QUESTIONS AND ANSWERS

On the Practice and Theory of

STEAM and HOT WATER HEATING

Tenth Edition

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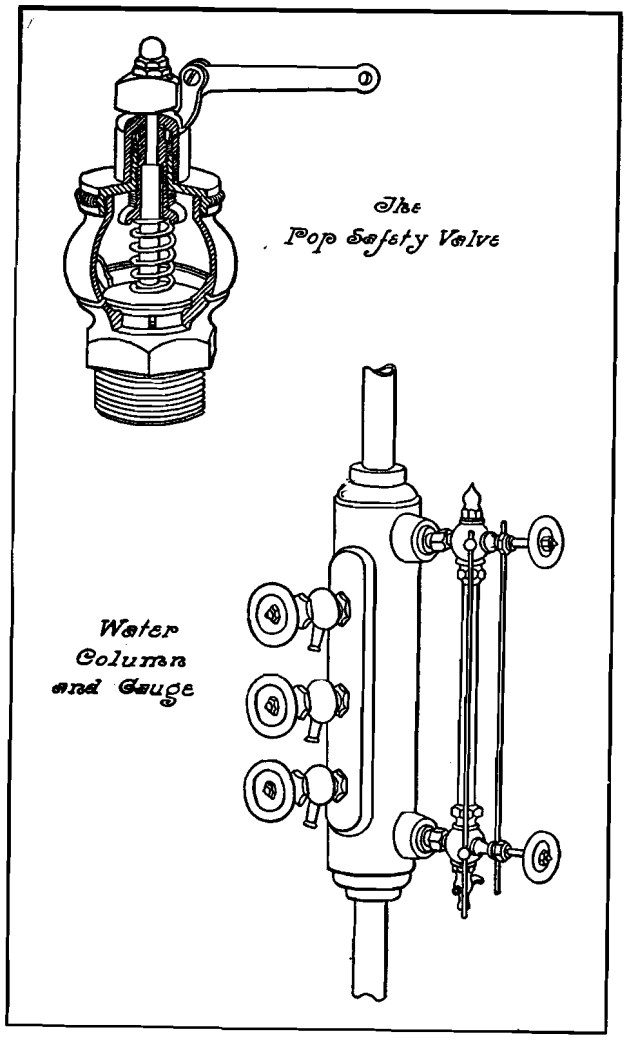


Water Column and Gauge—Pop Safety Valve

What styles of boilers are used for power purposes?

Either upright or horizontal tubular, or fire-box boilers are those generally in use for this purpose. A type of tubular boiler known as the water tube boiler has come into general use, and many claims as to its utility have been made by manufacturers of this style of boiler. In any tubular boiler much depends upon the character of its construction, and upon its proper setting.

How is the horsepower of a tubular boiler determined?

15 square feet of heating surface is estimated as one nominal horsepower.

What materials are necessary to properly set or brick in a standard type of horizontal tubular boiler?

The materials required in this work, and their proper amounts are given in the following table.

MATERIALS FOR BRICKWORK, REGULAR TUBULAR BOILERS

Boilers	No. Common Brick	No. Fire Brick	No. Bushels Sand	No. Barrels Cement	Pounds Fire Clay	No. Bbls. Lime
30 in.x 8 ft.	5200	320	42	5	192	2
30 in.x 10 ft.	5800	320	46	5½	192	2¼
36 in.x 8 ft.	6200	480	50	6	288	2½
36 in.x 9 ft.	6600	480	53	6½	288	2¾
36 in.x 10 ft.	7000	480	56	7	288	3
36 in.x 12 ft.	7800	480	62	8	288	3¼
42 in.x 10 ft.	10000	720	80	10	432	4
42 in.x 12 ft.	10800	720	86	11	432	4¼
42 in.x 14 ft.	11600	720	92	11¾	432	4½
42 in.x 16 ft.	12400	720	99	12½	432	5
48 in.x 10 ft.	12500	980	100	12½	590	5¼
48 in.x 12 ft.	13200	980	108	13½	590	5½
48 in.x 14 ft.	14200	980	116	14½	590	5¾
48 in.x 16 ft.	15200	980	124	15½	590	6
54 in.x 12 ft.	13800	1150	108	13¾	690	5½
54 in.x 14 ft.	14900	1150	117	15	690	6
54 in.x 16 ft.	16000	1150	126	16	690	6¼
60 in.x 10 ft.	13500	1280	108	13½	768	5½
60 in.x 12 ft.	14800	1280	118	14¾	768	6
60 in.x 14 ft.	16100	1280	128	16	768	6½
60 in.x 16 ft.	17400	1280	140	17½	768	7
60 in.x 18 ft.	18700	1280	148	18¾	768	7½
66 in.x 16 ft.	19700	1400	157	19¾	840	8
72 in.x 16 ft.	20800	1550	166	20¾	930	8½

It is well to state that the above amounts allow a small percentage for necessary or unavoidable waste.

When wrought iron tubular or fire-box boilers are used for heating purposes, how are their capacities determined?

For each rated horsepower there is figured 100 square feet of direct radiation for steam, and 160 to 170 square feet of direct radiation for hot water, and the same allowance must be made for mains and risers and for other styles than direct radiating surface, as made when cast iron heaters are used.

What are the principal types of cast iron boilers generally used for heating purposes?

Round or sectional boilers are generally used for this purpose.

Describe the round boiler.

Round boilers are usually made up of a series of cylindrical parts or sections bolted or nippled together. In this boiler, the smoke and products of combustion pass into various spaces or flues, and upward through the boiler into the smoke pipe, which in this type is usually placed at or near the top, and at the rear of the upper section or cylinder. Boilers of this class are made in a variety of styles for both steam and hot water heating.

Describe the sectional boiler.

Sectional boilers as used for heating purposes may properly be divided into two classes, brick set or portable. This form of boiler is usually made up of a number of upright sections in the form of an inverted U, narrow legs or water ways being connected to a hollow base or header containing water, into which base return water from the heating system is conveyed. The upper part of the boiler or heating surface above the fire is usually divided into a series of openings or horizontal flues giving a passage for the smoke and products of combustion to the rear of the boiler. In some types of boilers of this class, the smoke and gases of combustion are carried two or three times across or through the length of the boiler. These boilers are spoken of as of the slab type of construction. Boilers of this class by means of the arrangement of the castings are built for either brick setting or portable setting. In the former case, with the exception of the front, the boiler is encased in brick and in the latter case, the outside surface of the casting, with the exception of the front, is covered with a plastic cement, usually a mixture of asbestos and magnesia. The smoke hood or bonnet for a boiler of this type is placed at the top end of the rear section, in the center of the boiler.

How are cast iron heating boilers rated?

The capacity or rating of cast iron boilers for heating purposes depends largely on the character of construction. Some

boilers are so constructed as to have a large amount of prime or direct heating surface in proportion to the amount of grate surface, and when so constructed as to utilize all heat and gases of combustion, they may be put down as much more efficient than those types of boilers which do not utilize all the products of fuel consumed. It is impossible to give accurate data on grate and heating surface as so much depends on the type or character of boilers, that no two types can be figured alike. It may be well to state that our readers will find this idea more clearly discussed under the subject of the requirements for a good boiler.

We give the following table as illustrative of the comparison of heating and grate surface, square inches of smoke flue, and square feet of radiation.

