	54	7– 6	18–4¾	14,200	980
48	16	14¾	16	54	70	100	22	21	24	9	20	18	42	21	54	7– 6	20–4¾	15,200	980
54	14	16½	16	48	64	110	25	22½	24	10	24	22	46½	25	60	8– 8	19–2½	14,900	1,154
54	16	16½	16	54	70	110	25	22½	24	10	24	22	46½	25	60	8– 8	21–2½	16,000	1,154
60	14	16½	16	48	64	118	27½	22½	24	10	24	22	49	25	66	9– 2	19–2½	16,100	1,280
60	16	16½	16	54	70	118	27½	22½	24	10	24	22	49	25	66	9– 2	21–2½	17,400	1,280
60	18	16½	16	60	76	118	27½	22½	24	10	24	22	49	25	66	9– 2	23–2½	18,700	1,280
66	16	17½	16	54	70	124	27½	22½	24	10	24	22	49	25	72	9– 8	21–3½	19,700	1,400
66	18	17½	16	60	76	124	27½	22½	24	10	24	22	49	25	72	9– 8	23–3½	21,000	1,400
72	16	19½	18	54	72	133	30	26	30	12	28	22	55	25	78	10– 2	21–9½	20,800	1,550
72	18	19½	18	60	78	133	30	26	30	12	28	22	55	25	78	10– 2	23–9½	22,000	1,550

Fig. 29 shows the brick setting plan for horizontal tubular boilers with full-arch front, and Fig. 30 the same plan for hori-

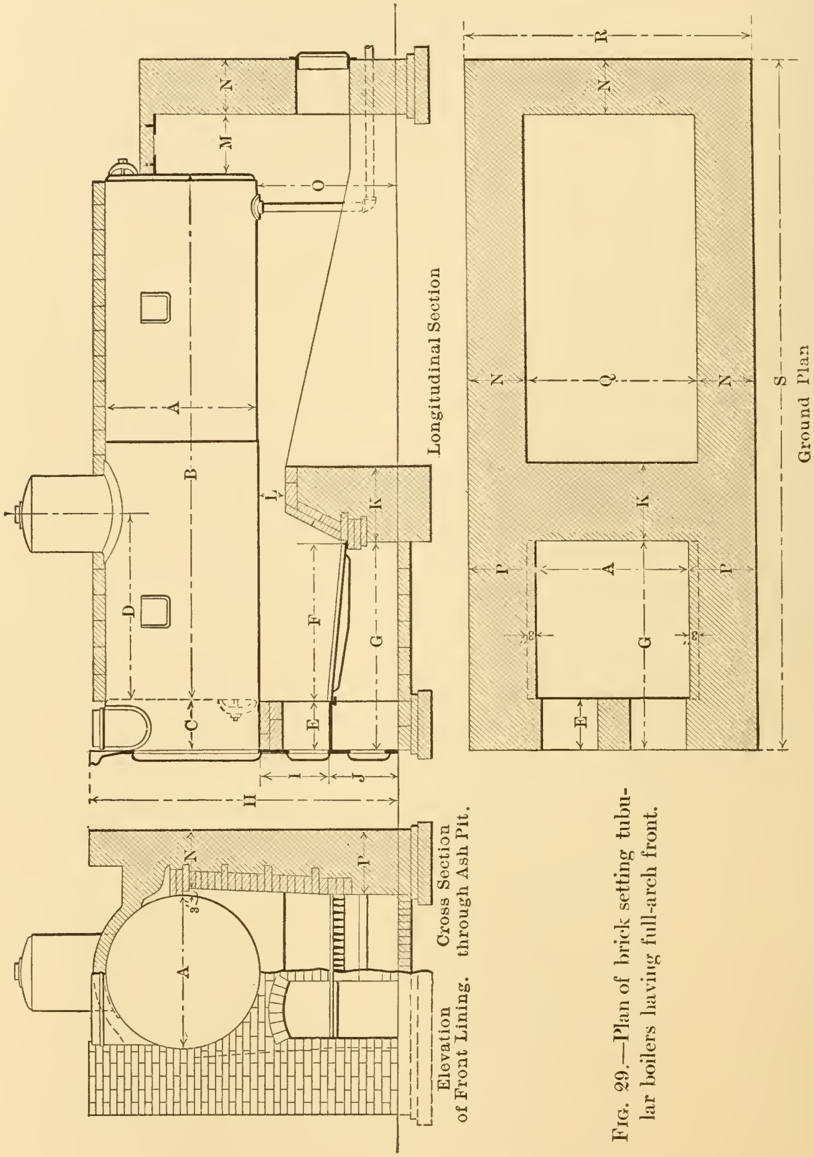

Fig. 29.—Plan of brick setting tubular boilers having full-arch front.

zontal tubular boilers with half-arch front. With a setting of this character it is necessary to use fire brick. On the illustrations

TABLE III

MEASUREMENTS FOR SETTING TUBULAR BOILERS WITH HALF FRONTS

Reference Letters on Diagram

A	B	C	E	F	G	I	J	K	L	M	N	O	P	Q	R	S	Common Brick.	Fire Brick.
In.	Ft.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	Ft. In.	Ft. In.		
30	8	12½	9	30	39	21	20	18	8	18	13	40	16	36	5– 2	10– 7	5,110	320
30	10	12½	9	36	45	21	20	18	8	18	13	40	16	36	5– 2	12– 7	5,710	320
36	8	12½	9	36	45	21	20	18	8	18	13	40	16	42	5– 8	10– 7	6,100	480
36	10	12½	9	36	45	21	20	18	8	18	13	40	16	42	5– 8	12– 7	6,900	480
40	10	14¾	9	30	39	21	20	21	8	18	18	40	21	46	6–10	13– 0	7,530	600
40	12	14¾	9	42	51	21	20	21	8	18	18	40	21	46	6–10	15– 0	8,630	600
42	10	14¾	9	36	45	25	22	21	9	20	18	46	21	48	7– 0	13– 2	9,380	720
42	12	14¾	9	42	51	25	22	21	9	20	18	46	21	48	7– 0	15– 2	10,630	720
42	14	14¾	9	42	51	25	22	21	9	20	18	46	21	48	7– 0	17– 2	11,430	720
48	12	14¾	9	42	51	25	22	24	9	20	18	46	21	54	7– 6	15– 2	13,000	980
48	14	14¾	9	48	57	25	22	24	9	20	18	46	21	54	7– 6	17– 2	14,000	980
48	16	14¾	9	54	63	25	22	24	9	20	18	46	21	54	7– 6	19– 2	15,000	980
54	14	16½	9	48	57	25	22	24	10	24	22	46	25	60	8– 8	17–10	14,520	1,154
54	16	16½	9	54	63	25	22	24	10	24	22	46	25	60	8– 8	19–10	15,720	1,154
60	14	16½	9	48	57	25	22	24	10	24	22	46	25	66	9– 2	17–10	15,780	1,280
60	16	16½	9	54	63	25	22	24	10	24	22	46	25	66	9– 2	19–10	17,080	1,280
60	18	16½	9	60	69	25	22	24	10	24	22	46	25	66	9– 2	21–10	18,380	1,280
66	16	17½	9	54	63	25	22	24	10	24	22	46	25	72	9– 8	19–10	19,350	1,400
66	18	17½	9	60	69	25	22	24	10	24	22	46	25	72	9– 8	21–10	20,650	1,400
72	16	19½	9	54	63	25	22	30	12	28	22	46	25	78	10– 2	20– 2	20,350	1,550
72	18	19½	9	60	69	25	22	30	12	28	22	46	25	78	10– 2	22– 2	21,550	1,550

given, the fire brick are indicated by the heavy shading of the drawing. The tables given, accompanying each illustration, give

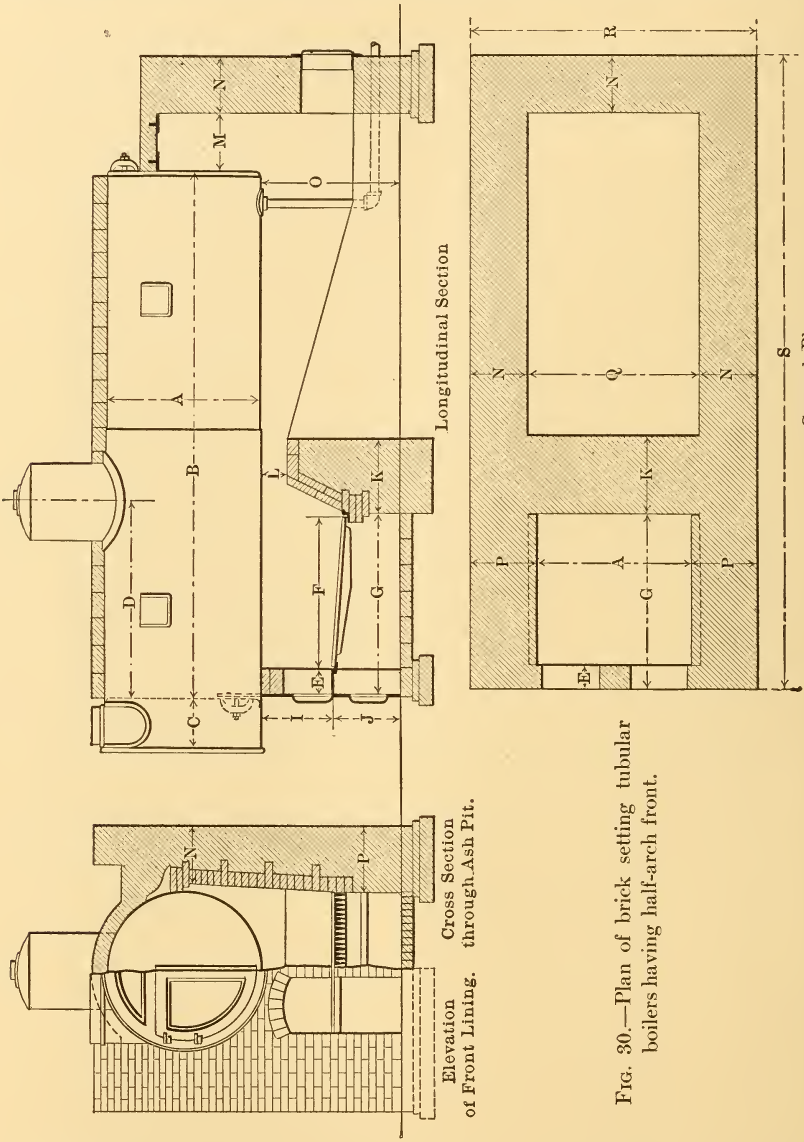

FIG. 30.—Plan of brick setting tubular boilers having half-arch front.

measurements, as indicated by the letters on the drawing and the number of common and fire brick necessary for each size of boiler that is given.

All steam boilers used for heating should be provided with the regulation set of trimmings. By "regulation set" we mean safety valve, steam gauge, automatic damper regulator, water column and glass, blow-off or draw-off cock, and a complete set of cleaning and firing tools, and of these trimmings and tools we wish to speak in detail.

The Safety Valve

The safety valve on a steam boiler should be of a kind not liable to stick or become inoperative, as accidents are frequently the result of this occurrence.

There are three kinds of safety valves in general use, the weighted valve, as shown by Fig. 31, the lever valve, shown by

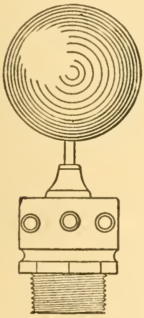

FIG. 31.—Weighted safety valve.

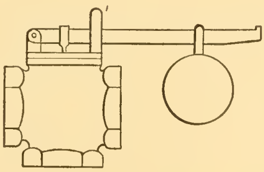

FIG. 32.—Lever safety valve.

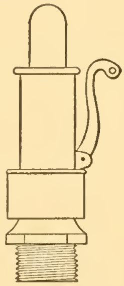

FIG. 33.—Spring safety valve.

Fig. 32, and the spring valve, often called the "pop safety valve," shown by Fig. 33.

The weighted safety valve is a simple ground seat valve, the disc of which is held against the seat by a weight usually in the form of a cast-iron ball placed or screwed on the top of the stem. This ball varies in weight, according to the size of the valve.

The lever safety valve shown is a type of valve in general use not only on steam boilers, but on other work as well, and this is an excellent form of safety valve. It may be regulated to operate at different pressures by adjusting the weight or hanging it in different positions on the lever until sufficient pressure has accumulated to operate it.

This type of valve, as well as the others mentioned, is used extensively on low-pressure as well as high-pressure boilers.

The safety valve should never be weighted down with a weight heavier than that accompanying the valve. We have seen the levers of safety valves held down by a block or board wedged between the lever and a joist of the floor above—a very careless practice and one liable to cause serious damage to person or property. We, therefore, favor the spring, or "pop," valve, owing to the fact that it cannot be easily tampered with. The attendant of a steam boiler should frequently try the safety valve by releasing it, in order that he may know that it is in good condition.

The Steam Gauge

Low-pressure steam gauges, as used with boilers for heating, are made to register about thirty pounds. Fig. 34 illustrates a gauge of this character and while it is customary to provide for all boilers, high or low pressure, a gauge registering double the working pressure, it is very seldom that the pressure exceeds ten pounds on a boiler used for low-pressure heating.

A stopcock should always be provided with the gauge in case it is found necessary to remove it for cleaning or adjustment. In connecting the gauge, a siphon should be used to prevent dry steam from entering the gauge. It is good practice to fill the loop of this siphon with water before screwing on the gauge.

The Automatic Damper Regulator

All steam boilers, high or low pressure, should be provided with an automatic damper regulator. Without this regulation it would be impossible to control the boiler except by constant watching and work of the attendant in charge of the boiler.

Automatic damper regulators for low-pressure boilers are very simple affairs, the regulators for high pressure being more complicated. There are a variety of high-pressure regulators on the market, which our space will not permit of illustrating or describing. It is of the low-pressure regulator that we desire more particularly to speak. All of them are alike in principle and very similar in design, to that shown by Fig. 35. Two castings shaped almost exactly like the old-fashioned soup plate form the bowl of the regulator, the upper one inverted and bolted face to face with the lower, with the rubber diaphragm between, the lower casting of the bowl being tapped for a connection with the boiler. The upper casting of the bowl has a round orifice or opening in the center, through which a small plunger protrudes, the lower side of the plunger resting on the rubber diaphragm. As the pressure increases under the rubber diaphragm, it is expanded, forcing the plunger upward. To the top of the plunger is bolted a wrought-iron rod or lever, at point marked " A " on the illustration. At point marked " B " there are two lips which extend upward from the outer edge of the upper bowl casting, these lips forming the fulcrum, the lever being bolted between the lips at this point. The

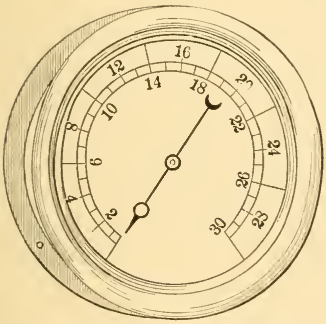

FIG. 34.—Low-pressure steam gauge.

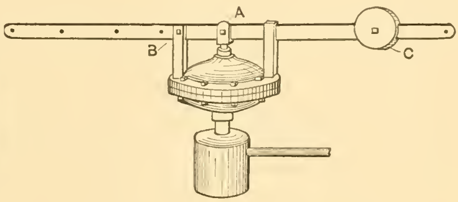

FIG. 35.—Low-pressure damper regulator.

regulator is set so that the fulcrum is on the side toward the front of the boiler. A weight, marked " C," is placed on the lever at a point back of the plunger. This weight is movable and by placing it on the lever farther from or nearer to the plunger, a greater or lesser pressure is required to operate the lever.

On some regulators there is a chain extending from the front end of the lever only, this chain connecting with the draught door of the boiler. On most regulators, however, there are two chains, one from either end of the rod. The front chain connects with the draught door and the rear chain connects with the cold-air check door at the rear of the boiler, the chains being so adjusted that when the lever moves to close the draught door, it will also open the cold-air check.

The steam should never come in contact with the rubber diaphragm, and for this reason a water bottle or trap is used in connecting the regulator to the boiler.

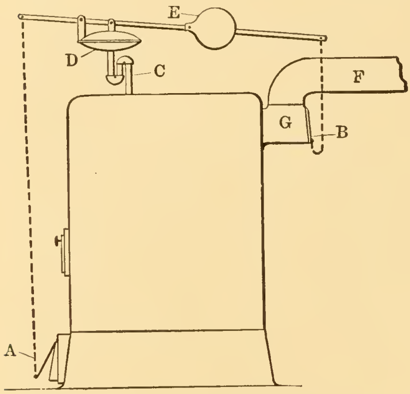

Fig. 36.—Showing connection and action of regulator.

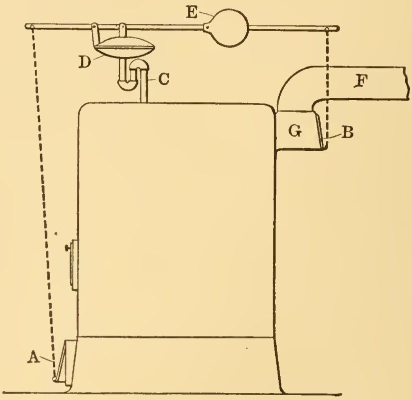

Fig. 37.—Showing connection and action of regulator.

Many fitters of limited experience become confused in adjusting the chains to draught and check doors, and in order to make this plain, we illustrate as in Figs. 36, 37 and 38, showing the three positions of the regulator in action. "A" represents the

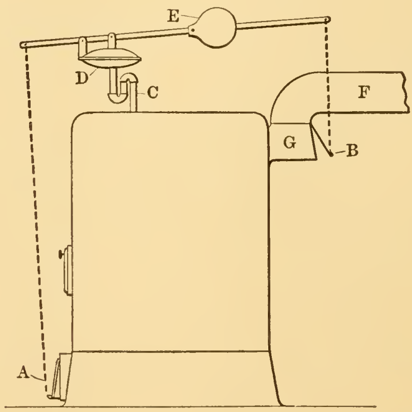

Fig. 38.—Showing connection and action of regulator.

draught door being a part of the base or ash-pit front; "B" the cold-air check, a door on the smoke connection at rear of boiler; "C" the trap used in connecting regulator to boiler; "D" the diaphragm castings with rubber between; " E " the weight, or ball, on lever; " F " the smoke pipe, and " G " the smoke connection to boiler.

Fig. 36 shows the adjustment of chains when draught is on the boiler. Note that the front chain is taut, the draught door being held open. The rear chain is slack, the check door being shut. In this position the doors remain until sufficient pressure is raised to operate regulator, when the plunger is slowly raised, the lever allowing draught door " A " to gradually close.

Fig. 37 shows the operation of the chains when draught door is closed. Note that the rear chain is yet slack, although there is no draught on the boiler. If the pressure of the boiler is not held in check by the closing of the draught door, the plunger in the diaphragm will continue to rise until, as shown by Fig. 38, the rear chain becomes taut and opens the check draught door at the rear of boiler, thus effectually checking the fire. The weight on the lever may be set in such a manner that both draught and check doors remain closed.

The Water Column and Gauge Glass

Fig. 39 shows a standard size of water column, with gauge cocks and water gauge. The try cocks, of which there are three, are not shown on the drawing. These try cocks are screwed into the water column at points marked " A " on the drawing. While it is desirable to use three try cocks, it is not absolutely necessary, and many manufacturers of heating boilers make use of but two. The water column should be at least two and one half inches (2½″) in diameter and fourteen (14″) or fifteen (15″) inches in length.

On the illustration, " B " is the gauge glass, " C " the guard rods, " D " the drip cock, which should be placed at the bottom of all water gauges, and " E " the packing or rubber washer used to make tight joints around the glass.

The Blow-Off Cock

Fig. 40, the blow off or drain cock, often called, also, sediment cock, is a necessary trimming to every boiler. At the lowest part of the boiler, there should be an opening to which a pipe connection can be made to drain the boiler or heating system. This connection must have a valve, and we have seen all sorts of valves used for this purpose. A drain cock, known also as a plug cock, should always be used, as it has a straight opening through which

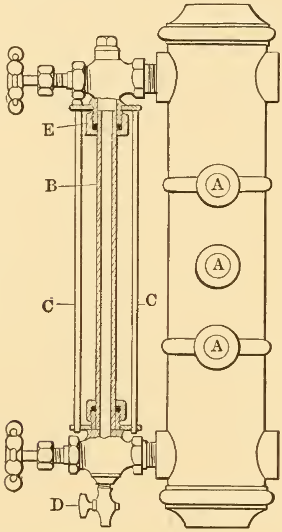

Fig. 39.—Water column and gauge.

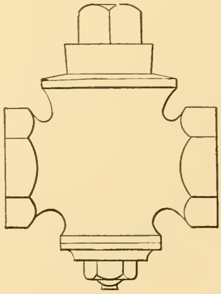

Fig. 40.—Steam or "blow-off" cock.

the sediment or scale from the boiler can pass without choking. Many of the smaller sizes of boilers are tapped for a 3/4″ blow off; a 1″ or 1 1/4″ opening would be better.

Firing Tools and Brushes

All boilers should be provided with firing tools, consisting of ash hoe, poker and slice bar, and with brushes for cleaning the heating surfaces and flues, in order that the attendant may properly fire and clean the boiler. Nearly all makers of low-pressure boilers furnish firing tools, as well as specially designed brushes.

Fusible Plug

When we take into consideration the thousands of boilers in use for heating purposes and the fact that but very few explosions occur, it would seem that all necessary precautions had been taken when the boiler is provided with a complete set of trimmings. However the Boiler Inspection Bureaus of some states, and some insurance companies, demand that a fusible plug be placed on all heating boilers.

This consists of a brass plug, having usually a hexagon head, through the center of which there is an opening or core. This core is filled with Banca Tin, a metal which melts at about 430 degrees Fahr. The boiler is tapped at a point below what might be termed the low-water line, and the fusible plug inserted. Should the water in the boiler get below the plug, the heat from the hot iron will melt the tin, thus making an opening to the atmosphere and giving relief.

CHAPTER V

The Chimney Flue

There is no one part of a steam or hot-water heating apparatus which contributes so largely to its success or failure as the chimney to which the boiler or heater is connected.

The chimney is comparatively a modern invention. It is said that none of the old Roman ruins, nor the restored buildings in Herculaneum or Pompeii have chimneys; the chimney of that period consisted of a hole in the roof. The modern chimney was first used in the fourteenth century.

At the time steam and hot water were first used for heating

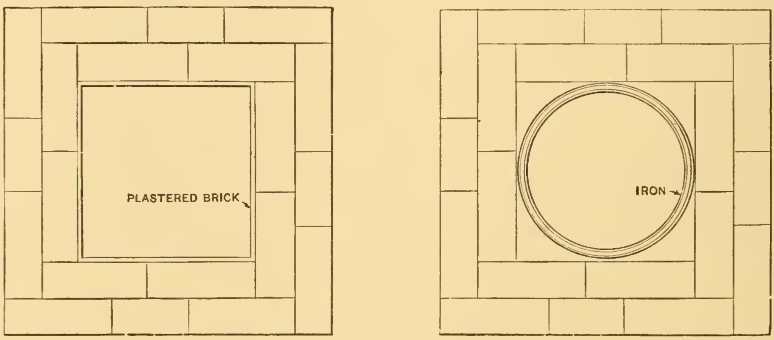

Fig. 41.—Round and square chimney flues.

purposes in this country but very little attention was given to the chimney, with the result that many of the heating plants then installed failed to work satisfactorily. Experience has taught us several facts in the building and use of chimneys:

First:—A chimney used for a low-pressure steam or a hot-water heating apparatus should have no other opening than that used for the heating apparatus.

Second:—The draught in a chimney is spiral; therefore, round chimneys, or those as nearly square as possible, are most effective. A round chimney 12″ in diameter, having an area of approximately 113 sq. in., is as effective as a chimney 12″ × 12″ having an area of 144 sq. in. See Fig. 41.

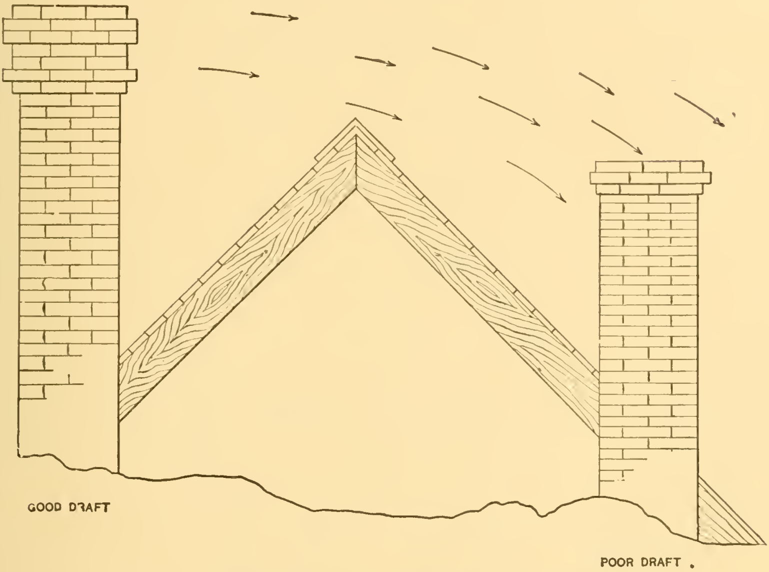

Fig. 42.—Proper and improper construction of chimneys.

Third:—Adding height to a chimney will increase the velocity of the draught and add to the fuel consumption. As we desire a low rate of combustion in a low-pressure boiler or hot-water heater, greater area and less proportionate height of the flue is desirable.

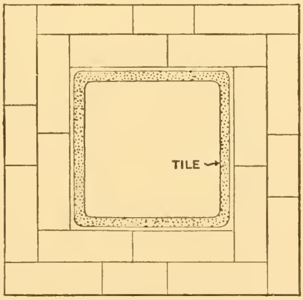

Fig. 43.—Tile-lined chimney flue.

Fourth:—The height of a chimney should be great enough to preclude the possibility of interference with the draught by surrounding buildings, trees, or the roof of the building of which the chimney forms a part. Fig. 42 illustrates the character of this interference.

Fifth:—The chimney should be built straight upward without any offsets, which cause friction and interfere with the draught; and the inside lining should be as smooth as possible, a tile-lined flue being superior to all others. See Fig. 43.

Sizes of Chimneys

The following table we give as the result of practical experience with chimneys on heating work and may be safely accepted:

TABLE IV

Cubic Feet. Contents of Building.	Sq. Ft. Direct Steam Radn.	Sq. Ft. Hot-Water Radn.	Round, Tile or Iron —Inside. Inches.	Square or Rectangular—Tile or Brick. Inches.
10,000- 20,000	250 to 450	300 to 800	8	8× 8
20,000- 45,000	450 to 700	800 to 1,200	10	8×12
45,000- 75,000	700 to 1,200	1,200 to 2,200	12	12×12
75,000-140,000	1,200 to 2,400	2,200 to 3,600	14	12×16
140,000-200,000	2,400 to 3,500	3,600 to 5,200	16	16×16
200,000-350,000	3,500 to 5,000	5,200 to 8,000	18	16×20

It will interest our readers to know what other authorities say regarding chimney sizes, and we shall therefore quote from some of them.

Lawler in his work on steam and hot-water heating gives a graphic diagram (see Fig. 44) which gives the proportion of grate surface, heating surface and chimney area, and he says: "It will be noticed that one square foot of grate surface will supply 36 sq. ft. of boiler surface; and this amount of grate and boiler surface will carry 196 sq. ft. of direct radiating surface for heating purposes. The area of the chimney must be taken into consideration and for this amount of grate and boiler surface. we allow 49 sq. in. For low-pressure gravity steam-heating plants, carrying over 1,000 sq. ft. of radiation, the size of chimney may be reduced somewhat less in proportion to that shown."

Jones, an English authority, says: "For steam boilers where a keen or rapid draught is required, it is necessary to have lofty chimneys, but for hot-water boilers they are not often available, low chimneys being generally sufficient. Where practicable the height of chimney should be twenty-five per cent to fifty per cent greater than the total length of horizontal flues."

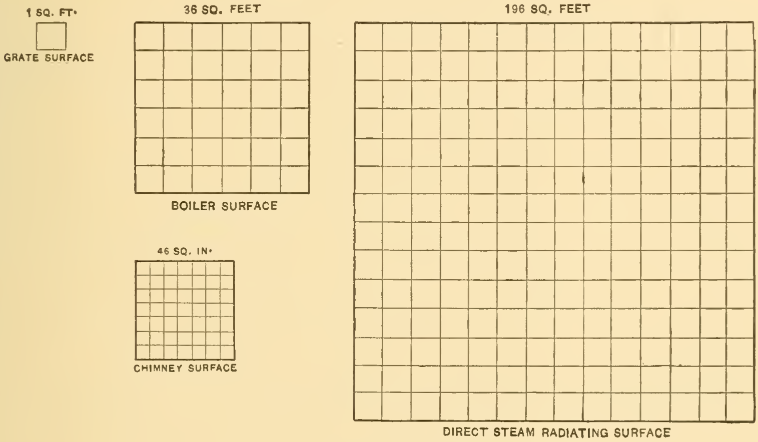

Fig. 44.—Diagram of flue capacity.

(The author refers to length of fire travel.) "The total length (horizontal) of flues should not in any case exceed the height of the chimney."

Baldwin says: "The chimney must be capable of passing sufficient air for the greatest consumption of fuel ever likely to be used in the apparatus. Less air will not do. More than is needed does no harm, for it is within the power of the operator or the automatic draught regulator to diminish the quantity of air."

We would like to add to the above by saying that a chimney is only as large as its smallest area, and if at any point in its construction, for no matter how short a distance, the area is reduced for any cause whatsoever, the area of the entire flue must be figured according to its size at the point of reduction.

Elements of a Good Flue

The flue should be properly proportioned according to the size of heater or amount of radiating surface used.

It should have no obstructions, and in height should extend well above the roof and higher than surrounding buildings, trees, etc.

There should be only one smoke-pipe hole, and that used to connect with boiler.

The area of the flue should be maintained full size from bottom to top without offsets.

A flue 8″ × 8″ is the smallest that should be provided for a heating apparatus. Velocity sufficient to carry burning paper up the flue does not indicate a perfect chimney. See that area is provided as well as velocity (meaning height).

If flue opening extends below the smoke-pipe entrance, fill it up with dirt, broken brick or other material at hand, to a point level with the bottom of smoke-pipe hole. If this is neglected, an air pocket will be formed, causing down draught in the chimney.

Take no chances on a chimney until the above conditions are fulfilled.

There are some few facts regarding chimney construction that are worthy of note. We have particular reference to the materials used in their erection and to the location of the chimneys. In the observance of various chimneys note that at the top, frequently for a distance of from four to five feet, the bricks have become loosened and seem about ready to fall. The reason for this is that such bricks were laid with lime mortar, and the action of the sulphuric acid on the lime decomposes it, thus allowing the sand to loosen. Through the action of the wind and weather and also the settling of the bricks they blow or fall out, leaving cracks or openings in the brickwork of the chimney.

Brick chimneys laid with cement are better, as the sulphuric acid will not injuriously affect the cement.

Unlined chimneys should be plastered smooth on the inside in order to reduce the friction as much as possible and thereby increase the velocity of the draught.

It is a very good plan to build the chimney up through the center of the house. The warmer the air surrounding the chimney, the less condensation of the smoke and gases and the greater the efficiency of the flue.

The foundation for the chimney should be adequate to support the weight upon it without settling. Cracked walls, loose chimneys and the like can usually be traced to a weak foundation, which is also frequently the cause of disastrous fires. With the pressure of the atmosphere exerted against the ascending column of smoke and gases, the smallest crack or opening in the walls of the chimney will prove troublesome and dangerous.

Masons and contractors give too little attention to chimney building, with the result that many chimneys are improperly and loosely built, of too small area or poor design. In order to justly protect themselves from the unsatisfactory results arising from such methods of chimney erection, many heating contractors state clearly in their specifications that the owner must furnish a good and sufficient flue, and that the heating contractor will not be responsible for failure of the apparatus due to poor draught.

Heights of Chimneys

The following table of heights and area will be found to be substantially correct. One hundred square feet of radiation may be allowed for each H. P. given in the table.

TABLE V

Square Chimney. Side of Square.	Round Chimney. Diam. in Inches.	Area in Square Feet.	Effective Area in Square Feet.	Height of Chimneys in Feet. 50	60	70	80	90	100	110	125	150	175
				Commercial Horse Power of Boilers.									
16×16	18	1.77	.97	23	25	27	....	....	....	....	....	....	....
19×19	21	2.41	1.47	35	38	41	....	....	....	....	....	....	....
22×22	24	3.14	2.08	49	54	58	62	....	....	....	....	....	....
24×24	27	3.98	2.78	65	72	78	83	....	....	....	....	....	....
27×27	30	4.91	3.58	84	92	100	107	113	....	....	....	....	....
30×30	33	5.94	4.48	....	115	125	133	141	....	....	....	....	....
32×32	36	7.07	5.47	....	141	152	163	173	183	....	....	....	....
35×35	39	8.30	6.57	....	....	183	196	208	219	....	....	....	....
38×38	42	9.62	7.76	....	....	216	231	245	258	271	....	....	....
43×43	48	12.57	10.44	....	....	....	311	330	348	365	389	....	....
48×48	54	15.90	13.51	....	....	....	....	427	448	472	503	551	....
54×54	60	19.64	16.98	....	....	....	....	536	565	593	632	692	748
59×59	66	23.76	20.83	....	....	....	....	....	694	728	776	849	918
64×64	72	28.27	25.08	....	....	....	....	....	835	876	934	1,023	1,105
70×70	78	33.18	29.73	....	....	....	....	....	....	1,038	1,107	1,212	1,300
75×75	84	38.48	34.76	....	....	....	....	....	....	1,214	1,294	1,418	1,500
80×80	90	44.18	40.19	....	....	....	....	....	....	....	1,496	1,639	1,800
86×86	96	50.27	46.01	....	....	....	....	....	....	....	....	1,876	2,000

Attention is called to the table "Capacities of Stacks" given in the last chapter of this book.

The height of the average house or other building is usually sufficient for a chimney of ordinary area. However, for larger work it is well that the height, area, etc., of the chimney be carefully proportioned in order that the best results may be obtained from the heating apparatus and the most economical service from the amount of fuel consumed.

CHAPTER VI

PIPE AND FITTINGS

Pipe

Wrought-iron tubes of the character we to-day call pipe were first made in England and later (about the year 1834) were originally manufactured in this country by the firm of Morris, Tasker & Morris at Philadelphia, who afterwards built a tube mill known as the Pascal Iron Works. In 1849 a tube plant was erected at Malden, Mass., known as the Wanalancet Iron & Tube Works, the firm of Walworth & Nason, of Boston, being the principal owners of this Company. The manufacture of pipe has now come to be a very important part of the iron and steel industry of this country.

TABLE VI

Standard Wrought Iron Pipe

Internal Diameter. Inches.	Thickness.	Nominal Weight Per Ft. lbs.	No. of Threads Per In.	Length of Pipe Containing 1 Cubic Ft.	Cu. Ft. in 1 Lineal Ft. of Pipe.	Weight of Water in 1 Ft. of Pipe. Pounds.	Internal Area. Square Inches.	Length of Pipe Per Sq. Ft. Outside. Surface.
1/8	.068	.24	27	2513.	....	.024	0.0583	9.44
1/4	.088	.42	18	1383.3	....	.044	0.1041	7.075
3/8	.091	.56	18	751.5	....	.082	0.1917	5.657
1/2	.109	.84	14	472.4	....	.132	0.3048	4.547
3/4	.113	1.12	14	270.00	....	.25	0.5333	3.637
1	.134	1.67	11½	160.90	.006	.37	0.8627	2.903
1¼	.140	2.24	11½	96.25	.010	.647	1.496	2.301
1½	.145	2.68	11½	70.66	.014	.881	2.038	2.010
2	.154	3.61	11½	42.91	.023	1.45	3.356	1.608
2½	.204	5.74	8	30.10	.032	2.07	4.784	1.328
3	.217	7.54	8	19.50	.051	3.20	7.388	1.091
3½	.226	9.00	8	14.57	.069	4.28	9.887	0.955
4	.237	10.66	8	11.31	.088	5.50	12.730	0.849
4½	.246	12.49	8	9.02	.111	6.92	15.961	0.764
5	.259	14.50	8	7.20	.138	8.63	19.990	0.687
6	.280	18.76	8	4.98	.197	12.25	28.889	0.577
7	.301	23.27	8	3.72	.270	16.87	38.738	0.501
8	.322	28.18	8	2.88	.340	21.61	50.039	0.443
9	.344	33.70	8	2.29	.440	27.25	62.733	0.397
10	.366	40.00	8	1.82	.550	34.50	78.838	0.355

The pipe used for steam, water and gas is graded in size from ⅛″ upward to the larger sizes. The internal diameter forms the basis of the pipe size as given. Pipe at present is manufactured in three thicknesses or weights, known commercially as "Standard," "Extra Strong" and "Double Extra Strong," the "Standard" weight being used on all steam and hot-water heating work, and all reference to pipe in this book will apply to the standard weight unless stated otherwise.

Among the tables published in the last chapter of this work will be found tables of sizes, weights, etc., of "Extra Strong" and "Double Extra Strong" pipe.

Pipe up to and including 1¼″ in size is what is known as "butt welded," 1½″ and larger, being "lap welded" and is manufactured in lengths varying from 16 to 20 feet.

Threading of Pipe

All pipe is now threaded uniformly, the Briggs' standard of pipe-thread sizes being used by all manufacturers. The taper is an inclination of 1 in 32 to the axis, or ¾″ to 1 foot.

Bending of Pipe

Some years ago it was a common occurrence to bend pipe, where offsets were needed, or change of direction required. The piece of pipe to be bent was filled with sand and both ends capped, the sand acting as an aid in preserving the form of the pipe, without flattening. It was then heated to a cherry-red color and bent to the desired form. In these later years but very little pipe is bent, the offsets or changes of direction being made with the use of cast-iron or malleable-iron fittings.

The smaller sizes of pipe, such as are used for water or gas service, are frequently bent by the plumber without heating and without the use of sand. When it becomes necessary to do any considerable amount of work of this character, it is better to use bending blocks or bending forms.

Expansion of Pipe

In heating work the expansion of pipe, when heated, must always be taken into consideration and opportunity given the pipe to stretch without breaking fittings or straining joints. To this end all mains should be hung or supported by expansion hangers as shown by Fig. 45. Pipe connections, particularly on steam work, should be made by using elbows to form a swing or expansion joint. We shall speak of this more fully in discussing methods of steam piping.

Whenever pipe is run through boxing, tile or other form of conduit, a roller support (see Fig. 46) should be used.

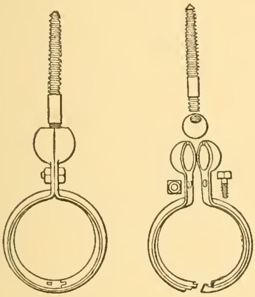

Fig. 45.—Expansion pipe hangers.

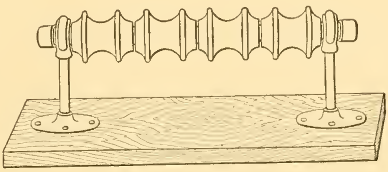

Fig. 46.—Roller support for piping.

Pipe heated from 30 degrees to 212 degrees will expand about 1⅜″ in 100 feet of length.

The following table gives the expansion of 100 lineal feet of pipe heated to various degrees of temperature.

TABLE VII

Expansion of Wrought-Iron Pipe

Temperature of the Air When Pipe Is Fitted.	Length of Pipe When Fitted. Ft.	Length of Pipe When Heated to—							
		215°		265°		297°		338°	
		Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
Zero	100	100	1.72	100	2.12	100	2.31	100	2.70
32°	100	100	1.47	100	1.78	100	2.12	100	2.45
64°	100	100	1.21	100	1.61	100	1.87	100	2.19

The number of degrees pipe is heated, corresponding approximately to steam pressure, as follows:

215° = 1 lb. pressure.
265° = 25 lbs. pressure.
297° = 50 lbs. pressure.
338° = 100 lbs. pressure.

Wrought-Iron or Steel Pipe

Up to the year 1885, approximately, all pipe was made of wrought iron. At about this time the manufacture of welded steel pipe on a commercial basis was started. The difficulties experienced before in its manufacture, principally in welding, had been overcome by improvement, so that it could now be readily welded. The first of the steel pipe seemed hard and brittle and the steam fitter had considerable trouble in threading it. However, as now manufactured it is soft and tough in fiber and a die, if blunt, will tear the thread. Consequently it is necessary that the die be sharp in threading steel pipe.

In appearance, iron pipe is rough and has a heavy scale, while steel pipe has a lighter scale, underneath which the surface is smooth. The grain of steel pipe is fine, while that of wrought-iron pipe is coarse. The author of this work is located near the center of the iron and steel industry and has endeavored to ascertain the difference in value between steel and wrought-iron pipe and our investigation may be summed up as follows:

Steel pipe costs less to manufacture than wrought-iron pipe; it is, therefore, cheaper. With improved dies, threads may be cut on steel pipe as good, but not as quickly, as on wrought-iron pipe. When steel pipe is new it has a higher tensile strength than wrought iron. We are told that after a few years' use the reverse is the case.

There seems to be no doubt but that wrought-iron pipe will last much longer than pipe made of steel, as it is less liable to corrode, the difference in longevity, under certain conditions, more than making up for the increased cost.

To Ascertain Whether Pipe Is Made of Iron or Steel

The following test is given us by an officer of an iron company:

"Cut off a short piece of pipe—file the end smooth to obliterate the marks of the cutting tool. Suspend the piece of pipe in a solution of nine parts of water, three parts of sulphuric acid and one part muriatic acid. Place the water in a porcelain or glass dish, adding the sulphuric and then the muriatic acid. Suspend the pipe in such a manner that the end will not touch the bottom of the dish. After an immersion of about two hours, remove the piece of pipe and wash off the acid. If the pipe is steel, the end will present a bright, solid, unbroken surface; if made of iron,

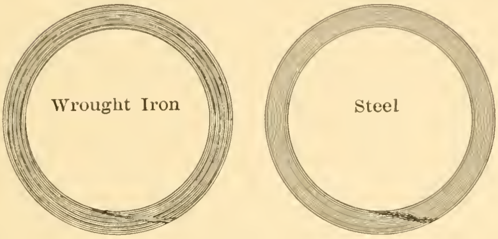

FIG. 47.—Wrought-iron and steel pipe.

it will show faint ridges or rings, displaying the different layers of iron and streaks of cinder," as shown by Fig. 47.

Nipples

Short pieces of standard pipe threaded at both ends are called "nipples" and are known commercially as "close," "short," or "long."

A close nipple is one so short that in threading the ends, the threads join at the center of the nipple, and by the use of which two fittings or valves may be joined together close to each other. From this fact the nipple is called "close."

The short nipple is one showing a small amount of bare pipe between the threads, the length varying from 1½″ for ⅛″ to ½″ nipples to 5″ for nipples made from 7″ to 12″ pipe.

FIG. 48.—Nipples.

Long nipples run from 2″ to 6½″ in length, according to the size of pipe. Fig. 48 shows the two kinds of nipples and the following table gives lists of lengths and sizes.

TABLE VIII

WROUGHT-IRON NIPPLES

Length in Inches.						Sizes.
Close.	Short.	Long.				
¾	1½	2	2½	3	3½	⅛
⅞	1½	2	2½	3	3½	¼
1	1½	2	2½	3	3½	⅜
1⅛	1½	2	2½	3	3½	½
1⅜	2	2½	3	3½	4	¾
1½	2	2½	3	3½	4	1
1⅝	2½	3	3½	4	4½	1¼
1¾	2½	3	3½	4	4½	1½
2	2½	3	3½	4	4½	2
2½	3	3½	4	4½	5	2½
2½	3	3½	4	4½	5	3
2¾	4	4½	5	5½	6	3½
3	4	4½	5	5½	6	4
3	4	4½	5	5½	6	4½
3½	4½	5	5½	6	6½	5
3½	4½	5	5½	6	6½	6
4	5	6	....	....	....	7
4	5	6	....	....	....	8
5	6	8	....	....	....	9
5	6	8	....	....	....	10

Couplings

Pipe is joined together by what is known as a coupling—a sleeve of wrought iron tapped out or threaded right hand on the inside. Pipe mills furnish one coupling with each full length of pipe. They may also be obtained tapped right and left hand, if desired, although it is customary when using a right and left coupling to use one made of malleable iron. Reducing couplings

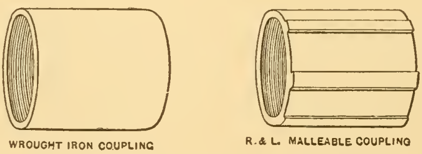

FIG. 49.—Couplings.

are also made of malleable iron, reducing from one pipe size to another of smaller size. Fig. 49 shows the wrought-iron right-hand coupling and the malleable right and left hand coupling.

Fittings

The fittings used in connection with steam, gas or water pipe are of two general kinds, viz.: those made of cast iron and those made of malleable iron. By fittings we mean elbows, tees, crosses, flanges, bushings, caps, plugs, etc.

For heating work the cast-iron fitting is used; for gas piping, the malleable-iron fitting, and for domestic water supply, the galvanized malleable-iron fitting. We shall illustrate and describe only the cast-iron fitting.

Cast-iron fittings are of two kinds, viz.: those having a flat bead, and those having a round bead,—Fig. 50. "Straight" fittings are those having all openings tapped for the same size of pipe. "Reducing" fittings are those tapped for different sizes of pipes. Fig. 51 shows a group of flat beaded fittings.

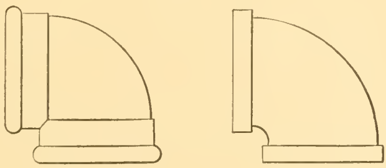

Fig. 50.—Beaded fittings.

The terms "male" and "female" fittings are sometimes used. By "male" fitting we mean one with the threads on the outside; by "female" fitting we mean one with the threads on the inside.

When reading or describing a tee fitting, the run is named first, the side opening last. If the run is tapped reducing, the larger tapping is read first. Thus a tee whose tappings are $3'' \times 2'' \times 1\frac{1}{2}''$ is read: three by two by one and one half inch.

The top and side outlets of a cross are all of the same size, while the inlet may be the same size or larger. Thus a $2 \times 1 \times 1''$ cross would indicate that the bottom or inlet was $2''$ and the top and side outlets $1''$ in size.

Branch Tees

A fitting used largely on coil work is known as a Branch Tee, frequently (but erroneously) called a Branch Header. Shown by Fig. 52. All branch tees are tapped right hand in the run and in the branches, excepting when used in making box coils, when the branches are tapped left hand and the back opening right hand.

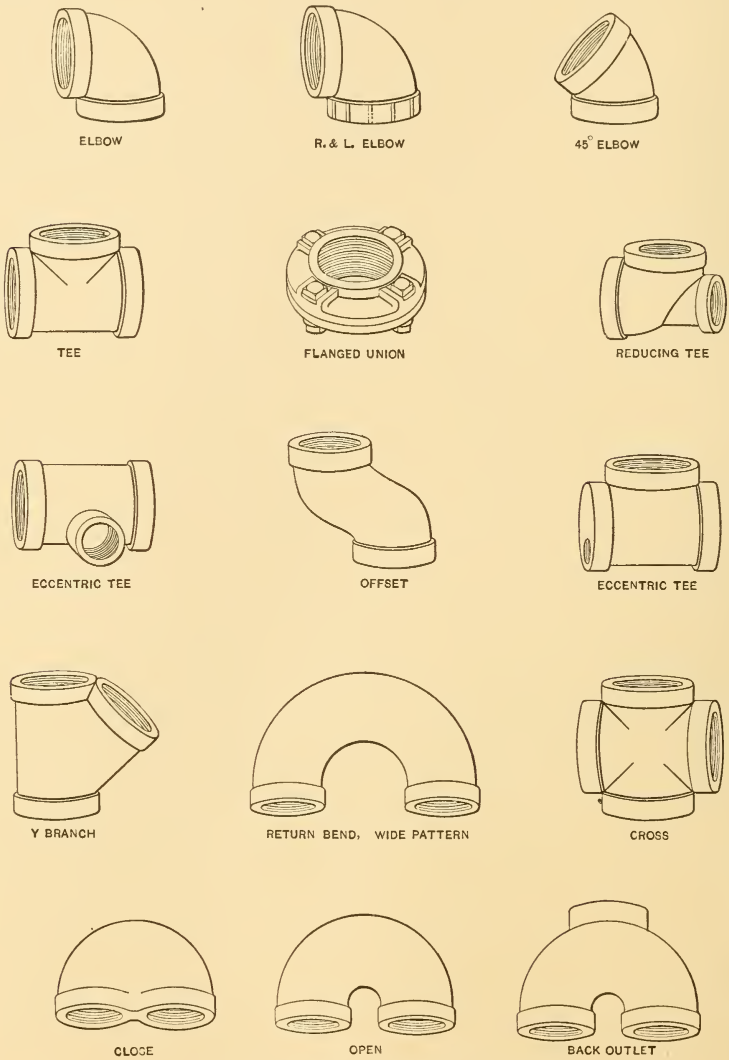

Fig. 51.—Types of cast-iron fittings.

Cast-Iron Flanges

Cast-iron flanges are now made according to two uniform standards. A joint committee of the Master Steam Fitters Association and the American Society of Heating Engineers recommended a standard for a working pressure up to 125 pounds. This standard has been adopted by all manufacturers, who also have a stand-

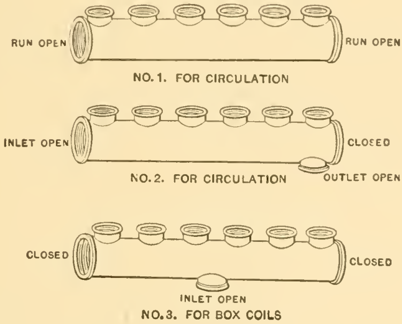

Fig. 52.—Branch tees.

ard of their own for pressures up to 250 pounds. The following gives all measurements for flanges, as used on heating work.

TABLE IX

Schedule of Standard Flanges

Size of Flange Pipe Size × Diam.	Diameter of Bolt Circle.	Number of Bolts.	Size of Bolts, Pressure Under 80 Lbs.	Size of Bolts, Pressure 80 Lbs. and Over.	Flange Thickness at Hub for Iron Pipe.	Flange Thickness at Edge.	Width of Flange Face.
2 × 6	4¾	4	½×2¼	⅝×2	1	⅝	2
2½ × 7	5½	4	½×2	⅝×2¼	1⅛	11/16	2¼
3 × 7½	6	4	½×2½	⅝×2½	1¼	¾	2¼
3½ × 8½	7	4	½×2½	⅝×2½	1¼	13/16	2½
4 × 9	7½	4	⅝×2¾	¾×2¾	1⅜	15/16	2½
4½ × 9¼	7¾	8	⅝×3	¾×3	1⅜	15/16	2⅜
5 × 10	8½	8	⅝×3	¾×3	1½	15/16	2½
6 × 11	9½	8	⅝×3	¾×3	1½	1	2½
7 × 12½	10¾	8	⅝×3¼	¾×3¼	1½	1 1/16	2¾
8 × 13½	11¾	8	⅝×3½	¾×3½	1¾	1⅛	2¾
9 × 15	13¼	12	⅝×3½	¾×3½	1¾	1⅛	3
10 × 16	14¼	12	¾×3⅝	⅞×3⅝	2	1 3/16	3
12 × 19	17	12	¾×3¾	⅞×3¾	2	1¼	3½
14 × 21	18¾	12	⅞×4¼	1 ×4¼	2	1⅜	3½
15 × 22¼	20	16	⅞×4¼	1 ×4¼	2	1⅜	3⅝
16 × 23½	21¼	16	⅞×4¼	1 ×4¼	2¼	1 7/16	3¾
18 × 25	22¾	16	1 ×4¾	1⅛×4¾	....	1 9/16	3½
20 × 27½	25	20	1 ×4¾	1⅛×4¾	....	1 11/16	3¾

Do not drill bolt holes on center line but symmetrically each side.

Measuring Pipe and Fittings

The proper method of measuring pipe and fittings is by "end-to-center" measure, or "center to center," the former being used in measuring a piece or length of pipe with a fitting on one end; for example, with an elbow on the end of the pipe, measure from end of pipe to center of the elbow, or in case of a tee, measure from end of pipe to center of the side outlet of the tee.

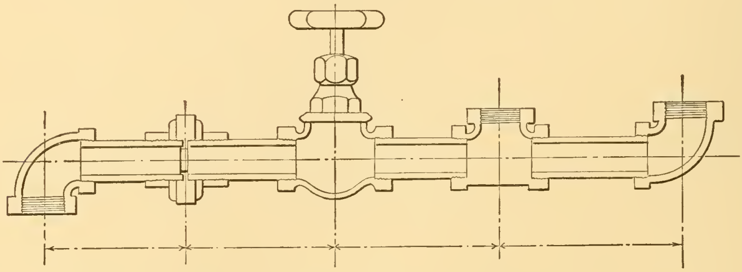

Fig. 53.—Measuring pipe and fittings.

In measuring center to center measurements, Fig. 53 shows the method employed. The illustration shows two elbows, a valve, a union and a tee, with dotted lines indicating method of measurement. When ordering pipe "cut to sketch" this manner of indicating measurements, no matter how crude the drawing, will guard against possible errors.

CHAPTER VII

Valves

The method employed in blocking or stopping the flow of steam or hot water in the piping or in the supply to the radiating surfaces of a steam or water warming apparatus is the placing of a cock or valve at some convenient point or points on the system, which may be opened or closed at will.

The early types of cocks and valves, as used in connection with a heating apparatus, were very crude when compared with those used at the present time, and there is probably no part of the heating apparatus which has received closer attention in the way of improvement in manufacture, utility and appearance, than the steam, water and air valves.

The valves used in shutting off or supplying steam or water to the radiators are customarily called Radiator Valves. These are of several kinds, and, as a matter of convenience in connecting piping to a radiator, are usually provided with a union connection. As a rule, radiator valves are nickel plated all over, the body of the valve being left rough, the other portion being finished or polished.

Fig. 54 shows the regular form of steam radiator valve with union, and has a ground seat and composition disk, the Jenkins Disk being the standard. Fig. 55 shows the regular form of the hot-water radiator valve. This is known as a quick-opening valve from the fact that it is made in such a manner that a quarter turn of the wheel will open or close the valve. A sleeve, with opening in the side, is attached to the stem and fitted closely inside the body of the valve. To operate the valve the opening in the sleeve is turned in the direction of the discharge opening of the valve; to close the valve the opening in the sleeve is turned back from the discharge opening of the valve. In the early days of steam and hot-water heating, the valves used on hot-water radiators were of practically the same design as those used on steam radiators. A change in the construction of the hot-water radiator valve was found necessary, as with the old type the water within the radiator ceased circulating when the valve was closed. This

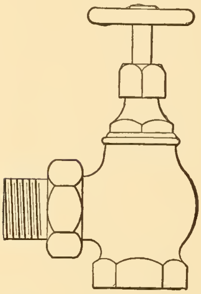

FIG. 54.—Steam radiator valve with union.

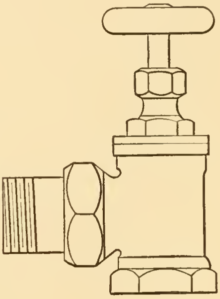

FIG. 55.—Hot-water radiator valve with union.

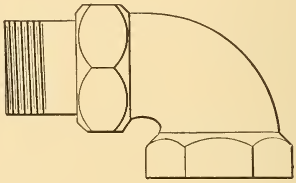

FIG. 56.—Union elbow.

complete stoppage frequently resulted in a freezing of the water in the radiating surface. To overcome this difficulty the sleeve of a hot-water radiator valve is now made with a small opening through it, so that, though the valve be closed tight, there is still a slight circulation within the radiator, and this effectually prevents freezing of the water.

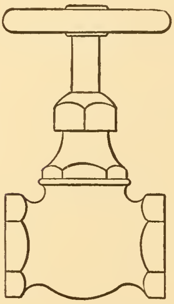

FIG. 57.—Globe valve.

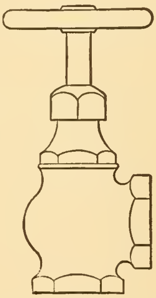

FIG. 58.—Angle valve.

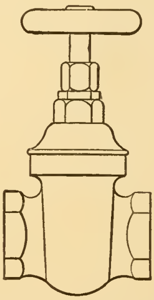

FIG. 59.—Gate valve.

Hot-water radiator valves of other patterns are manufactured and quite extensively used.

As a matter of appearance and also of convenience in connecting the return end of a hot-water radiator with the piping, a nickel-plated brass elbow, with union connection, is used. This is commonly called a Union Elbow and is illustrated by Fig. 56.

The principal valves used on piping are the Globe Valve, Fig. 57, the Angle Valve, Fig. 58, and the Gate Valve, Fig. 59, and there are many varieties of each.

Some globe valves are made with a solid metal disk and seat; others have a seat made of soft metal, while some are provided with a composition disk of the Jenkins type, or similar. The diaphragm of a globe valve forms an obstruction in the valve, as will be noticed by referring to Fig. 60, which illustrates the interior of the valve. Consequently it is well to use this valve only on a vertical pipe, unless so set that the stem of the valve is horizontal.

The angle valve is used on the piping in place of an elbow

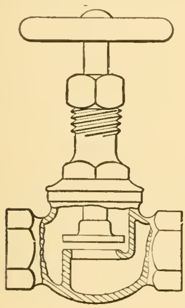

FIG. 60.—Interior of globe valve.

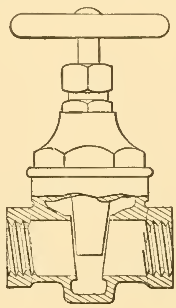

FIG. 61.—Interior of gate valve.

when change of direction is desired and it is found convenient to place the valve at this point.

The gate valve (known also as the straightway valve) has superseded the globe and angle types of valves on nearly all work, as it has so many important advantages in comparison. It should always be made use of on hot-water piping, owing to the fact that, when open, there is nothing to prevent the free flow of water through the valve. See illustration, Fig. 61.

Extra large globe and gate valves are frequently provided with a yoke or saddle, as shown by Figs. 62 and 63.

We have still another form of valve, known as the Cross Valve, which, in construction, is quite similar to the angle valve, with the exception, however, that it has two discharge openings instead of a single one. The cross valve is a convenient one to use when it is desired to discharge in opposite directions.

All of the above valves, shown in Fig. 57 to Fig. 63, inclusive, may be had in the larger sizes with flanges for bolting to companion flanges on the piping.

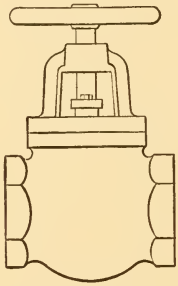

Fig. 62.—Globe valve with yoke.

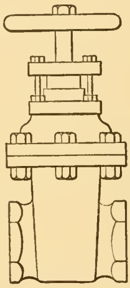

Fig. 63.—Gate valve with yoke.

When it is desired that the flow through a pipe should be in one direction only, the result is secured by the use of a form of valve, known as a Check Valve. It takes its name from the fact that it checks the reverse flow of steam or water in the pipe. These valves are of three varieties, the horizontal check, the vertical check and the angle check. The common type of check valve is what is known as the Swinging Check Valve, and is illustrated by Fig.

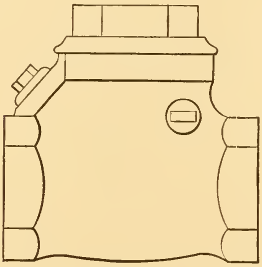

Fig. 64.—Swing check valve.

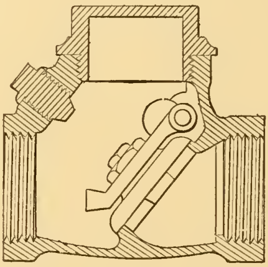

Fig. 65.—Interior of swing check valve.

64 and Fig. 65, the views showing the exterior and interior of the valve.

There are other types of valves manufactured for special purposes, but those as above described and illustrated are those generally used by the heating contractor.

Air Valves

Doubtless no portion of a heating apparatus has received more attention or has been more experimented with and improved than has the air valve. In all heating apparatus it is necessary to provide a means of escape for the air in the system, piping or radiators, and this is accomplished by the use of an air valve. The simplest form of an air valve is the compression valve. Fig. 66

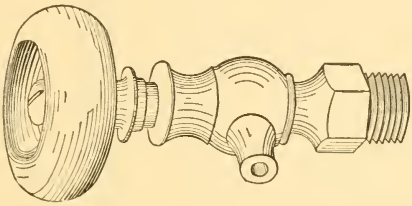

Fig. 66.—Wood wheel compression air valve.

shows the common type of a wood-wheel compression air valve. Fig. 67 shows the type of compression air valve as used on a hot-water system; this air valve is operated with a key.

While we wish our readers to become familiar with the various types of air valves, it would be next to impossible to illustrate or describe all of them in a book of this character, as there is such a multiplicity of styles. In fact, nearly all manufacturers of radiator valves also make several patterns or designs of air valves.

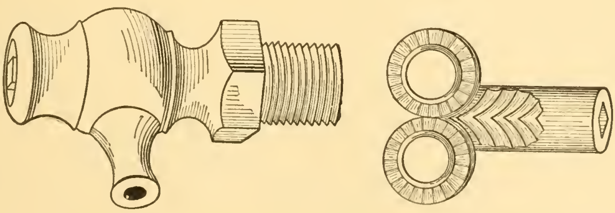

Fig. 67.—Lock and shield compression air valve.

Air valves are of two general kinds: *positive* and *automatic.* The positive type is of the compression variety, which we have already described and illustrated.

Automatic air valves are all made on the same general principle, although various different metals or substances are employed in their manufacture. Most of the automatic air valves close by the expansion of and open by the contraction of the metal or substance employed in the interior of the valve. The early types of automatic air valves are the Breckenridge, shown by Fig. 68 and Fig. 69, the Baker, shown by Fig. 70 and Fig. 71. In this type

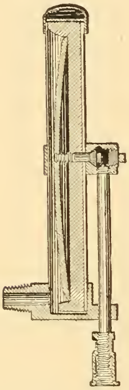

Fig. 68.—Breckenridge automatic air valve.

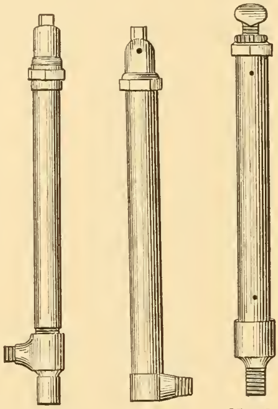

Fig. 70.—Baker automatic air valve.

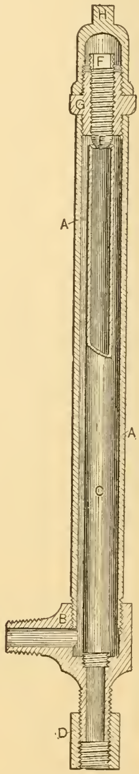

Fig. 71.—Interior of Baker automatic air valve.

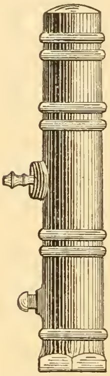

Fig. 69.—Breckenridge automatic air valve with drip.

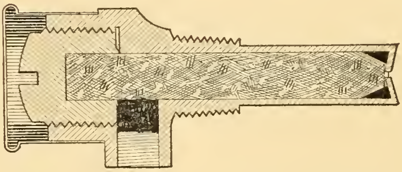

Fig. 72.—Interior of Victor automatic air valve.

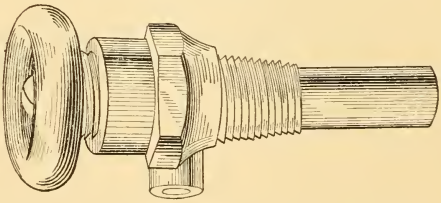

Fig. 73.—Victor automatic air valve with wood wheel.

of valve the strip of brass or tube used in the interior of the valve, when expanded by contact with the steam, will seat or close the valve, which will again open when the steam pressure is removed.

As automatic valves are now manufactured, the expansion post or tube is made of carbon or a composite material, which will expand more quickly than metal, as shown by Fig. 72 and Fig. 73. Others are made with a combination of the expansion post and a float, which temporarily closes the valve should there be any water forced through the air-valve opening of the radiator. Fig. 74 shows an air valve of this type.

Still another variety is that shown by Fig. 75. The float of this valve is sealed and contains a liquid extremely sensitive to

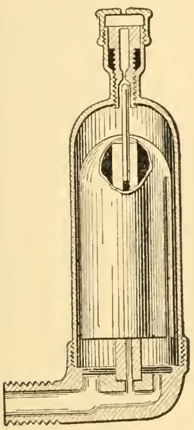

Fig. 74.—Automatic air valve with expansion post and float.

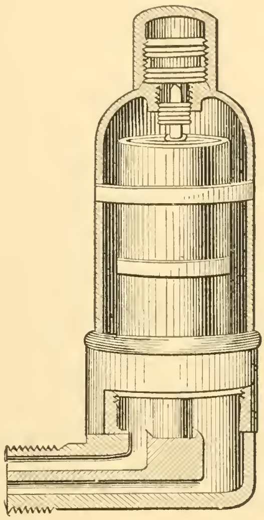

Fig. 75.—Russell automatic air valve.

heat, which vaporizes at a temperature of 151° Fahr., expanding the ends of the float, which are corrugated, closing the valve.

Some makes of air valves are provided with a vacuum attachment, which, working in connection with the float and expansion post, allows the air to escape under pressure from the steam, closing against the steam when all air is expelled. When the steam pressure is removed, or the system is cooled, the attachment effectually closes the air port preventing the return again of air through the valve. Thus the system is placed under a partial vacuum.

One of the greatest of the troubles that the steam fitter has to contend with is air in the system. The radiators or radiating surfaces becoming air bound, the steam cannot enter, nor the hot water circulate. It is of importance then that the steam fitter should use a type of air valve which will effectually do the work required.

CHAPTER VIII

Forms of Radiating Surfaces

One of the most interesting parts of the study of the science of steam and hot-water heating is to be found in following up the improvements in the beauty and utility of the radiating surfaces employed in the distribution of heat. Perhaps no part of a heating apparatus shows so well the effort of "Yankee" ingenuity

Fig. 76.—The Verona radiator.

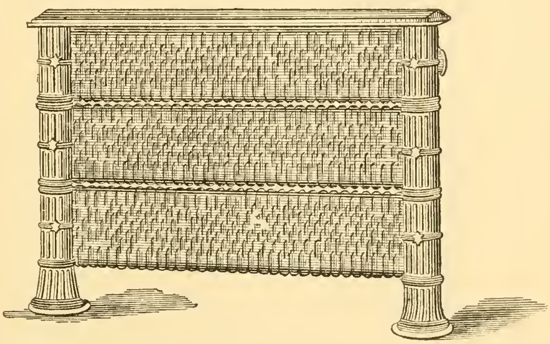

Fig. 77.—The Whittier radiator.

as the various styles of heating surfaces we to-day call radiators, for the radiator is of American origin.

From the old pipe box coil, or the "pan" radiator made of sheet iron, to the American Radiator Company's "Verona," as shown by Fig. 76, or, in fact, almost any one of the present ornamental cast-iron radiators, is an achievement of which any person connected with the heating industry may be justly proud.

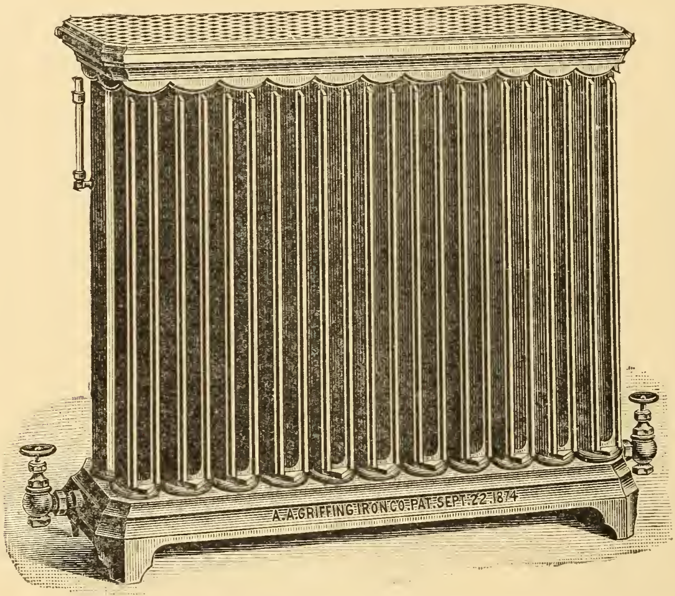

FIG. 78.—The Bundy loop radiator.

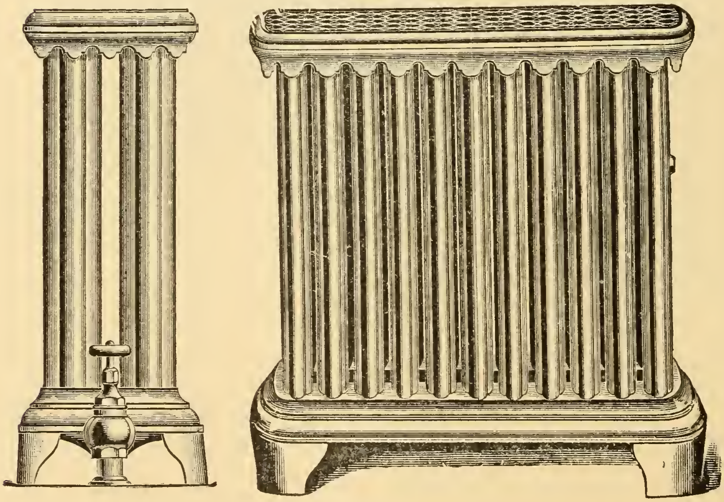

FIG. 79.—The Reed radiator.

It is probable that the first direct radiator to be manufactured and sold in any quantity was the original "Bundy" radiator, made with a cast-iron base into which were screwed short lengths of one-inch pipe capped at the top and covered with a cast-iron

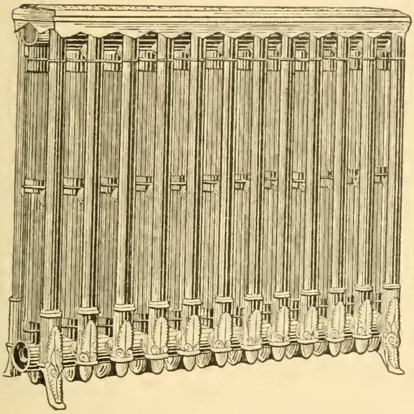

FIG. 80.—The Union radiator.

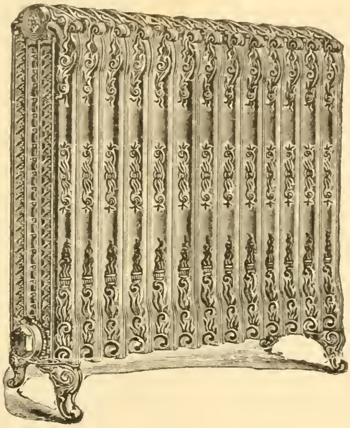

FIG. 81.—The Pyro radiator.

fretwork top. This was followed by other makes of pipe-tube radiators of similar design.

The first of the cast-iron direct radiators were the "Whittier,"

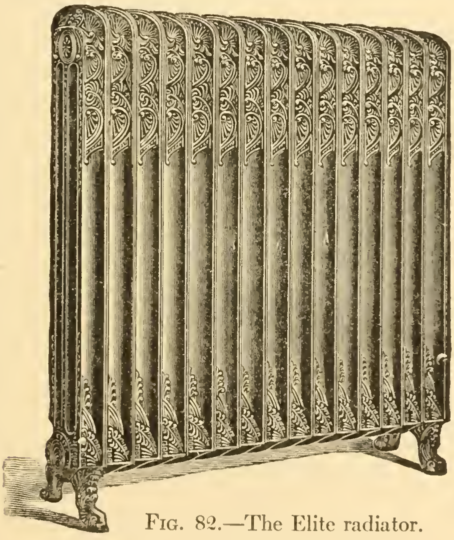

FIG. 82.—The Elite radiator.

Fig. 77, and the "Bundy" loop radiator, shown by Fig. 78. These radiators were placed on the market about the year 1873 or 1874, the former by the H. B. Smith Co. and the latter by the

A. A. Griffing Iron Co. Improvements in design and manufacture followed almost immediately, the H. B. Smith Co. bringing out the "Reed" radiator, Fig. 79, and still later the "Union," shown by Fig. 80. The A. A. Griffing Iron Co. followed the "Bundy" with the "Pyro," Fig. 81 (1876), and the "Elite," Fig. 82 (1877). The Exeter Machine Co., of Exeter, N. H., were early in the field with the "Exeter," a cast-iron radiator of double-tube construction.

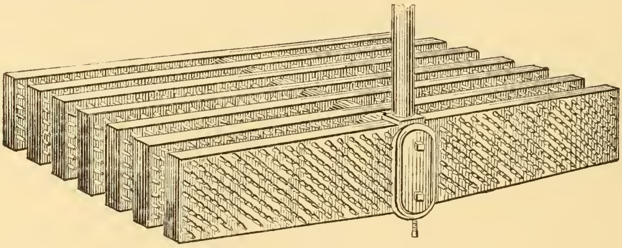

Fig. 83.—The Gold Pin indirect radiator.

Of the cast-iron indirect radiators the "Gold" pin radiator, Fig. 83, was the first, the original being manufactured as early as 1862, and is no doubt the oldest of the cast-iron radiators in any form used for heating. The illustration shows the improved style which, however, is quite similar to the original.

The "Bundy Climax," Fig. 84, is another type of the early indirect radiators.

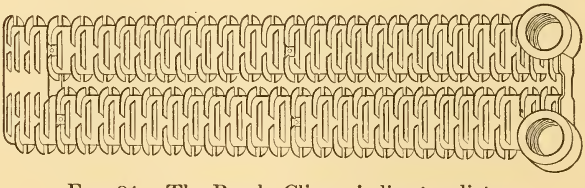

Fig. 84.—The Bundy Climax indirect radiator.

Radiators may now be obtained in numerous heights and widths to fill any desired space and in a multitude of designs of ornamentation, which when properly decorated become a thing of beauty as compared with the ugly looking box coil. Illustrative of this we show a low-down window radiator, Fig. 85, of such a height that a seat may be built over it, thus making not only a warm and comfortable window seat, but adding also largely to the beauty of the room.

Pipe coils in residence heating have been almost entirely superseded by what is known as the Wall Radiator, Fig. 86. This

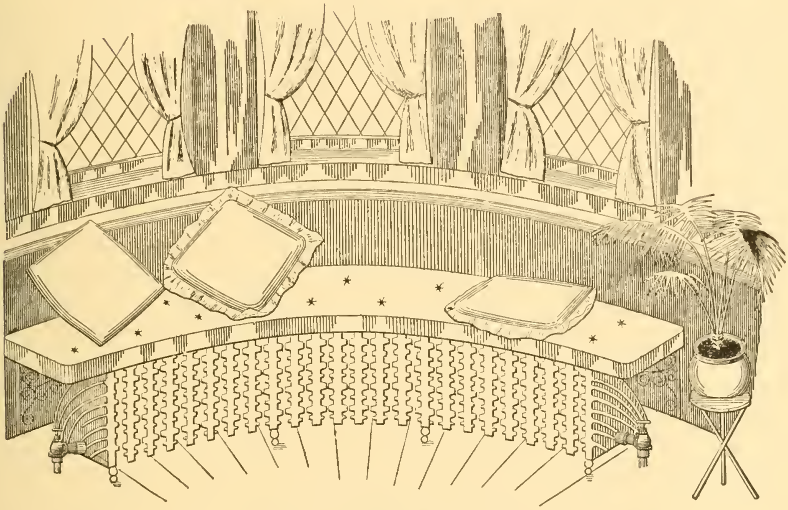

Fig. 85.—Window radiator.

type of radiator is largely used in narrow halls, bath rooms, or in fact, any place where there is an abundance of wall space and

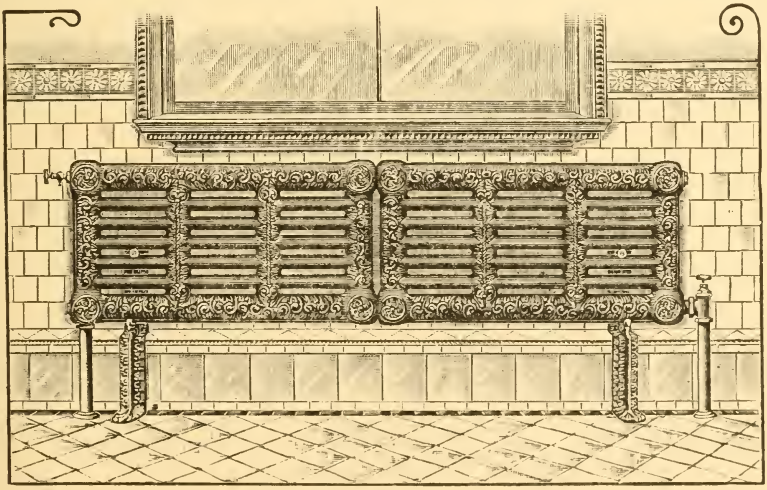

Fig. 86.—Wall radiator.

but little floor space, and while not so effective as a pipe coil, is much more effective than the regular type of radiator.

Cast-iron radiators, direct and indirect, and direct-indirect, are now manufactured by many concerns, the largest of which is the American Radiator Company, originally formed by the merging of the Pierce Company, of Buffalo, and the Detroit and Perfection Radiator Companies, of Detroit. The extremely large output of this concern, together with the other manufacturers of radiators, bears witness to the great popularity of steam and hot-water heating in this country.

Pipe Coils

Pipe coils are still used largely on factory or other work where their appearance is not objectionable. There are several styles of pipe coils as generally used. Fig. 87 illustrates the Miter Coil

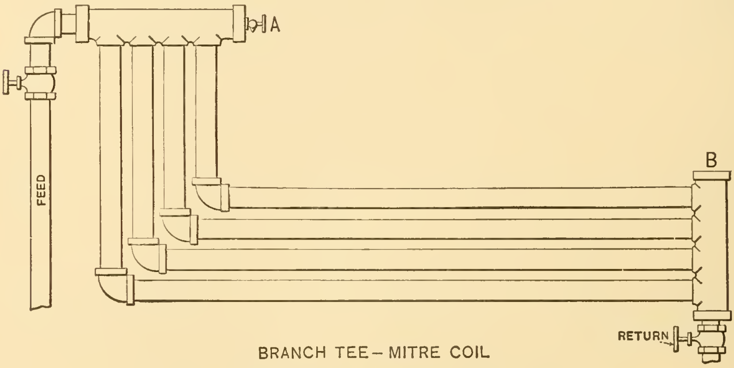

FIG. 87.—Mitre pipe coil.

made with branch tees and right and left elbows. The position of the air valve, as shown at A, is for hot water. If for steam, the coil should be vented at end marked B and the air valve should be placed on the branch tee just above the lowest pipe of the coil. In building all coils used for steam, expansion must be provided for, and the angles in this style of coil formed by the right and left elbows provide for the expansion. It should always be used on walls at the position shown in the illustration, with the miter end up, and it may also be used as a ceiling coil.

Fig. 88 shows the Corner Coil. This coil as shown and vented is for hot water, but may also be used for steam.

The Return Bend Coil, Fig. 89, is not so good for steam

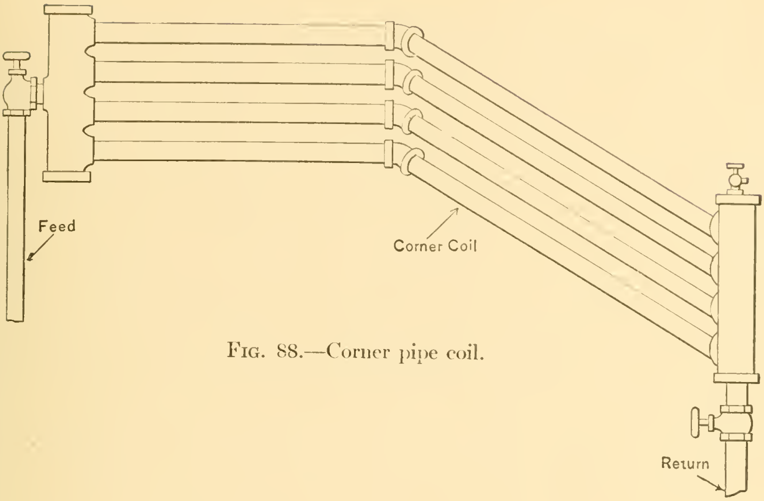

Fig. 88.—Corner pipe coil.

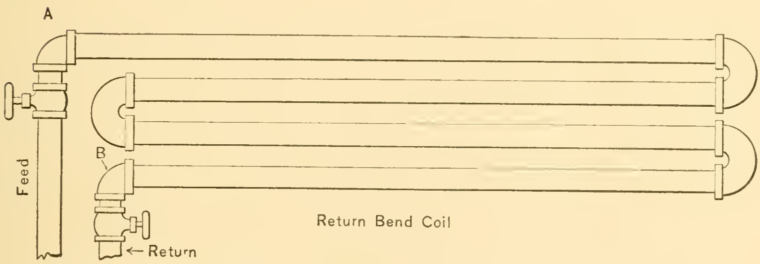

Fig. 89.—Return bend pipe coil.

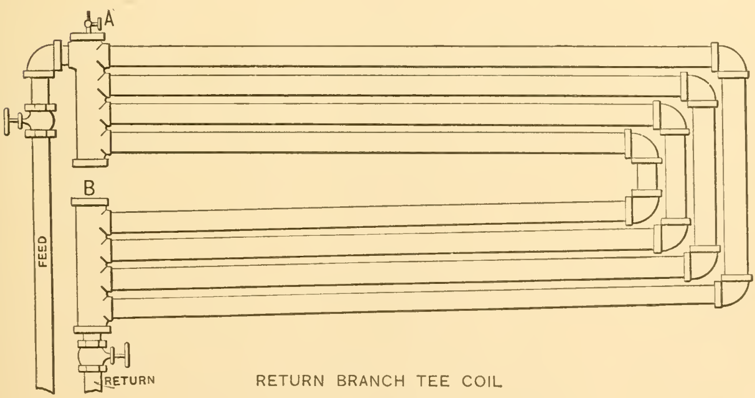

Fig. 90.—Return branch tee pipe coil.

as either of those already mentioned, as the steam must travel through the entire coil in a single pipe. When used for steam it should be vented at B; when used for hot water it should be vented at A.

Fig. 90 illustrates the Return Branch Tee Coil. Where the length of wall space is limited, this is a very compact type of coil

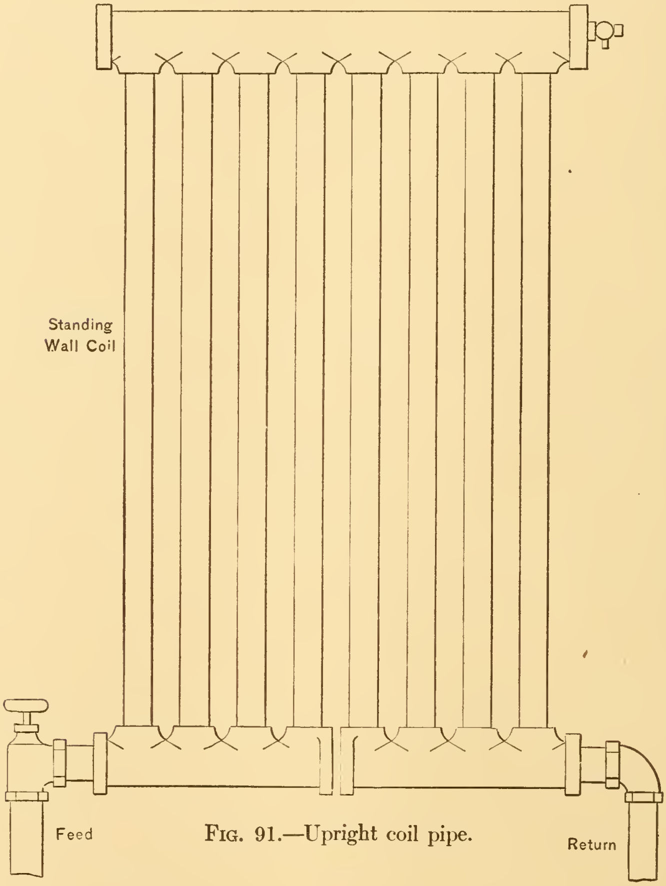

FIG. 91.—Upright coil pipe.

to use. It is made with one set of right hand elbows, the other set being right and left hand elbows. When used for hot water, vent as shown at A; when used for steam, vent at end marked B, but place vent lower down on the coil, as recommended for coil shown by Fig. 87.

A style of coil used for hot water is shown by Fig. 91. Do not use a coil of this character for steam, as suitable provision is not made for expansion and trouble would ensue.

To those who have had no very great experience in building coils it may not be amiss to say a few words regarding coil building. There are many methods of procedure, any one of which when the details are properly worked out will result in a neat and well-proportioned coil.

We will take the miter coil for illustration, and our method is as follows: Determine the center to center measurements of the openings of the branch tees to be used and with an ordinary chalked

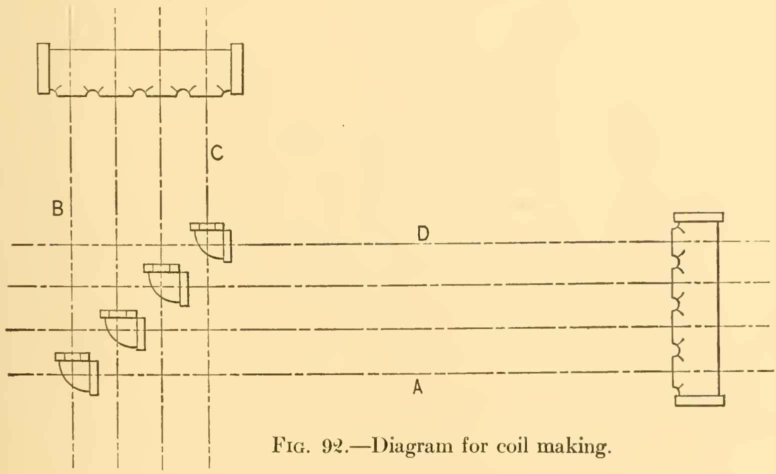

FIG. 92.—Diagram for coil making.

line snap as many chalk lines upon the shop floor as there are openings in the branch tees to be used, making the distance between the lines the center to center measurement of the openings in the branch tees. Calling these the horizontal lines, make at one end the same number of vertical lines the same distance apart. Determine the length and height of coil according to the space to be used, and then lay the branch tees and R. and L. elbows on the marks as shown by Fig. 92. It is well to have the left hand thread of the elbow looking toward the short or expansion end of the coil.

Accurate measurements for the pipes may now be taken. The line A is the longest pipe of the coil. The line B is the longest of the upright or expansion pipes. To make a symmetrical and neat appearing coil the shortest upright pipe C should be in length but one third that of D, the shortest horizontal pipe.

Cut right hand threads on each end of the long pipes and a right hand thread on one end of the short pipes and a left hand thread on the other end. Make the right hand side of the elbows on one end of the long pipes and make the other end of the pipe into one of the branch tees, with the elbows in proper position to receive the short end of the coil.

Fig. 93.—Coil partially completed.

This portion of the coil now looks as shown by Fig. 93. Next begin with the pipe marked C on Fig. 92 and make this up in the usual manner of making right and left hand connections, following with the next shortest pipe and so on until coil is completed. While yet on the shop floor, see that the alignment of the pipes is perfect. If not, make it so, when the coil is ready to hang in position.

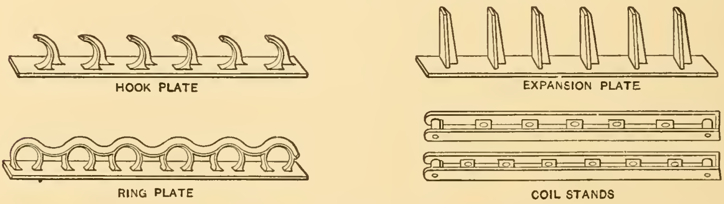

Fig. 94.—Hook plates and coil stands.

The same general method of laying out measurements is used in making all styles of coils. Wall coils are held in place by hook plates fastened singly or in groups, as shown by Fig. 94. Ceiling coils are hung or suspended by different forms of hangers so arranged as to give the proper pitch or drip to the coil and to allow of expansion and contraction.

CHAPTER IX

Locating Radiating Surfaces

The proper location of the radiator, whether direct, indirect, or direct-indirect, has much to do with the success of a heating plant.

Direct radiators should be located on outside walls or under the windows of the most exposed parts of a building. Indirect radia-

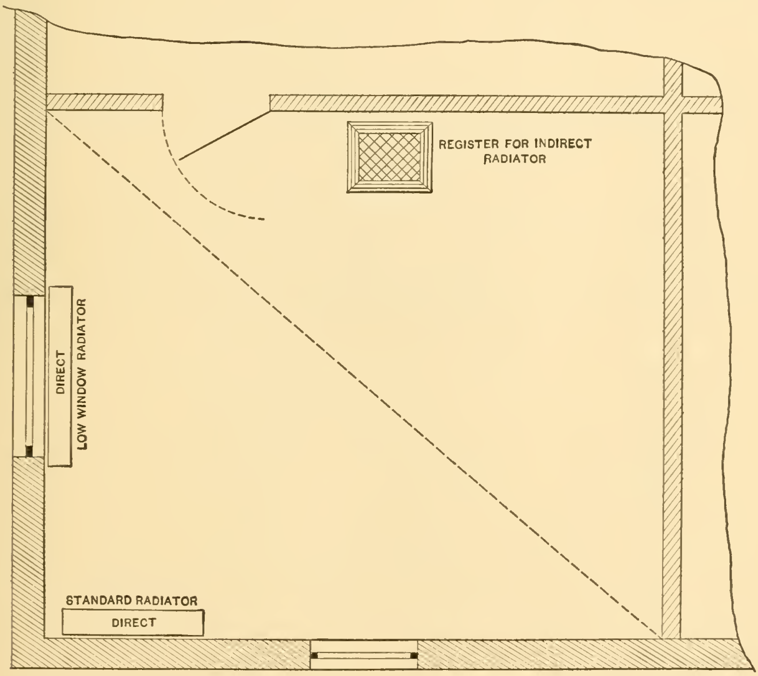

FIG. 95.—Locating radiators and registers.

tors, or more properly speaking, the register openings from indirect radiators, should be located on the warmer or less exposed side of the room. With direct-indirect radiators it is well, if possible, to place them under windows. To illustrate this we show by Fig. 95 a room with two walls exposed. The dotted line dividing the room cornerwise shows the warm and cold or exposed parts of the room. If heated by a direct radiator, it should be located in either of the positions shown, and if heated by indirect radiation the register should be located in the floor or wall at or near either position shown on the illustration.

When called upon to place and box an indirect radiator the steam fitter frequently becomes confused. As an aid to the proper hanging and boxing of indirects we shall illustrate and describe the usual methods followed.

Fig. 96 shows a method of installing an indirect where the hot-air flue and register are placed in the wall. Figs. 97 and 98 show

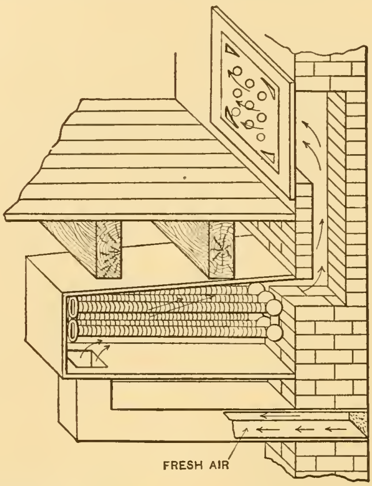

Fig. 96.—Indirect radiator—register in wall.

two methods of installing indirect radiators when floor registers are used. The casing or boxing should fit snugly against the radiator sections in order that the air will pass through the radiator and not around it, and the cold-air supply or duct should always be provided with a damper. It is well to take the hot-air duct from the boxing at the end opposite to that where the cold air enters in order that the air will travel as great a distance through the radiator sections as possible.

A number of sections of indirect radiation when nippled or bolted together are usually referred to as a " stack " of indirect radiation, or as an "indirect stack." The space between the top of a stack and the casing should be from eight to ten inches and the space between the bottom of the stack and the lower side of the casing should be six or eight inches.

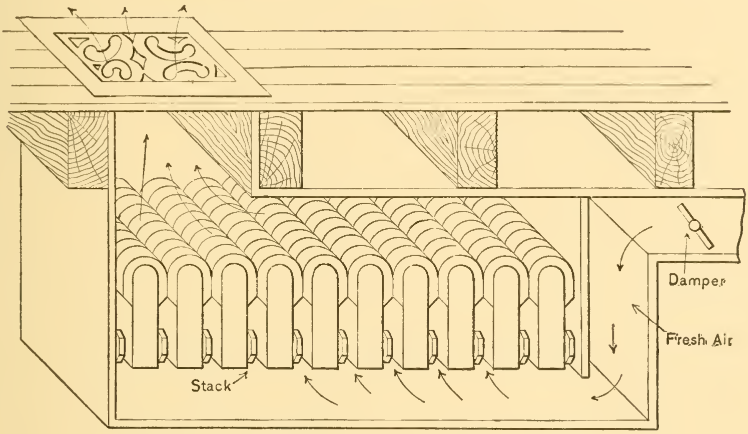

FIG. 97.—Indirect radiator—register in floor.

The hot-air supply or area of the hot-air duct should be, for hot water, 2 sq. in. of area, or for steam $1\frac{1}{2}$ sq. in. of area for each sq. ft. of radiation in the stack. As a general rule, the cold-

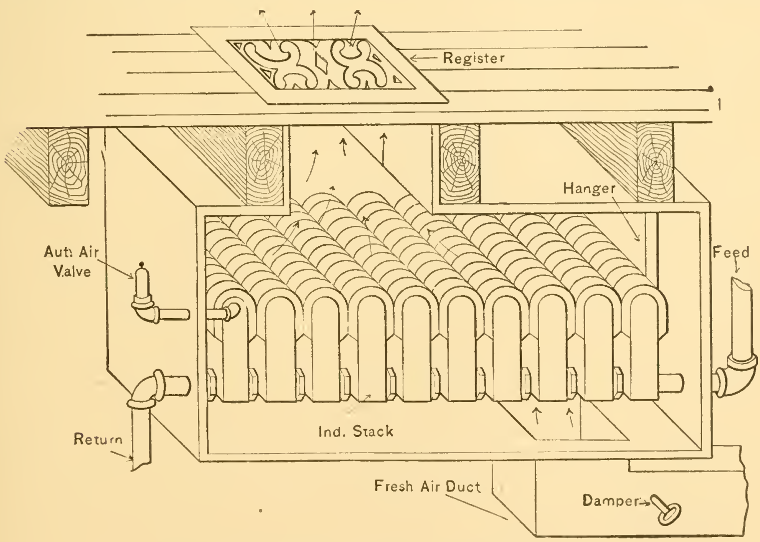

FIG. 98.—Indirect radiator—register in floor.

air supply or area of the cold-air duct should be from two thirds (66⅔%) to three fourths (75%) of the area of the hot-air flue. Circumstances vary these figures somewhat, but the above represents a fair average. The following table gives the proper sizes of hot and cold air ducts and sizes of registers for both steam and hot-water indirect heating under ordinary conditions.

TABLE X

Indirect Work.—Sizes of Cold and Hot Air Ducts and Registers—For First Floor

Indirect Hot Water				Indirect Steam			
Sq. ft. of Heating Surface.	Sq. in. Cold-air Duct.	Sq. in. Hot-air Duct.	Size of Register.	Sq. ft. of Heating Surface.	Sq. in. Cold-air Duct.	Sq. in. Hot-air Duct.	Size of Register.
26	36	48	8×12	13	36	48	8×12
52	54	72	9×12	26	54	72	9×12
78	72	96	10×14	39	72	96	10×14
104	96	120	12×15	52	90	120	12×15
130	108	144	12×19	65	108	144	12×19
156	126	168	14×22	78	126	168	14×22
182	144	192	14×24	91	144	192	14×24
208	162	216	16×20	104	162	216	20×20
234	180	240	16×24	117	180	240	20×24
260	198	264	20×20	130	198	264	20×24
286	216	288	20×24	143	216	288	24×24
312	234	312	20×24	156	234	312	24×24

Note.—Registers and hot-air ducts to upper floors should be from 25 to 30 per cent. smaller than for first floor as given above.

It is well to be generous in the size of flues, as if properly dampered they may be reduced at any time as desired.

There are two good methods in vogue of hanging a stack of indirect radiation. Fig. 99 shows one method,—that of eye bolts screwed into the joists, suspending a cross bar of pipe on which the stack rests. Fig. 100 shows another method and one which we favor, owing to the fact that the weight of the radiator is distributed across several joists. Heavy stacks suspended on a pair of supports or hangers in this manner will not weaken or strain the flooring as much as when the former method is employed.

Casings may be made of wood lined with tin or of sheet iron, as may be desired. A casing of galvanized iron with joints seamed or bolted together is without doubt the best method to use, as it not only presents a neat appearance, but is the most durable.

Fig. 101 shows the method of setting a direct-indirect radiator

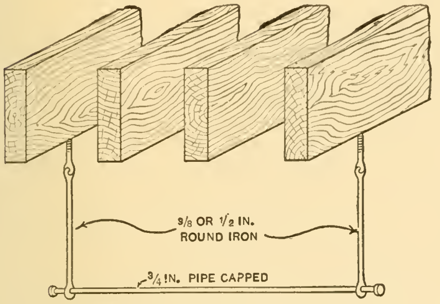

Fig. 99.—Method of supporting indirect stack.

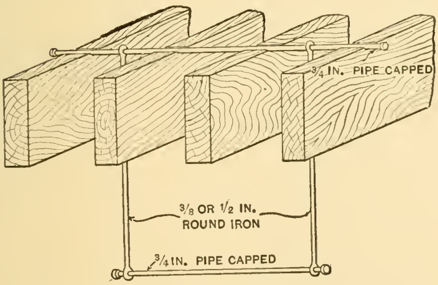

Fig. 100.—Another method of supporting indirect stack.

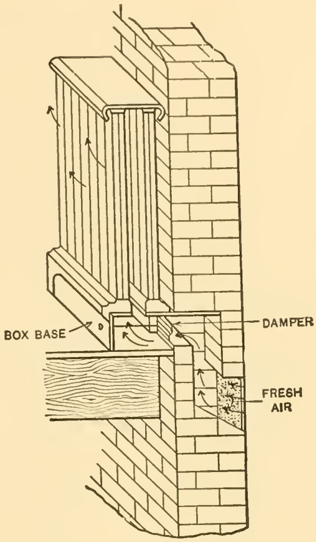

Fig. 101.—Method of setting direct-indirect radiator.

and while there are several modifications of this style, the principle for the setting of all direct-indirects is the same.

The wall boxes, Fig. 102, are of standard size, conforming to brick measurements and are furnished by all manufacturers of ra-

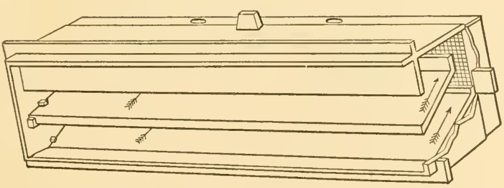

Fig. 102.—Wall box for direct-indirect radiator.

diators. The radiator itself is of the ordinary direct pattern. It is fitted with and rests on a box base. This base is provided with a damper and is connected to the cold-air wall box by a boxing made of galvanized iron or tin. Fig. 103 shows a base of this kind. By closing the damper to the cold-air duct and opening the damper in the box base, the radiator may be used as a direct radiator. This

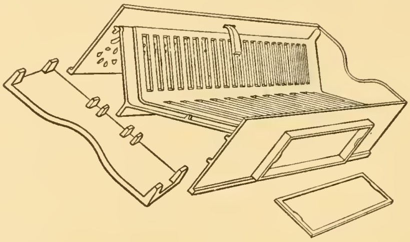

Fig. 103.—Box base for direct-indirect radiator.

is of importance in connection with the heating of a cold room or when ventilation is not necessary.

The "flue" type of radiator is the best design for direct-indirect, owing to the length of air travel through the flues between

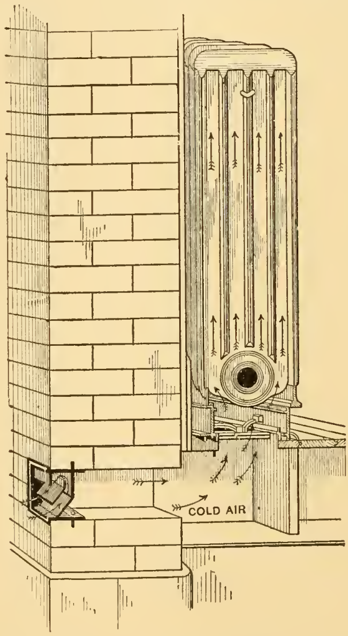

Fig. 104.—Flue type of direct-indirect radiator.

the sections. Fig. 104 shows a section of a flue radiator. By reference to the following chapter our readers will learn why we believe a radiator of this type is best adapted for work of this character.

CHAPTER X

Estimating Radiation

Having considered the various forms of radiating surfaces and their proper location, we have now reached that part of the work which the steam fitter frequently finds confusing, viz.: the estimating of radiation. This requires careful thought and study on the part of the steam fitter, as no two jobs of heating are alike, excepting, of course, there be two buildings erected from the same plans; therefore, each job or contract for heating must be considered separately and the radiation estimated accordingly.

As a rule, all radiation is first estimated as direct, that is to say, the amount of direct radiation necessary to do the work required, and certain percentages are added if the radiation or any portion of it is to be direct-indirect or indirect.

Many good rules are in vogue for estimating, any one of which will give proper results if applied with good judgment, but just as there are exceptions to all other rules, so that it is in estimating radiation. To use good judgment it is necessary that we should understand something of the cooling surfaces in a room or building, the action of the heat from a radiator upon the air in a room and the heat loss from a radiator under certain varying conditions.

The principal cooling surfaces of a room are the exposed or exterior walls and the glass surface (windows) and outside doors. A room with two sides exposed, for instance, a corner room, will require more radiation than an intermediate room with but one wall exposed, while a room having two windows and an outside door will require correspondingly more radiation than a room with but one window. Just how much more is determined by rule.

Again, if there be no objects such as trees or adjacent buildings to protect any one of the sides of a house, the north, west, or northwest rooms will need more radiating surface than the rooms on the south, east, or southeast sides of the building. The reason for this is readily seen, as practically all the chilly winter winds come from the north, west, or northwest.

A frame building without weather board or paper used in its construction requires more radiation than one with this additional protection, and either one requires more than a brick or stone building.

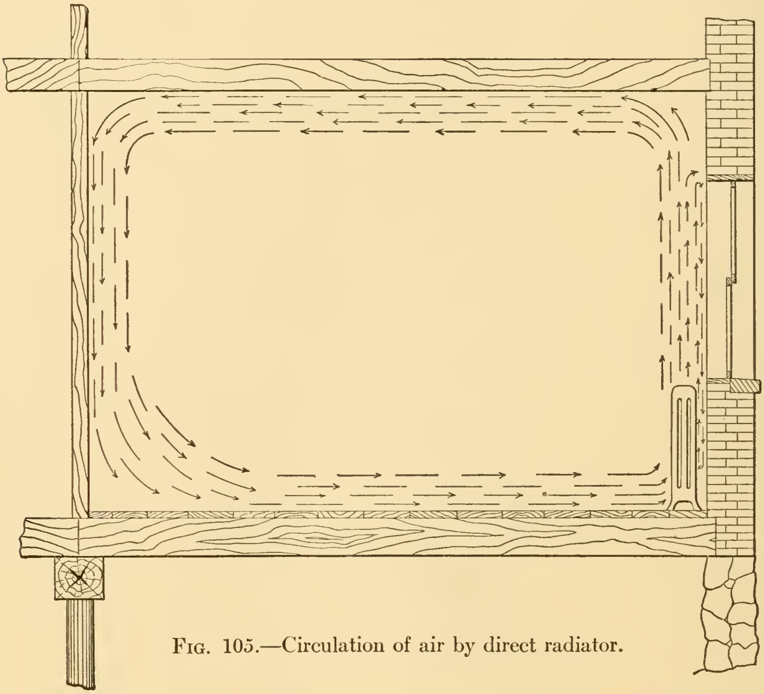

Fig. 105.—Circulation of air by direct radiator.

As to the action of the heat from a radiator upon the air of the room, the radiator, if direct, should be placed in the coldest place in the room, as stated in the preceding chapter, for the reason that it meets and warms the cold air entering through the outside walls and windows, tempers and heats it, causing it to circulate or turn in the room, thus warming all portions of the room to a uniform temperature.

Fig. 105 shows the action of a direct radiator upon the air in a room, the arrows indicating the direction of the air currents. We note that the heated air first rises to the ceiling where the air of the room is lighter than below, then passes to an inside wall, where it is forced downward and drawn across the floor again to the radiator, where it receives the same treatment as before, the rapidity of the circulation depending upon the volume of heat from the radiator. Note also the downward draught of the cold air entering at the window, and how it is prevented from entering the

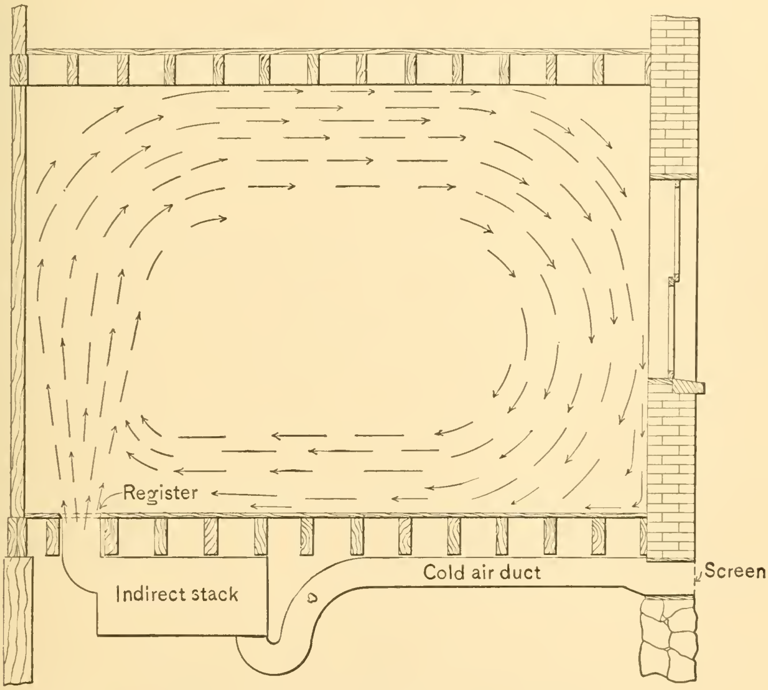

FIG. 106.—Circulation of air by indirect radiator.

body of the room. Should the radiator be placed along an outside wall between two windows, or in a corner, the cold air entering through the windows would pass downward to the floor and then be drawn along the floor to the radiator.

Heat, or more properly, heated air, from an indirect radiator passes directly to the ceiling, then across to the windows or outside wall where, as it cools, it settles to the floor and is drawn across the floor again to the register as shown by Fig. 106. It is for this reason that churches or rooms with very high ceilings are very difficult to heat with indirect radiation without the assistance of some direct radiators to aid in turning the air of the room.

Where direct-indirect radiation is placed the action upon the air in the room is similar to that of the direct radiator as shown by Fig. 105.

Rules for Estimating Radiation

Some one has aptly said, "We gain knowledge and profit by the mistakes of others," and truly this is exemplified in figuring radiation. Many years ago the writer was taught to estimate radiation by the following rule:

For Steam

To ascertain the amount of radiation required find the cubical contents and divide the result by the following factors:

Living rooms, ordinary exposure	50
Living rooms, extraordinary exposure	40
Bath and dressing rooms	40
Staircase halls	50– 70
Sleeping rooms	55– 70
School rooms	60– 80
Churches, theaters, halls, etc.	65–100
Factories	75–150

For Hot Water

Add one third to the result obtained for steam.

For direct-indirect, add twenty-five per cent, and for indirect, add fifty per cent.

It will readily be seen that the results obtained by this old rule, which is now almost entirely obsolete, were anything but correct, and unless the person using the rule was thoroughly conversant as to the requirements of certain rooms, or was endowed with extraordinary good judgment, many errors would result. Yet many heating contractors are to-day using this rule or some other "rule of thumb" just as antiquated.

Some Dependable Rules

Baldwin's Rule: Divide the difference in temperature, between that at which the room is to be kept and the coldest outside atmosphere, by the difference between the temperature of the steam pipes and that at which you wish to keep the room, and the product will be the square feet, or fraction thereof of plate or pipe surface to each square foot of glass (or its equivalent in wall surface).

Thus: Temperature of room, 70 degrees; less temperature outside, 0; difference, 70 degrees. Again: Temperature of steam pipe, 212 degrees; less temperature of room, 70 degrees; difference, 142 degrees. Thus: 142 ÷ 70 equals 0.493, or about one-half a square foot of heating surface to each square foot of glass, or its equivalent.

The above covers only the exposure of the room and is for a well-built building. Loose windows, poor construction, etc., must be taken into consideration and the proper allowances made.

Another rule (and the one used by the author for quick figuring) is that of Mills, and briefly stated, is as follows:

To find the amount of radiation required to heat a room with low-pressure steam to 70° Fahr. when the outside temperature is at 0° Fahr., allow one square foot of radiation for each 200 cubic feet of contents, one square foot of radiation for each 20 square feet of outside wall surface, and one square foot of radiation for each 2 square feet of glass surface (counting outside doors as glass surface). The product of these results will be the amount of radiation required.

For hot water add 60 per cent to this result.

As an example consider a room 12′ × 15′ in size, having a 10 ft. ceiling. The cubical contents, found by multiplying 12 × 15 × 10, equals 1,800 cu. ft. One 12 ft. side is exposed wall:

$12 \times 10 = 120$ sq. ft. of exposed wall surface. The room has two windows $3 \times 6'$: $3 \times 6 = 18 \times 2 = 36$ sq. ft. of glass surface.

$$
\begin{array}{rrr}
1{,}800 \div & 200 = & 9 \\
120 \div & 20 = & 6 \\
36 \div & 2 = & 18 \\
\hline
\text{Total} & & 33 \text{ sq. ft. radiation.}
\end{array}
$$

For hot water: $33 \times 60\% = 19.8 + 33 = 52.8$ sq. ft. of radiation required.

It is the custom of the author to add 25% to the amount of direct for direct-indirect, either steam or hot water, and for indirect to add 50% for steam and 60% for hot water.

While there are many rules for estimating and some of them possibly a little more accurate than the above, we consider either Baldwin's or Mills's rule to be the simplest and best, as they are free from complicated methods not readily understood.

The author has found that it was excellent practice to increase the radiation somewhat on the north and west sides of a building, also that when a building is heated intermittently (as is the case with some churches, halls, etc.) the radiation should be increased 25% over and above the normal amount required should the building be heated continuously.

It is well to become familiar with two or more rules, using one as a check upon the other.

CHAPTER XI

Steam-Heating Apparatus

In one of the early chapters of this book we gave a brief history of steam heating and its introduction in this country. We shall now take up the many various systems and consider the advantages or disadvantages of each, showing also the various styles of piping.

The early method of heating by steam was with the two-pipe system, small sizes of pipe being used and a high pressure of steam maintained. As our knowledge of steam heating increased, larger piping and a lower pressure were made use of.

At the present time there are many buildings, such as factories and offices, or commercial buildings, where a medium or comparatively high pressure is used, the steam being generated at high pressure by the boilers and reduced for use in the heating system. On work of this character the water of condensation is returned to the boiler by return steam traps or by a pump.

For the heating of residences and small buildings, we use what is called a "gravity system," the pressure of steam being from one to five pounds, the condensed steam returning to boiler by its own gravity. The boiler is located below the level of all mains and radiators. It is of this latter method that we shall treat, illustrating and explaining each system.

Low-pressure gravity steam heating may be divided into several systems or styles of construction, as follows:

(a) The one-pipe system, where the radiators are connected by a single pipe which is used both as flow and return.

(b) The two-pipe system, where each radiator has a separate flow and return pipe. This system also necessitates a double system of cellar piping.

These two methods may be subdivided into several styles or systems, viz.:

(a) The Circuit System.
(b) The Divided Circuit System.
(c) The One-pipe System with Dry Returns.
(d) The Overhead System.

Fig. 107 illustrates the regular circuit system. The steam main rises from the boiler as high as possible, or as high as circum-

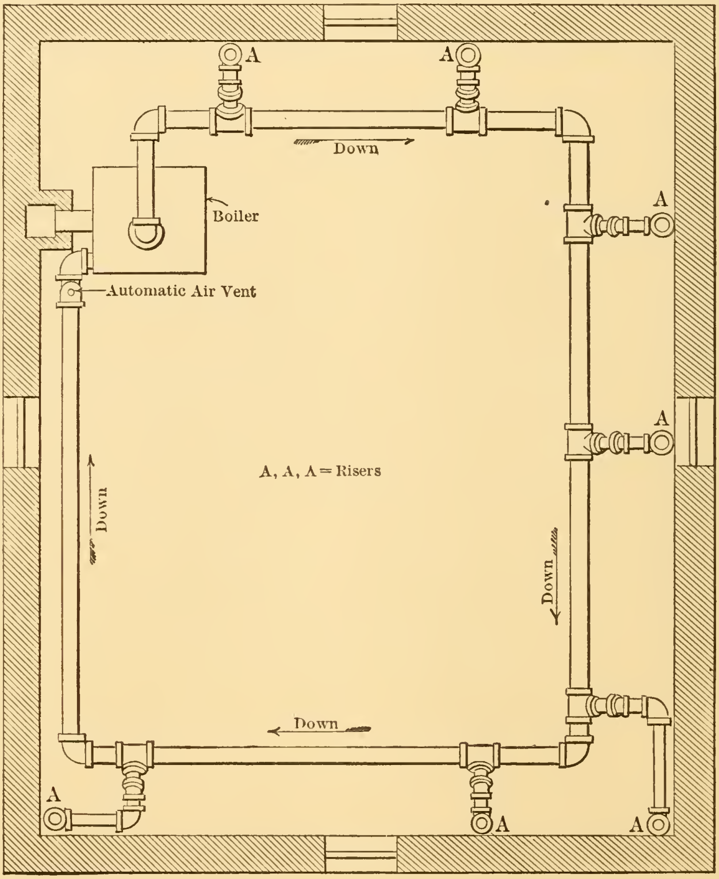

Fig. 107.—Circuit system of steam heating.

stances or height of basement will permit. This is the high point of the system, so far as the steam main is concerned. From this point the main makes a circuit of the building, as shown by illustration. This circuit is made at a distance of from two to six feet from basement wall (circumstances governing this distance), the main pitching downward from the boiler from ½″ to 1″ in each ten feet of length. In making the circuit of the basement, the main is carried to a point as near to the boiler as is possible. At this point a reducing elbow is placed on the end of the main, reducing one or two sizes. Connection is then made with return opening of boiler. This reducing elbow should be tapped for an air vent and an automatic air vent be placed on the same.

As the main acts as a steam reservoir to supply the various radiators, it is well to free it of all air, in order that the steam may be supplied to all radiators at the same time, thus allowing them to

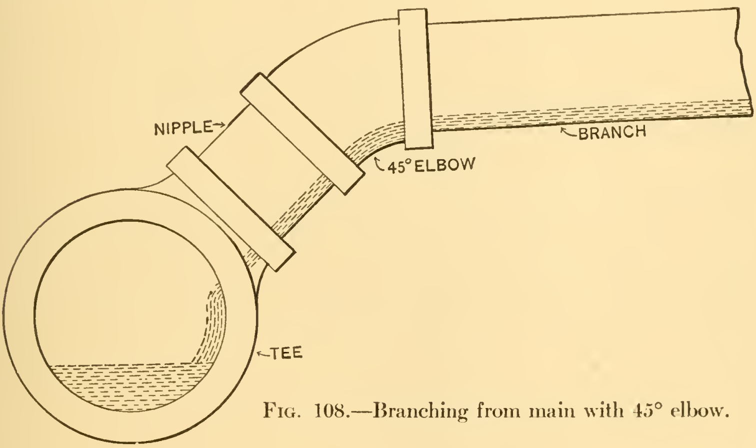

Fig. 108.—Branching from main with 45° elbow.

heat uniformly. The automatic air vent placed on the elbow at the end of the main accomplishes this purpose.

The various branches should be taken from the main by the use of a nipple and a 45-degree elbow, as shown by Fig. 108. As a general rule, the branches should be one size larger than the vertical pipe or " spud " supplying the radiator valve, or one size larger than the risers which they feed.

Most of the old-time steam fitters, as well as many fitters of the present day, make a practice of taking the connection for branch from the top of the main. This practice is wrong, as the condensation returning through the branch to the main drops directly into the steam supply, saturating and cooling it. Fig. 109 illustrates this. We may add, for example, that a main where all the branches are taken off with the use of 45-degree elbows, as shown by Fig. 108, will do 25% more work, and prove 25% more economical than if taken off main from the top.

Fig. 108 also shows how the water of condensation joins that in the main without interference with the steam, when 45-degree elbows are used.

The main on a circuit job of heating should not be reduced in size, but should be carried full size to point where air vent is used. The principal reason for this is that it is constantly being reduced

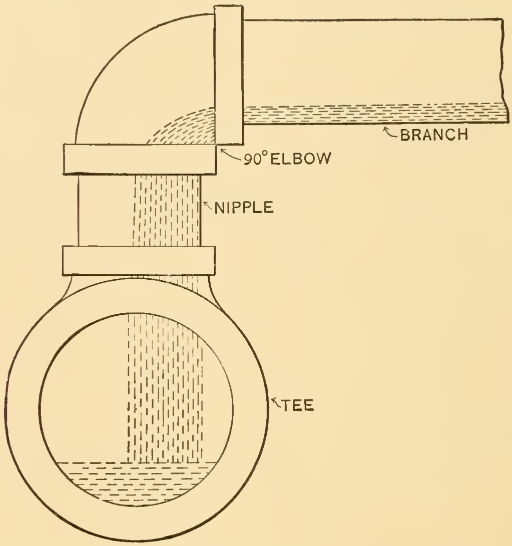

Fig. 109.—Branching from main with 90° elbow.

in area by the water of condensation from the various radiators entering it, so that its area at the end may not be more than one half the full capacity of the pipe.

The branches should have a pitch upward from main of at least 1″ in 5 feet of length, and a greater pitch is desirable. Special elbows, called pitch elbows, for use on end of branch, in order to throw the vertical spud or riser straight, may be purchased from those who deal in steam-fitting supplies.

Where the circuit system can be used to advantage, we would recommend it on account of its utility and good appearance. For an L-shaped building, it is necessary to take a separate loop from the main circuit, as shown by Fig. 110; otherwise the work is similar to the single loop.

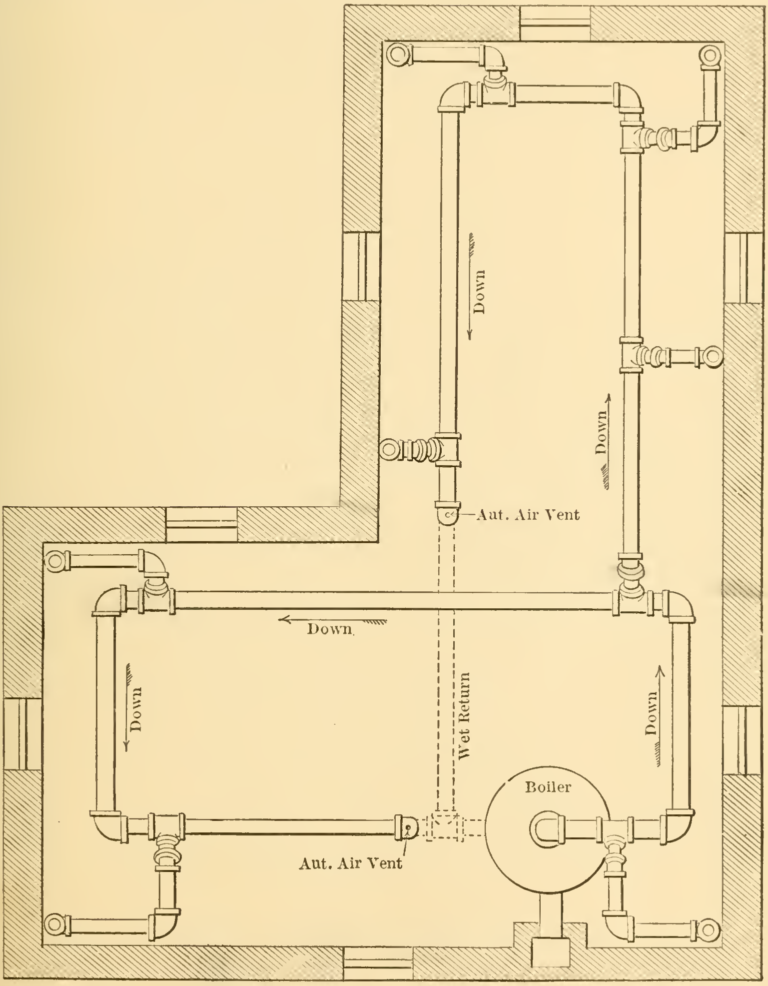

FIG. 110.—Circuit system of steam heating with loop.

The Divided Circuit System

When installing a steam-heating apparatus in a long building where the boiler is located near the center of the basement, and on either side of the same, we may use what is called the Divided

Circuit System, as illustrated by Fig. 111. The convenience of installing this system can be readily seen from the illustration. In installing this system and also the Single Circuit, it is well to keep the end of mains at least 14″ above the water line of the boiler. With the Divided Circuit System it is necessary that an automatic air vent be placed on the end of each loop. The returns should be connected together below the water line of the boiler, as shown by illustration.

The One-pipe System—Dry Returns

When it is necessary to install steam heat in a long, narrow building, such as one side of a double house, where the radiators are all placed along the outside wall, this system, as illustrated by Fig. 112, is particularly adaptable. The flow pipes, as shown, pitch downward from the boiler to end of main. On the end of main a reducing elbow is placed. Into this elbow is connected a close nipple with a 90-degree elbow on the end of same, and from this elbow the return is taken dry to the boiler, as shown. These elbows should be " thrown " or turned upward until the top of the return is level with the bottom of the main, in order to gain head room. A short piece of pipe, with crooked thread on one end, should be used in starting the return; the longer pipe should be attached to this piece with an ordinary coupling. In this manner the return may be taken to boiler almost directly under and parallel to the main, making a good appearing and workmanlike job.

At a point near the boiler, elbows should be placed on end of returns and drop made to return opening of boiler. These elbows should be tapped for air vent and automatic air vents placed on same.

Note the coil shown on illustration. All pipe coils should be connected " two pipe " with return connected below the water line of the boiler.

The Overhead System

The Overhead System of steam heating is necessarily a combination of the one and two pipe systems and it may have either a wet or a dry return, although the wet return is by far preferable. We illustrate by Fig. 113 an adaptation of the overhead system

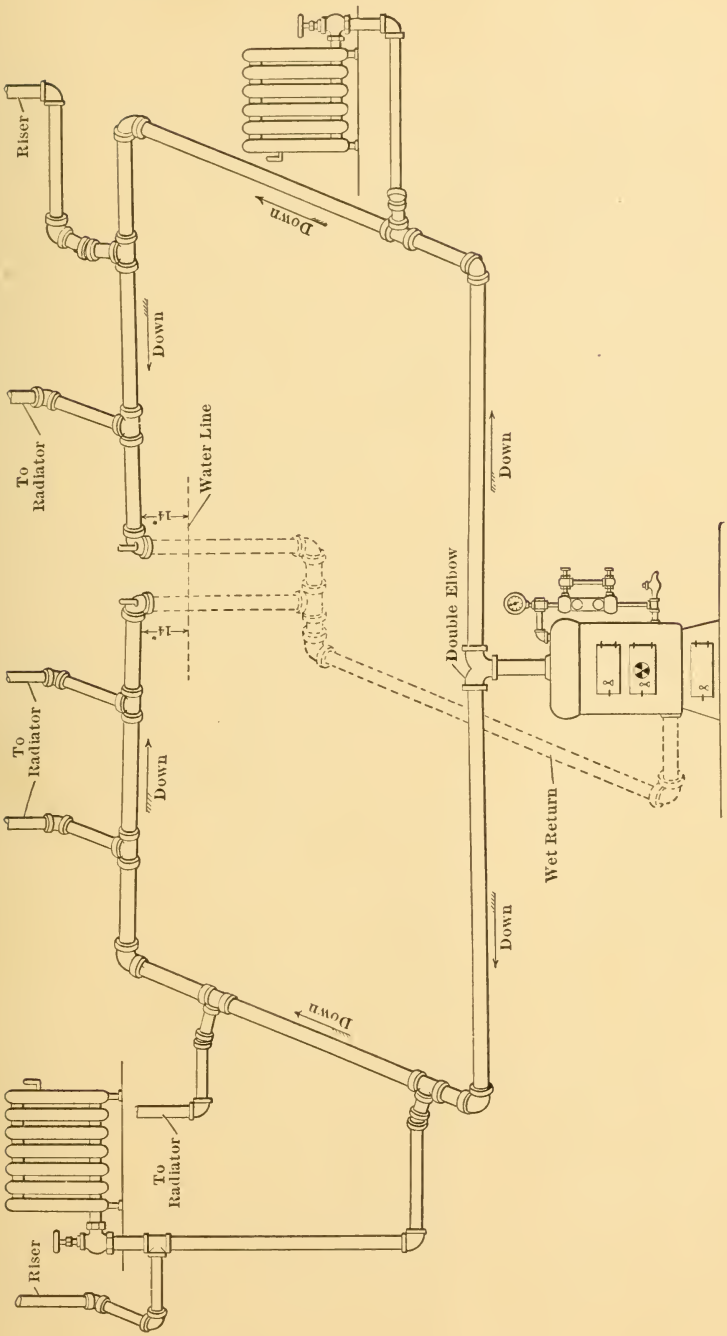

FIG. 111.—Divided circuit system of steam heating.

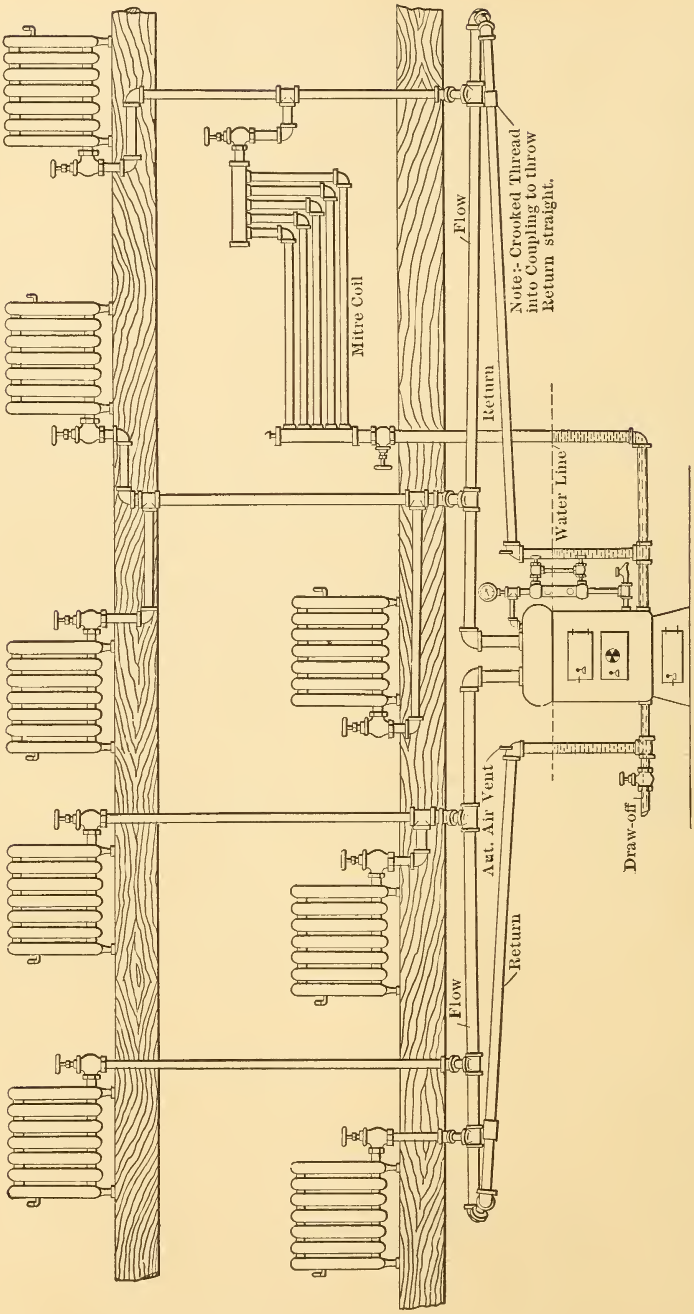

Fig. 112.—One-pipe system of steam heating dry returns.

and show the many different methods by which the radiators may be connected.

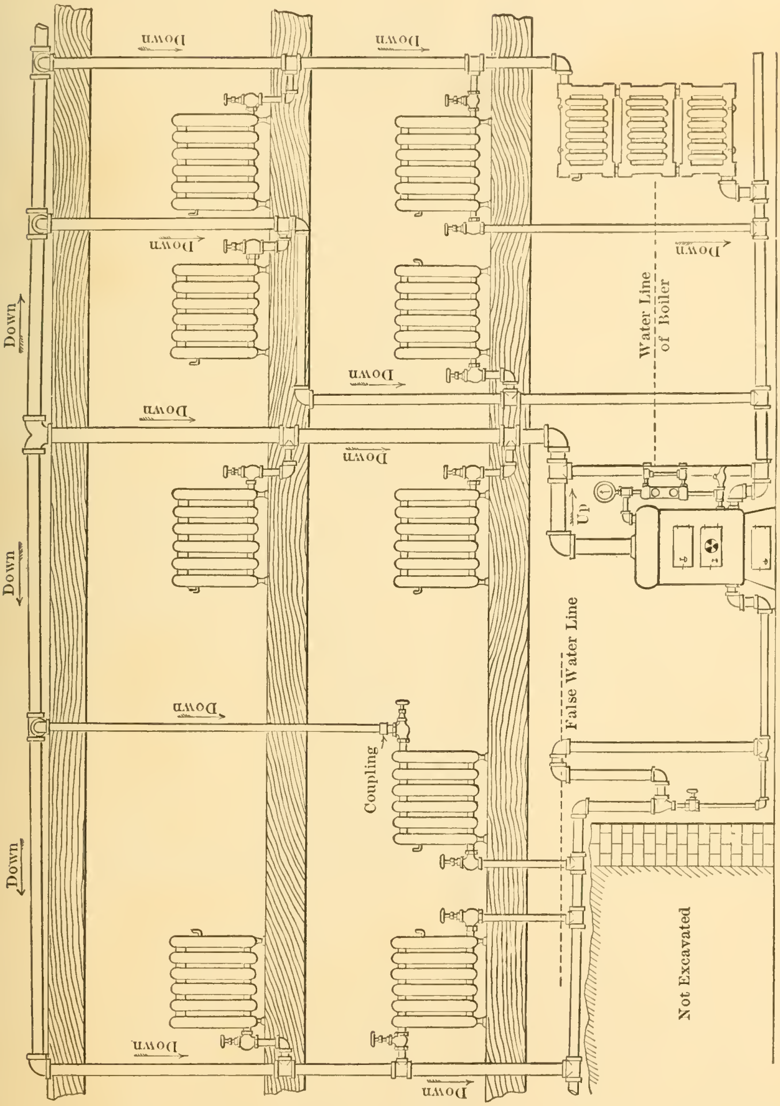

FIG. 113.—Overhead system of steam heating.

The riser or risers (there may be more than one) rise directly to the top floor or attic of the building and here branch in the several directions necessary to feed the various drop risers supplying the radiators. The branches connecting these risers are

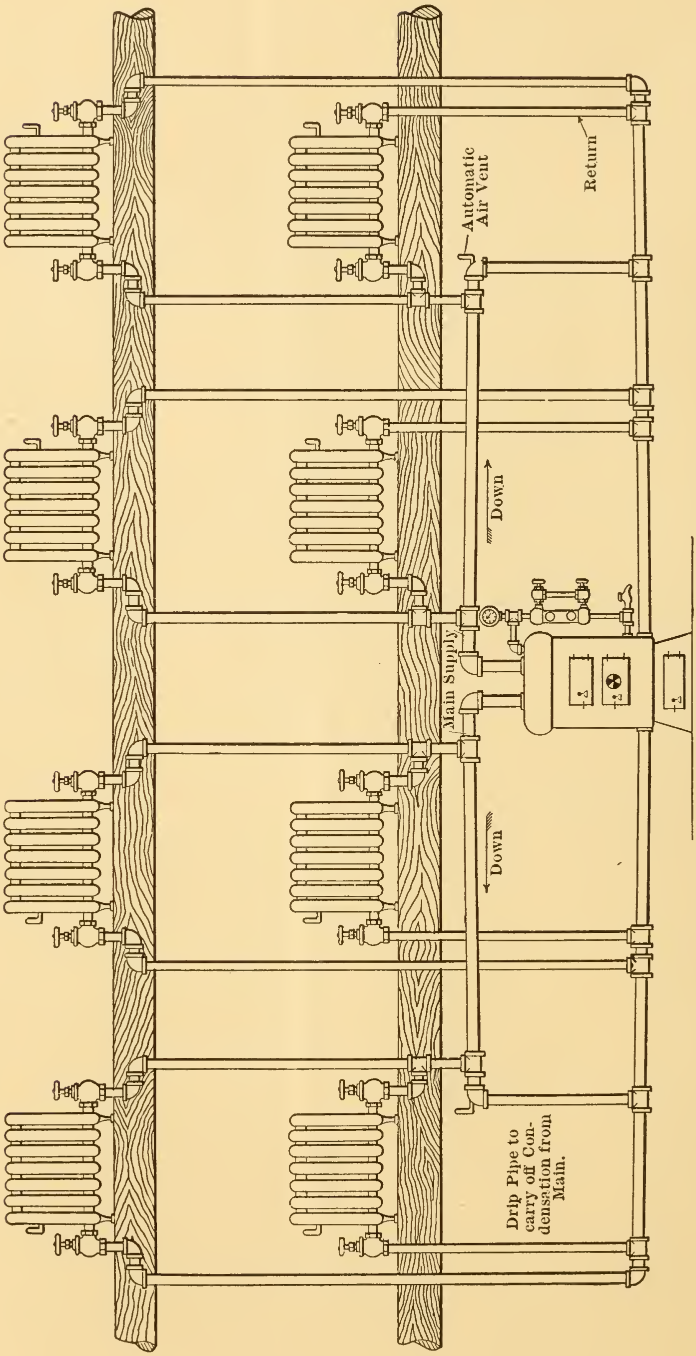

FIG. 114.—The two-pipe system of steam heating.

taken from the side of the main. Should it be necessary to run the main any considerable distance from the boiler in the basement before rising to top of building, it is well to "heel drip" the elbow at bottom of the riser and connect the drip with the wet return.

At the left of the illustration in the basement we show one method of creating a false water line, in order that the returns from risers in an unexcavated portion of the basement may be connected into a wet return. We shall in a later chapter illustrate and describe the false water line more fully.

At the right of the illustration we show in the basement a wall radiator for heating a basement room, which is warmed partially by steam, above the water line of the boiler, and partially by the water of condensation, below the water line of the boiler and is connected in such a manner, without valves, that it might be designated as a cooling coil. The illustration shown is composed of three sections of wall radiation, although a pipe coil could be used in the same manner.

The Two-pipe System

Illustrated by Fig. 114 we show the Two-pipe System of steam heating. This system has been discarded generally on ordinary work, being succeeded by the One-pipe System, although it still has some adherents among the fitters.

Smaller piping for both flow and returns and flow and return risers is used for this system than for either of those already described. The cost of installation will, however, exceed that of either style of the single-pipe systems. It is customary when using the

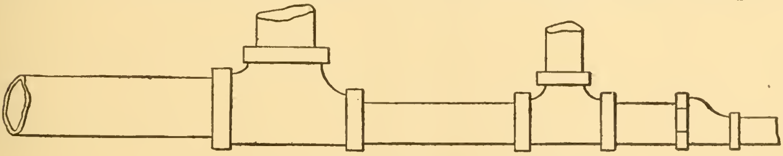

FIG. 115.—Eccentric fittings—the right method.

two-pipe system, to reduce the size of the main as the various radiators are taken off. We would caution against reducing the main too rapidly, as so much friction would result that it would be necessary to carry a considerable pressure at the boiler in order to supply the radiators at the far end of the system and this would thereby destroy the economical features of the job. Whenever the main is reduced, a tee should be used and a drip connected to return, or, what is better, eccentric fittings should be used,

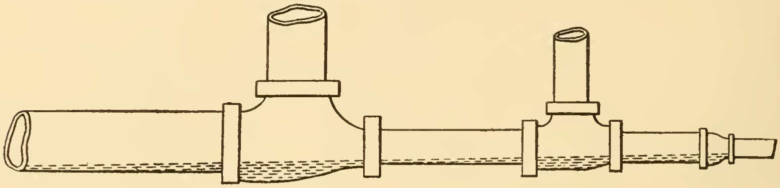

Fig. 116.—Common fittings—the wrong method.

as shown by Fig. 115. Unless this course is pursued, the water of condensation will lodge in the main (see Fig. 116) and cause " water hammer " or pounding in the piping.

Advantages of Steam Heating

The advantages of steam heating over other systems, not considering the patented vacuum or vapor systems, are: (1) there is less liability of damage by frost; (2) smaller radiators and piping are used; (3) rooms are more quickly warmed and cooled, and (4) where a system of ventilation is used, the air is more quickly purified.

By the use of automatic damper regulators, safety valves, etc., the danger of explosion has been practically eliminated, so that now steam may be used with as great a degree of safety as any other system.

TABLE XI

Sizes of Steam Mains

One-Pipe System.		Two-Pipe System.		
Size of Main.	Radiation Supplied.	Size of Steam Main. Flow.	Size of Steam Main. Return.	Radiation Supplied.
1½″	125 to 250 sq. ft.	1½″	1¼″	250 to 400 sq. ft.
2″	250 to 400 " "	2″	1½″	400 to 650 " "
2½″	400 to 650 " "	2½″	2″	650 to 900 " "
3″	650 to 900 " "	3″	2½″	900 to 1,200 " "
3½″	900 to 1,200 " "	3½″	3″	1,200 to 1,600 " "
4″	1,200 to 1,600 " "	4″	3″	1,600 to 2,000 " "
4½″	1,600 to 2,000 " "	4½″	3½″	2,000 to 2,500 " "
5″	2,000 to 2,500 " "	5″	4″	2,500 to 3,500 " "
6″	2,500 to 3,500 " "	6″	4½″	3,500 to 5,000 " "
7″	3,500 to 5,000 " "	7″	5″	5,000 to 6,500 " "
8″	5,000 to 6,500 " "	8″	6″	6,500 to 8,000 " "

CHAPTER XII

Exhaust Steam Heating

WHILE exhaust steam for many years has been used for heating factories, its use in heating office and public buildings, stores, etc., may be said to cover a period of probably the past ten years. We mean by this its general use, as in the larger cities it has been more or less employed for the past score of years.

Of later years numerous improvements have been made in utilizing and controlling the steam, both live and exhaust, and the heating contractor or engineer who does not familiarize himself with these new and improved methods is neglecting a very important part of his business education.

We now desire to treat only of the value and utility of using the exhaust from the engine and the ordinary method of applying the same for heating purposes. The improved methods will be found illustrated and described in a later chapter of this book.

Value of Exhaust Steam

It is a lamentable fact that in many factories and business buildings a very great percentage of the steam from the engines is allowed to exhaust into the outside atmosphere. We think we are perfectly safe in saying that over 50% of the steam produced by the boilers is thus wasted. Could the value of this waste be brought directly and forcibly to the attention of the owners, in such a manner as to be thoroughly understood by them, without doubt they would lose no time in taking such steps as would be necessary to stop the loss. The amount of steam used by the average non-condensing engine is but about from 7½% to 10% of the amount produced by the boiler; in other words, the steam exhausted from the engine has practically 90% of its original energy and value. Should the exhaust be employed in supplying a feed-water heater, five per cent more should be deducted, leaving eighty-five per cent of the original amount available for heating purposes or other uses.

Many concerns do not make a practice of heating their feed water, although some of them discharge their exhaust into an open well or tank and thus warm the water supply that is pumped to the boiler.

Steam specialties such as feed-water heaters, separators, steam traps, etc., will usually pay for themselves by their saving in one or two seasons, and, when the excess steam is utilized for heating, the saving will equal about one half of the usual coal pile. When there is not a sufficient amount of exhaust steam to supply the heating system, the piping may be so arranged that enough live steam may be introduced into the heating system to make up the deficiency. There are many methods of arranging the piping and fixtures for making use of exhaust steam. We show one of them in the illustration, Fig. 117.

Necessary Fixtures

In connecting the exhaust to supply the heating system, care must be exercised not to increase the resistance and thus cause back pressure on the engine. A back pressure of from one to three pounds may be readily overcome by a slight increase of pressure at the boiler. A steam main of generous size for the heating system, as free from right-angle turns (elbows), or bends, as possible, is recommended, and a back-pressure valve should be placed on the exhaust pipe a considerable distance from the engine. The engine delivers steam into the exhaust intermittently, that is, at the end of each stroke, the engine governor admitting only sufficient steam to the engine for the work required of it. It may be "running light" with but a small proportion of the machinery in the factory in use. Thus the amount of exhaust steam delivered to the heating system may not be sufficient, in which case a supply of live steam is admitted to it. This steam supply is admitted at a reduced pressure, hence a reducing-pressure valve is necessary on the live steam connection. A valve partially open or "throttled" may be used, but it is much better to have a reducing valve set to reduce to the pressure required.

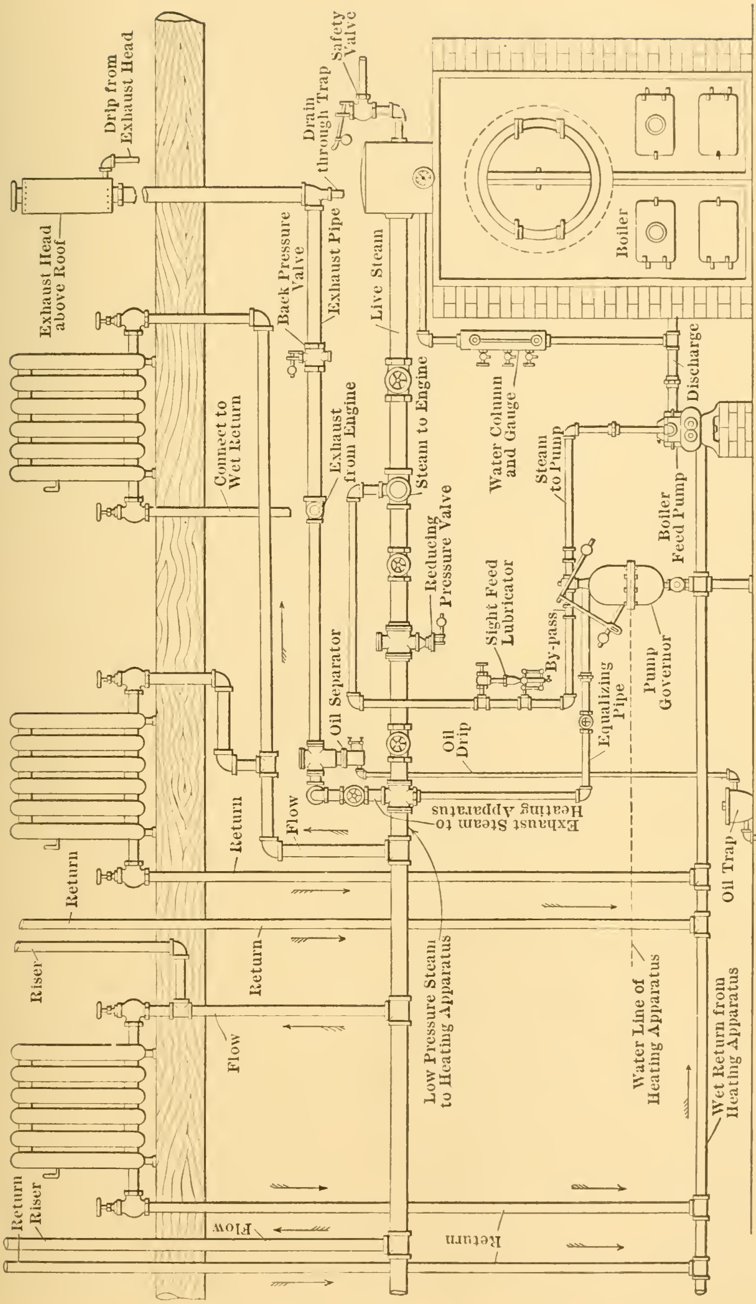

Fig. 117.—Fixtures for exhaust-steam heating.

In the exhaust as delivered by the engine, there is considerable water, which is more or less filled with particles of lubricating oil, small particles of dirt and packing. This must be removed before the steam is admitted to the heating system; consequently a separator which will separate both oil and water is placed on the exhaust pipe before it is connected to the heating system. A small drip pipe or waste should be connected from the bottom of the separator to a trap, which will discharge outside the building or to a sewer. Were it not for this separator the oil, etc., in the exhaust would pass through the return of the heating system to the pump or trap feeding the boiler. This must be guarded against. Reference to Fig. 117 will show in general the fixtures used and method of connecting the same.

The exhaust may be taken direct from the engine to a large closed tank, which is provided with baffle plates for separating the oil and other impurities from the steam. This is called a "grease tank" and a drip should be taken from the bottom to a trap emptying to sewer in the same manner as though taken from a separator, as before described. A relief pipe may be used, connecting the tank with back-pressure valve. This tank should be placed at the top of the heating system, and from it connection to heating main should be made.

Different engineers have various methods of making connections. We have found that it is well to have the heating main connected as high above the engine as possible. An overhead supply or overhead system is preferable to all others. When connecting valves and fixtures, it is well to make frequent and generous use of flanges, as these will be found of great convenience when changing valves or making repairs.

Heating Capacity of Exhaust Steam

For estimating the amount of exhaust steam available from a certain size of engine, many rules, more or less complicated, have been given by various authorities. For the practical use of the fitter would say a safe rule is to allow from 100 to 125 feet of direct radiation (pipe and fittings covered, or figured as radiation) per H. P. of the engine. Thus a 100 H. P. engine, working to its regular capacity, should exhaust sufficient steam to heat the necessary feed-water for the boiler or boilers and have sufficient excess to heat 10,000 sq. ft. of direct radiation.

Of the character of steam appliances or specialties we shall treat in a future chapter.

CHAPTER XIII

Hot-water Heating

The growth of hot-water heating in this country, as a means of warming our homes, has been little short of phenomenal. The personal experience of the writer, covering a little less than twenty years, shows that, where twenty years ago for residence heating there were four or five times as many steam boilers installed as there were hot-water heaters, at this period the great percentage is in favor of hot water. While we have no accurate data on the subject, the records of two or three manufacturers of heaters show a ratio of about ten or eleven to one in favor of hot water.

Steam is, as a rule, used for heating factories, business buildings, public and semipublic buildings, although for this class of work hot water is beginning to be more generally employed.

There are two general systems of hot-water warming, namely, "low pressure" and "high pressure." It is the former method which is in general use. Low-pressure hot-water heating has many advantages to recommend it for residence work.

Very little attention to the apparatus is required, aside from coaling the heater and removing the ashes. This is of considerable importance, however, as the man or men of the family may frequently be compelled to absent themselves from home for extended periods and the care of the heating apparatus be left to inexperienced hands.

Hot-water heat is very easily controlled and an even temperature can be readily maintained. Regulators are now used with hot-water apparatus, and it is possible to so adjust these that any desired temperature can be maintained within the rooms.

As to consumption of fuel, the hot-water apparatus is the most economical of any of the various heating systems.

As the average hot-water apparatus works at a temperature ranging from 100 to 120 degrees in mild weather, and from 160 to

180 degrees in cold weather, the heat from it is very mild and the atmosphere is not robbed of any of its healthy qualities. Some years ago it was customary to maintain a temperature of from 180 to 212 degrees. Experience has demonstrated that the greatest economy and most satisfactory heat are obtained by carrying the water at a much lower temperature, and the heating contractor of to-day, as a rule, places sufficient radiation in the building to warm the same with the water at the lower temperature.

Low-pressure hot-water heating may be divided into three systems, or methods of piping, viz.:

(*a*) The regular two-pipe system.

(*b*) The overhead system.

(*c*) The single main or circuit style of piping.

The Two-pipe System

The two-pipe system is the oldest of the various styles of piping for hot water, hence is best understood by the fitter and heating contractor, and is more generally used than either of the other systems.

The flow pipe, or pipes, of sufficient size to feed the necessary amount of radiation, are carried to such a height above the heater as to allow of a proper pitch of the main. On the top of this riser an elbow is placed and the lateral pipe or main is run with a pitch upward of from one half to one inch in each ten feet of length to the end of the system, or to the branch supplying the radiator farthest from the boiler.

The general design of this system is shown by Fig. 118. We show several styles of radiator connections, and attention is called to the manner of supplying the branch at the end of the main, the elbow on the end being tipped to an angle of 45°, and a 45° elbow and nipple used in making the connection. This manner of connecting the branch is a help to the circulation at this point and the radiator will heat better than when the connection is made with 90° elbows.

All tees on the mains supplying branches should be tipped to an angle of 45 degrees and the branch supplied by using a nipple and 45° elbow. Many fitters seem to think that by taking branches

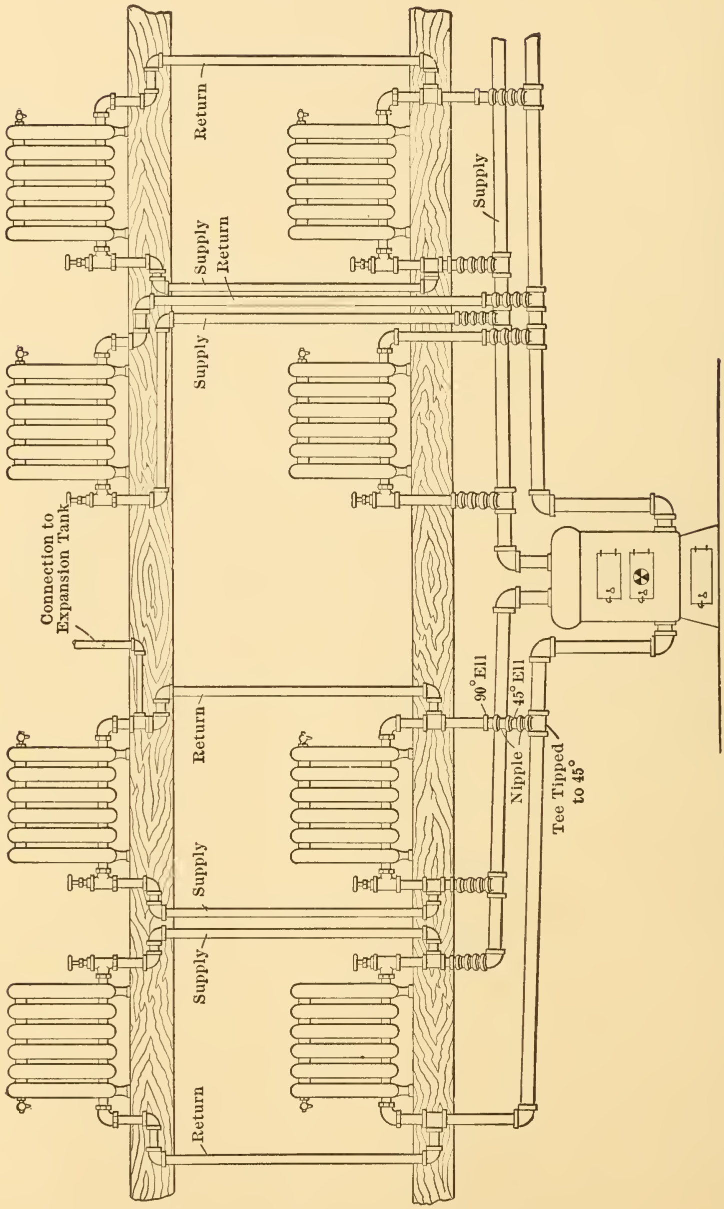

FIG. 118.—The two-pipe system of hot-water heating.

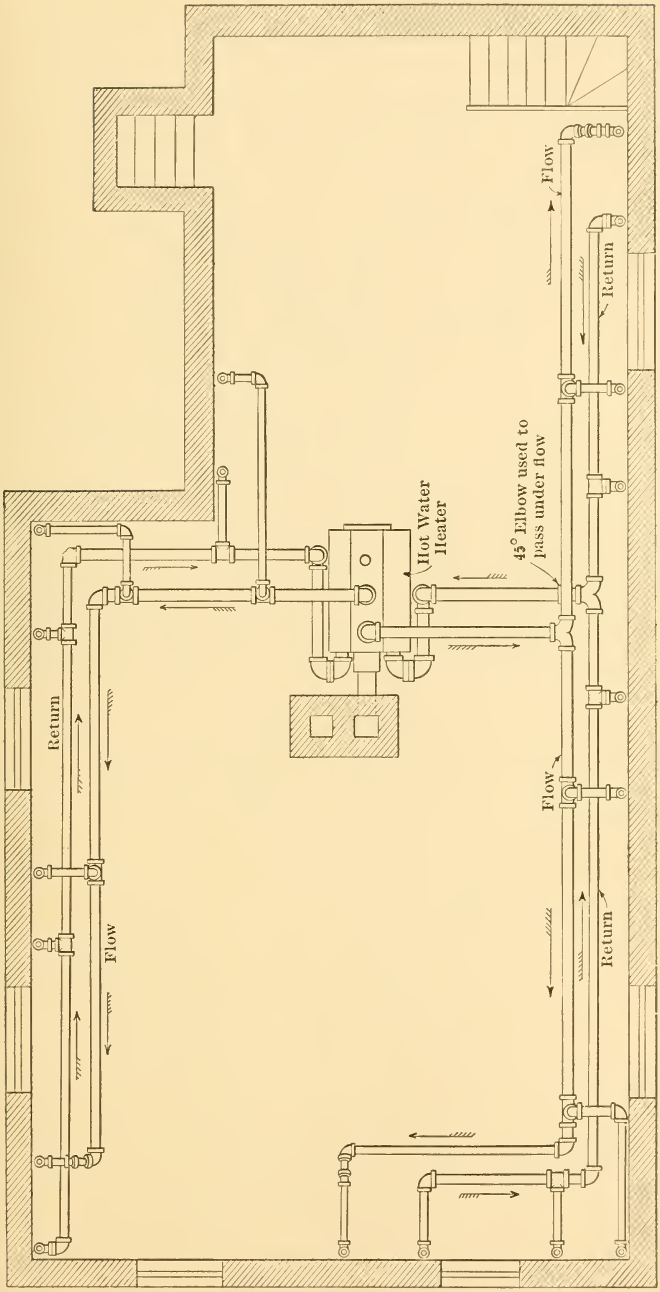

Fig. 119.—Basement plan of piping—two-pipe system.

out of the top they are increasing the circulation, but such is not the case, as every 90° elbow used on hot-water work increases the friction and impedes the circulation. Any "choking" of the circulation necessary to make radiators heat uniformly should be done by using a reducing elbow at the end of the branch. Great care should be taken not to reduce the size of the main too rapidly. Frequently the reducing in size of a short piece of pipe between two tees supplying branches, has "killed" the circulation beyond the point of reduction.

As a better means of understanding this system we show by Fig. 119 a basement plan of the cellar piping of a hot-water apparatus. For convenience in illustrating we have shown branches taken from top of main; *45° connections are preferable*, as explained above. Where the flow pipe is divided in order to feed radiators in opposite directions, it is well to use double elbows. See Fig. 120. In fact, this fitting should be employed on all piping either for steam or hot water. The tee as used "bull head" not only increases the friction but frequently is the means of causing an uneven circulation in the piping supplied by it.

TABLE XII

Sizes of Mains—Two-pipe Hot-water System

Size of Main.	Radiation Supplied.
1½″	125 to 175 sq. ft.
2″	175 to 300 " "
2½″	300 to 475 " "
3″	475 to 700 " "
3½″	700 to 1,000 " "
4″	1,000 to 1,400 " "
4½″	1,400 to 1,750 " "
5″	1,750 to 2.200 " "
6″	2,200 to 3,000 " "

There seems to be quite a difference of opinion among heating engineers as to the size of mains necessary for hot-water heating, many of them advocating much smaller piping than is given in the above table; that is, they increase the amount of radiation a certain size of pipe will supply by from one third to one half of the amount as given above.

In an experience covering nearly a score of years the writer has used both large and small piping, and we find that while the character of the work to a great extent governs the size of pipe to be used, it is well to be generous in the size of piping, particularly for the main supply pipes. For all ordinary two-pipe

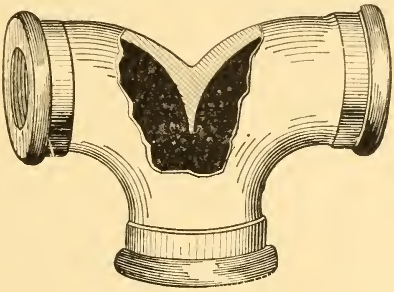

FIG. 120.—The double elbow.

work we consider the sizes as given in the schedule conservative. Friction should be avoided and as the friction in a horizontal pipe is much greater than in a vertical pipe, the horizontal pipe must of necessity be larger than the vertical to accomplish the same service.

The Expansion Tank

As water heated to 180 or 212 degrees expands from one twenty-fourth to one thirtieth of its volume, it is necessary on hot-water work to make some provision for the increased volume of water and for this purpose we make use of a tank, which we call an "expansion tank." There are several methods of connecting this tank with the hot-water system. It should, however, in each instance be located at least three feet above the highest radiator on the system and the expansion pipe should be connected to the return pipe of the radiator. The vent pipe leading from the top of the tank should be carried through the roof above the tank, or through the side of the building into the outside atmosphere. This vent pipe may also be used as the overflow; in case the system overflows by reason of being filled too full, the excess water will empty on the roof or outside the building.

When the expansion tank is placed in the bathroom of a residence, many fitters make a practice of carrying the overflow into the closet tank, while others take the pipe to a basement drain. The former method is poor practice, and the latter a waste of material entirely unnecessary.

By Fig. 121 we show the simplest form of connecting the expansion tank. When this style of connection is used, the tank must be located in a room which is heated, or where there is no liability of freezing.

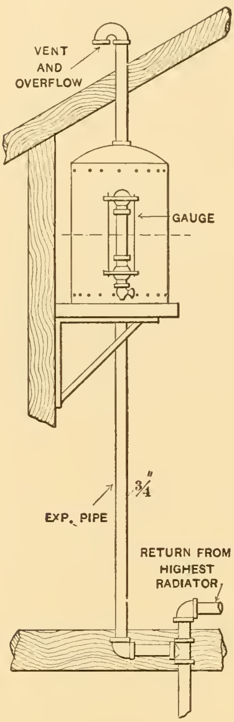

Fig. 121.—Connecting expansion tank—common method.

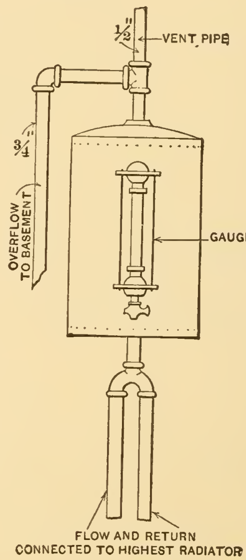

Fig. 122.—Connecting expansion tank—circulating water to tank.

Fig. 122 shows a method of tank connection where the water is circulated to the tank or directly underneath it. In employing this style of connection, one pipe must be connected to the flow and the other to the return pipe of one of the highest radiators on the system. When it is necessary to place the tank in a cold room or an exposed place, we recommend the connection as shown by Fig. 123. We also recommend that nothing less than 1″ pipe be used for the connections. With this method the water in the tank is circulated or warmed. Either of the latter two methods

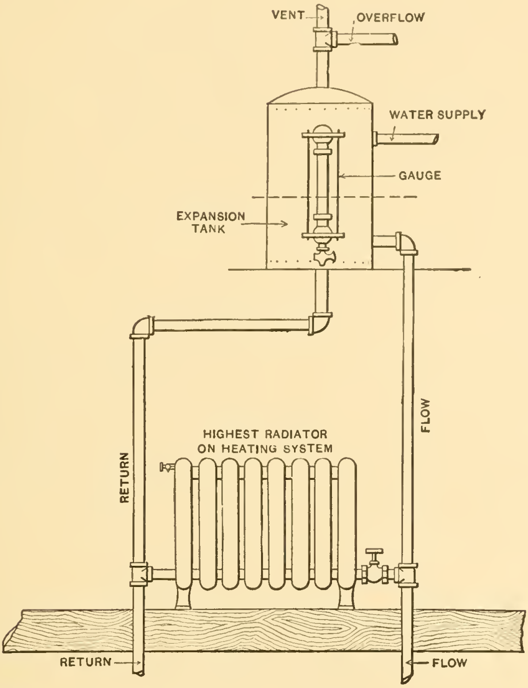

FIG. 123.—Connecting expansion tank—circulating water in tank.

of connection will prove of assistance in keeping air out of the system.

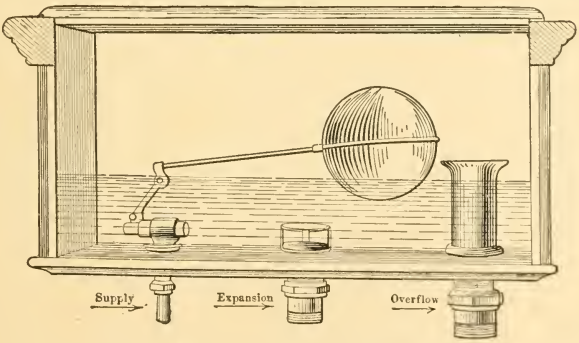

FIG. 124.—Automatic expansion tank.

A later style of expansion tank and one which has met with favor is the automatic expansion tank which operates with a ball cock and float. Fig. 124 shows an interior view of the tank. It is made of wood and has a copper lining. They are also constructed of steel and of a form similar in appearance to the regular style of tank. That illustrated has much the appearance of the regular closet tank and when placed in a bathroom or other occupied room is commendable for its neat appearance. No valves of any description should be placed on any of the expansion-tank connections. They are not only unnecessary, but are liable to be closed (by error) and the system thereby be put under pressure, with liability to damage by explosion.

Water Connection

The water connection to a hot-water heating apparatus should be made by connecting into the return pipe at the rear of the boiler. Where there is no regular water supply and it is necessary to fill the system by hand or with a pump, the connection must of necessity be made at the tank or the top of the system.

Table of Expansion-tank Sizes

The following table gives the proper size of expansion tank for any hot-water heating apparatus up to 6,000 sq. ft. of radiation.

TABLE XIII

	Capacity.	Size.
300 sq. ft. radiation	10 gal.	12×20″
500 " " "	15 "	12×30″
700 " " "	20 "	14×30″
950 " " "	26 "	16×30″
1,300 " " "	32 "	16×36″
2,000 " " "	42 "	16×48″
3,000 " " "	66 "	18×60″
5,000 " " "	82 "	20×60″
6,000 " " "	100 "	22×60″

The Overhead System

A style of piping for hot water which, when it has been properly erected, has met with much favor, is the so-called " overhead system." We do not hesitate to say that it is the best method of hot-water piping in use to-day, and while it is not adaptable

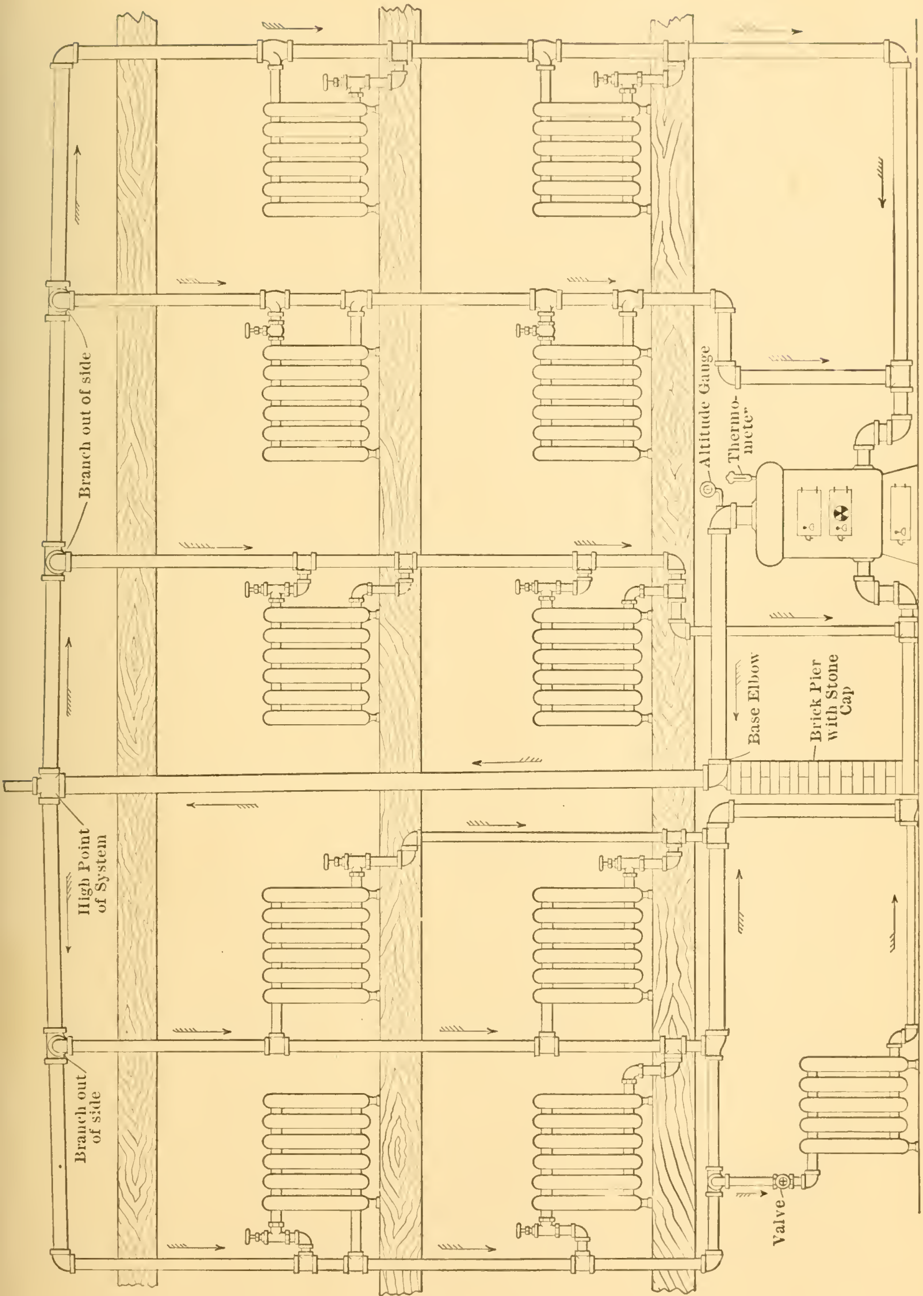

FIG. 125.—The overhead system of hot-water heating.

to all classes of buildings, there are many, such as flat or apartment buildings, store and office buildings, hotels or factories, where the character of construction, manner of dividing the space into living rooms, offices, etc., render the overhead system particularly serviceable. There are many advantages to be gained by the use of this system, the principal one being that but one riser or drop pipe is necessary for supplying a line of radiators, and also that the circulation of the water is both positive and rapid. No air vents are necessary at any point on the system, as the piping is so arranged that all air works to the top of the system into the expansion tank and through this to the atmosphere, thus keeping the system free from air at all times and as the removal of air from the heating system is one of the great troubles of the steam fitter, much good has been accomplished by this alone.