RELATIVE PROPORTIONS OF STEAM HEATING APPARATUS

Sq.Ft.of Heating Surface	Sq.Ft.of Grate Area	Sq. Ins. of Flue	Sq.Ft.of Radiation	Ratio of Surface to Contents 1:50	1:70	1:90
67	3.5	96	400	20,000	28,000	36,000
83	4	96	500	25,000	35,000	45,000
116	5.8	96	700	35,000	49,000	63,000
167	8.3	110	1000	50,000	70,000	90,000
250	12.5	150	1500	75,000	105,000	135,000
333	16.5	195	2000	100,000	140,000	180,000
416	15.5	248	2500	125,000	175,000	225,000
500	18.6	300	3000	150,000	210,000	270,000
584	21.6	348	3500	175,000	245,000	315,000
666	24.5	398	4000	200,000	280,000	360,000
750	27.5	445	4500	225,000	315,000	405,000
834	26	485	5000	250,000	350,000	450,000
916	28.5	530	5500	275,000	385,000	495,000
1000	31	575	6000	300,000	420,000	540,000
1250	38.5	715	7500	375,000	525,000	675,000
1333	41	760	8000	400,000	560,000	720,000
1500	45.5	860	9000	450,000	630,000	810,000
1666	50	955	10000	500,000	700,000	900,000

What is meant by the prime or direct heating surface of a boiler?

That part of the boiler is called prime or direct heating surface, which receives the direct action of the fire, or which receives direct radiant heat from the fuel.

What is meant by the indirect heating surface of a boiler?

That part of the surface, which receives convected or indirect heat from smoke and the gases of combustion is called indirect heating surface.

What are the requirments of a good boiler?

A good heating boiler is one made of good material, carefully constructed, and put together in such a manner as to be

free from leakage at its joints when expansion due to heavy firing takes place. Boilers built in such a manner as to allow each each part of the boiler to expand under such conditions, are likely to be free from the possibility of the cracking of casting or sections.

It is conceded by the larger manufacturers of low pressure boilers that the nipple joint (either screw or push nipple), is the proper connection between castings or sections. Several years ago packed joints were largely used, that is, a packing was used between water openings, the sections being held together by bolts. Under conditions of possible heavy firing, or expansion due to rust, these joints gave way, and proved of considerable expense and annoyance. For this reason, this particular style of connection has been generally discarded. There should be no water connections or joints exposed to the direct action of the fire. The combustion chamber should be so constructed as to give room for the expanding gases and products of combustion, without choking, or deadening the action of the fire. The boiler should be so constructed as to produce a free, easy circulation within all its parts, and in the case of the steam boiler it should have a sufficient area of water surface to allow the disengagement of steam from the water without the possibility of the boiler foaming or priming.

Knowing the capacity of a boiler in square feet of radiation, how may the number of gallons of water the boiler is able to heat per hour be determined?

This depends upon the temperature to which the water is to be heated. Generally speaking, for house use, the square feet of capacity of boiler being given, add 33 1/3% to that amount, and the result will be the number of gallons that may be heated per hour.

Should a boiler be used to its full rated capacity?

It is economy to use a boiler of at least 25% greater capacity than that actually required by the amount of radiation called for. If coils are used instead of radiators, 50% should be added to the boiler capacity if it is to be run economically.

For direct-indirect work, about 25% should be added, and about 50% for indirect work.

How may the capacity of a boiler be determined?

To give a clear idea of the manner in which this calculation is made, we give the following as an example.

Suppose that a steam heating system is to supply the following amounts of radiation: 550 square feet direct radiation, 300 square feet indirect radiation, 275 square feet direct-indirect

radiation, 125 feet of 1-inch coil, 50 feet of 3-inch main, 150 feet of 1¼-inch risers, and 125 feet of 1-inch risers.

The equivalent in square feet of direct radiation of these several amounts would be the following:

550	square feet direct radiation.....	equals 550	sq. ft.
300	square feet indirect radiation.....	equals 450	sq. ft.
275	square feet direct-indirect radiation....	equals 344	sq. ft.
125	lineal feet 1-inch coil.....	equals 63	sq. ft.
60	lineal feet 3-inch main.....	equals 54	sq. ft.
150	lineal feet 1¼-inch risers.....	equals 65	sq. ft.
125	lineal feet 1-inch risers.....	equals 41	sq. ft.
	Total.....	1567	sq. ft.

This system calls for 1567 square feet of direct radiation according to the above calculation, and would therefore require a boiler having a gross rating of 1600 feet.

What constitutes the trimmings of a steam boiler?

The safety valve, steam gauge, water column and try cocks, damper regulator, and draw-off cocks.

What is the purpose of the safety valve?

Its purpose is to relieve the pressure when it reaches a certain point, above which it would be dangerous to rise.

How is the safety valve regulated?

Usually by a lever on which there is a movable weight, which can be set at any pressure.

What style of safety valve is generally used on low pressure boilers?

Low pressure boilers are generally provided with "pop" or spring safety valves.

How should the safety valve be located?

It should be located on the top of the boiler or steam dome.

At what point should the safety valve be set on low pressure systems?

It should be set to blow off at a pressure not exceeding five to ten pounds.

What is the purpose of the steam gauge?

Its purpose is to indicate the pressure of steam within the boiler.

Where should the steam gauge be located and connected?

It should be connected direct to the steam space in the boiler, and be provided with a siphon.

What kind of steam gauge should be used on a low pressure heating plant?

One that will register up to 15 pounds.

What is the water column and gauge, and its purpose?

It is a hollow tube provided with a gauge glass, located at the side of the boiler, and connecting at top and bottom into the boiler. Its purpose is to show the height at which the water stands in the boiler.

What precautions are necessary in the care of the gauge glass and safety valve?

The gauge glass should always be kept clean, and the safety valve should be occasionally tested to make sure that it is not sticking to the valve seat.

How may the gauge glass be cleaned?

Remove the gauge glass and immerse it in a strong ammonia solution or in an acid which will remove grease from glass.

What is the damper regulator, and how does it work?

The damper regulator consists of a hollow vessel formed by two castings bolted together, with a rubber diaphragm between them, the lower casting being connected to the steam space of the boiler by means of a short nipple. Through an opening in the top of the upper casting a plunger works, and across this plunger and connected to an upright lip on the edge of the diaphragm casting is a rod, from the ends of which chains connect to the draft door and check damper door of the boiler.

As steam pressure rises, the pressure against the under side of the rubber diaphragm is transmitted to the plunger which is raised, thereby operating the rod or lever, and the chains connecting with the draft and check damper doors. The sliding weight usually on the rod, may be set so that the leverage may be smaller or greater according to the pressure of steam carried on the apparatus, before the operation of the doors will take place. By means of the damper regulator the rise and fall of temperature in the boiler may so regulate the draft that an even temperature may be obtained.

How should the damper regulator be adjusted?

The chains should be so set that the draft door and check

draft will each be closed when the regulator lever is level, and there is no steam in the boiler.

What is the purpose of the altitude gauge on a hot water heating system?

By the use of an altitude gauge at the boiler, the necessity of watching the expansion tank to know the amount of water in it, is avoided, as the gauge at the boiler registers the height of water in feet in the system.

Explain the action and method of adjusting the altitude gauge.

The gauge has two dials, the red one being moveable only by hand, the black one being connected with the mechanism of the gauge. When the system is first filled to the required height, the spring dial of the gauge shows the height in feet of the water in the system. The face of the gauge is then taken off, and the red dial moved to a point directly under the steam dial, and pointing to the same number on the gauge. As the water in the system evaporates by use, the spring dial drops away from the red dial, indicating less water in the system, and the operator may know that the water is low in the system, when he should refill it until the two dials are in exactly the same position.

At what pressure is a low pressure boiler most economically run?

At two pounds pressure or less.

What precaution should always be taken before starting the fire or putting on the draught in a steam boiler?

The water gauge should always be examined. Many boilers have been injured by neglecting this precaution.

What precaution should be taken when the water in the steam boiler is found to be low?

The fire should be banked with ashes, wet or dry, and the feed door opened. When the boiler has cooled sufficiently, it may be slowly filled.

What should be done after the boiler is first fired?

The fire should be drawn and the boiler blown off while under pressure.

How often should steam boilers be cleaned?

Every steam boiler should be cleaned and tested twice each year.

How may a boiler be cleaned?

Kerosene oil will clean a boiler, and remove the scale.

In starting a fire where should the water stand?

About midway of the water gauge.

Should the ash pit door be opened to secure a draft?

It should not, as the opening in the door should be sufficient to give the fire all the draft it needs.

What is a common reason for the water leaving a steam boiler and rushing up into the radiation?

A common reason is that when steam gets low, the person operating the boiler in his anxiety to get steam up quickly, opens all drafts and gets up a fire far heavier than the boiler requires, with the result that the water in the boiler boils so strongly that it forces itself out of the boiler and into the piping and radiation.

What is the cause of nervous or unsteady water lines in low pressure boilers?

This trouble often results from oil in the boiler, the oil usually being present by reason of its use in the construction of the piping and manufacture of the boiler and radiators. The oil rests on the surface of the water in the boiler, forming a sort of scum, and when this occurs, the bubbles of air formed by the boiling water cannot reach the surface of the water and burst off into steam. This causes a commotion, the bubbles seeking an outlet naturally finding it in the connection to the water column, or gathering in such force under a portion of the scum, that they break together, and with such force as to frequently force water into the steam main, often causing a vacuum which will empty the water glass and water column connections entirely. There are other causes for water leaving the gauge glass, due in some instances to the character of construction of the boiler, or to the manner of connecting the water column.

What is the remedy for nervous or unsteady water lines in low pressure boilers?

Blow the boiler off under pressure. This will usually remove most of the oil, if the unsteady line is due to oil. It may be necessary to repeat this operation several times, at intervals of a few days, before the boiler is entirely clean. If the cause be due to the construction of the heater, it may be necessary to use an equalizing pipe, that is, to make a direct connection from an opening in the top of the boiler to a return opening in the bottom of the boiler, or to change the piping or boiler connections in such a way as to prevent the siphonage of water into the steam mains.

CHAPTER III

THE CHIMNEY FLUE

What are the purposes of the chimney?

To carry off smoke and gases, and to create the draft necessary to burn the fuel.

How is draft produced?

It is impossible to create a draft in a chimney unless the upward velocity of the heated gases is sufficient to overcome the pressure of the atmosphere, which is 14.7 pounds per square inch at sea level. As the gases expand, they are forced upward by the heavier air which enters through the draft door in the heater. This action overcomes the pressure of the atmosphere, and results in what is called draft.

What height does a chimney need to produce a good draft?

Thirty-five or forty feet seem from experience to be the minimum height which a chimney should have to produce a satisfactory draft. Flues of less height often give fairly good results, but are not dependable.

Chimneys should always be carried at least two feet above the highest point of the roof. In the case of a low chimney, the wind will often travel over the roof and actually destroy the draft.

What is the effect of draft?

Its effect is to increase combustion.

What is required of a flue in order that it may produce good draft?

Height is an important factor, and also area, the latter being dependent on the size of the boiler.

Upon what does the amount of draft necessary for a boiler depend?

The two principal features upon which draft is dependent are the nature of the fuel used, and the construction of the boiler, that is, whether it has a direct draft or not.

DIMENSIONS AND CAPACITIES OF STANDARD WROUGHT IRON PIPES

Nominal Inside Diameter	Actual Diameter Inches: Inside	Actual Diameter Inches: Outside	Area Square In. Inside	Lineal Feet per sq. ft. External Surface	Nominal wt. Pounds per Lineal Foot	Length of Full Thread	Size of Tap Drill	Gallons of Water per 100 Ft. of Length
⅛	.27	.41	.06	9.43	.24	.19	21/64	.3
¼	.36	.54	.10	7.08	.42	.29	29/64	.5
⅜	.49	.68	.19	5.66	.56	.30	19/32	1.0
½	.62	.84	.30	4.55	.83	.39	23/32	1.6
¾	.82	1.05	.53	3.64	1.12	.40	15/16	2.7
1	1.05	1.32	.86	2.90	1.67	.51	1 3/16	4.5
1¼	1.38	1.66	1.50	2.30	2.24	.54	1 15/32	7.7
1½	1.61	1.90	2.04	2.01	2.68	.55	1 23/32	10.6
2	2.07	2.38	3.36	1.61	3.61	.58	2 3/16	17.4
2½	2.47	2.88	4.78	1.33	5.74	.89	2 11/16	24.8
3	3.07	3.50	7.38	1.09	7.54	.95	3 5/16	38.4
3½	3.55	4.	9.89	.96	9.	1.	3 13/16	51.3
4	4.03	4.50	12.73	.85	10.67	1.05	4 7/32	66.1
4½	4.51	5.	15.96	.76	12.34	1.10	4 21/32	82.9
5	5.05	5.56	19.99	.69	14.50	1.16	5 15/64	103.8
6	6.07	6.63	28.89	.58	18.76	1.26	6 1/4	150.0
7	7.02	7.63	38.74	.50	23.27	1.36	7 5/16	202.0
8	7.98	8.63	50.02	.44	28.18	1.46	8 5/16	260.0
9	8.94	9.63	62.73	.40	33.70	1.57	9 5/16	326.0
10	10.02	10.75	78.82	.36	40.07	1.68	10 5/16	410.0
11	11.	11.75	95.03	.33	45.00	1.79	11 5/16	495.0
12	12.	12.75	113.09	.30	48.99	1.90	12 5/16	590.0

CHAPTER XI

STEAM HEATING

What are some of the relative advantages of steam and hot water heating?

The first cost of a steam heating system is considerably less than that of a hot water system, probably from 20 to 25 per cent. less. This is due to the smaller sizes of pipes and radiators used on steam work. However, the cost of operation is in favor of the hot water system.

When steam radiators are shut off because of too great heat, they cool much more rapidly than hot water radiators, but in many cases this fact may prove to be an advantage on the side of the hot water system.

A steam plant requires more attention and skill on the part of the attendant than the hot water system. As to freezing, the preference is with steam, and in public buildings, this is often a matter of importance. A hot water system may be run during mild weather to give off much less heat than a steam system, which must always be brought to a temperature of 212 degrees before any heat whatever is felt. Another advantage which the hot water system has, is that hot water may be heated below the water line of the boiler.

What systems of steam heating are in general use?

The low pressure gravity system, and the high pressure system, each being installed according to several different methods.

What is the chief feature of the low pressure gravity system of steam heating?

In this system all condensation returns to the boiler by gravity, that is, by its own weight.

What is known as low pressure steam?

Any pressure of steam below 10 pounds above atmospheric pressure is low pressure steam. This is the form of steam heating generally used in house heating.

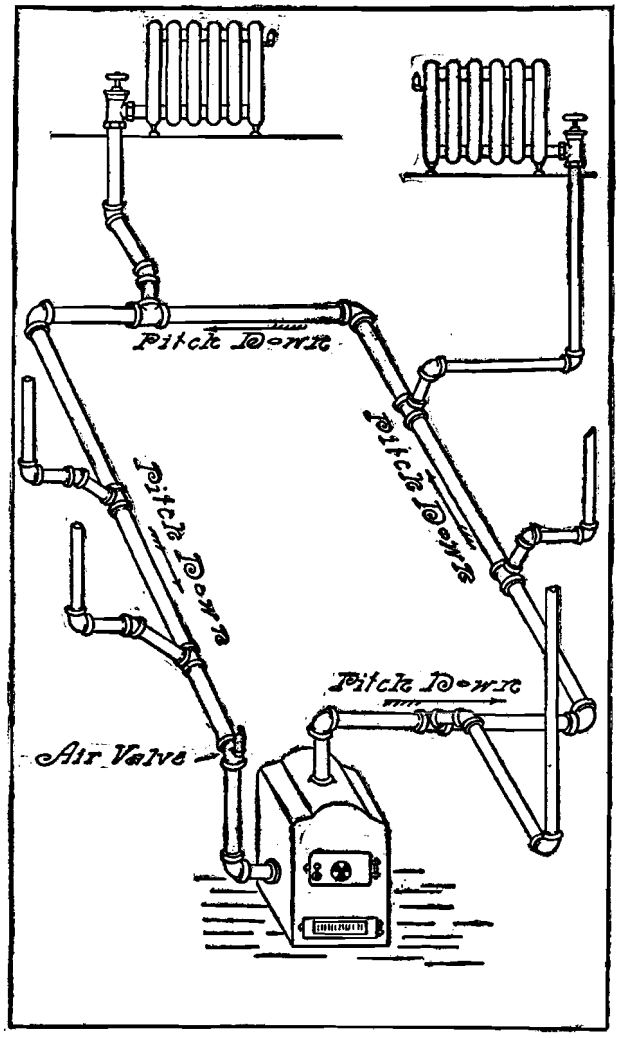


Fig. 15—Circuit System of Steam Heating

Why is the low pressure steam system mostly used in house heating?