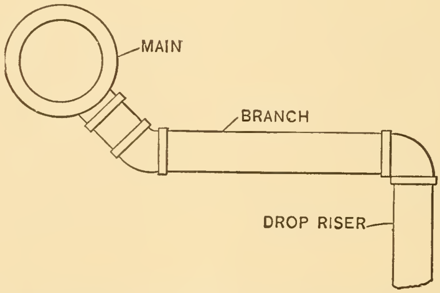

Fig. 126.—The overhead system branch from main.

In illustrating this system (Fig. 125) we show in detail some of the many methods of connecting the radiators and the general mode of piping. The main flow pipe is taken from the top of the heater, as with the regular two-pipe system, and run to some convenient point to allow it to be run vertically to the attic or top floor of the building. This should be the high point of the system and from this point the connection to the expansion tank should be made. From the top of the main riser, the various branch mains are run. These have a drop of at least one half inch in each ten feet of length and from these mains the branches supplying the drop risers are taken. Those shown on Fig. 125 are taken out of the side of the main. We favor a 45° connection as shown by Fig. 126. The size of the drop risers depends entirely upon the amount of radiation fed by them. As a rule, they should be larger at the top than at the bottom, reducing gradually as the various radiators are supplied. The radiator connections from the risers should be smaller at the top of the building, increasing in size (the same size of radiators considered) toward the bottom of the riser.

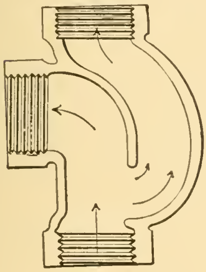

Fig. 127.—The O. S. distributing fitting.

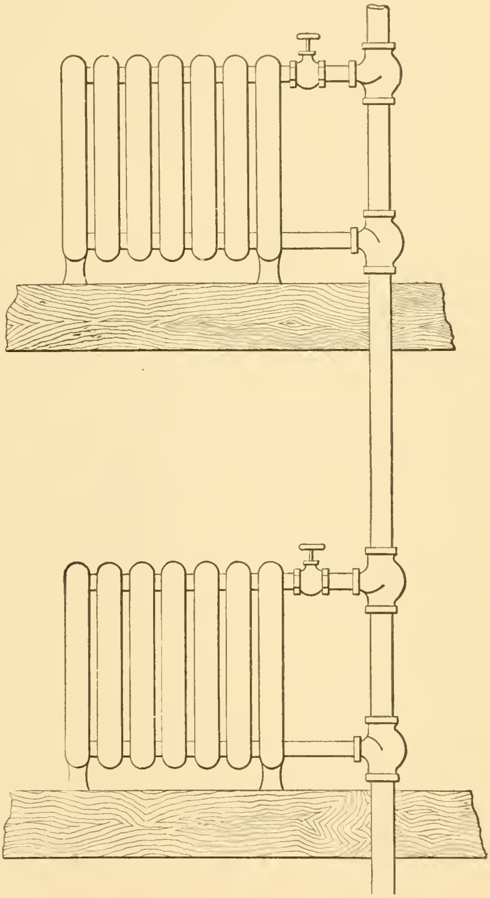

Fig. 128.—Application of O. S. distributing fitting.

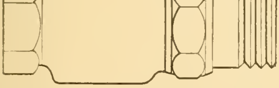

Fig. 129.—Straightway valve with union.

In the basement the risers are connected into returns in the same manner as with the regular two-pipe system, these returns being increased in size as the various branches are connected until finally the water is returned to the boiler through approximately the same size of pipe as the main riser.

An advantage where this system is used and one which should not be overlooked, is the ability to circulate the water through

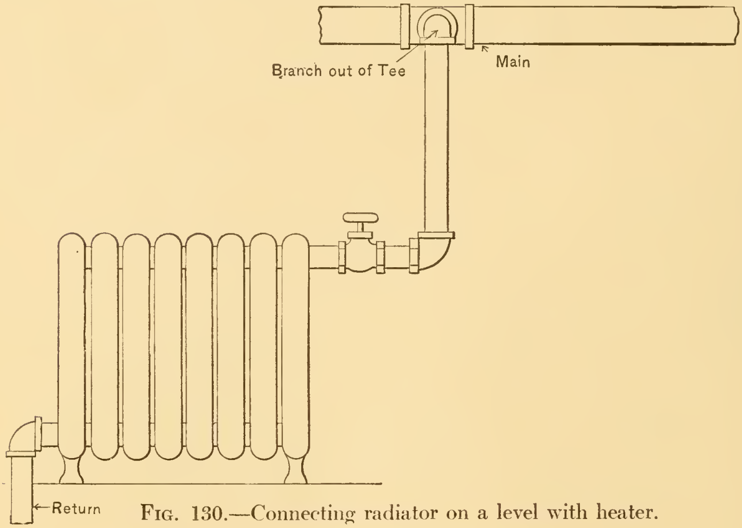

FIG. 130.—Connecting radiator on a level with heater.

and supply heat to radiators located on the same floor as the heater, or even lower than it. This is by reason of the weight of the

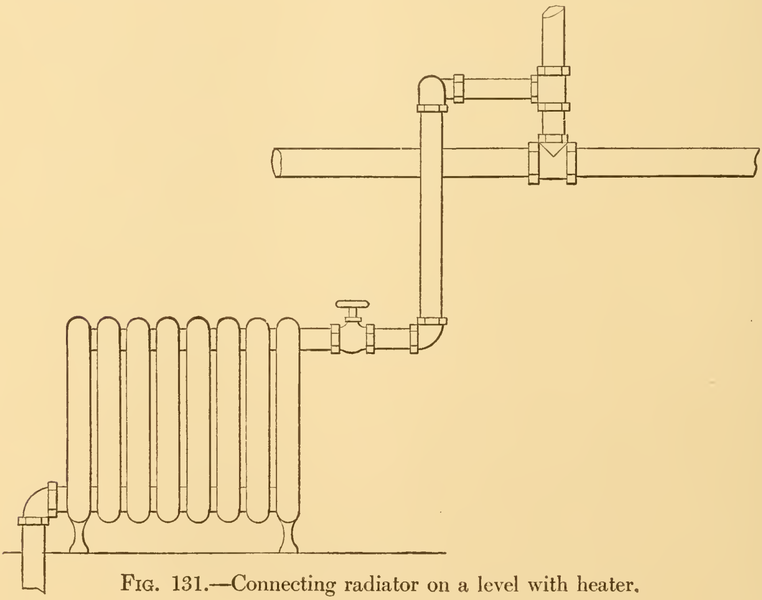

FIG. 131.—Connecting radiator on a level with heater.

water or pressure on the system, there being one pound pressure for each two feet of height of the water in the system. We have shown by Fig. 125 several methods of using the ordinary tees on the riser from which connections to radiators are made. We also show on the two risers, at the right hand of the illustration, a special fitting (Fig. 127) known as the "O. S." fitting and we commend it to the use of all heating contractors as an aid to the reduction of friction and a quickening of the circulation, and also on account of the labor saved by its use. In order that it may be better understood, we show an enlarged riser (Fig. 128), illustrating two radiators connected by the use of this fitting.

A style of radiator valve which is particularly adaptable for use with this system is shown by Fig. 129. It is known as the

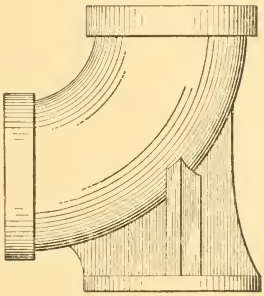

Fig. 132.—Base elbow.

" straightway " valve, and is a quick-opening valve. As its name indicates, it is for use on a straight pipe or connection. When connecting radiators on or below the level of the heater, care must be taken not to make a connection which will get air bound. If the connection is taken from one of the overhead return pipes, we recommend that it be done as shown by Fig. 130. If taken from the drop riser it should be connected as shown by Fig. 131.

The sizes of mains for the overhead system are practically the same as for the two-pipe system, although the main riser may be somewhat reduced in size. When this riser exceeds 3″ in size, it is well to use a special elbow at its base (Fig. 132). This should be supported by a brick or cement pier, in order to relieve the building of the weight of water in this portion of the apparatus.

Expansion Tank Connections

The expansion tank should be placed somewhat higher than the fitting on the top of the main riser. A very simple method of connecting the tank is shown by Fig. 133. The tank should be placed on a support or framework of sufficient strength to make it stationary. No gauge on the tank is necessary, although many fitters use it.

Another method is that shown by Fig. 134. The tank is

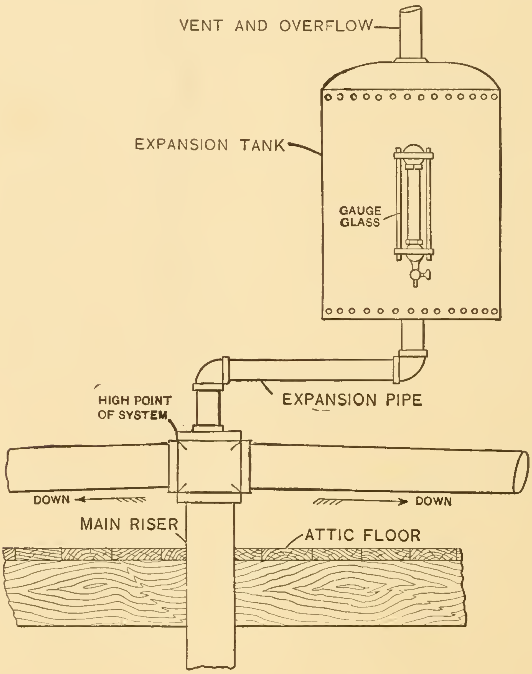

Fig. 133.—Expansion tank connection—overhead system.

suspended in a horizontal position by iron straps hung from the roof timbers, which are strengthened sufficiently to support the extra weight. The overflow may empty into a pan, from which there is a drip to the sewer in the basement. As is the case with the regular two-pipe system, no valves should be placed on the connections to the tank.

There are several modifications of the overhead system, which lack of space will not allow us to illustrate. There is one method,

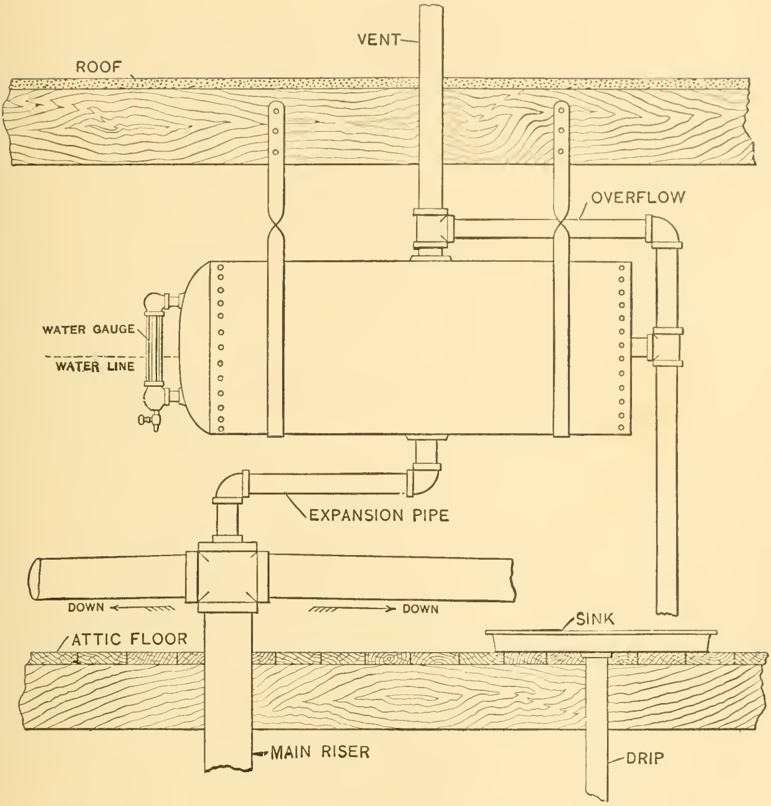

FIG. 134.—Expansion tank connection with drip—overhead system.

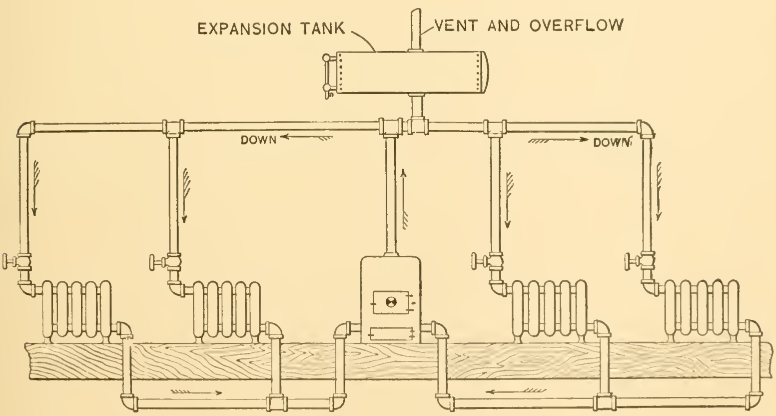

FIG. 135.—Modified overhead system.

however, which we should be familiar with. It is frequently necessary in heating a store or small building to place both boiler and radiators on the same floor. To do this successfully, the main flow pipe should be run on the ceiling as shown by Fig. 135. The illustration shows an elevation plan without the branch connections. The branches should be taken out of the side of the main. The drop pipes supplying radiators should be connected into the top of one end of the radiator, the return being taken from the bottom of the opposite end. The expansion tank should be hung horizontally from the ceiling, with vent and overflow to the roof. No air vents are necessary, as all air in the system works out through the expansion tank. The work may be put under pressure, if desired, by sealing the tank and using a safety valve, as described in a later chapter.

The Circuit System of Hot-water Heating

The circuit system commonly called the "single-main system," has in the past few years gained considerable favor among heating contractors. A single main pipe, which also acts as a return, is taken from the top of heater to a point as high as desired under the first floor joists. From this point the connection to expansion tank is made. This main pipe is then run around the basement, in a circuit, near to the ceiling and with a gradual pitch from the heater, which should never be less than ½ inch in each 10 feet of length, but may be more, if desired. This main, which is of extra large size, supplies all of the branches feeding the radiators on the first floor or risers to the floors above. The flow pipes or branches are taken from the top of the main, the returns entering at the side.

After supplying the various radiators, the main is run directly back to the heater, where it drops and is connected into the return opening of the same. The main must never be reduced, but should be run full size until it enters the return of the heater.

Illustration Fig. 136 shows a general view of this system of piping. The fittings shown on the main, which supply branches, are of three kinds. Those marked A A are the regular tee fittings; those marked B B are the Eureka fittings, an enlarged view of which is shown by Fig. 137. This is a single fitting

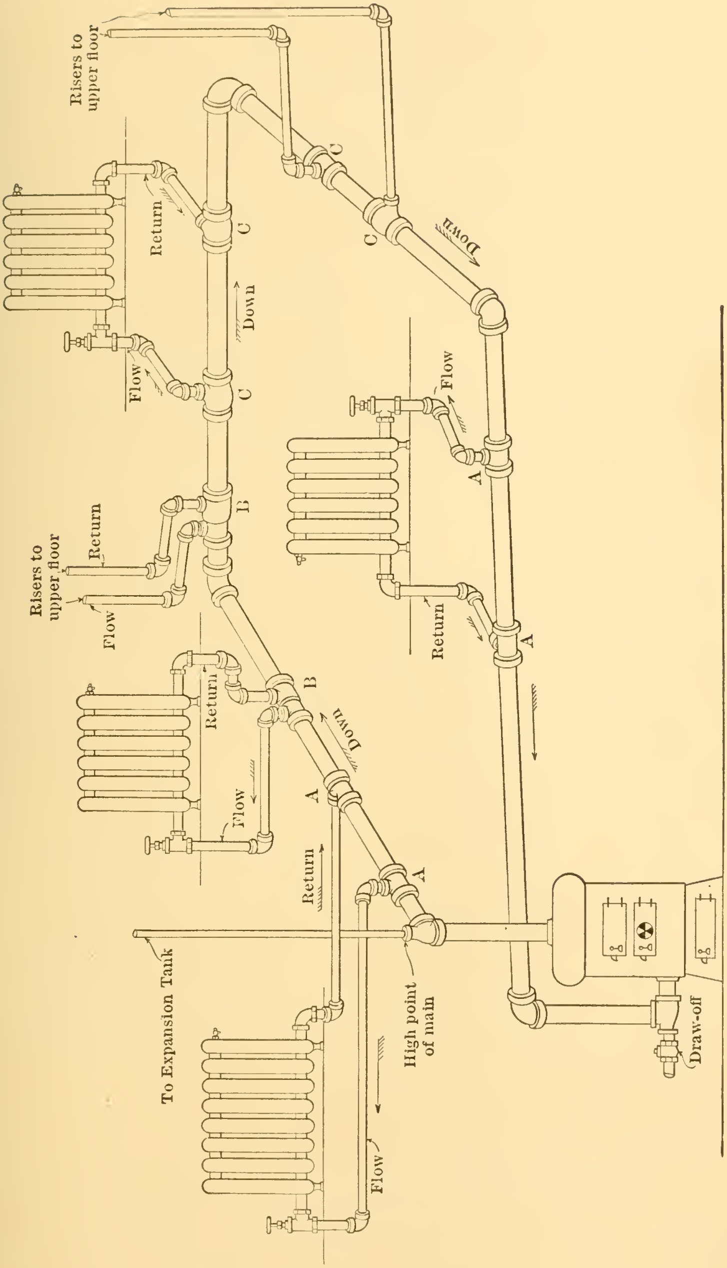

FIG. 136.—The circuit system of hot-water heating.

used for connecting both flow and return, the flow leaving the top of the main and the return entering the bottom. It is as easily placed as the regular tee and the saving in labor and cutting of threads is considerable. Those marked C C are the O. S. fittings for use on single-main work and they divide the

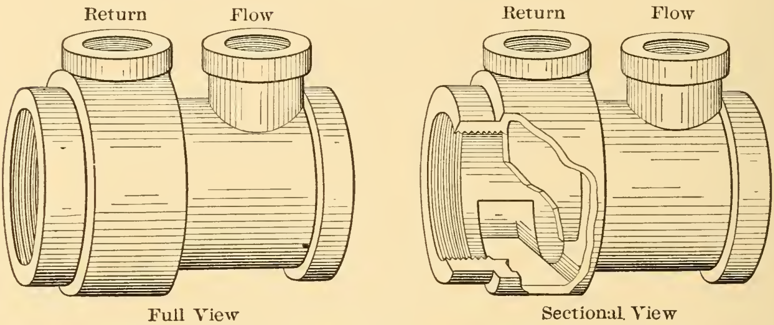

Fig. 137.—Eureka combination fitting.

circulation in the same manner as the regular O. S. distributing fitting.

Yet another style of fitting for use on the main of a circuit job is known as the " Phelps Ideal " fitting, as illustrated by Fig. 138. This fitting is quite like a tee with side outlet tapped eccentric. The flow is taken from the top of main and the return re-

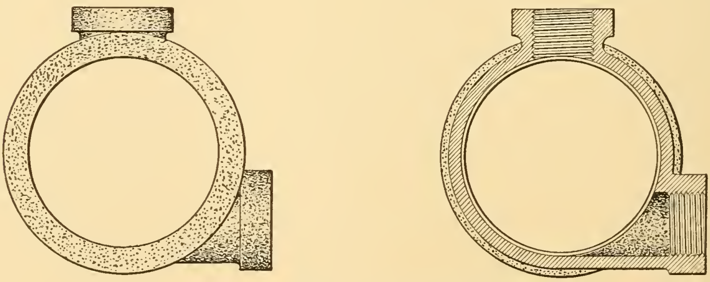

Fig. 138.—Phelps combination fitting.

enters it at the side on a level with the bottom of the main. This is a much better fitting to use than the regular tee, as one fitting on the main does the work of two, saving thread cutting and labor, and it also has the advantage of delivering the return circulation lower down in the main.

The branches should have an upward pitch from main; also, the radiator connections are made the same as for the regular two-pipe system.

We have found it excellent practice on work of any considerable size to increase the size of the radiators somewhat, that are connected on the last two sides of the circuit. The water in the main being cooled somewhat before it reaches this part of the system, it is necessary to provide more radiation in order that all portions of the work will heat evenly. The sizes of the branches may be somewhat smaller nearest the boiler than those toward the end of the main. It will be found that this system of piping will prove most efficient and acceptable when properly proportioned and erected.

TABLE XIV

SIZE OF MAIN FOR ONE PIPE—HOT WATER

Size of Main.	Direct Radiation Supplied.
2 inches	175 sq. ft.
2½ "	300 " "
3 "	500 " "
3½ "	700 " "
4 "	1,000 " "
4½ "	1,200 " "
5 "	1,600 " "
6 "	2,200 " "

The systems of low-pressure hot-water work we have described and illustrated are the principal forms of this class of work. There are several modifications of each, which it is not necessary to describe as the same general principles of piping, etc., prevail. Having detailed the character of this work, it is well that we should understand the principles which underlie it, and will therefore treat briefly on the cause of hot-water circulation.

Why Water Circulates

In answering the question—What causes circulation?—we say that unquestionably it is heat which causes the water to circulate in a hot-water heating system. When heating by hot water first came into general use in the United States, the writer was taught that water, being heated, became lighter and when confined in a heating system would ascend to the top and circulate through the piping and radiators. This statement was a gross error, although we believed it at the time, and as we have heard the same statement made many times since, it is undoubtedly a very common error. As a matter of fact, hot water will move only when there is a cooler and heavier body of water displacing it and forcing it upward, and were it not for the difference in temperature between the flow and return pipes of a hot-water heating system, there would be no circulation at all.

Hot water, as it cools, becomes compact and outweighs the warmer water in the heater, causing it to rise in the system and circulate through the piping and radiators, the difference in the mean temperature of the water as it ascends and descends in the system keeping the circulation constant. The higher the water in the system, the more rapid the circulation, or, stated in another form, the greater the height of the return pipe (in which the cooler water is descending), the more energy and push against the warmer water in the heater and consequently the more rapid the circulation. The height of the flow riser (the ascending water) makes no difference in the rapidity of the circulation of the water in the apparatus, except as the height of the return is increased. The velocity of the flow of water in a heating apparatus depends upon the difference in weight of the ascending and descending columns of water, with due allowance made for friction. There are several methods of determining theoretically this velocity. However, as this book is written only from a practical standpoint, we shall not burden our readers with a discussion of these theories.

CHAPTER XIV

Pressure Systems of Hot-water Work

The high-pressure system of hot-water heating is not, as a rule, practiced in this country. In England we find it used for various purposes, such as laundry dryers, bake ovens, enameling, etc., the apparatus carrying from 250 to 350 degrees temperature. The piping used is small in diameter and extra strong, or extra heavy in weight. The fittings used are also much heavier than it is our custom to use on heating work. This system was designed and used originally by Mr. A. M. Perkins, of London, Eng., and is known as the "Perkins System."

Pressure work as practiced in this country (closed-tank system), consists of sealing the outlets of the expansion tank, thus putting the apparatus under pressure, a safety valve being used on the overflow at the tank to regulate the same. On ordinary work it is seldom that a pressure exceeding ten pounds is employed, the water in the apparatus at this pressure having a temperature of about 240 degrees. This style of work is probably used in greenhouses more frequently than in any other manner, and among its advantages are the use of less radiation, a less volume of water in the apparatus and a more quickly controlled apparatus. For use in heating dwellings or apartments it is objectionable because of the element of danger connected with its operation. Should the safety valve at the expansion tank become inoperative from any cause, an explosion would be the probable result.

We have known heating contractors to use this method when they find that too little radiation had been installed to give the temperature required, and frequently to adopt this seeming remedy without giving notice to or obtaining the consent of the owner of the property, which involves not only a dishonest, but a very dangerous practice as well.

The following table gives the temperatures at which water will boil at various pressures (atmospheric), with the equivalent head in feet:

TABLE XV

Pressure.		Boiling Point (Degrees).
Pounds above Atmosphere.	Head in Feet.	
0	0	212
5	12	228
10	24	240
15	36	250
20	48	259
25	60	267
30	72	274
35	84	280
40	96	287
45	108	292
50	120	297
60	144	307
70	168	316
80	192	324
90	216	332
100	240	338

When it is necessary to place both boiler and radiator on the same floor, as is shown by Fig. 135 in the previous chapter, it is sometimes advantageous to put the work under a moderate pressure in order to quicken and maintain a more positive circulation throughout the system.

On certain work of this character it is sometimes impossible to run the overhead piping sufficiently high to admit of a free circulation through all of the radiators, those farthest from the heater not working as well as those placed nearer the heater. This is readily remedied by placing the system under sufficient pressure to maintain a free circulation in all parts of the apparatus.

Expansion-tank Connections

The expansion-tank connections for pressure work may be made in the same manner as for the open-tank system. The opening in the tank used for air vent is plugged and the safety valve, which is usually of the lever variety, is placed on the overflow pipe at a point near the tank.

Where a vertical tank is used, the connections should be made as shown by Fig. 139. Where a horizontal tank is used, the con-

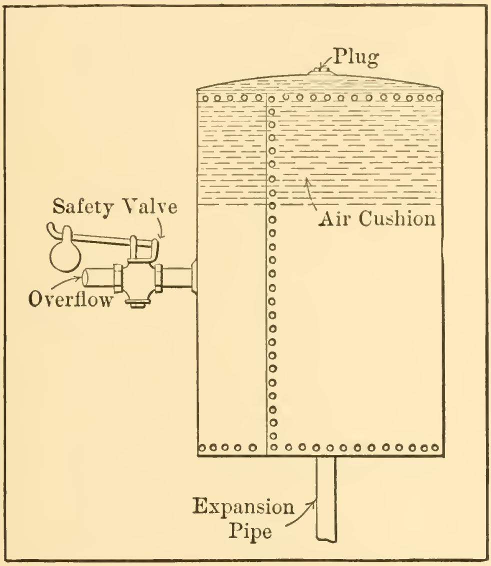

FIG. 139.—Expansion tank with safety valve.

nections should be made as shown by Fig. 140. We show on this illustration the use of a vacuum valve. When the safety valve

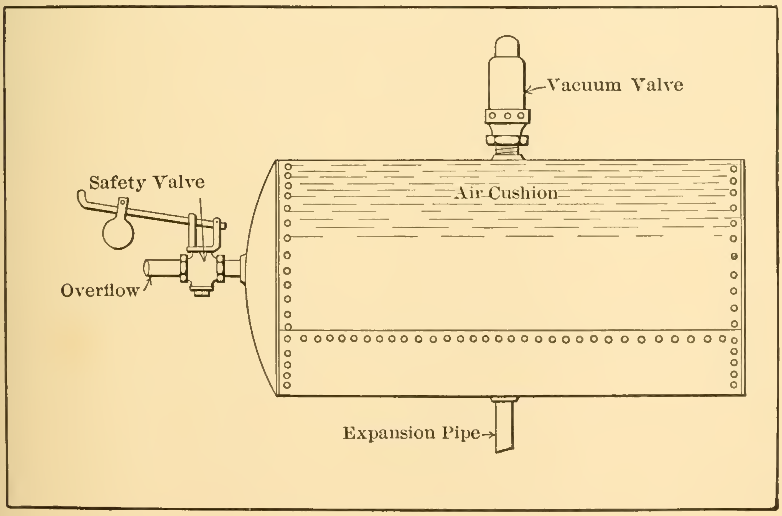

FIG. 140.—Expansion tank with safety and vacuum valves.

is opened from excess pressure, trouble is frequently experienced in relieving the vacuum at this point, and for this purpose the vacuum valve is used. There are times, however, when the vacuum valve does not relieve the vacuum, due probably to the failure of the valve to operate. A very simple method of relieving the

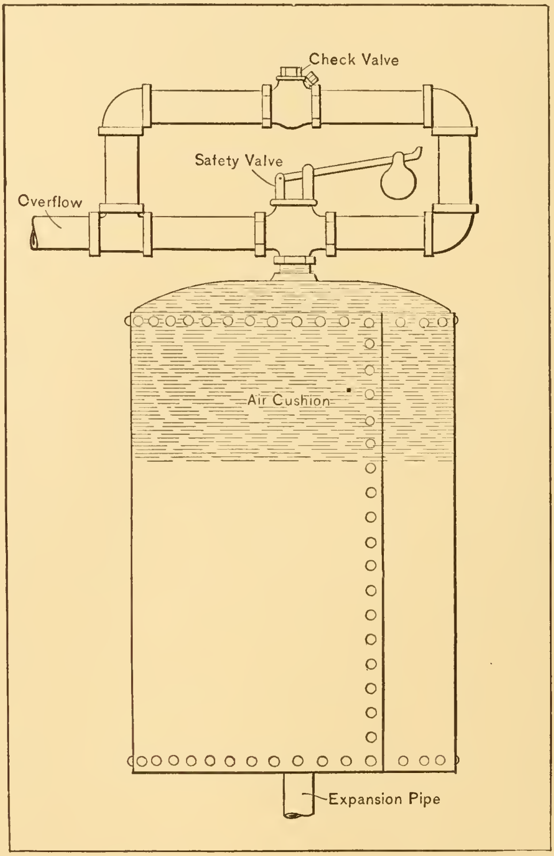

Fig. 141.—Expansion tank with method of relieving vacuum.

vacuum without the use of a valve is shown by Fig. 141. It consists of a check valve used in connection with the safety valve. The connection shown from the check valve into a tee placed on the overflow pipe is made for the purpose of discharging any water which might leak through the check valve.

A pressure system of hot-water heating that has been used extensively in this country is that of Evans & Almirall. This system is only applicable to large work, as the water is heated by the exhaust steam from engines, pumps or other mechanism requiring live steam. The water of the heating system is passed through a tank or heater constructed in much the same manner as a feed-water heater. Its interior is filled with copper tubes through which the water circulates and is heated by the exhaust steam which is carried through the heater and which surrounds the copper pipes. The excess steam, or that which is not condensed in warming the water of the heating system, is discharged into the atmosphere through an exhaust pipe. The water in the heating system is circulated under pressure by a pump, the velocity of the circulation depending upon the speed of the pump, which may be regulated at will by the attendant. Where the exhaust steam is not sufficient to heat the water to the temperature desired, a supplementary heater is used, such a heater being fed with live steam.

This system makes an ideal method for the heating of detached buildings, or buildings adjacent to that in which the engines, etc., are located, as there is no dependence placed on gravity piping or the use of traps as with steam heat. The temperature of the water may be carried just as high as the pump will handle it.

Other systems which are in some respects similar to the above are in use, but are not so well known or as extensively used.

Hot water under pressure is made use of by numerous manufacturers for the purposes of drying, heating, etc. However, it probably will not, in this country at least, replace steam as used for similar purposes.

CHAPTER XV

Hot-water Heating Appliances

We might, in the broader sense of the words, designate all portions of a hot-water system as "heating appliances." We confine our use of the term, however, to cover only those parts or "trimmings" which tend to finish or render the appearance more comely; also to those appliances which assist in maintaining a uniform temperature and which render the care and attention due the apparatus less of a burden.

The early systems of hot-water heating had a small pipe, of usually ½″ or ¾″ in size, running from the overflow of the expansion tank to the basement. This was called a "tell-tale," and the operator in filling the apparatus would leave the water pressure turned on until the water was heard running from the tell-tale.

The Altitude Gauge

This crude arrangement has been dispensed with and in its place we now employ the altitude gauge, Fig. 142. This is ordinarily a spring gauge of the Bourdon type. The gauge has two dials, a black and a red one. The black dial is attached to the mechanism of the gauge and registers the height of the water in the system, by feet. The red dial is stationary and is movable only by hand. After filling the system to the proper height, the same being registered on the gauge, the face of the gauge is removed and the red dial moved to the same position as that occupied by the black dial, when the face of the gauge is then replaced. As the water in the system evaporates, the black dial will drop away from the red one, indicating to the attendant that the water is low in the system. As the gauge is attached to the apparatus at or near the heater, it is necessary only for the attendant to admit sufficient water to the system to bring the black dial back to the position held by the red one, thus indicating that the system is properly filled.

The Hot-water Thermometer

The hot-water thermometer used on a hot-water heating apparatus is a mercurial thermometer, as shown by Fig. 143. The framework is of iron, or brass, on the face of which is the indicator. Attached to the face of the indicator is the glass mercury tube, the lower end of which extends through the center of a small

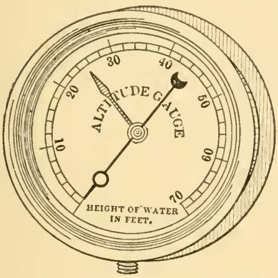

Fig. 142.—Altitude gauge.

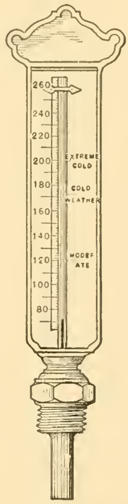

Fig. 143.—Hot-water thermometer.

brass casting. The lower part of this brass casting forms a cup, and this cup part of the casting is turned down until it is very thin.

This renders this portion of it very susceptible to the heat. A standard pipe thread is cut on the outside of the casting, which may then be screwed into an opening in the heater or other portion of the heating apparatus. This leaves the lower and thinner part of the appliance submerged in the water.

In order to get a true register of the temperature of the water it is necessary that the lower part of the thermometer containing the bulb of mercury be submerged in the water, as shown by Fig. 144. Unless this is done the thermometer will register falsely.

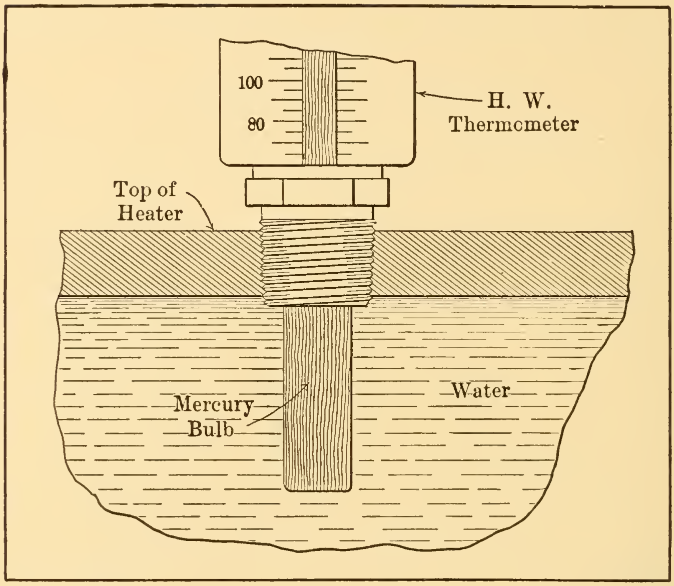

FIG. 144.—Right method of attaching thermometer.

We have seen thermometers used where they were screwed into an opening which had been reduced in size by the use of several

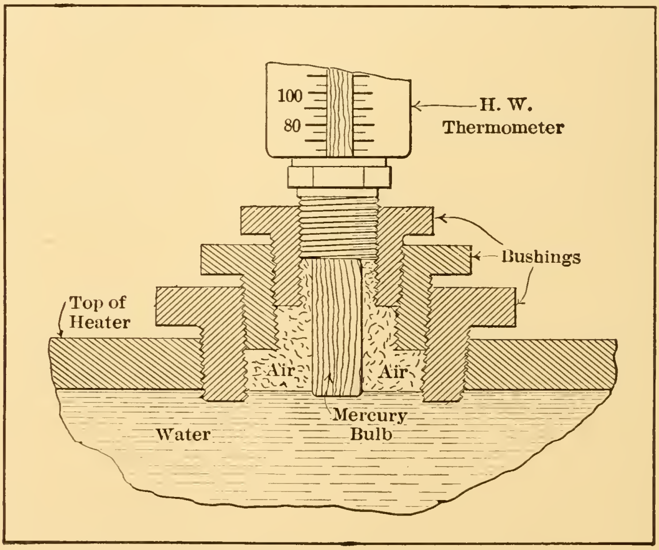

FIG. 145.—Wrong method of attaching thermometer.

bushings, with the result that the thermometer did not reach the water in the system. Fig. 145 illustrates this, and under such conditions it is impossible to register the correct temperature.

Floor and Ceiling Plates

Not a very long time ago we were accustomed to notice cumbersome cast-iron plates surrounding the pipes where they passed through floors or ceilings. They would frequently drop a distance

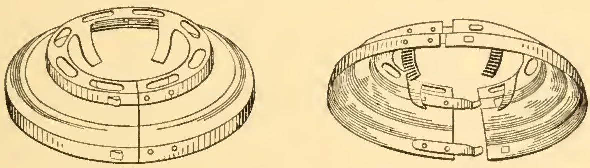

Fig. 146.—Brass floor and ceiling plates nickeled.

from the ceiling, and sometimes fall entirely to the floor below, because they were insecurely fastened in place. These crude affairs have been replaced by a nickeled plate of spun brass, Fig. 146, or iron, Fig. 147. These plates are made in two parts and so

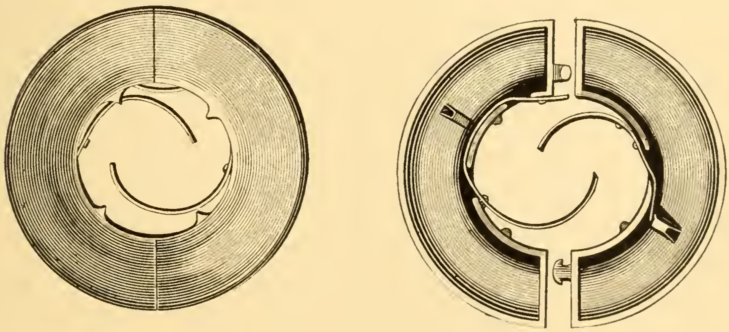

Fig. 147.—Cast-iron floor and ceiling plates nickeled.

constructed as to be adjustable. They are held to the pipe by springs and this method keeps them firmly in their proper positions.

The heating contractor now gives much attention to the finished appearance of his work and this fact, no doubt, has led to the use of better trimmings on heating jobs.

Pressure Appliances

Some of the more recent developments in accessories to a hot-water heating apparatus are various appliances for putting the system under a nominal pressure without sealing or closing the vent opening of the expansion tank. There is no element of danger presented by the use of any one of these appliances, as the system remains an open one, but is, however, weighted down in a manner which allows of a nominal pressure under the force caused by the expansion of the water within the apparatus. A considerable saving is made in the first cost of the heating apparatus by using an appliance of this character, as not only may there be a reduction made in the amount of radiation installed, but smaller piping may be used, the same as for a pressure system.

The Honeywell system is operated by mercury. This appliance is designated as a " Heat Generator " and is illustrated by Fig. 148. It consists of two pipes, one within the other, the larger pipe termed the " stand pipe," the inner one, the " circulating pipe." The upper end of the stand pipe is screwed into the bottom opening of a hollow bulb, termed a " separating chamber," which has also an opening at the top into which the pipe connection to the expansion tank is made.

The lower half of the stand pipe is screwed into a bottle-shaped hollow casting, as shown by Fig. 149 (12), terminating in a hollow cup or " shoe " screwed on the bottom of the pipe. The plug (16) screwed into the bottom of the bottle makes it tight, except for opening (6) on one side near the top of the casting, into which expansion pipe from heating system is connected. The lower part of the bottle is termed the " mercury chamber," being filled with mercury to the height of the small plug shown (10), making it approximately 1½″ in depth.

The principle of the operation of the generator is based on the fact that mercury is thirteen times heavier than water, and the apparatus is really a mercury seal, requiring a pressure of about ten pounds to break the seal and allow the pressure to reach the expansion tank. The various parts of the generator are so arranged as to allow the mercury to circulate under pressure and to be separated from the water (by plate 2) when the mercury seal is broken by excess of pressure on the system. As the mercury is heavier than the water, it settles again through space 8, as per sketch, into the mercury chamber at the bottom of the generator.

The rapidity of the circulation through small piping and reduced radiation, under a temperature equal to steam at ten pounds

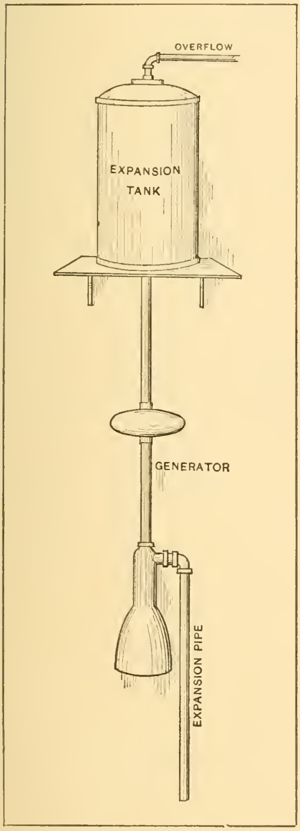

FIG. 148.—Honeywell heat generator.

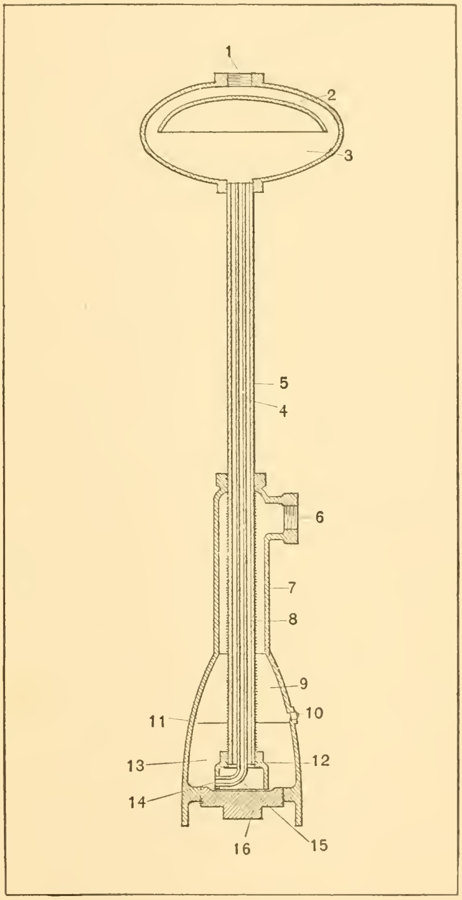

FIG. 149.—Sectional view of Honeywell heat generator.

pressure, renders the reduced amount of radiation (10% reduction) effective for cold weather and the wide range of temperature allows of a mild degree of heat in warmer weather.

When installing this system there are a few points to be considered, viz.:

(a) The radiation should be figured as for the regular hot-water system, then a deduction of 10% made.

(b) The heater should remain the full size.

(c) In proportioning size of mains, allow 1 sq. in. of area for each 100 sq. ft. to be supplied.

(d) Make branches and risers of the same size and take branches from side of main.

(e) Take branches for second or third floor risers from side of other branches, not from end of the branch to first floor.

(f) Radiator tappings should be as follows:

For first floor—up to 25 sq. ft. ½″; 25 to 60 sq. ft. ¾″; over 60 sq. ft. 1″.

For second floor—up to 30 sq. ft. ½″; 30 to 100 sq. ft. ¾″; over 100 sq. ft. 1″.

For third floor—up to 50 sq. ft. ½″; 50 to 125 sq. ft. ¾″; over 125 sq. ft. 1″.

The length of the pipe which screws down into the mercury chamber and connects it with the oval separating chamber is regularly 21 inches, which allows of a pressure of ten pounds upon the apparatus.

A feature of the generator is that no mercury will be forced out of it and lost through the overflow pipe during the operation of filling the apparatus from the regular water-service pipes. When the water supply valve is opened the mercury is forced up into the separating chamber and held there until the apparatus is filled with water, or until the supply valve is closed, when it falls into the mercury pot and is ready for service.

A detailed description of the operation of the generator may be given as follows: When the fire in the heater has warmed the water in the apparatus sufficiently for it to begin to expand, the pressure is exerted downward upon the mercury in the bowl or chamber, forcing it upward through the circulating tube and the space between it and the stand pipe. As soon as sufficient pressure has accumulated to force the mercury to the top of the stand pipe and the circulating tube, the mercury in the bowl will be lowered until its level is at the top of the lower inlet of the circulating tube.

The two pipes now stand full of mercury, which, owing to the connection of the two columns at the top of the pipes, begins immediately to circulate. Unless the fire in the heater is checked the pressure will continue to increase until the mercury is forced below the inlet of the circulating tube, allowing the water to enter and

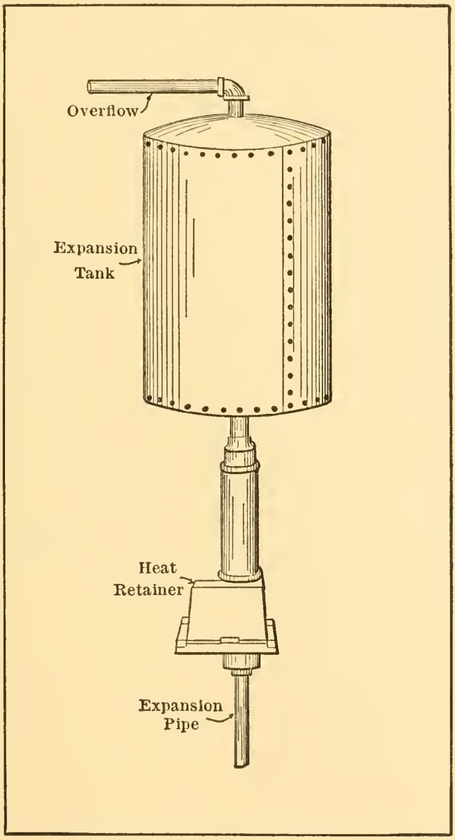

Fig. 150.—Phelps heat retainer.

pass upward to the tank until the pressure is reduced or removed, the baffle plate in the separating chamber dividing the mercury from the water and preventing it from leaving the generator. Owing to the small size of piping used, it is well to ream the ends of each length or piece of pipe used in the installation of the system and it is well also to test the circulation at as low a temperature as 110° and see that a perfect circulation may be maintained at this temperature.

An appliance quite similar to the Honeywell Generator in the results attained is known as the "Phelps Heat Retainer." However, this has no mercury attachment, but consists of a double-acting valve inclosed in a cast-iron box, as illustrated by Fig. 150. A weight rests upon the valve disc that opens toward the expansion tank, so that the pressure on the heating system must lift this weight in order that the water may overflow into the tank. The opposite end of the valve opens into the heating system and as there is no weight upon it, the least condensing of the water in the system, due to a low temperature, will open the valve and allow the water in the expansion tank to feed down into the system, thus preventing a vacuum. The pressure on the system at which the retainer operates is sixteen and one half pounds, allowing of a temperature of 250 degrees before the water can boil.

As with other appliances of this kind, a large reduction may be made in the amount of radiation; also small piping and radiator tappings may be used, but the heater capacity should remain unchanged, as it is necessary that this should be of ample size.

As a cure for sluggish circulation, due to improper methods of piping on work already installed, or a heating plant with insufficient radiation, it would seem that the use of a "generator" or a "retainer" should remedy the defect.

CHAPTER XVI

Greenhouse Heating

THE earlier methods of heating greenhouses were both crude and unsatisfactory. The improvement over the old forms of greenhouse heating and greenhouse construction has been such as to result in a complete revolution in building and heating the same.

The earliest method of heating a greenhouse, and one which for a time was more or less followed in this country, was the brick furnace and flue. This consisted of a brick combustion chamber, which was fitted with a cast-iron front, and the lower part provided with grate bars and an ash pit. The furnace was built in a pit or cellar at one end of the greenhouse, the brick or tile smoke flue connecting with the furnace, rising at a sharp angle to the floor of the house, where it was continued at a slight rise under the bed in the center of the house to the chimney at the opposite end. The hot air radiated by this flue was sufficient to heat a small greenhouse. There were so many objections to the use of this apparatus, such as the overheating and withering of plants, the killing of flowers by escaping gas through the tile or brickwork, etc., that it was discarded in favor of steam or hot water heat, as soon as the latter methods were generally adopted for greenhouse heating.

The original method of hot-water heating in this country, as applied to greenhouse work, consisted of a cast-iron heater of a type similar to that as shown by Figs. 23 and 24. The piping was of cast iron, about 4″ in diameter, with a hub or socket on one end. These were fastened together by using iron filings and other ingredients, making a rust joint.

The various lines of pipe had an upward pitch to the far end of the house, where they terminated in a hollow cast-iron post with air openings through the top. These were called expansion tanks, though they might more properly have been called "expansion posts." They not only took care of the increase in the volume of water, when heated, but served at the same time to extract the air from the system. We believe Hitchings & Company were the pioneers in this class of work in the United States.

Greenhouses are of two kinds, viz.: the commercial greenhouses in which are grown flowers and vegetables for profit, and the greenhouses or conservatories of the wealthier class and as found also in many of our public parks and botanical gardens. In the heating of the latter the first consideration is the efficiency of the apparatus, without reference to the matter of economy in the consumption cf fuel. On the other hand, with the former class (the commercial houses) both efficiency and economy in fuel are a constant study with the owner. The increase in the number of commercial greenhouses has been such that at the present time there is scarcely a town of any size which does not have one or more greenhouses, and in the towns adjacent to or within easy communication of the larger cities, they may be counted by the dozen. It is, therefore, important that the heating contractor become familiar with the modern methods of greenhouse heating—how to estimate the radiation required and in what manner the piping should be erected and the general conditions surrounding the work.

Modern Greenhouse Heating

The modern methods of greenhouse heating are by steam or hot water. There is a diversity of opinion among florists and gardeners as to which system of the two is perferable, some florists of large experience advocating steam, while others of equal experience and standing favor hot water. We are inclined to believe that hot water is best adapted for the use of florists for the following reasons.

(a) Greater economy in fuel consumption.

(b) Uniformity of temperature, hot-water heat being more constant and even. Should the fire for any reason get low, the water continues to circulate for hours.

(c) Where hot water is used for heating, the atmosphere in the greenhouse is mild and humid, insuring a healthy growth of the plants and flowers.

(d) The hot-water apparatus may be put under pressure, if desired, and thus equal low-pressure steam in intensity and quickness of action.

There are some groups of houses so situated that a steam-heating apparatus is better adapted for heating than would be a hot-water apparatus or where a hot-water apparatus could not be properly installed; hence it is well that the heating contractor become conversant with each of the two methods.

Estimating Radiation

A greenhouse structure offers less resistance to cold and frost than any other type of building, and, therefore, requires not only a greater amount of heat but greater care in its distribution in order to insure an even temperature throughout the house.

In order to intelligently estimate we must know what temperature is required for each house, as different plants require different degrees of heat. For instance, carnations require a temperature of from 50 to 55 degrees, roses from 60 to 65 degrees, chrysanthemums from 55 to 60 degrees, and houses for ferns, orchids, palms, etc., or, as they are called by florists, "general purpose houses" require from 55 to 70 degrees. Many florists have become growers of mushrooms, and these require a temperature of from 54 to 56 degrees.

Exposed surface is alone considered in estimating radiation and there are several methods of figuring. Where houses are already erected and it is possible to measure them, the amount of glass and exposed surface may be easily and quickly figured. Where this is not possible, the following rule will be found fairly accurate.

For houses not exceeding three or four feet in height at the eaves and when built in groups with no side glass, find the floor area of the house and add one third for ends and pitch of roof. The result will be the amount of exposed glass surface.

Example: a house 16′ × 100′—no glass on sides.

$$16 \times 100 = 1600 \div \tfrac{1}{3} = 533$$
$$1600 + 533 = 2133 \text{ sq. ft. of glass.}$$

For a house 16′ × 100′ with a belt of glass 2′ high under eaves: Proceed as before, and to the result of 2133 sq. ft. add the side glass $100 \times 2 = 200 \times 2 = 400 + 2133 = 2533$ sq. ft. of glass.

To determine the amount of radiation necessary, use the following table. This table is based on the temperature of a climate similar to that of New York City, where the temperature is seldom at or below zero and then for only a short period of time.

TABLE XVI

Temperature Required.		For Steam.	For Water.
45°	Divide square feet of glass by	8	5
50°	" " " " " "	7	4
55°	" " " " " "	6½	3¾
60°	" " " " " "	6	3⅓
65°	" " " " " "	5½	3¼
70°	" " " " " "	5	3

It is the custom to build greenhouses in as protected a position as possible and this fact is taken into consideration in formulating the above table. When the houses are in a particularly exposed position, to give 70° inside, use the figures "4" for steam and "2½" for hot water as divisors and the same proportionate addition for other temperatures.

When estimating for the pressure system (sealed tank) of hot water, use the same divisors as for steam.

TABLE XVII

Temperature of Air in House.	Sq. Ft. of glass and its equivalent proportioned to one sq. ft. of surface in heating pipes or radiator. Temperature of Water in Heating Pipes. 140°	160°	180°	200°
40°	4.33	5.25	6.66	7.69
45°	3.63	4.65	5.55	6.66
50°	3.07	3.92	4.76	5.71
55°	2.63	3.39	4.16	5.00
60°	2.19	2.89	3.63	4.33
65°	1.86	2.53	3.22	3.84
70°	1.58	2.19	2.81	3.44
75°	1.37	1.92	2.50	3.07
80°	1.16	1.63	2.17	2.73
85°	.99	1.42	1.92	2.46

For a greenhouse exposed on all sides (not one of a group) it is well to figure all wall surface, sides and ends, and for each five square feet of wall surface add one sq. ft. to the glass surface.

The preceding table will assist in determining the proportionate amount of glass to heating surface for various temperatures in the greenhouse, the outside temperature being at zero.

Methods of Greenhouse Piping

There has been much discussion among florists as to the relative merits of various styles of piping for greenhouses and we believe the consensus of opinion to be in favor of what is termed the "overfed system." By this is meant a running of the flow pipes overhead from one end of the house to the other and bringing back a sufficient number of return pipes under the benches or beds to give the necessary amount of heating surface in the house. In arranging for the heating of a greenhouse the boiler pit or cellar should, if possible, be placed at the low end of the house in order better to allow for the proper pitch and drainage of the piping, which in a house of considerable length is often a troublesome matter. If the greenhouse is built on level ground the boiler may be placed at either end and in the event of using one boiler to heat a group of houses, the boiler house and cellar should be centrally located in order to facilitate the arrangement of the piping.

There are many advantages to be gained by the use of the overfed system, chief of which is the placing of a share of the heating surface in the most exposed portion of the house, thus tempering a large portion of the cold air which finds entrance through or around the ventilators or through the laps in the glass. In setting the glass in a greenhouse the panes are lapped over each other in much the same manner as shingles or slate are laid on a roof, and the lap made in laying each pane is in many instances not air tight.

Again, in securing an even temperature of the air in the house the overhead pipes are of great assistance. We show by Fig. 151 a small hot-water apparatus for heating a single house. The potting shed and cellar for the heater are built against the side of the house at one end. The flow pipe rises from the heater in the most convenient manner to a point well toward the top of the shed. This is the high point of the system and from this point the connection to the expansion tank is made. The flow is then

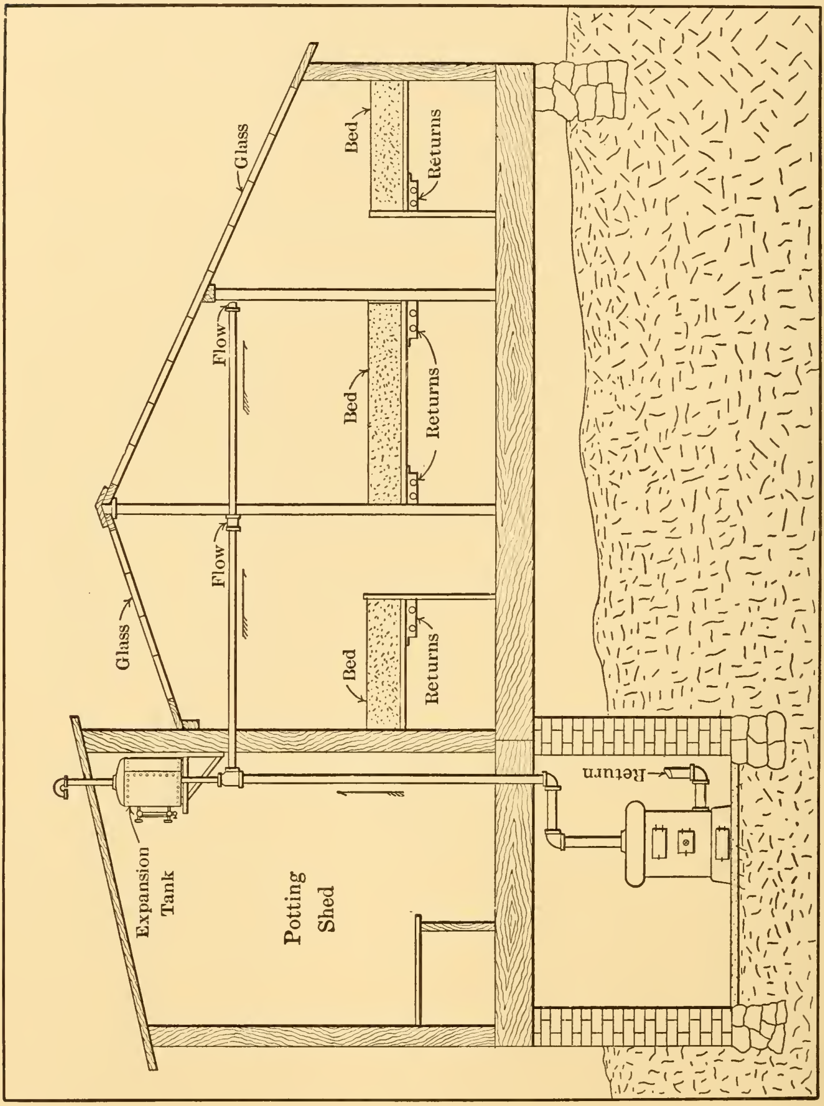

FIG. 151.—Method of greenhouse heating.

taken into and across one end of the greenhouse and supplies two main pipes which are hung overhead on the posts supporting the roof. These have a slight fall to the far end of the house where a drop is made, each flow feeding four return pipes which are hung under the benches. The piping (both flows and returns) have a slight fall from the expansion-tank connection to the connection to main return.

Fig. 152 shows a skeleton view of one half of the piping, and illustrates the system very clearly. Valves should be placed on the connections to each group of return pipes; those for hot water may be placed on either the flow or return connection. This will enable the florist to cut out from service any portion of the apparatus as desired—a very necessary operation in the mild days of the spring and fall months.

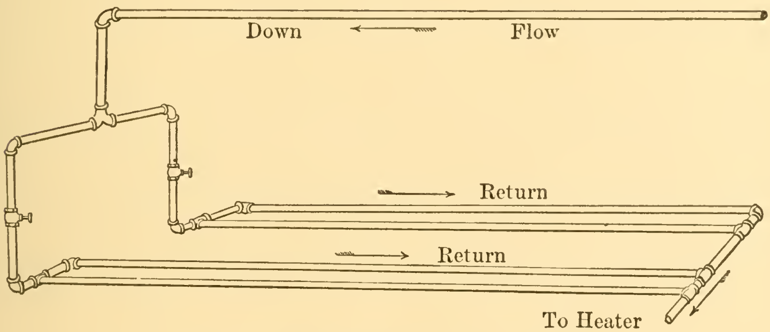

FIG. 152.—Method of piping for greenhouse.

The arrangement of the piping for steam is quite similar to that for hot water, the expansion tank and connections, of course, being omitted. When piping a greenhouse for steam, valves must be placed on both supply and return pipes, the air vents being placed on the return end of each group of return pipes and care must be taken to avoid all trapping of pipes and the forming of air pockets in the system. Should the house be a large one and a number of return pipes be placed in each group it is well to use branch tees (see Fig. 52) on the supply and return end of each group of pipes.

Where the side walls of a greenhouse are built high from the ground it is sometimes found advisable to place a portion of the piping on the sides. When a number of houses are built side by side it is an excellent plan to build a potting shed or inclosed passage along one end of the houses, and the main supply pipe of the heating apparatus should be run through this shed, branch mains being taken off as frequently as is found necessary. In determining the quantity and size of pipes to obtain a certain amount of heating surface, the table of pipe size and capacities given in Chapter VI will be found of great assistance.

For the mains running through the center of the house it is not advisable to use pipe larger than 3″ in size. As these mains are usually hung on the center posts supporting the roof, the increased weight of the heavy piping might cause damage from breakage or sagging.

CHAPTER XVII

Vacuum, Vapor and Vacuum Exhaust Heating

VACUUM heating is the operation or running of a steam-heating plant at a less pressure than the atmosphere, which at sea level is 14.7 pounds per square inch. On the ordinary steam-heating plant we are accustomed to say, for instance, that we have two, five or ten pounds pressure. By this we mean, *pressure above that of the atmosphere*, and therefore the true pressure on such a plant would be 16.7, 19.7, or 24.7 pounds as the case might be.

To state this matter in another form: water boils at sea level. atmospheric pressure, at 212 degrees Fahr., in an open vessel or in the ordinary steam apparatus with air vents open to the atmosphere. Supposing we relieve the apparatus from all atmospheric pressure—the water in it will boil at a temperature of 98 degrees. The word "vacuum" means empty space, or space void of matter. We are accustomed to speak of a bottle or other vessel from which the contents have been drawn off as being empty. This is not true, because as fast as the receptacle is emptied of its visible contents an invisible volume of air or atmosphere takes its place.

Steam and air being of different densities will not mix. Close tightly the air valve on a radiator when there is no pressure of steam on the apparatus and the result will be that as the steam pressure is increased the air in the radiator will be compressed, making it impossible for the steam to fill all of the radiator. Open the air vent and the radiator will fill with steam as the air is pushed ahead of the steam and exhausted through the air vent opening. Steam is an elastic gas, or properly, is water turned into gas by expansion due to heating it to a temperature above the boiling point. If unconfined, water thus turned into steam is expanded seventeen hundred times. Therefore, reverting again to the radiator, after the steam with which it is filled condenses, it occupies but a very small part of the space within the radiator, the remainder of the space again filling with air, which must repeatedly be exhausted before the radiator will fill with steam. Vacuum as applied to steam heating means the use of some form of apparatus, such as an exhauster, pump, or other appliance, to keep the radiators and other parts of the heating apparatus free from air, or under a vacuum in order that the water in the system will boil at a low temperature and be converted into steam, which may then flow unobstructed through all piping and radiators. The flow of steam in a vacuum attains a velocity of 1,550 feet per second. Thus it will be seen how quickly a circulation in a heating system can be established.

With an apparatus capable of producing steam at 98 degrees (complete vacuum) to 240 degrees (10 lbs. atmospheric pressure), there seems no doubt but what any building may be readily and easily heated no matter how quickly weather conditions and the outside temperature may change, and that a minimum degree of economy in fuel consumption may be attained.

With a regular system of steam heating the air in apparatus is never entirely removed from radiators and piping, particularly from the radiating surface. When the vacuum system is attached to an apparatus of this kind all air in every portion of the radiators and piping is exhausted from the system, rendering the heating surface more efficient. Thus old systems are benefited by the addition of the vacuum appliances and even though but a partial vacuum be maintained, the betterment of the job in efficiency and the saving of fuel are quickly noticeable.

To this may be added other features which make a system of this character particularly desirable, among which may be mentioned:

(a) The low cost of installation, it averaging much less than for hot water, yet retaining all of the various degrees of temperature regulation possible with a hot-water system.

(b) Economy in fuel over either steam or hot water.

(c) Less radiation required than for hot water, while still retaining the range of temperature.

(d) No danger from frosts or leaks, which frequently occur in a hot-water heating apparatus.

(e) Long runs of piping which very often cause trouble, owing to inability to drain them properly, can with a vacuum system be entirely freed from the water of condensation.

Improved Methods of Exhaust Heating

In Chapter XII we briefly called the attention of our readers to the advantages of utilizing the exhaust steam from the engine. We now desire to describe several of the more modern methods of applying this exhaust to the heating of a building. To derive the greatest benefit from a steam-heating apparatus, it is necessary to keep the system free of air, and this is particularly true when heating with exhaust steam.

Air in a greater or less quantity is always present in water used for boiler-feed purposes. As the water in the boiler is generated into steam, all air collects in the various radiators or coils of the heating system and this accumulation of air obstructs the flow of the incoming steam and prevents it from distributing uniformly over the heating service, with the result that the radiator or coil is never working at its full efficiency.

Vacuum heating when originally used was applied to a system of exhaust heating and for some time was employed in no other manner. The original patents were taken out by Mr. N. P. Williams, in 1882. This was followed by the "Webster System" by Warren Webster & Co., the "Paul System," by Andrew G. Paul, and the vacuum system was applied to all classes of steam work.

Fig. 153 shows the application of the Webster System on an exhaust steam-heating apparatus. Reference to the same will show the various appliances and connections necessary for a system of this character. "The operation of the Webster System is based upon the flow of steam and condensation from a pressure slightly above into a pressure slightly below that of the atmosphere or into a partial vacuum." This is the explanation given of the principles of the Webster System and is, we think, sufficiently clear to be readily understood.

With this system a partial vacuum is maintained only on the return pipes and the system is, therefore, applicable only to two-pipe work. At the return end of each radiator or coil, in the place

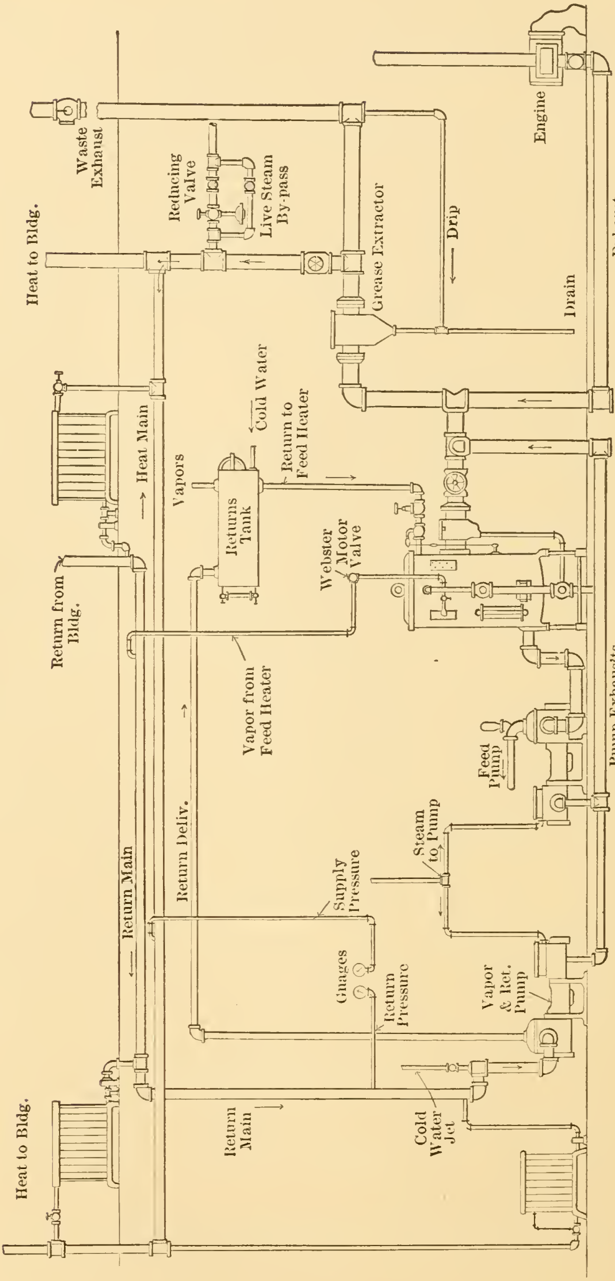

Fig. 153.—Webster system of vacuum heating.

of an ordinary valve there is put a motor valve, as shown by Fig. 154 and Fig. 155. The working of this valve is automatic. It prevents the escape of steam from the radiator or coil and at the same time removes all air and all water of condensation from the same, thus making the entire surface of the radiator or coil effective for heating purposes. The pressure of steam in these radiators or coils is not reduced by the vacuum on the returns. This pres-

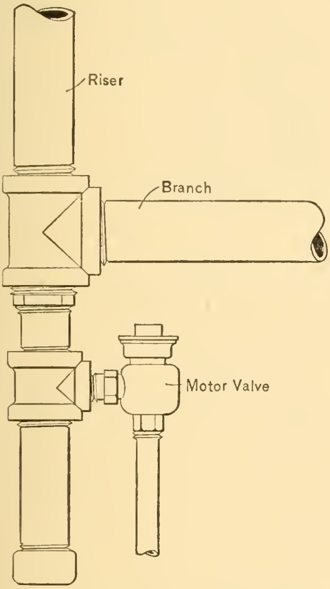

FIG. 153A.—Webster motor valve at base of riser.

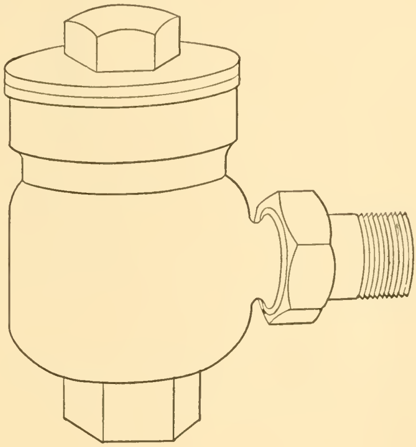

FIG. 154.—Exterior of motor valve.

sure is dependent on the volume of steam which can enter through the supply valve. At the base of each riser a motor valve is placed as shown by Fig. 153A.

The vacuum on a Webster system is produced by the operation of a pump, which pumps the return water and the vapor (air) out of the system and delivers them into a tank which is open to the atmosphere to allow all vapor to escape. The return water is fed from this tank into a feed-water heater, and from this is delivered to the boiler by a feed pump. When a low-pressure boiler is used the vacuum pump is usually driven by a chain-connected electric motor, and the water and air are delivered to a tank placed sufficiently high above the boiler to feed the water into the same by gravity against the low pressure carried on the boiler.

With this system smaller flow and return pipes may be used than for the regular two-pipe system of steam heating, and radia-

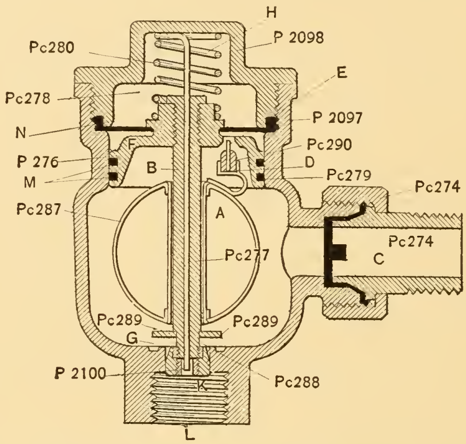

FIG. 155.—Cross section of motor valve.

tors or heating coils may be placed below the line of the main feed or return pipes and work successfully.

The Paul System

Mr. Andrew G. Paul in seeking a method of keeping a heating apparatus free from air perfected a system which is known as the "Paul System." This is quite different from the other systems of vacuum heating in that it removes the air only, the water of condensation finding its way to the boiler by gravity. It is thus applicable to either low-pressure or high-pressure steam heating, and to either the one or two pipe system.

A special apparatus called an exhauster removes all air from the system before the steam is allowed to enter, the automatic or thermostatic air valves on each unit of radiation closing against the steam immediately all air is exhausted and the steam comes in contact with the air valve. This exhausting apparatus is of two kinds, namely, for high pressure and for low pressure. Fig. 156 shows the high-pressure exhauster. It is operated by a jet of steam, and is the kind of appliance used on a system of exhaust

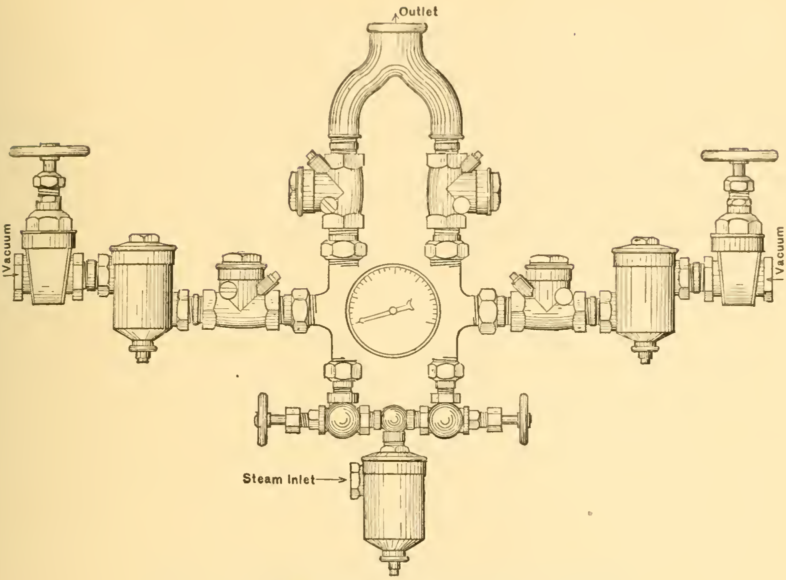

FIG. 156.—Paul system—high-pressure exhauster.

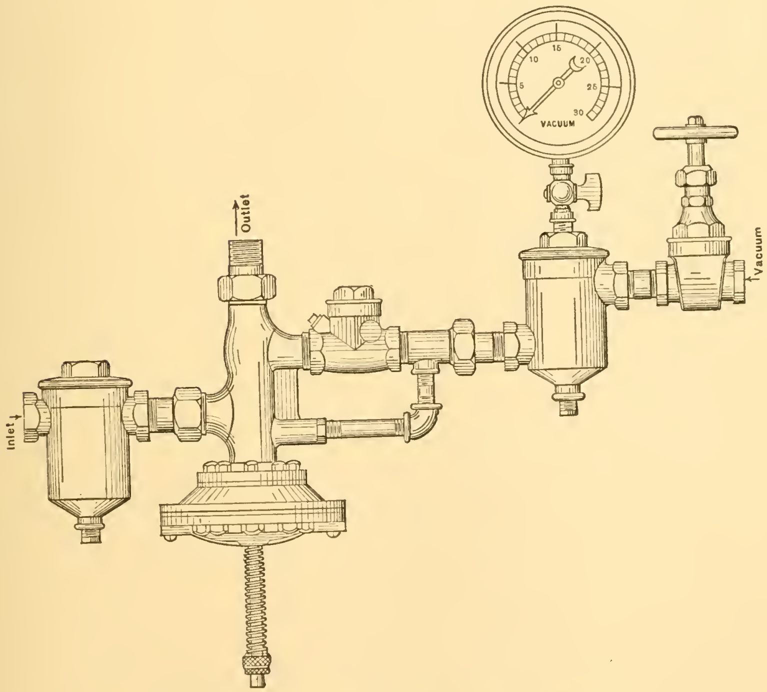

FIG. 157.—Paul system—Low-pressure exhauster.

heating. Fig. 157 shows the low-pressure exhauster, which may be operated by water pressure. The return pipes and drips connect into a receiving tank, from which the condensation is pumped back to the boiler. This receiver is a closed tank and on it is placed a thermostatic valve for the removal of all air.

Key to Fig. 158

A. Boiler
B. Feed-water Heater
C. Engine
D. Exhauster
F. Feed Pump
G. Reducing-pressure Valve
H. Back-pressure Valve
I. Exhaust from Engine
J. Exhaust from Pump
K. Compound Gauge
L. Vacuum Gauge
M. Gate Valves
N. Check Valves
O. Live Steam to Pump
P. Live Steam to Engine
Q. Live Steam to Exhauster
R. Cold-water Feed
S. Feed to Boiler
T. Suction to Pump
U. Discharge from Exhauster
V. Exhaust to Atmosphere
W. Radiators
X. Air Valves
Y. Returns
Z. Drips
a. Air Pipes
b. Supply Heating Pipes
d. Blow-off and Overflow
e. Relief Pipe
f. Angle Valve
h. Water Column
i. Radiator Valves

Key to Fig. 159

A. Boiler
B. Engine
C. Feed-water Heater
D. Aut. Return Tank and Pump
E. Back-pressure Valve
G. Live-steam Separator
H. Grease Extractor
I. Steam Gauge
J. Compound Gauge
K. Vacuum Gauge
L. Exhauster
M. Safety Valve
N. Water-relief Valve
O. Gate Valve
P. Angle Valve
Q. Check Valve
R. Reducing-pressure Valve
S. By-Pass for Red.-pressure Valve
T. Automatic Air Valve
U. Live Steam to Engine
V. Live Steam to Reducing-pressure V.
W. Live Steam to Pump
X. Live Steam to Exhauster
Y. Exhaust from Engine
Z. Exhaust to Atmosphere
a. Drip from Exhaust Head
b. Heating Supply Pipe
c. Drip from Heater
d. Drip from Grease Extractor
e. Drip from Exhaust Pipe
f. Feed-water Pipe
g. Discharge from Exhauster
h. Drip from Separator
i. Return Pipe
j. Air Pipe

Fig. 158 shows the application of the system on a two-pipe system and Fig. 159 shows a single pipe overhead or down-fed

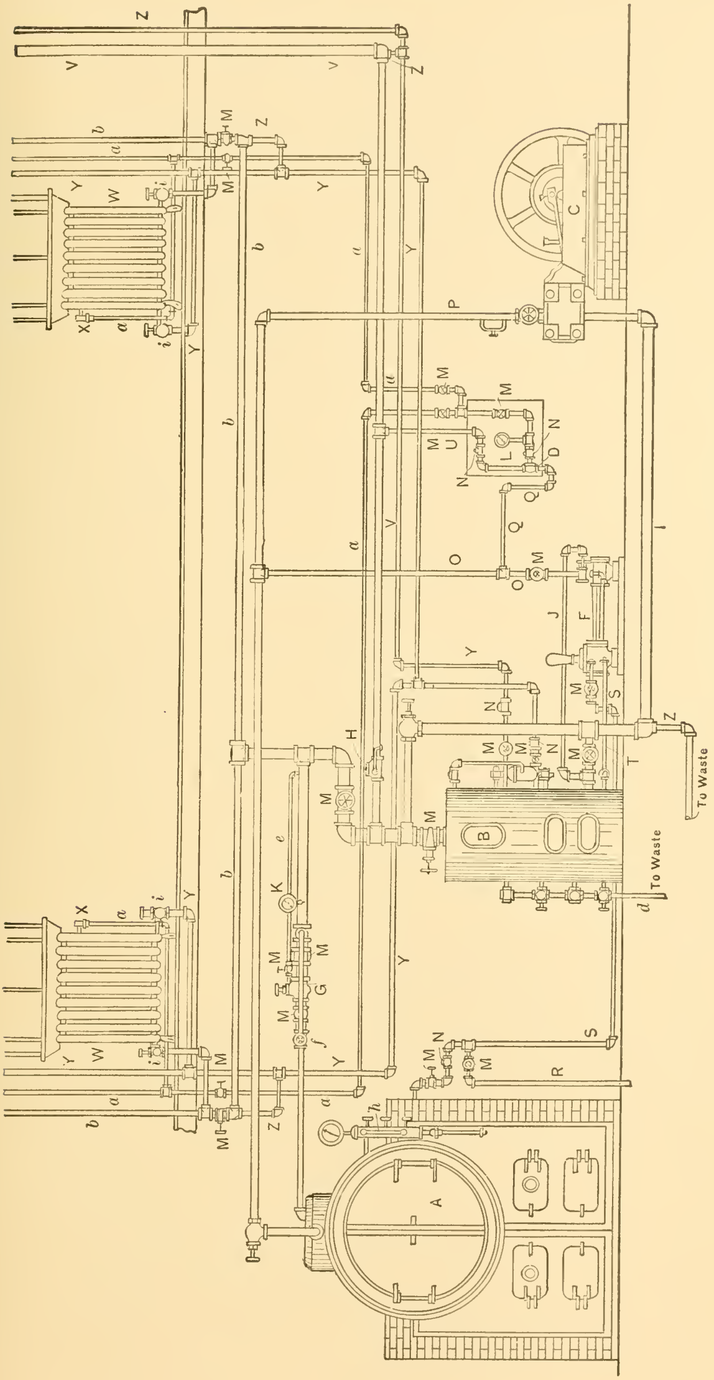

FIG. 158.—Paul system applied to two-pipe work.

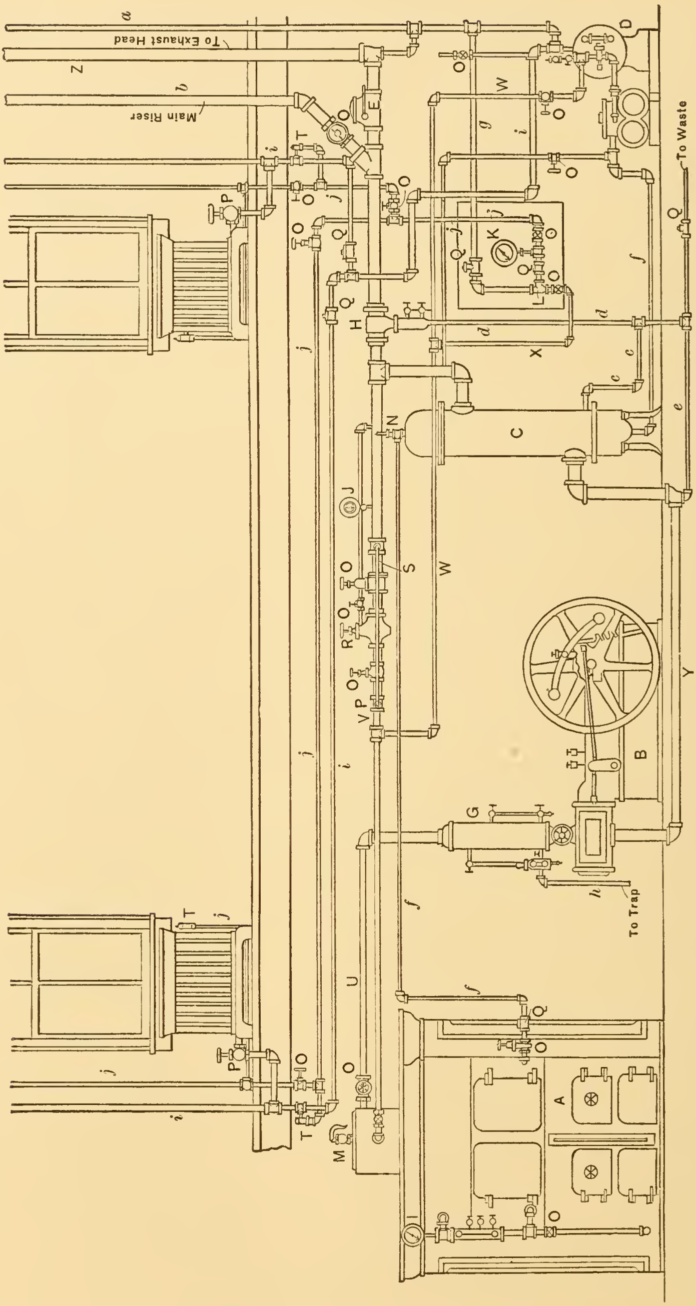

FIG. 159.—Paul system applied to one-pipe work.

system. In operating, the exhausting apparatus is first put in operation and all air removed from the system. The steam as it is turned on the system finding no air pressure to impede its progress flows naturally and unobstructed into each radiator and coil, when having completely filled them reaches the thermostatic air valve, which closes as the steam touches it. When the steam is turned off and the radiator cooled, the air valve again opens, all air in it is exhausted, thus leaving the radiator in condition to receive the steam again. There is a constant vacuum on the air line below the air valves. After the air has been sucked out of the radiators, however, these valves close.

The Van-Auken System

In many respects this is similar to the Webster and the Paul systems. An exhausting device known as a " Belvac Thermofier " is used on the return end of each radiator, which works in much the same manner as the Webster Motor Valve. A vacuum pump, receiving tank, together with the usual specialties employed in exhaust heating, are also used in much the same manner as on the Webster System.

In application several styles of piping may be used. For a heating plant with gravity returns a drip tank or receiver is made use of, into which the gravity return discharges. The drops from the various risers discharge to the tank through a trap. The main vacuum return is connected to this tank, which feeds directly to the vacuum pump.

Mercury Seal Systems

The systems described in the preceding pages are what might be called mechanical systems, that is, they require a pump, exhauster, or other device in maintaining a vacuum and removing the condensation from radiators and piping. A system of this kind would scarcely be applicable for heating an ordinary residence, or small-sized building.

In order to maintain a vacuum on a heating system it is essential that after having once exhausted or driven the air out of the radiators and piping it be prevented from entering again. It can be readily comprehended how that any simple method of accomplishing this would be as productive of results as either one of the larger systems. The success of the larger mechanical heating plants led to much experimenting with the smaller systems. Owing to its density, mercury was brought into use in conducting these experiments, with the result that two systems have been evolved and patented, one by D. F. Morgan, now known as the "K-M-C" system, and the other by Jas. A. Trane, known as the "Mercury Seal" system. Both are similar in principle, employing a mercury device for preventing the air from reëntering the system after once having been exhausted.

The "K-M-C" System

Fig. 160 shows the general arrangement of the piping, boiler connections and special devices of this system.

The air is driven from the apparatus by a slight pressure of steam and is prevented from reëntering the system by a mercury

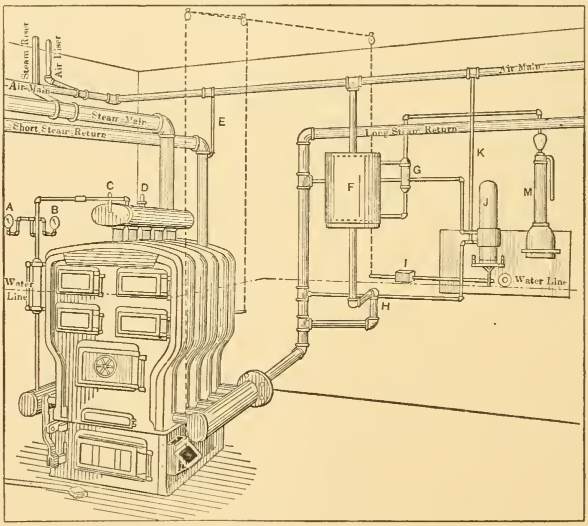

FIG. 160.—"K-M-C" system of vacuum heating.

seal. The end of the air line is submerged in mercury to the depth of about one half of an inch. This offers but little resistance in expelling the air, but effectually prevents it from reëntering the system. An accumulating tank is used to prevent any water from entering the mercury seal. Sufficient water is always present in this tank to condense any steam which might enter through the air line.

Fig. 161 shows a descriptive cut of the system with the various specialties connected.

The damper regulator is a very important part of this arrangement; it effectually controls the fire and prevents overheating. It consists of a drawn copper cylinder with a rubber diaphragm

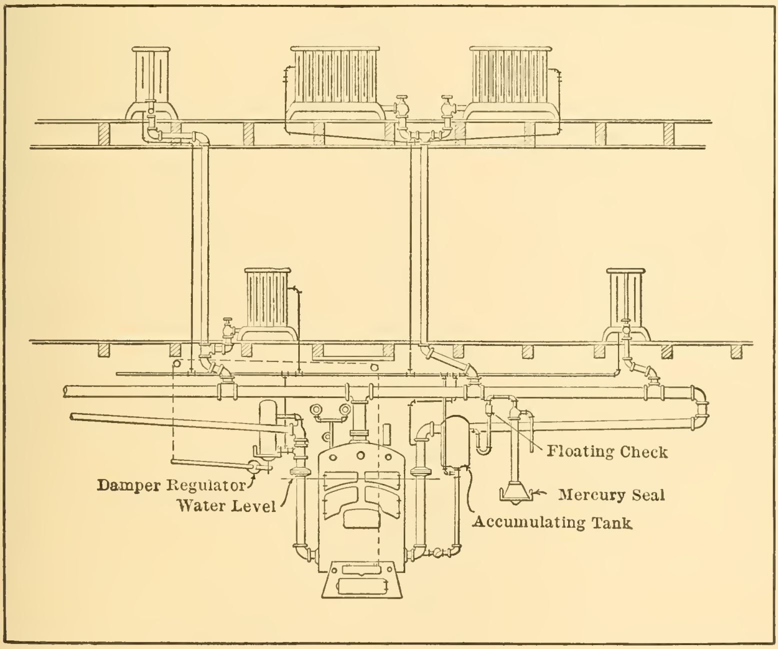

FIG. 161.—"K-M-C" system showing attachment of fixtures.

at the bottom. The expansion of air in the copper cylinder, when heated, operates the regulator, which may be set to open or close the dampers either above or below atmospheric pressure.

A special type of automatic air valve known as a "retarder" is used on the radiators and coils and to which the air lines are connected. The supply end of the radiator is provided with a Packless Diaphragm radiator valve, which prevents air leaks at the valve, which would destroy the vacuum on the system. The air lines are run in quite the same manner as described for the following system.

The Trane System

The Trane System, as designed by Jas. A. Trane, is also known as the "Mercury Seal System" from the fact that all air from the system is discharged through a mercury seal or trap which effectually prevents the air from reëntering the system through the air valves, after having been expelled by the steam pressure.

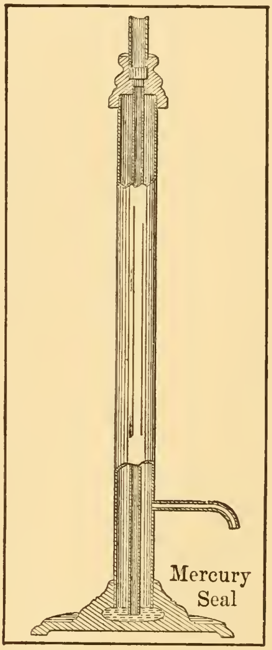

Fig. 162.—Mercury seal—Trane system.

Each radiator is provided with an automatic air valve quite similar to the Paul air valve, having a union drip connection. An air-line pipe is run around the basement, convenient to the steam main and the air pipe from each radiator is connected into it. This air line terminates at a point near the boiler and drops down, connecting into the top of the device known as a mercury seal. See Fig. 162.

The steam piping may be either one of the regular systems, and there is nothing special in the way of erecting the same, except to see that all joints are made tight and that the stuffing boxes of all valves are tightly packed. A safety valve which is air tight should be used, the " pop " spring valve being recommended. A compound gauge registering vacuum and steam pressure should be placed on the system.

The mercury seal device shown by Fig. 162 is constructed somewhat on the principle of the ordinary mercury barometer, the end of the air pipe dipping into the mercury, which is held in the cup-

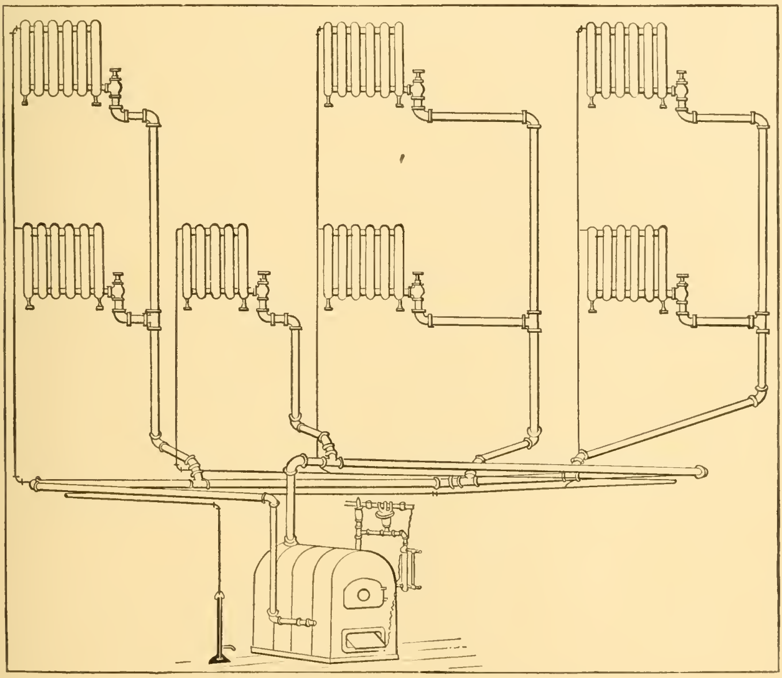

Fig. 163.—The Trane system of vacuum heating.

shaped interior of the hollow base of the seal. While forming a seal preventing air from entering the system, the mercury offers very litle resistance to the expulsion of air from the system, a pressure of but one half pound being necessary to accomplish this.

A general idea of the application of this system is shown by Fig. 163, which illustrates the air lines and mercury seal attached to a one-pipe circuit system. The operation of it is as follows:

After starting a fire in the apparatus, a steam pressure of from two to three pounds should be maintained for a short period, in order to drive all air out of the system and determine whether or not it is free from leaks. The draught door of the boiler is then closed and the temperature at the boiler falls. As the steam pressure is removed from the radiators, the automatic air valves open and the air endeavors to enter the system, but is prevented by the mercury seal. However, the mercury will be drawn up into the tube above the seal to a height representing the difference between the pressure within the radiator and the atmospheric pressure without, and this height representing inches of vacuum will be registered by the compound gauge.

The apparatus may then be operated at a very low temperature and should any air again enter the system it is easily expelled by raising a slight pressure of steam on the system.

The Ryan System

The piping for the Ryan system of vacuum heating is installed the same as for the other styles making use of air pipes.

An air trap is used instead of mercury for sealing the system. The main air line connects into a side opening in the trap, which is so located that this opening is 27″ or more above the water line of the apparatus. A drip pipe from bottom of the trap connecting into the return below the water line of the boiler, relieves it of all water carried into it through the air line. At the top of the trap is the opening through which the air is exhausted and an equalizing pipe from boiler is also connected into it at this point.

A special automatic air valve is used on each radiator, which closes against the steam and opens again as the radiator cools, permitting the exhausting of all air carried into the radiator by the steam. Fig. 164 shows the application of this system.

Vapor Heating

The Broomell System is distinctly a vapor system, the temperature never exceeding that of water at the boiling point, namely 212 degrees. The piping for this system while smaller than used for steam has the appearance of the piping of a two-pipe system, the smaller pipe being the drip through which the air and water of condensation are carried back to the boiler through an apparatus

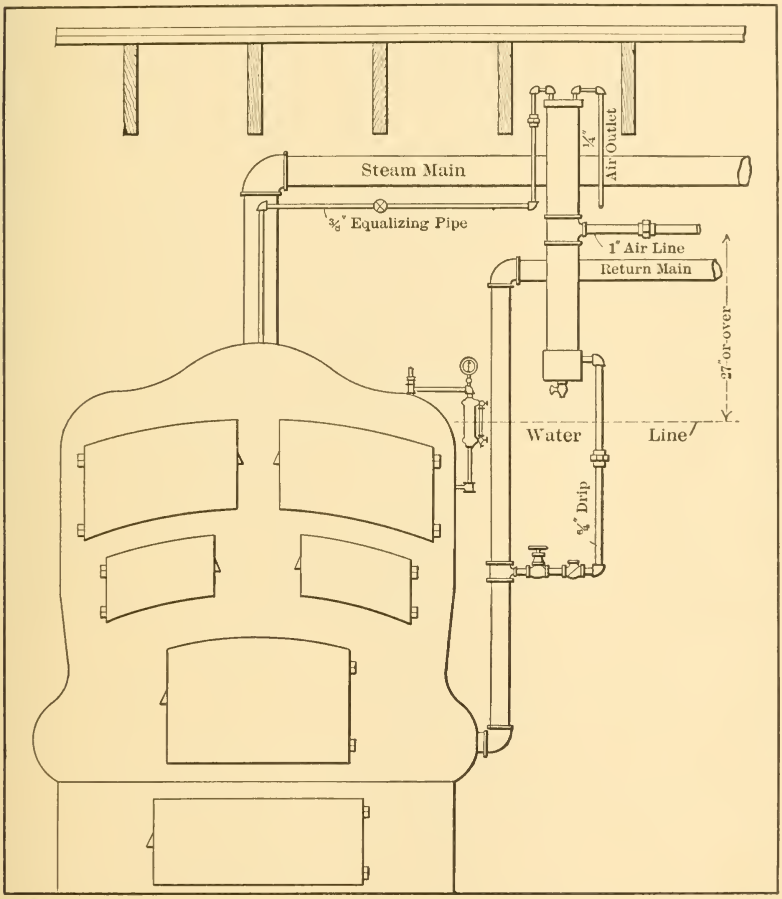

FIG. 164.—The Ryan system of vacuum heating.

which is described as a "combined receiver, relief apparatus and draught regulator." A few loops of indirect radiation termed a condensing coil are located adjacent to and above this receiver and a connection is made from the top of the receiver to the bottom of the coil. From the top of this coil an air pipe is run into the chimney. The draught in the chimney exerts a pull on the apparatus, causing a partial vacuum on the system, which not only exhausts the air, but at the same time accelerates the flow of vapor through the radiators and coils. The pressure on this system is slightly above that of the atmosphere and is registered in ounces on the receiver. See Fig. 165. This receiver is the real heart of the system, regulating the draughts of the boiler by a ball-float attachment and acting as a separator and equalizer in dividing the

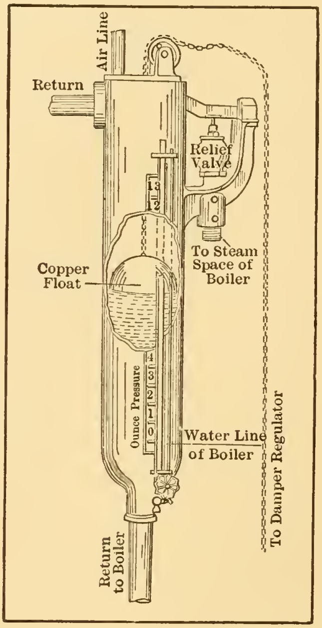

Fig. 165.—Combined receiver, relief, and draught regulator—Broomell system.

return water and the air which accumulates in the system, and again acting as a relief from any overpressure at the boiler. It can be so adjusted as a regulator that the draught doors of the boiler will close under the slightest pressure.

Hot-water radiators are used with this system. The supply is connected at the top of one end by what is termed a quintuple valve, that is, a valve having four holes or ports through the disc, which engage with similar ports in the bottom or seat of the valve.

Thus it may be entirely closed or opened one, two, three or four ports, thereby fully regulating the amount of heat or vapor delivered to each radiator. At the bottom of the opposite end of the radiator—the return end—the air and return pipes are con-

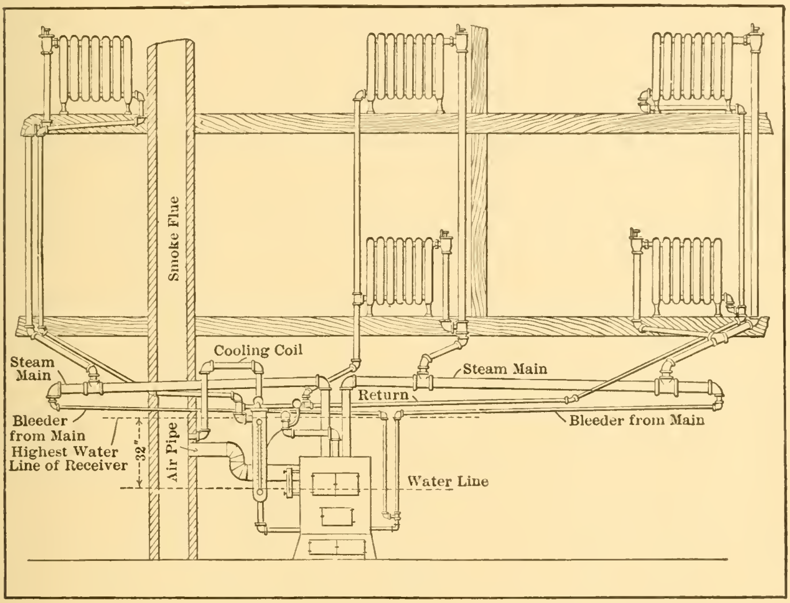

FIG. 166.—The Broomell system of vapor heating.

nected by a specially constructed union elbow, which, while allowing all air and water to escape from the radiator, is closed against any pressure on the return line.

It is recommended that the same amount of radiation be installed as would be used for hot-water heating. Fig. 166 clearly illustrates the installation of this system.

Vacuum-Vapor Systems

There are some systems of heating at a pressure below that of the atmosphere, which embody some of the principles of both the vacuum and the vapor systems, and these are aptly called vacuum-vapor heating systems. Representing this style of heating we have the Gorton System and the Vacuum Vapor Company's System.

The Gorton System

With the regular system of vacuum heating it is not possible to regulate the heat in any single radiator except by automatic heat control. With the regular vapor system the heat in each individual radiator may be controlled, but it is not possible to attain a temperature on the apparatus of over 212° to 215°; therefore the radiators must be larger than would be required for steam. The Gorton System is capable of heating under a vacuum or at ten pounds pressure.

The method of piping used is practically the two-pipe system. An ordinary or a special type of a radiator valve is used on the

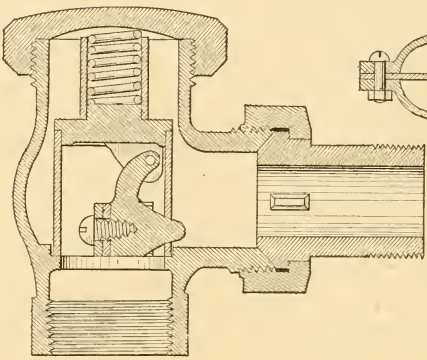

FIG. 167.—Cross section of Gorton automatic drainage valve.

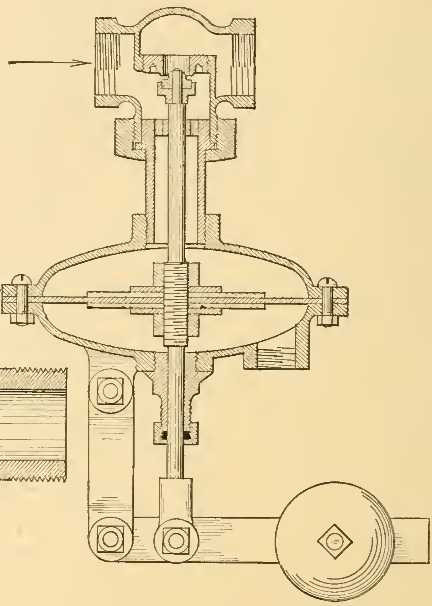

FIG. 168.—Cross section of Gorton automatic relief valve.

supply end of the radiator. The radiators may be built for steam or hot water. On the return end is placed an automatic drainage valve—Fig. 167. When the radiator valve is opened the drainage valve opens sufficiently so that all air and the water of condensation pass into the return pipe and down to the automatic relief valve—

Fig. 168—where the air is exhausted and the water returns to the boiler. The relief valve is operated by the difference in pressure between the steam and the return mains. It opens to relieve the air just as soon as the air in the return main increases the pressure, when, having relieved the system, it will again close.

This system has the advantage of a wide range of temperature, the use of steam or hot-water radiators and the ability to control the heat in any one radiator. It has this disadvantage, however, that it is applicable only to two-pipe work.

Fig. 169 shows a view of the correct position of the automatic relief valve and the pipe connections at the boiler. The return

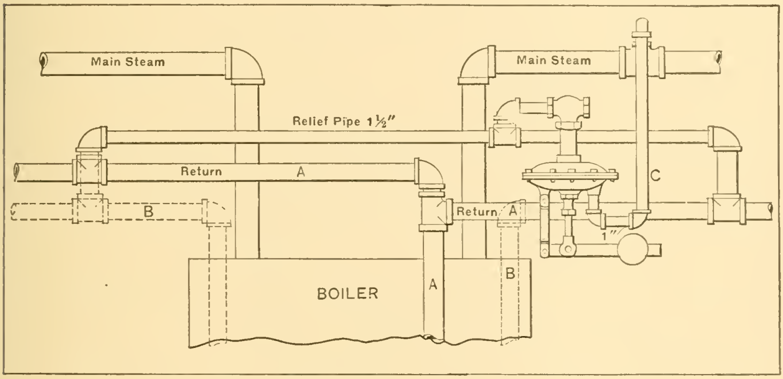

FIG. 169.—Gorton system of vacuum-vapor heating.

mains may be connected above the water line, as shown, or they may drop as indicated by dotted lines on Fig. 169 and be connected below the water line. The lowest point of return mains should be at least 18″ above the water line of the boiler, and the relief pipe should be 4″ above the return mains. The automatic relief valve is connected to the relief pipe and to the steam main as shown.

The Vacuum-Vapor System

The vacuum-vapor method may be applied to almost any style of piping. The special appliances necessary are an air trap, a float valve and an ejector.

A condensing radiator is used as shown on Fig. 170. The

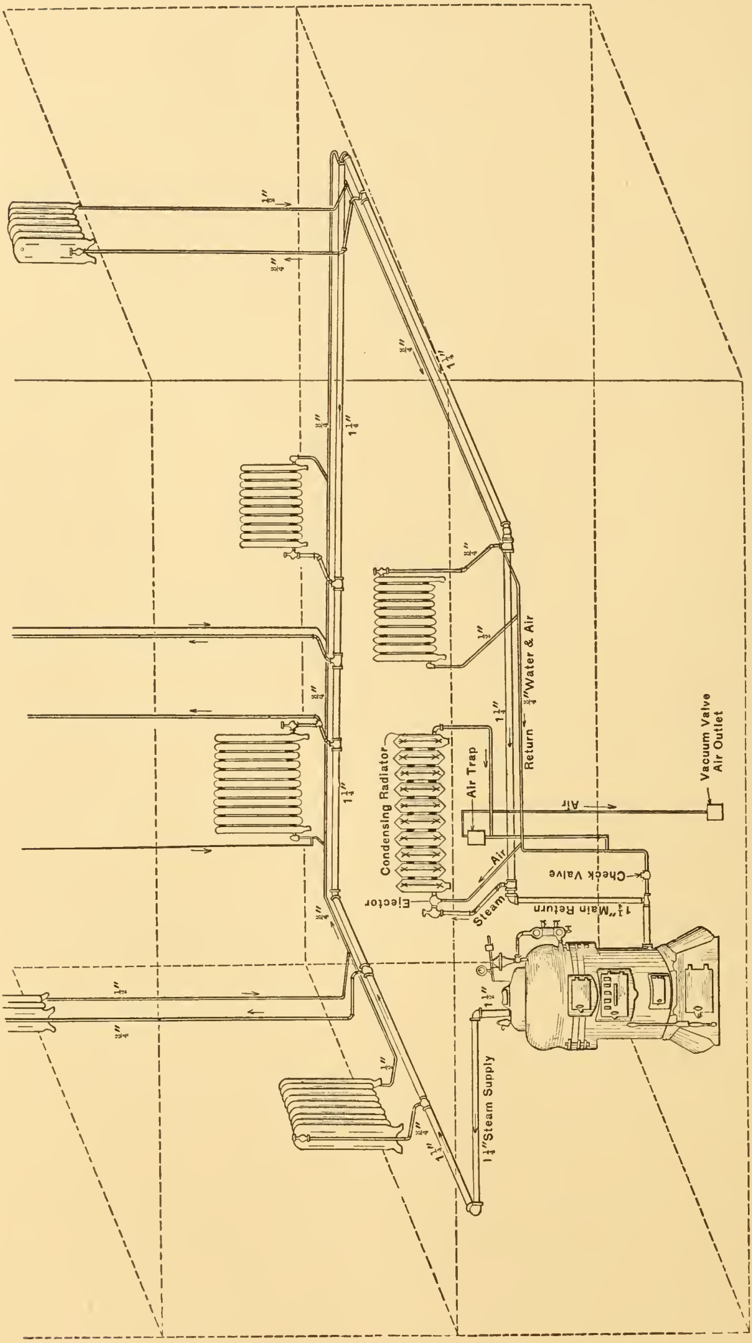

FIG. 170.—Vacuum Vapor Company's system.

air lines containing vapor and more or less water are discharged into the condensing radiator by means of an ejector. This ejector is connected directly to the boiler or steam main, from which it receives the necessary force to operate it. The air and water pass through the return outlet of the condensing radiator, the water of condensation returning to the boiler by gravity. The air passes through the air trap and thence to the float or vacuum valve and into the atmosphere.

In other respects this system is similar to those already described.

The Dunham Vacuo-Vapor System

A method of vacuum heating styled "Vacuo-Vapor" has been developed by Mr. C. A. Dunham, which is in some respects both novel and interesting, mainly in that the appliances employed maintain a constant difference in pressure between the steam or flow pipe and the return pipe without any mechanical means. The maintenance of this difference in pressure proves of great assistance to the circulation on the regular gravity system of steam heating.

Like many of the vacuum systems, air valves on the radiators are dispensed with, the air and return water of condensation being taken to the basement into a small tank hung 18″ or more above the regular water line of the boiler. A drip from this tank drops to the return opening of the boiler, the water of condensation returning to the boiler through this drip, which has a horizontal check valve on it near to the boiler. The condensation in entering the tank passes through a horizontal check placed on the return near the tank. The air, separated from the water in the tank, passes through a thermostatic and vacuum air valve to the atmosphere.

An air trap, Fig. 170A, is placed on the return end of each radiator, remaining open when cold and closing as soon as the heated vapor or steam reaches it. The closed trap retards the steam until the water of condensation collects in sufficient quantity to operate the trap, when it, together with the accumulated air, passes through the returns to the separating tank.

When the system is working above atmospheric pressure, the accumulated air passes freely through the air trap or thermostatic air valve and the vacuum air valve above the tank, the water continuing to collect in the tank until such an amount has been evaporated from the boiler as will lower the water line below the end of the equalizing pipe. This equalizing pipe forms a loop approximately four feet in length connecting the receiving tank with the boiler, the end of the loop entering the boiler through an opening, tapped for the purpose, and extending below the water line.

This permits live steam to enter the loop, equalizing the pressure between the tank and the boiler, permitting the water to flow

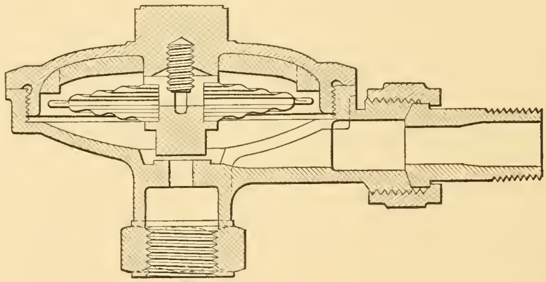

Fig. 170a.—Air trap Dunham vacuo-vapor system.

down into the return pipes and through the check valves into the boiler. This action again raises the water line above the bottom of the loop or equalizing pipe, effectually sealing it.

The partial vacuum created by the condensing of the steam in the tank after the discharging process, relieves the pressure against the check valves on the return pipes, allowing the accumulated air and water to enter the tank, and relieving the returns of any pressure, as the partial vacuum reaches to the radiators.

To obtain the most economical results from a system of this character, the supply valves on the radiators should be opened only enough to admit sufficient steam to properly heat the room, the pressure at the boiler being slightly above that of the atmosphere and not greater than one pound. The fire should be banked at night and the system operated under a vacuum.

Fig. 170B shows the application of this system for ordinary low-pressure work. Smaller piping is employed than that used on a regular steam job. The return connections from all radiators should be ½″ in size, and the supply end of radiators tapped up to 50 sq. ft. ¾″, 50 to 90 sq. ft. 1″, 90 to 185 sq. ft. 1¼″.

A special form of this system is devised for larger jobs, using live or exhaust steam, the regular form of air trap being employed

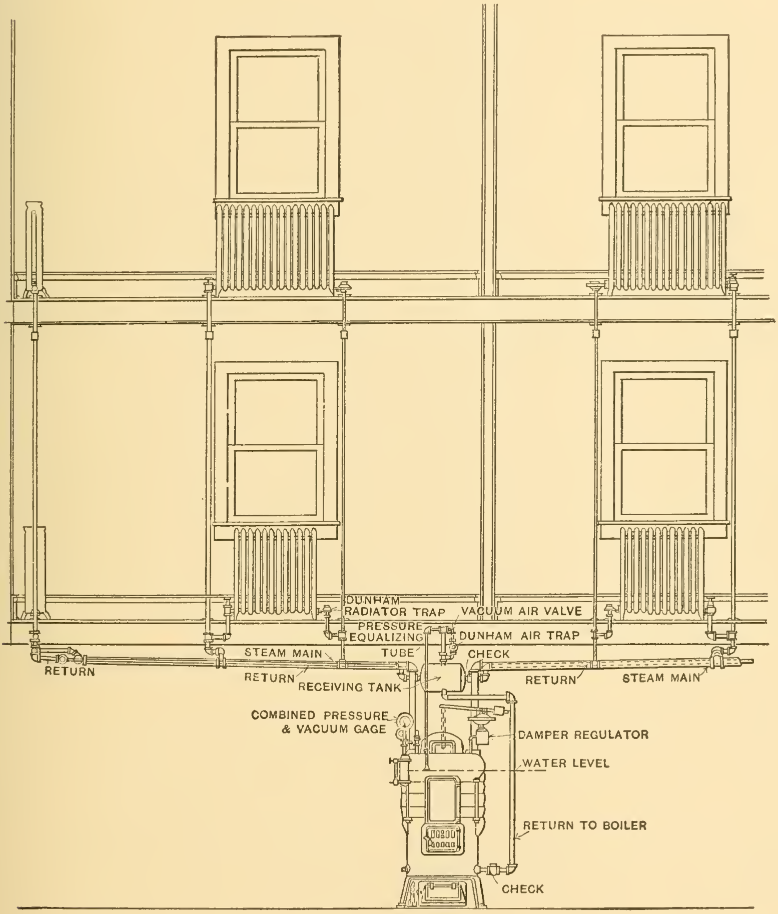

FIG. 170B.—Dunham system for low pressure.

on all radiators, and an air relief and pump governor or controller, which acts as a receiver for all condensation, is placed near the pump and is so connected that the pump may assist the circulation by pulling directly on the returns.

The Future of Vacuum Heating

But a few years ago (1895) a heating engineer made use of the following expression in discussing the future of the heating business before a trade association:

"If you can circulate a system below atmosphere in a large building you can certainly circulate it below atmosphere in a dwelling house. If you can circulate it below, how much below can you circulate it? It is possible that in a few years from now we will be heating houses not by hot water but by steam below atmospheric pressure, of such a low temperature that it gives all of the advantages of hot water without any of its disadvantages."

His prediction is now an accepted fact and vacuum and vapor heating, as we may observe by following up the many ideas and the many systems already before us, have by the use of various devices described on the preceding pages become adaptable to any size of residence or building.

CHAPTER XVIII

MISCELLANEOUS HEATING

The Heating of Swimming Pools

The simplest method of heating an open body of water such as a swimming pool or tank is by hot-water circulation. The heater should be placed sufficiently below the level or surface of the water that a natural circulation may be established between the heater and the tank. Fig. 171 shows an apparatus of this kind. The swimming pool illustrated contains approximately 30,000 gallons of water when filled to the normal water level. The size of flow pipe leaving the heater should be 6″ and this should supply two 4″ feed or flow pipes to the pool. These may be connected to it at points about 18″ below the water line, the first pipe entering the pool about midway of its length, the last pipe entering well toward the shallow end.

The return pipes should be connected from the deep end of the pool at a point about 6″ from the bottom. The direction of the circulation of the water is indicated by the arrows shown on the illustration. The heater must be so set that the return openings in it are at least 12″ below the bottom of the water in the pool.

Fig. 172 is an elevation plan of the same apparatus and shows the relative heights at which the circulation enters and leaves the pool. Some engineers favor the method of having the flow pipes enter at the bottom of the shallow end of the pool and the taking of the returns out of the bottom of the deep end. This is not as good a plan as that which we illustrate by Fig. 171. With an apparatus installed in this manner the cross currents in the circulation thoroughly excite and warm all portions of the pool.

In estimating heating capacity for work of this character it is safe to assume that each 100 sq. ft. of heater capacity will warm 1,000 gallons of water from 40 degrees to 90 degrees in from six

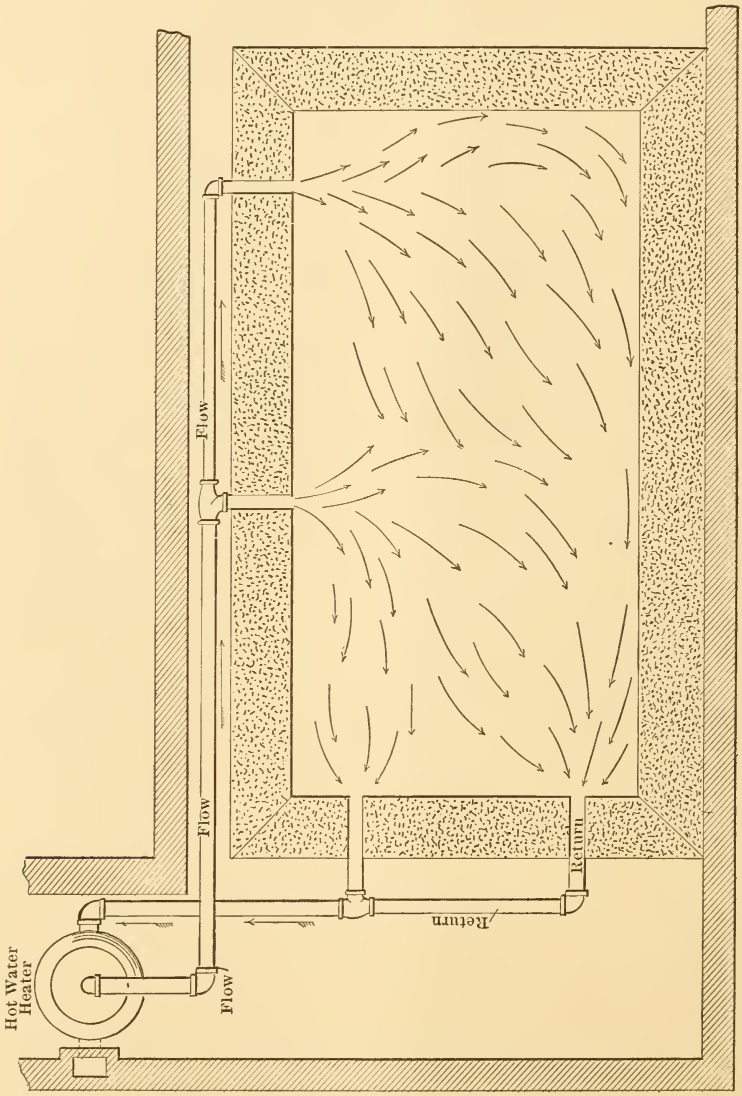

Fig. 171.—Plan of heating swimming pool—hot-water circulation.

to eight hours. Thus a 5,000-gallon tank would require a 500-ft. hot-water heater to properly do the work. As the tank capacity

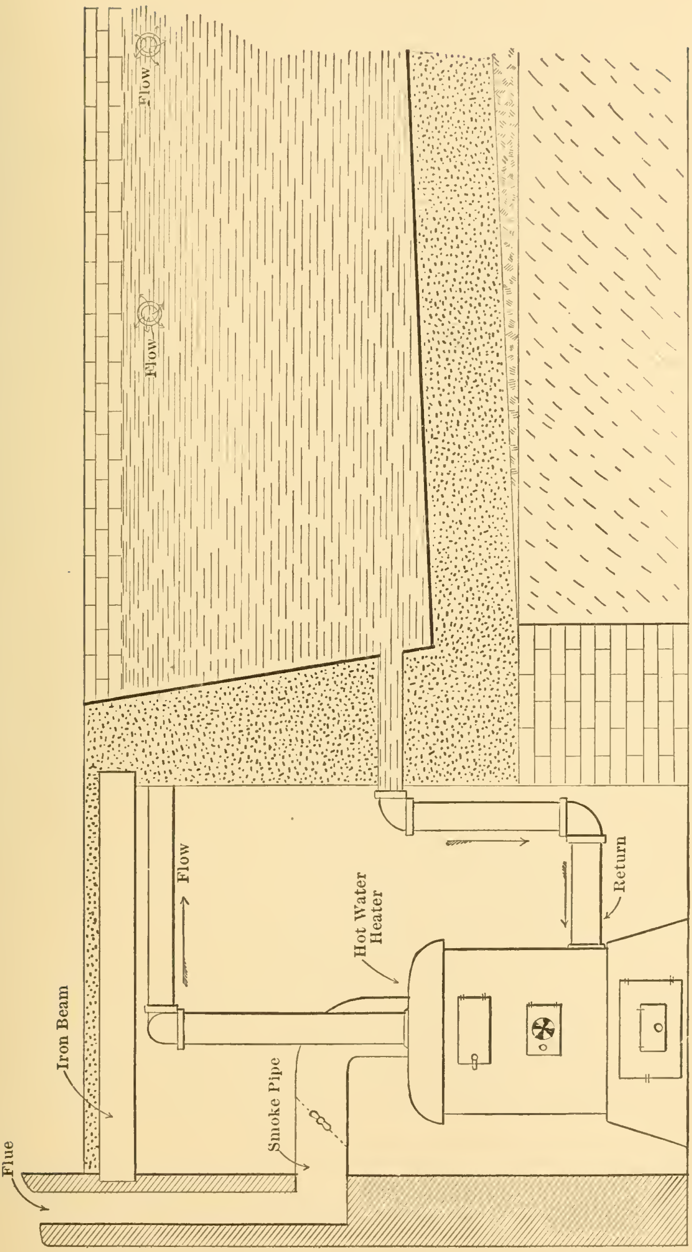

FIG. 172.—Elevation plan of hot-water circulation for swimming pool.

is increased in size the relative size of heater may be somewhat decreased as shown by the following table:

TABLE XVIII

Capacity of Pool or Tank—Gallons.	Rated Capacity of Hot-water Heater—Sq. Ft.	Capacity of Pool or Tank—Gallons.	Rated Capacity of Hot-water Heater—Sq. Ft.
5,000	500	40,000	3,450
10,000	950	45,000	3,800
15,000	1,350	50,000	4,200
20,000	1,800	55,000	4,600
25,000	2,200	60,000	5,000
30,000	2,550	70,000	6,000
35,000	2,950	80,000	6,800

There are many circumstances which would vary the above figures considerably. However, those given are sufficiently accurate for estimating and represent the gross rating of cast-iron hot-water heaters as listed by any one of the reliable manufacturers and whose named ratings may be accepted as correct.

It is a frequent occurrence to find that the necessary depth for heater room cannot be procured, owing to low ground, trouble with drainage, etc. In a case of this kind it is necessary to make use of steam for heating the water and an apparatus of this kind is somewhat more complicated than the one for hot water already described. Where the steam is obtained from pure water, the pool may be heated by blowing live steam into the water through an orifice of the nature of an injector. A large circulating pipe is arranged at the deep end of the pool as shown by Fig. 173. At the top connection a reducing tee is used, as shown, in making the injector. This not only heats the water but causes also a circulation through the large pipe in the manner shown. Where it has been correctly used this arrangement has proven to be very successful.

In the event of heating a large body of water, say 40,000 gallons or more, it is well to use two circulating pipes and injectors and they should each be placed at the deep end of the pool about from 18″ to 20″ from each corner. The manner of circulation of the water in the pool is shown on the illustration Fig. 173.

When making use of the injector method the greater the pressure of the steam the more quickly a circulation may be established and the water heated. For this work we recommend a boiler on which a pressure of from 30 to 60 pounds may be maintained.

The usual practice is to clean and refill a swimming pool about once in each week or ten days, depending somewhat upon the num-

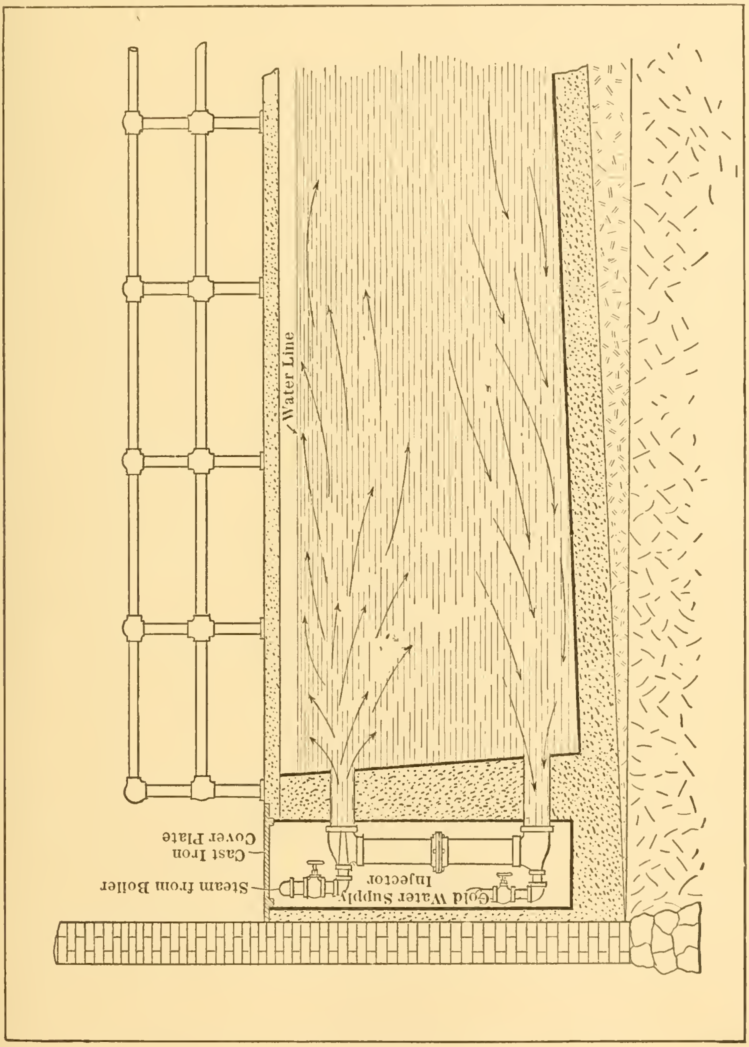

Fig. 173.—Steam heating of swimming pool—injector system.

ber of bathers using it. To keep the water as pure as possible during this period there is generally a small stream of fresh water entering the pool constantly, and the overflow openings of the pool empty the excess water. Therefore, it will be seen that it is but once in a period ranging from six to ten days that the full volume of water in the pool has to be heated. For this reason the steam-injector principle is the most economical as the excess of boiler power may be put to other uses, such as heating a tank of water for domestic uses or for shower baths.

In determining the size of boiler power the conditions of the work must be considered. A safe estimate is one-horse power of boiler capacity for each 2,500 gallons of water.

Still another method whereby steam can be employed for heating a pool is shown by Fig. 174. Coils of this nature are placed

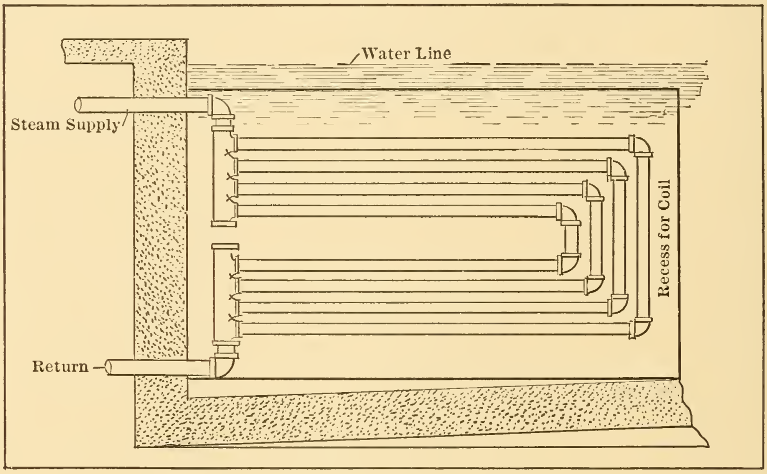

FIG. 174.—Heating swimming pool with steam coils.

in recesses along the sides and end of the pool, the condensation returning to the boiler room, where it is pumped into the boiler or fed to it by an injector or return trap.

Owing to the large amount of condensation in coils when used in this manner, it is well to use a header or branch tee coil and to make the runs as short as possible.

Heating Water for Domestic Purposes

A class of heating now largely practiced is that of heating water for domestic purposes. In the cities and towns of any considerable size we find numbers of flat or apartment buildings and it is customary in the better class of these buildings to furnish the various apartments with hot water from a central supply tank located in the basement. Such a tank is called a storage tank. There are two methods of heating the water, first by means of a small hot-water heater, called a tank heater, which is directly connected to the tank, and second by means of a steam coil within the tank. Such an apparatus becomes a part of the heating specifications and the methods as generally adopted should, therefore, be understood by the heating contractor.

Storage tanks are made in two styles, namely, horizontal and vertical. The horizontal tank is usually hung from the first-floor

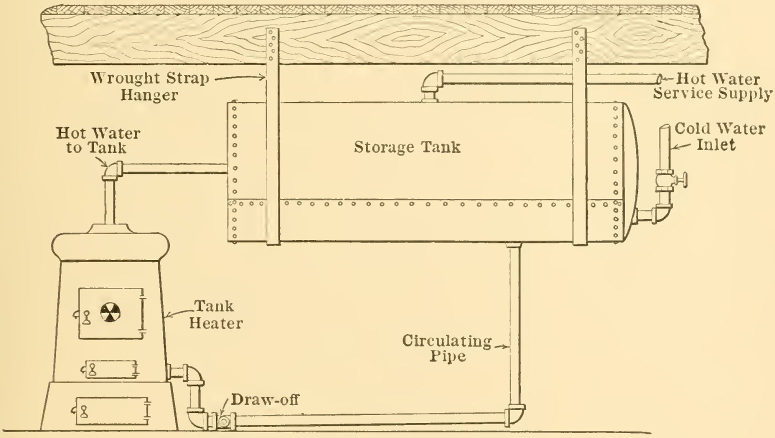

Fig. 175.—Domestic hot-water supply—horizontal tank.

joists by means of wrought-iron straps or hangers, or it may rest on brick piers. The vertical tanks are supported by cast-iron legs provided for the purpose. We have found the latter method to be better, as the weight of a large tank full of water is liable to strain the joists from which it is suspended, unless hung very close to a supporting wall.

Fig. 175 illustrates the method of hanging a horizontal tank and making the heater connections, and Fig. 176 shows the method of setting and connecting the vertical tank. In making use of the latter method the tank should stand sufficiently high so that the bottom of it is above the return opening of the tank heater, as the return pipe is connected to opening in the bottom of the tank.

When steam boilers are employed in heating the building or when steam is obtained from a central heating plant the water may be heated by means of a steam coil within the tank, as shown by Fig. 177. Black iron or steel pipe should never be used for this purpose, owing to liability of rust or corrosion. The coil should be made of galvanized iron or copper pipe, the latter being

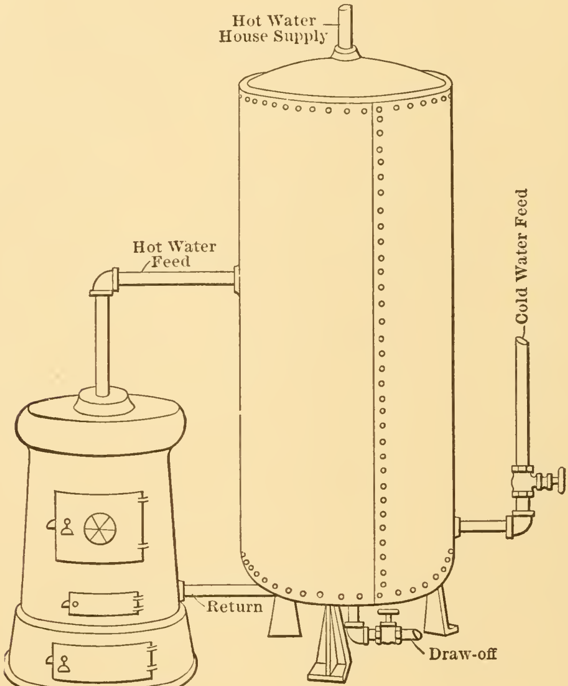

FIG. 176.—Domestic hot-water supply—vertical tank.

preferable, and it should be well braced or stayed in order that the expansion and contraction will not loosen it.

The tank may also be double connected, that is, directly connected to a tank heater for use in the summer months and provided with a coil, and connected to the steam boiler in order that steam may be utilized for heating in cold weather. This method makes a very satisfactory arrangement.

In determining the size or capacity of tank required several points should be considered. The ordinary tank capacity provided when each apartment has its separate supply from water front in range is thirty gallons. When providing for apartments having but one set of bathroom fixtures, it will be found that an allowance of from twenty to twenty-five-gallon-tank capacity for

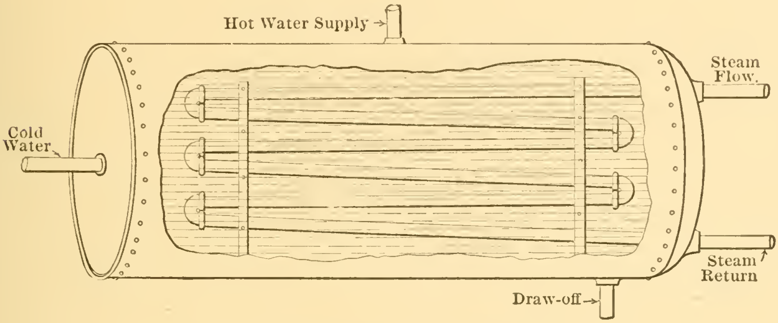

FIG. 177.—Storage tank with steam coil.

each apartment will prove sufficient. The tank heater should have a capacity of from 20% to 25% greater than that of the tank. The following table shows approximately the sizes of tank and heater necessary for from four to thirty-six apartments.

TABLE XIX

Number of Apartments.	Capacity of Tank.	Size of Tank.	Heater Capacity—Size of Grate.
4	100 gallons	22″×60″	78 sq. in.
6	120 "	24″×60″	78 " "
8	180 "	30″×60″	113 " "
10	215 "	30″×72″	132 " "
12	250 "	30″×84″	176 " "
16	365 "	36″×84″	254 " "
20	430 "	42″×72″	314 " "
24	575 "	42″×96″	380 " "
36	720 "	42″×120″	452 " "

Should the tank service be used for other than regular domestic purposes, additional capacity must be provided.

The manufacturers of storage tanks seldom place coils in them except according to specifications received with the order; therefore, the heating contractor must specify the length of coil or number of runs of pipe desired and the size of same. As a basis of what is required the following table will prove useful:

TABLE XX

Size of Tank.	Size of Coil.
100 and 120 gal.	4 1″ pipes
180 " 215 "	6 1″ "
250 " 365 "	6 1¼″ "
430 " 575 "	4 1½″ "
720 gal.	6 1½″ "

Steam for Cooking and Manufacturing Purposes

While the use of steam for cooking, or rather the adaptation of certain methods for accomplishing this, is in reality no part of a steam fitter's education, we wish in a general way to make mention of the subject in this chapter, and at the same time to call attention to the use of steam for manufacturing purposes.

No large hotel or restaurant is complete in its equipment without a steam carving table and in most of the hotel and restaurant kitchens all vegetables are cooked by steaming. Meats may be cooked or roasted in ovens made for the purpose, and when prepared in this manner, meat will be as tender as would be a pot-roast cooked in the usual way over the fire of a kitchen range, and will lose less weight in cooking than when roasted in an oven. Appliances for cooking and baking are marketed by the builders of such apparatus and the steam fitter, as a usual thing, has simply to make certain specified pipe connections to the apparatus.

The usages of steam for manufacturing purposes are many and varied in character. Double-bottomed kettles for the use of dyeing establishments, soap making, etc., and for heating glue, paste and numerous other purposes are in common use. For carpet cleaning, feather renovating and drying, in hat manufactories and for numerous other manufacturing purposes, steam is employed in a greater or lesser quantity, and the subject would require a volume to illustrate and describe the various fixtures and fittings. It is quite probable that more than two thirds of our manufactories make use of steam for purposes other than the generation of power.

CHAPTER XIX

Radiator and Pipe Connections

In those chapters of this book having reference to systems or methods of piping for steam or hot-water circulation we have frequently made mention of certain styles of radiator and pipe connections. We shall in this chapter illustrate and explain the several modes of radiator connections and show the method of using swing or expansion joints on piping, together with some special forms of pipe connections which are made desirable by conditions of building construction.

Steam Radiator Connections

Fig. 178 shows the most simple form of connecting a single steam radiator with the main. The illustration shows the branch connection taken from the top of the main with a 90° elbow. A

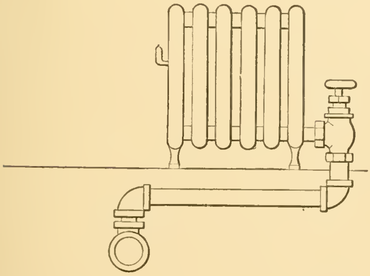

Fig. 178.—Simple form steam radiator connection.

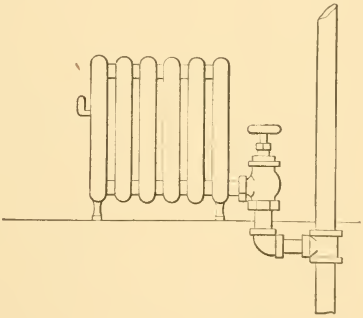

Fig. 179.—Steam radiator connected from riser.

45° elbow at this point would be preferable. The valve should be used on the end of radiator farthest from the riser or branch in order to provide for expansion. When a radiator is connected from a riser on single-pipe steam work the connection should be made as illustrated by Fig. 179. This is known as a " stiff " connection and when used in this manner there should be a " double swing " or expansion connection at the base of the riser. In order

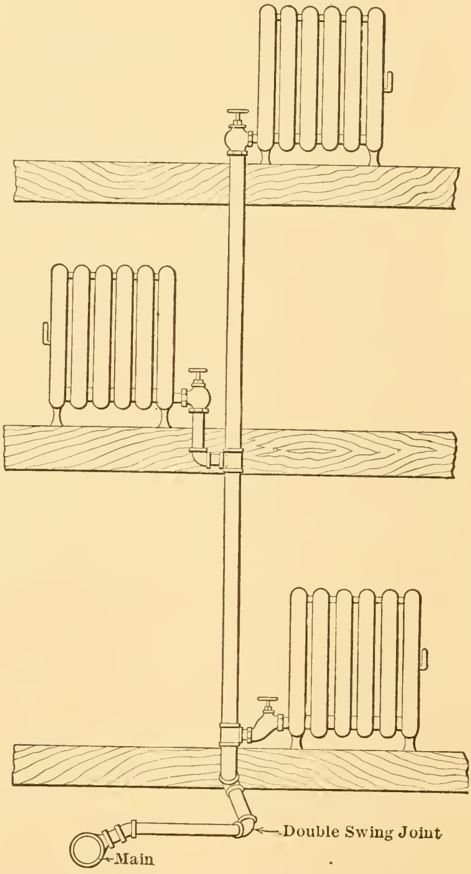

Fig. 180.—Double swing connection at bottom of riser.

that this form of radiator connection may be thoroughly understood we illustrate by Fig. 180 a riser feeding three radiators, all of which are connected with stiff joints. The radiator on the first floor is connected direct from riser with an offset valve; the radiator on the second floor is connected by a stiff joint, as described by Fig. 179, and the third-floor radiator is connected by a valve placed directly on the top of the riser. Note the double swing or

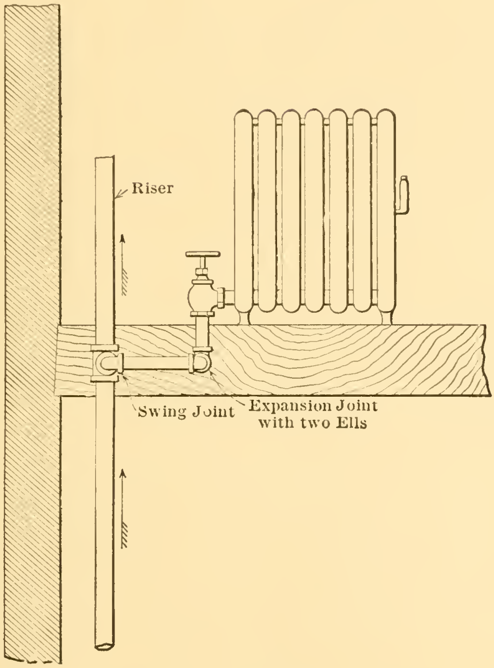

Fig. 181.—Radiator connected with expansion joints.

expansion joints at the base of the riser. When the riser is connected to main by a stiff joint on the branch, all radiators fed by it should be connected by expansion joints as shown by Fig. 181.

Hot-Water Radiator Connections

The regular form of connecting a single hot-water radiator from main and to the return is illustrated by Fig. 182 and needs no further explanation. When the same branch feeds a riser, as well as the first-floor radiator, the connection should be made as shown by Fig. 183. There is always a tendency for hot water in circulation to rise quickly to the highest radiator; hence the connection to upper radiator should be taken from the side of the riser as shown.

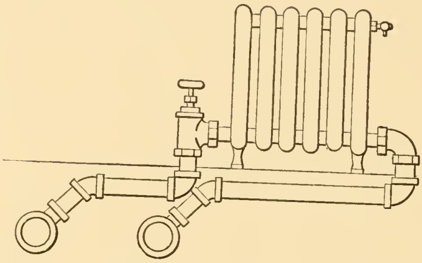

Fig. 182.—Hot-water radiator connection.

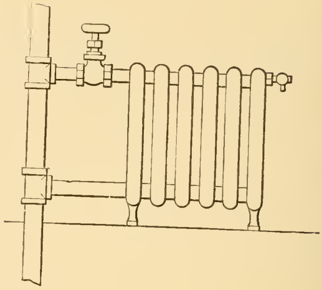

Fig. 184.—Radiator connection for overhead system.

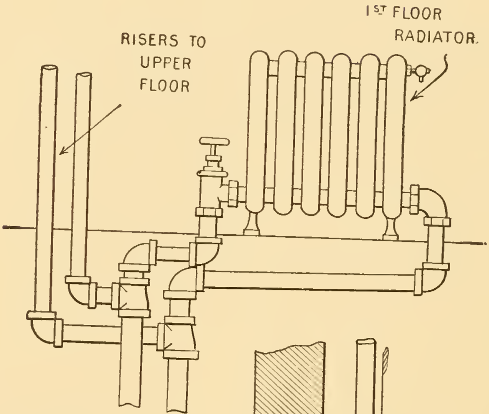

Fig. 183.—Radiator and riser fed from same pipe.

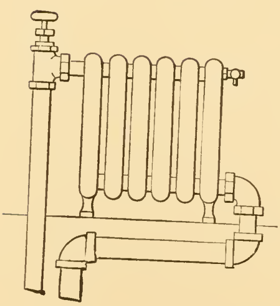

Fig. 186.—Flow connected at top of radiator.

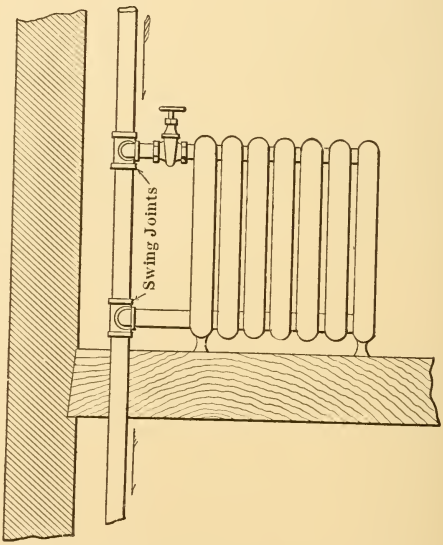

Fig. 185.—Connection for overhead system—swing joints.

Fig. 184 shows one method of connecting to a radiator when the riser is fed from above by the overhead system. But one valve is necessary and this may be placed either on the flow or return connection. In order to make the connection as illustrated the riser must be carried a considerable distance from the wall. We favor the use of a swing connection, as shown by Fig. 185, in order that the riser may be run well against the wall and thus make a better appearance.

Some fitters favor the method of connecting the flow into the top of one end of a radiator and the return out of the bottom of opposite end. There are some cases where this is advisable, but on regular hot-water work it is not necessary. By Fig. 186 we show the manner of making this form of connection.

Improper Use of Tees

Notwithstanding the fact that in nearly all of the text books on steam and hot-water heating the fitter has been warned against it, and that writers on the subject have repeatedly condemned the practice, some steam fitters will persist in using a tee " bull head,"

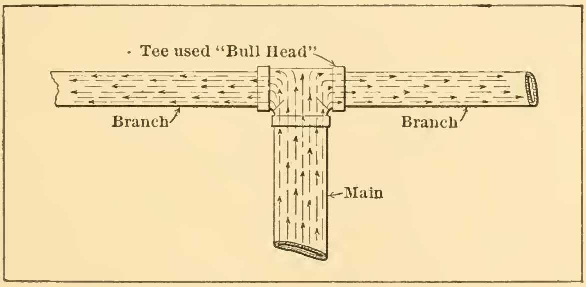

FIG. 187.—Wrong use of tee.

as illustrated by Fig. 187. The friction caused by using a tee in this manner must be apparent even to a person unacquainted with steam or hot-water circulation. This is more noticeable on hot-water circulation than on steam. The proper style of fitting to use is the double elbow, illustrated by Fig. 120, and when employed to divide a main into two branches the object is accomplished with the least possible amount of friction. Fig. 188 as compared with Fig. 187 clearly illustrates this.

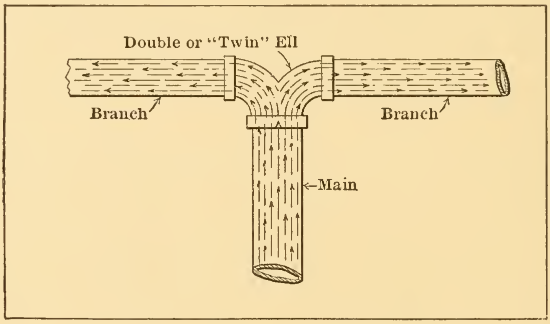

Fig. 188.—Double ell for dividing flow.

Methods of Pipe Construction

When a steam main is run at a considerable length from the boiler it frequently happens that in order to keep the end of it a sufficient distance above the water line it must be dripped and raised again to keep at the height necessary. When this is essential the connection should be made as shown by Fig. 189. The main

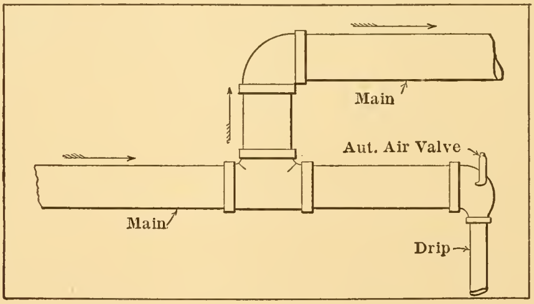

Fig. 189.—Method of relieving main.

should be carried a short distance beyond the point at which the rise is made, and a reducing elbow used in connecting the drip. This elbow should be tapped and fitted with an automatic air valve, as shown by the illustration. The use of this method will relieve the main of much friction and eliminates the use of a tee placed bullhead on the end of main at point where drip is made. On circuit work it occasionally happens that the main must be run very low owing to certain wood or iron beams supporting the joists. When it is possible to drip the main and rise again this difficulty may be easily overcome. Frequently, however, the basement is put to such use that a drip connection cannot be made

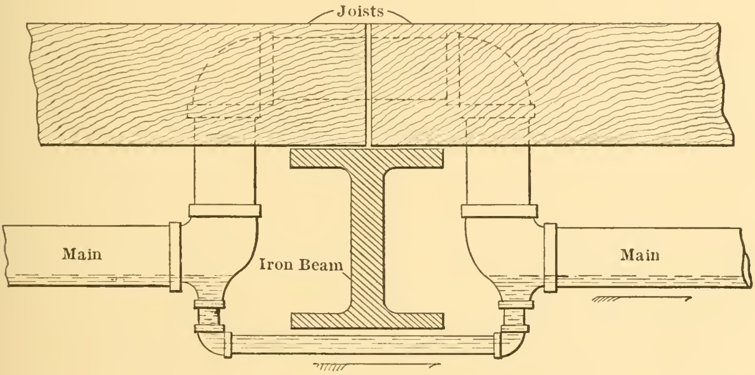

Fig. 190.—Method of crossing beam without drip.

or will not be permitted. By Fig. 190 we illustrate a simple method of surmounting this difficulty, which we think is self-explanatory. Care should be exercised in the alignment of the main on either side of the beam.

Artificial Water Line

When it is necessary to run a wet return under a building where the basement or a portion of it is unexcavated, it is sometimes essential to create what is known as a " false water line." By this is meant a water line above that of the boiler and it is required in order that the return may be kept full of the water of condensation. This will prevent the short-circuiting of steam into the return and thereby cause trouble by retaining the water of condensation in piping or radiators. There are several methods of doing this. Fig. 191 illustrates a mode quite commonly used, and the piping as arranged works all right, although we are inclined

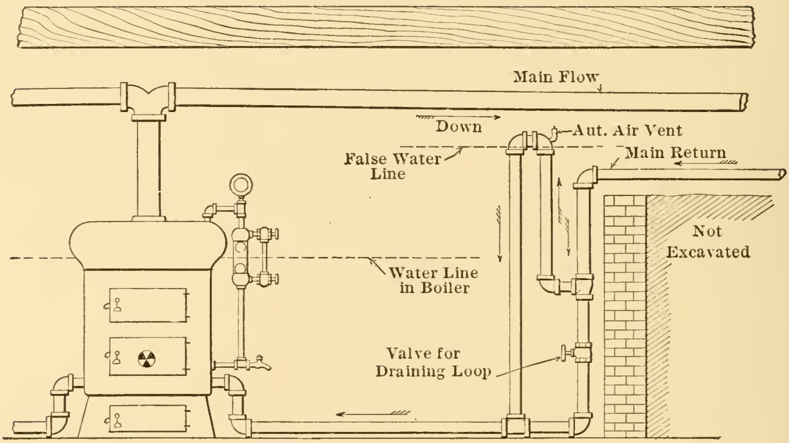

FIG. 191.—Common method of establishing a false water line.

to favor the method illustrated by Fig. 192. The equalizing pipe shown, connecting top of loop with the main, prevents any false

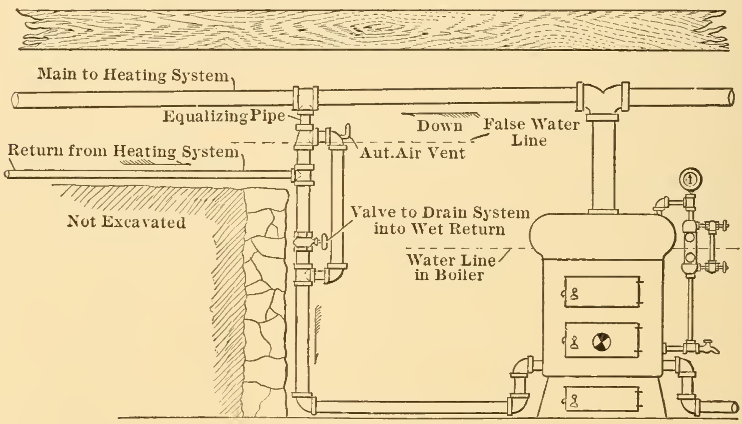

FIG. 192.—Another method of establishing a false water line.

register due to unequal pressure, which might be a result from the use of the method as first illustrated.

Cross-Connecting Boilers

When the boiler or heater capacity of a heating plant is divided the boilers or heaters should be so valved and cross-connected that either of them may be used independently of the other.

On work of any considerable size it has been discovered that as a matter of safety and economy this plan is advisable. It insures the use of one part of the apparatus in the event of an accident occurring to the other, and it is economical from the fact that in mild weather or with a portion of the radiation turned off one boiler is sufficient to furnish the amount of heat desired. There is considerable variance of opinion as to the utility of dividing the boiler power. Where the boiler capacity is fully large

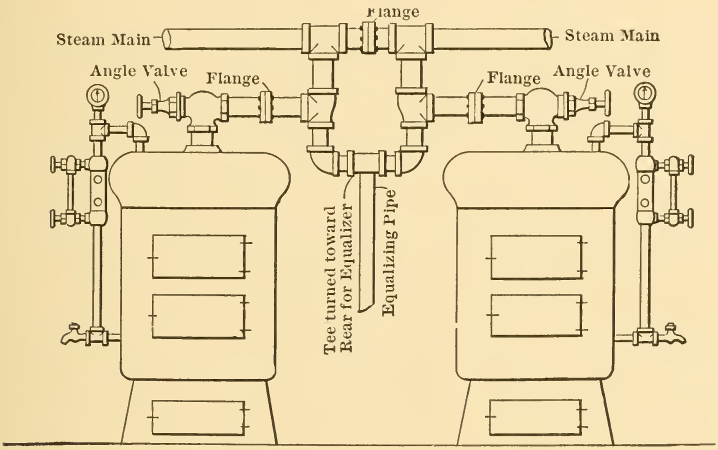

FIG. 193.—Cross-connecting steam boilers.

for the work we believe that a considerable saving may be effected in the consumption of fuel by dividing the boiler power and cross-connecting.

The methods or form of pipe connections in accomplishing this are many and varied. When cross-connecting steam boilers it is well to use an equalizing pipe connecting with the return header. The boilers may be connected as shown by Fig. 193 or Fig. 194. In the former style of connection angle valves are used on steam supply, while in the latter case a globe valve is placed on the vertical pipe leading from each boiler. The returns may be connected as shown on Fig. 194, or as shown on Fig. 195.

When cross-connecting two heaters for hot water, globe or angle valves should not be used owing to the obstruction offered by them to the free flow of the water. Gate valves are the proper style on both flow and return connections. Fig. 196 shows a

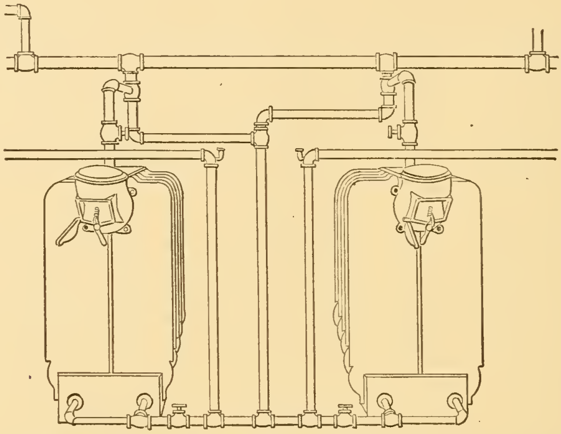

Fig. 194.—Another method of cross-connecting steam boilers.

good method of connecting the flow pipes, while that illustrated by Fig. 197 is an excellent method of connecting the returns.

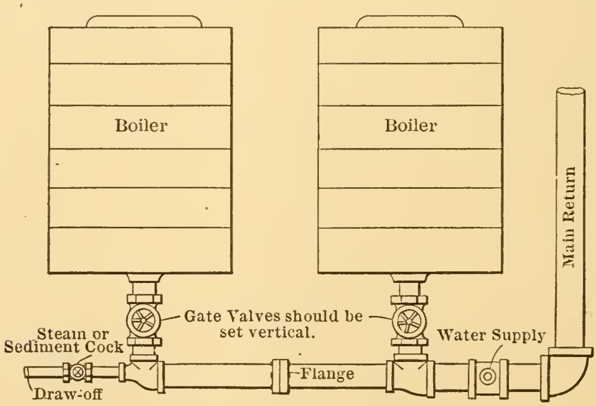

Fig. 195.—Return pipe cross connected.

Should there be several flow openings from each heater they should all be connected into a main header from which the supply pipes for the building are taken.

When cross-connecting two steam boilers of unequal size or height, care must be taken to place them in such relative positions

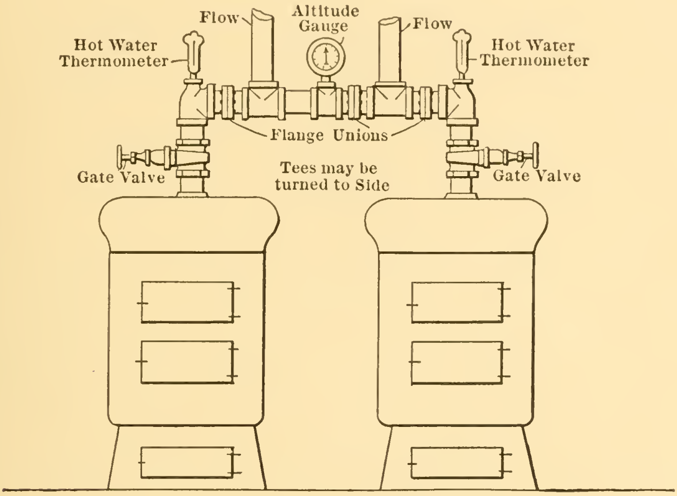

FIG. 196.—Cross-connecting hot-water boilers.

that the normal water line of one is on a level with that of the other boiler. It may be found necessary to set the larger boiler

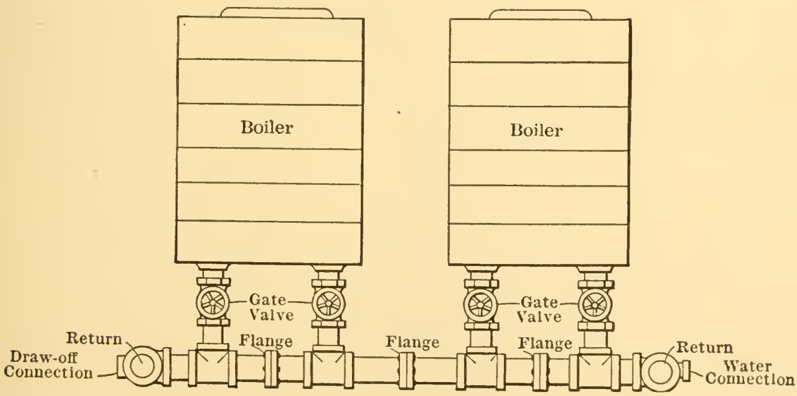

FIG. 197.—Cross-connecting returns—hot-water boilers.

in a pit or to place the smaller one upon a brick foundation, in order to level the water lines.

Pipe Measurements for 45-Degree and Other Angles

The base of the triangle being given the length of the hypothenuse may be determined by the use of constant multipliers

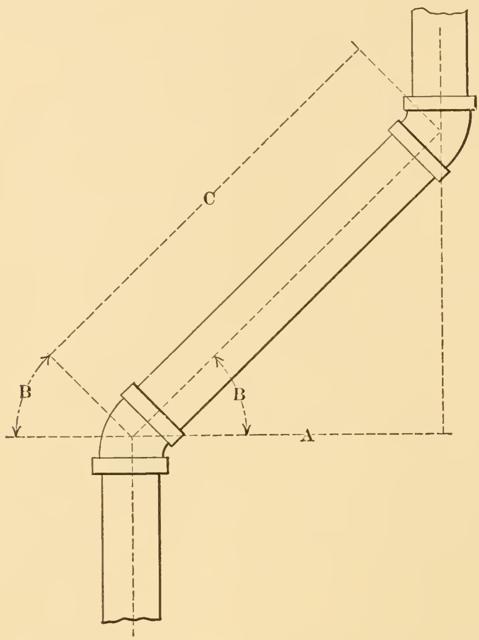

FIG. 198.—Measuring 45° angles.

for each different angle. Fig. 198 illustrates the method. The following constants are the multipliers.

TABLE XXI

Angle (line B).	Constants (Multipliers).
11¼°	1.0196
22½°	1.0824
30°	1.1547
45°	1.4143
60°	2.0000

RULE.—To determine the dimension C (the hypothenuse), center to center measure, multiply the distance A by the constant opposite the angle B.

CHAPTER XX

VENTILATION

Importance of Ventilation

The need or importance of ventilation has been recognized for many years. Probably the first effort to ventilate a room of any considerable size was made by Dr. J. F. Desaguliers, as briefly referred to in the introductory pages of this book, who in 1723 arranged a ventilating apparatus for the British House of Commons. This apparatus was used for upward of eighty years, being replaced early in the nineteenth century by a system of fans propelled by hand. These fans were arranged to exhaust the foul air at the top of the building.

Records of ventilation by means of bellows or blowers by the Romans and later by the Germans are to be had. Without doubt, however, the British attempt marked the beginning of ventilation as we to-day understand and use the term. The early attempts at ventilation were to remove the air vitiated by the exhalations of many people occupying a single room and by the candles or various styles of lamps used for lighting. With the advent of the present-day type of heating apparatus came the greater need of ventilation in order not only to exhaust the foul air but also to provide a supply of fresh air to replace that vitiated by the breath of the persons occupying a building and also the oxygen consumed by lamps or gas burners for illumination.

Oxygen is the all-important element or quality of the atmosphere and without it we can have neither heat nor light. It is required in the chemical process of combustion and without it fuel will not burn. It is necessary to sustain life and without its presence all living beings would die. The atmosphere we breathe is composed principally of about one part oxygen to four parts of nitrogen, together with more or less vapor or water in a gaseous state or held in suspension and is expressed by the term humidity. Oxygen is the life-sustaining quality of the air, which is diffused or diluted by the nitrogen. The percentage of watery vapor present varies with the temperature and the exposure or proximity to a body of water.

There is also present in the atmosphere carbon dioxide or carbonic-acid gas, which by itself is not particularly harmful. Under certain conditions, however, it is detrimental to health, not from the amount usually present in the air, which ranges but from two to four parts in 10,000, but when present in larger quantities due to the exhalations from the lungs of several persons congregated in a single room. It then produces a feeling of closeness or stuffiness, causing headaches and is otherwise detrimental to health. The poisonous matter thrown into the air or given off by our bodies is also the source of great danger to health. For example, confine a person in a tight inclosure. That person will live as long as there is oxygen to breathe, depending upon the size of the inclosure. The oxygen will eventually be consumed and the person choke or suffocate, being poisoned by the carbonic-acid gas and impurities exhaled from his own body. If our exhalations are poisonous to ourselves what then may be said of the risk entailed by living in or even temporarily occupying crowded rooms, such as offices, workrooms, or places of amusement where we are breathing the foul air exhaled from the lungs of our neighbors, some of whom may be suffering from tuberculosis or other diseases and so contaminate the air with the germs of such diseases. Not a very pleasant thought but true nevertheless and the fact should be carefully considered by every thinking person. *Ventilation is not a luxury—it is a necessity.*

As another example, enter a residence temporarily occupied for a social gathering. Entering the building from outside where the air is pure into brilliantly lighted rooms not sufficiently ventilated and possibly more or less crowded with people, a feeling of closeness, stuffiness, or suffocation is at once apparent. A person not strongly constituted or in good health may in a short time faint from lack of air, while a stronger individual may perhaps become acclimated and soon fail to notice the oppressing effects of the foul atmosphere of the room.

The use of electricity for lighting purposes has done much toward maintaining the purity of the atmosphere under conditions as cited above. Dr. Tidy after exhaustive tests compiled the following table showing the air consumed by various modes of artificial lighting and the percentage of carbonic-acid gas given off by the various burners:

TABLE XXII

Light Producing Material equal to 12 Standard Candles.	Cubic Feet of Oxygen Consumed.	Cubic Feet of Air Consumed.	Cubic Feet of Carbonic Acid given off.	Cubic Feet of Air Vitiated.	Heat, Equal Parts of, raised to 10° Fahr.
Common Gas.........	5.45	17.25	3.21	345.25	278.6
Sperm Oil............	4.75	23.75	3.33	356.75	233.5
Paraffin...............	6.81	34.05	4.50	484.05	361.9
Sperm Candles........	7.51	37.85	5.77	614.85	351.7
Wax Candles..........	8.41	42.05	5.90	632.25	383.1
Electric Light.........	None	None	None	None	13.8

That the need of ventilation has long been recognized by physicians, scientists and engineers is shown by the works of such men as Chas. Hood, London, whose writings and book published in 1879 are a fair treatise of the subject. Other works more or less practical were published by Dr. D. B. Reid (1844) and by Chas. Tomlinson (1864). Probably the most authentic American work is that from the pen of Dr. John S. Billings, of Washington, D. C., a Surgeon of the United States Navy, whose book on warming and ventilation is accepted as a standard authority. Other publications by Thos. Box, F. Schuman, C.E., Butler, Leeds, and the authorities mentioned in the introduction of this book will repay a careful reading.

Air Necessary for Ventilation

What amount of air is necessary for ventilation? This question may be answered by numerous examples. Perfect ventilation might be said to be the exhausting of the foul air and the admitting of the fresh air in such quantities that the inhabitants of a room or building would never inhale the same air twice, or, in other words, would breathe air inside the building of the same purity as that on the outside. Such a state, however, is neither practical nor necessary. With the size and conditions of a building and the probable number of occupants known it is possible to estimate very closely the air supply necessary to maintain a certain standard of purity of the air within the building.

Not so many years ago a fresh-air supply of 300 cubic feet per hour per person was considered sufficient. To-day we look upon 30 cubic feet per minute or 1,800 cubic feet per hour per person *as being the minimum supply essential.* Dr. Billings gives the hourly air supply necessary for certain requirements as follows:

TABLE XXIII

	Cubic Feet per Hour.
Hospitals	3,600 per Bed
Legislative Assembly Halls	3,600 per Seat
Barracks, Bedrooms and Workshops	3,600 per Person
Schools and Churches	2,400 per Person
Theaters and Ordinary Halls of Audience	2,000 per Seat
Office Rooms	1,800 per Person
Dining Rooms	1,800 per Person

It has been recently stated that within a certain congested district in the City of New York there are 70,000 consumptives. There is no question but that this terrible showing is due to the overcrowded offices, sleeping rooms and workshops, the latter more popularly designated as *sweat shops*, where the admission of only a very small percentage of air, as per Dr. Billings' schedule, would work wonders in the elimination of disease.

The average individual spends one third of his or her life in the bed or sleeping room. Without the necessary amount of fresh air to breathe how much solid rest or physical relaxation may we enjoy? Sleeping rooms should, therefore, be well ventilated and this may usually be accomplished by the thorough airing of the sleeping room during the day and the opening of the windows at night. By giving the matter a little thought and attention the bed may be so located that no severe draughts are felt by the occupants. However, to properly ventilate the room it should have its separate pure-air supply, tempered by heating, and a ventilating duct leading from the room to the main ventilating stack of the building.

Massachusetts was the pioneer among the states to enact laws governing the heating and ventilating of public-school buildings. A fresh-air supply of 30 cubic feet per person per minute is demanded and this commonwealth maintains a Board of Engineers to see that the provisions of the law are fulfilled. The laws are imperative, as the following extracts will show:

"1. The apparatus, with proper management, is to heat all the rooms including the corridors, to 70° Fahr. *in any weather*."

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

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

We have italicized such portions of the quotation as will bring them prominently before our readers. Other States have enacted laws quite similar and with the standard as set by Massachusetts as a guide, it is quite an uncommon thing to find at this date a school building of any considerable size which is not provided with some form of a ventilating apparatus in connection with the heating of the building.

The result is that, as a rule, our children attending school sit and study in an atmosphere much purer than that within the majority of our own homes. This very desirable condition relating to the ventilation of our public schools is due to two distinct causes. First, the writings of eminent physicians, scientists and heating and ventilating engineers, who having noted the former condition of our schools and other public or semipublic buildings and understanding what was necessary regarding a pure-air supply, have persistently for years conducted a campaign for pure air. Discussions of the subject by engineering societies, articles in the public press, books written and published in the interests of better heating and ventilating apparatus all had their weight and all have assisted materially in bringing about the improved conditions.

The second cause of the changed conditions may be credited to those manufacturers of ventilating necessities such as fans, heaters, blowers, etc., who have for several years spread broadcast expensive catalogues and much other literature and who maintain a corps of engineers to assist architects and builders in the proper arrangement and equipment of buildings for heating and ventilating. Aside from the monetary considerations and profits accruing from such work, there is a satisfaction which all must experience when they are contributing to the health and happiness of thousands of human beings.

There is still much to be desired, but with the architects alive to the situation and the public aware of the results possible to be obtained, we shall witness very few school buildings erected without the provision of an adequate heating and ventilating apparatus.

All government buildings and practically all theaters and places of amusement now planned and erected are provided with ventilating apparatus and the campaign for the ventilating of shops and factories is well under way.