For the reason that it is safer than high pressure steam, and as it works at a lower pressure is more economical to run, and requires less attention.

What is the general meaning of steam main?

A steam main is a flow pipe taken off the boiler and running horizontally on the basement ceiling to supply steam to the various branch lines which supply radiation.

What is a riser?

A riser is a pipe running vertically from the end of a branch to the radiation located at points above.

What is a drop riser?

A drop riser is the term applied to lines which are taken out of the mains in an overhead steam heating system. These mains run at the top of the building, and the drop risers extend downward to the basement, supplying radiation on the way down, the condensation passing down with the steam.

What is a return?

A return is a pipe for carrying water of condensation from the end of a main and from other points, back to the boiler. Return pipes may be run above the water-line of the boiler, or below it.

What is the smallest main that should be run on a steam heating system?

Nothing less than 1½ inch should be used for a steam main, and this size should not be run for a greater length than 25 feet.

What is the smallest riser that should be used on a steam system?

Regardless of the amount of work to be done, no steam riser less than 1 inch in size should be used.

Why should the use of small pipes be avoided in steam heating?

If too small, pipes will sometimes cause the raditors to fill with water. They also cause an increase of friction, which lessens the circulation.

How high should the steam main rise above the boiler?

It should be run as high as possible. A distance of 18 inches or more is desirable if conditions will allow it.

How should branches be taken from steam supply mains?

From the top, or at an angle of 45°, but never from the side. The 45° connection is preferable.

Why should branches not be taken from the side of the main?

Water hammer and the forcing of condensation from the main into the radiation may result.

How should a branch be run?

It should be run full size from the main to the riser, and connected with the latter by a reducing elbow.

What should be the relative size of a horizontal branch and its riser?

The horizontal branch should be one size larger than the riser, if more than 6 or 8 feet in length.

Why should the branch be larger than the riser?

Circulation is not so strong on a horizontal as on a vertical line.

Why should straight elbows on the main be avoided as far as possible?

They cause friction, which impedes circulation.

What pitch is necessary on a steam main?

A steam main should have a pitch of at least ½ inch to 1 inch for every 10 feet of length.

What pitch is necessary on branches?

Branches should have a pitch of at least 1 inch for each 5 feet.

Why should a perfect alignment be secured in the running of steam pipes?

Carelessness in the running of steam pipes is liable to form pockets or traps which impede the circulation and cause hammering, due to the water of condensation remaining in the pockets.

When necessary to form a pocket in a steam main, what precaution should be taken to relieve it of condensation?

When found necessary to make a direct rise in order to get over an obstruction or increase head room, the pocket formed because of this, should be dripped by a small pipe commonly termed a bleeder, into a wet return.

What precaution is necessary when radiators are located near the water line of the boiler, and a wet return is used?

A check valve should be placed on the return.

How should a steam heating plant be tested?

It may be tested at any season of the year, by the following rule, as laid down by Prof. Carpenter.

The following table shows the relative difference there should be between the outside and inside temperatures, to provide for a temperature of 70° when the outside air is at zero, with a pressure of 3 pounds.

Temperature of Outside Air	Temperature of Room
.10 degrees	64.7 degrees
0 degrees	70. degrees
10 degrees	75.1 degrees
20 degrees	81. degrees
30 degrees	86.5 degrees
40 degrees	93.1 degrees
50 degrees	98.7 degrees
60 degrees	104.7 degrees
70 degrees	110.5 degrees
80 degrees	117.1 degrees
90 degrees	123.5 degrees

What is the usual requirement as to temperature for residence heating?

It is customary for the heating contractor to guarantee to heat a residence to a temperature of 70 degrees in zero weather.

What causes water hammer in steam piping?

Traps or pockets in the piping, which allow water of condensation to lodge in them, are the cause. Steam, in passing such points, frequently makes a noise as if the pipe were being pounded with a hammer.

How can this trouble be avoided?

By carefully grading the steam main, allowing no traps or pockets, or whenever this occurs, dripping them into a wet return.

TEMPERATURE OF STEAM AT VARIOUS TEMPERATURES. PRESSURE IN POUNDS

By Steam Gauge	Above Atmosphere	Degrees Temperature
0	15	212
5	20	228
10	25	240
15	30	250
20	35	259
25	40	267
30	45	274
35	50	281
40	55	287
45	60	292
50	65	298
55	70	302
60	75	307
65	80	312
70	85	316
75	90	320
80	95	324
85	100	327
90	105	331
95	110	334
100	115	338
110	125	344
120	135	350
130	145	355
140	155	361
150	165	366

What is the best method of running pipe around a timber which cannot be removed or avoided?

This is best accomplished by the use of offset fittings, as they present the least resistance to circulation.

What is an equalizing pipe and its purpose?

It is a pipe connected from the steam dome or top of the boiler to one of the return openings below the water line of the boiler, or it may be connected from the main near the point where it is taken from the boiler, and connected into the return pipe at a point near the entrance of the return into the boiler. Its purpose is to steady the water line of the boiler, which may fluctuate, and cause annoyance, this trouble being due to the peculiar construction of the boiler or to the fact that a proper height cannot be reached by the main above the boiler, owing to a low ceiling or other cause.

What are the two systems of low pressure steam heating in common use?

The one-pipe and the two-pipe systems. The one-pipe system is installed as a circuit, divided circuit or as a relief system with

no returns. The two-pipe system is installed either by the regular method or as an overhead system. When the regular system is used, both flow and return mains are run in the basement, while in the case of the overhead system the mains are carried overhead with the returns in the basement.

Explain the meaning of high pressure steam as used in heating operations.

This generally applies to the use in heating operations of tubular or high pressure boilers which are primarily used for power purposes.

What pressures are used in high pressure steam work?

Pressures from 30 or 35 pounds up to 100 pounds or more are used in such work.

Is steam at high pressure generally used in a heating plant?

Steam at high pressure is not generally so used, but is first reduced by a pressure reducing valve located on the steam line, which reduces it to normal pressure.

Describe the exhaust heating system.

When steam which is under high pressure is supplied to an engine or other apparatus which uses steam in its operation, it does its work and finally escapes through the exhaust pipe. Only a comparatively small part of the heating power is used up when the steam is exhausted, and instead of allowing it to pass out into the air and be entirely wasted, it is made use of in a heating system. This method is called exhaust heating.

What is meant by a relief system?

This is a heating system in which all main flow pipes pitch upward from the boiler, and in which each has a drip or relief pipe connected at a point near the boiler, which carries all condensation to the bottom of the same. Condensation from the piping and radiators may also be relieved by drip connections on each riser or radiator connection. These should connect to a wet return.

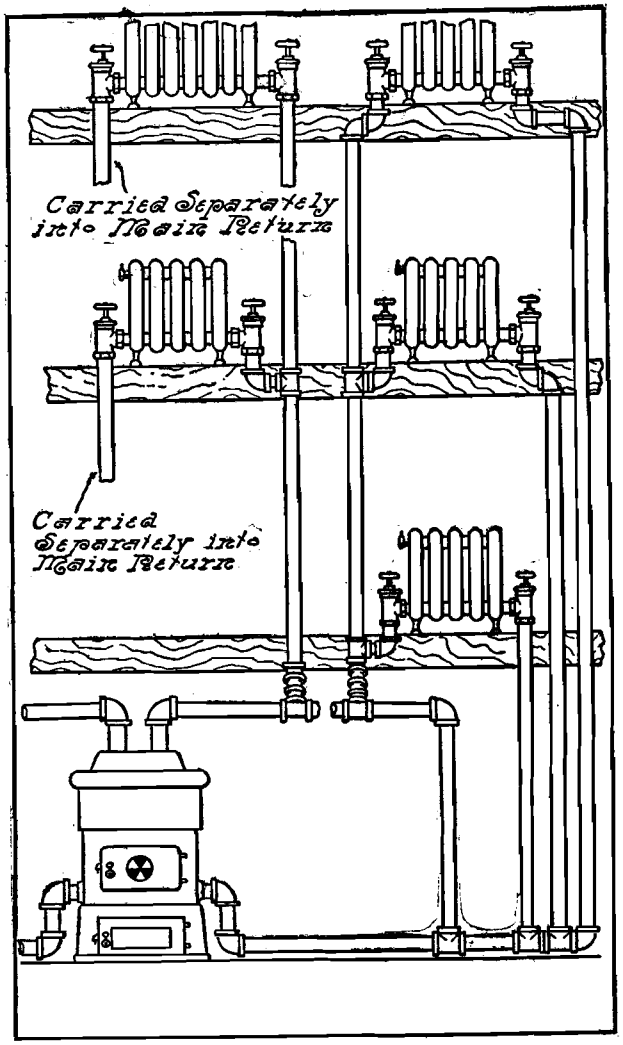


Fig. 17—Two-Pipe System of Steam Heating

CHAPTER XVI

HOT WATER HEATING

What systems of hot water heating are in general use?

The open tank, and the closed tank or pressure systems.

Which of these systems is preferable for house heating?

The open tank system is preferable to the closed tank system, as it may be more easily and safely operated.

What is the principal difference between the open and closed tank systems?

On the open tank, a vent pipe is carried from the expansion tank through the roof or side of the building, open to the atmosphere. The closed tank is not vented, and is therefore under pressure.

What advantage has the closed tank system?

In this system the water may be heated to a temperature above 212 degrees, the boiling point of the open tank system.

What precaution is necessary on the closed tank system?

A safety valve should be placed on the expansion tank, with a pipe running from the open side of the valve to the atmosphere, in order that when sufficient pressure is raised to operate the valve, an overflow of water may be carried off without damage to the property.

At what point should the safety valve be set on the closed tank system?

10 pounds is considered to be the proper pressure at which the safety valve should work.

What difference is there between the piping for the open and for the closed tank system?

The piping for the closed tank system may be somewhat smaller than for the open tank system, but the piping is run and connections taken off in the same manner for each system.

In running mains for hot water work, what pitch should be obtained to secure good service?

From ½ inch to 1 inch for each 10 feet of length.

What pitch should hot water branches have?

Double the pitch used on the main.

How should hot water mains pitch?

Upward from the boiler.

On hot water work, what should be the comparative size of flow and return pipes?

They should be of equal size.

How should flow and return pipes be run?

They should be run parallel to each other if possible.

What governs the size of hot water mains?

The sizes of the various branches, and the amount of radiation fed by them.

SIZES OF HOT WATER MAINS

Sizes of Mains	Radiation Supplied
1¼ inch	75 to 125 square feet
1½ inch	125 to 175 square feet
2 inch	175 to 300 square feet
2½ inch	300 to 475 square feet
3 inch	475 to 700 square feet
3½ inch	700 to 950 square feet
4 inch	950 to 1200 square feet
4½ inch	1200 to 1575 square feet
5 inch	1575 to 1975 square feet
5½ inch	1975 to 2375 square feet
6 inch	2375 to 2850 square feet

What should be the relative size of horizontal branches and risers?

Branches from the main, at or near the boiler, may be of the same size as the riser or pipe supplying the radiator. Towards the extreme end of the main, it is well to make the branch or horizontal pipe one size larger than the riser or radiator connection. This is equally true of an extremely long branch. A horizontal pipe or branch, longer than 6 feet, should be increased one size over that of the riser or radiator connection which it supplies.

What is the smallest hot water main that can be safely used?

1½ inch is the smallest practicable size, and this should not be used for more than a length of 25 feet.

NUMBER AND SIZES OF BRANCHES MAINS WILL SUPPLY

Main	Number and Size of Branches
1 inch	2 ¾-inch Branches
1¼ inch	2 1-inch Branches
1½ inch	2 1¼-inch Branches
2 inch	2 1½-inch Branches
2½ inch	2 1½-inch and 1 1¼-inch Branches
2½ inch	1 2-inch and 1 1¼-inch Branches
3 inch	1 2½-inch and 1 2-inch Branches
3½ inch	2 2½-inch Branches
3½ inch	3 2-inch Branches
3½ inch	1 3-inch and 1 2-inch Branches
4 inch	1 3½-inch and 1 2½-inch Branches
4 inch	2 3-inch Branches
4 inch	4 2-inch Branches
4½ inch	6 2-inch Branches
4½ inch	1 3½-inch and 1 3-inch Branches
4½ inch	1 4-inch and 1 2½-inch Branches
5 inch	1 4-inch and 1 3-inch Branches
5 inch	1 4½-inch and 1 2½-inch Branches
5 inch	8 2-inch Branches
6 inch	4 3-inch Branches
6 inch	10 2-inch Branches
6 inch	1 3-inch and 2 4-inch Branches

How should branch pipes be taken off the main?

From the top of the main, or at an angle of 45 degrees, the 45 degree connection being preferable.

Why is the connection of a branch at an angle of 45 degrees the preferable connection?

For the reason that this connection, made by tipping the tee at 45 degrees, and using a nipple and 45 degree ell, causes less friction in the flow of water than any other method of connection. Any choking or retarding of circulation should be done at the end of the branch as shown by illustrations under "Radiation."

Many fitters think that by taking the branch out of the top they are increasing the circulation, but they are using a 90 degree ell, and this causes an amount of friction ordinarily found by turning a column of water at right angles. This is not true of the 45 degree connection. The above applies to steam as well as to hot water work.

What precaution is necessary in reducing the size of mains?

They should not be reduced too rapidly as branches are taken

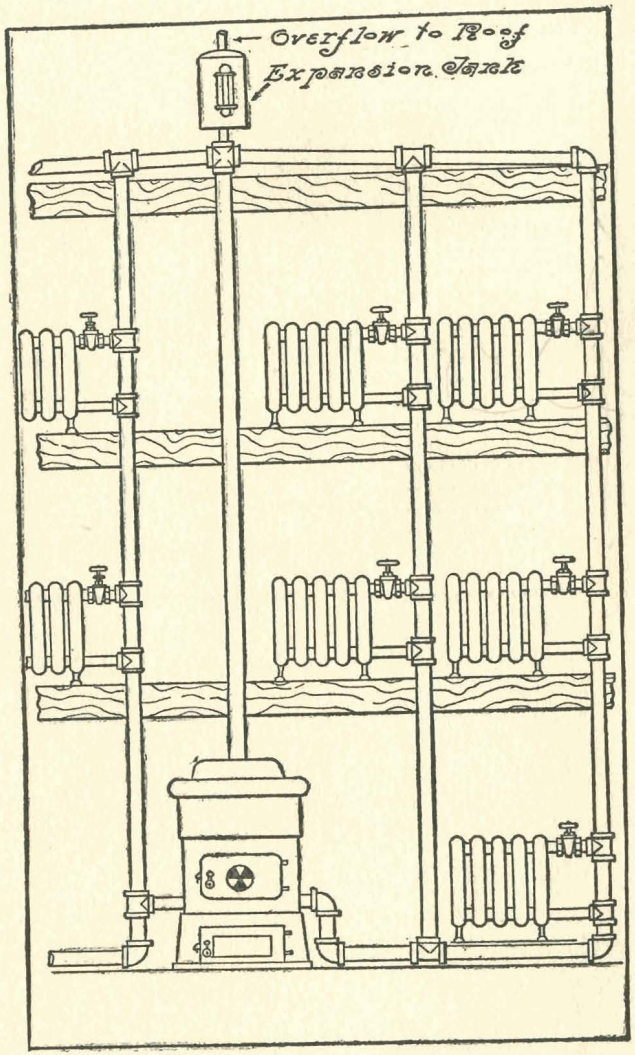


Fig. 18—Overhead System of Hot Water Heating

off, for the greater amount of friction in the smaller sizes of pipe will often cause trouble.