Probably no clearer idea of the air required for ventilation can be had than that given by the B. F. Sturtevant Company, which we reproduce in part.

"Amount of Air Required for Ventilation.—Under the general conditions of outdoor air, namely, 70° temperature and 70 per cent of complete saturation, an average adult man, when sitting at rest as in an audience, makes 16 respirations per minute of 30 cubic inches each, or 480 cubic inches per minute. Under the previously assumed conditions of 70° temperature and 70 per cent humidity, the air thus inhaled will consist of about $\frac{1}{5}$ oxygen and $\frac{4}{5}$ nitrogen, together with about $1\frac{7}{10}$ per cent aqueous vapor and $\frac{4}{100}$ of a per cent carbonic acid. By the process of respiration the air will, when exhaled, be found to have lost about $\frac{1}{5}$ of its oxygen by the formation of carbonic acid, which will have increased about one hundredfold, thus forming about 4 per cent, while the water vapor will form about 5 per cent of the volume. In addition, the inhaled air will have been warmed from 70° to 90°, and, notwithstanding the increased proportion of carbonic acid—which is about one and one half times heavier than air—will, owing to the increase of temperature and the levity of the water vapor, be about 3 per cent lighter than when inhaled. Thus it will be seen that this vitiated air will not fall to the ground, as has often been presumed, but will naturally rise above the level of the breathing line, and the carbonic acid will immediately diffuse itself into the surrounding air. In addition to the carbonic acid exhaled in the process of respiration, a small amount is given off by the skin. Furthermore, 1½ to 2½ lbs. of water are evaporated daily from the surface of the skin of a person in still life. If the air supply at 70° is assumed to have a humidity of 70 per cent and to be saturated when it leaves the body at a higher temperature, then at least four cubic feet of air per minute will be required to carry away this vapor.

"Taking into consideration these various factors, it becomes evident that at least 4½ cubic feet of fresh air will be required per minute for respiration and for the absorption of moisture and dilution of carbonic-acid gas from the skin. This, however, is only on the assumption that any given quantity of air having fulfilled its office, is immediately removed without contamination of the surrounding atmosphere; but this condition is impossible, for the spent air from the lungs, containing about 400 parts of carbonic-acid gas in 10,000, is immediately diffused in the atmosphere. The carbonic-acid gas does not fall to the floor as a separate gas, but is intimately mixed with the air and equally distributed throughout the apartment.

"It must then be evident that ventilation is in effect but a process of dilution and that when the vitiation of the air discharged from the lungs is known and the degree of vitiation to be maintained in the apartments is decided, the necessary constant supply of fresh air to maintain this standard may be very easily determined. For the purpose of calculation, 0.6 cubic foot per hour is accepted as the average production of carbonic acid by an adult at rest and the proportion of this gas in the external air as 4 parts in 10,000. If, therefore, the degree of vitiation of the occupied room be maintained at, say, 6 parts in 10,000, there will be permissible an increment of only 2 parts in 10,000 above that of the normal atmosphere, or 2–10,000 = .0002 of a cubic foot of carbonic acid in each cubic foot of air. The 0.6 cubic foot of carbonic acid produced per hour by a single individual will, therefore, require for its dilution to this degree 0.6 ÷ .0002 = 3,000 cubic feet of air per hour. Upon this basis the following table has been calculated:

TABLE XXIV

Cubic Feet of Air Containing Four Parts of Carbonic Acid in Ten Thousand Supplied per Person

Per Hour...	6,000	4,000	3,000	2,400	2,000	1,800	1,714	1,500	1,200	1,000	525	375	231
Per Min....	100	66.6	50	40	33.3	30	28.6	25	20	16.6	9.1	6.2	3.8
Degree of Vitiation of the Air in the Room													
Parts of Carbonic Acid in 10,000..	5	5.5	6	6.5	7	7.33	7.5	8	9	10	15	20	30

"The figures indicate absolute relations under the stated conditions, and are generally applicable to the ventilation of schools, churches, halls of audience and the like, where the occupants are reasonably healthy and remain at rest. But the absolute air volume to be supplied cannot be specified with certainty in advance, without a thorough knowledge of all the conditions and modifying circumstances—in fact, the climate, the construction of the building, the size of the rooms, the number of occupants, their healthfulness and their activity, together with the time during which the rooms are occupied, all have their direct influences. Under all these considerations, it is readily seen that no standard allowance can be made to suit all circumstances, and results will be satisfactory only in so far as the designer understandingly, with the knowledge of the various requirements as they have here been given, makes such allowance."

Methods of Ventilation

A building may be properly ventilated only when adequate provision has been made by the architect and builder of such stacks, flues or ducts as may be necessary for the use of the system of ventilation to be adopted. There are two general methods of producing ventilation, namely, natural and mechanical. Natural ventilation as expressed and understood is caused by ducts so constructed that the velocity of the outside air or difference in temperatures produces a change of air within a building. This method by itself is quite unsatisfactory, but when assisted by heating surfaces placed within the exhaust flues and warming the entering air by passing it over or between the heated surfaces of radiators in a manner commonly styled indirect heating, is productive of fairly good results.

This method is shown by Figs. 96, 97 and 98. These radiators are located in the basement of the building and connected to the supply or hot-air register by a galvanized-iron duct, the foul air being exhausted through a ventilating duct which is heated by means of an aspirating coil or other device. The entering air may also be warmed by passing between the surfaces of a direct radiator, the bottom of which rests on or is inclosed in an iron boxing connecting with and receiving air through a duct from outside the building. This air is passed from the boxing upward between the sections of the radiator into the room. An arrangement of this kind is styled a direct-indirect or semidirect radiator. See Fig. 101.

By placing gas jets, a pipe coil or small radiator in the ventilating flue, the air is expanded, creating an upward current which sucks the foul air from the room into the duct. This system of ventilating may be so arranged as to be entirely adequate for a small residence or a larger building if sparsely occupied, and may be employed to good advantage for small schools or kindred buildings, although as a usual thing, a school should be provided with a system of mechanical ventilation, of which we shall speak later on.

In ventilating the living rooms of a residence a main ventilating shaft should be provided, centrally located, into which foul-air ducts from the various rooms should be connected. In this shaft there should be placed an aspirating coil connected with the house-heating apparatus, steam or hot water, for use during the period when the heating apparatus is operated. For summer use the gas supply should be piped into the shaft and one or more gas burners attached. An opening into the shaft in the basement, fitted with a door, should be provided to gain admittance to the gas burners. This is a requirement needed only when the rooms are occupied by an unusual number of persons. Fig.

199 shows a method of connecting the foul-air duct with the ventilating shaft. A register should be set in an inside wall of each living room at a point just above the baseboard and a foul-air duct run as shown by the illustration.

Rooms having open fireplaces are easily ventilated in warm weather by gas jets placed within the opening to chimney. The fresh-air supply for a residence may be furnished by indirect or semidirect radiators placed as we have shown by Figs. 96, 97, 98 and 101. When no special provision is made for the admission of pure air to a residence, or where the cost of indirect heating seems to make its use prohibitive, there should be at least one fresh-air inlet. This should be placed in the lower or reception hall and as great a volume of air admitted as can be tempered by an indirect radiator placed beneath the floor, the

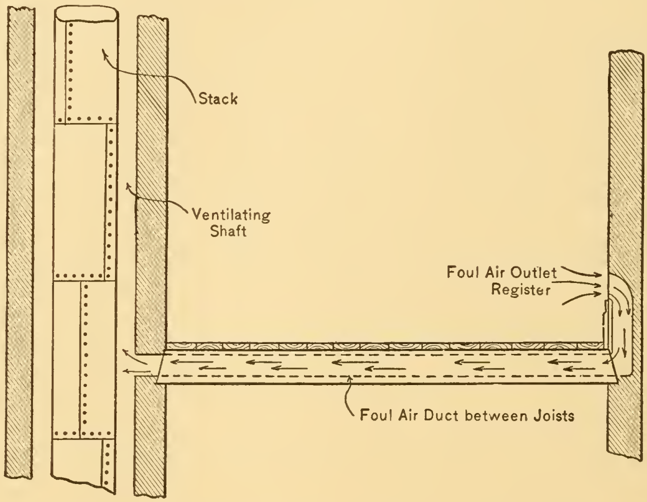

Fig. 199.—Connecting foul-air duct to ventilating shaft.

size of same depending upon existing conditions. The inlet registers for all ventilation of this character should be placed in the wall at a point about two thirds the height of the ceiling and they should be located at a point opposite to the fireplace, if there be one in the room. See Fig. 200.

The importance of chimneys as ventilating shafts is not generally recognized. The open fireplace, when in use, provides a most successful means of exhausting the foul air from a room. A chimney or shaft may be successfully used for ventilation by running a smoke flue constructed of boiler iron through the center of the shaft and surrounding it with ventilating ducts of such number and size as may be necessary to accommodate the rooms to be ventilated. When used in this connection a chimney should

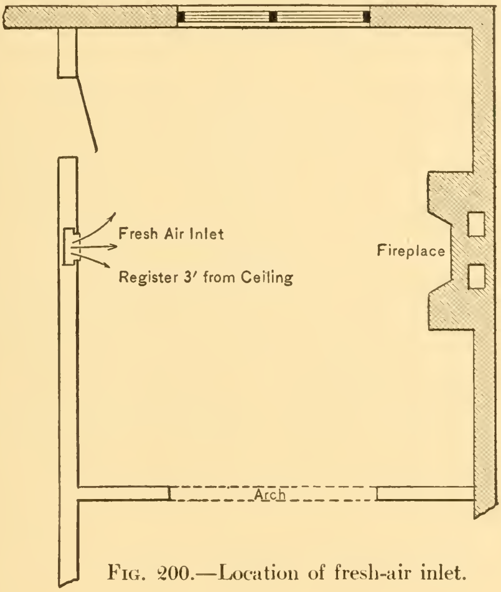

FIG. 200.—Location of fresh-air inlet.

be located in the center of the building and the bottom of the smoke flue should rest on a cast-iron plate supported on a brick or stone foundation, as shown by Fig. 201.

The arrangement of ventilating ducts is shown by Fig. 202. These ducts rise to the height of the brickwork of the chimney, on the top of which there should be erected an iron canopy open at the sides. The smoke flue should protrude through the top of the canopy and may have a cowl at the extreme end, if desired. The smoke flue should be anchored to the brick walls by iron clamps, as illustrated by Fig. 203. These anchor clamps should be attached at the line of each floor, at the roof line and at the top of the brick chimney. The smoke flue warms and expands the air in the ventilating ducts, inducing an upward circulation, which exhausts the foul air from each room and discharges it into the atmosphere under the canopy at the top of the chimney.

This method of ventilation, in connection with indirect or semidirect radiators for warming, is quite successful and by slight modifications may be readily adapted for many small build-

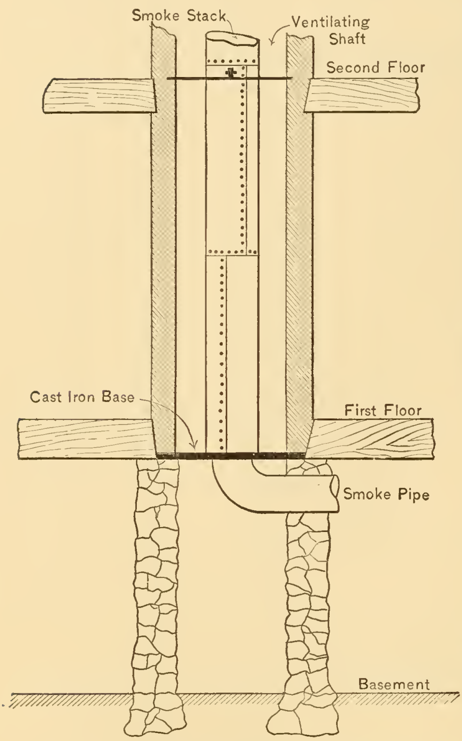

Fig. 201.—Construction of ventilating shaft.

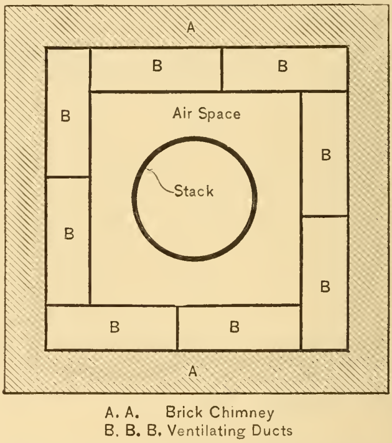

Fig. 202.—Ventilating ducts in shaft.

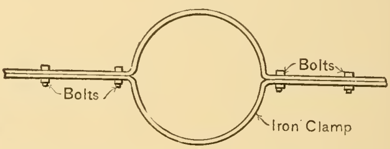

Fig. 203.—Iron clamps for supporting stack.

ings. For residences this method may be employed in place of the ventilating shaft as previously mentioned.

The movement of air in the vertical or main vent flues should not be less than 6 feet per second. With an arrangement of the flues as described above, if properly constructed, this velocity, or even a greater, should be easily obtained.

Make the register openings of such sizes that the velocity of the air through them will not be more than one half that in the vertical duct, or in other words, not more than 3 feet per second. If this schedule is adhered to, no perceptible draughts will abound or be felt by the occupants of a room.

When semidirect radiators are used for warming the entering air, the dampers may be adjusted to suit the state of the weather. With indirect radiation the registers should equal in size and open area those used for foul air.

Definite results as to air volume and velocity may be obtained by properly proportioning the amount of heating surface and the sizes of hot and cold air ducts. This is particularly true in cold weather when the maximum amount of pure air would be supplied to the building.

There seems to be no question but that the combination of gravity ventilation and indirect heating is one that gives varying quantities of air dependent on atmospheric conditions. In warmer weather, when the minimum amount of heat is necessary, the resulting temperatures and velocities of the air in the ventilating flues are less than in colder weather; consequently the volume of fresh air admitted and the volume of air exhausted are less.

With this understanding we should not use the average volume necessary as a basis for estimating, but should so plan the work that the volume of air moved in warmer weather would be adequate for the character of the building in which the apparatus is placed.

CHAPTER XXI

MECHANICAL VENTILATION AND HOT-BLAST HEATING

Growth and Improvement

The phenomenal growth of the various systems of hot-blast heating and mechanical ventilation during the past twenty-five years is due largely to the better understanding of those who plan and erect buildings as to the need of a positive system of heating and ventilation. Many excellent works have been published covering the advantages of this type of apparatus and the application of the various methods employed in performing the work. These books and papers are more or less necessarily technical in character and, therefore, useful principally to experienced engineers and are intelligible only to those who have received the benefit of a higher education.

While we may not be able to add to the value of what has already been written on the subject, we hope to so describe and illustrate the various methods employed that the average steam fitter or heating contractor will obtain an intelligent idea of the principles applied and the methods practiced in installing work of this character.

Our thanks are due to such representative manufacturers of fans and ventilating apparatus as The Buffalo Forge Company, The B. F. Sturtevant Company, American Blower Company, New York Blower Company and The Massachusetts Fan Company and the engineers employed by them for much valuable assistance and for permission granted to use such tables relating to the movement of air, etc., etc., as appear in the last chapter of this book.

Experience has clearly demonstrated that mechanical heating and ventilation should go hand in hand, and in order that the cost of installation and operation may be reduced to a minimum, they should be considered unitedly, planned for unitedly and installed unitedly. A system of heating and ventilating cannot be perfectly controlled where one part is installed independent of the other and without perfect control the cost of operation must be excessive and the results obtained be intermittent, if not a complete failure.

Mechanical systems for heating and ventilating are at this date installed principally in buildings of large size, such as schools, theaters, churches, hospitals, factories, etc., and in comparatively few residences. This latter condition is due undoubtedly to the cost, both of apparatus and of maintenance. When as a people we shall have decided that we are willing to pay as much for health and comfort (which result from the breathing of pure, fresh air) as we do for the heating of our homes, then, without question, we shall see mechanical methods of heating and ventilating more generally practiced. Another influence operating against the adoption of methods of mechanical heating and ventilation, which possibly has not been heretofore fully recognized, has been the antagonism of the steam-fitting trade in many localities to the approval and acceptance of the blower system. In all likelihood this situation is due to two reasons, namely (1) ignorance of the modes applied and the results obtained, and (2) the question of personal gain arising from the adoption of some one of the old orthodox systems of heating.

Methods Employed

There are two general methods practiced in supplying a building with heat and fresh air and in exhausting or expelling the foul air. These methods are known as the *exhaust* and *plenum* methods. In arranging the apparatus for an exhaust system, the fan is placed in the main ventilating shaft or duct and cold or fresh air ducts lead to the heating surfaces supplying each room, as would be the case if indirect radiators were used. The entire heating surface may also be placed within a single chamber (brick or iron) and from this chamber the warm-air supply pipes connect with ducts leading to each room. Again, the heating surface may be direct, that is to say, direct cast-iron radiators or pipe coils placed under windows or at points where the inward leakage is the greatest.

In action the fan produces a partial vacuum within the room. This results in drawing the fresh air from outside the building through the coils or other heating surfaces and from them into the various rooms. At the same time it exhausts the foul air through ducts provided for the purpose, which are connected with the main ventilating shaft. In so far as the heating and ventilating results are concerned, it is possible to thoroughly warm and ventilate a building by this method and there are a great many structures heated in this manner. The objections to this mode are that in operation the partial vacuum created draws all air currents inwardly through the crevices around doors or windows, thus often producing a draught which is dangerous to the occupants of the rooms; also, that it is difficult to control a system of this character, particularly in a changeable climate. Again, the locations of the inlet and outlet registers must be arranged with great care, owing to the direct course of the air from the inlets to the outlets, and often the conditions of the building (particularly if previously erected) are such that the ducts and openings cannot be distributed as desired. For these reasons this system is not now generally used; it has been replaced by the so-called "plenum" method.

With the plenum method the heated air is forced into each room under a slight pressure and all leaks of air around doors, windows or other openings are outward and no perceptible draughts are felt or experienced by the occupants of the room. As the slight pressure exerted is from the source of the pure-air supply it is impossible for any obnoxious odors or gases to enter into and contaminate the air of the room. With this system the supply of heated air, as well as the supply of fresh air, or we might say the quality, quantity and temperature of the air are always under perfect control.

There are several adaptations of the plenum system of heating and ventilating. The older method employed is where the cold air is supplied to the fan direct from a cold-air chamber or cold-air duct, the fan driving it through the heater or heating coils into the various warm air ducts supplying the rooms of the building. The air may be sufficiently heated by these coils, or it may be driven through supplementary heaters located at the base of the hot-air flues and be increasingly heated before delivery to the room or rooms to be warmed. Separate ducts may be arranged to connect the main hot-air supply with the rising flues, or the heated air from the coil may be discharged under a slight pressure into a plenum chamber with which all supply pipes or warm-air ducts are connected.

Heat Losses and Heating Capacity Required

The proportion of heat losses depends principally upon the construction of the building, whether of frame, stone or brick, the conditions of exposure, that is to say, whether standing alone in an isolated position or protected from chilling winds by surrounding buildings, the number and sizes of windows and the amount of exposed wall surface. Brick buildings lose less heat through walls than buildings constructed of wood or stone and of the three classes, the frame structure is usually less compactly erected and correspondingly harder to heat. The percentage of loss through walls of varying thicknesses has been ascertained with sufficient accuracy for estimating purposes, as has also been the percentage of heat transmission through windows (glass), doors, floors and ceilings.

The use to which the building is put largely governs the heating capacity required. A schoolhouse or similar structure, built in the open and having a large proportion of exposed glass and wall surface, and where a certain number of changes of air per hour is desired, or a definite amount of fresh air per hour per person required, is proportionately harder to warm than would be a theater with its small glass exposure and usually well protected walls, to say nothing of the animal heat emanating from a large number of people closely assembled. In the latter type of building the matter of furnishing fresh air to replace that vitiated by the breaths of the individuals within the structure, and exhausting the air so contaminated without producing draughts or dangerous air currents, is a problem not easily solved. Assembly halls, churches, hospitals, factories and other types of buildings present conditions of heat losses and air vitiation which vary according to the diversified uses to which each building is put; therefore each type of building must be considered separately in planning the heating and ventilating of it.

The heating capacity of the apparatus is therefore based on two conditions, namely, the temperature of the air necessary to warm the building and the volume of fresh air necessary to be supplied in order to maintain a given standard of purity of the atmosphere within the building. Reference to the table "Volume of Air Necessary to Maintain a Standard of Purity" given in the last chapter of this book will show the volume of air essential under certain stated conditions.

Quality of the Air Supplied

When a blower apparatus is placed in a building erected in a location where the purity of the air is unquestioned, it may be supplied in its natural state to the building. As a matter of fact, the large proportion of buildings heated and ventilated by mechanical methods are located in the cities, in congested districts, or in factory towns where the atmosphere surrounding the structure is contaminated by dust and soot and which, aside from the possibility of being more or less filled with the germs of disease, is unfit to breathe. Again, in all buildings heated by artificial means, the air is deficient in moisture, the dryness being so apparent that it is necessary to heat the rooms to a temperature much higher than would be required were proper attention given to the quality of the air supplied.

Proper provision for a desirable degree of moisture in the air supplied to a building is as necessary, indeed we may say, more necessary, for health of its occupants, than the heating of it. Proper protection in the way of clothing will prevent chilling in a structure insufficiently warmed, but there is no individual resource whereby a person may prevent the oppressive feeling resulting from the dryness or overheating of a room, causing the evaporation of the moisture from the body to such an extent as to produce irritation of the skin and other unpleasant sensations. One can never feel as comfortable inside a room heated to 70° as in the open and balmy outside air when the temperature is at 70°. This fact alone shows conclusively that the nearer we can come to maintaining a fixed standard of humidity within a building, the richer will be the conditions of health and comfort. With these circumstances provided for it is possible at times to breathe better air within than without an edifice, because the weight of moisture in the outside air is variable, as it depends upon the conditions of humidity and temperature and these change daily, often hourly. Prof. Kinealy states that the weight of moisture brought into a room per hour by air which enters from the outside, is equal to the number of cubic feet of air, *measured at the outside temperature*, which enters per hour, multiplied by the weight in grains of the moisture in one cubic foot of air, and that the amount of moisture in one cubic foot of external air is obtained by multiplying its humidity by the weight of moisture required to saturate it at the outside temperature.

Again, the same authority states that as it is customary in this country to keep the air of the rooms at 70°, and to assume that the volume of the air supplied for ventilation is measured at 70°, the following table has been calculated to show the weight of moisture in one cubic foot of air at 70°, when the air is taken in a saturated condition at different outside temperatures and heated to 70°.

TABLE XXV

Temperature of Saturated Outside Air.	Weight of Vapor in One Cubic Foot of Air when Temperature is Raised to 70 Degrees.	Humidity of Air when Heated to 70 Degrees.
0	0.68	8.5
10	0.98	12.3
20	1.43	17.9
30	2.04	25.5
40	2.92	36.5
50	4.13	51.6
60	5.76	72.0

An Ideal System

The ideal system of mechanical heating and ventilation must, therefore, be the system which will not only properly warm a building, but which will at the same time expel the foul air in such quantities as to thoroughly remove all excess carbonic-acid gas and all poisons of respiration from the atmosphere within the building and replace the air expelled with air which has been washed of its soot, dirt and germs and moistened to such a degree as will insure healthfulness and comfort to the occupants. Further, the ideal system is one which is always under perfect control, giving certain definite results within a minimum cost of maintenance. Our readers may ask if all this is possible, to which we reply: Yes, not only possible, but further, that systems of this character are now in constant use. Installations of this kind are known as the "double-duct system" or more familiarly as the "hot and cold system." The reason for these appellations is shown in the following descriptions of apparatus.

Taking the modern school or public building for illustration, Fig. 204 shows a system of this kind as designed by the Buffalo Forge Company. The fan, heaters and air ducts are arranged in the usual manner. The tempering coils are located nearest to the fresh-air inlet and are of sufficient capacity to maintain any temperature desired up to 70° or 80°. The coils are specially constructed to admit of temperature regulation by hand, or the temperature in the spray or humidifying chamber may be automatically controlled by means of a by-pass damper under tempering coils. At one end of the spray chamber are located the spray nozzles. These are made of brass and are of simple construction, practically atomizing the water and distributing it uniformly throughout the chamber, the discharge being parallel to the air currents. At the opposite end of the chamber is located the eliminator or separator, which removes all free particles of moisture from the air before it enters the fan which draws the air direct from the humidifying chamber through the eliminator. The air thus cleansed and moistened is then discharged through the coils of the heater into the plenum chamber from which the various ducts supplying the building are taken.

Reference to Fig. 205 (which is an elevation plan of an apparatus designed for the Carnegie Library at St. Louis, Mo.) will show that the entire volume of air from the fan may be delivered through the heater, or a portion of it may be passed around the heater through the by-pass shown and mixed with the hot air in such quantities as desired or necessary to maintain a given

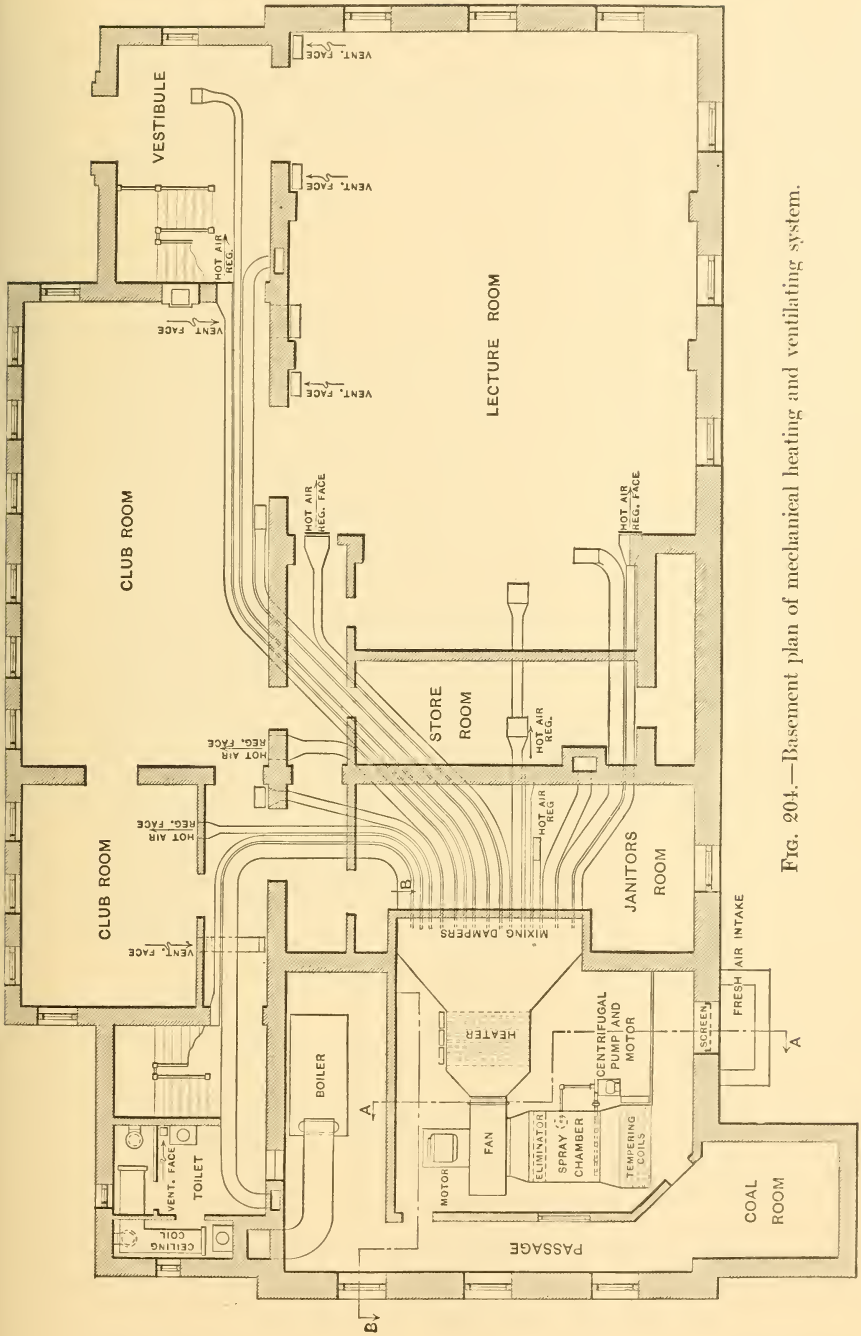

FIG. 204.—Basement plan of mechanical heating and ventilating system.

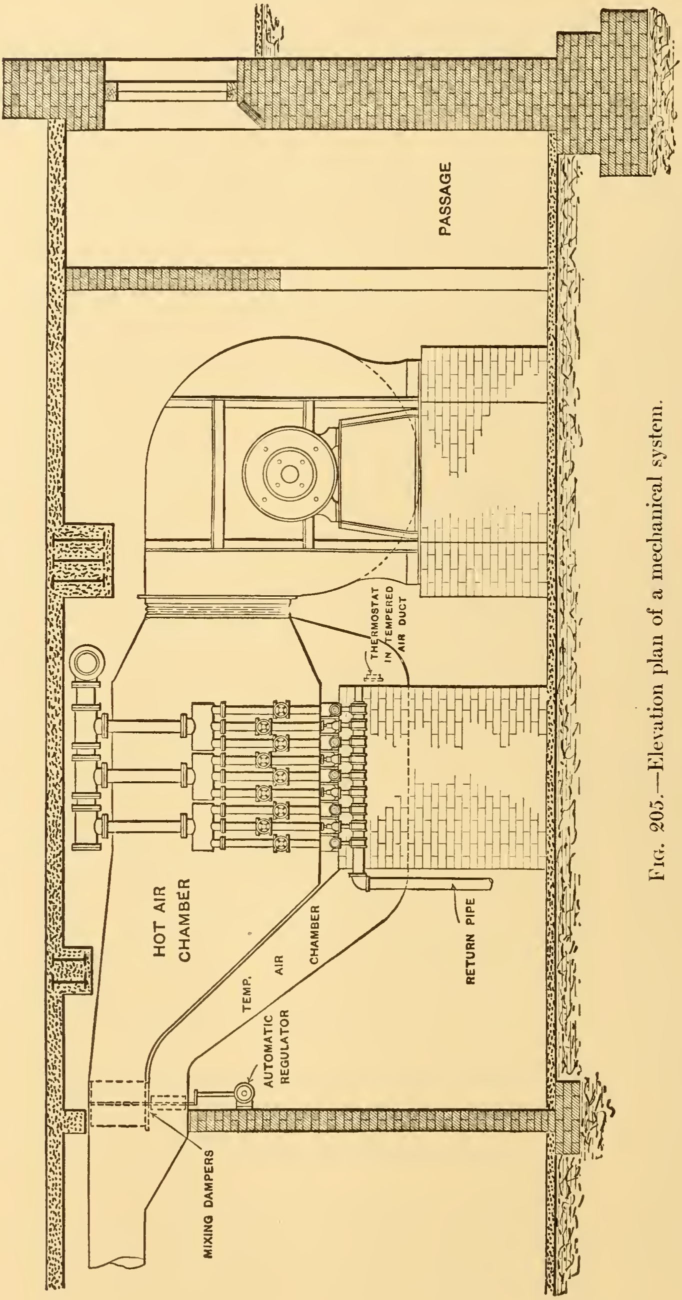

Fig. 205.—Elevation plan of a mechanical system.

temperature within the building. Thermostatic control at the mixing dampers for each room is an essential and special feature for a system of this character.

It may be well to state that the water for the sprays may be furnished from city pressure. The most economical method, however, is to use the water continuously until it is unfit for further use. This is achieved by draining the water separated from the air by the eliminator into a well, from which it is

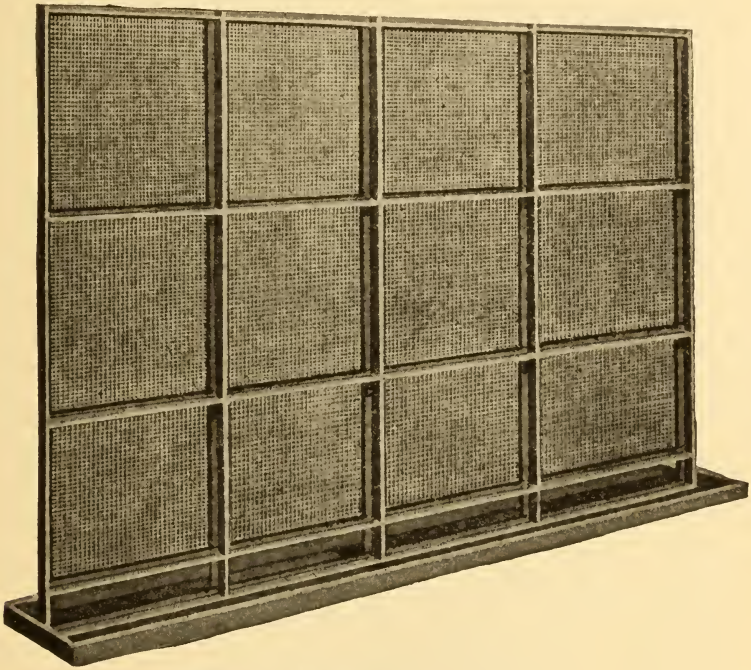

Fig. 206.—Wire screen for cleansing air.

pumped by a centrifugal pump and delivered again to the spray system. This pump may be direct connected or driven by belt from the fan, or a separate motor.

Air cleansing and humidifying may be secured by several methods. For cleaning it of soot and dust, the air may be passed through a fine wire screen similar to that shown by Fig. 206. Originally cheese cloth stretched over wooden frames was used. These frames were made removable, to be replaced when clogged with dirt.

Coke washing and purifying seems to be a very good method of removing dust and dirt and at the same time moistening the air. The coke is placed on shelving within a wire cage, through

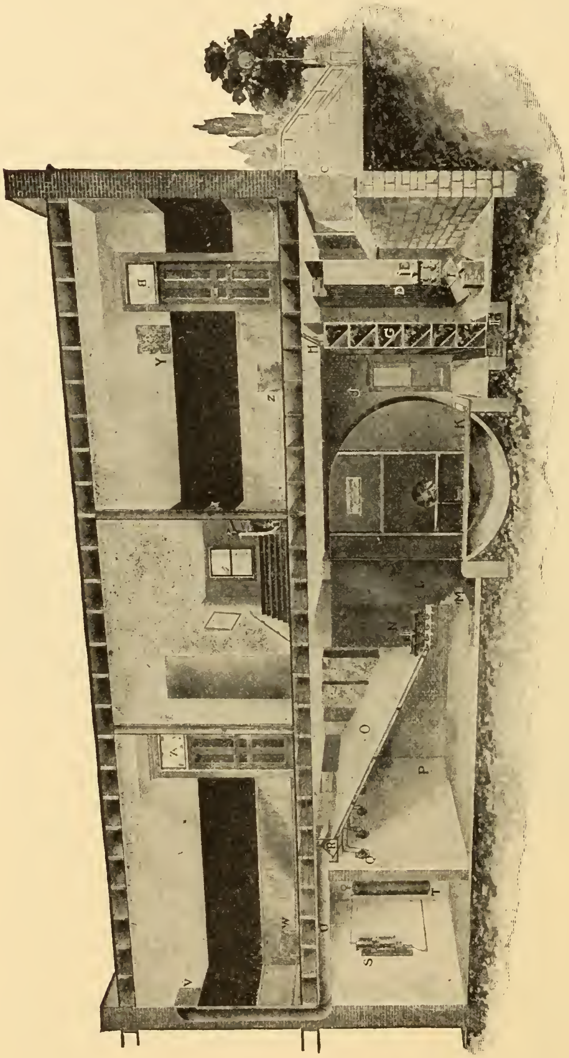

Fig. 207.—American Blower Company's method.

which the air is passed on its way to the fan. At the top of the cage the water supply is placed. The water is allowed to trickle down over and through the coke, while the air passing through

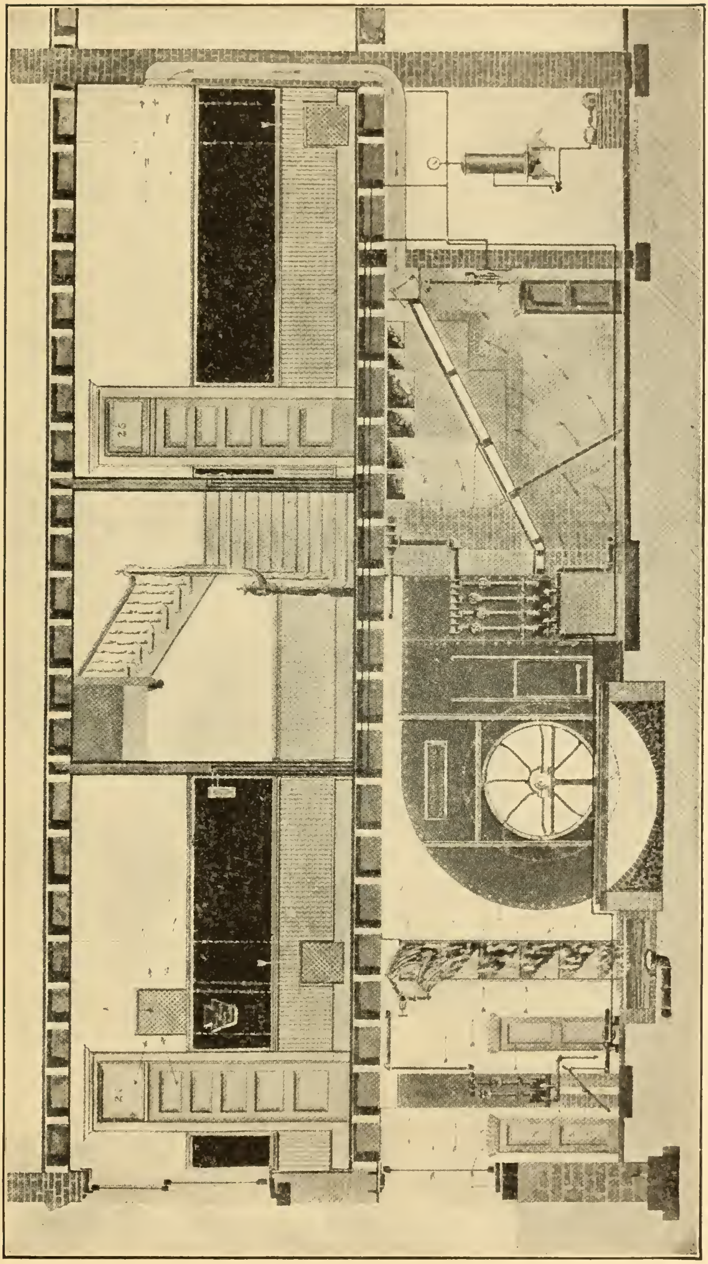

FIG. 208.—New York Blower Company's method.

at right angles is purified and moistened. Fig. 207 shows a perspective section of a school with heater, fan, coke washer, etc., as installed by the American Blower Company. The fresh air enters

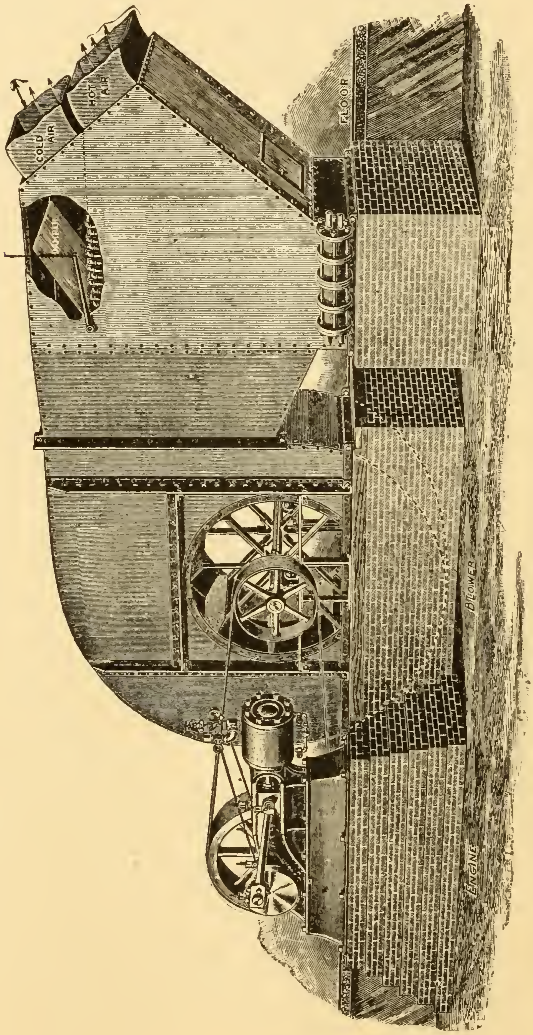

FIG. 209.—Sturtevant blow-through heater.

the building in the usual manner, through a screened opening in basement wall, passes through tempering coils, or direct through by-pass under the coils, to the coke washer and from here to the fan.

It is delivered to the heater or passed around it in the usual manner and under thermostatic control is admitted to the various rooms through ducts leading out of the plenum chamber.

Quite similar is the apparatus of the New York Blower Company, as illustrated by Fig. 208.

As conditions of area, location, etc., largely govern the character of the apparatus installed, each particular building must be separately considered and this fact is responsible in no small degree for the many arrangements and designs of the blower system.

One of the many Sturtevant methods is shown by illustration Fig. 209. It is a three-quarter housing pulley fan with blow-through heater for the "hot-and-cold" or "double-duct" system. An apparatus of this kind is used on work where space is limited, or where the space allotted is in such form as to preclude the placing of apparatus of the ordinary form with moistening chamber and tempering coils. The outlet from the heater may be made to discharge directly outward from the end, or upward or downward in either direction. In fact, the methods of setting and housing of the fan, whether a steam fan or operated by a pulley, are such as may be adapted for any special form of installation.

A typical apparatus for heating and ventilating a school is shown by the small basement plan Fig. 210. In this case the fan discharges in opposite directions through separate heaters to the right and to the left into separate plenum chambers, as shown. This arrangement of the apparatus is particularly commendable owing to the centralizing of the fan and heaters and the direct delivery of the warm air. One engineer summarizes the features of this system as follows:

"The entire heating surface is centrally located, inclosed within a fireproof casing, and placed under the control of a single individual, thereby avoiding the possibility of damage by leakage or freezing incident to a scattered system of steam piping and radiators. The heater itself is adapted for the use of either exhaust or live steam, and provision is made for utilizing the exhaust of the fan engine, thereby reducing the cost of operation (of the fan) to practically nothing. At all times ample and positive ventilation may be provided with air tempered to the desired degree. Absolute control may be had over the quality and quantity of air supplied. *It may be filtered, cleansed, heated*

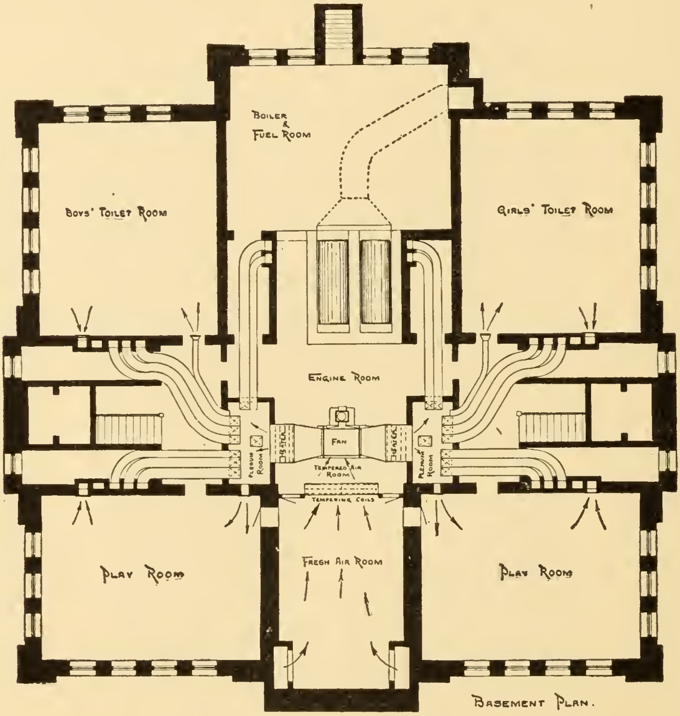

FIG. 210.—A typical method for schools.

or cooled, dried or moistened at will. By means of the hot and cold system, the temperature of the air admitted to any given apartment may be instantly and radically changed without the employment of supplementary heating surface."

Fans for Blowing and Exhausting

For exhaust ventilation and the removal of smoke, obnoxious gases, etc., from factories or other buildings, the regular forms of fan wheels used are of the disc or the cone type. Fans of this character are lightly constructed, are easily installed and require but little power to operate when run at low speed.

The Cone type of peripheral discharge, without any casing whatever, is thought to give the highest efficiency. They are said to produce better results in volume of air moved than could be secured by the use of the ordinary type of disc fan with straight blades.

The fan may be driven by a direct-connected motor, as shown by Fig. 211, or may be pulley driven, as shown by Fig. 212. These illustrations also show the manner of setting or installation. This type of fan is frequently used in the main vent shaft of a church, school or similar building in place of an aspirating coil where " assisted ventilation " is necessary.

The centrifugal fan wheel illustrated by Fig. 213 is the type of steel-plate fan as used in all blowers whether the housings are made of steel, brick or wood. There are several adaptations of this type of steel-plate fan, which space will not allow us to illustrate or describe. The blades may be curved or they may be bent backward to avoid noise. Various manufacturers have varying ideas of efficiency and forms of construction. The fans illustrated may be considered as representative of the several types.

The propeller or disc fan, as the name implies, propels the air forward by impact and centrifugal force and is efficient for moving large bodies of air under slight resistance. For driving air through heaters and long pipes or ducts, or delivering a fixed volume of air in a stated period or under great resistance, the type of fan wheel illustrated by Fig. 213 is now almost universally employed.

Types of Heaters

There are several types of heaters as used for mechanical or hot-blast heating and ventilation. The form of the heater employed depends largely upon the character of work to be performed and the space to be occupied for its installation. Different requirements demand different heaters and it would be hard to select one make or type of a heater which could always be adopted. Again, the size and shape of the heater depend upon the extent or number of degrees the air is to be heated, the volume of air passed by the fan and the steam pressure available. As a rule, the heater installed for this class of work takes the form of what might be designated as a " set " or " group " of steam coils made from

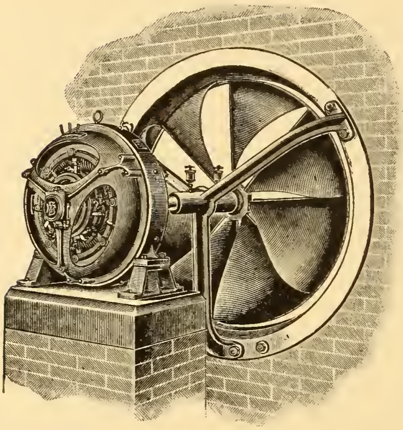

Fig. 211.—Ventilating fan with direct-connected motor.

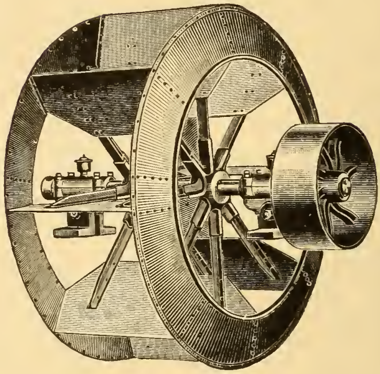

Fig. 213.—Type of steel plate fan.

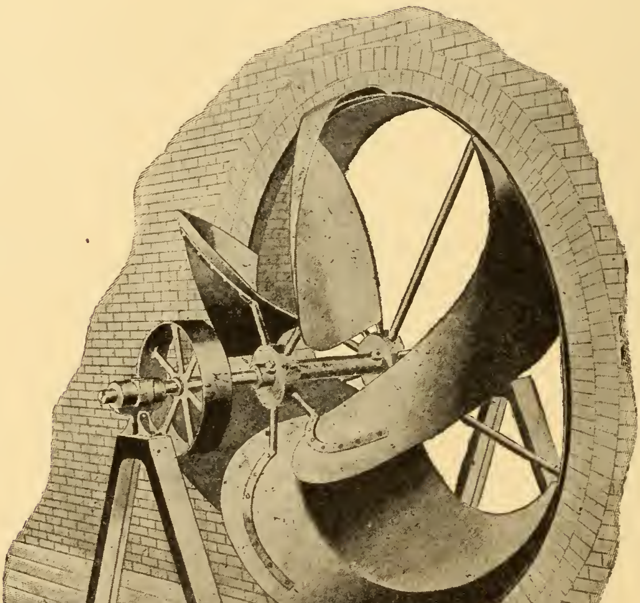

Fig. 212.—Pulley-driven ventilating fan.

wrought-iron pipe, usually 1″ in diameter and screwed into cast-iron bases of various forms, composing sections, the sections being then assembled in groups of two or more, according to the needs of the work.

The Sturtevant mitre type of heater is illustrated by Fig. 214. Steam is admitted at the top of the inlet header or section and the condensation removed at the end of the outlet section, each of the sections having an independent feed and drip.

The regular Sturtevant type of heater and the construction of the base are shown by Fig. 215. In this type of heater (made

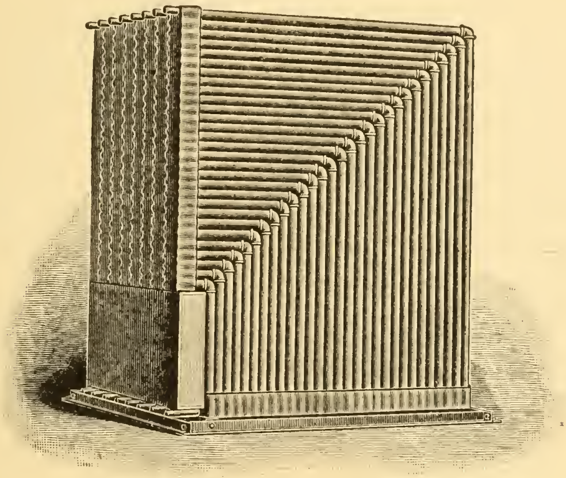

Fig. 214.—Sturtevant mitre type of heater.

also of 1″ pipe) the pipes are set 2½″ on centers, providing a free area for passage of air equal to about 40% of the full area of the face of the section. The arrangement of the interior of the cast-iron base and the division partition or diaphragm are clearly shown by the illustration. The steam enters the upper part of the base and feeds one end of the various pipe loops, passing upward and across the top and down the opposite side of the loop, the condensation entering the lower division of each header, from which it passes to the return drip.

The headers or bases are made to accommodate either two or four rows of pipe, and the compactness of the heating surface is shown by the fact that within a space of 6 feet in length, 7 feet in height, and 7½ inches deep, nearly 1,000 lineal feet of pipe may be massed.

The Buffalo Manifold Heater is illustrated by Figs. 216 and

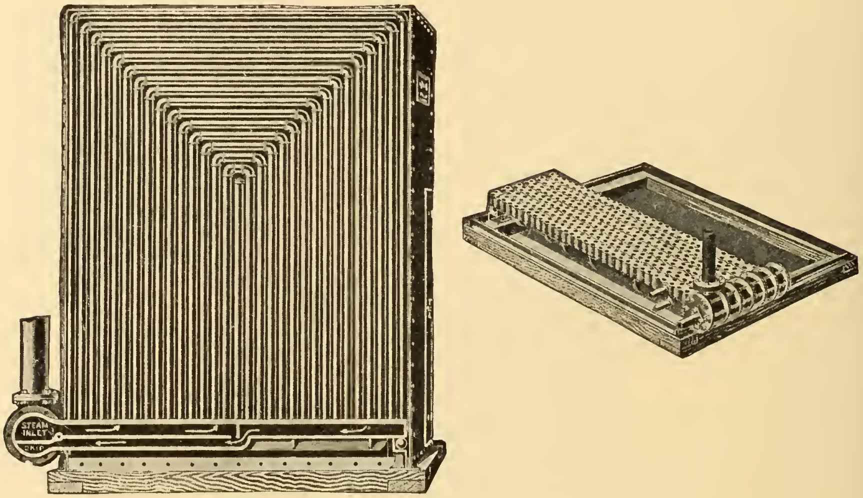

Fig. 215.—Sturtevant heater and base.

217, and the Mitre Coil Heater by Figs. 218 and 219. The Buffalo Manifold Heater is particularly efficient due to the peculiar form of the heater base.

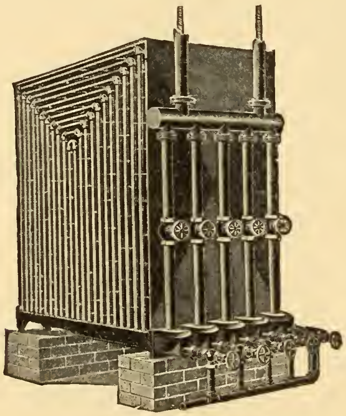

Fig. 216.—Buffalo heater showing connections.

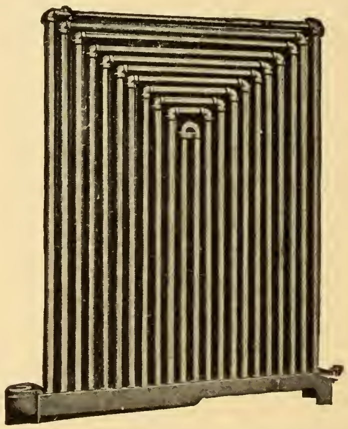

Fig. 217.—Buffalo heater showing base.

The heaters of the American Blower Company and of the New York Blower Company take the usual form in construction, but differ in the arrangement of the heater bases. The A. B. C. heater base is divided lengthwise by a diaphragm, the flow entering from one side of the partition, the return passing through the chamber on the opposite side of the partition. The form of the New York heater base is shown by illustration Fig. 220, which also shows this particular heater with a part of the casing removed. Fig. 221 shows the A. B. C. Heater complete ready for the casing.

The regular form of cast-iron indirect sections may be used in connection with the blower system for heating and ventilating schools, churches or buildings where it is not necessary to heat the

Fig. 218.—Buffalo mitre type of heater.

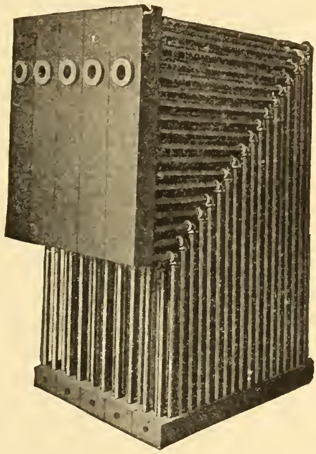

Fig. 219.—Assembling of mitre type of heater.

air to a very high temperature. A hot-air chamber is provided in the basement and the indirect sections assembled into stacks and arranged in two, three, four or more tiers, as occasion demands. Each tier is supported on I beams or railroad rails. There are also special forms of cast-iron sections available for use with a blower apparatus.

The fact of so large a heating surface being contained within a comparatively small space, as with any one of the heaters mentioned and illustrated, and the further truth that but one fifth of the surface ordinarily required for direct heating is necessary for the hot-blast system, are points of economy worthy of serious consideration. To these advantages we may add efficiency of service, as it is conceded that, owing to the rapid movement of the air over the heating surfaces, they become three times more efficient than heating surfaces in comparatively still air, as in the case of direct radiation.

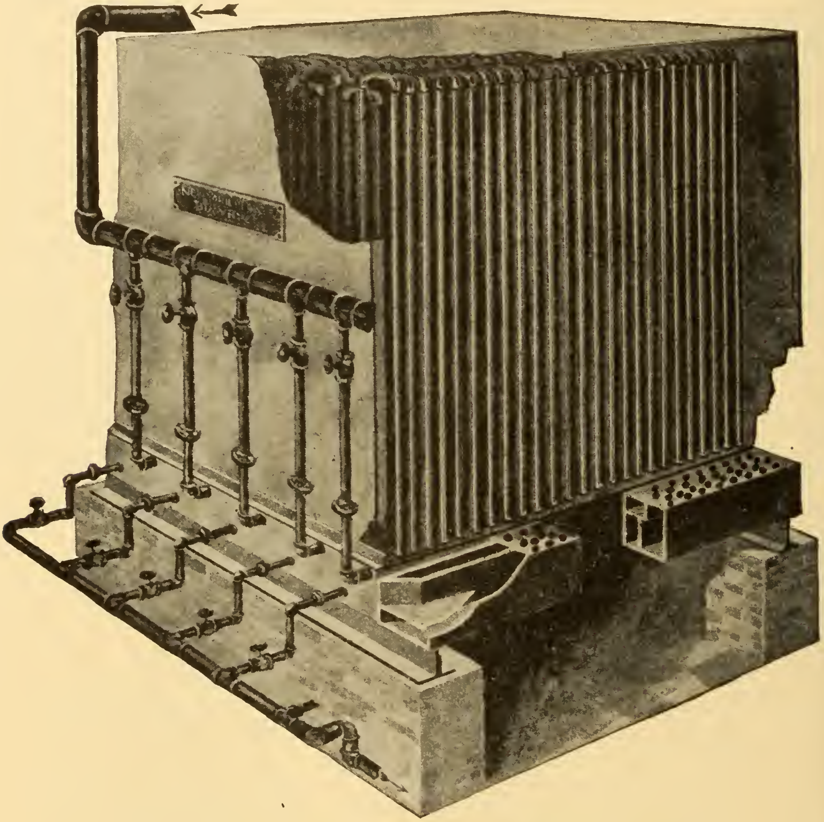

FIG. 220.—New York heater showing construction of base.

One point in heater construction we wish to make plain. The heater may be so valved and connected that certain sections may be used for live steam, certain sections for exhaust steam from an engine-driven fan or other source, or all of the sections may be used for live or exhaust steam as the case may demand.

Methods of Driving Fans

The method of driving fans for ventilating or for a combined system of heating and ventilation includes a detail of construction unnecessary to discuss at length. In so far as efficiency is concerned, fans of all types may be driven by electricity (a direct connected or independent motor) or by steam.

It frequently happens that fans are installed in positions where electric power is available and where it would be inconvenient to use an engine. In such a situation an electric-driven fan with motor directly attached is without doubt the most suitable and economical. Again, when a fan is used to accelerate the movement of air in a ventilating shaft or duct, it is easy to install an electric-

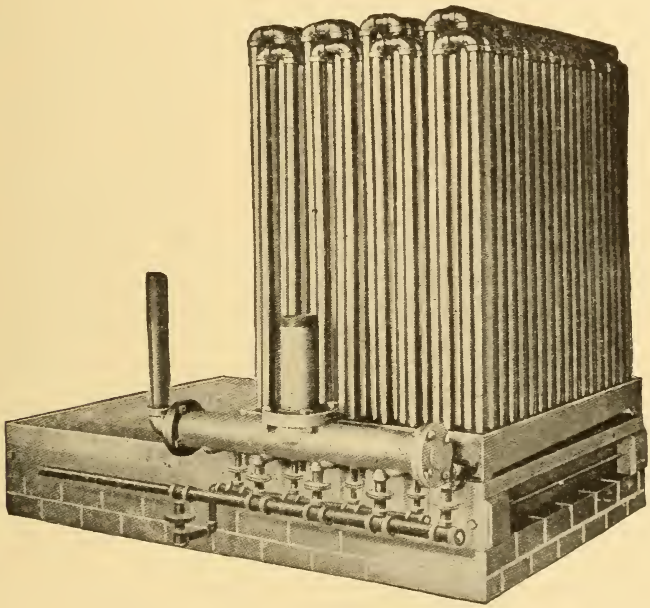

Fig. 221.—A. B. C. heater ready for casing.

driven fan, which may be started, stopped and controlled from a switch located in a convenient position for the attendant's use. The motor used should be independent, that is, should be used for no other purpose than that of driving the fan. An engine-driven fan in an instance of this kind would not be desirable. For an apparatus used for heating and ventilating, such as described in the preceding pages of this book, an engine-driven fan is no doubt the best and most economical.

The heater connections are so arranged that the exhaust from the engine driving the fan may be employed for heating purposes and as this exhaust has probably 95% of its original value in heat units, the cost of driving the fan is reduced to practically nothing. The requirements for an engine of this kind are lightness of weight and freedom from noise and vibration when run at high speed.

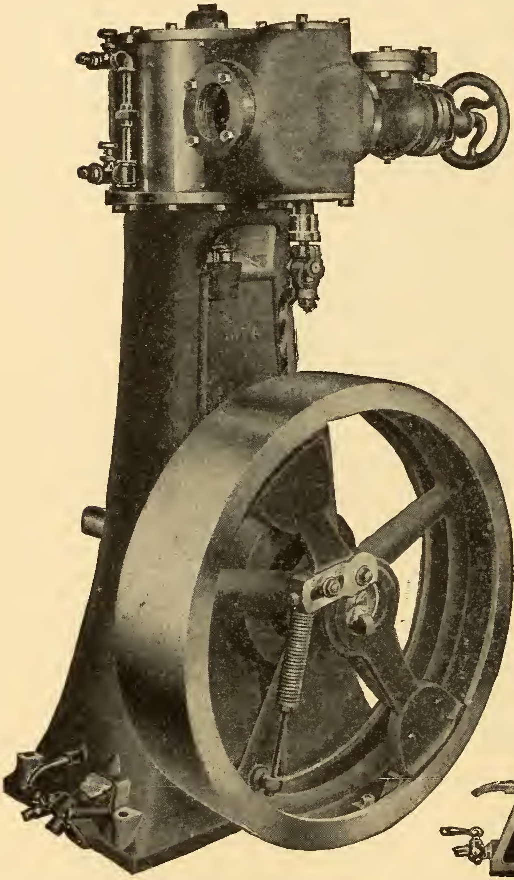

Fig. 222.—Type of A. B. C. vertical engine.

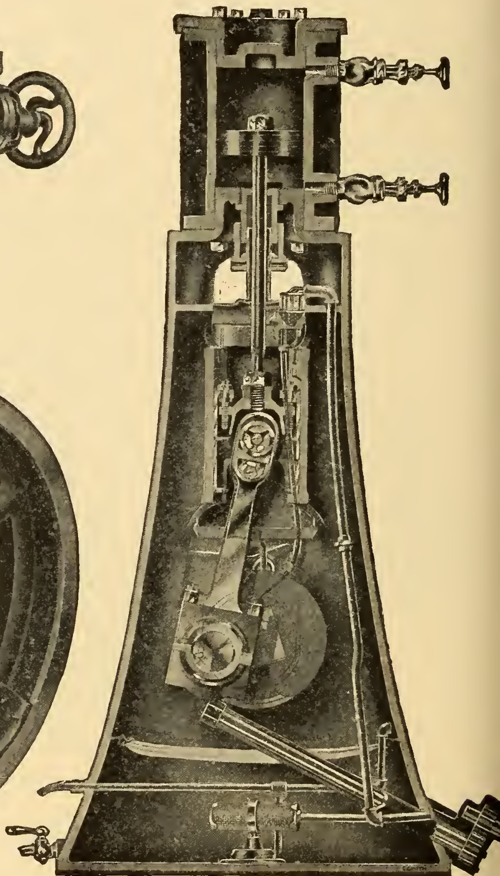

Fig. 223.—Showing A. B. C. self-lubricating device.

Simplicity and reliability are at all times essential. Fig. 222 shows one of the many types of the A. B. C. engine. It is for low pressure and of the vertical type, inclosed to keep the parts free from dust and dirt, and self-oiling or automatic. An interior view showing the mechanism of the self-lubricating system is shown

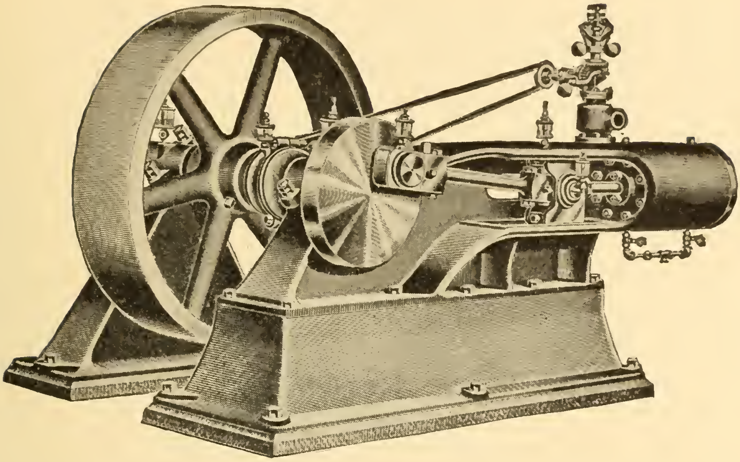

FIG. 224.—The Sturtevant horizontal engine.

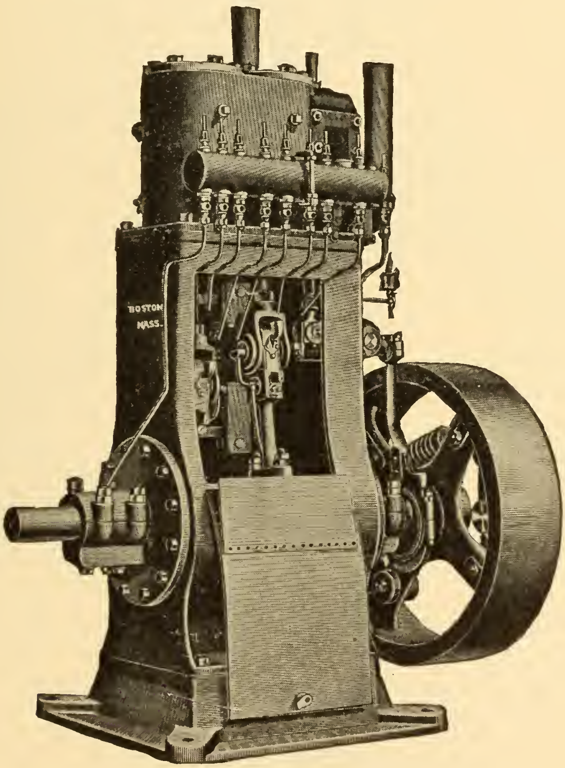

FIG. 225.—The Sturtevant double upright engine.

by Fig. 223. When used in connection with a heating and ventilating apparatus, such as would be required for a school or similar building, it is desirable that a pressure of not more than 30 lbs. be carried; therefore the engine must be supplied with large cylinders in order that the required power may be produced.

Fig. 224 shows a horizontal engine of this kind. When located where there is more or less dust in the atmosphere an engine of the vertical, inclosed type is more desirable. The double-upright or vertical inclosed engine illustrated by Fig. 225 represents another type of engine specially designed for this class of work.

Some Details of Construction

The following details of Sturtevant methods are typical of those in use on blower system construction.

The planning of a mechanical system of heating and ventilation, the determining of the size of each portion of the apparatus

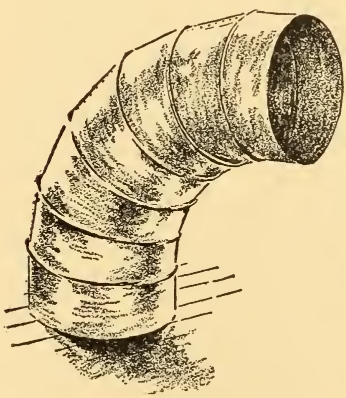

Fig. 226.—Form of elbow for hot-air duct.

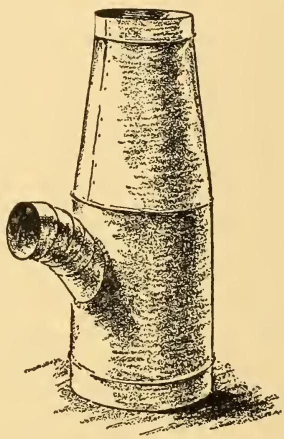

Fig. 227.—Manner of reducing size of air duct.

and the ordinary details of construction should be left with an engineer whose experience at work of this character qualifies him to handle it accurately and competently. There are some few details of construction with which we should become thoroughly familiar.

From illustrations and descriptions given on the preceding pages we should have a good understanding of the methods of placing the mechanical portion of the apparatus, arrangement of air chambers, moistening apparatus and eliminators.

The flues, which should be built in the walls as the construction of the building progresses, should, if possible, be tile-lined. If not tile-lined, they should be plastered smooth. The ducts (the name given to all horizontal air passages) are usually made of galvanized iron, although in many instances it is necessary to run a portion of them underground, in which cases they should be constructed of brick or tiling. Sudden turns or angles in the ducts should be avoided. In making a 90° angle turn, the elbow should

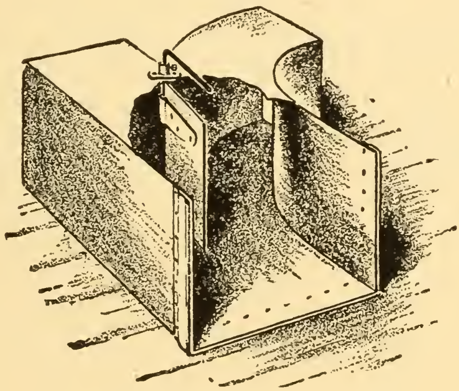

FIG. 228.—Iron duct construction.

be built with as large a sweep as possible. Illustration Fig. 226 shows the proper construction of the elbow.

An abrupt reduction in the size of the diameter of the pipe should be avoided; all unnecessary friction is eliminated by a gradual diminution of the pipe size. This is illustrated by Fig. 227, whereby we show the manner in which a small pipe should be taken from a main duct.

Fig. 228 shows the method of constructing an iron duct and by Fig. 229 we illustrate the method of constructing a brick duct when it is essential for a portion of the air supply to turn at right angles, the remaining quantity continuing in the same direction.

The movements of air and water are in many respects quite similar. The same methods employed for the elimination of friction from the pipes conveying water may be used with good results in conducting air. This is very clearly illustrated by the use of a double elbow when it is necessary to divide the supply, sending a portion of it in either direction.

The proper arrangement of ducts and dampers has much to do with the success or failure of an apparatus of this character. Two ducts, one conveying the hot air, the other conveying the cold air, are run to the base of the flue supplying a room. It is understood that each room should have an independent supply. Mixing dampers are placed where the hot air and cold air enter the flue.

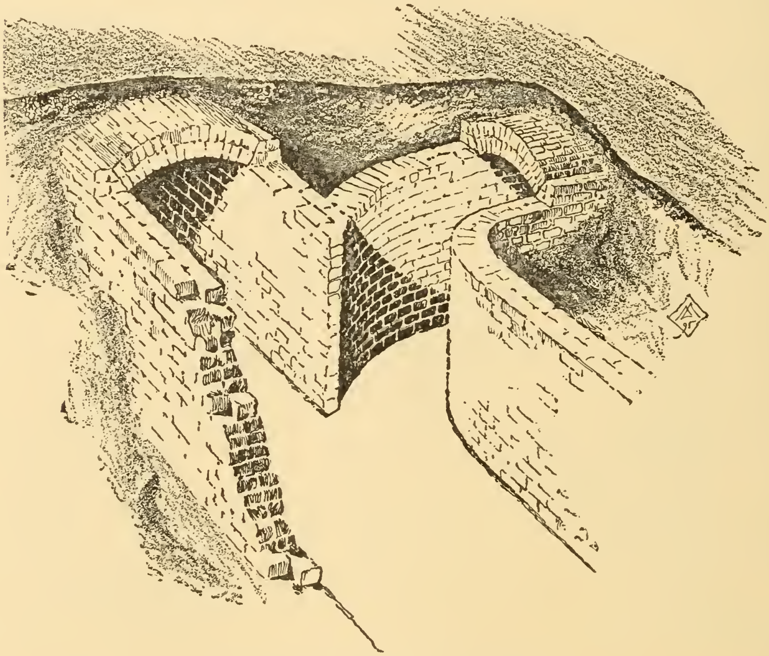

Fig. 229.—Brick duct construction.

Fig. 230 shows an arrangement of a damper of this character and the method of operating the damper from within the room. While this mode is extensively used, nevertheless it is open to some objections. The air currents strike squarely against the damper plate, causing considerable friction. The Sturtevant method is commendable and is clearly illustrated by Fig. 231 and Fig. 232. As the damper is cylindrical in form it allows the air to mix in proper quantities at the will of the operator and without friction. The dial placed within each room and the chain attachment are shown by Fig. 233. These dampers may be manipulated by a thermostat. This arrangement we will show in a later chapter.

The screen or register opening for the entering air should be placed at a point about two thirds the height of the ceiling and

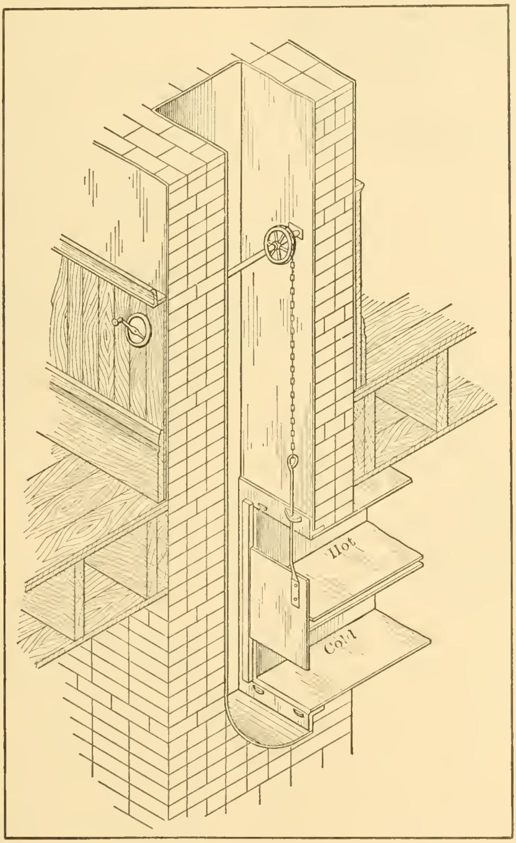

Fig. 230.—Type of mixing damper.

in such a part of the room as will insure the complete distribution of the air. Frequently the proper location may not be utilized, due to the particular construction of the building and it, therefore, becomes necessary to assist the distribution of the air in certain directions. This is accomplished by means of a diffuser placed over the face of the register, as shown by Fig. 234. This appliance breaks up the volume of air admitted, deflecting it into separate currents and thereby more effectually warming the room.

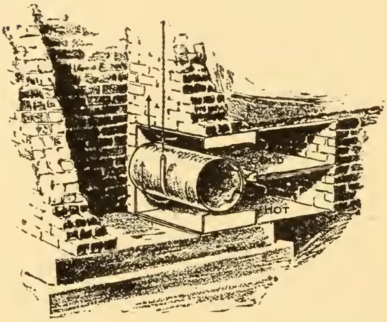

Fig. 231.—Sturtevant mixing damper.

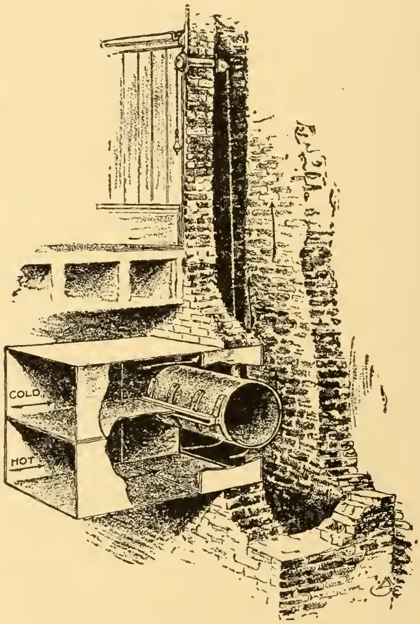

Fig. 232.—Sturtevant mixing damper showing chain for operating.

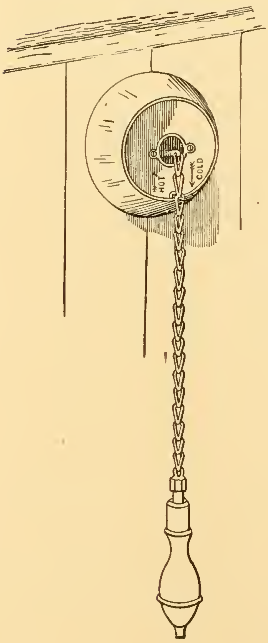

Fig. 233.—Enlarged view of dial and chain.

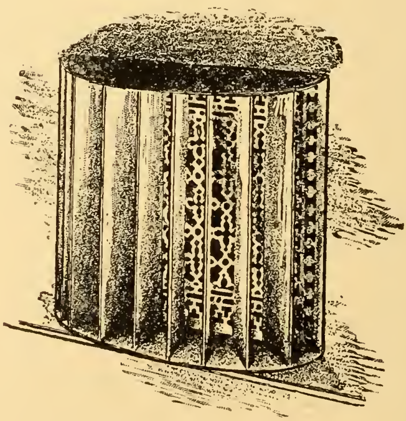

Fig. 234.—Diffuser placed over register face.

Factory Heating

Before the fan and blower came into general use the problem of satisfactorily heating and ventilating factories of any considerable size, was often a vexatious one and the results as often obtained were far from being efficient or desirable. The use of fans for exhausting the foul air, smoke or gases incident to the manufacturing of some classes of products, and for forcing the distribution of heated air has revolutionized the methods of factory heating and now definite results and efficiency are assured.

The exhaust type of fan as illustrated by Fig. 211 and Fig. 212 may be employed with successful results in the removal of foul air and gases and for heating a blower fan and pipe heater arranged for use of all available exhaust steam may be utilized.

Probably the most simple and the easiest type of factory building to heat and ventilate is the one-story building. They are usually sparsely occupied and the amount of floor space devoted to the use of each employé is considerably larger than the space per capita in offices or public buildings; therefore, the ordinary ventilation of the building is not a difficult matter. On the contrary, with regard to heating, the customary factory structure is well lighted by many windows and not only presents large exposed wall surface to the action of the wind and weather, but also from the form of its construction has a very large loss of heat or leakage through the roof.

In a building where the process of manufacturing does not fill the air with poisonous gases, the fan may be supplied with air from within the building. Therefore, the loss of heat is only that wasted by leakage, the air being turned over and over and heated to the necessary degree of temperature to allow for heat losses through windows, walls and roof. The fan and heater should be centrally located in order that an even distribution of the heat may be secured throughout the building. The air is carried around the building in galvanized pipes and distributed through openings located at intervals in the piping. Fig. 235 shows an adaptation of this method and is the type of an apparatus designed by the Sturtevant Company.

When a factory building of more than one story in height is in process of erection, flues for the distribution of the heated air may be built up through the pilasters and thus not engage any space within the building. The heated air may be supplied to these flues through a brick underground duct or through an iron duct located in the basement. For certain classes of mills or factories this method is preferable above all others.

Where a blower system is installed in an old factory structure, the most simple form of air distribution is by a galvanized iron stand pipe, as shown by Fig. 236. The openings for each floor may be made in the manner shown, or the piping on each floor carried to a central point, the distribution there taking place.

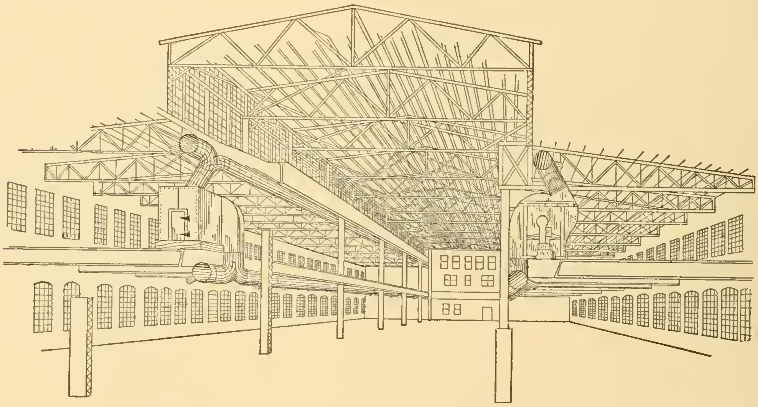

Fig. 235.—Sturtevant method of factory heating.

In one sense the heating of factories in this manner far excels all other methods. The moving belting, shafting and machinery all tend to break up the currents of air and assist in its distribution, and the further fact that the operatives in a large percentage of all factories are on their feet and moving about, are not as susceptible to draughts or air currents as would be the case in a factory where the employés were continually sitting or remained inactive. This circumstance renders the location of air outlets and the installation of blower systems a comparatively easy task.

The shape and size of the building and the usage to which it is put are factors which largely govern the form of the apparatus and the method of installation.

Relative Cost of Installation and Operation

No direct comparison between the cost of installing a fan or blower system and any one of the other methods of heating, viz.,

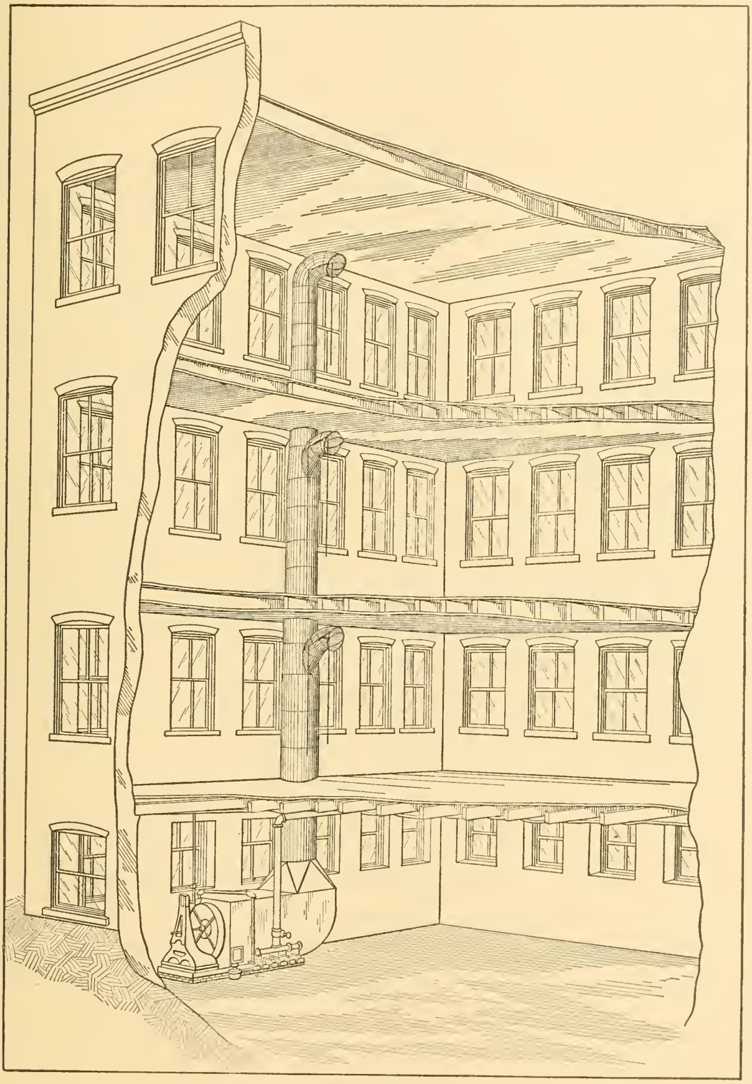

FIG. 236.—Another form of factory heating.

furnaces, steam or hot water, can well be made, as the cost of a blower system increases or decreases according to the rates of air change demanded, that is, the number of times per hour, the air within each room shall be changed; in other words, according to the size of the apparatus and not necessarily according to the size of the building. On the contrary, the cost of a direct or indirect system of heating, steam or hot water, without ventilation, increases in proportion to the size of the building and the added cost for ventilation may be much or little, corresponding to the amount of ventilation or air changes secured.

It has been suggested that as a people we will not tolerate cold rooms, but that we will tolerate a vitiated atmosphere, to which we would add that such toleration on the part of the owners of many buildings is carried to such an extent that the buildings frequently are unsanitary and unhealthy, conditions which are remedied only when pressure is brought to bear upon the owner. It is probable that the cost of installing an indirect system of heating with "assisted" ventilation is in excess of the cost of the blower system *when the volume of air moved is considered.*

The cost of operation, labor of attention required and expense for fuel for the blower system of heating are not very much in excess of the cost of operating other systems. Our public schools, a class of buildings, many of them quite similar in arrangement and design, the rooms averaging 30′ × 36′ in size and from 12 to 14 feet high, and provided for the use of from fifty to sixty scholars, form a very good basis for comparison as to expense of maintenance (labor and fuel) for the heating and ventilating apparatus. Carefully preserved records show some interesting data. The cost for mechanical heating and ventilation for a school building of, say, twenty rooms is less per room than for an eight or ten room school. Where furnaces are used there is very little difference in the cost of labor of attendance, or for fuel per room.