With radiator and riser close together, which should be taken off first?

The radiator connection should be made first.

Why should the radiator connection be made first?

In order to favor the radiator in the matter of circulation.

Can radiators be heated by hot water on the same level as the boiler, or below it?

They can be heated in these positions. Under such conditions, circulation results from the weight of water above the low radiators. This depends on the fact that a column of water 2 feet in height will produce about 1 pound of pressure.

How can a radiator or coil be heated below the line of the top of the boiler?

By carrying the flow pipe up so as to get a pressure from the weight of water above, to produce circulation.

From what point should a hot water system be filled?

From the lowest point.

Why should it be filled in this manner?

For the reason that this method will drive the air out of the system as the water rises.

What should be done with the air vents in filling a hot water system?

They should all be opened, to allow the air to escape, being closed one by one as each radiator is completely filled with water.

HOT WATER DIRECT RADIATOR TAPPINGS

Size of Radiator	Tappings for First Floor
15 square feet and less	¾ inch
15 to 50 square feet	1 inch
50 to 100 square feet	1¼ inch
100 square feet and larger	1½ inch
	Tappings for Second Floor
20 square feet and less	¾ inch
20 to 70 square feet	1 inch
70 to 125 square feet	1¼ inch
125 square feet and larger	1½ inch

HOT WATER INDIRECT RADIATOR TAPPINGS

Size of Radiator	Tapping
40 square feet and less	1 inch
40 to 90 square feet	1¼ inch
90 to 150 square feet	1½ inch
150 square feet and larger	2 inch

At what temperature should water leave the boiler to obtain satisfactory results from a hot water heating system?

Generally at about 180 degrees.

At what temperature should water return to the boiler?

With water leaving the boiler at 180 degrees, it should return at least at 160 degrees.

What is the least amount of loss in heat that should occur in hot water heating?

There should not be a loss of more than 20 per cent. in traversing the building, if good results are to be obtained.

Under the flow and return temperatures named above, what will be the temperature at the radiators?

The average temperature at the raditors would be about 170 degrees.

How should the grate surface and heating surface of a hot water heater be proportioned?

On small work, the area of grate surface should be 1 square foot for 30 square feet of heating surface. On work where there is more than 500 feet of radiation, the ratio may be 1 to 40. As an example—For 1000 square feet of radiation, 125 square feet of heating surface is necessary, with a fraction over 4 square feet of grate surface.

What precautions should be observed in running hot water risers?

In running risers for hot water work, it is well to avoid outside walls. If risers are to be concealed they should be run up through inside walls. If necessary, for any unavoidable reason, to run risers through or against an outside wall, they should be carefully covered to prevent chilling or freezing.

CHAPTER XVII

THE CIRCUIT SYSTEM OF HOT WATER HEATING

Describe the piping for the circuit system of hot water heating.

The main is carried entirely around the cellar or basement, from the top of the boiler, dropping into the return of the boiler after the last radiator has been passed.

Is it best to use one or more circuits in this system?

When possible, only one circuit should be used, but owing to the shape of the basement, it is often best to run two circuits.

What pitch should the main have, down from the boiler?

At least ½ inch for each 10 feet of length.

Should the main be run full size, or reduced?

It should be run full size until it enters the return of the boiler.

What is the highest point on the circuit?

Directly above the boiler.

How should the air be relieved at the high point?

By making connection to expansion tank at that point.

What size pipe should be used on a circuit main?

A size somewhat larger than that of the ordinary hot water main when it leaves the boiler, for the reason that in this system, the one pipe does the work of both the flow and return on other systems.

SIZE OF CIRCUIT MAINS

Size of Main	Direct Radiation Supplied
2 inch	175 square feet
2½ inch	300 square feet
3 inch	500 square feet
3½ inch	700 square feet
4 inch	1000 square feet
4½ inch	1200 square feet
5 inch	1600 square feet
5½ inch	2000 square feet
6 inch	2400 square feet

How should the risers be run on this system?

They should first feed the highest radiator.

Should air vents be used on radiators on the overhead system?

They should not be used, as this system has the advantage of venting itself at the top of the main riser, where connection is made to the expansion tank.

In the overhead system, what size of pipe should be run from the high point on the system to the expansion tank?

¾-inch pipe on small work, and 1-inch on large work should be used.

Why is circulation stronger on the overhead system?

The higher the system is run, the greater will be the weight of water and the greater will be its help to the circulation. On some buildings the weight of water is sufficient to heat radiators in the basement below the bottom of the boiler.

What are some of the advantages of the overhead system of hot water heating?

The main supply pipe will supply a greater amount of radiation than it will in a system where cellar piping is used. In this system the air is taken care of automatically, without the aid of air valves, and as stated above, the circulation is stronger, and takes place with less loss of heat than in other hot water systems.

CHAPTER XIX

THE REGULAR SYSTEM OF HOT WATER HEATING

Describe the piping for the regular hot water heating system.

The main flow pipe rises above the boiler to such height that there will be sufficient space between the top of it and the extreme end of the system to allow a proper pitch to the end of the piping.

This main is run in the most convenient manner possible, supplying the various branches or risers to radiators, and being reduced in size as this is done, the return being run the same size as the flow.

How should the piping of this system be run?

The flow and return pipes should be run parallel.

Should the main run full size throughout?

It should not run full size, but should reduce as branches are taken off.

What regulates size of pipes for mains and branches?

Sizes are based on valve area of radiators served. The area of the main flow pipe should never be less than the sum of the areas of all radiator valves which it has to supply.

What size should the main be at the point where the last radiator is connected?

It should be one or two sizes larger than the riser supplying the radiator, two sizes being preferable.

When the main flow pipe divides into two lines running in opposite directions, what kind of fitting should be used?

A double elbow should be used. This fitting divides the flow evenly, with the least possible friction.

How should the return main be run?

The return main should follow the direction of the flow, and is generally run side by side with it, at a distance of eight or ten inches. At the boiler the return drops vertically into the return opening of the boiler.

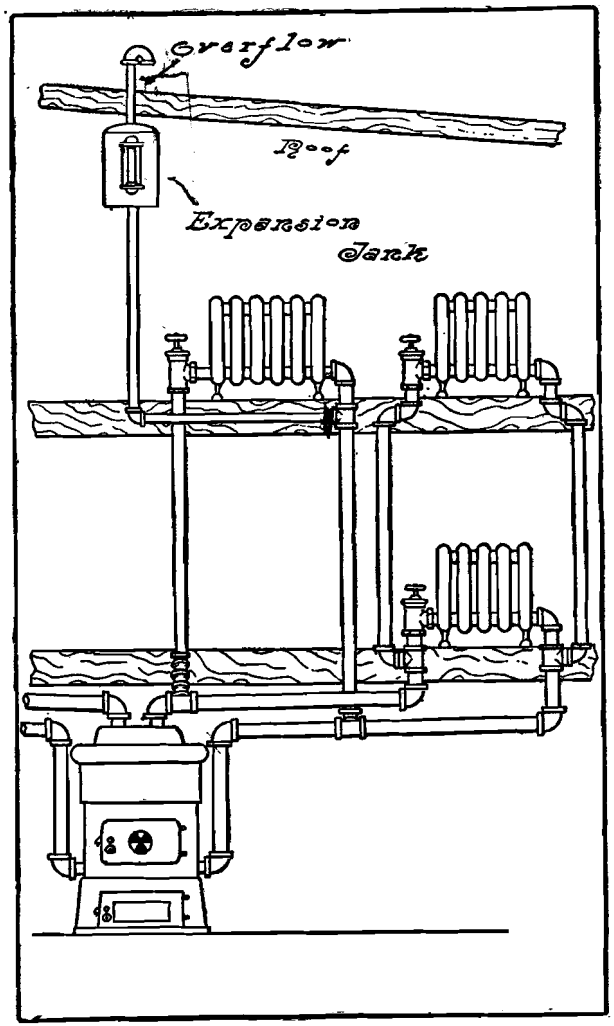


Fig. 22—Two-Pipe System of Hot Water Heating

What should be the size of branch returns in this system?