The records of one city show a comparison of costs, as follows: For five schools provided with a fan and direct and indirect system the cost per room for attendance averaged $62.00 and for fuel $71.00. For six schools provided with a direct and indirect system (assisted ventilation) the cost per room for attendance averaged $61.00 and for fuel $70.00. For twelve schools with furnace heat and ventilation the attendance averaged $52.00 per room and the fuel $72.00. For two schools heated with a direct steam apparatus (no ventilation) the cost of attendance averaged $58.00 per room and fuel $45.00.

Upon comparing the figures we find that the fuel bill for heat without ventilation averaged $45.00, or $27.00 per room less than for furnaces with the amount of ventilation they provided; $25.00 less than for direct and indirect heating and assisted ventilation and $26.00 less than for the fan system of ventilation with direct and indirect heating. Thus the cost of ventilation approximated $25.00, $26.00 or $27.00 per room for fuel, with attendance costing but a very little more than for direct steam and no ventilation, and there seems to be no question but what those schools equipped with a fan were better ventilated than any of the others.

Many other comparisons show the expense for fuel with a mechanical ventilating apparatus to be less than that incurred with furnaces, while the cost of attendance, due to more skillful labor demanded, was approximately one third greater than for the attendance given the furnaces.

Another item of interest in the comparison of tests shows that year by year the expense of maintenance for the mechanical systems remained very nearly the same, while the figures furnished for furnaces and other systems vary largely.

An average of all records at hand reveals that the actual cost of heating is less for the blower system than for other methods, and that whatever further increase in cost is shown is chargeable to the ventilating portion of the apparatus, this increase being much or little in proportion to the quantity and quality of the air provided for ventilation.

Apparatus for Testing Systems of Heating and Ventilation

In order to make a test of any mechanical apparatus it is necessary that instruments of absolute and positive accuracy be used in making and recording the test. This is particularly true in testing systems of mechanical heating and ventilation, as regards temperature of steam or highly heated air, the velocity and the amount of moisture or humidity in the air under varying conditions.

A type of thermometer for conducting a test at high temperatures is illustrated by Fig. 237. This consists of a highgrade thermometer, the tube of which is inclosed in a brass casing. The thread at the bottom is a standard-pipe thread and can be screwed into any ordinary fitting. As shown by the illustration, the bulb extends well down into the opening into which it is

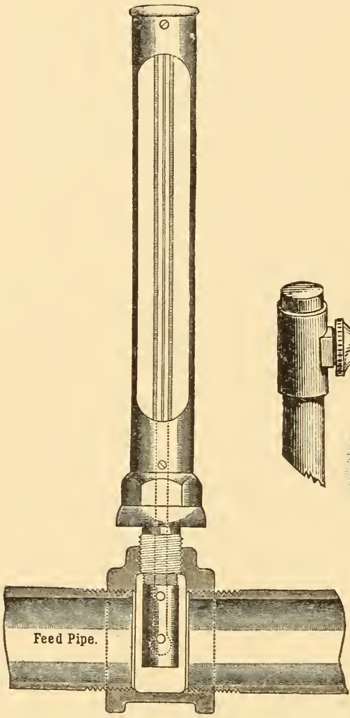

Fig. 237.—High-temperature thermometer.

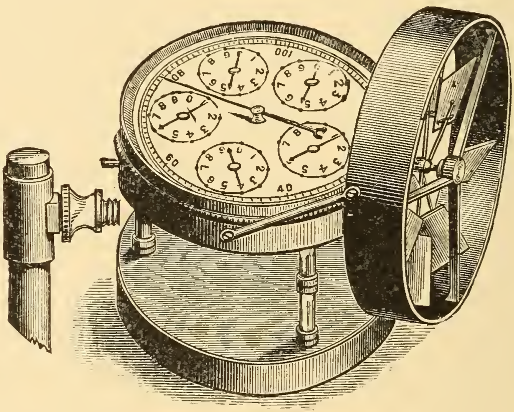

Fig. 238.—Anemometer.

screwed in order to insure that the reading on the instrument scale will be accurate. The bulb is protected by a section of thin brass pipe as shown.

The movement or velocity of air through ducts or openings may be readily determined by the anemometer, or air meter, as shown by Fig. 238. The indications are obtained by the revolution of a series of fans, acting first on a long hand, capable of recording the low velocity of fifty feet per minute on a large dial divided to 100 feet, and then successively by a train of wheels on the indices of five smaller dials, each divided into ten parts, and recording respectively 1,000, 10,000, 100,000 and

10,000,000 feet or 1,894 miles, an amount found to be more than adequate to the most protracted observations. A disconnection is provided on the rim of the instrument, which sets the recording hands in or out of gear without influencing the uniform rotation of the fans. The velocity recorded by the anemometer multiplied

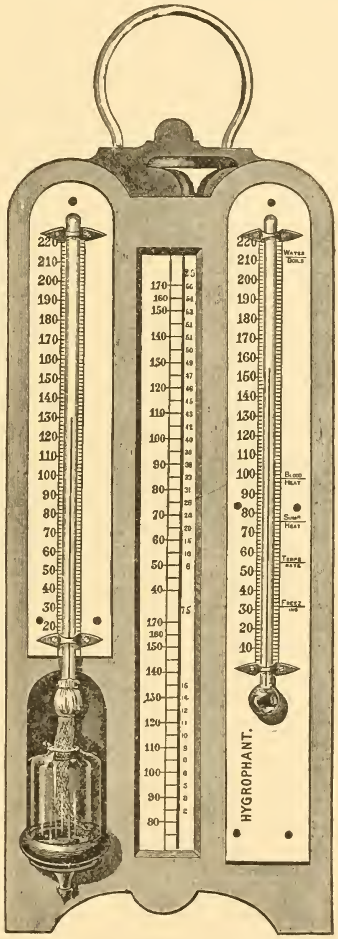

Fig. 239.—Wet-bulb hygrometer.

by the area of the air pipe or orifice through which the air is moving will give the total volume of air passing.

An instrument for noting the percentage of saturation of the air (humidity) is called a Hygrometer and is illustrated by Fig.

239. Various forms of this instrument have been devised; that shown by the illustration is a standard type.

The atmosphere surrounding us is seldom dry or completely saturated with moisture and the amount of aqueous vapor held in suspension is very changeable. This fact bears an important part when considering the hygienic qualities of the atmosphere. As we have already noted, a certain amount of moisture in the air is essential to good health and the importance of maintaining the proper proportion of moisture in the atmosphere within our homes and public buildings we have commented upon in a former chapter of this book. Particularly is this true in hospitals or in the sick chamber.

In speaking of the humidity in the air we hear much of the "dew point." Dew is formed by the radiation of heat from the surfaces of trees, plants, etc., consequently reducing the temperature of the air near the immediate surfaces of such objects to the point of complete saturation, causing moisture to be deposited.

With a complete heating and ventilating apparatus, that is, with an air heating, cleansing and moistening apparatus, any kind of climate may be produced and is registered or recorded by the Hygrometer. The Hygrometer has two thermometers—a "dry" thermometer and a "wet" thermometer, as indicated by the illustration. These are mounted on the face of the instrument. The bulb of the dry thermometer is exposed to the air; the bulb of the wet thermometer is surrounded by a piece of silk, cotton or wick. As evaporation causes a loss of heat, the thermometer with the wet bulb will read lower than the other, provided there is any degree of dryness in the air. When the air is very dry the difference of register between the two thermometers will be great, the variation lessening according to the degree of moisture in the air, until at complete saturation both will read alike, as then there can be no evaporation. To use the hygrometer the wet bulb and attached wicking should be thoroughly saturated with water. The small reservoir under the wet bulb should be filled with water and the loose end of the wicking should dip into it. As fast as the water evaporates from the wet wicking covering the bulb, it will draw its supply from the reservoir by capillary action of the wick and so keep the bulb constantly wet.

Having prepared the hygrometer for work, expose it in the atmosphere to be tested for a period of fifteen or twenty minutes. Then note the readings of both thermometers, the dry and wet bulbs. Ascertain the number of degrees difference by subtraction. In the center of the instrument is a cylinder with a knob at the top for turning by hand, upon which is inscribed a series of columns of figures numbered at their headings from 1 to 22. These numbers represent the difference in the readings of the wet bulb and dry bulb thermometers and the columns show the relative humidity or percentage of moisture in the air for every degree of temperature indicated by the thermometers. Having ascertained the number of degrees difference in the reading of the thermometers, turn the knob of the cylinder until this number is exposed at the top of the column and opposite the opening in front and in line with the reading of the wet bulb thermometer. On the scale of the cylinder will be found the number representing the percentage of humidity in the atmosphere, absolute saturation being 100°.

Various forms of siphon gauges for water or mercury are manufactured for indicating vacuum or pressure. These are provided with couplings for attaching to pipe or reservoir, the pressure or vacuum being shown by the difference in the level of the liquid in the two arms of the glass siphon.

CHAPTER XXII

Steam Appliances

THE appliances used in connection with a steam boiler for power or heating purposes are many and varied in character. Steam Traps for removing the water of condensation without waste of steam, Separators for removing oil and other impurities from the water within the apparatus, or the water held in suspension in saturated steam, Steam Pumps, Inspirators, Injectors, Boiler Feeders and Return Traps for returning the water of condensation or feed water to the boiler against whatever pressure is used, Mechanical Apparatus for automatically controlling the draught, Pump Governors and Feed-water Heaters, etc., all have their separate and several offices to perform.

While our work has to do only with boilers as used for heating and ventilation, the same conditions of handling the water of condensation, regulation of pressures and separation of impurities apply as to a boiler used for power purposes.

These steam specialties are so numerous and different in character that we can illustrate but few of them, mention the salient features of each and discuss with our readers their work in connection with a power or heating apparatus.

Steam Traps

Steam traps are of two general kinds or classes: Those used to separate the water from and thereby relieve steam pipes or heating surfaces, and those used for returning to the boiler the water of condensation from the steam employed for heating or for mechanical purposes.

In the first division there are many kinds: Expansion traps, whose action depends upon the difference in the expansion of two metals, such as the Heintz Trap, Fig. 240 and the Kieley Cantilever Expansion Trap, Fig. 241: Bucket or "Pot" Traps constructed with a hollow metal bucket inside the trap, which, when

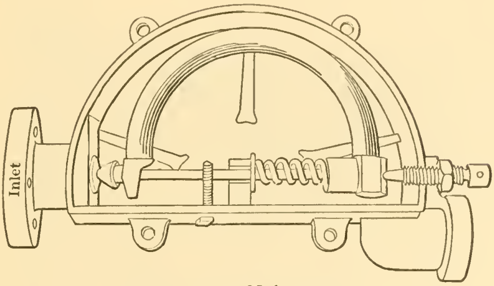

Fig. 240.—Heintz trap.

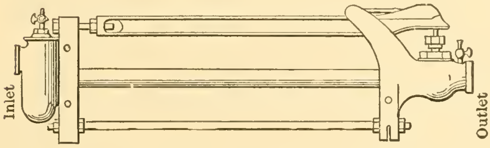

Fig. 241.—Kieley cantilever expansion trap.

filled with the return water, opens a valve, allowing the trap to operate and the bucket to empty. A trap of this character is

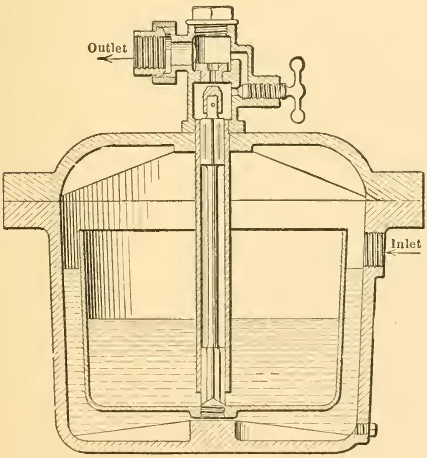

Fig. 242.—Albany bucket trap.

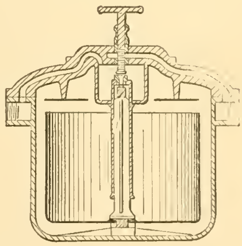

Fig. 243.—Nason bucket trap.

shown by Fig. 242, which illustrates the Albany Trap, and Fig. 243 which illustrates a trap of the familiar Nason type.

The Kieley Special Trap, shown by Fig. 244 is not unlike the others in the principle of making use of a metal bucket. It

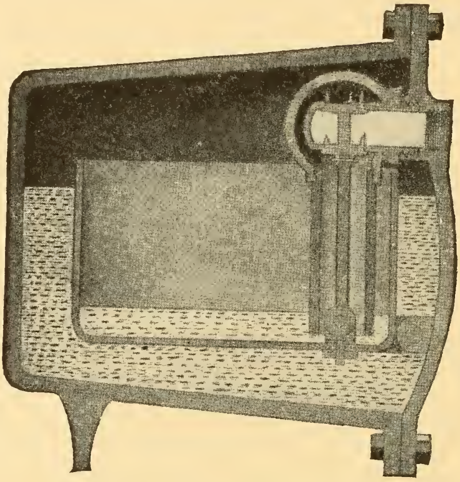

Fig. 244.—Kieley special trap.

has, however, a special form of valve—a balanced or double-seated valve, giving it an extremely large capacity for handling rapid condensation, as in a low-pressure heating apparatus.

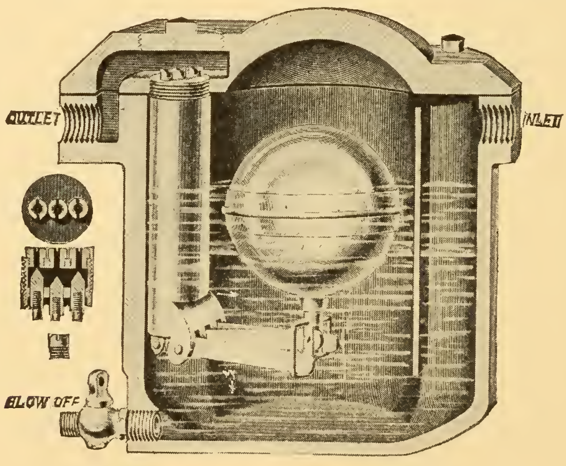

Fig. 245.—Wright emergency trap.

The float type of trap has many adherents. The Wright Emergency Trap, as illustrated by Fig. 245, is a particularly good representation of this type of trap, the illustration being so clear as to require almost no explanation. The condensation enters the trap through the inlet opening and fills the pot somewhat more than half of its height, when the copper float rises, opening the discharge valves (of which there are three) at the top of the trap. Note by the small detail of the valve shown on the left of the illustration that the points of the three valve stems are set at varying heights. The center valve is the one in regular operation. Should a rush of water enter the trap, the float will quickly rise, the arms at the bottom engaging the rods on either side cnnecting with the valve stems, thus allowing the three valves to act in unison while the rush of water continues.

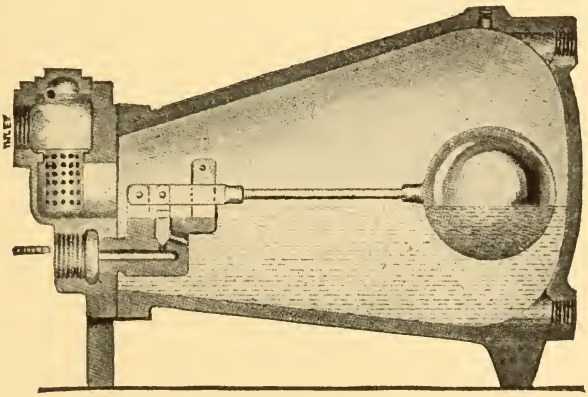

FIG. 246.—Standard ball float trap.

Another of this type of trap is shown by illustration Fig. 246, which is the Standard Ball Float Trap, the operation of which is quite similar to that already described, excepting that it has but one valve.

Other traps combining the float principle with the balanced valve, or with the expansion feature are manufactured, as are also others making use of the expansion and contraction of some chemical or sensitive liquid. Those illustrated, however, may be considered as representative types of traps employing the principles described.

The open trap discharging into the atmosphere, or against slight pressure was invented by Mr. Joseph Nason, a heating engineer and contractor of New York, and the original Nason Trap was quite similar to those of the same name in use at the present time.

Return Traps

The returning of the water of condensation to a boiler on which the pressure is much greater than on the return pipes presents an altogether different problem from that of drawing the water from a system without the loss of steam. To Mr. Jas. H. Blessing, of Albany, is due the credit for the first successful efforts in this direction. Circumstances arising with regard to the heating of the factory of Townsend & Jackson, known as the Townsend Furnace & Machine Works, by whom Mr. Blessing was employed as superintendent, made it necessary to return the water of condensation to the boiler by some other means than gravity. Mr. Blessing tells some interesting facts regarding this. He says:

"During the year 1870 the proprietors of the Townsend works deemed it best to remove their establishment down to the river front. As the area of the new works was to be considerably greater than that of the old, it was necessary to make some changes in the heating system. I concluded to use the exhaust steam for heating the foundry and part of the upper floors, and to heat the offices, machine and pattern shops with direct steam taken from a boiler to be specially installed for that purpose. I intended that the boiler should be set in a pit so that the water of condensation from the heating system of the lower floors would gravitate into it. After having settled on this plan, believing it to be all right, I arranged with a contractor to remove as much as possible of the old heating system and replace it in the new works and to furnish all the extra pipe and fittings necessary to complete the system as I had planned it. After arranging with the contractor I paid very little attention to the matter as we had over a hundred men employed in the different shops and my time and attention were fully occupied with the details of the business and the removal of the works. Therefore, I did not discover the gross error I had made until after nearly all the work was done, with the exception of the setting of the boiler.

You can imagine my position, after explaining to my employers what a simple and effective plan I had devised for the return of the water of condensation back to the boiler, when I learned how impracticable it was to place the boiler low enough to have the water from the lower floors gravitate into it, owing to the fact that each tide caused the level of the water in the river to rise higher than the fire box of the boiler. In order to overcome this condition it would be necessary to set the boiler in a tank anchored to prevent its floating.

"This would have been very expensive and, under the circumstances, impossible.

"After having discovered the character of the problem that confronted me, my first thought was to secure a trap that would

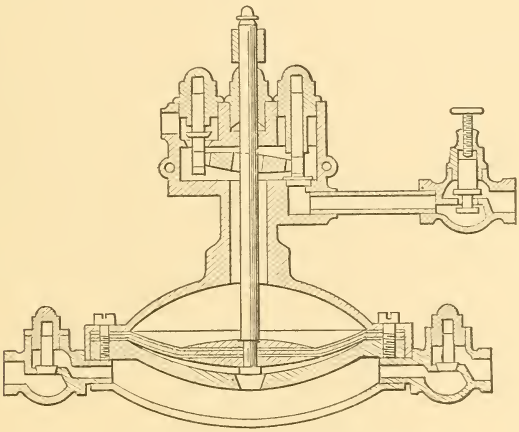

FIG. 247.—Early type of Albany return trap.

return the water of condensation to the boiler without the aid of pumps. After making a thorough inquiry, I failed to learn of any such device.

"In an effort to solve the problem presented, my mind turned naturally to the thought of returning the water of condensation to the boiler by gravity, and my first experiments were all in that direction. My first return-steam traps, invented during the year 1871, Fig. 247, were placed above the water level in the boiler, the steam being taken from the steam space of the boiler and acting upon the upper side of a diaphragm contained within the trap and intended for equalizing the pressures. This diaphragm acted simply as a dividing wall between the water on the one side and the steam on the other. The steam used for each discharge of water from the trap was, as in the case of a steam pump, exhausted to the atmosphere. Although the diaphragm trap was successful in its operation, yet it failed to return all of the water and did not make up for the error I had made.

" In my experiments with the diaphragm trap several interesting facts came to light. Among other things, I discovered that the inlet pipe for conveying the water of condensation to the trap receiver from the coils contained steam and water, for, after the first condensation, due to the extra amount of steam condensed when steam was first let into the heating apparatus, was worked off by a few rapid discharges of the trap, it would require several minutes to collect water enough to again fill the trap. While this was filling up one could hear the inlet check valve on the inlet pipe rattling on its seat, caused by the water and steam passing through it. As a result of this observation and the experiments I had been making, it occurred to me that after all the coils and radiators were only a part of the direct steam pipe that conveyed the steam from the boiler through them and finally terminated in the small pipes used for collecting the water of condensation.

" If this smaller return pipe were connected, so I reasoned, to the top of a vessel of proper size placed a certain distance above the water level of the boiler, the water and steam would pass over into such receiver, the water falling to the bottom and separating itself from the steam. The steam pressure in the receiving vessel would be about the same as the pressure in the system at its farthest point from the boiler. If this pressure were near enough to that in the boiler and the receiver were placed at a height sufficient above the water level in the boiler so that the solid water column would make up for the difference in the pressures, the water would gravitate back into the boiler through a return pipe extending from the bottom of the receiver. With this understanding of the conditions, I prepared a spherical vessel twelve inches in diameter as the receiver to be used in the system with which I was experimenting. I believed that a receiver of the size mentioned would be ample for the purpose as the capacity was less than one gallon per minute. The receiver was placed on the floor above the boiler where the coils were situated and about nine feet above the water level in the boiler. After the receiver was connected up and steam turned on and the first water and air removed by blowing to the atmosphere, circulation began and was perfectly maintained. This, I believe, was the first steam loop ever made to return the water of condensation from a steam system situated below the water level of the boiler whence the water issued in the form of steam, all without in any way opening to the atmosphere.

" After the steam loop had been in successful operation for some time in the Townsend & Jackson works I thought I would test it in another place. Accordingly, I selected the plant of Mess. Weed & Parsons, printers, of Albany, where a modern heating system, using steam direct from the boiler, had just been installed. On investigation, I found a place about ten feet above the water level in the boiler where the receiver could be placed. After getting the system connected up and making several attempts to start a circulation, I met only with failure. I next concluded to try the steam pressures and found a difference of about eight pounds between that of the boiler and the coils. This explained to me the reason for the failure to get up a circulation, for it would require for the height of the return column of water about twenty-four feet, or over twice the space available. Owing to the conditions under which the system was installed I could not get a place sufficiently high for the receiver and could not without great expense enlarge the main steam-supply pipe so as to make the pressures more nearly equal. I then made a change by taking the receiver and suspending it on one end of a counterbalanced lever and added a steam valve for admitting steam direct from the boiler into the top of the receiver for the purpose of equalizing the pressure with that in the boiler. This steam valve was caused to open and close automatically by the rising and falling of the receiver. In the form here shown in the cut, Fig. 248, this trap was known as the Albany Gravity Return-steam Trap."

During the period following the introduction of this trap, improvements were added and the Albany Return Trap as used at the present time has all valves and other mechanism inclosed within the body of the Trap itself. As will be seen by the illus-

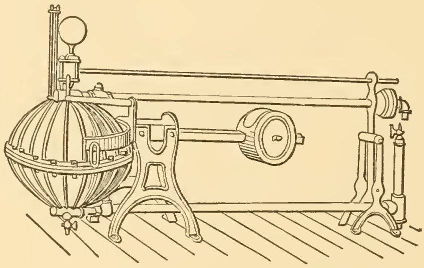

Fig. 248.—Albany gravity return trap.

tration, Fig. 249, the bucket of the Trap rests on a hinged pivot at one side of the bucket. As the return water enters the space between the bucket and the outer wall of the Trap, the bucket is

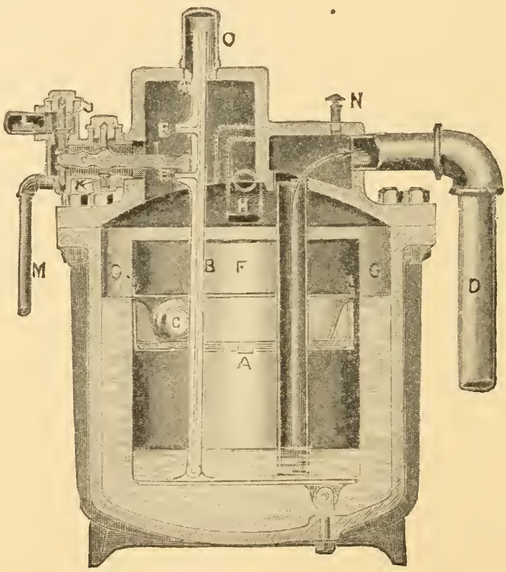

Fig. 249.—The Albany return trap.

tilted slightly, allowing the ball weight " C " to slide to the opposite side of the Trap, giving a sudden impetus to the tilting movement, which seats the equalizing steam valve and at the same time opens the exhaust valve. The bucket is held in this position until the water flows over the top edge and fills it, when it again tilts downward under the impetus of the preponderance of weight and the movement of the ball weight returning to its original position. This movement opens the equalizing valve, admitting steam direct from the boiler into the trap, thus equalizing the pressure between the boiler and the trap, whereupon the water in the bucket will feed through the siphon-pipe connection down and into the boiler. As the bucket is again tilted it closes the equal-

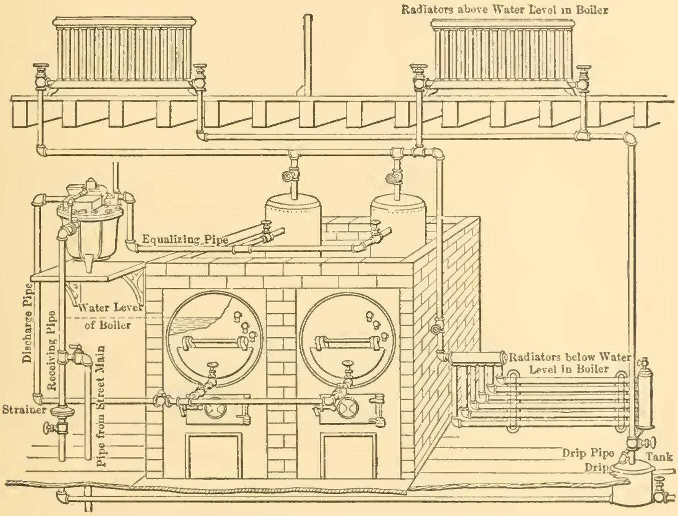

Fig. 250.—Method of connecting Albany return trap.

izing valve against the steam pressure, the Trap refilling as before. The Return Trap should be located at least three feet above the water line of the boiler.

We illustrate by Fig. 250 the general method of connecting the trap. The condensation collects in the cast-iron pot or receiver. The pressure on this receiver from the heating system raises the water to the trap, which returns it to the boiler.

There are several kinds of return traps, the same general principle of equalizing pressures being employed, although the methods of operating the traps differ widely. The Champion and the Pratt & Cady Traps work by balanced weights. The Bundy Return Trap differs from all of the others in that no movable or balanced weights are used. Fig. 251 shows the form of this trap and the method of making connections. The trap consists of a cast-iron bowl which swings on trunnions, moving in a vertical travel. When the trap is empty the bowl rests against the top of the frame surrounding it, the weight of the ball on the overhanging lever holding it in this position when empty or while filling. When the bowl fills with water to a point where the weight of the water combined with the weight of the

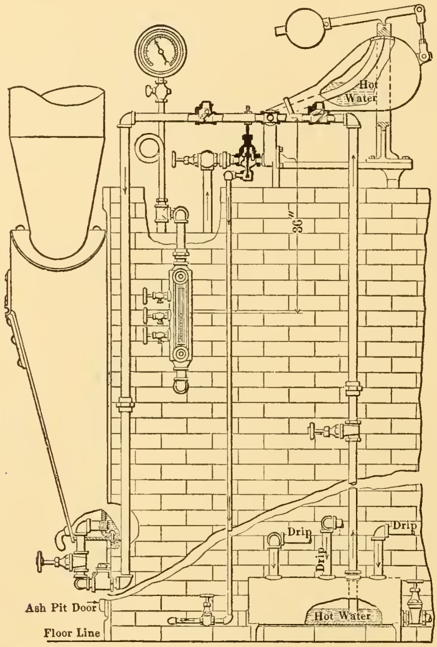

Fig. 251.—Bundy return trap and method of connecting.

bowl overbalances the weight of the ball, the trap drops until it rests on the under side of the frame already alluded to. In making this movement it closes the air valve and opens the equalizing valve, allowing the steam at boiler pressure to enter the bowl on top of the water, through the curved equalizing pipe shown in the bowl of the trap. Thus the pressures on the trap and the boiler are equalized. The water in the bowl now runs unobstructed out of the opening through which it entered the bowl and drops by gravity through the check valve on the return pipe and into the boiler. In returning to its first position the bowl closes the equalizing valve and opens the air valve and is again in readiness to receive the returning condensation. There must always be sufficient pressure on the returns or receiver to lift the water to the trap. Where this pressure (one pound for each two feet of lift) is not available, the duplex system, or use of two traps, is necessary.

The office of the lower or secondary trap is to receive the water of condensation from the heating coils, or other source, by gravity and in turn lift or deliver it to the upper trap, which returns it to the boiler. It is claimed for return traps that they will handle water much hotter than a pump and with less loss in heat units.

Separators

Separators for removing moisture from steam and oil, or other impurities from feed water, are made in various forms. The nature of all of them is to receive the steam through the inlet

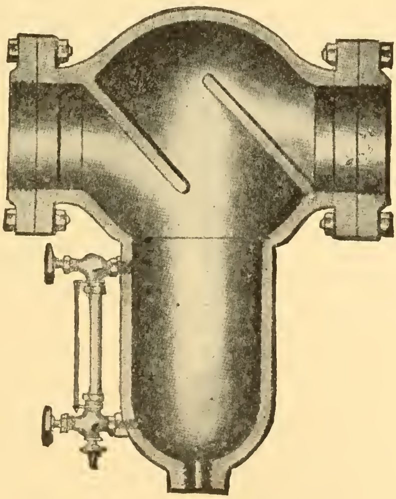

Fig. 252.—Kieley separator.

opening of the separator, directing it against a series of baffle plates. This action removes the oil or water and delivers the purified steam without loss of pressure into the supply main of the heating system. The oil or water so extracted drips into the lower chamber of the separator, from which it is removed through a drip pipe. On an exhaust heating system the separator is indispensable. When used to extract oil or other impurities from the exhaust it is placed on the exhaust pipe with the baffle plates facing toward the engine. When employed to remove the moisture from steam it is placed on the main steam pipe with the plates facing toward the boiler.

Many separators are in satisfactory use. An Austin, Bundy,

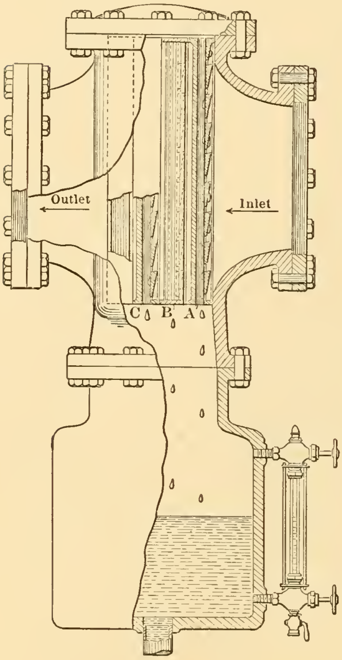

FIG. 253.—Bundy separator.

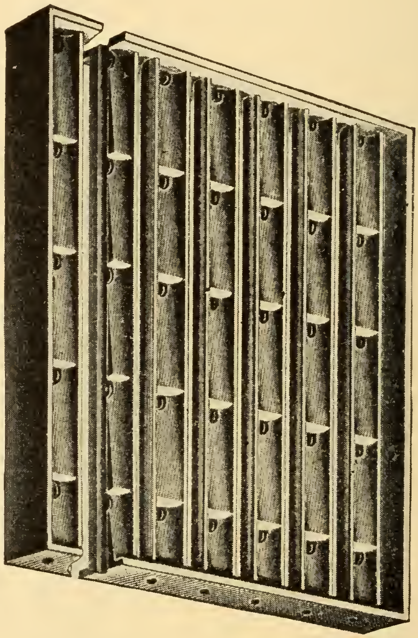

FIG. 254.—Bundy separator baffle or separating plate.

Kieley, or other make, may be found in the boiler room of nearly every power or heating plant.

As representative of the separators having stationary cast-iron baffle plates in the chamber of the separator, we illustrate the Kieley design, Fig. 252.

The Bundy Separator, Fig. 253, is illustrative of the type of separator with removable baffle plates and shows clearly the character of it. A nest of six or more baffle plates, or more properly, separating plates, as shown by Fig. 254, are grouped in the upper chamber of the separator. The pillars of these plates are staggered, the steam passing through and around them. Each pillar or column is channeled its entire length, the small openings through the face of each column communicating with the vertical channel through which the water or oil passes by gravity to the receiving chamber below.

The plates may be easily removed for cleaning,—a very necessary factor when the separator is employed to remove oil or other impurities from the exhaust.

Feed-water Heaters

When the hot water from the condensed steam is used for other purposes and it is necessary to feed the boiler with fresh water, or, again, when the return water, trapped or pumped to the boiler, has lost the bulk of heat units contained in it, a very great saving may be effected by reheating this water before supplying it to the boiler. Engineers are agreed that for each 10 degrees this water is heated, a saving of 1 per cent of the fuel is realized.

Before the closed type of feed-water heater came into use it was customary to run the water of condensation or the fresh water into an open tank or hot well, heating it by steam coils or by turning the exhaust into it, whence it was pumped into the boiler.

Frequently the water supplied to the feed-water heater is partially heated by coils in drip tanks, thereby making use of heat units which otherwise might be wasted. Progress along the lines of steam engineering has shown the advisability of saving all heat units possible, being conducive to economy in the consumption of fuel. The fact has been demonstrated that the feeding of cold water direct to the boiler creates a straining, due to expansion and contraction, which must necessarily shorten the life of the boiler.

When the temperature of the feed water is raised from an average of 60 degrees to a temperature of from 200 to 212 degrees, a saving of about 15 per cent of the fuel is effected. Without entering into a discussion of the relative merits of various types of feed-water heaters we may say that a good heater to adopt is one which is so constructed as to admit of easy cleaning, one whose area for the passage of the exhaust is sufficiently great

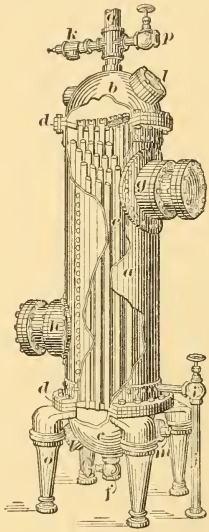

FIG. 255.—Bundy type of feed-water heater.

to show no back pressure, and one in which the expansion and contraction of the inner tubes are fully provided for. Fig. 255 illustrates one type of a feed-water heater of this character.

Steam Pumps

One method of returning water to a boiler is by the use of a boiler feed pump. It is entirely probable that no branch of steam engineering has received more attention than that of pumping machinery. Steam pumps are manufactured in a multitude of designs and sizes for regular and special purposes, the evolution of the pump having been carried to such an extent that all liquids, including chemicals, may be pumped from one receptacle and delivered to another under all sorts of conditions. Air or gas may be pumped and where steam power is not available, electrically operated pumps may be employed. Our use of pumps has only to do with pumping the water supply to the boiler or in removing the condensation from a heating system and creating and maintaining a vacuum on the heating system.

Boiler Feed Pumps

For this purpose many standard makes are in evidence, among which may be mentioned the Knowles, Marsh, Blake and Deane Pumps. Fig. 256 illustrates the Knowles Direct-acting Steam Pump. This pump has many features to recommend it, chief of which is the simplicity of its construction. An auxiliary piston working in the steam chest drives the main valve, preventing what is known to engineers as a " dead center." The meaning conveyed by this expression is that there is a dead point which would stop and prevent the operation of the pump.

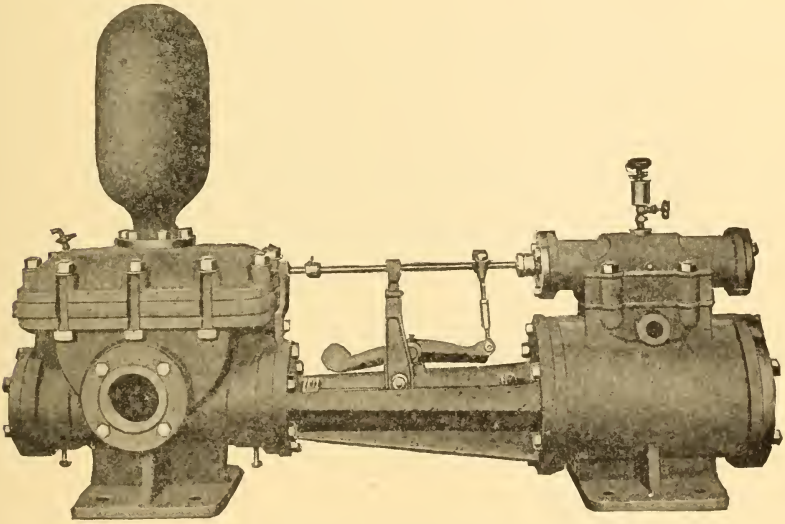

FIG. 256.—Knowles direct-acting steam pump.

This piston driven backward and forward by the steam carries with it the main valve, which in turn supplies the steam to the main piston operating the pump, there being no point in the stroke at which either of the pistons is not open to direct steam pressure.

The Marsh Boiler Feed Pump, Fig. 257, is the style used of this particular make for low pressure as with a heating apparatus. It is essential that a pump employed for this purpose shall be of sufficient size to allow of slow running. While reducing its pumping capacity this is best for low-pressure work. The motion

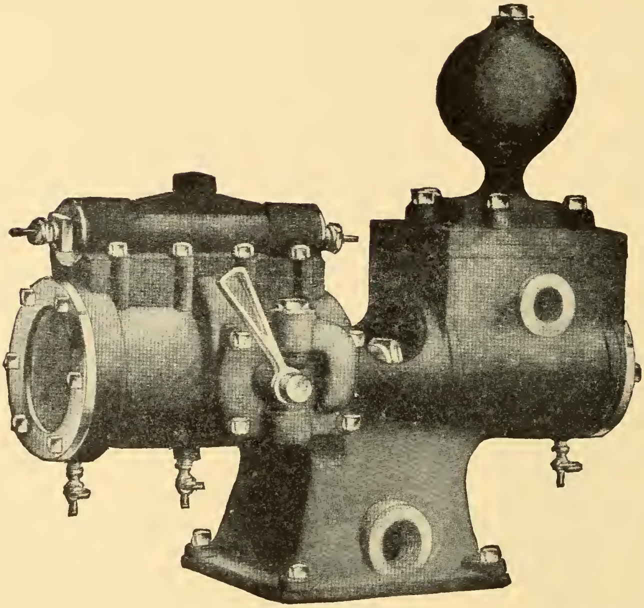

FIG. 257.—Marsh boiler feed pump.

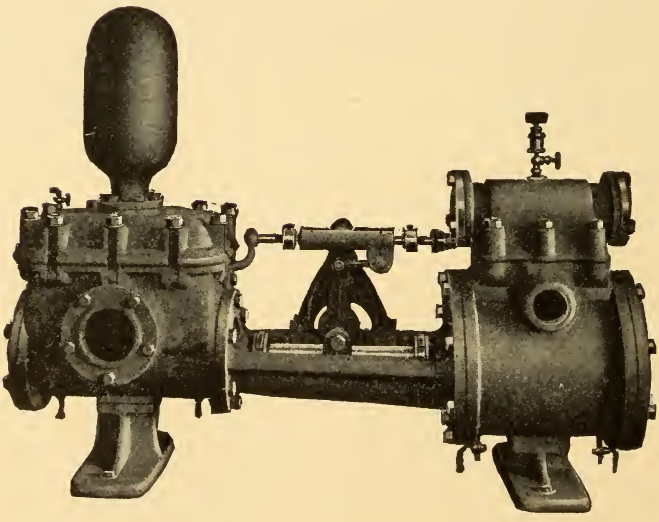

FIG. 258.—Blake boiler feed pump.

is less, requiring increased difference between the steam and water pistons.

The Blake Pump used for boiler feed purposes in connection with a heating system is shown by Fig. 258. It has large direct water passages, conducive to the reducing of water friction and its operation is continuous at slow speed.

Vacuum Pumps

Certain mechanical work such as sugar making, etc., demand a "dry" vacuum pump. For vacuum systems of heating where

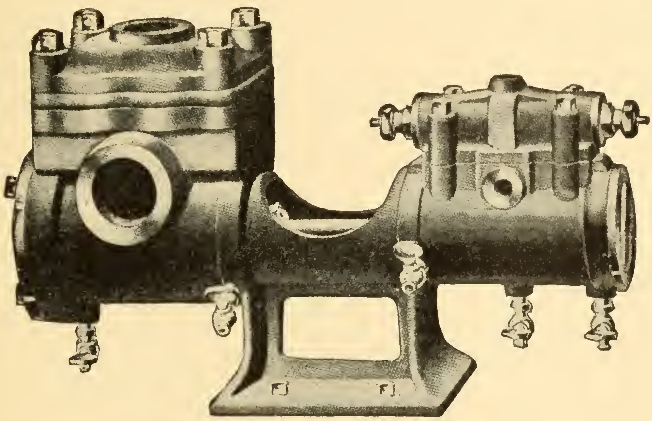

Fig. 259.—Marsh vacuum pump.

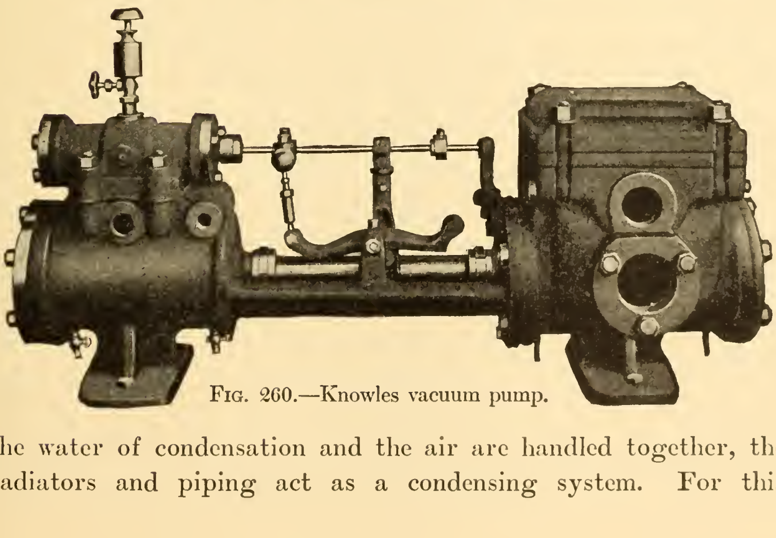

Fig. 260.—Knowles vacuum pump.

the water of condensation and the air are handled together, the radiators and piping act as a condensing system. For this purpose pumps with large cylinders must be employed and the valve areas must be sufficiently large to insure the filling of the pump cylinder. It is customary to pump the water and air to a separating tank from which the water, at a high temperature, is delivered to the boiler, the air being delivered to the atmosphere. Fig. 259 shows the Marsh type of vacuum pump and Fig. 260 the Knowles Vacuum Pump. Each of these types has a horizontal stroke; other styles have a vertical stroke and one, two or more cylinders.

Pump Governors and Regulators

To give the best of service steam pumps should be operated automatically. This is accomplished by a pump governor or regulator which controls the steam to the pump, thereby reducing

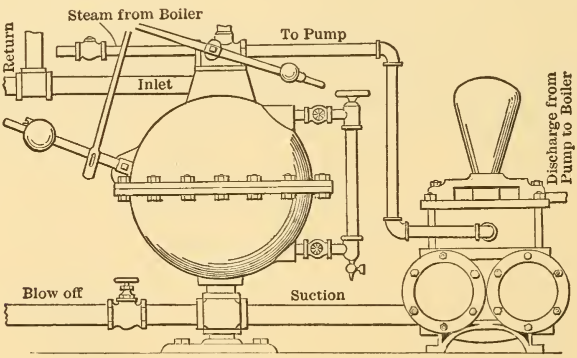

Fig. 261.—Kieley pump governor.

or increasing the speed of the pump, according to the amount of condensation to be handled. On heating systems the establishing of a fixed water line, as may be accomplished with a pump governor, is a distinct advantage and a material help to the apparatus.

There are two general types of pump governors, the first operating quite similar to a trap with a bucket or float. The Kieley Pump Governor, Fig. 261, has a ball float inside the cast-iron chamber, which rises and falls according to the amount of water delivered through the return pipe. This float connects with an arm or lever outside the casting, which operates the steam supply valve to the pump. The suction pipe to pump is connected at the bottom of the receiving chamber of the pump governor.

The Blessing Pump Governor operates the steam valve by the rise and fall of an iron bucket within the receiving chamber of the governor, the general principle employed being quite similar to that already described.

Quite different in style and operation are the pump regulators of the Knowles, Blake and Worthington types. These consist of a cast-iron receiver placed just above the pump. The drips or return pipes from the heating apparatus drain by gravity into

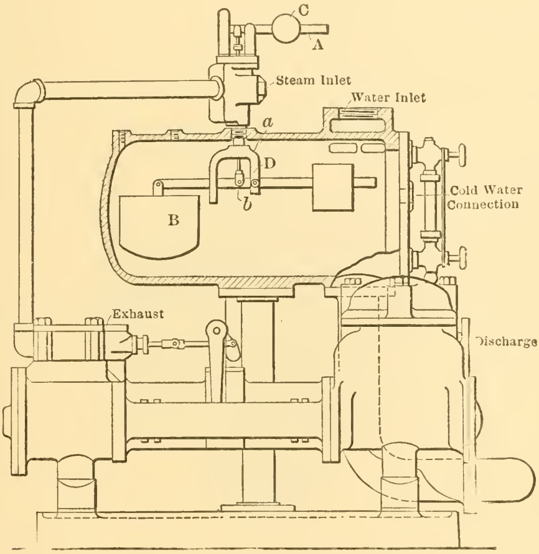

FIG. 262.—Knowles pump and receiver.

these receivers. In the interior of each one is placed a float and balance valve. The return water enters the receiver through an opening in the top and falls to the bottom of the receiver. When it accumulates in sufficient quantity to raise the float, the pump is started, which immediately takes the accumulation from the receiver and delivers it to the boiler. When the float falls again the steam supply to the pump is shut off and the pump ceases to work, the speed of it being regulated entirely by the amount of water entering the receiver. Fig. 262 shows the arrangement of a pump, receiver, and regulator of this character.

Back-Pressure Valves

On exhaust-heating work there must be sufficient pressure to circulate the steam to all portions of the heating surfaces. The piping supplying the exhaust mains of the heating system should be plenty large in area in order to avoid an increase of back pressure on the engine. As has heretofore been stated, the exhaust from the engine is intermittent, the pressure on the exhaust pipe being greater or less, varying with the stroke of the engine. The heating system, acting as a condensing apparatus, does not always use or condense all of the exhaust steam and there must essentially be a relief provided. This is accomplished by placing a special form of valve on the exhaust between the exhaust opening from the engine and the exhaust head, acting as a check on the

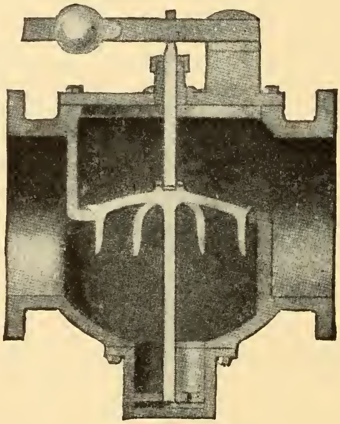

Fig. 263.—Back-pressure valve.

steam in its forward motion toward the opening to the atmosphere. At the same time it provides a preventive to the backward motion of the steam. When the excess of pressure occurs the valve opens and relieves the pressure through the exhaust pipe to the atmosphere. It is virtually an adjustable check valve with a lever and weight attachment for balancing the pressure. The unequal pressure from the engine causes a throbbing or vibration, which in many of the back-pressure valves is objectionable, owing to the noise.

While there are many excellent makes of back-pressure valves, practically the same methods of operation are employed in each and every one, and for this reason we illustrate but the one type as shown by Fig. 263.

Pressure-Reducing Valves

When live steam is turned into the piping of a heating system it is at a high pressure, the same varying with the initial pressure at the boiler. Such a pressure must be reduced or checked before admission to the heating system. In order to accomplish this many styles of valves are used, which may be set to regulate the pressure to any amount desired. As the regulation is from the low-pressure side of the valve, the reduced pressure remains constant, regardless of its fluctuation on the high-pressure side. In heating practice, gate valves are usually placed on the piping on either side of the reducing-pressure valve in order that the steam may be cut off from it to make adjustment or repairs.

Injectors

An injector is a device used for forcing feed water into a boiler against boiler pressure, that is to say, against whatever pressure may be carried on it. There are two distinct types of injectors, positive and automatic. The injector performs two offices. It lifts the water from whatever source of supply is provided and it also tempers it and delivers it into the boiler.

The positive or double-tube injector has an overflow which closes mechanically and has two sets of jets, one for lifting the water, the other for forcing it into the boiler.

The automatic injector has an overflow which opens and closes through the action of the injector itself and, as a usual thing, has but one set of jets.

The operation of the injector is such that the steam at boiler pressure is passed into a vacuum through a very small opening. As this jet of steam strikes the water it is quickly condensed, creating a velocity or forward movement of the water. All of the energy of the steam is imparted to the water warming it and forcing it into the boiler.

Owing to these features the range of the injector depends upon the temperature of the feed water, it having a greater range, lift and pressure, with water at a low temperature. The best results are obtained with the feed water at from 60 to 100 degrees Fahr.,

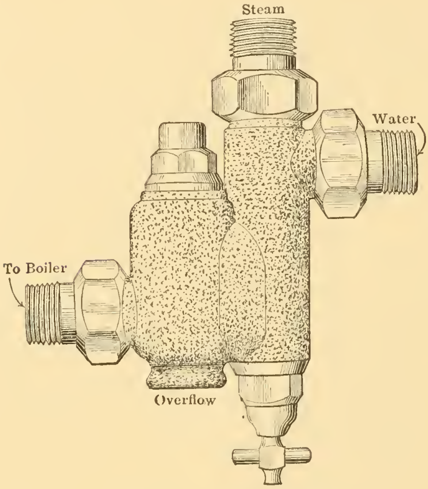

Fig. 264.—U. S. injector.

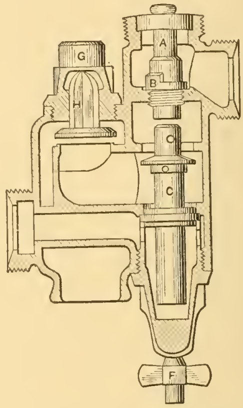

Fig. 265.—U. S. injector (interior).

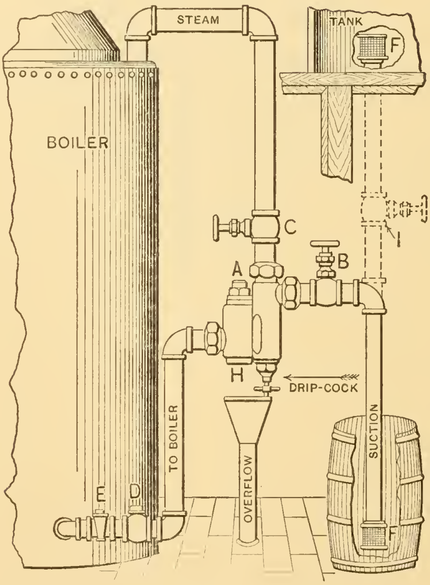

Fig. 266.—Method of connecting injector.

although the injector will satisfactorily handle water at a temperature up to 140 degrees.

The double-tube injector is a German invention. There are several styles of injectors, one of which we illustrate by Fig. 264, showing an interior view of the same by Fig. 265.

In order to show the method of connecting the steam supply, suction pipe and delivery to boiler, we illustrate one method of connection, Fig. 266. When the boiler feed water is supplied from a tank above the boiler, the suction pipe should be connected as shown by dotted lines. Gate or globe valves should be placed on steam supply and suction pipes and a check valve on a horizontal portion of the boiler feed pipe. The nearer the boiler and the farther from the injector this check valve is located, the better. A stopcock should be placed on the pipe between this check valve and the boiler.

Inspirators

This is a type of injector and operates along the same lines as the injector above described. That used for feeding boilers of the stationary type, as used for heating or power, is shown by Fig. 267 and the interior mechanism of it by Fig. 268. The name "inspirator" was given to it by Mr. John Hancock under conditions as follows:

"In the year 1868, John Hancock, a civil engineer, began experiments having in view the entraining of air and compressing it to a certain extent, to be used as a blast for forges and furnaces. These experiments led to the exhausting of air by means of a jet apparatus, which is now known commercially as an ejector. He found it possible by this method to create a vacuum to the extent of twenty-five or twenty-six inches mercury column; also that water could be lifted from a depth of twenty-five feet and elevated into a tank. Later he found that he could make a jet apparatus which would, with its own steam pressure, force water into a boiler when the water flowed to it from an overhead tank or under pressure. This type of apparatus is now called a non-lifting injector. He therefore applied these two methods, using the ejector to lift the water from a well and deliver it into a tank located above the injector. The water then flowed to the injector and was forced into the boiler. This combination was placed in successful operation in several instances.

"Following up this idea, Mr. Hancock became convinced that the tank could be eliminated and the ejector or lifting apparatus be attached direct to the injector or forcing apparatus. He accomplished this arrangement and the two connected were eminently satisfactory; in fact, much more so than the first arrange-

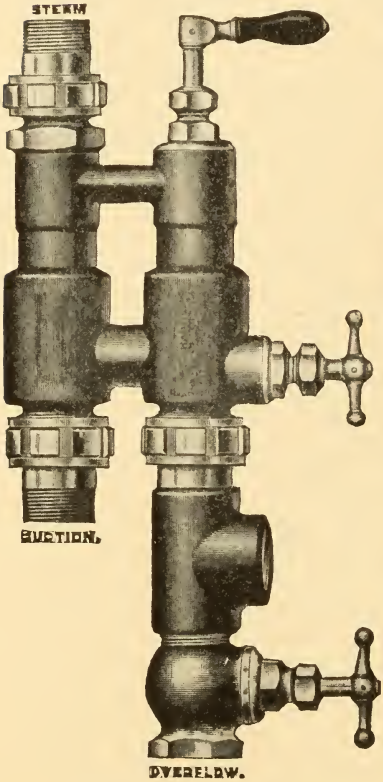

Fig. 267.—Hancock inspirator.

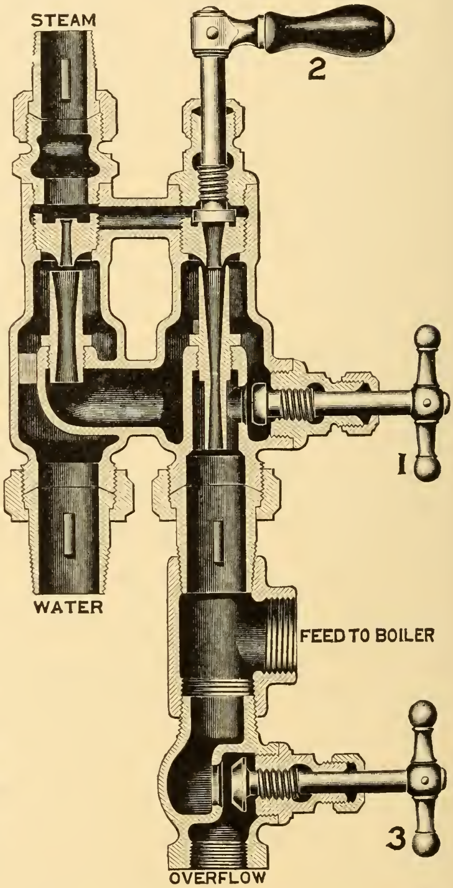

Fig. 268.—Interior mechanism of Hancock inspirator.

ment, as the ejector varied its quantity of water as the steam pressure varied, which was just what the injector required to obtain a good working range. He considered this idea in the nature of an inspiration and thereupon called the apparatus the Hancock Inspirator."

Automatic Water Feeders

Automatic water feeders, or devices for feeding water to the boiler in order to maintain a certain definite water line in the same,

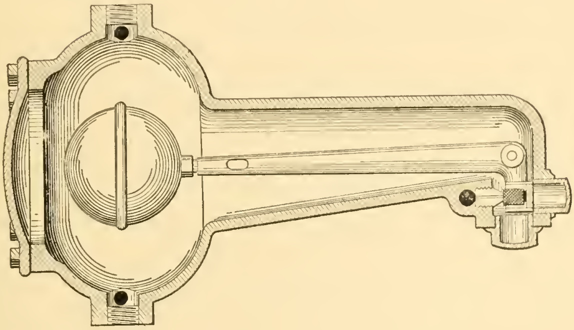

Fig. 269.—Automatic water feeder—Nason type.

are manufactured in a great variety of styles. The action of the valves is controlled by a copper-ball float, the water raising this float until the normal level of the water line has been reached, when the valve to the water supply is closed. The pressure of the water supply must exceed the pressure carried on the boiler. The Nason type of boiler feeder is shown by Fig. 269. The Lawler type of water feeder is shown by Fig. 270. As will be noted by the illustration, this feeder is used in place of the regulation water column and is provided with a water gauge. Water feeders are now manufactured which, when used on heating boilers, not only keep the boiler supplied to its normal water line, but also prevent the flooding of the boiler by reason of the sudden return to the boiler of any water of condensation which might have become entrained in piping or radiators.

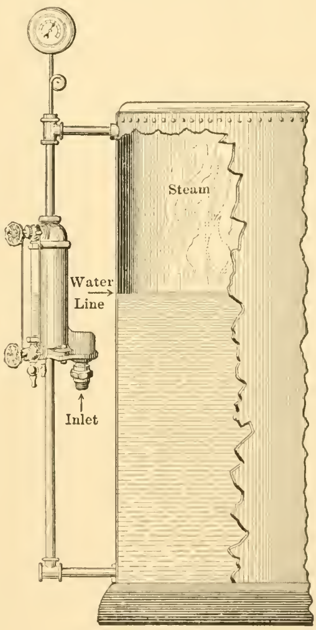

Fig. 270.—Lawler automatic water feeder.

CHAPTER XXIII

District Heating

This type, if it may be so termed, of steam and hot-water heating owes its inception to an eminent engineer, Mr. Birdsall Holly, of Lockport, N. Y., who, in the year 1877, introduced the system of underground steam distribution which bears his name. The original plant, with about one mile of underground mains, was installed at Lockport, N. Y., then a city of about 20,000 inhabitants, and the first buildings connected with and heated by the same were five stores, seven residences and two churches, and the original system, with extensions and improvements, is now in operation.

Mr. Holly's first idea in the construction of this plant was to make use of live steam, the main object being to relieve the users from the necessity of the care and attention essential where individual heating apparatus was used, and to eliminate the dirt and other unpleasant features unavoidably present in connection with the operation of a heating apparatus. Mr. Holly reasoned that those persons owning and operating such plants would pay well to be freed of such care and attention and the trouble occasioned by the purchasing and handling of fuel. In using steam from a district plant there would also be a freedom from the danger of fire consequent to the operation of a heating plant within each separate building.

That the inventor reasoned along correct lines is clearly demonstrated by the fact that this original plant has been added to from time to time until some three hundred and fifty consumers are customers of the company operating it, the plant at the present time having in successful operation some six miles of street mains.

Many obstacles, which had to be met or eliminated altogether, were encountered in the operation of such a plant and years of effort and experimenting were required to perfect it.

The proper insulation of the pipes to prevent loss of heat by radiation from the street mains and service connections, the construction of devices for providing for expansion and contraction, anchorage, etc., together with other features of construction, were tested exhaustively in a practical manner, with the result that the Holly System is to-day free from the defects prevalent in its original form.

The fact that steam can be manufactured in an isolated position, from cheap fuel at small expense and delivered without any considerable loss in temperature through ten miles or more of street mains, and the further circumstance that special devices regulate and register the amount of steam used by each consumer, all these, together with other incident conditions, have made this class of heating a paying investment and at this period there are hundreds of district systems in successful operation.

The early methods of district heating were such that the water of condensation was returned to the central station through a system of piping separate from the steam mains. This has now been generally abandoned and the surplus of heat available in the water of condensation is fed through a trap to an economizing coil (made usually of several sections of indirect radiation), where the remaining heat units are extracted and delivered to a room above through a register in the same manner as from an indirect radiator on an ordinary job of heating. The water of condensation is then carried to a special condensation meter, where it is weighed and quantities registered and is finally emptied into the sewer.

The system of piping in the building to be heated may be of either the one-pipe or two-pipe style, and, if hot-water heat is employed, a special type of hot-water heater is used, through which the steam passes in much the same manner as through a feed-water heater. In this event steam rather than coal or other fuel, is used to heat the water. Probably the best adaptation of district steam heating is by the method of piping known as the "Atmospheric System." The hot-water type of radiator is used and the steam is supplied to each radiator at the top of one end through a special form of valve with small ports or openings in the seat. Thus a valve may be opened one, two, three or four ports, supplying a greater or lesser amount of heat to a radiator, or such an amount as may be required to maintain a uniform temperature within the room to be heated. This system is operated under a few ounces of pressure above that of the atmosphere and such heat units as are contained in the steam or water are extracted before the water of condensation enters the returns.

A finely adjusted regulating pressure valve is used on the supply from the street main and as the condensation is metered and weighed the consumer pays only for such heat as he has used.

As stated before, the first idea of central-station heating was that of the production and sale of live steam. At the present time this class of enterprise has found favor with the management of large electric lighting and railway plants, as it gives an opportunity to increase their revenues by providing a profitable method for disposing of their exhaust steam.

There are several systems of central-station steam heating now in use. The different systems vary somewhat in the manner of constructing the piping or underground mains and also in the method of handling the steam supply after it has been introduced to the building to be heated. We would divide the methods of central-station or district steam heating into two classes, the first, where the steam is manufactured only for the purpose of heating; the second, where the steam generated is used for power and the "by-product," if so it may be termed, is used for heating purposes. It is the latter method which is more generally used, and a wonderful saving is effected by the company which disposes of their exhaust in this manner. It is customary to divide the boiler power of each station into units of 150 or 200 H. P. each. A one-thousand H. P. plant would have five 200 H. P. boilers, one of them held in reserve, the other four in daily operation. It has been shown that after allowing this one-fifth, or 20%, boiler reserve, a further allowance of 15% for heating feed water and a 5% loss for leakage and deterioration from condensation, each of the 1,000 H. P. capacity of the plant can supply 80 sq. ft. of radiation with the necessary units of heat, or 80,000 sq. ft. of ordinary cast-iron radiation. During periods of intense cold weather the reserve boiler may be employed to prevent overwork on the part of those in regular use.

It is worth noting that in many instances the revenue from the steam sold for heating has been sufficient to pay the fuel bill for the entire plant for the full twelve months of the year.

Central-Station Hot-Water Heating

Heating by hot water supplied from a central station has during the past ten years resulted in the installation of over one hundred plants of this nature. While the process of heating several buildings from a single plant is not new, it having been more or less used for fifty years or more, the improvements in methods of installation and control have advanced materially during the last decade. The systems of Evans-Almiral Company, H. T. Yaryan and also Schott's balanced column system have been largely used and to-day there are over one hundred of them in operation.

This work includes some features which will prove of interest to the fitter. The matter of estimating the amount of radiation required to heat a building depends upon the system employed and the manner of operating the plant. Some systems deliver water at 140° at freezing and raise or lower the temperature one degree for each degree of variation of the outside temperature. Provided the service or street mains are large and there is a sufficient amount of radiation installed, this plan works out nicely. We would prefer seeing the water at 155° or 160° at freezing and then vary the temperature according to the weather.

TABLE XXVI

Outside Temperature.	Water Temperature.	
60°	120°	
50°	140°	
40°	150°	
30°	160°	An estimated loss of 3° in temperature for each mile delivered.
20°	180°	
10°	190°	
Zero	200°	
−10°	210°	
−20°	220°	
−30°	230°	

In estimating radiation one square foot of radiating surface for each square foot of glass surface and its equivalent in exposed wall and cubical contents will, as a rule, prove a sufficient ratio in figuring work. Schott advises a schedule of temperatures, as shown on page 291.

As to which system is preferable—steam or hot water—it would be a hard matter to decide, as each one seems to have particular and individual advantages peculiar to itself and not possessed by the other.

CHAPTER XXIV

Pipe and Boiler Covering

The insulating of exposed boiler or heater surfaces and pipe for conveying hot air, steam or hot water and the value of so doing are matters which ofttimes do not receive proper attention from the steam fitter or heating contractor. Many steam fitters doing work in a small way, installing but few jobs in the course of a season, look upon the subject of covering as an increased expenditure for material which, added to the cost of the work, is apt to destroy all their chances for securing the contracts for the jobs, and this especially if competition be close. An argument of this kind is wrong in its entirety, and steam fitters generally who are contracting for heating work should understand the benefits accruing from thoroughly covering the boiler and such exposed piping as is not used for radiating surface, and should become so familiar with the subject and so versed in its application that the owner may be enlightened as to the saving effected and thus be made to feel willing to pay whatever sum may be necessary for the work.

Just as heat is conveyed by three distinct methods, viz., by radiation, by conduction and by convection, as explained in Chapter II, just so is heat lost or dissipated from the bare surfaces of boilers, heaters and piping for conveying steam or hot water. What this loss is has been quite accurately determined by various authorities.

One authority states that a square foot of uncovered pipe, filled with steam at 100 lbs. pressure, will radiate and dissipate in a year the heat put into 3,716 pounds of steam by the economic combustion of 398 pounds of coal; thus 10 square feet of bare steam pipe (steam at 100 lbs. pressure) corresponds approximately to the waste or loss of two tons of coal per annum.

Some tests reported in Volume XXIII of the proceedings of the American Society of Mechanical Engineers (tests made in 1901) show that on 100 lineal feet of 2-inch pipe, carrying steam at 80 lbs. pressure, tests based on 300 working days of 10 hours each, with temperature of room about 65° Fahr., a very material saving was effected. The following table shows the results of the test:

TABLE XXVII

Name of Pipe Covering.	Condensation per Hour Lbs.	Net Tons of Coal consumed per Year.	Net Tons of Coal saved per Year by use of Covering.	Cost of Coal per Net Ton.	Net Saving in Cost of Coal per Annum by use of Covering.	Approximate Cost of Coverings.
Bare Pipe......	59.16	7.76	....	$4.00	$31.04 loss	.....
Asbestocel.....	13.47	1.83	5.93	4.00	23.72 saving	$16.20
Asbetos Molded	14.35	1.96	5.80	4.00	23.20 "	15.95
Air Cell.......	14.60	1.99	5.77	4.00	23.08 "	15.90

When we consider that there are about 64 square feet of heating surface in 100 lineal feet of 2″ pipe, the annual saving amounts practically to 35 cents per square foot, which will pay the entire cost of the covering, leaving the saving of future years as a clear profit on the investment. While the above tests were made at a comparatively high pressure, with 1 lb. of coal evaporating about 11 lbs. of water, the same proportionate showing may be made with steam at one or two lbs. pressure or on hot-water piping where the temperature of water averages 160 degrees. Stated in a different manner, the saving effected by the use of covering on low-pressure steam or hot-water work averages from 10% to 30% of the entire yearly expense for fuel, dependent on the character and quality of the covering used.

Asbestos, magnesia, mineral wool, cork, wood and felt paper are the materials principally employed in the manufacture of pipe covering, although for underground piping, ashes, charcoal and sawdust have been used.

The thermal conductivity of the material used governs the effective character of a covering applied to prevent loss of heat, the efficiency of asbestos, magnesia, hair felt or cork being greater than all other materials in this respect.

Asbestos is a fibrous rock, Fig. 271, found in many parts of the world. It lies in thin strata or layers and, when broken, separates in long silky fibers, which may be spun into threads

FIG. 271.—Asbestos rock.

or woven into wicking or sheets. This material is not only fire-proof, but acid-proof as well and serves as an insulation for electric currents.

Cork, as used for covering, is ground or granulated and then pressed into the desired shape. In places where the covering is

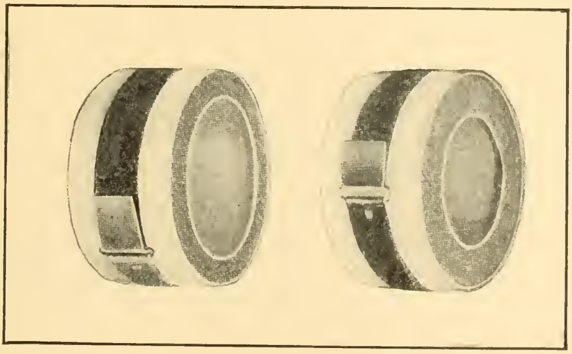

FIG. 272.—Method of fastening sectional pipe covering.

affected by dampness or water, cork covering is, no doubt, superior to all others on account of its non-absorbent and odorless qualities.

Pressed cork, magnesia, asbestos and, in fact, all coverings of this nature are manufactured in three-foot lengths and split lengthwise for easy adjustment on the piping. The different varieties have an outer covering of muslin or light canvas, glued or pasted on them, to give a finish. Covering is secured to the pipe by japanned tin or brass bands, as shown by Fig. 272.

Air when confined within a space to prevent circulation is a non-conductor of heat and provides good insulation. A covering which has met with much favor for low-pressure work and

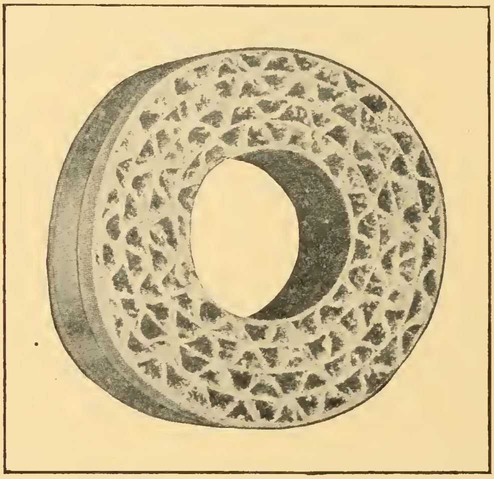

Fig. 273.—Asbestos air-cell pipe covering.

for hot-water piping is known as the " air-cell " covering. It is made of corrugated asbestos paper of various thicknesses. A cross section of this covering is illustrated by Fig. 273.

As a rule, on ordinary heating work, the exposed boiler and heater surfaces and the pipe fittings are covered with a magnesia-asbestos plastic cement, mixed with water to the desired consistency and applied with a trowel. However, molded fittings may be obtained for use with all sectional covering. See Fig. 274. These are secured to the fittings by bands of tin or brass, as shown by illustration.

For underground piping or for steam pipes run in the open there is probably no better type of covering than the Wyckoff wood covering, as illustrated by Fig. 275. It is constructed of eight thoroughly seasoned white pine staves, one inch thick, closely jointed together and wound with heavy galvanized steel wire, as shown by the illustration. It is then wrapped with two

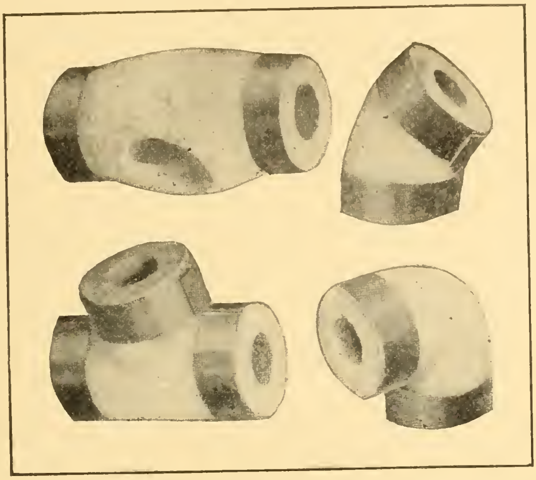

FIG. 274.—Molded fittings.

layers of heavy corrugated paper and again surrounded by a pine wood casing one inch in thickness, jointed and wire wound as before. When used underground, the exterior of the covering is

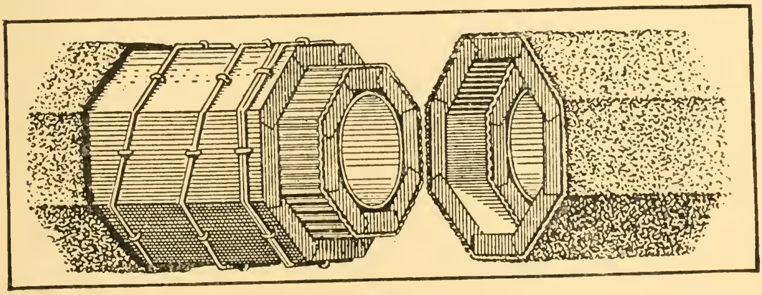

FIG. 275.—Wyckoff wood covering.

completely coated with asphaltum pitch. A covering of this kind for such service will undoubtedly outlast all others and is thoroughly effective as an insulator.

There are now so many different varieties and grades of coverings on the market that it would be next to impossible to illustrate and describe them, nor can we discuss the merits of the various makes. It is sufficient to state that in the same manner as the thickness and texture of clothing retain the heat of the human body so does insulation retain the heat within the steam or hot-water heating system, the quality of the covering governing the amount of heat retained and the saving made.

CHAPTER XXV

Temperature Regulation and Heat Control

Automatic government of pressures and temperatures is one of the most important adjuncts to an artificial heating apparatus. We have shown in Chapter IV by illustration Fig. 35, a simple automatic steam damper regulator for regulating steam pressures, and by Figs. 36, 37 and 38, the application of it to the draught and check damper doors of a steam boiler.

For the draught regulation of a high-pressure boiler, the damper regulator is heavier and more powerful, the rubber diaphragm larger and the lever longer. A better regulator is one in which a compound lever is employed. A very slight movement of the rubber and the plunger resting against it will give a movement of from four to eight inches at the end of the lever where the chain to draught door is connected. In this style of regulator the rubber diaphragm is less apt to get strained or broken.

Probably the best high-pressure damper regulator is one where a piston working in a cylinder is used, the piston being operated by water pressure. The employment of a compound lever on this type of regulator makes it extremely sensitive and will successfully operate the dampers at less than one-pound pressure. The Lock and Climax Regulators are of this character, that illustrated by Fig. 276 being the Imperial Climax.

The successful and economical working of a steam boiler, either high or low pressure, depends largely upon the methods employed in regulating the pressure by means of the draught and check damper doors. All methods formerly applied depended upon the power furnished by the boiler itself. During the last twenty years such rapid strides have been made in temperature regulation that we now have regulators for controlling temperatures of air, water and steam, as well as other liquids and gases, and it would require a volume to adequately describe, illustrate and comment upon the various makes of regulators. We shall, therefore, select some regulators and systems representative of the various styles in use, and endeavor to give the reader an idea of the scope and character of this important industry.

The automatic temperature regulator consists of three parts:

(*a*) The thermostat, which by reason of the changes in the

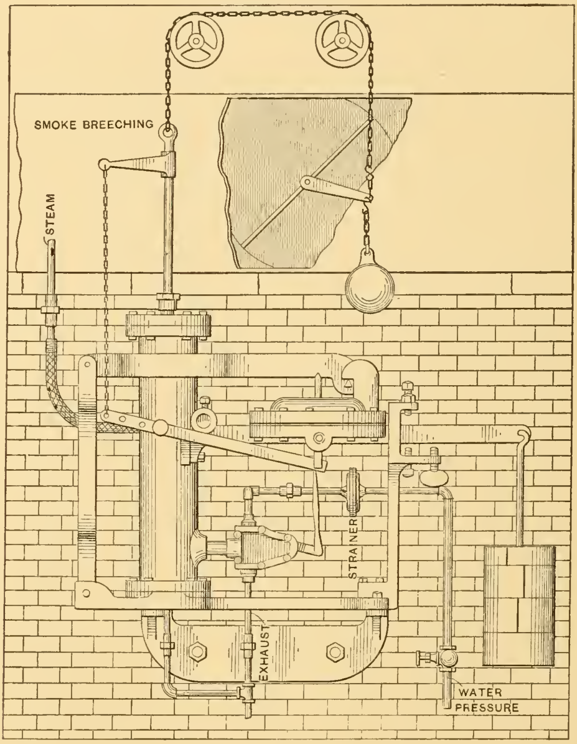

FIG. 276.—Climax high-pressure regulator.

temperatures of the room, furnishes the *primary* motor power for operating the damper-controlling device.

(*b*) The means of transmitting this energy to the damper-controlling mechanism.

(*c*) The damper-controlling mechanism, or device for opening or closing the dampers.

The thermostat is placed within the room or at a point where the temperature is to be controlled. This is the primary motor operating the apparatus by means of certain mechanism employed for opening and closing the draught doors, check draught doors or dampers.

The Powers Thermostat, Fig. 277, operates on the vapor principle. This disc is composed of two metal plates spun in cor-

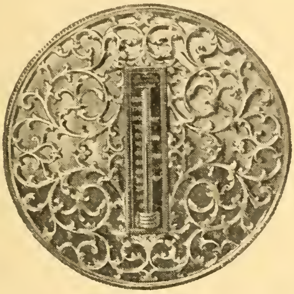

FIG. 277.—The Powers' thermostat.

rugations to give flexibility. Fastened together at the outside edges these plates form a hollow disc. A volatile liquid is placed within the disc. This liquid will boil and vaporize at a temperature below that of the water in the apparatus, or at a tem-

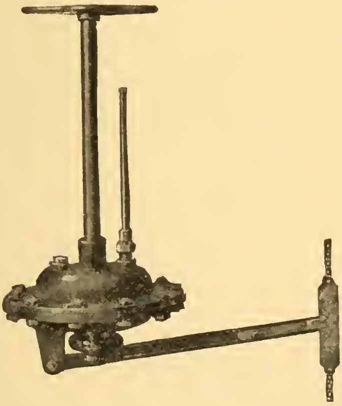

FIG. 278.—Regulator for hot-water heater or furnace.

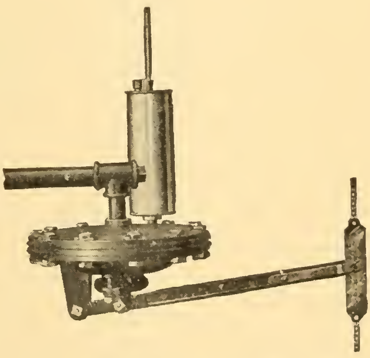

FIG. 279.—Regulator for low-pressure steam boiler.

perature of 50 degrees Fahr., generating a pressure which expands the disc. At a temperature of 70 degrees a pressure of about six pounds to the square inch is exerted and this amount of pressure is sufficient to operate the valves controlling the compressed air.

For the regulation of the ordinary house-heating apparatus, this regulator is made in three styles, the same disc as shown by Fig. 277 furnishing the primary motor power:

(*a*) which controls the temperature of the rooms by operating the draught and check doors of the hot-water heater or hot-air furnace by a diaphragm motor as shown by Fig. 278;

(*b*) which controls the draught and check doors of a low-pressure steam heater by a diaphragm motor of double construction, as shown by Fig. 279, which also takes the place of the ordinary pressure diaphragm regulator usually furnished with steam boilers;

(*c*) which regulates the temperature of the room by regulating the temperature of the water in a hot-water heater by means of a generator in connection with the diaphragm motor—

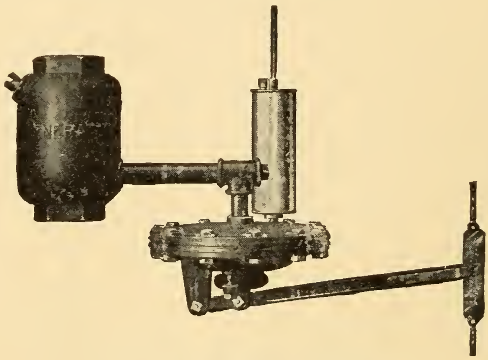

FIG. 280.—Hot-water regulator.

Fig. 280. This generator is attached directly to the heater and one of the flow pipes from the heater is connected to it.

The diaphragm motor consists of two castings, slightly oval, bolted together, with an elastic material between. The reverse action of the plunger is accelerated by a steel spring placed around the plunger under the lever connection. The generator is a hollow casting having a double shell or wall. The inner chamber is filled with cold water. The hot water passing from the heater into the flow pipe flows through the space between the inner and outer shells of the generator, thus surrounding the chamber into which the cold water has been placed. As the water in this inner chamber is under less pressure than that in the heater, it will boil quicker, producing a pressure which is exerted against the under side of the diaphragm through a pipe connected directly to it. This pressure is sufficient to operate the dampers of the heater and prevent the boiling of the water in the system.

In order to obtain the best results from a regulator of this kind, it is essential that very light or counterbalanced check and

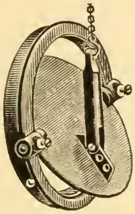

FIG. 281.—Counterbalanced check door.

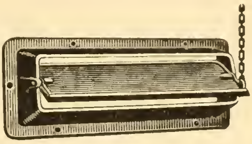

FIG. 282.—Counterbalanced draught door.

draught doors be used. Fig. 281 shows a very good style of check damper and Fig. 282 an excellent draught damper. The exertion of a very slight force will open or close either of these doors.

The Powers System of controlling the temperature of a large building provides for the control of the valves admitting the

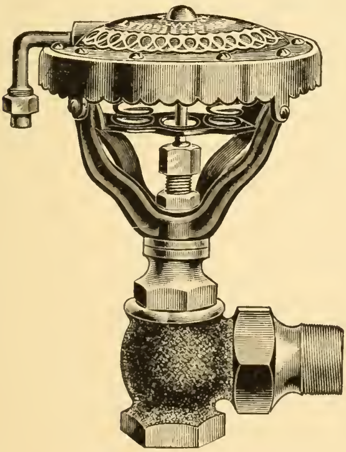

FIG. 283.—Powers' diaphragm radiator valve.

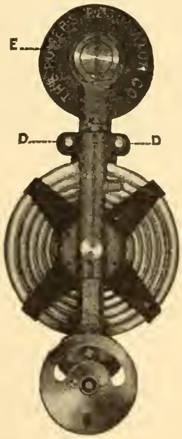

FIG. 284.—Thermostat for controlling radiator valve.

steam, or regulating the flow of hot water to the radiators. We know that an occupant of a room, by watching the thermometer and attending constantly to the operation of the radiator valves, may control the temperature of the room in a very satisfactory manner. The Powers System accomplishes this work automatically by means of diaphragm radiator valves, Fig. 283, which are placed on all radiators and operated by compressed air regulated by a thermostat, which is placed in each room and may be adjusted with a key to operate the valves at any temperature from 60° to 80° Fahr. This thermostat is shown by Fig. 284, without the cover. The cover is composed of metal, plated to correspond with the decoration of the room, and has a tested thermometer attached to its face.

For controlling the mixing dampers of a blower system of heating, or the by-pass dampers of the air supply, the same type of thermostat as that already described is used, the dampers being operated by a diaphragm motor, Fig. 285.

Compressed-air pipes lead from the storage tank to each of the thermostats and from the thermostat to each motor. The variation of temperature at the thermostat causes it to operate

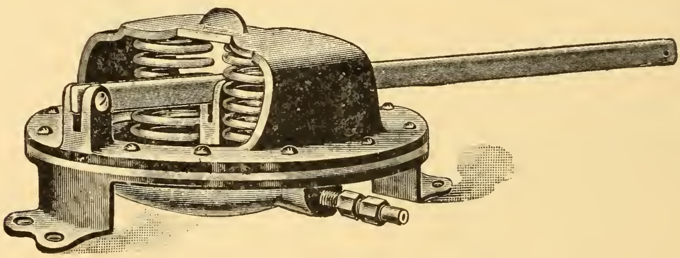

FIG. 285.—Powers' diaphragm motor.

as the primary force for releasing or retaining the air pressure upon the motor. With the air pressure removed the springs of the motor operate the dampers in a motion opposite to that effected by the compressed air. Possibly a clearer conception of this arrangement may be had from Fig. 286, which shows an elevation of a fan apparatus as used in a school building. "A" shows the location of the thermostats in the school rooms; "B" the motor; "C" the mixing dampers controlled by them.