They should be the same size as branch flow pipes.

How should the expansion tank be connected on this system?

The expansion tank should be placed at a point at least three feet above the top radiator, the connection to it being made from the bottom of the tank to the nearest return riser.

What should be the size of the expansion tank connection?

This depends on the size of the system. A small system will require not larger than ¾ inch pipe, while larger systems will require larger sizes.

to increase after the drafts of the heater are closed, the float will finally lift the lever operating the relief valve. The appliance may be set to close the drafts of the heater at any point between zero and full pressure.

This system also requires a condensing radiator, usually composed of several sections of indirect radiation, which is hung from the ceiling of the basement, above the piping system. This fixture is employed to condense any vapor which may enter the return line, so that air and water only enter the receiver.

In Fig. 18 are shown complete connections for the Broomell vapor system.

The method of operation of the Kriebel system is clearly shown by Fig. 19.

Are vacuum and vapor systems dependable and positive in operation?

Yes, they are dependable, positive, safe and economical. The time is rapidly approaching when these systems will entirely supersede steam heating, as they not only provide for a greater range of temperatures, but they also are much more economical in operation, and their cost but little more than cost of a steam apparatus, and no trouble from air in the system, or from leaky air valves.

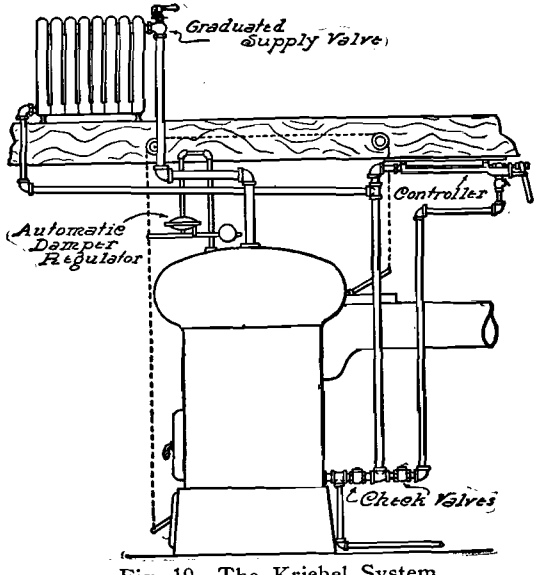


Fig. 19—The Kriebel System

CHAPTER XXIV

ACCELERATED HOT WATER HEATING

What has always been the great objection to the use of pressure hot water heating systems?

Pressure systems have been in use for years, but as the pressure on such systems was maintained by the use of valves, as by placing a valve on the expansion tank, it was an extremely hazardous method to employ, owing to the liability of the valve to stick, and the pressure to increase beyond the point of safety.

If the use of a safety valve on the hot water system is dangerous, is there any other device for increasing pressure, which may be used with safety?

Yes, any one of several mercurial devices, similar to those hereafter described, may be successfully used for this purpose.

Briefly, what is the operation of such a device as is now generally employed to make pressure systems safe and efficient?

A few years ago there was placed on the market a mercurial device, which, when placed on the return line, and connected to the expansion line, will hold a pressure on the system up to 10 pounds, and will maintain this pressure with perfect safety, as at the time the extreme pressure of 10 pounds has been reached, the mercury in the device will act in such a manner as to temporarily relieve the system from any excess pressure.

Describe the construction of the device employed for this purpose.

Possibly the original mercurial device is what is known as the Honeywell generator as illustrated by Fig. 1, which shows an outline cut of the exterior of the generator, which is composed of an elliptical shaped casting at the top, connected to a bottle shaped casting at the bottom, by a pipe which screws down into the bottle to a point near the bottom. Inside of this connecting pipe is

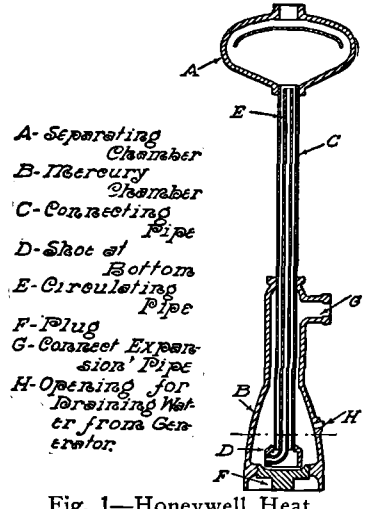


Fig. 1—Honeywell Heat Generator

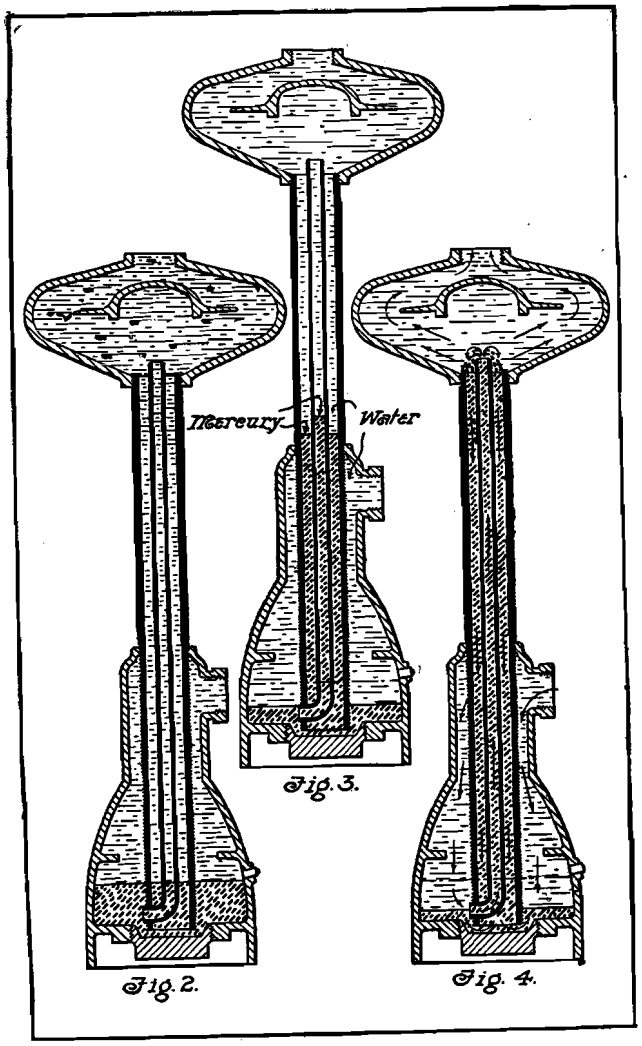


Fig. 2—Generator Producing no Pressure
Fig. 3—Producing 5 Pounds Pressure
Fig. 4—In Complete Operation, Producing 10 Pounds Pressure

a secondary or circulating pipe of small size which extends slightly above the connecting pipe into the top compartment of the generator.

What is the action of the Honeywell generator?