"D" shows the location of the thermostat for controlling the temperature of the tempered air before admission to the fan; "E" the motor which operates this damper.

"F" shows the reservoir or storage tank for the compressed air. A pressure of air at fifteen pounds is automatically main-

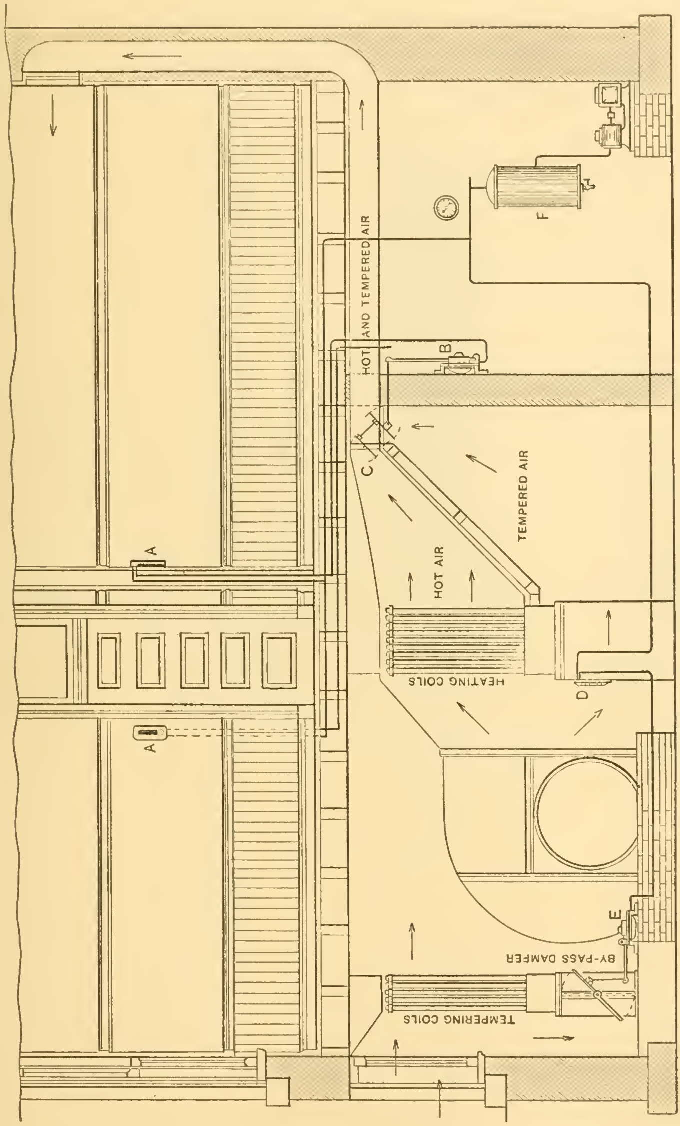

Fig. 286.—Application of the Powers' system.

tained in this tank. The air compressor may be operated by steam, electric or hydraulic pressure.

The operation of the National Regulator for the above class of work is quite similar to that already described.

For control of a direct-heating apparatus a diaphragm valve is used on the radiators, and for a fan system a diaphragm or damper motor is used and compressed air is employed to operate each of these.

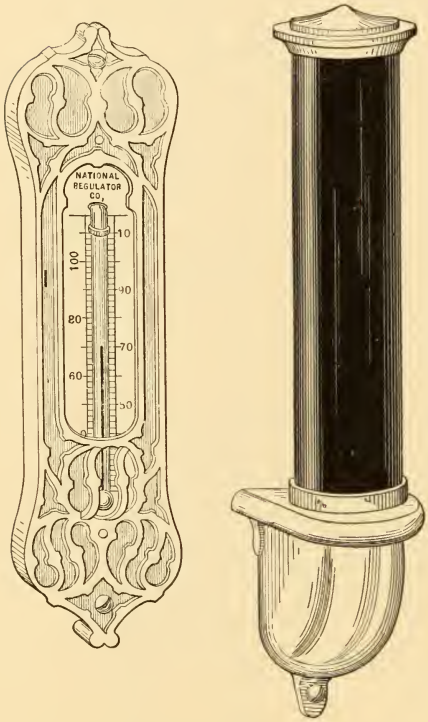

Fig. 287.—National regulator thermostat.

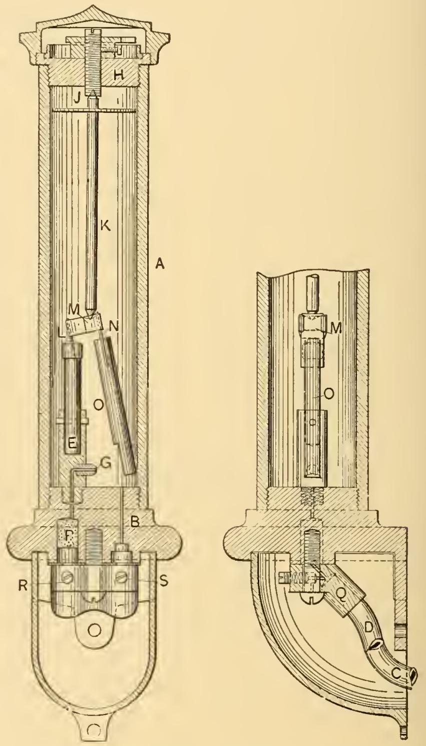

Fig. 288.—National regulator thermostat interior mechanism.

The thermostat, however, is entirely different from all others, a vulcanized rubber tube being the element made use of in controlling the compressed-air force which operates the system. Fig. 287 shows the thermostat and the ornamental thermometer used in connection with it. Contained within the rubber tube are the air valve and the valves for operating the compressed air. Vulcanized rubber is very sensitive to changes of temperature, expanding or contracting instantly with the varying temperatures of the room, and when such expansion or contraction occurs it results in the opening or closing of the compressed air valves.

The interior of this thermostat is shown by Fig. 288. Two air pipes are used, one from the air reservoir to the thermostat and the other from the thermostat to the valve or motor.

The expansion or lengthening, or the contraction or shortening of the rubber tube A raises or sets the point of the rod K upon the seat M, opening or closing the valves of the air supply.

For the regulation of the temperature of water in storage tanks we show the D. & R. (Davis & Roesch) regulator. Fig.

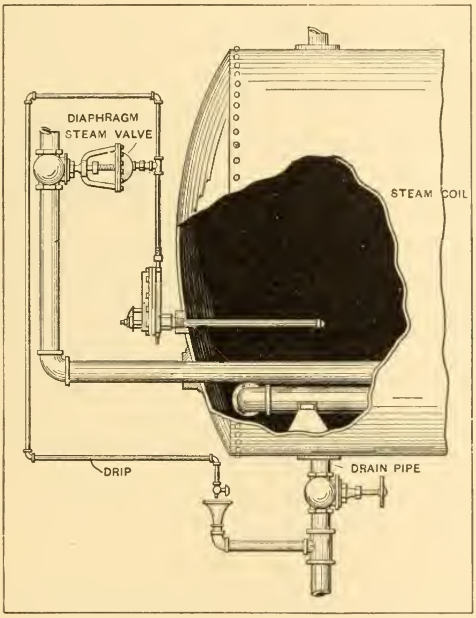

Fig. 289.—D. & R. tank regulator.

289 shows the application of it to a tank heated by a steam coil. The motor employed is a diaphragm valve, using the rubber diaphragm against which water or air pressure is exerted to close the valve, a spring on the stem of the under side of the valve holding it open until the pressure upon the diaphragm is sufficient to close it. The primary motive power is obtained from a regulator with an expansion post or plug screwed into an

opening of the tank and extending into the same, as shown on the illustration. The mechanism is such that the expansion of the post pushes a spring which opens a valve, allowing the pressure of the water supply, or compressed air, to close the diaphragm valve by exerting a pressure upon the diaphragm. When the temperature of the water cools sufficiently to allow the post within the regulator to contract, this pressure is removed, the diaphragm valve opening by the spring, and steam is allowed to enter the heating coil.

In a slightly different form this regulator is made to use on tanks supplied directly from a hot-water heater and adapted for

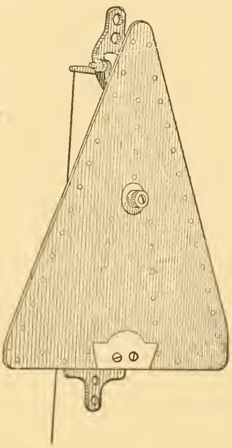

Fig. 290.—The Howard thermostat.

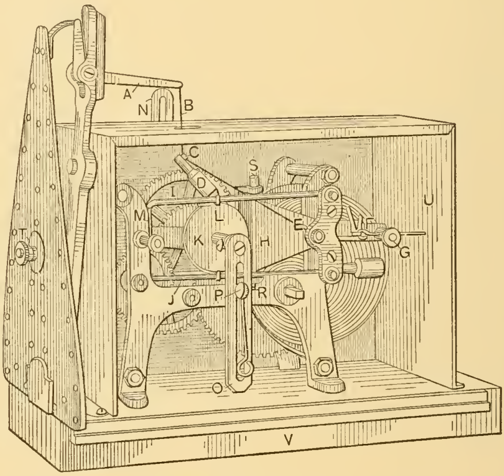

Fig. 291.—Motor for Howard thermostat.

domestic hot-water supply, pasteurizing or sterilizing, and is also employed for directly controlling the draught and check dampers of a hot-water heater.

It is best known as a device to prevent the overheating of water in a storage-tank supply system.

Of the regulators operated by expansion we show the Howard and the Minneapolis as representing two distinct types. Each of these regulators makes use of a motor having a strong spring mechanism which furnishes power to operate the dampers.

The Howard thermostat is composed of a sensitive plate, triangular in form, as shown by Fig. 290, attached to the side wall of the room. As the temperature rises, the plate curves or warps toward the wall. A wire and chain connection concealed within the partition leads from the top of the plate, over frictionless pulleys, to a weight within the motor box. The relaxing of this wire and chain allows the weight to drop sufficiently to release the motor, which makes one half turn of the crank arbor, when it stops automatically. The crank connecting with chain to the check damper, points down, holding the check damper door open; the crank connecting with the draught door, points up, slacking the

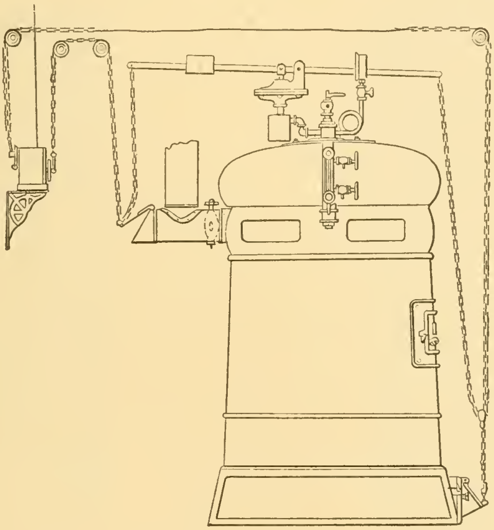

FIG. 292.—Method of attaching Howard thermostat.

chain connection to the draught door, which closes by its own weight, or, if this be insufficient, by a weight attached to the bottom of it. As the temperature of the room cools below the degree of heat desired, this action is reversed, the check door being closed and the draught door opened. This is better illustrated by Fig. 291 which shows the mechanism of the motor, a thermostatic plate being attached to show the operation of the weight due to the curving of the plate.

The operation of the motor and the method of attaching the chains to draught and check doors are clearly illustrated by Fig. 292. The spring of the motor is occasionally wound with a key.

The motor of the Minneapolis regulator and the method of attaching the chain connections to the draught and check doors are quite similar to that already described. Otherwise the regulator consists of a thermostat and two cells of open circuit battery. The thermostat, Fig. 293, is operated by the expansion and contraction of a curved metal blade, imparting a side motion to a suspended arm, as illustrated by Fig. 294, which shows the thermostat with the screen removed. The wires from the battery are connected to the two posts shown just above the indicator of the

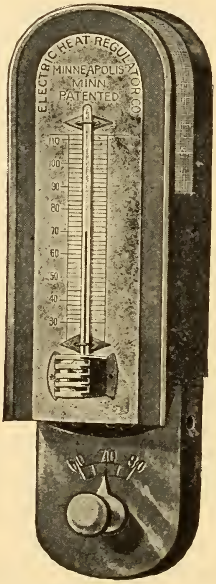

Fig. 293.—Minneapolis thermostat.

Fig. 294.—Interior of Minneapolis thermostat.

thermostat. Needle-pointed adjustable set screws pass through these posts, the pendant blade hanging between them. As the temperature of the room rises, the side motion of the pendant moves it against the point of one set screw, forming a contact, which closes the electric circuit. As the circuit is closed an electric current flows through the magnets of the motor, releasing the brake, and the driving shaft of the motor makes a half revolution. As the temperature of the room lowers, the projecting arm or pendant is, by contraction of the circular blade, thrown against the opposite pin, when the operation above described is reversed. The releasing feature of the motor consists of a pair of magnets, which become energized and attract an armature. The movement of the armature releases the motor, and when it starts, the armature is secured until the driving shaft of the motor makes a half revolution, when it resumes its normal position.

Temperature controlling devices of the Howard and Minneapolis types are best adapted for operating the dampers of the boiler or heater of a low-pressure heating apparatus.

The Lawler thermostatic regulator shown by Fig. 295 is of another type. The expansion of the metal used is multiplied by a

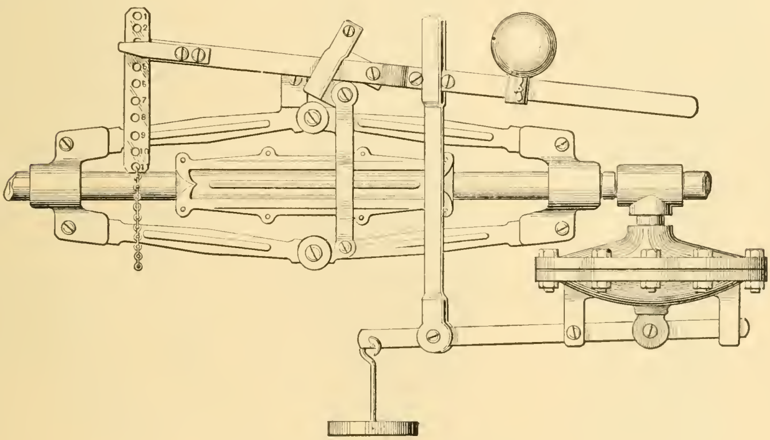

Fig. 295.—The Lawler thermostat.

series of levers to a range or force sufficient to operate the dampers of a steam or hot-water heating apparatus. It is also used, with a slight variation of the adjustment of the levers, to control the temperature of water in a storage tank for domestic or other use, the mixing of water to a certain temperature for baths, or for the controlling of the air supply of an indirect heating system.

The Johnson System is one of the oldest of the systems of automatic control of temperatures. The motive force employed is compressed air, which is supplied by an automatic air compressor and stored in a tank. For ordinary service a hydraulic air compressor, Fig. 296, is used. This is connected to the water supply to the building and to some convenient waste pipe. It is noiseless in operation and automatically keeps up a pressure of

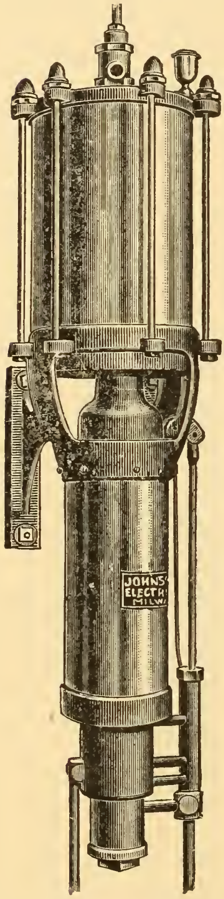

Fig. 296.—Johnson hydraulic air compressor.

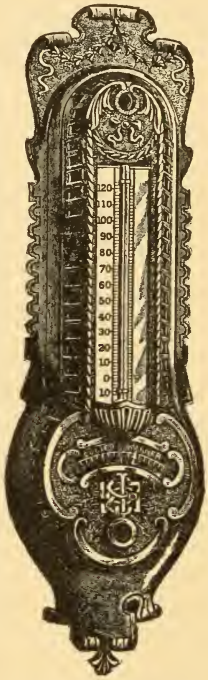

Fig. 297.—Johnson thermostat.

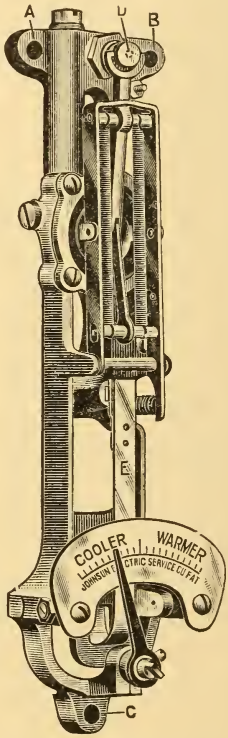

Fig. 298.—Mechanism of Johnson thermostat.

from ten to fifteen pounds. Compressors are also furnished which operate by electric power and by steam.

A thermostat is placed on the wall of each room in which the heat is to be regulated. The external appearance of this thermostat is shown by Fig. 297; the interior mechanism is shown by Fig. 298. The strip E is composed of two metals, soldered together. Observe that the top of this strip is fastened to D:

the bottom, forming a hook, is fastened to the frame of the thermostat. A variation of but two degrees in the temperature of a room will cause this little tongue to expand, moving D and operating the valve of the air pipe. Two air pipes are connected to the upper part of the thermostat, one of them being the direct connection from the air main from the storage tank. The other connects the thermostat with the air motor of the valve at the radiator or with the damper to be operated, thus directly operating the valve and limiting the steam supply at each radiator or the flow of hot water to it, if it be a hot-water system, or the air-mixing dampers should it be a blower system.

In order that the operation of the diaphragm valve may be clearly understood we show by Fig. 299 a sectional view of

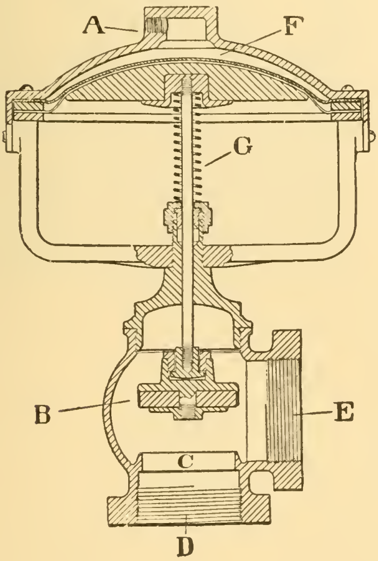

Fig. 299.—Interior of diaphragm radiator valve.

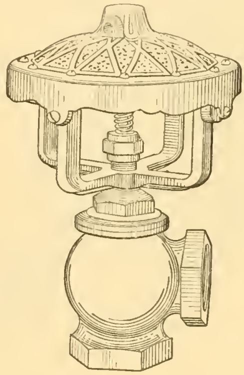

Fig. 300.—Exterior of diaphragm radiator valve.

it. D and E show the openings for supply pipe and radiator connections. C is the seat of the valve and B the disc. Up to this point the body of the valve is built the same as an ordinary radiator valve. The frame supporting the diaphragm is adjusted to the valve immediately below the stuffing box. A spring is slipped on the valve spindle and an oval shell, with air opening A, is fastened to the saddle or frame.

To the under side of this shell is placed a rubber diaphragm. Note that in place of the valve wheel on the top of the valve spindle is a curved top fitting against the rubber diaphragm. The spring G keeps the valve open until the temperature of the room is sufficiently high for the thermostat to open the air valve and admit the compressed air to the chamber F, which presses down on the diaphragm, closing the valve and holding it in this position as long as the temperature of the room is above

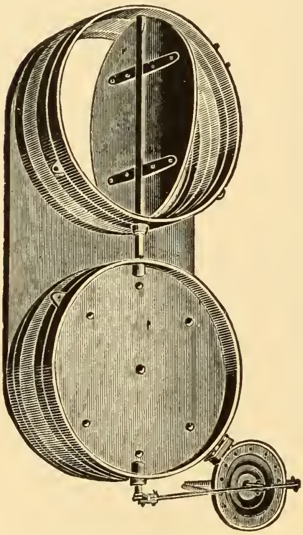

Fig. 301.—Double damper for round flue.

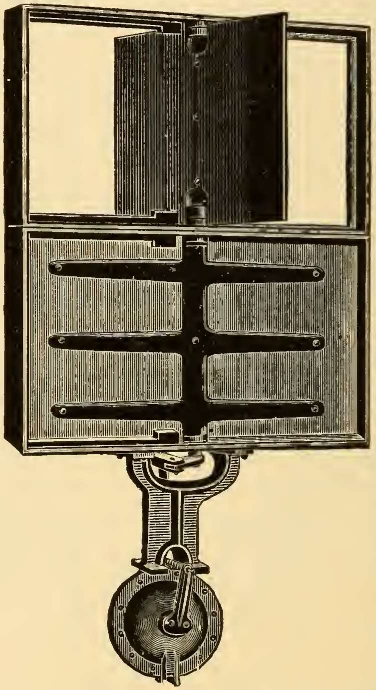

Fig. 302.—Double damper for square flue.

the point desired. When the temperature cools to such a degree as to cause the thermostat to act, the air pressure is removed and the spring G opens the valve. Fig. 300 shows an exterior view of the valve. The action of the thermostat is positive and quick in moving the valves. When impelling the dampers of a fan or hot-air system, that is, the air supply, another form of the thermostat is used, which operates gradually. This is also employed on a hot-water heating apparatus.

Special forms of thermostats for air ducts, hot-water tank supply, etc., etc., are applied in connection with the Johnson pneumatic system, and a system for handling the valves of a vapor system of heating is one of their achievements of later date.

When handling air or controlling the temperature in the air ducts of a " hot and cold " or fan system the air motor is attached to the dampers as shown by Fig. 301, which shows a double damper for a round flue, or by Fig. 302, which shows a double square damper.

The value of a successful system of heat control is not measured entirely by the saving in fuel, which is variously estimated from 20% to 35%; the fact of having an apparatus which without any thought or action from the occupants of a room or building, will automatically maintain the temperature at any desired degree, is something on which a value cannot very readily be placed. In schools, the teachers are relieved from the time lost and attention given the heating apparatus, in hospitals the value of an even temperature cannot be calculated, while for our homes, churches and offices the results from temperature regulation cannot be measured.

CHAPTER XXVI

Business Methods

There are certain business methods in connection with the estimating on, the contracting for and the installing of an apparatus for heating and ventilation, which should be adopted by those already engaged in or about to enter into the business of contracting for work of this character. Quite frequently the owner of a building will let his heating work to the contractor whose bid for the job may not be the lowest, but who has described his proposition and appliances in a clear and concise manner, who has submitted a bid or proposal itemizing and enumerating the various portions of the apparatus and the commendatory features of whose proposition are reinforced by a carefully worded guaranty, covering the character of materials and class of workmanship to be furnished on the work. Such a business method cannot fail to be compared with that of the contractor who, in submitting his figure, simply notes a few words upon a letterhead bearing his business title. The owner is justified in expecting a higher class of work from that heating man who approaches him in a business way and with business methods, and undoubtedly is willing to pay more for it.

Estimating

In this, as in nearly every other business, competition is apt to be close and consequently the estimate covering any heating work should be carefully prepared, diligence and caution being exercised that no important items are omitted. For this purpose an estimate book or a carefully arranged sheet should be employed. Various large jobs require special items. The ordinary job of steam or hot-water heating may be thoroughly covered by the sample estimate sheet shown on the following pages. The

Steam or Water? *Both* Date, *January 1, 1907* Architect, *M. B. Smith*

For *Mr. R. D. Blank* Business Address, *Ledyard, Pa.* Address, *Pittsburgh, Pa.*

Kind of Building, *Brick Residence* Location, *Ledyard, Pa.* Nearest Freight Station, *Ledyard, Pa.*

Height of Cellar, *9′* Size of Smoke Flue, *10×12* in.

Rooms.	Wide.	Long.	High.	Cubic Ft.	Wall Surface, Square Ft.	Glass Surface, Square Ft.	Radiators. Water. Sq. Ft. Direct.	Water. Sq. Ft. Indirect.	Water. No.	Water. Tap.	Water. High.	Steam. Sq. Ft. Direct.	Steam. Sq. Ft. Indirect.	Steam. No.	Steam. Tap.	Steam. High.	Style.	Tempera-ture.
First Floor:																		
Parlor.	12	15	10	1,800	270	54	80	. . . .	1	1½″	38″	50	. . . .	1	1¼″	38″	3 column	70 degrees
Sitting Room.	15	18	10	2,700	210	72	95	. . . .	1	1½″	38″	60	. . . .	1	1¼″	38″	"	70 "
Library.	12	16	10	1,920	220	54	80	. . . .	1	1½″	38″	50	. . . .	1	1¼″	38″	"	70 "
Dining Room.	16	20	10	3,200	420	90	135	. . . .	2	1¼″	38″	85	. . . .	1	1½″	38″	"	70 "
Reception Hall (Stairs out).	14	16	10	2,240	300	72	. . . .	200	1	1½″	. . . .	. . . .	120	1	1¼″×1″		Pin Indirect	70 "
Second Floor:																		
Over Parlor.	12	15	9	1,620	243	54	70	. . . .	1	1¼″	38″	45	. . . .	1	1¼″	38″	3 column	70 "
Over Sitting Room	15	15	9	2,025	189	54	80	. . . .	1	1¼″	38″	50	. . . .	1	1¼″	38″	"	70 "
Over Library.	12	13	9	1,404	225	36	55	. . . .	1	1″	38″	35	. . . .	1	1¼″	38″	"	70 "
Over Dining Room	12	16	9	1,728	216	54	70	. . . .	1	1¼″	38″	45	. . . .	1	1¼″	38″	"	70 "
Over Hall.	12	14	9	1,512	234	36	65	. . . .	1	1¼″	38″	40	. . . .	1	1¼″	38″	"	70 "
Bath Room.	8	12	9	864	72	15	30	. . . .	1	1″	38″	20	. . . .	1	1¼″	38″	"	70 "
Upper Hall.	8	16	9	1,152	72	18	(Included in Reception Hall)											
Third Floor:																		
Front Chamber. . .	12	14	8′–6″	1,428	210	36	55	. . . .	1	1″	38″	35	. . . .	1	1¼″	38″	"	70 "
Middle Chamber.	12	16	8′–6″	1,632	180	36	55	. . . .	1	1″	38″	35	. . . .	1	1¼″	38″	"	70 "
Rear Chamber . . .	10	14	8′–6″	1,190	176	36	50	. . . .	1	1″	38″	30	. . . .	1	1¼″	38″	"	70 "
Bath Room.	6	8	8′–6″	408	51	15	20	. . . .	1	1″	38″	15	. . . .	1	1″	38″	"	70 "
							940	200	16			595	120	15				

	Steam.	H. W.
Direct Radiation.	595	940
Indirect Radiation.	120	200
Add 50 per cent of Indirect for Boiler capacity.	60	100
Add radiation in Mains and Risers.	195	435

	Steam.	H. W.
Total heater capacity required.	970	1,675

Heater No. 20 *Success.*

Capacity { Steam, 1,000′. Hot Water, 1,675′.

ESTIMATE

Water.			Steam.		
Quantity.	Items.	Price.	Quantity.	Items.	Price.
1	Success Heater No. 20	$190.00	1	Success Heater No. 20	$195.00
940 Ft.	38″ Direct Radiation @ .25	235.00	595 Ft.	38″ Direct Radiation @ .24	142.80
200 Ft.	Pin Indirect Radiation .20	40.00	120 Ft.	Pin Indirect Radiation .20	24.00
6	1″ Radiator Valves	4.38	1	1″ Radiator Valve	1.41
6	1¼″ " "	6.06	12	1¼″ " "	23.04
3	1½″ " "	4.26	1	1½″ " "	2.45
..	2″ " "	....	..	2″ " "	....
6	1″ Union Ells	3.00	..		....
6	1¼″ " "	3.84	..		....
3	1½″ " "	2.40	..		....
..	2″ " "	....	1	1¼″ Gate Valve for Indirect	1.40
2	1½″ Gate Valves for Indirect	4.00	1	1″ " " " "	1.00
16	Key Air Valves	1.60	17	Star Automatic Air Valves	13.60
1	32 Gal. Expansion Tank	7.65	..	Wood Wheel Air Valves	....
1	Altitude Gauge	1.75	..	Key Air Valves	....
1	Thermometer	1.25	..	Pipe and Fittings	65.00
..	Pipe and Fittings	96.00	..	Bronzing, 2 cents per sq. ft.	12.00
..	Bronzing, 2 cents per sq. ft.	18.80	..	Pipe Covering	24.00
..	Pipe Covering	42.00	..	Smoke Pipe and Damper	4.50
..	Smoke Pipe and Damper	4.50	..	Extra Risers	....
..	Extra Risers	....	..	Concealed Risers	....
..	Concealed Risers	....	..	Valves on Mains	....
..	Valves on Mains	....	..	Cold-air Ducts }	
..	Cold-air Ducts—Hot-air Ducts }	30.00	..	Hot-air Ducts } 1 Radiator	30.00
..	Indirect Boxing }		..	Indirect Boxing }	
1	Register 16″×20″	4.70	1	Register 16″×20″	4.70
..	Water Supply	1.50	..	Water Supply	1.50
..	Blow-off Connection	1.50	..	Blow-off Connection	1.50
..	Labor	120.00	..	Labor	85.00
..	Board	....	..	Board	....
..	Freight	15.00	..	Freight	12.00
..	Cartage	8.00	..	Cartage	6.00
..	Radiator Boards	....	..	Radiator Boards	....
..	Foundation (owner)	....	..	Foundation (owner)	....
..	Car Fares and Incidentals	15.00	..	Car Fares and Incidentals	12.00
	Total Net Cost	$862.19		Total Net Cost	$642.90
	Profit....15 per cent	129.33		Profit, 15 per cent	96.44
	Amount of Bid	$991.52		Amount of Bid	$739.34

detail represents an estimate for both steam and hot water for a brick three-story dwelling. The rule "2—20—200" is used in estimating the amount of radiation required; the prices inserted are fictitious, being given for the sole purpose of instructing our readers in the right course to pursue in correctly filling out the blanks on estimate sheet.

Having estimated carefully the requirements of the work, size of heater, square feet of radiation, etc., etc., and checked over the cost figures to insure accuracy, the next step is to prepare a proposal and bid to submit to the owner.

Proposal and Bid

Printed forms arranged with spaces left blank for filling in with a pen may be procured for this purpose. It is our belief, however, that a typewritten form of proposal and bid is better suited to the purpose, as the printed forms must necessarily contain much matter which has to be crossed off or eliminated to cover certain work, but which, if excluded from the printed form, would for certain other work have to be inserted with a pen. We submit the following form of proposal as covering such detail as is necessary, and the bid attached becomes a legal contract after the signatures of both the contractor and the owner are added to it. The usual practice is to make two copies, the contractor signing both of them before submitting to the owner, who, if he accepts the proposition submitted, signs the acceptance clause and returns one copy to the heating contractor.

As no one style of proposal can cover both steam and hot water work, we give separate forms for each. Where the dotted horizontal line ". . . . ." occurs it denotes space in which the name of the boiler, radiator or other goods to be used, should be inserted.

Proposal and Bid for Steam-Heating Apparatus

General.—These specifications are intended to cover a complete low-pressure steam-heating apparatus and it is understood that the same will be placed exactly as specified.

1. *Boiler.*—I will furnish and erect in basement one No. . . . . Steam Boiler. The exterior surface of the boiler, with

the exception of the front, to be thoroughly covered with asbestos cement. The boiler will be provided with a complete set of trimmings, which shall consist of automatic damper regulator, safety valve, water column and gauge, steam gauge and blow-off cock, and a complete set of firing tools, consisting of poker, slice bar, ash hoe and flue-cleaning brushes. Connection is to be made to the boiler from water pipe in basement to supply water to the boiler. A ¾″ steam cock or globe valve will be placed on this pipe.

2. *Foundation.*—A suitable and substantial brick and cement foundation for the boiler will be constructed by me.

3. *Smoke Pipe.*—I will make necessary smoke connection from boiler to chimney by means of a galvanized iron smoke pipe . . . . inches in diameter, made of . . . . gauge iron and provided with a suitable damper. Owner is to provide a good chimney with sufficient draught for the work.

SCHEDULE OF RADIATION

		Ft. Rad.	Style.	Height.	Tap.	Temperature.
First Floor.						
Parlor............	1 Rad.	50	....	38″	1¼″	70°
Sitting Room......	1 "	60	......	38″	1¼″	70°
Library...........	1 "	50	....	38″	1¼″	70°
Dining Room.....	1 "	85	....	38″	1½″	70°
Reception Hall.... (Stairs out)	1 "	120	Pin Indirect		1¼×1″	70°
Second Floor.						
Over Parlor.......	1 Rad.	45	....	38″	1¼″	70°
Over Sitting Room.	1 "	50	....	38″	1¼″	70°
Over Library......	1 "	35	....	38″	1¼″	70°
Over Dining Room	1 "	45	....	38″	1¼″	70°
Over Hall.........	1 "	40	....	38″	1¼″	70°
Bathroom	1 "	20	....	38″	1¼″	70°
Upper Hall (Included in Reception Hall).						
Third Floor.						
Front Chamber....	1 Rad.	35	....	38″	1¼″	70°
Middle Chamber..	1 "	35	....	38″	1¼″	70°
Rear Chamber....	1 "	30	....	38″	1¼″	70°
Bathroom	1 "	15	....	38″	1″	70°
		715 sq. ft.				

4. *System of Warming.*—Building is to be warmed throughout by direct radiators, except as noted in the schedule of radiation. Radiators are to be of such kinds and heights as indicated. Wherever possible radiators will be placed along outside or exposed walls, their positions conforming, in so far as possible, to the wishes of the owner.

5. *Radiation.*—I will erect and connect in building the total amount of radiating surface as indicated in the schedule given. All direct radiators shall be of . . . . make, ... or . . . . column and divided and placed as specified.

6. *Radiator Valves.*—All radiators shall be connected to piping, using a heavy pattern, wood wheel, Jenkins Disc radiator valve in each instance, with rough body, nickel plated all over, and of a size to conform to the tapping as given for each radiator in the schedule.

7. *Air Valves.*—Each radiator and the steam mains in the basement, where necessary, shall be provided with a first-class automatic air valve of the . . . . pattern.

8. *Pipe and Fittings.*—The piping is to be erected according to what is known as the . . . . system of gravity steam heating. All main pipes shall have a pitch downward from the boiler at least ½″ in each 10 feet of length. All branches shall pitch upward from mains at least ½″ in each 5 feet of length. In the event of it being necessary to pitch any branches downward, there will be a heel drip taken from the bottom of the riser so supplied and this drip will be connected into a wet return. All pipe to be of full weight and standard quality. All risers to be put up plumb and straight and all joints made tight. All fittings to be of the best gray iron, flat beaded and having clean-cut taper threads.

9. *Hangers.*—Pipe in basement is to be hung on expansion pipe hangers of approved pattern, to allow of perfect freedom from expansion and contraction.

10. *Cutting.*—I will do all necessary cutting of holes through floors and walls for the passage of pipes. Any breakages to walls or floors resulting from such work will be remedied by me and the walls and floors left in first-class condition.

11. *Floor and Ceiling Plates.*—Where pipes pass through

floors or ceilings, ... nickel-plated floor and ceiling plates shall be used. In case of pipes coming in contact with woodwork, the opening shall be lined with a good quality of tin.

12. *Bronzing and Painting.*—All exposed piping and radiators above the basement will be given a priming coat of paint, followed by a coat of gold or aluminum bronze, as may be desired by the owner. All basement piping and all portions of the boiler uncovered shall be painted with black asphaltum.

13. *Pipe Covering.*—All steam pipes in the basement, both flow and return, will be covered with . . . . low-pressure sectional pipe covering. Same to be neatly and securely fastened with brass bands placed three to each length of covering. All fittings to be covered with magnesia-asbestos plastic cement.

14. *Setting of Direct-Indirect Radiators.*—I shall provide box bases with suitable dampers for all direct-indirect radiators and shall provide proper wall boxes to be set by the mason in the walls of the building. On connecting the radiator to the piping will make proper connection from the wall box to the box base by means of a galvanized iron duct or sleeve.

15. *Hanging Indirect Radiators.*—All indirect radiators shall be suspended from the ceiling of the basement by suitable wrought iron hangers, at such a height that the bottom of the radiators will be at least 18″ above the water line of boiler. All stacks of indirect radiation so hung shall be piped in such a manner as to permit of a free and easy circulation throughout their entire surfaces.

16. *Casing, Air Ducts, etc.*—All indirect radiators shall be cased with a boxing made of heavy galvanized iron, constructed in such a manner that a portion of the bottom may be readily removed for cleaning purposes. The casing shall fit snugly around the sides of the radiators in order that the cold air shall pass between the surfaces instead of around them. The cold-air ducts will be made of galvanized iron and provided with a suitable damper and will be of such sizes as are necessary to supply the proper amount of cold air to the radiators. The hot-air duct shall be connected from the top of the casing to the register boxing in floor above.

17. *Registers and Register Boxes.*—All registers shall be of

. . . . design. The area of the openings in same will not be less than the area of the warm-air duct. Registers will be set firmly in the wall or floor and flush with the same. Register boxes made of bright I. C. tin shall be provided for each of the register openings.

(The clauses 14, 15, 16 and 17 should be omitted except where direct-indirect or indirect radiators are specified in a contract.)

18. *In General.*—The material used in the construction of this apparatus will be new and of the best quality and the work put up by skilled workmen. When the apparatus is completed it will be fired up and tested in the presence of the owner or his representative and left in good order ready for use.

19. *Guaranty.*—I guarantee this work in every respect: that when completed it shall be free from mechanical defects and noiseless in operation, and that after the apparatus shall have been accepted by the owner, any part thereof shall fail to accomplish the guaranty herein contained by reason of any defect due to my workmanship or the materials furnished, I agree to remedy such defects at once at my expense. It is understood that the term "defect" as above used shall not be construed as embracing such imperfections as would naturally follow improper treatment, accident, or the wear and tear of use.

20. *Bid.*—I agree to furnish the material herein specified and do the work as herein enumerated for the sum of Seven Hundred and Thirty-nine Dollars and thirty-four cents ($739.34).

Payments to be made as follows: One third when boiler is erected and material delivered on the job, one third when radiators are delivered and connected to the system, and the remaining one third after job shall have been completed and tested.

(Signed) JOHN H. JONES.

21. *Acceptance.*

To JOHN H. JONES, *Heating Contractor.*

I hereby accept your proposal and bid for installing a complete steam-heating apparatus in my residence and for the same agree to pay you Seven Hundred and Thirty-nine Dollars and thirty-four cents ($739.34).

Payments to be made as above specified.

. . . .(Date). . . . . (Signed) R. D. BLANK.

Proposal and Bid for Hot-Water Heating Apparatus

General.—These specifications are intended to cover a complete hot-water heating apparatus and it is understood that the same will be placed exactly as specified.

1. *Heater.*—I will furnish and erect in basement one No. .... Hot-water Heater. The exterior surface of the boiler, with the exception of the front, to be thoroughly covered with asbestos cement. The heater will be provided with a complete set of firing tools, consisting of poker, slice bar, ash hoe, and flue-cleaning brushes.

2. *Foundation.*—A suitable and substantial brick and cement foundation for the heater will be constructed by me.

3. *Smoke Pipe.*—I will make necessary smoke connection from heater to chimney by means of a galvanized iron smoke pipe .... inches in diameter, made of .... gauge iron and provided with a suitable damper. Owner is to provide a good chimney with sufficient draught for the work.

SCHEDULE OF RADIATION

		Ft. Rad.	Style.	Height.	Tap.	Temperature.
First Floor.						
Parlor...........	1 Rad.	80	....	38″	1½″	70°
Sitting Room......	1 "	95	....	38″	1½″	70°
Library...........	1 "	80	....	38″	1½″	70°
Dining Room.....	2 Rads.	135	....	38″	1¼″	70°
Reception Hall....	1 Rad.	200	Pin Indirect		1½″	70°
Second Floor.						
Over Parlor.......	1 Rad.	70	....	38″	1¼″	70°
Over Sitting Room	1 "	80	....	38″	1¼″	70°
Over Library......	1 "	55	....	38″	1″	70°
Over Dining Room	1 "	70	....	38″	1¼″	70°
Over Hall.........	1 "	65	....	38″	1¼″	70°
Bathroom	1 "	30	....	38″	1″	70°
Upper Hall (Included in Reception Hall)						
Third Floor.						
Front Chamber...	1 Rad.	55	....	38″	1″	70°
Middle Chamber..	1 "	55	....	38″	1″	70°
Rear Chamber....	1 "	50	....	38″	1″	70°
Bathroom	1 "	20	....	38″	1″	70°
		1,140 sq. ft.				

4. *System of Warming.*—Building is to be warmed throughout by direct radiators, except as noted in the schedule of radiation. Radiators are to be of such kinds and heights as indicated. Wherever possible, radiators will be placed along outside or exposed walls, their positions conforming, in so far as possible, to the wishes of the owner.

5. *Radiation.*—I will erect and connect in building the total amount of radiating surface as indicated in the schedule given. All direct radiators shall be of . . . . make, ...or . . . . column and divided and placed as specified.

6. *Altitude Gauge and Thermometer.*—I shall place on the heater an altitude gauge in order to show at the heater the height of the water in the expansion tank. I shall also place on the heater a first-class hot-water thermometer.

7. *Expansion Tank and Gauge.*—I shall place on the work a heavy galvanized steel expansion tank of suitable size, with gauge glass complete. Tank to be placed on suitable shelf in bath or other room at least three feet above one of the highest radiators on the system. Overflow connection shall be made through roof.

8. *Water Connection.*—I will make necessary water connection from water pipe in basement to bottom and rear of heater and place on this connection a suitable globe valve or stopcock.

9. *Radiator Valves and Union Elbows.*—Each radiator will be connected to the system of piping with a rough body, wood wheel, quick opening hot-water radiator valve with union, to be of heavy pattern and nickel plated all over. Return ends of radiators to be connected to return pipes by the use of a heavy pattern, nickel-plated brass union elbow. Sizes of valves and elbows to conform to the tappings as given in above schedule of radiation.

10. *Air Valves.*—Each radiator shall be provided with a lock-shield nickel-plated brass air valve operated with a key.

11. *Pipe and Fittings.*—System of piping used shall be the gravity return system of hot-water piping. All mains shall pitch upward from boiler at least 1″ in each 10 feet of length, and all branches shall pitch upward from mains at least 1″ in each 5 feet of length. All flow and return mains to be put up plumb and straight and all joints made tight. All pipe to be of best quality

wrought iron, of standard weight, and all fittings to be of the best gray iron of heavy pattern, flat beaded, having clean-cut taper threads.

12. *Hangers.*—Pipe in basement is to be hung on expansion pipe hangers of approved pattern, to allow of perfect freedom from expansion and contraction.

13. *Cutting.*—I will do all necessary cutting of holes through floors and walls for the passage of pipes. Any breakages to walls or floors resulting from such work will be remedied by me and the walls and floors left in first-class condition.

14. *Floor and Ceiling Plates.*—Where pipes pass through floors or ceilings, ... nickel-plated floor and ceiling plates shall be used. In case of pipes coming in contact with woodwork, the opening shall be lined with a good quality of tin.

15. *Bronzing and Painting.*—All exposed piping and radiators above the basement will be given a priming coat of paint, followed by a coat of gold or aluminum bronze, as may be selected by the owner. All basement piping and all portions of the boiler uncovered shall be painted with black asphaltum.

16. *Pipe Covering.*—All pipes in the basement, both flow and return, will be covered with . . . . low-pressure sectional pipe covering. Same to be neatly and securely fastened with brass bands placed three to each length of the covering. All fittings to be covered with magnesia-asbestos plastic cement.

17. *Setting of Direct-Indirect Radiators.*—I shall provide box bases with suitable dampers for all direct-indirect radiators and shall provide proper wall boxes to be set by the mason in the walls of the building. On connecting the radiator to the piping I will make proper connection from the wall box to the box base by means of a galvanized iron duct or sleeve.

18. *Hanging Indirect Radiators.*—All indirect radiators shall be suspended from the ceiling of the basement by suitable wrought-iron hangers. The connections to the same shall be made in such a manner as to permit of a perfect circulation throughout their entire surfaces.

19. *Casing, Air Ducts, etc.*—All indirect radiators shall be cased with a boxing made of heavy galvanized iron, constructed in such a manner that a portion of the bottom may be readily removed

for cleaning purposes. The casing shall fit snugly around the sides of the radiators in order that the cold air shall pass between the surfaces instead of around them. The cold-air ducts will be made of galvanized iron and provided with a suitable damper and will be of such sizes as are necessary to supply the proper amount of cold air to the radiators. The hot-air duct shall be connected from the top of the casing to the register boxing in floor above.

20. *Registers and Register Boxes.*—All registers shall be of . . . . design. The area of the openings in same will not be less than the area of the warm-air duct. Registers will be set firmly in the wall or floor and flush with the same. Register boxes made of bright I. C. tin shall be provided for each of the register openings.

(The clauses 17, 18, 19 and 20 should be omitted, except where direct-indirect or indirect radiators are specified in a contract.)

21. *In General.*—The material used in the construction of this apparatus shall be new and of the best quality and the work put up by skilled workmen. When the apparatus is completed it will be fired up and tested in the presence of the owner or his representative and left in good order ready for use.

22. *Guaranty.*—I guarantee this work in every respect, that when completed it shall be free from mechanical defects and noiseless in operation, and that after the apparatus shall have been accepted by the owner, any part thereof shall fail to accomplish the guaranty herein contained by reason of any defect due to my workmanship or the materials furnished, I agree to remedy such defects at once at my expense. It is understood that the term "defect" as above used shall not be construed as embracing such imperfections as would naturally follow improper treatment, accident, or the wear and tear of use.

23. *Bid.*—I agree to furnish the material herein specified and do the work as herein enumerated for the sum of Nine Hundred and Ninety-one Dollars and fifty-two cents ($991.52).

Payments to be made as follows: One third when boiler is erected and material delivered on the job, one third when radiators are delivered and connected to the system, and the remaining one third after job shall have been completed and tested.

(Signed) JOHN H. JONES.

24. *Acceptance.*

To John H. Jones, *Heating Contractor.*

I hereby accept your proposal and bid for installing a complete hot-water heating apparatus in my residence and for the same agree to pay you Nine Hundred and Ninety-one Dollars and fifty-two cents ($991.52).

Payments to be made as above specified.

........(Date).......... (Signed) R. D. Blank.

Special Features of Contracts

Should there be any special materials or extra work demanded, each additional item should be made the subject of a special paragraph and incorporated in the specifications. The following include some such items as might be necessary:

Radiator boards,

Temporary use of apparatus (charge for same),

Coil in heater or boiler for heating water for domestic use,

Domestic water supply where a tank with steam coil in same is provided for use with a steam boiler.

There should also be figured such "extras" on the work, as additional charges for low radiators, peculiar decoration of radiators, etc., etc. Again, it is customary for some contractors to insert a clause in the specifications relative to the construction of the building. For example, if it should be afterwards discovered that the plans of the job or the building to be heated or the information respecting same, which had been received from the owner or his representative, did not conform to the building or plans of same as figured, the heating contractor charges for any alterations occasioned by such misrepresentation as an "extra." Some heating contractors desire to insert a paragraph in the specifications to the effect that if when the work is partially finished or nearly completed, delay shall arise, due to no fault of the heating contractor, he shall be entitled to receive settlement, the same as though the work was entirely completed, except that a certain percentage is allowed to be withheld pending the actual completion of the job. Matters of the above kind are sure to arise on heating contracts and it is well to make mention of the same in the specifications in cases where the heating contractor considers it essential.

CHAPTER XXVII

MISCELLANEOUS

Care of Heating Apparatus

The life and efficiency of a steam or hot water heating apparatus of whatever nature depend largely upon the care and attention given it, both when in service and during the summer period when the apparatus is not in use.

Summer Care

It is when the apparatus is inoperative that the greatest damage to it is wrought by disintegration due to rust and the chemical action of soot and ashes. It is, therefore, a good plan as soon as the season for artificial heating is past and the fire is allowed to go out in the heater, to thoroughly clean the grate and ash pit of all ashes. Remove the casing of the heater, if of portable construction. If not so provided, open all clean-out doors and thoroughly clean all heating and flue surfaces with a steel brush. Remove the smoke connection and clean it in a thorough manner. Find a dry place in which to store the smoke pipe for the summer. Open all doors of the heater—clean-out, fire and draught doors—and allow them to remain open until the fire is again built in the heater. There has been much discussion, pro and con, as to the advisability of emptying the steam boiler or the hot-water heating apparatus during the summer season. Many engineers and heater manufacturers contend that the apparatus should be left full of water; others affirming just as positively that it should not be. Our own opinion, based upon our personal experience together with that of others, is that it is well to empty the system and free it of all moisture. We advocate the following procedure:

Open the draw-off connection to the sewer, or with the use of pails drain all water from the boiler or system. Open all air vents and valves in order that none of the water may be entrained in the piping or radiators. Then build a light wood fire in the heater and evaporate all remaining water and moisture from the system, allowing all valves and air vents to remain open until the time has arrived when the use of the apparatus is again necessary, when the boiler or system can be refilled with fresh water.

By following the directions given the inner surfaces of the apparatus may rust slightly, *but will not scale* and the bronzing or other decoration of radiators and piping will retain its luster for a longer period of time.

Proper Attention to Boilers

There are some few rules regarding the proper attention to a steam boiler or hot-water heater which should be followed in order to escape possible damage to the heater and at the same time obtain good results from the use of the apparatus. Manufacturers of heaters, as a rule, furnish each customer with directions for the care and operation of every heater sold by them. There are, however, some few instructions which it may be well to repeat. To put the apparatus in condition for service, proceed as follows. (We assume that the directions for summer care have been followed.)

Put the smoke connection in position and see that the damper in the same works freely. Replace all fixtures, which may have previously been removed, in their proper positions. Refill the apparatus with water. If a steam boiler, it should be refilled to such an extent that the gauge on the water column stands about one half full of water. If a hot-water apparatus, the system should be refilled to such an extent that the gauge glass on the expansion tank stands about one quarter full of water. With a key suitable for the purpose, open each one of the air valves, using a small cup to catch any water that may flow out. Go over the entire system, freeing each radiator of all air.

Now examine the gauge on the expansion tank and in all probability you will discover that it is necessary to turn more water into the system. If a steam apparatus, see that the damper regulator is properly connected to draught and check doors and try the safety valve to insure its working freely.

The apparatus is now ready for the season's service. In building the first fire, note with care that the grate is thoroughly covered with wood before putting on any coal in order that no unburnt coal will fall down on the grate and thereby deaden the fire. Add a quantity of coal from time to time until there is a deep clean fire in the heater. Endeavor to keep it in this condition while the apparatus is in use, remembering that *there is no economy in a shallow fire* and that a heater fire pot partially filled with ashes or the grate with unburnt coal will not give proper results. The ashes should be removed daily to prevent the possible burning out or warping of the grate.

Should the water in a steam boiler become low through accident or neglect, do not refill the apparatus until the fire has been drawn and the boiler castings allowed to cool. With some of those boilers constructed with a water base, this course is not absolutely necessary, although it is the safer plan to pursue. As long as any water shows in the gauge glass of a steam boiler, fresh water may be supplied with safety.

Clean all heating and flue surfaces of soot at least once each week. Soot is a great non-conductor of heat and the boilers whose surfaces are allowed to remain coated with soot, require more attention and consume a greater amount of fuel than those in which the surfaces are kept thoroughly clean from all accumulation of such dirt. Steel wire brushes are made for this purpose and with their proper use a satisfactory cleaning of the heating surfaces can be obtained.

Should a building remain unoccupied during cold weather, or should it be closed temporarily in winter, all water should be drawn off and evaporated from the system in order to offset a possible danger from freezing.

Removing Oil and Dirt

In all new heating systems there is more or less oil and dirt present. The oil from machined castings, radiator tappings and pipe threading will work down into the boiler as will also particles of core sand from the radiator and boiler castings. The oil with considerable dirt forms a scum on the surface of the water in the boiler, causing it to foam and at the same time preventing the generation of steam. This action frequently produces an unsteady water-line and hinders the proper working of the apparatus.

The remedy for this condition is to blow off the boiler while under pressure. This should be done several times at intervals of a week or more until the oil has been thoroughly removed.

To successfully blow off a steam boiler, close all radiator valves and build a good wood fire in the heater, generating a pressure of from ten to fifteen pounds. Open the blow-off valve and let the pressure of the steam blow all water out of the boiler. With it this water will carry most of the dirt and the greasy scum or oil. Allow the fire to burn out and the castings to cool, after which the boiler can be again refilled and the fire started.

The blow-off is usually located at the bottom and rear of the boiler and as much of the oil will adhere to the inner surfaces of the boiler, as the water settles or is forced out, it is often necessary to repeat this cleaning operation several times.

Some manufacturers of sectional boilers, recognizing the extent of the trouble due to the presence of oil, have provided their boilers with a blow-off located at the rear a few inches below the water line. Where such an opening is furnished, the scum and oil are readily blown out from the surface of the water, the accumulation of dirt being removed through the draw-off cock at the bottom of the boiler. The blow-off opening should be at least 1½″ in diameter, and a still larger opening is preferable. Such a provision is styled a "surface blow-off" by some fitters and engineers.

Summer Tests to Determine Efficiency

Although the fact is not generally recognized by the contracting fitter, a heating apparatus may be tested as to its efficiency on a warm summer's day as well as in midwinter. Prof. R. C. Carpenter has laid down a rule which the writer has for some years followed in actual practice and we can, therefore, testify and vouch to the correctness of it. The table given shows in Column Four (Resulting Temperature of Room) the temperatures which a room would have for various degrees of heat outside, provided the radiation placed was sufficient to warm the room to 70° in zero weather with three pounds pressure of steam or 220° temperature.

TABLE XXVIII

Temperature Outside Air.	Coefficient Heat per Square Foot per Hour per Degree.	Total Heat per Square Foot per Hour.	Resulting Temperature of Room.	Difference Temperature Radiator and Room.
−10	1.85	288	64.7	155.3
0	1.8	270	70	150
10	1.75	253	75.1	144.9
20	1.7	236	81	139
30	1.65	218	86.5	133.5
40	1.6	203	93.1	128
50	1.55	188	98.7	122.5
60	1.5	172	104.7	116.5
70	1.45	158	110.5	109.5
80	1.4	142	117.1	102.9
90	1.35	130.5	123.5	96.5
100	1.3	117	130.3	89.7

Example showing application of Table: To determine by a test of the apparatus, when weather is 60°, whether a guaranty to heat to 70° in zero weather is maintained, operate the apparatus as though in regular use and note the average temperature of the room. If the room has a temperature equal to or in excess of 104.7° F., it would have a temperature of 70° in zero weather, all other conditions, such as wind, position of windows, etc., being the same as on the day of the test.

Care of Tools

In order to perform good work rapidly it is necessary to have serviceable and sharp tools, particularly wrenches and those for pipe cutting and threading. Judging from the author's personal experience the old axiom "A workman is known by his tools" was apparently never intended to apply to a journeyman steam fitter for, as a class, the ordinary steam fitter can break, mutilate or otherwise destroy the efficiency of a tool quicker and with more reckless abandon than any other tradesman we have ever come in contact with in spite of the fact that there is absolutely no other trade where good and sharp tools are more necessary for efficient and rapid work than that of pipe fitting. There are some shop rules governing the care and use of tools which might be adopted by all heating contractors to good advantage.

First, a complete kit of tools should be furnished each journeyman fitter and he should be charged with and held personally responsible for them and their condition. A steam fitter cannot be expected to make good time on work when he is furnished with wrenches that will not "bite" nor take proper hold of a pipe until after possibly three or four trials. Neither can good, clean threads be cut with dull or imperfect dies. For the reasons given these tools should have frequent and careful scrutiny by the master fitter or his shop boss.

Second, the fitter should be instructed to allow his helper to spend the last fifteen or thirty minutes of each working day in gathering together and cleaning all tools which have been in use and all broken or dulled tools should be promptly returned to the shop. It is well to have a tool chest for each individual kit of tools. Iron chests, made for this purpose, are models of convenience.

To a contractor doing any considerable amount of work a pipe-cutting and threading machine will pay for itself in the labor saved on one or two fair-sized jobs. It is well to have one large machine for shop use and one or more portable machines cutting and threading up to 4″ for use on the job.

Labor Saving Suggestions

There are some methods of saving time and money on contract work which are worthy of consideration. Do not allow the fitter to do the unskilled work of a laborer. Large pipe should be handled by laborers and the radiation on a job should be carried into and distributed throughout the building by the teamster and one or two laborers under the direction of the fitter or in accordance with an itemized list furnished the driver.

Do not allow the cutting off of a short piece of pipe without first threading one end of it. These short pieces of pipe may then be returned to the shop and the other end of each piece threaded by a helper or unskilled workman.

We have found it excellent practice to send to each job a box each of short pieces of pipe in sizes 1″, 1¼″ and 1½″ with both ends threaded. These may be laid out on the basement floor in a place conveniently near to the pipe vise, to be quickly measured and used by the fitter in order to save the cutting of short measurements. As soon as the vise and bench are in position the helper should arrange all fittings on the floor in rows according to their sizes and in such a place near the vise that they can be reached rapidly by the fitter. A pad of paper on which to make memoranda of measures or supplies needed from the shop should be tacked up close to the work bench.

We would urge the advisability of making plans of all work, plans which will show in a general way the sizes of pipe and fittings and the method of running same and the manner of making the different connections. Such plans should be adhered to by the fitter as closely as the conditions of the work will permit.

Adopt a system for handling all work and the results will show time and labor saved and increased profits accruing from the contracts.

Bronzing, Painting and Decoration

There are some few facts relating to the bronzing or painting of radiators or radiating surfaces of a heating plant which the steam fitter should be fully posted on and thoroughly understand. It is well to give all direct radiators or exposed piping above the basement a priming coat of paint before applying the bronze, as the bronze will then cover more surface, look brighter and retain its luster for a longer period of time. Where gold bronze is to be used, a priming coat of yellow ochre is the best to apply; where aluminum bronze is made use of the priming coat should be white. If color bronzes are desired, the priming coats should conform as nearly as possible to the tints of the bronze. The priming coat should not contain oil of any kind, but should be mixed with japan and turpentine.

One pound of gold bronze will cover 150 ft. of iron surface not primed and 200 ft. of primed surface. Each four pounds of gold bronze requires one gallon of liquid.

As one pound of aluminum bronze powder is more than twice as bulky as gold bronze, it will cover more than double the surface, the amount varying from 350 to 400 ft. of surface.

Uncovered basement piping should be painted with black japan or asphaltum varnish.

In painting the piping in greenhouses, do not use tar paints or asphaltum, as the odor or fumes given off, when heated, will injure the plants. The best policy is to leave unpainted all greenhouse piping. However, in case it is necessary, use lampblack mixed with turpentine and a very little boiled linseed oil.

In mixing colors to harmonize with other decorations, the following table will prove useful as a guide. The first color named in each combination is the base or predominant shade. Remember to use only japan and turpentine in your mixing.

Gray: Use white lead and lampblack.

Buff: Use white lead, yellow ochre and red.

Orange: Use yellow and red.

Snuff: Use yellow and Vandyke brown.

Pearl: Use white, black and blue.

Drab: Use white, raw and burnt umber; or white, yellow ochre, red and black.

Fawn: Use white, yellow and red.

Flesh: Use white, yellow ochre and vermilion.

Gold: Use white, stone ochre and red.

Copper: Use red, yellow and black.

Lemon: Use white and yellow.

Pea Green: Use white and chrome green.

Bronze-Green: Use chrome green, black and yellow; or white, yellow ochre, red and black.

In tinting use nearly as much of the base or first-named color, as is desired and tint with the following named or supplementary colors.

Colored enameled paints for the decoration of radiators may be procured. However, we advise against their use, as they tend to subtract from the efficiency of the radiating surfaces by filling and sealing the pores of the iron, thus making necessary a larger amount of heating surface than would otherwise be required.

Care should be taken to remove all oil or grease from the surfaces to be painted or bronzed.

Guaranty

It may not be amiss to make mention of and comment on the above term as used verbally or written in contracts by the heating contractor. While, no doubt, the man who is doing honest and conscientious work, figuring a sufficiency of radiation and plenty of boiler power, has little to fear from the employment of this word, there are occasions where it becomes unwise to make use of it in a heating contract. In contracts for heating work we have noted many times the words "I guarantee satisfaction," or "I guarantee to give you a satisfactory job." This word "satisfaction" employed in this connection is apt to prove a troublesome one and a contractor is making a great mistake when he incorporates it in a heating contract. He may be perfectly honest in his intentions to give the owner a "satisfactory" job and may go to extremes in his endeavors to do perfect work and satisfy the owner. However, it leaves a loophole for the sharp and unscrupulous man to crawl into and although the job may be perfect in its working and effectiveness he may withhold payment for it indefinitely on the plea that he is not satisfied.

If a guaranty is included, it should be carefully worded to cover certain specific things. A certain temperature in each room in which radiation is placed, a workmanlike job, a boiler or heater to be of sufficient size to do the work easily, all or any one of these conditions may be safely guaranteed by the contractor who does good work.

Architects, unwisely, frequently draw up specifications in which certain conditions are set forth and the heating contractor is requested to sign a contract of which these specifications become a part. He should refuse to affix his name to them until all the circumstances are clearly stated.

Commercially the clause "70° in zero weather" implies that the apparatus must be of sufficient size to heat a certain building in which it is placed to this degree when the prevailing temperature outside the building stands at zero. In many sections of this country in which artificial heat is required, the thermometer may not register a zero weather temperature once in five years or more, and therefore should the architect or owner resort to unprincipled practice the heating contractor would be compelled to wait an indefinite time for payment.

As stated in a former chapter of this book, Prof. Carpenter has given a very good and accurate rule for summer or warm weather tests and where a 70° clause is inserted in a contract, there should be a reference made to this or some other equally good rule governing a test which will be acceptable alike to owner and contractor.

Quite frequently we find an architect or owner who requires the heating contractor to give a bond that the apparatus when completed will perform a certain work. Where a bond of this nature is insisted upon, the contractor should be paid in full the moment his work is finished. We have always regarded the furnishing of a bond as tending to operate against the best interests of the owner. In his anxiety to have the work completed at as low a price as possible, he may accept the low bid of a contractor without responsibility or reputation, require a bond from him and save a few dollars on the original cost of the contract. When difficulty arises, as is quite likely in such cases, and it becomes necessary to bring suit, the expenses incident to such action more than offset the amount originally saved and the owner has the further trouble, discomfort and expense of the temporary maintenance of an unsatisfactory job. Had the work been awarded to a contractor of experience and reputation no such trouble would be experienced.

It would seem that the over-anxiety of some heating contractors to secure work is largely responsible for many of the conditions we have enumerated. In some instances they seem willing to agree to anything or to sign any document in order to obtain a contract, and this of itself should furnish a danger signal to both architect and owner, as the responsible man will not affix his name or agree to anything which he cannot consistently perform, or which is against his best interests.

In examining the contracts of some heating contractors of large experience, we find some clauses included which are well worth our consideration. In connection with the "Acceptance" clause we find the following:

"Upon notification from us that the work herein specified is complete, it shall be promptly inspected and accepted or rejected, so that our man, while still on the premises, may, without delay, complete it or remedy any defect that may appear, after which you are to give said man written acceptance of the work herein specified, it being agreed that such acceptance is not a waiver of our guaranties.

"If not inspected immediately on completion, the apparatus will be left in your charge, and our responsibility for it ceases.

"Failure to so promptly inspect and accept or reject said work shall be construed as an acceptance of it, and shall entitle us to payment according to contract."

Or this:

"The apparatus, in so far as the mechanical work thereof and the construction of the same are concerned, shall be considered as accepted immediately upon completion. If it be found that the same does not comply with said specifications, notice thereof shall be given in writing immediately to the heating contractor.

"It is distinctly understood that no payments or part thereof are to be delayed on account of lack of cold weather in which to test the heating apparatus, as the guaranty herein contained is binding upon the heating contractor as to the fulfillment of the contract. It is further understood that such acceptance shall not be deemed a waiver of our guaranty as to efficiency of the heating apparatus."

As to the forms of guaranties, we have given in the chapter on "Business Methods" a short concise form. Some others, which in certain cases cover more of the detail of the work, are as follows:

(*a*) "We hereby guarantee that the apparatus shall be noiseless in operation, of ample capacity and, under proper conditions of firing and management, to be capable of warming all rooms in which radiators are placed to — degrees in coldest weather.

(*b*) "The apparatus is guaranteed for a period of one year from this date against any defects of workmanship or materials. Should any defect or deficiency develop, we will, upon notice, make good such defect or deficiency at our expense."

Or this:

"When the apparatus herein proposed to be furnished is completed in accordance with the conditions hereof, we guarantee that it will be so constructed as to permit steam to circulate in all its parts with — pressure thereon, or any higher pressure; and that the said apparatus shall be capable of continuously warming all parts of said building that are enumerated in Section 8 of this proposal (schedule of radiation and temperatures) to the temperature mentioned therein when the outside temperature is — degrees below zero; further, the buildings and apparatus being kept in repair, and the apparatus properly operated, there shall be no snapping, cracking or pounding in the piping or radiators. We further guarantee all materials furnished shall be free from all defects for a period of one year from the date of this instrument."

Several of the guaranties examined contain this or a similar clause:

"The chimney furnished by the owner shall be large enough to be capable of passing sufficient air to insure rapid combustion of fuel. We will not be responsible for failure of apparatus due to insufficient draught."

A steam or hot-water heating apparatus or a ventilating apparatus is designed to secure certain results under certain given conditions and these should be clearly stated in and be made the subject matter of all conditions and guaranties of a contract.

Boiler Explosions

The danger arising from the explosion of a low-pressure cast-iron steam or hot-water heater is very remote, yet it is a feature which causes fear in the mind of every nervous person whose duty it is to attend to such a heater or to be in any manner brought into close contact with it. While it is a fact that many boilers explode, the percentage is small, even considering the vast number of boilers used for generating steam for power purposes as well as for heating. There is no question but that excess of pressure is the cause of all explosions; we mean by this, excess over the ability of the boiler to stand. For instance, a boiler may be built originally to withstand a pressure of 250 pounds, but through frequent scaling, or from rupture, or some other damaging cause, may become weakened to such an extent that 100 lbs. would be an excess of pressure for it to carry with safety.

Low water in such a boiler, with the consequent rapid vaporizing into steam, due to a hot fire, would cause it to explode, and were the explosion to occur instantly it would be accompanied with disastrous results. If, on the contrary, there were a gradual tearing of the iron at the weak point or gradual opening of the rupture, no very great damage might occur.

Most of the disastrous explosions of heating boilers have occurred where boilers of the tubular (vertical or horizontal) or fire-box type were used and but few have happened with cast-iron boilers.

There are many theories as to the causes of boiler explosions, and when applied to boilers employed for warming, the principal one seems to be that the explosion is caused by admitting cold water into red-hot boilers. When for some unaccountable reason the boiler has been drained or the water in it lowered well below the crown-sheet surface, the sudden admission of a quantity of cold water will cause trouble; not necessarily an explosion, for we do not believe this would be the result once in ten times. If a cast-iron boiler, the sections would undoubtedly crack; if a wrought-iron boiler, a rupturing of the plates and riveting would likely result, requiring in either case extensive repairs.

We have alluded especially to steam boilers as being liable to explode under certain conditions, but, as a matter of fact, the most dangerous explosions of heating apparatus might occur with a hot-water system. The pent-up or stored energy in a hot-water apparatus is very much greater than that from steam at an equal volume. The sudden releasing of this force, due to a break in the apparatus, is liable to cause great damage, including a possible loss of life.

Prevention of Explosions

In the operation of a steam-heating apparatus only ordinary caution is necessary to prevent a rupture or explosion of the boiler, provided the usual safeguards are furnished with the apparatus. These safeguards are, first, a safety valve of adequate size, kept operative by frequent testing; second, the providing of a fusible plug, which should be placed at a point just below the low water-line of the boiler, that is, the lowest level at which the water may stand with safety; third, the provision of a sediment cock at a low point, where sediment (mud, sand, etc.) may be frequently drawn from the boiler.

Should valves be placed on the flow and return pipes at the boiler, they must be used with caution. Never entirely close the valves on the steam main without checking and thereby cooling the fire. *Never* close all valves on the return pipes while the valves on steam-supply pipes are open, or when heat is on the building.

We have known cases where a slothful janitor left the valves on the returns closed, with the result that the rapid condensing of the steam and collection of the condensation in the returns lowered the water in the boiler below the level of safety.

When this condition occurs, or should the water become low from any other cause, do not open the valves on the returns and admit the water of condensation, which has cooled, and do not admit any other supply of cold water until, as a precautionary measure, the fire has been dampened or drawn and the boiler allowed to cool for two hours.

In operating a hot-water heating apparatus but few precautions are necessary, provided the contractor in erecting the work has exercised due care. There should be no valves placed on the expansion-tank connections. The tank should be placed in a warm room in order that these connections will not freeze. If of necessity the tank must be located in a cold spot, it should be circulated in a manner illustrated in a previous chapter of this book, in order to prevent freezing. With the tank open to the atmosphere the attendant of a hot-water boiler may feel absolutely safe as far as any danger or damage from explosion is concerned.

Utilizing Waste Heat

Wasted heat units in the process of heating or manufacturing often represent an expense for fuel, which, if saved, would materially lessen the cost of production and add to the profits of the business. Many of our readers are no doubt more or less familiar with the old methods of heating dryers, dry kilns, etc., by the use of steam coils.

The waste of heat in an ordinary heating apparatus, due to poor draught or an imperfect chimney, we have commented upon and shown the advantages and saving accruing from perfect combustion and a properly constructed chimney. We have also shown the benefit resulting from the use of the exhaust steam from engines, pumps, etc. In this chapter we wish to make mention of the saving effected by a proper use of fans.

The trouble encountered in using the old style of dryer and heat from steam coils was principally due to the slow and often uncertain movement of the air in the dryer. In drying lumber, bricks and pottery the circulation of air is as important as the heat provided. The same is true regarding the drying of manufactured wooden articles, of laundry and all the various woolen and cotton products. High temperatures are maintained in the dry-room or kiln and under the original methods of drying by steam the hotter the dry-room the quicker and the cheaper the desired results could be obtained.

The character of the work, that is to say, the nature of the material to be dried and the temperature necessary to be maintained govern the method of installing the apparatus. There are two general methods of utilizing waste heat for this purpose, the first, the utilizing of exhaust steam in heating coils within the dryer, air being forced into and through it by a pulley-driven fan located at one end of the dryer. The second is that which is adapted for the drying of bricks or pottery, where the waste heat from cooling kilns is drawn through ducts to a fan, which in turn delivers it, in such quantities as desired, to the dryer. An exhaust fan is located at the opposite end of the dryer to facilitate the movement of the air.

To illustrate this method we have chosen the apparatus as designed by the New York Blower Company and show by Fig. 303 an elevation plan and by Fig. 304 a ground-floor plan of the same. There are so many adaptations of this method that it is not convenient to illustrate or discuss all of them.

When no waste heat is available, an ordinary type of pipe heater may be used with a blower fan and exhaust steam used in the heater.

On many jobs a large proportion of the heat units from the

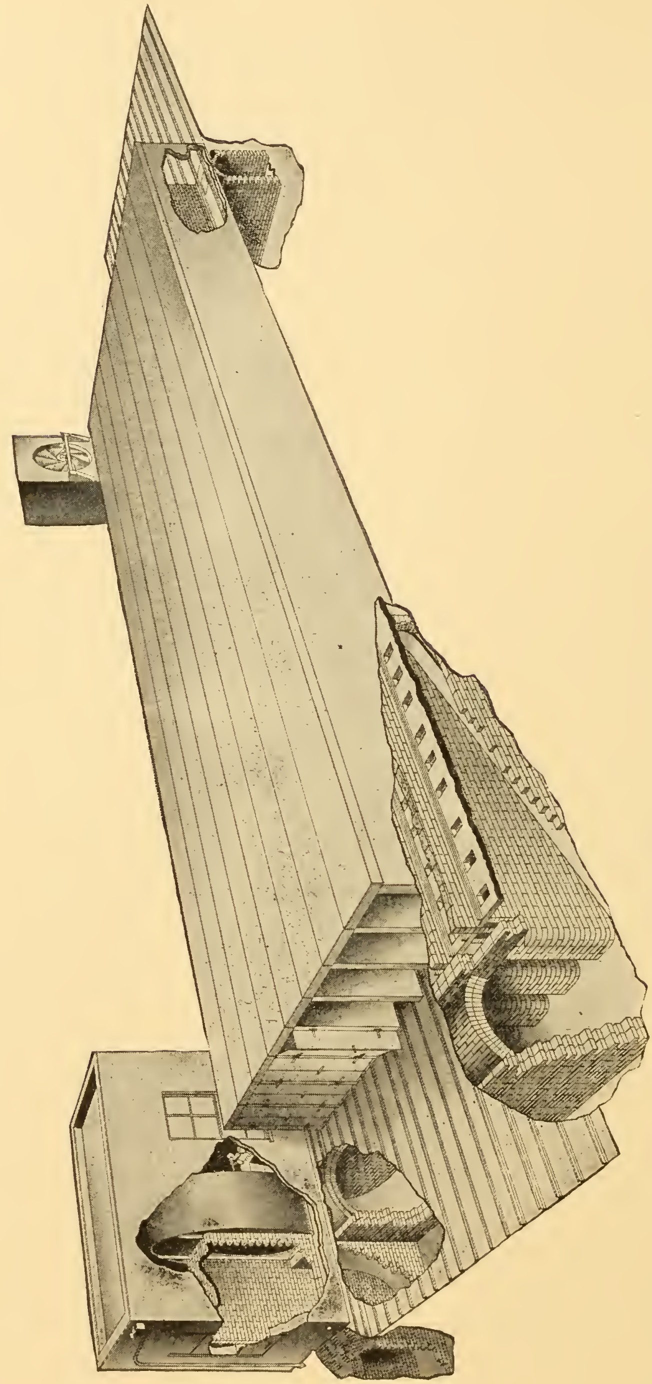

Fig. 303.—Utilizing waste heat in brick dryer.

coal consumed will be lost in the chimney flue, the amount of loss being dependent on the character of the boiler, as some boilers

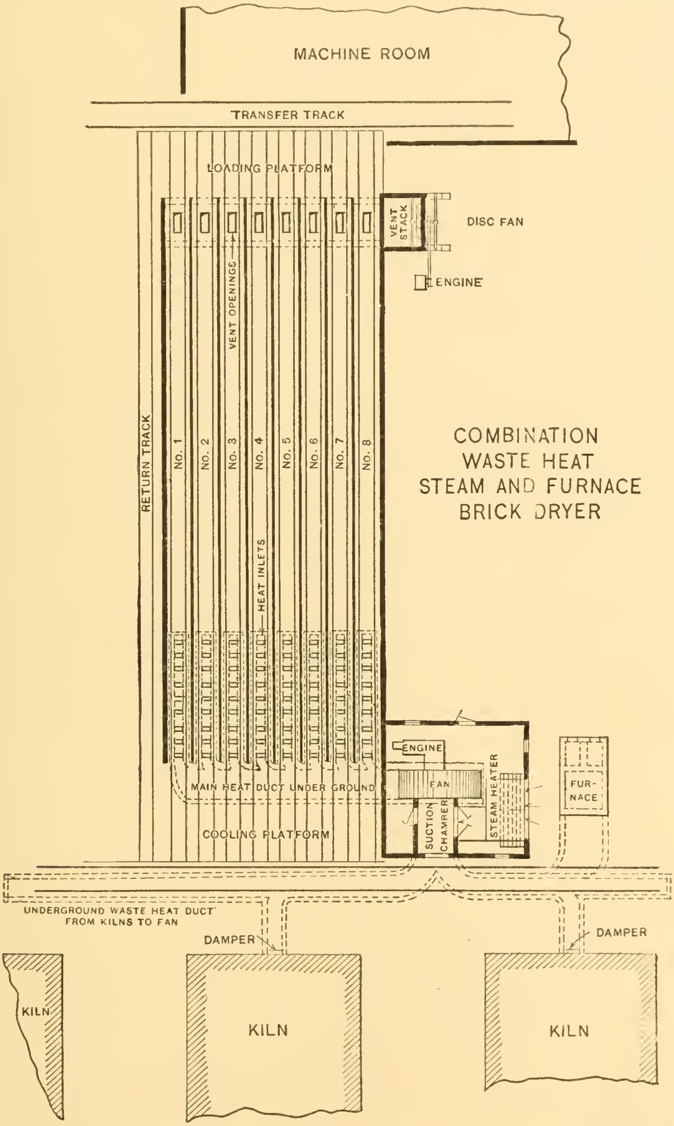

FIG. 304.—Ground-floor plan waste-heat utilizer.

have more of a direct draught than others and consequently lose more of the heat units from the fuel consumed. It is true that a certain percentage of this loss is necessary—the chimney must be provided with sufficient heat to expand the air in the flue and to produce sufficient draught in the same.

There are several methods of utilizing the heat units ordinarily wasted in this manner. The hot smoke and gases may be passed through the flues of a cylindrical jacket or water heater, thus warming a sufficient quantity of water for domestic purposes. Again, they may pass through a supplementary casing under the ordinary type of hot-water storage tank, the smoke and gases entering this compartment at one end of the tank and leaving the compartment at the opposite end. It is a fact in heating practice that the hotter the return water, the more easily it is reheated by the boiler and circulated, if a hot-water apparatus, or generated into steam, if a steam-heating apparatus.

The smoke and hot gases usually wasted may be utilized in heating the return water on a steam job by returning the condensation through a heater having large flues through which the hot gases pass en route to the chimney, thus adding to the capacity of the boiler and accomplishing at the same time a material saving in fuel.

While to a certain extent mechanical methods of drying and utilizing waste heat, or the reheating of return water, have no particular bearing on general steam-fitting practice, it is well to become familiar with the various methods employed in this direction.

CHAPTER XXVIII

Rules, Tables, and Other Information

The author has selected the following information and tables from a large mass of data gathered from all reliable sources, as being of value to the steam fitter and heating contractor.

While we cannot in every case guarantee the correctness of the data given, we believe all the information to be fully reliable, as it has been compiled from standard authorities and by men of practical experience.

As we have previously remarked in the pages of this book, there is no rule but what must be applied with judgment, as existing conditions necessarily govern its application. Where this care is exercised the information given will prove of very great value and assistance to the practical steam fitter.

Rules, Tables, and Useful Information

A U. S. gallon weighs 8.331 lbs. and contains 231 cubic inches or .13667 cubic feet.

224 gallons of pure water weigh one ton; 13.44 gallons weigh 100 lbs.

A cubic foot of water at a temperature of 32° Fahr. weighs 62.418 lbs.; at 212° Fahr. it weighs 59.76 lbs.

The expansion of water from 32° Fahr. (freezing) to 212° Fahr. (boiling) is one gallon in each twenty-three, or approximately $4\frac{1}{3}\%$.

Water boils in vacuum at 98° Fahr, at sea level at 212° Fahr.

In figuring *weight* of water its *bulk* or *quantity* is considered. In determining *pressure*, the *height of its column* (vertical) is figured, approximately ½ lb. for each foot of height.

A column of water one foot high equals a pressure of .433 lb. per square inch. A pressure of 1 lb. per square inch equals 2.31 feet of water in height..

Water transformed into steam expands 1,700 times its volume. One cubic inch of water will produce approximately one cubic foot of steam.

A pound of anthracite coal contains about 14,500 heat units.

A bushel of anthracite coal weighs about 86 lbs. A ton of anthracite contains about 40 cubic feet.

A bushel of bituminous coal weighs about 76 lbs. A ton of bituminous contains about 49 cubic feet.

The average consumption of fuel in a power boiler is 7½ pounds of coal or 15 pounds of dry pine wood for each cubic foot of water evaporated.

One square foot of grate (tubular boiler) will with natural draught consume 12 pounds of anthracite or 20 pounds of bituminous coal per hour. Double this amount can be burned with forced draught.

Each nominal Horse Power in a tubular boiler requires 1 cubic foot of water per hour.

Condensing engines require from 20 to 25 gallons of water to condense the steam from one gallon of water.

In calculating Horse Power of tubular or flue boilers, 15 square feet of heating surface is equivalent to one *nominal* Horse Power.

The specific gravity of steam at atmospheric pressure is .411 that of air at 34° Fahr., and .0006 that of water at the same temperature.

To determine necessary surface in square feet for aspirating coil in ventilating flue, divide the cubic feet of air to be moved per hour by .95 when steam is used, or .60 when hot water.

To find capacity of expansion tank required, multiply the square feet of radiation by .03 if less than 1,000 sq. ft. Multiply by .025 between 1,000 and 2,000 sq. ft. and by .02 if more than 2,000 sq. ft. The result will be the size in gallons.

To find the length of pipe required when making an offset with 45° fittings, a simple rule is as follows: For each inch of offset add $\frac{13}{32}$ of an inch and the result will be the center-to-center measurement of the 45° angle.

Twelve pounds of air are required to supply oxygen enough to burn one pound of coal.

Perfectly dry air expands one-four-hundred-ninetieth (1/490) of its volume when heated from 32 degrees to 190 degrees. When saturated with vapor it expands nearly four times its former volume.

The velocity of hot air from a furnace is approximately 10 feet per second at the register, with ordinarily good circulation.

To find the circumference of a circle multiply the diameter by 3.1414 or by $3\frac{1}{7}$.

To find diameter of circle, multiply the circumference by 0.3183.

To find the area of a circle multiply .7854 by the square of the diameter, that is, by the diameter multiplied by itself.

Cement for Steam Boilers: Red or white lead in oil four parts, iron borings three parts, makes a soft cement.

Cement for Leaky Boilers: A cement for leaky boilers (steam or hot water) consists of two parts powdered litharge, two parts of fine sand and one part of slacked lime. Mix with linseed oil and apply quickly.

Rule for Calculating Speed and Size of Pulleys

To Find the Size of Driving Pulley: Multiply the diameter of the driven by the number of revolutions it shall make and divide the answer by the revolutions of the driver per minute. The answer will be the diameter of the driver.

To Find the Diameter of the Driven That Shall Make a Given Number of Revolutions: Multiply the diameter of the driver by its number of revolutions and divide the answer by the number of revolutions of the driven. The answer will be the diameter of the driven.

To Find the Number of Revolutions of the Driven Pulley: Multiply the diameter of the driver by its number of revolutions and divide by the diameter of the driven. The answer will be the number of revolutions of the driven.

When it is not convenient to measure with the tape line the length required, apply the following rule: Add the diameter of the two pulleys together, divide the result by 2, and multiply the quotient by 3¼, then add this product to twice the distance between the centers of the shafts, and you have the length required.

The working adhesion of a belt to the pulley will be in proportion both to the number of square inches of belt contact with the surface of the pulley and also to the arc of the circumference of the pulley touched by the belt. This adhesion forms the basis of all right calculation in ascertaining the width of belt necessary to transmit a given horse power.

TABLE XXIX

GAUGES AND THEIR EQUIVALENTS

No. 27, equal to $\frac{1}{64}$ inch.	No. 12, equal to $\frac{7}{64}$ inch.
No. 21, equal to $\frac{1}{32}$ inch.	No. 10, equal to $\frac{1}{8}$ inch.
No. 18, equal to $\frac{3}{64}$ inch.	No. 8, equal to $\frac{11}{64}$ inch.
No. 16, equal to $\frac{1}{16}$ inch.	No. 6, equal to $\frac{3}{16}$ inch.
No. 14, equal to $\frac{5}{64}$ inch.	No. 5, equal to $\frac{7}{32}$ inch.
No. 13, equal to $\frac{3}{32}$ inch.	No. 4, equal to $\frac{1}{4}$ inch.

To Find Expansion of Pipe: Deduct the temperature of pipe at time of installation from the maximum temperature to which it will be heated, take $\frac{8}{10}$ of this difference and divide by 100. The result will equal the expansion in inches for each 100 lineal feet of pipe.

To Determine the Capacity of a Cylinder or Round Tank in Gallons: Multiply the diameter in inches by itself, this by the height in inches, and the result by 24.

Another rule is to multiply the square of the diameter in feet by 0.7854 and this by the depth in feet. This result multiplied by 7.476 will give the capacity in gallons.

To Clean Brass: Mix in a stone jar one part of nitric acid, and one half part of sulphuric acid. Dip the brass into this mixture, wash in water, and dry in sawdust. If greasy, first clean the brass by dipping in a strong mixture of potash, soda, and water, and wash thoroughly in water.

To Remove Stains from Marble: Mix two parts of soda, one of ground pumice, and one of finely-powdered chalk. Sift through a fine sieve and with water mix into a paste. Rub this composition on the marble and wash with soap and water.

To Remove Grease Stains from Marble: Mix one and one half parts of soft soap, three parts of fuller's earth, and one and one half parts of potash with boiling water. Cover grease spots with this mixture and allow it to stand twenty-four hours, after which wash with hot water.

To Remove Rust from Steel: Steel which has been rusted can be cleaned by brushing with a paste compound of ½ oz. cyanide of potassium, ½ oz. castile soap, 1 oz. whiting, and water sufficient to form a paste. The steel should be washed with a solution of ½ oz. cyanide of potassium in 2 oz. of water.

To Prevent Machinery from Rusting: Take 1 oz. of camphor and dissolve in one pound of melted lard. Remove the scum and mix enough lamp-black to give an iron color. Clean the machinery and smear it with the mixture. Under ordinary circumstances it will not rust for months.

To Harden Cast Iron: Cast iron can be hardened as easily as steel, and to such a degree of hardness that a file will not touch it. Take one half pint of vitriol, one peck of salt, one half pound of saltpetre, two pounds of alum, one quarter pound prussic potash, one quarter pound of cyanide of potash and dissolve in ten gallons of rain water. Stir until thoroughly dissolved. Heat the iron to a cherry red and dip it into the solution. If the iron needs to be very hard, reheat it and dip a second or a third time.

To Inscribe Metal: Cover the part with melted beeswax; when cold, write what you desire plainly in the wax, taking care that the scriber cleans the wax from the metal. Then with a mixture of ½ oz. nitric acid and 1 oz. of muriatic acid carefully fill each letter of the inscription. For this service a feather will be found to be very adaptable. Let the acid remain for from one to ten minutes and then throw on water to arrest the action of the acid. Remove the wax by heating and the inscription will be completed.

TABLE XXX

Melting Points of Metals

Tin	446°	Brass	1,900°
Bismuth	507°	Copper	1,996°
Lead	617°	Gold	2,066°
Zinc	773°	Glass	2,377°
Antimony	810°	Steel	4,000°
Aluminum	1,400°	Cast iron	2,250°
Bronze	1,692°	Wrought iron	2,912°
Silver	1,873°	Platinum	3,080°

TABLE XXXI

Boiling Points of Fluids

Water (Complete Vacuum)	98°	Linseed Oil	597°
Water (At Sea Level)	212°	Mercury (Atmospheric Pressure)	676°
Alcohol	173°	Ammonia	140°
Sulphuric Acid	240°	Coal Tar	325°
Refined Petroleum	316°	Olive Oil	413°
Turpentine	315°	Sea Water (Average)	213°
Sulphur	570°		

TABLE XXXII

Tables of Weights and Measures

Liquid Measure

4 gills	make	1 pint	4 quarts	make	1 gallon
2 pints	"	1 quart	31½ gallons	"	1 barrel

Measures of Length

4 inches	make	1 hand	5½ yards	make	1 rod or pole
7.92 "	"	1 link	40 poles	"	1 furlong
18 "	"	1 cubit	8 furlongs	"	1 mile
12 "	"	1 foot	69⅙ miles	"	1 degree
6 feet	"	1 fathom	60 geographical miles	"	1 degree
3 "	"	1 yard	1,760 yards or 5,280 feet	"	1 mile

Measures of Surface

144 square inches	make	1 square foot
9 square feet	"	1 square yard
30¼ square yards	"	1 square rod
40 square rods	"	1 square rood
4 square roods	"	1 square acre
10 square chains	"	1 square acre
640 square acres	"	1 square mile

Cubic Measures

1,728 cubic inches	make	1 cubic foot
2,150.42 cubic inches	"	1 bushel
46,656 cubic inches	"	1 cubic yard
7,276.5 cubic inches	"	1 barrel
27 cubic feet	"	1 cubic yard
128 cubic feet	"	1 cord
4.21 cubic feet	"	1 barrel

Weight of Metals

Lead	1 foot square, 1 inch thick, weighs	59.06	pounds
Copper	1 " " 1 " " "	45.3	"
Cast Iron	1 " " 1 " " "	37.54	"
Wrought Iron	1 " " 1 " " "	40.5	"
Cast Steel	1 " " 1 " " "	40.83	"

Table of Weights (avoirdupois)

16 drams	make	1 ounce (oz.)
16 ounces	"	1 pound (lb.)
25 pounds	"	1 quarter (qr.)
4 quarters	"	1 hundred (cwt.)
20 cwt. or 2,000 lbs	"	1 net ton

The gross ton is 2,240 pounds.

Weights, etc.

One Cubic Inch of Cast Iron weighs	0.26	pound
One Cubic Inch of Wrought Iron weighs	0.28	pound
One Cubic Inch of Water weighs	0.36	pound
One United States Gallon weighs	8.33	pounds
One Imperial Gallon weighs	10.00	pounds
One United States Gallon equals	231.00	cubic inches
One Imperial Gallon equals	277.274	cubic inches
One Cubic Foot of Water equals	7.48	U. S. gallons
One Pound of Steam equals	27.222	cubic feet
One Pound of Air equals	13.817	cubic feet

TABLE XXXIII

Metric System

Prefixes of Multiples and Sub-Multiples of Meter, Liter, and Gram

Deka = 10	Deci = 0.1
Hecto = 100	Centi = 0.01
Kilo = 1000	Milli = 0.001
10 millimeters = 1 centimeter.	10 meters = 1 dekameter.
10 centimeters = 1 decimeter.	10 dekameters = 1 hectometer.
10 decimeters = 1 meter.	10 hectometers = 1 kilometer.

Metric Equivalents

Linear Measure

1 centimeter = 0.3937 in.	1 in. = 2.54 centimeters or 0.254 meter.
1 decimeter = 3.937 in. = 0.328 ft.	1 ft. = 3.048 decimeters or 0.3048 meter.
1 meter = 39.27 in. = 1.0936 yards.	1 yard = 0.9144 meter.
1 dekameter = 1.9884 rods.	1 rod = 0.5029 dekameter.
1 kilometer = 0.62137 mile.	1 mile = 1.6093 kilometers.

Surface or Square Measure

1 sq. centimeter = 0.1550 sq. in.	1 sq. inch = 6.452 sq. centimeters.
1 sq. decimeter = 0.1076 sq. ft.	1 sq. foot = 9.2903 sq. decimeters.
1 sq. meter = 1.196 sq. yd.	1 sq. yard = 0.8361 sq. meter.
1 are = 3.954 sq. rods.	1 sq. rod = 0.2529 are.
1 hektar = 2.47 acres.	1 sq. acre = 0.4047 hektar.
1 sq. kilometer = 0.386 sq. mile.	1 sq. mile = 2.59 sq. kilometers.

Measure of Volume and Capacity

1 cu. centimeter = 0.061 cu. in.	1 cu. inch = 16.39 cu. centimeters.
1 cu. decimeter = 0.0353 cu. ft.	1 cu. foot = 28.317 cu. decimeters.
1 cu. meter } = { 1.308 cu. yards.	1 cu. yard = 0.7646 cu. meter.
1 ster } = { 0.2759 cord.	1 cord = 3.624 sters.
1 liter = { 0.908 quart dry.	1 quart dry = 1.101 liters.
1.0567 quarts liq.	1 quart liq. = 0.9463 liter.
1 dekaliter = { 2.6417 gallons.	1 gallon = 0.3785 dekaliter.
.135 peck.	1 peck = 0.881 dekaliter.
1 hectoliter = 2.8375 bushels.	1 bushel = 0.3524 hectoliter.

Weights

1 gram = 0.0527 ounce.	1 ounce = 28.35 grams.
1 kilogram = 2.2046 lbs.	1 lb. = 0.4536 kilogram.
1 metric ton = 1.1023 English tons.	1 English ton = 0.9072 metric ton.

TABLE XXXIV

MINIMUM AND MEAN TEMPERATURE OF EIGHT MONTHS FOR CITIES OF THE UNITED STATES AND CANADA

Compiled from Observations of the Signal Service, U. S. A.

STATIONS.	Minimum and mean temperature of each month. Sept. min.	Sept. mean.	Oct. min.	Oct. mean.	Nov. min.	Nov. mean.	Dec. min.	Dec. mean.	Jan. min.	Jan. mean.	Feb. min.	Feb. mean.	Mar. min.	Mar. mean.	April. min.	April. mean.	No. of months fire is required.	Mean temperature of winter months	Max. number degrees temperature to be raised.	Relative demand for radiators.
Albany, N. Y.	33	61	23	49	10	39	17	28	16	24	18	25	4	35	13	47	7	26	87	100
Baltimore, Md.	40	67	30	55	16	44	1	34	2	31	3	32	9	39	23	52	6	32	72	90
Boston, Mass.	35	62	26	51	2	40	11	30	3	27	5	28	2	36	11	46	7	28	81	100
Buffalo, N. Y.	21	65	25	48	2	31	6	30	5	28	13	28	3	30	13	34	8	29	83	100
Burlington, Vt.	32	60	22	48	10	36	18	24	16	20	20	20	1	31	10	42	7	21	90	110
Chicago, Ill.	37	60	25	48	0	38	14	29	20	24	13	25	5	32	17	46	7	25	90	110
Charleston, S. C.	57	76	39	64	28	55	23	51	26	52	28	52	28	60	39	68	3	52	47	60
Cincinnati, Ohio	41	66	27	53	6	42	6	34	7	33	1	34	13	43	18	54	7	34	77	100
Cleveland, Ohio	38	67	26	51	8	37	5	37	13	33	11	33	0	37	15	39	7	34	83	100
Detroit, Mich.	35	60	22	48	4	38	9	27	15	27	20	27	2	35	8	46	7	27	90	110
Duluth, Minn.	34	59	21	43	29	24	30	20	38	13	34	16	26	24	3	33	8	16	108	130
Indianapolis, Ind.	35	70	25	51	2	37	15	37	18	36	8	36	9	42	19	46	7	36	88	100
Leavenworth, Kan.	37	67	19	57	3	42	4	32	20	28	9	29	2	40	20	49	6	30	90	100
Louisville, Ky.	42	72	28	54	10	41	5	39	10	37	0	39	16	46	21	49	6	38	80	110
Memphis, Tenn.	41	73	30	56	25	49	3	44	2	45	13	45	18	53	35	55	5	45	68	70
Milwaukee, Wis.	32	61	23	51	14	38	19	23	25	25	22	29	3	35	12	41	8	26	95	110
New York, N. Y.	42	66	31	54	7	43	2	33	6	30	1	30	8	38	20	49	7	31	76	100
Philadelphia, Pa.	45	64	31	51	8	41	4	33	5	32	1	33	9	42	21	51	7	33	75	100
Pittsburgh, Pa.	36	64	28	51	8	40	6	31	12	29	10	31	2	39	14	50	7	30	82	100
Portland, Me.	37	57	28	46	6	35	12	24	7	20	7	21	1	30	14	40	8	22	82	110
Portland, Ore.	39	61	32	50	27	47	17	37	3	43	24	44	31	45	28	54	6	41	67	80
San Francisco, Cal.	50	61	49	59	44	57	39	51	36	49	41	51	41	51	40	55	4	50	34	60
St. Louis, Mo.	40	69	25	55	11	41	5	34	16	33	3	35	8	44	22	58	5	34	86	100
St. Paul, Minn.	30	61	21	41	24	26	27	19	30	14	32	14	15	24	7	37	7	16	102	130
Washington, D. C.	40	68	26	58	16	45	3	37	3	34	2	37	12	45	22	56	5	36	73	90
Wilmington, Del.	50	74	32	61	25	52	15	49	17	50	15	48	22	57	28	63	4	49	55	70
Halifax, N. S.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	7	25	80	100
Montreal, P. Q.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8	21	91	110
Toronto, Ont.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8	27	82	110
Chatham, N. B.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8	15	94	130

TABLE XXXV

COMPARISON OF THERMOMETRIC SCALES

Fahrenheit.	Centigrade.	Reaumur.	Fahrenheit.	Centigrade.	Reaumur.
− 40	− 40.00	− 32.00	+ 125	+ 51.67	+ 41.33
" 35	" 37.22	" 29.78	" 130	" 54.44	" 43.56
" 30	" 34.44	" 27.56	" 135	" 57.22	" 45.78
" 25	" 31.67	" 25.33	" 140	" 60.00	" 48.00
" 20	" 28.89	" 23.11	" 145	" 62.78	" 50.22
" 15	" 26.11	" 20.89	" 150	" 65.55	" 52.44
" 10	" 23.33	" 18.67	" 155	" 68.33	" 54.67
" 5	" 20.55	" 16.44	" 160	" 71.11	" 56.89
0	" 17.78	" 14.22	" 165	" 73.89	" 59.11
+ 5	" 15.00	" 12.00	" 170	" 76.67	" 61.33
" 10	" 12.22	" 9.78	" 175	" 79.44	" 63.56
" 15	" 9.44	" 7.56	" 180	" 82.22	" 65.78
" 20	" 6.67	" 5.33	" 185	" 85.00	" 68.00
" 25	" 3.89	" 3.11	" 190	" 87.78	" 70.22
" 30	" 1.11	" 0.89	" 195	" 90.55	" 72.44
" 32	0.0	0.00	" 200	" 93.33	" 74.67
" 35	+ 1.67	+ 1.33	" 205	" 96.11	" 76.89
" 40	" 4.44	" 3.56	" 210	" 98.89	" 79.11
" 45	" 7.22	" 5.78	" 212	" 100.00	" 80.00
" 50	" 10.00	" 8.00	" 250	" 121.10	" 96.90
" 55	" 12.78	" 10.22	" 300	" 148.89	" 119.20
" 60	" 15.55	" 12.44	" 302	" 150.00	" 120.00
" 65	" 18.33	" 14.67	" 350	" 176.66	" 141.40
" 70	" 21.11	" 16.89	" 392	" 200.00	" 160.00
" 75	" 23.89	" 19.11	" 464	" 240.00	" 192.00
" 80	" 26.67	" 21.33	" 500	" 260.00	" 208.00
" 85	" 29.44	" 23.56	" 572	" 300.00	" 240.00
" 90	" 32.22	" 25.78	" 600	" 315.06	" 252.40
" 95	" 35.00	" 28.00	" 662	" 350.00	" 280.00
" 100	" 37.78	" 30.22	" 700	" 371.11	" 296.90
" 105	" 40.55	" 32.44	" 752	" 400.00	" 320.00
" 110	" 43.33	" 34.67	" 800	" 426.66	" 341.30
" 115	" 46.11	" 36.89	" 932	" 500.00	" 400.00
" 120	" 48.89	" 39.11	....	....	....

TABLE XXXVI

TABLE OF THE AREAS OF CIRCLES AND OF THE SIDES OF SQUARES OF THE SAME AREA

Diameter of Circle in inches.	Area of Circle in square inches.	Sides of Sq. of same area in square inches.	Diameter of Circle in inches.	Area of Circle in square inches.	Sides of Sq. of same area in square inches.	Diameter of Circle in inches.	Area of Circle in square inches.	Sides of Sq. of same area in square inches.
1	.785	.89	21	346.36	18.61	41	1,320.26	36.34
½	1.767	1.33	½	363.05	19.05	½	1,352.66	36.78
2	3.142	1.77	22	380.13	19.50	42	1,385.45	37.22
½	4.909	2.22	½	397.61	19.94	½	1,418.63	37.66
3	7.069	2.66	23	415.48	20.38	43	1,452.20	38.11
½	9.621	3.10	½	433.74	20.83	½	1,486.17	38.55
4	12.566	3.54	24	452.39	21.27	44	1,520.53	38.99
½	15.904	3.99	½	471.44	21.71	½	1,555.29	39.44
5	19.635	4.43	25	490.88	22.16	45	1,590.43	39.88
½	23.758	4.87	½	510.71	22.60	½	1,625.97	40.32
6	28.274	5.32	26	530.93	23.04	46	1,661.91	40.77
½	33.183	5.76	½	551.55	23.49	½	1,698.23	41.21
7	38.485	6.20	27	572.56	23.93	47	1,734.95	41.65
½	44.179	6.65	½	593.96	24.37	½	1,772.06	42.10
8	50.266	7.09	28	615.75	24.81	48	1,809.56	42.58
½	56.745	7.53	½	637.94	25.26	½	1,847.46	42.98
9	63.617	7.98	29	660.52	25.70	49	1,885.75	43.43
½	70.882	8.42	½	683.49	26.14	½	1,924.43	43.87
10	78.540	8.86	30	706.86	26.59	50	1,963.50	44.31
½	86.590	9.30	½	730.62	27.03	½	2,002.97	44.75
11	95.03	9.75	31	754.77	27.47	51	2,042.83	45.20
½	103.87	10.19	½	779.31	27.92	½	2,083.08	45.64
12	113.10	10.63	32	804.25	28.36	52	2,123.72	46.08
½	122.72	11.08	½	829.58	28.80	½	2,164.76	46.53
13	132.73	11.52	33	855.30	29.25	53	2,206.19	46.97
½	143.14	11.96	½	881.41	29.69	½	2,248.01	47.41
14	153.94	12.41	34	907.92	30.13	54	2,290.23	47.86
½	165.13	12.85	½	934.82	30.57	½	2,332.83	48.30
15	176.72	13.29	35	962.11	31.02	55	2,375.83	48.74
½	188.69	13.74	½	989.80	31.46	½	2,419.23	49.19
16	201.06	14.18	36	1,017.88	31.90	56	2,463.01	49.63
½	213.83	14.62	½	1,046.35	32.35	½	2,507.19	50.07
17	226.98	15.07	37	1,075.21	32.79	57	2,551.76	50.51
½	240.53	15.51	½	1,104.47	33.23	½	2,596.73	50.96
18	254.47	15.95	38	1,134.12	33.68	58	2,642.09	51.40
½	268.80	16.40	½	1,164.16	34.12	½	2,687.84	51.84
19	283.53	16.84	39	1,194.59	34.56	59	2,733.98	52.29
½	298.65	17.28	½	1,225.42	35.01	½	2,780.51	52.73
20	314.16	17.72	40	1,256.64	35.45	60	2,827.74	53.17
½	330.06	18.17	½	1,288.25	35.89	½	2,874.76	53.62

TABLE XXXVII

Temperature of Steam at Various Pressures above that of the Atmosphere (14.7 lbs.)

Pounds Pressure.	Degrees Fahrenheit.	Pounds Pressure.	Degrees Fahrenheit.	Pounds Pressure.	Degrees Fahrenheit.
0	212	18	254.5	100	337.5
1	215.5	19	256	105	341
2	219	20	257.5	115	347
3	222	25	265	125	353
4	225	30	272.5	135	358
5	227.5	35	279.5	145	363
6	230	40	285.5	155	368
7	232.5	45	291	165	373
8	235	50	297	175	377
9	237.5	55	302	185	381
10	240	60	307	235	401
11	242	65	311	285	417
12	244	70	315	335	430
13	246	75	320	385	445
14	248	80	323	435	456
15	250	85	327	485	467
16	252	90	331	585	487
17	253.5	95	334	685	504

TABLE XXXVIII

Properties of Saturated Steam

Pressure.	Absolute Pressure.	Temperature Fahrenheit.	Total Heat above 32 degrees.		Latent Heat.	Relative Volume 39° = 1.	Volume C. F. in 1 lb. Steam.	Weight 1 cubic foot Steam. Lbs.
			Heat Units in the Water.	Heat Units in the Steam.				
0.0	14.7	212.0	180.9	1,146.6	965.7	1,646.0	26.36	.03794
1.3	16.0	216.3	185.3	1,147.9	962.7	1,519.0	24.33	.04110
2.3	17.0	219.4	188.4	1,148.9	960.5	1,434.0	22.98	.04352
3.3	18.0	222.4	191.4	1,149.8	958.3	1,359.0	21.78	.04592
4.3	19.0	225.2	194.3	1,150.6	956.3	1,292.0	20.70	.04831
5.3	20.0	227.9	197.0	1,151.5	954.4	1,231.0	19.72	.05070
10.3	25.0	240.0	209.3	1,155.1	945.8	998.4	15.99	.06253
15.3	30.0	250.2	219.7	1,158.3	938.9	841.3	13.48	.07420
20.3	35.0	259.2	228.8	1,161.0	932.2	727.9	11.66	.08576
25.3	40.0	267.1	236.9	1,163.4	926.5	642.0	10.28	.09721
30.3	45.0	274.3	244.3	1,165.6	921.3	574.7	9.21	.1086
40.3	55.0	286.9	257.2	1,169.4	912.3	475.9	7.63	.1311
50.3	65.0	297.8	268.3	1,172.8	904.5	406.6	6.53	.1533
60.3	75.0	307.4	278.2	1,175.7	897.5	355.5	5.71	.1753
70.3	85.0	316.0	287.0	1,178.3	891.3	315.9	5.07	.1971
80.3	95.0	323.9	295.1	1,180.7	885.6	284.5	4.57	.2188
90.3	105.0	331.1	302.6	1,182.9	880.3	258.9	4.16	.2403
100.3	115.0	337.8	309.5	1,185.0	875.5	237.6	3.82	.2617
125.3	140.0	352.8	325.0	1,189.5	864.6	197.3	3.18	.3147
150.3	165.0	365.7	338.4	1,193.5	855.1	169.0	2.72	.3671
200.3	215.0	387.7	361.3	1,200.2	838.9	131.5	2.12	.4707

TABLE XXXIX

Materials for Brickwork of Tubular Boilers

Boilers.	Common Brick.	Fire Brick.	Sand, Bushels.	Cement, Barrels.	Fire Clay, Pounds.	Lime, Barrels.
Single Setting						
30 in. x 8 ft.	5,200	320	42	5	192	2
30 in. x 10 ft.	5,800	320	46	5½	192	2¼
36 in. x 8 ft.	6,200	480	50	6	288	2½
36 in. x 9 ft.	6,600	480	53	6½	288	2¾
36 in. x 10 ft.	7,000	480	56	7	288	3
36 in. x 12 ft.	7,800	480	62	8	288	3¼
42 in. x 10 ft.	10,000	720	80	10	432	4
42 in. x 12 ft.	10,800	720	86	11	432	4¼
42 in. x 14 ft.	11,600	720	92	11¾	432	4½
42 in. x 16 ft.	12,400	720	99	12½	432	5
48 in. x 10 ft.	12,500	980	100	12½	590	5¼
48 in. x 12 ft.	13,200	980	108	13½	590	5½
48 in. x 14 ft.	14,200	980	116	14½	590	5¾
48 in. x 16 ft.	15,200	980	124	15½	590	6
54 in. x 12 ft.	13,800	1,150	108	13¾	690	5½
54 in. x 14 ft.	14,900	1,150	117	15	690	6
54 in. x 16 ft.	16,000	1,150	126	16	690	6¼
60 in. x 10 ft.	13,500	1,280	108	13½	768	5½
60 in. x 12 ft.	14,800	1,280	118	14¾	768	6
60 in. x 14 ft.	16,[illegible]00	1,280	128	16	768	6½
60 in. x 16 ft.	17,400	1,280	140	17½	768	7
60 in. x 18 ft.	18,[illegible]00	1,280	148	18¾	768	7½
66 in. x 16 ft.	19,700	1,400	157	19¾	840	8
66 in. x 18 ft.	21,000	1,400	168	21	840	8½
72 in. x 16 ft.	20,800	1,550	166	20¾	930	8½
72 in. x 18 ft.	22,000	1,550	175	22	930	9
Two Boilers in a Battery						
30 in. x 8 ft.	8,900	640	70	9	384	3½
30 in. x 10 ft.	9,600	640	76	9½	384	4
36 in. x 8 ft.	10,500	960	84	10½	576	4¼
36 in. x 9 ft.	11,100	960	88	11	576	4½
36 in. x 10 ft.	11,800	960	95	12	576	4¾
36 in. x 12 ft.	13,000	960	104	13	576	5¼
42 in. x 10 ft.	17,500	1,440	140	17½	864	7
42 in. x 12 ft.	18,600	1,440	148	18½	864	7½
42 in. x 14 ft.	19,900	1,440	159	20	864	8
42 in. x 16 ft.	21,200	1,440	168	21	864	8½
48 in. x 10 ft.	21,400	1,960	170	21½	1,180	8¾
48 in. x 12 ft.	22,300	1,960	178	22⅓	1,180	9
48 in. x 14 ft.	23,900	1,960	190	24	1,180	9½
48 in. x 16 ft.	25,100	1,960	200	25	1,180	10
54 in. x 12 ft.	23,300	2,300	186	23⅓	1,380	9⅓
54 in. x 14 ft.	24,800	2,300	198	25	1,380	10
54 in. x 16 ft.	26,300	2,300	210	26⅓	1,380	10½
60 in. x 10 ft.	22,600	2,560	180	22½	1,536	9
60 in. x 12 ft.	24,800	2,560	198	25	1,536	10
60 in. x 14 ft.	26,800	2,560	214	27	1,536	10¾
60 in. x 16 ft.	28,900	2,560	230	29	1,536	11½
60 in. x 18 ft.	31,000	2,560	248	31	1,536	12½
66 in. x 16 ft.	33,100	2,800	264	33	1,680	13¼
66 in. x 18 ft.	36,500	2,800	276	35	1,680	14
72 in. x 16 ft.	34,000	3,100	272	34	1,860	13¾
72 in. x 18 ft.	38,000	3,100	282	36	1,860	15

TABLE XL

Standard Pipe

Extra Strong

Size, Inches.	Price per Foot.	Actual Outside Diameter, Inches.	Nominal Inside Diameter, Inches.	Thickness, Inches.	Nominal Weight, per Foot, Pounds.
1/8	.11	.405	.205	.100	.29
1/4	.11	.540	.294	.123	.54
3/8	.11	.675	.421	.127	.74
1/2	.12	.840	.542	.149	1.09
3/4	.15	1.05	.736	.157	1.39
1	.22	1.315	.951	.182	2.17
1 1/4	.30	1.66	1.272	.194	3.00
1 1/2	.36	1.900	1.494	.203	3.63
2	.50	2.375	1.933	.221	5.02
2 1/2	.81	2.875	2.315	.280	7.67
3	1.05	3.500	2.892	.304	10.25
3 1/2	1.33	4.000	3.358	.321	12.47
4	1.50	4.500	3.818	.341	14.97
4 1/2	1.95	5.000	4.280	.360	18.22
5	2.16	5.563	4.813	.375	20.54
6	2.90	6.625	5.750	.437	28.58
7	3.80	7.625	6.625	.500	37.67
8	4.30	8.625	7.625	.500	43.00

Double Extra Strong

Size, Inches.	Price per Foot.	Actual Outside Diameter, Inches.	Nominal Inside Diameter, Inches.	Thickness, Inches.	Nominal Weight per Foot, Pounds.
1/2	.25	.84	.244	.298	1.70
3/4	.30	1.05	.422	.314	2.44
1	.37	1.315	.587	.364	3.65
1 1/4	.52	1.66	.885	.388	5.20
1 1/2	.65	1.90	1.088	.406	6.40
2	.95	2.375	1.491	.442	9.02
2 1/2	1.37	2.875	1.755	.560	13.68
3	1.92	3.50	2.284	.608	18.56
3 1/2	2.45	4.00	2.716	.642	22.75
4	2.85	4.50	3.136	.682	27.48
4 1/2	3.30	5.00	3.564	.718	32.53
5	3.80	5.563	4.063	.750	38.12
6	5.30	6.625	4.875	.875	53.11
7	6.25	7.625	5.875	.875	62.38
8	7.20	8.625	6.875	.875	71.62

TABLE XLI

Cost of Coal for Steam Power

Horse Power.	Coal consumption at 4 lbs. per H.P. per hour; 10 hrs. a day; 300 days in a year					$1.50		$2.00		$3.00		$4.00	
	lbs.	long tons.		short tons.		Per Short Ton.		Per Short Ton.		Per Short Ton.		Per Short Ton.	
						Cost in Dollars.		Cost in Dollars.		Cost in Dollars.		Cost in Dollars.	
	Per Day.	Per Day.	Per Year.	Per Day.	Per Year.	Per Day.	Per Year.	Per Day.	Per Year.	Per Day.	Per Year.	Per Day.	Per Year.
1	40	.0179	5.357	.02	6	.03	9	.04	12	.06	18	.08	24
10	400	.1786	53.57	.20	60	.30	90	.40	120	.60	180	.80	240
25	1,000	.4464	133.92	.50	150	.75	225	1.00	300	1.50	450	2.00	600
50	2,000	.8928	267.85	1.00	300	1.50	450	2.00	600	3.00	900	4.00	1,200
75	3,000	1.3393	401.78	1.50	450	2.25	675	3.00	900	4.50	1,350	6.00	1,800
100	4,000	1.7857	535.71	2.00	600	3.00	900	4.00	1,200	6.00	1,800	8.00	2,400
150	6,000	2.6785	803.56	3.00	900	4.50	1,350	6.00	1,800	9.00	2,700	12.00	3,600
200	8,000	3.5714	1,071.42	4.00	1,200	6.00	1,800	8.00	2,400	12.00	3,600	16.00	4,800
250	10,000	4.4642	1,339.27	5.00	1,500	7.50	2,250	10.00	3,000	15.00	4,500	20.00	6,000
300	12,000	5.3571	1,607.13	6.00	1,800	9.00	2,700	12.00	3,600	18.00	5,400	24.00	7,200
350	14,000	6.2500	1,874.98	7.00	2,100	10.50	3,150	14.00	4,200	21.00	6,200	28.00	8,400
400	16,000	7.1428	2,142.84	8.00	2,400	12.00	3,600	16.00	4,800	24.00	7,200	32.00	9,600
450	18,000	8.0356	2,410.69	9.00	2,700	13.50	4,050	18.00	5,400	27.00	8,100	36.00	10,800
500	20,000	8.9285	2,678.55	10.00	3,000	15.00	4,500	20.00	6,000	30.00	9,000	40.00	12,000

TABLE XLII

Capacity of Stacks

Diameter in inches.	Height of Stacks and Commercial Horse Power of Boilers.										
	50 Ft.	60 Ft.	70 Ft.	80 Ft.	90 Ft.	100 Ft.	110 Ft.	125 Ft.	150 Ft.	175 Ft.	200 Ft.
	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.
18	23	25	27	.....	.....	.....	.....	.....	.....	.....	.....
21	35	38	41	.....	.....	.....	.....	.....	.....	.....	.....
24	49	54	58	62	.....	.....	.....	.....	.....	.....	.....
27	65	72	78	83	87	.....	.....	.....	.....	.....	.....
30	84	92	100	107	113	119	.....	.....	.....	.....	.....
33	105	115	125	133	141	149	.....	.....	.....	.....	.....
36	128	141	152	163	173	182	191	.....	.....	.....	.....
39	154	168	183	196	208	219	229	.....	.....	.....	.....
42	182	200	216	231	245	258	271	288	.....	.....	.....
48	...	269	290	311	330	348	365	389	.....	.....	.....
54	...	348	376	402	427	449	472	503	551	.....	.....
60	...	436	471	503	536	565	593	632	692	748	.....
66	...	...	579	620	658	694	728	776	849	918	981
72	...	...	698	746	792	835	876	934	1,023	1,105	1,181
78	...	...	...	885	949	990	1,038	1,107	1,212	1,310	1,400
84	...	...	...	1,035	1,098	1,157	1,214	1,294	1,418	1,531	1,637
90	...	...	...	.....	1,269	1,338	1,403	1,496	1,639	1,770	1,893
96	...	...	...	.....	.....	1,532	1,606	1,712	1,876	2,027	2,167
100	...	...	...	.....	.....	.....	1,760	1,865	2,043	2,197	2,359
104	...	...	...	.....	.....	.....	1,899	2,024	2,218	2,395	2,560
108	...	...	...	.....	.....	.....	2,051	2,190	2,399	2,591	2,770

TABLE XLIII

RELATION BETWEEN TEMPERATURE OF FEED WATER AND EVAPORATIVE CAPACITY OF BOILER

Temperature of Feed Water, Degrees Fahr.	Steam Pressure, Pounds.	Feed Water per Horse Power per Hour, Pounds.	Gallons per Minute per 100 Horse Power.
100	70	*30.00	6.02+10 per cent. = 6.62
70	100	29.04	5.79+10 " " = 6.36
100	100	29.82	5.98+10 " " = 6.57
150	100	31.22	6.34+10 " " = 6.97
180	100	32.14	6.61+10 " " = 7.27
200	100	32.77	6.65+10 " " = 7.31
212	100	33.17	6.94+10 " " = 7.63

* This is the standard adopted by the American Society of Mechanical Engineers, and is the generally accepted commercial standard by boiler makers and users.

The evaporative capacity of a boiler depends, among other things, upon the steam pressure and temperature of the feed water. The pressure makes so little difference that it has been estimated for 100 pounds as practically correct for all pressures. The difference between making steam at atmospheric pressure and 100 pounds pressure is only 3½ per cent. Changing the temperature of the feed water from 100 degrees to 212 degrees will vary the evaporative capacity of a boiler over 11 per cent.

TABLE XLIV

QUANTITY OF FEED WATER REQUIRED TO SUPPLY BOILER

Horse Power of Boiler.	Quantity of Feed Water Required.		Temperature of Feed Water. Degrees Fahr.
	Gallons per Minute.	Pounds per Hour.	
50	3.60 to 4.20	1,599 to 2,029	100 to 212
100	6.57 to 7.63	3,285 to 3,815	100 to 212
200	13.14 to 15.26	6,590 to 7,630	100 to 212
250	16.43 to 19.07	8,215 to 9,535	100 to 212
300	19.71 to 22.89	9,855 to 11,445	100 to 212
400	26.28 to 30.52	13,140 to 15,260	100 to 212
500	32.85 to 38.15	16,425 to 19,075	100 to 212
600	39.42 to 45.78	19,710 to 22,890	100 to 212
800	52.26 to 61.04	26,280 to 30,520	100 to 212
1,000	65.70 to 76.30	32,350 to 38,150	100 to 212
1,200	78.84 to 91.56	39,420 to 45,780	100 to 212
1,500	98.55 to 114.45	49,275 to 57,225	100 to 212
1,800	118.26 to 137.34	59,130 to 68,670	100 to 212
2,200	144.50 to 167.80	71,290 to 83,930	100 to 212
3,000	197.10 to 228.90	98,500 to 114,500	100 to 212
3,500	229.95 to 267.05	114,975 to 133,525	100 to 212
4,500	295.65 to 343.35	147,825 to 171,675	100 to 212
6,000	394.20 to 457.80	197,100 to 228,900	100 to 212
7,000	459.90 to 534.10	229,950 to 267,050	100 to 212

TABLE XLV

Vacuum, Pressure and Temperature, Etc.

Vacuum measured in inches of Mercury.	Absolute pressure in inches of Mercury.	Absolute pressure in lbs. per square inch.	Temperature of boiling point. Fahr.	Latent heat of evaporation in B. T. U.	Sensible heat of Evaporation.
29½	½	.245	59.1	1072.8	27.1
29	1	.490	79.3	1058.8	47.3
28½	1½	.735	92.0	1049.9	60.1
28	2	.980	101.4	1044.4	69.5
27	3	1.470	115.3	1033.7	83.4
26	4	1.960	125.6	1026.5	93.8
25	5	2.450	134.0	1020.6	102.2
24	6	2.940	141.0	1015.7	109.3
23	7	3.430	147.0	1011.5	115.3
22	8	3.920	152.3	1007.8	120.5
21	9	4.410	157.0	1004.5	125.4
20	10	4.900	161.5	1001.3	129.9
19	11	5.390	165.6	998.4	134.1
18	12	5.880	169.2	995.9	137.7
17	13	6.370	172.8	993.4	140.3
16	14	6.860	176.0	991.1	144.5
15	15	7.350	179.1	988.8	147.7
14	16	7.840	182.0	986.9	150.6
12	17	8.820	187.4	983.1	156.0
10	20	9.800	192.3	979.6	161.0
5	25	12.25	203.0	972.1	171.8
0	30	14.70	212.0	965.7	180.9

TABLE XLVI

Pump Diameters and Capacities in Gallons

Diameter.	Area Inches.	Displacement in Gals. per Ft. of Travel.	Diameter.	Area Inches.	Displacement in Gals. per Ft. of Travel.
1/8	.0129	.0006	8	50.26	2.548
1/4	.0490	.0025	8 1/4	53.45	2.7739
3/8	.1104	.0056	8 1/2	56.74	2.944
1/2	.1963	.0101	8 3/4	60.13	3.0105
5/8	.3068	.0135	9	63.61	3.2505
3/4	.4417	.0228	9 1/4	67.20	3.407
7/8	.6018	.0311	9 1/2	70.88	3.678
1	.7854	.0407	9 3/4	74.66	3.874
1 1/8	.9940	.0505	10	78.54	3.997
1 1/4	1.227	.0624	10 1/4	82.51	4.281
1 3/8	1.484	.0629	10 1/2	86.59	4.493
1 1/2	1.767	.0896	10 3/4	90.76	4.708
1 5/8	2.073	.1073	11	95.03	4.931
1 3/4	2.405	.1237	11 1/4	99.40	5.158
1 7/8	2.761	.1432	11 1/2	103.8	5.386
2	3.141	.1639	11 3/4	108.4	5.634
2 1/8	3.546	.1839	12	113.0	5.852
2 1/4	3.970	.2063	12 1/4	117.8	6.015
2 3/8	4.430	.2296	12 1/2	122.7	6.366
2 1/2	4.908	.2545	12 3/4	127.6	6.620
2 5/8	5.411	.2807	13	132.7	6.884
2 3/4	5.939	.2948	13 1/4	137.8	7.149
2 7/8	6.491	.3411	13 1/2	143.1	7.254
3	7.068	.3667	13 3/4	148.4	7.688
3 1/8	7.669	.3979	14	153.9	7.966
3 1/4	8.295	.4304	14 1/4	159.4	8.270
3 3/8	8.946	.4641	14 1/2	165.1	8.565
3 1/2	9.621	.4992	14 3/4	170.8	8.874
3 5/8	10.32	.5355	15	176.7	9.167
3 3/4	11.04	.5728	15 1/4	182.6	9.474
3 7/8	11.79	.5953	15 1/2	188.6	9.785
4	12.56	.6522	15 3/4	194.8	10.098
4 1/4	14.18	.7356	16	201.0	10.435
4 1/2	15.90	.8250	16 1/4	207.3	10.720
4 3/4	17.72	.9194	16 1/2	213.8	11.079
5	19.63	.9954	16 3/4	220.3	11.43
5 1/4	21.54	1.123	17	226.9	11.775
5 1/2	23.75	1.2035	17 1/4	233.7	12.125
5 3/4	25.96	1.346	17 1/2	240.5	12.172
6	28.27	1.433	17 3/4	247.4	12.838
6 1/4	30.67	1.5915	18	254.4	13.208
6 1/2	33.18	1.6817	18 1/4	261.5	13.57
6 3/4	35.78	1.8137	18 1/2	268.8	13.975
7	38.48	1.9965	18 3/4	276.1	14.375
7 1/4	41.28	2.1416	19	283.5	14.711
7 1/2	44.17	2.2958	19 1/4	291.0	15.10
7 3/4	47.17	2.4465	19 1/2	298.6	15.55

TABLE XLVII

Table of Decimal Equivalents of an Inch

By 64ths; from 1–64th to 1 Inch

Fraction.	Decimal.	Fraction.	Decimal.
1/64	.015625	33/64	.515625
1/32	.031250	17/32	.531250
3/64	.046875	35/64	.546875
1/16	.062500	9/16	.562500
5/64	.078125	37/64	.578125
3/32	.093750	19/32	.593750
7/64	.109375	39/64	.609375
1/8	.125000	5/8	.625000
9/64	.140625	41/64	.640625
5/32	.156250	21/32	.656250
11/64	.171875	43/64	.671875
3/16	.187500	11/16	.687500
13/64	.203125	45/64	.703125
7/32	.218750	23/32	.718750
15/64	.234375	47/64	.734375
1/4	.250000	3/4	.750000
17/64	.265625	49/64	.765625
9/32	.281250	25/32	.781250
19/64	.296875	51/64	.796875
5/16	.312500	13/16	.812500
21/64	.328125	53/64	.828125
11/32	.343750	27/32	.843750
23/64	.359375	55/64	.859375
3/8	.375000	7/8	.875000
25/64	.390625	57/64	.890625
13/32	.406250	29/32	.906250
27/64	.421875	59/64	.921875
7/16	.437500	15/16	.937500
29/64	.453125	61/64	.953125
15/32	.468750	31/32	.968750
31/64	.484375	63/64	.984375
1/2	.500000	1	1.000000

Belting

Horse power of a belt velocity in feet per minute, multiplied by the width the product divided by 1,000.

1 in. single belt moving at 1,000 feet per minute, 1 H. P.

1 in. double " " " 700 " " " 1 H. P.

It is desirable that the angle of the belt with the floor should not exceed 45. It is also desirable to locate the shafting and machinery so that the belts should run off from each shaft in opposite directions, as this arrangement will relieve the bearings from the friction that would result when the belts all pull one way on the shaft.

The diameter of the pulleys should be as large as can be admitted.

The pulleys should be a little wider than the belt required for the work.

Belts should be kept soft and pliable. For this purpose blood-warm tallow, dried in by the heat of fire or the sun, is advised. Castor-oil dressing is also good.

TABLE XLVIII

Horse Power of a Leather Belt One Inch Wide

Velocity in Feet per Second.	Laced Belts—Thickness in Inches.						
	$\frac{1}{7}$ .143	$\frac{1}{6}$ .167	$\frac{3}{16}$ .187	$\frac{7}{32}$ .219	$\frac{1}{4}$ .250	$\frac{5}{16}$ .312	$\frac{1}{3}$ .333
10	.51	.59	.63	.73	.84	1.05	1.18
15	.75	.88	1.00	1.16	1.32	1.66	1.77
20	1.00	1.17	1.32	1.54	1.75	2.19	2.34
25	1.23	1.43	1.61	1.88	2.16	2.69	2.86
30	1.47	1.72	1.93	2.25	2.58	3.22	3.44
35	1.69	1.97	2.22	2.59	2.96	3.70	3.94
40	1.90	2.22	2.49	2.90	3.32	4.15	4.44
45	2.09	2.45	2.75	3.21	3.67	4.58	4.89
50	2.27	2.65	2.98	3.48	3.98	4.97	5.30
55	2.44	2.84	3.19	3.72	4.26	5.32	5.69
60	2.58	3.01	3.38	3.95	4.51	5.64	6.02
65	2.71	3.16	3.55	4.14	4.74	5.92	6.32
70	2.81	3.27	3.68	4.29	4.91	6.14	6.54
75	2.89	3.37	3.79	4.42	5.05	6.31	6.73
80	2.94	3.43	3.86	4.50	5.15	6.44	6.86
85	2.97	3.47	3.90	4.55	5.20	6.50	6.93
90	2.97	3.47	3.90	4.55	5.20	6.50	6.93

The horse power becomes a maximum at 87.41 feet per second, 5,245 per minute.

If possible to avoid it, connected shafts should never be placed one directly over the other, as in such case the belt must be kept very tight to do the work. For this purpose belts should be carefully selected of well-stretched leather.

RULE FOR FINDING LENGTH OF BELTS

Add the diameter of the two pulleys together, multiply by $3\frac{1}{8}$, divide the product by two, add to the quotient twice the distance between the centers of the shafts, and product will be the required length.

THE TABLES ON THE FOLLOWING PAGES HAVE TO DO WITH THE TEMPERATURES AND MOVEMENTS OF AIR, VOLUMES AND VELOCITIES, SIZES OF DUCTS, ETC., AS USED IN COMPUTATIONS FOR THE BLOWER SYSTEM OF HEATING AND VENTILATION

TABLE XLIX

NUMBER OF SQUARE INCHES OF FLUE AREA REQUIRED PER 1,000 CUBIC FEET OF CONTENTS FOR GIVEN VELOCITY AND AIR CHANGE

No. Minutes to Change Air.	VELOCITY OF AIR IN FLUE IN FEET PER MINUTE.												
	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500
4	120.	90.	72.	60.	51.6	45.	40.	36.	32.2	30.	27.6	25.6	21.4
5	96.	72.2	57.6	48.	41.1	36.1	32.	28.8	26.2	24.	22.2	20.5	19.2
6	80.	60.	48.	40.	34.3	30.	26.6	24.	21.8	20.	18.5	17.1	16.
7	68.6	51.4	41.1	34.3	29.4	25.7	22.9	20.6	18.7	17.2	15.7	14.7	13.7
8	60.	45.	36.	30.	25.8	22.5	20.	18.	16.1	15.	13.8	12.8	12.
9	53.3	40.	32.	26.6	22.9	20.	17.8	16.	14.5	13.3	12.3	11.4	10.7
10	48.	36.	28.8	24.	20.6	18.	16.	14.4	13.1	12.	11.1	10.3	9.6
11	43.6	32.2	26.2	21.8	18.7	16.1	14.5	13.1	11.9	10.9	10.1	9.5	8.7
12	40.	30.	24.	20.	17.2	15.	13.3	12.	10.9	10.	9.2	8.6	8.
13	36.9	27.7	22.2	18.5	15.7	13.8	12.3	11.1	10.1	9.2	8.5	7.9	7.4
14	34.3	25.7	20.6	17.2	14.7	12.8	11.4	10.3	9.5	8.6	7.9	7.4	6.9
15	32.	24.	19.2	16.	13.7	12.	10.7	9.6	8.7	8.	7.4	6.9	6.4
16	30.	22.5	18.	15.	12.9	11.2	10.	9.	8.2	7.5	6.9	6.4	6.
17	28.2	21.2	16.9	14.1	12.1	10.6	9.4	8.5	7.7	7.	6.5	6.1	5.6
18	26.6	20.	16.	13.3	11.5	10.	8.9	8.	7.3	6.6	6.2	5.7	5.3
19	25.3	18.9	15.2	12.6	10.8	9.5	8.4	7.6	6.9	6.3	5.8	5.4	5.1
20	24.	18.	14.4	12.	10.3	9	8.	7.2	6.5	6.	5.5	5.1	4.8

To facilitate calculation of flue areas for different requirements in heating, ventilation and the general movement of air, the table above and that upon the three succeeding pages have been prepared. The former is to be employed when in a ventilating system the area of the flue is to be based upon the time required to change the air within the room and upon the permissible velocity in the flue. The latter table indicates the flue area necessary for the passage of a predetermined volume of air at stated velocity. Values for volumes below 100 or above 1,000 cubic feet may be readily determined from the latter table by reading for the multiple of the given volume, and then pointing off the requisite number of places. Thus, if a volume of 8,750 cubic feet of air is required to pass through a flue at a velocity of 900 feet per minute, the cross sectional area of that must be 1,400 square inches.

TABLE L

FLUE AREA REQUIRED FOR THE PASSAGE OF A GIVEN VOLUME OF AIR AT A GIVEN VELOCITY

Volume in Cubic Feet per Minute.	VELOCITY IN FEET PER MINUTE.								
	300	400	500	600	700	800	900	1,000	1,100
100	48	36	29	24	21	18	16	14	13
125	60	45	36	30	26	23	20	18	16
150	72	54	43	36	31	27	24	22	20
175	84	63	50	42	36	32	28	25	23
200	96	72	58	48	41	36	32	29	26
225	108	81	65	54	46	41	36	32	29
250	120	90	72	60	51	45	40	36	33
275	132	99	79	66	57	50	44	40	36
300	144	108	86	72	62	54	48	43	39
325	156	117	94	78	67	59	52	47	43
350	168	126	101	84	72	63	56	50	46
375	180	135	108	90	77	68	60	54	49
400	192	144	115	96	82	72	64	58	52
425	204	153	122	102	87	77	68	61	56
450	216	162	130	108	93	81	72	65	59
475	228	171	137	114	98	86	76	68	62
500	240	180	144	120	103	90	80	72	65
525	252	189	151	126	108	95	84	76	69
550	264	198	158	132	113	99	88	79	72
575	276	207	166	138	118	104	92	83	75
600	288	216	173	144	123	108	96	86	79
625	300	225	180	150	129	113	100	90	82
650	312	234	187	156	134	117	104	94	85
675	324	243	194	162	139	122	108	97	88
700	336	252	202	168	144	126	112	101	92
725	348	261	209	174	149	131	116	104	95
750	360	270	216	180	154	135	120	108	98
775	372	279	223	186	159	140	124	112	101
800	384	288	230	192	165	144	128	115	105
825	396	297	238	198	170	149	132	119	108
850	408	306	245	204	175	153	136	122	111
875	420	315	252	210	180	158	140	126	115
900	432	324	259	216	185	162	144	130	118
925	444	333	266	222	190	167	148	133	121
950	456	342	274	228	195	171	152	137	124
975	468	351	281	234	201	176	156	140	128
1,000	480	360	288	240	206	180	160	144	131

TABLE LI

FLUE AREA REQUIRED FOR THE PASSAGE OF A GIVEN VOLUME OF AIR AT A GIVEN VELOCITY—(*Continued*)

Volume in Cubic Feet per Minute.	VELOCITY IN FEET PER MINUTE.								
	1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000
100	12	11	10	9.6	9.	8.5	8	7.6	7.2
125	15	14	13	12.	11.3	10.6	10	9.5	9.
150	18	16	15	14.4	13.5	12.7	12	11.4	10.8
175	21	19	18	16.8	15.8	14.8	14	13.3	12.6
200	24	22	21	19.2	18.	16.9	16	15.2	14.4
225	27	25	23	21.6	20.3	19.1	18	17.1	16.2
250	30	28	26	24.	22.5	21.2	20	19.	18.
275	33	30	28	26.4	24.8	23.3	22	21.8	19.8
300	36	33	31	28.8	27.	25.4	24	22.7	21.6
325	39	36	33	31.2	29.3	27.5	26	24.6	23.4
350	42	39	36	33.6	31.5	29.6	28	26.5	25.2
375	45	42	39	36.	33.8	31.8	30	28.4	27.
400	48	44	41	38.4	36.	33.9	32	30.3	28.8
425	51	47	44	40.8	38.3	36.	34	32.2	30.6
450	54	50	46	43.2	40.5	38.1	36	34.1	32.4
475	57	53	49	45.6	42.8	40.2	38	36.	34.2
500	60	55	51	48.	45.	42.4	40	37.9	36.
525	63	58	54	50.4	47.3	44.5	42	39.8	37.8
550	66	61	57	52.8	49.5	46.6	44	41.7	38.6
575	69	64	59	55.2	51.8	48.7	46	43.6	41.4
600	72	66	62	57.6	54.	50.8	48	45.5	43.2
625	75	69	64	60.	56.3	52.9	50	47.4	45.
650	78	72	67	62.4	58.5	55.1	52	49.3	46.8
675	81	75	69	64.8	60.8	57.2	54	51.2	48.6
700	84	78	72	67.2	63.	59.3	56	53.1	50.4
725	87	80	75	69.6	65.3	61.4	58	55.	52.2
750	90	83	77	72.	67.5	63.5	60	56.9	54.
775	93	86	80	74.4	69.8	65.6	62	58.8	56.3
800	96	89	82	76.8	72.	67.8	64	60.6	57.6
825	99	91	85	79.2	74.3	69.9	66	62.5	59.4
850	102	94	87	81.6	76.5	72.	68	64.4	61.2
875	105	97	90	84.	78.8	74.	70	67.3	63.
900	108	100	93	86.4	81.	76.2	72	68.2	64.8
925	111	103	95	88.8	83.3	78.4	74	70.1	66.6
950	114	105	98	91.2	85.5	80.5	76	72.	68.4
975	117	108	100	93.6	87.8	82.6	78	73.9	70.2
1,000	120	111	103	96.	90.	84.7	80	75.8	72.

TABLE LII

Flue Area Required for the Passage of a Given Volume of Air at a Given Velocity—(*Continued*)

Volume in Cubic Feet per Minute.	Velocity in feet per minute.									
	2,100	2,200	2,300	2,400	2,600	2,700	2,800	2,900	3,000	3,100
100	6.9	6.6	6.3	6.	5.5	5.3	5.1	5.	4.8	4.6
125	8.6	8.2	7.8	7.5	6.9	6.7	6.4	6.2	6.	5.8
150	10.3	9.8	9.4	9.	8.	8.	7.7	7.5	7.2	7.
175	12.	11.5	11.	10.5	9.7	9.3	9.	8.7	8.4	8.1
200	13.7	13.1	12.5	12.	11.1	10.7	10.3	9.9	9.6	9.3
225	15.6	14.7	14.1	13.5	12.5	12.	11.6	11.2	10.8	10.4
250	17.1	16.4	15.7	15.	13.9	13.3	12.9	12.4	12.	11.6
275	18.9	18.	17.2	16.5	15.2	14.7	14.1	13.7	13.2	12.8
300	20.6	19.6	18.8	18.	16.6	16.	15.4	14.9	14.4	13.9
325	22.3	21.3	20.6	19.5	18.	17.3	16.7	16.1	15.6	15.1
350	24.	22.9	21.9	21.	19.4	18.7	18.	17.4	16.8	16.3
375	25.7	24.5	23.5	22.5	20.8	20.	19.3	18.6	18.	17.4
400	27.4	26.2	25.	24.	22.2	21.3	20.6	19.8	19.2	18.6
425	29.1	27.8	26.6	25.5	23.5	22.7	21.9	21.1	20.4	19.7
450	30.9	29.5	28.2	27.	24.9	24.	23.1	22.3	21.6	20.9
475	32.6	31.1	29.7	28.5	26.3	25.3	24.4	23.6	22.8	22.1
500	34.3	32.7	31.3	30.	27.7	26.7	25.7	24.8	24.	23.2
525	36.	34.4	32.9	31.5	29.1	28.	26.9	25.	25.2	24.4
550	37.7	36.	34.4	33.	30.5	29.3	28.3	27.3	26.4	25.5
575	39.4	37.6	36.	34.5	31.9	30.7	29.6	28.5	27.6	26.7
600	41.1	39.3	37.6	36.	33.2	32.	30.8	29.8	28.8	27.8
625	42.9	40.9	39.1	37.5	34.6	33.3	32.1	31.	30.	29.
650	44.6	42.5	40.7	39.	36.	34.7	33.4	32.2	31.2	30.2
675	46.3	44.1	42.3	40.5	37.5	36.	34.7	33.5	32.4	31.3
700	48.	45.8	43.8	42.	38.8	37.3	36.	34.7	33.6	32.5
725	49.7	47.4	45.4	43.5	40.2	38.7	37.3	36.	34.8	33.6
750	51.4	49.1	47.	45.	41.5	40.	38.6	37.2	36.	34.8
775	53.1	50.7	48.5	46.5	42.9	41.3	39.9	38.5	37.2	36.
800	54.9	52.4	50.1	48.	44.3	42.7	41.2	39.7	38.4	37.1
825	56.6	54.	51.7	49.5	45.7	44.	42.4	40.9	39.6	38.3
850	58.4	55.6	53.2	51.	47.1	45.3	43.7	42.2	40.8	39.4
875	60.	57.3	54.8	52.5	48.5	46.7	45.	43.4	42.	40.6
900	61.7	58.9	56.3	54.	49.9	48.	46.3	44.6	43.2	41.8
925	63.4	60.5	57.9	55.5	51.3	49.3	47.6	46.	44.4	42.9
950	65.1	62.2	59.5	57.	52.6	50.7	48.8	47.1	45.6	44.1
975	66.8	63.8	61.0	58.5	54.	52.	50.2	48.4	46.8	45.3
1,000	68.7	66.	62.6	60.	55.4	53.3	51.4	49.6	48.	46.4

TABLE LIII

WEIGHT OF ROUND GALVANIZED IRON PIPE AND ELBOWS, OF THE PROPER GAUGES FOR HEATING AND VENTILATING SYSTEMS

Gauge and Weight per Sq. Ft.	Diam. of Pipe.	Area in Sq. Ins.	Weight per Running Foot.	Weight of Full Elbow.	Gauge and Weight per Sq. Ft.	Diam. of Pipe.	Area in Sq. Ins.	Weight per Running Foot.	Weight of Full Elbow.
No. 28 0.78	3	7.1	0.7	0.4	No. 20 1.66	36	1,017.9	17.2	124.4
	4	12.6	1.1	0.9		37	1,075.2	17.8	131.4
	5	19.6	1.2	1.2		38	1,134.1	18.2	139.4
	6	28.3	1.4	1.7		39	1,194.6	18.7	146.0
	7	38.5	1.7	2.3		40	1,256.6	19.1	152.9
	8	50.3	1.9	2.9		41	1,320.3	19.6	160.7
						42	1,385.4	20.1	168.6
No. 26 0.91						43	1,452.2	20.6	176.7
	9	63.6	2.4	4.3		44	1,520.5	21.0	185.0
	10	78.5	2.7	5.3		45	1,590.4	21.5	193.4
	11	95.0	2.9	6.4		46	1,661.9	22.0	202.2
	12	113.1	3.2	7.6					
	13	132.7	3.4	8.9	No. 18 2.16				
	14	153.9	3.7	10.4		47	1,734.9	29.2	274.3
						48	1,809.6	29.8	286.6
No. 25 1.03						49	1,885.7	30.4	298.8
	15	176.7	4.5	13.5		50	1,963.5	31.0	309.9
	16	201.1	4.7	15.1		51	2,042.8	31.6	322.5
	17	227.0	5.0	17.0		52	2,123.7	32.2	335.1
	18	254.5	5.3	19.1		53	2,206.2	33.0	349.7
	19	283.5	5.6	21.4		54	2,290.2	33.6	363.4
	20	314.2	6.0	23.9		55	2,375.8	34.4	377.2
						56	2,463.0	34.9	390.7
No. 24 1.16						57	2,551.8	35.6	405.1
	21	346.4	7.0	29.6		58	2,642.1	36.1	418.8
	22	380.1	7.3	32.3		59	2,734.0	36.7	433.1
	23	415.5	7.7	35.6		60	2,827.4	37.4	448.6
	24	452.4	8.0	38.6					
	25	490.9	8.3	41.7	No. 16 2.66				
	26	530.9	8.7	45.1		61	2,922.5	46.7	569.7
						62	3,019.1	47.5	589.0
No. 22 1.41						63	3,117.3	48.3	608.6
	27	572.6	10.9	59.1		64	3,217.0	49.1	628.5
	28	615.7	11.4	64.2		65	3,318.3	49.8	647.4
	29	660.5	11.8	68.6		66	3,421.2	50.5	666.6
	30	706.9	12.2	73.4		67	3,525.7	51.3	687.4
	31	754.8	12.6	78.3		68	3,631.7	52.1	708.6
	32	804.3	13.0	83.4		69	3,739.3	52.8	728.6
	33	855.3	13.5	88.9		70	3,848.5	53.6	750.4
	34	907.9	13.9	94.3		71	3,959.2	54.3	771.0
	35	962.1	14.3	99.9		72	4,071.5	55.1	793.4

TABLE LIV

Table for Equalizing the Diameter of Pipes

"Figures in bold face type at the top of the column are the diameters of the branches, those in the first, or left-hand column are the diameter of the mains."

Diameter of Main Blast-pipe in Inches.																													
1	**1**																												
2	5.7	**2**																											
3	16	2.7	**3**																										
4	32	5.7	2.	**4**																									
5	56	9.8	3.6	1.8	**5**																								
6	88	16	5.7	2.8	1.6	**6**																							
7	129	23	8.3	4.1	2.3	1.5	**7**																						
8	180	32	12	5.7	3.2	2.1	1.4	**8**																					
9	244	42	16	7.6	4.3	2.8	1.9	1.3	**9**																				
10	317	56	20	9.9	5.7	3.6	2.4	1.7	1.3	**10**																			
11	402	71	26	12	7.0	4.5	3.1	2.2	1.7	1.3	**11**																		
12	501	88	32	16	9.0	5.7	3.8	2.8	2.0	1.6	1.2	**12**																	
13	613	107	39	19	11	6.9	4.7	3.4	2.5	1.9	1.5	1.2	**13**																
14	737	129	47	23	13	8.3	5.7	4.1	3.0	2.3	1.8	1.5	1.2	**14**															
15	876	152	56	27	16	9.9	6.7	4.8	3.6	2.8	2.2	1.8	1.4	1.2	**15**														
16	1,026	180	65	32	18	11	7.9	5.7	4.2	3.2	2.6	2.1	1.7	1.4	1.2	**16**													
17	1,197	208	76	37	21	13	9.2	6.6	4.9	3.8	2.9	2.4	2.0	1.6	1.4	1.2	**17**												
18	1,375	239	88	43	24	16	10	7.7	5.7	4.3	3.4	2.8	2.3	1.9	1.6	1.3	1.2	**18**											
19	1,580	275	100	49	28	18	12	8.8	6.5	5.	3.9	3.2	2.6	2.2	1.8	1.5	1.3	1.2	**19**										
20	1,797	313	114	56	32	20	14	9.9	7.4	5.7	4.5	3.6	2.9	2.5	2.1	1.7	1.5	1.3	1.1	**20**									
22	2,284	398	145	71	41	26	18	13	9.3	7.2	5.7	4.5	3.7	3.1	2.6	2.2	1.9	1.7	1.4	1.3	**22**								
24	2,834	493	180	88	50	32	22	16	12	8.9	7.6	5.7	4.6	3.8	3.2	2.9	2.4	2.1	1.8	1.6	1.2	**24**							
26	3,474	605	219	108	62	39	27	19	14	11	8.6	6.9	5.7	4.7	4.0	3.4	2.9	2.5	2.2	1.9	1.5	1.2	**26**						
28	4,165	725	265	129	74	48	32	23	17	13	10	8.3	6.8	5.7	4.8	4.1	3.5	3.0	2.6	2.3	1.8	1.5	1.2	**28**					
30	4,963	864	315	154	88	56	38	28	20	16	12	9.9	8.0	6.7	5.7	4.7	4.1	3.6	3.0	2.6	2.2	1.7	1.4	1.2	**30**				
36	7,818	1,361	497	243	139	88	60	43	32	25	19	16	13	11	8.9	7.6	6.5	5.7	5.0	4.3	3.4	2.7	2.2	1.9	1.6	**36**			
42	11,488	2,000	730	358	205	129	88	63	47	36	29	23	19	16	13	11	9.6	8.5	7.3	6.4	5.0	4.1	3.3	2.8	2.3	1.5	**42**		
48	15,989	2,792	1,081	492	282	180	123	88	66	50	39	32	26	22	18	16	13	12	10	8.9	7.0	5.7	4.7	3 8	3.2	2.1	1.4	**48**	
54	21,560	3,753	1,368	671	384	244	166	119	88	68	53	43	35	29	24	21	18	16	15	12	9.4	7.6	6.2	5.2	4.3	2.8	1.9	1.3	**54**
60	27,913	4,879	1,781	872	499	314	215	154	115	88	69	56	46	38	32	27	23	20	18	16	12	9.9	8.1	6.7	5.7	3.6	2.4	1.8	1.3

TABLE LV

AIR

Loss of Pressure in Ounces per Square Inch for Varying Velocities and Varying Diameters of Pipes

Velocity of Air, Feet per Minute.	DIAMETER OF PIPE IN INCHES.					
	1	2	3	4	5	6
	LOSS OF PRESSURE IN OUNCES.					
600	.400	.200	.133	.100	.080	.067
1,200	1.600	.800	.533	.400	.320	.267
1,800	3.600	1.800	1.200	.900	.720	.600
2,400	6.400	3.200	2.133	1.600	1.280	1.067
3,000	10.000	5.000	3.333	2.500	2.000	1.667
3,600	14.400	7.200	4.800	3.600	2.880	2.400
4,200	......	9.800	6.553	4.900	3.920	3.267
4,800	......	12.800	8.533	6.400	5.120	4.267
6,000	......	20.000	13.333	10.000	8.000	6.667
	DIAMETER OF PIPE IN INCHES.					
	7	8	9	10	11	12
	LOSS OF PRESSURE IN OUNCES.					
600	.057	.050	.044	.040	.036	.033
1,200	.229	.200	.178	.160	.145	.133
1,800	.514	.450	.400	.360	.327	.300
2,400	.914	.800	.711	.640	.582	.533
3,000	1.429	1.250	1.111	1.000	.909	.833
3,600	2.057	1.800	1.600	1.440	1.309	1.200
4,200	2.800	2.450	2.178	1.960	1.782	1.633
4,800	3.657	3.200	2.844	2.560	2.327	2.133
6,000	5.714	5.000	4.444	4.000	3.636	3.333
	DIAMETER OF PIPE IN INCHES.					
	14	16	18	20	22	24
	LOSS OF PRESSURE IN OUNCES.					
600	.029	.026	.022	.020	.018	.017
1,200	.114	.100	.089	.080	.073	.067
1,800	.257	.225	.200	.180	.164	.156
2,400	.457	.400	.356	.320	.291	.267
3,600	1.029	.900	.800	.720	.655	.600
4,200	1.400	1.225	1.089	.980	.891	.817
4,800	1.829	1.600	1.422	1.280	1.164	1.067
6,000	2.857	2.500	2.222	2.000	1.818	1.667
	DIAMETER OF PIPE IN INCHES.					
	28	32	36	40	44	48
	LOSS OF PRESSURE IN OUNCES.					
600	.014	.012	.011	.010	.009	.008
1,200	.057	.050	.044	.040	.036	.033
1,800	.129	.112	.100	.090	.082	.075
2,400	.239	.200	.178	.160	.145	.133
3,600	.514	.450	.400	.360	.327	.300
4,200	.700	.612	.544	.490	.445	.408
4,800	.914	.800	.711	.640	.582	.533
6,000	1.429	1.250	1.111	1.000	.909	.833

TABLE LVI

Of the Number of Cubic Feet of Dry Air that may be Heated through 1° (F.) by the Condensation of One Pound of Steam

Steam Pressure above Vacuum.	INITIAL TEMPERATURE OF AIR.										
	0°	12°	22°	32°	42°	52°	62°	72°	82°	92°	102°
15	46,946	48,173	49,225	50,262	51,279	52,270	53,300	54,299	55,343	56,336	57,371
25	46,014	47,217	48,249	49,265	50,262	51,233	52,243	53,222	54,239	55,218	56,233
35	45,349	46,535	47,551	48,553	49,535	50,492	51,488	52,452	53,454	54,419	55,420
45	44,823	45,994	46,999	47,989	48,834	49,907	50,890	51,844	52,834	53,788	54,777
55	44,391	45,551	46,546	47,527	48,488	49,413	50,399	51,344	52,325	53,270	54,248
65	44,002	45,140	46,139	47,110	48,064	48,993	49,956	50,907	51,866	52,831	53,774
75	43,665	44,806	45,785	46,746	47,695	48,616	49,575	50,504	51,469	52,399	53,362
85	43,361	44,493	45,466	46,424	47,361	48,279	49,230	50,153	51,111	52,034	52,990
95	43,084	44,209	45,176	46,127	47,060	47,969	48,905	49,832	50,784	51,701	52,652
105	42,829	43,972	44,908	45,854	46,780	47,684	48,626	49,538	50,485	51,395	52,339
Per cent. of above amounts that will be heated 1° if air is saturated.	99.8	99.6	99.4	99.0	98.6	98.0	97.1	96.0	94.5	92.5	90.1

From a knowledge of the number of units of heat required, or the total weight of steam necessary per unit of time for any given building, it is a simple matter to deduce the size and capacity of the boiler to be provided. A proper understanding of the relative values of high and low pressure steam will result in due consideration being given to this factor in deciding upon the boiler capacity.

TABLE LVII

Of the Number of Thermal Units Contained in One Pound of Water

Temperature.	Number of Thermal Units.	Increase.	Temperature.	Number of Thermal Units.	Increase.	Temperature.	Number of Thermal Units.	Increase.
35°	35.000	.....	155°	155.339	5.034	275°	276.985	5.107
40	40.001	5.001	160	160.374	5.035	280	282.095	5.110
45	45.002	5.001	165	165.413	5.039	285	287.210	5.115
50	50.003	5.001	170	170.453	5.040	290	292.329	5.119
55	55.006	5.003	175	175.497	5.044	295	297.452	5.123
60	60.009	5.003	180	180.542	5.045	300	302.580	5.128
65	65.014	5.005	185	185.591	5.049	305	307.712	5.132
70	70.020	5.006	190	190.643	5.052	310	312.848	5.136
75	75.027	5.007	195	195.697	5.054	315	317.988	5.140
80	80.036	5.009	200	200.753	5.056	320	323.134	5.146
85	85.045	5.009	205	205.813	5.060	325	328.284	5.150
90	90.055	5.010	210	210.874	5.061	330	333.438	5.154
95	95.067	5.012	215	215.939	5.065	335	338.596	5.158
100	100.080	5.013	220	221.007	5.068	340	343.759	5.163
105	105.095	5.015	225	226.078	5.071	345	348.927	5.168
110	110.110	5.015	230	231.153	5.075	350	354.101	5.174
115	115.129	5.019	235	236.232	5.079	355	359.280	5.179
120	120.149	5.020	240	241.313	5.081	360	364.464	5.184
125	125.169	5.020	245	246.398	5.085	365	369.653	5.189
130	130.192	5.023	250	251.487	5.089	370	374.846	5.193
135	135.217	5.025	255	256.579	5.092	375	380.044	5.198
140	140.245	5.028	260	261.674	5.095	380	385.247	5.203
145	145.175	5.030	265	266.774	5.100	385	390.456	5.209
150	150.305	5.030	270	271.878	5.104	390	395.672	5.216

TABLE LVIII

VOLUME AND DENSITY OF AIR AT VARIOUS TEMPERATURES

Temperature. Degrees.	Volume of 1 lb. of Air at Atmospheric Presssure of 14.7 lbs. Cubic Feet.	Density or Weight of 1 Cubic foot of Air at 14.7 lbs. Lbs.
0	11.583	.086331
32	12.387	.080728
40	12.586	.079439
50	12.84	.077884
62	13.141	.076097
70	13.342	.07495
80	13.593	.073565
90	13.845	.07223
100	14.096	.070942
120	14.592	.0685
140	15.1	.066221
160	15.603	.064088
180	16.106	.06209
200	16.606	.06021
210	16.86	.059313
212	16.91	.059135
220	17.111	.058442
240	17.612	.056774
260	18.116	.0552
280	18.621	.05371
300	19.121	.052297
320	19.624	.050959
340	20.126	.049686
360	20.63	.048476
380	21.131	.047323
400	21.634	.046223
425	22.262	.04492
450	22.89	.043686
475	23.518	.04252
500	24.146	.041414
525	24.775	.040364
550	25.403	.039365
575	26.031	.038415
600	26.659	.03751
650	27.915	.035822
700	29.171	.03428
750	30.428	.032865
800	31.684	.031561
850	32.941	.030358
900	34.197	.029242
950	35.454	.028206
1,000	36.811	.027241
1,500	49.375	.020295
2,000	61.94	.016172
2,500	74.565	.013441
3,000	87.13	.011499

TABLE LIX

Influence of the Temperature of Air upon the Conditions of Its Movement

Temperature in Degrees, Fahr. 1	Relative Velocity Due to the Same Pressure. 2	Relative Pressure Necessary to Produce the Same Velocity. 3	Relative Weight of Air Moved at the Same Velocity. 4	Relative Velocity Necessary to Move the Same Weight of Air. 5	Relative Pressure Necessary to Produce the Velocity to Move the Same Weight of Air. 6	Relative Power Necessary to Move the Same Volume of Air at the Same Velocity. 7	Relative Power Necessary to Move the Same Weight of Air at the Velocity in Column 5 and the Pressure in Column 6. 8
30	0.98	1.04	1.04	0.96	0.96	1.04	0.92
40	0.99	1.02	1.02	0.98	0.98	1.02	0.96
50	1.00	1.00	1.00	1.00	1.00	1.00	1.00
60	1.01	0.98	0.98	1.02	1.02	0.98	1.04
70	1.02	0.96	0.96	1.04	1.04	0.96	1.08
80	1.03	0.94	0.94	1.06	1.06	0.94	1.12
90	1.04	0.93	0.93	1.08	1.08	0.93	1.17
100	1.05	0.91	0.91	1.10	1.10	0.91	1.21
125	1.07	0.87	0.87	1.15	1.15	0.87	1.32
150	1.09	0.84	0.84	1.20	1.20	0.84	1.43
175	1.11	0.81	0.81	1.24	1.24	0.81	1.55
200	1.14	0.78	0.78	1.29	1.29	0.78	1.67
225	1.16	0.75	0.75	1.34	1.34	0.75	1.80
250	1.18	0.72	0.72	1.39	1.39	0.72	1.93
275	1.20	0.69	0.69	1.44	1.44	0.69	2.07
300	1.22	0.67	0.67	1.49	1.49	0.67	2.22
325	1.24	0.65	0.65	1.54	1.54	0.65	2.36
350	1.26	0.63	0.63	1.59	1.59	0.63	2.51
375	1.28	0.61	0.61	1.63	1.63	0.61	2.66
400	1.30	0.59	0.59	1.68	1.68	0.59	2.82
425	1.32	0.58	0.58	1.73	1.73	0.58	2.99
450	1.34	0.56	0.56	1.78	1.78	0.56	3.17
475	1.35	0.55	0.55	1.83	1.83	0.55	3.35
500	1.37	0.53	0.53	1.88	1.88	0.53	3.53
525	1.39	0.52	0.52	1.93	1.93	0.52	3.72
550	1.41	0.51	0.51	1.98	1.98	0.51	3.92
575	1.43	0.49	0.49	2.03	2.03	0.49	4.12
600	1.44	0.48	0.48	2.08	2.08	0.48	4.33
625	1.46	0.47	0.47	2.13	2.13	0.47	4.54
650	1.48	0.46	0.46	2.18	2.18	0.46	4.75
675	1.49	0.45	0.45	2.22	2.22	0.45	4.93
700	1.51	0.44	0.44	2.27	2.27	0.44	5.15
725	1.52	0.43	0.43	2.32	2.32	0.43	5.38
750	1.54	0.42	0.42	2.37	2.37	0.42	5.62
775	1.56	0.41	0.41	2.42	2.42	0.41	5.86
800	1.57	0.40	0.40	2.47	2.47	0.40	6.10

TABLE LX

Velocity Created, Volume Discharged and Horse Power Required when Air under a Given Pressure in Ounces per Square Inch is Allowed to Escape into the Atmosphere

In the following table the volume is proportional to the velocity.

The power varies as the cube of the velocity.

"Blast area" generally means the maximum area over which the velocity of the air will equal the velocity of the pipes at the tips of the floats. If this area is decreased the volume will be decreased, but the pressure will remain constant. If this area is increased the pressure is lowered, but the volume somewhat increased.

This table is calculated for 50° F. temperature. Different temperature will effect the result. The movement of air through pipes will also change results.

Pressure Ounces per Square Inch.	Velocity of Air Escaping into Atmosphere.		Volume Discharged in One Minute Through Effective Area of One Square Inch, in Cubic Feet.	Horse Power of Air Blast.
	In Feet per Second.	In Feet per Minute.		
1/8	30.47	1,828	12.69	0.0004
1/4	43.08	2,585	17.95	0.001
3/8	52.75	3,165	21.98	0.002
1/2	60.90	3,654	25.37	0.003
5/8	68.07	4,084	28.36	0.005
3/4	74.54	4,473	31.06	0.006
7/8	80.50	4,830	33.54	0.008
1	86.03	5,162	35.85	0.01
1 1/4	96.13	5,768	40.06	0.014
1 1/2	105.25	6,315	43.86	0.02
1 3/4	113.64	6,818	47.34	0.023
2	121.41	7,284	50.59	0.028
2 1/4	128.70	7,722	53.63	0.033
2 1/2	135.59	8,136	56.50	0.039
2 3/4	142.14	8,528	59.22	0.044
3	148.38	8,903	61.83	0.05
3 1/2	160.10	9,606	66.71	0.06
4	170.98	10,259	71.24	0.08
4 1/2	181.16	10,870	75.48	0.09
5	190.76	11,446	79.48	0.11
5 1/2	199.86	11,992	83.24	0.12
6	208.53	12,512	86.89	0.14
7	224.77	13,486	93.66	0.18
8	239.80	14,388	99.92	0.22
9	253.83	15,230	105.76	0.26
10	267.00	16,020	111.25	0.30
11	279.70	16,768	116.45	0.35
12	291.30	17,478	121.38	0.40
13	302.59	18,155	126.06	0.45
14	313.38	18,803	130.57	0.50
15	323.73	19,424	134.89	0.55
16	333.68	20,021	139.03	0.61
17	343.26	20,596	143.03	0.66
18	352.52	21,151	146.88	0.72
19	361.46	21,688	150.61	0.78
20	370.13	22,208	154.22	0.84

TABLE LXI

Moisture Absorbed by Air

The Quantity of Water Which Air is Capable of Absorbing to the Point of Maximum Saturation, in Grains per Cubic Foot for Various Temperatures

Degrees. Fahrenheit.	Grains in a Cubic Foot.	Degrees Fahrenheit.	Grains in a Cubic Foot.
10	1.1	85	12.43
15	1.31	90	14.38
20	1.56	95	16.60
25	1.85	100	19.12
30	2.19	105	22.0
32	2.35	110	25.5
35	2.59	115	30.0
40	3.06	130	42.5
45	3.61	141	58.0
50	4.24	157	85.0
55	4.97	170	112.5
60	5.82	179	138.0
65	6.81	188	166.0
70	7.94	195	194.0
75	9.24	212	265.0
80	10.73	...	.....

TABLE LXII

Moisture in the Atmosphere

Indications of the Hygrometer (Dry and Wet Bulb)

Temperature of the Air, Degrees Fahrenheit.	Difference of Temperature or Degrees of Cold in the Wet-Bulb Thermometer.																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Degrees of Humidity, Saturation Being 100.																							
32	87	75	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
42	92	85	78	72	66	60	54	49	44	40	36	33	30	27	..	..	..	..	..	..	..	..	..	..
52	93	86	80	74	69	64	59	54	50	46	42	39	36	33	30	27	25	..	..	..	..	..	..	..
62	94	88	82	77	72	67	62	58	54	50	47	44	41	38	35	32	30	28	26	24	..	..	..	..
72	94	89	84	79	74	69	65	61	57	54	51	48	45	42	39	36	34	32	30	28	26	24	23	22
82	95	90	85	80	76	72	68	64	60	57	54	51	48	45	42	40	38	35	33	31	29	27	26	25
92	95	90	85	81	77	73	70	66	62	59	56	53	50	47	45	43	41	38	36	34	32	30	28	26

TABLE LXIII

Volume of Air Necessary to Maintain a Standard of Purity

Cubic Feet of Space in Room per Individual.	Proportion of Carbonic Acid in 10,000 Parts of the Air, Not to be Exceeded at End of Hour.						
	6	7	8	9	10	15	20
	Cubic Feet of Air, of Composition Four Parts of Carbonic Acid in 10,000 to be Supplied the First Hour.						
100	2,900	1,900	1,400	1,100	900	445	275
200	2,800	1,800	1,300	1,000	800	345	175
300	2,700	1,700	1,200	900	700	245	75
400	2,600	1,600	1,100	800	600	145	None
500	2,500	1,500	1,000	700	500	45	....
600	2,400	1,400	900	600	400	None	....
700	2,300	1,300	800	500	300	....	....
800	2,200	1,200	700	400	200	....	....
900	2,100	1,100	600	300	100	....	....
1,000	2,000	1,000	500	200	None	....	....
1,500	1,500	500	None	None	....	....	....
2,000	1,000	None	....	....	....	....	....
2,500	500	....	....	....	....	....	....

TABLE LXIV

Pressure in Inches of Water and Corresponding Pressure in Ounces, with Velocities of Air Due to Pressures

Pressure per Square Inch in Inches of Water.	Corresponding Pressure in Ounces per Square Inch.	Velocity Due to the Pressure in Feet per Minute.	Pressure per Square Inch in Inches of Water.	Corresponding Pressure in Ounces per Square Inch.	Velocity Due to the Pressure in Feet per Minute.
1/32	.01817	696.78	5/8	.36340	3,118.38
1/16	.03634	987.66	3/4	.43608	3,416.64
1/8	.07268	1,393.75	7/8	.50870	3,690.62
3/16	.10902	1,707.00	1	.58140	3,946.17
1/4	.14536	1,971.30	1 1/4	.7267	4,362.62
5/16	.18170	2,204.16	1 1/2	.8721	4,836.06
3/8	.21804	2,414.70	1 3/4	1.0174	5,224.98
1/2	.29072	2,788.74	2	1.1628	5,587.58

TABLE LXV

Pressure in Ounces per Square Inch with Velocities of Air Due to Pressures

Pressure in Ounces per Square Inch.	Velocity Due to the Pressure in Feet per Minute.	Pressure in Ounces per Square Inch.	Velocity Due to the Pressure in Feet per Minute.	Pressure in Ounces per Square inch.	Velocity Due to the Pressure in Feet per Minute.
.25	2,582	2.75	8,618	7.50	14,374
.50	3,658	3.00	9,006	8.00	14,861
.75	4,482	3.50	9,739	9.00	15,795
1.00	5,178	4.00	10,421	10.00	16,684
1.25	5,792	4.50	11,065	11.00	17,534
1.50	6,349	5.00	11,676	12.00	18,350
1.75	6,861	5.50	12,259	13.00	19,138
2.00	7,338	6.00	12,817	14.00	19,901
2.25	7,787	6.50	13,354	15.00	20,641
2.50	8,213	7.00	13,873	16.00	21,360

TABLE LXVI

Weights of Galvanized Iron Pipe per Lineal Foot

Diameter of Pipe in Inches.	Gauge of Iron—Numbers.				
	18	20	22	24	26
3	2¼	1¾	1½	1¼	**1**
4	2¾	2¼	1¾	1½	**1¼**
5	3¼	2¾	2	1¾	**1½**
6	3¾	3	2¼	2	**1¾**
7	4½	3½	2¾	2¼	**2**
8	5¼	4	3	2¾	**2¼**
9	5¾	4½	3¼	3	**2⅜**
10	6¼	4¾	3½	3¼	**2½**
11	6¾	5¼	3¾	3½	**2¾**
12	7½	5¾	4¼	3¾	**3**
13	8	6¼	4½	4	**3¼**
14	8½	6¾	4¾	4¼	**3½**
15	9¼	7¼	5¼	4¾	**3¾**
16	9¾	7¾	5½	**5**	4
17	10¼	8	6	**5¼**	4¼
18	10¾	8½	6¼	**5½**	4½
19	11½	9	6¾	**5¾**	4¾
20	12	9½	7	**6**	5¼
21	12½	9¾	7½	**6½**	5½
22	13¼	10¼	7¾	**6¾**	5¾
23	14	11	8¼	**7**	6
24	14¾	11½	8¾	**7½**	6½
26	15¾	12½	9¼	**7¾**	6½
28	16¾	13½	9¾	**8½**	7
30	18	14	10½	**9**	7½
32	19¼	15	**11¼**	9¾	8
34	20¼	15¾	**12**	10¼	8½
36	21½	16¾	**12½**	10¾	9
38	22¼	18	**13½**	11½	9½
40	24	18¾	**14**	12	10
42	25	19½	**14¾**	12½	10½
44	26¼	**20½**	15½	13	11
46	27½	**21¼**	16	13¾	11½
48	28½	**22¼**	16¾	14¼	12
50	29¾	**23**	17½	15	12½
52	31¼	**24¼**	18¼	....	....
54	32½	**25**	18¾	....	....
56	**33¾**	26	19	....	....
58	**35**	26¾	20¼	....	....
60	**36¼**	27½	20¾	....	....
63	**38¼**	29	21¾	....	....
66	**40**	30¼	22¾	....	....
69	**41¾**	32¼	23¾	....	....
72	**43½**	33¼	25	....	....

The figures in bold-faced type represent weight of round piping ordinarily used in heating work.

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