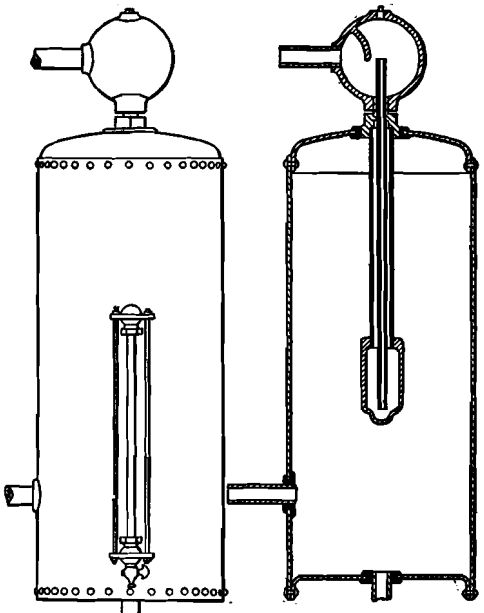
The expansion line is connected into the side of the bottle shaped casting, in the bottom of which is a pot of mercury sufficient in quantity to hold the pressure of the expansion until approximately 10 pounds has been reached. The mercury meanwhile circulates up and down through the tube connections, acting on the system much like an air cushion.

The water in the system therefore cannot boil until a pressure in excess of 10 pounds has been reached, and as 10 pounds pressure represents a temperature of 240 degrees of the water, the use of the device gives a range of temperatures from that at which hot water begins to circulate (about 90 degrees) up to 240 degrees, or the equal of steam at 10 pounds pressure.

What benefits are derived from the use of the accelerated heating system?

Owing to the range of temperatures available, the amount of hot water radiation ordinarily required, is lessened from 10 to 15 per cent., and in addition the piping of the system is much smaller in size than would be installed for an open hot water job.

The water in the system is therefore reduced about one-third in bulk. As the problem of hot water heating is to transpose the heat from the coal burned to the water, and then to the air to be heated, with as little loss as possible, and from the further fact that the circulation in the accelerated system is from three to five times faster than in the open system, it is easily understood why accelerated heating



Two Views of "Milwaukee" Heat Generator

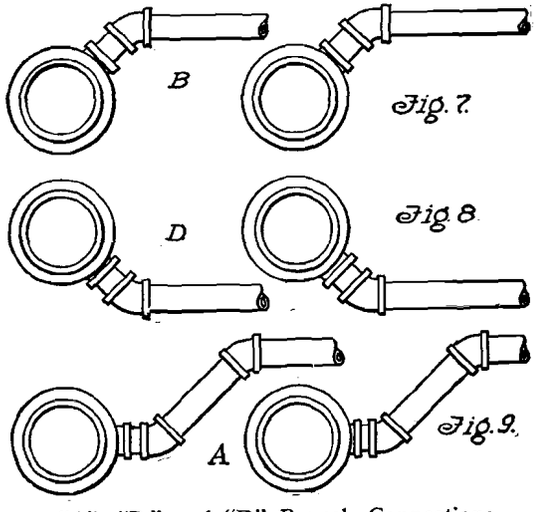
is so positive in the results obtained, and in the economy of its operation. Smaller valves, smaller pipes, smaller fittings, smaller covering, and a reduction of from 10 to 15 per cent. in the footage of the radiation mean a considerable saving in the estimated cost of a heating plant.

Describe the action of the mercury in the Honeywell generator under varying pressures.

Fig. 2 shows an interior view of the Honeywell generator at the time of no pressure on the apparatus, or before the fire in the heater has been lighted. Fig. 3 shows an interior view of the generator after a pressure of 5 pounds has been obtained on the system. Note that the mercury is forced up the connecting pipe and circulating pipe, to a point about half way of their length, or a little above the top of the bottle. Fig. 4 shows an interior view of the generator at the time the pressure of 10 pounds has been reached. Note that the mercury has reached the top of the tubes, and is overflowing from the smaller tube into the larger space surrounding it, and owing to the difference in weight, is circulating up and down the tubes; the mercury in the bottom of the generator has been lowered to such a point that the water in the system can pass upward, with the mercury finding its way into the expansion tank in the usual manner.

Name other commercial devices similar to the generator described above.

The Mercury Heat Economizer is a device similar to the



"A", "B," and "D" Branch Connections

Honeywell Generator, and is placed on the heating system in a similar manner. Still another mercury device is known as the Milwaukee Heat Generator. The mercury sealing device is on the interior of the tank as illustrated by Figs. 5 and 6.

How is the radiation for an accelerated heating system estimated?

When the accelerated system is installed, the radiation is estimated by the usual method, and a reduction made in the same, of from 10 to 15 per cent.

How are sizes of pipes estimated for an accelerated heating system?

The piping of an accelerated system is an all-important feature of its successful working, and the size of pipes is estimated entirely from the area of the valves used on the radiators. The radiators are tapped somewhat smaller than is usual, and it is seldom that a radiator above the first floor is supplied with larger than a ¾-inch connection. The tapping of the radiators should be as follows:

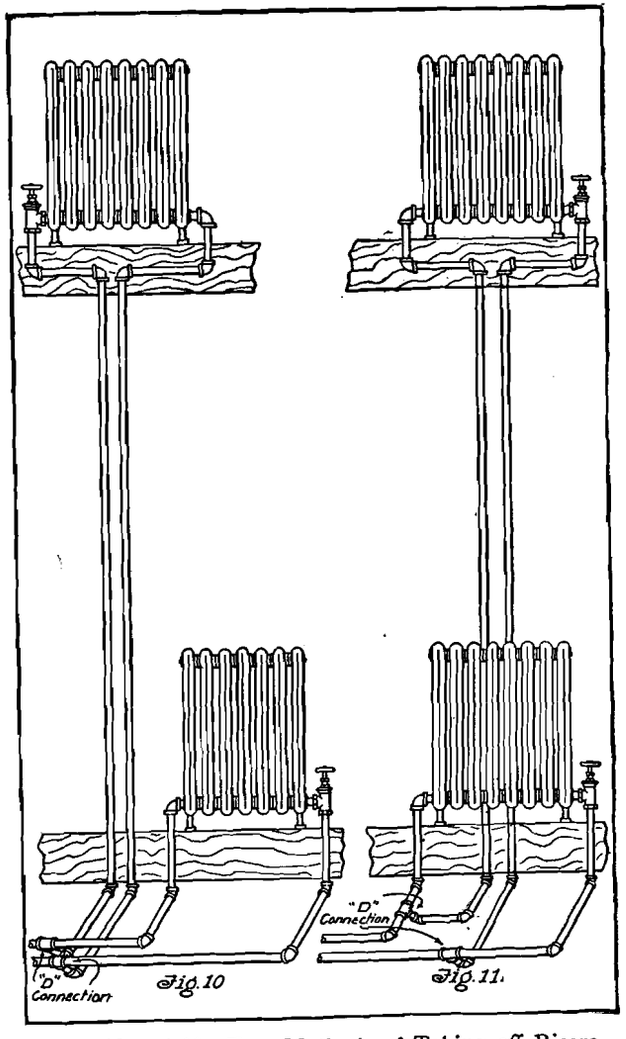
Up to 30 square feet	½ inch
From 30 square feet to 75 square feet	¾ inch
Over 75 square feet	1 inch
Up to 40 square feet	½ inch
From 40 square feet to 100 square feet	¾ inch
Over 100 square feet	1 inch
Up to 50 square feet	½ inch
From 50 square feet to 125 square feet	¾ inch
Over 125 square feet	1 inch

How are the sizes of mains generally determined in planning an accelerated heating system?

There is an established rule that the size of the main supplying the last riser or radiator connection, should be of two sizes larger pipe than the riser or the connection to the radiator. Therefore in planning the piping of an accelerated system, after laying out the general direction of the mains, begin with the last radiator connection and work towards the boiler, increasing the area of the main to an amount just in excess of the area of the valves used on the radiator connections.

Of what size should branches be, and how should they be taken off the main?

All branches to radiators or risers are of the same size as the radiator connection or riser which they feed, and are taken from the main by one of three styles of connection. Fig. 7 shows the



Figs. 10 and 11—Two Methods of Taking off Risers on the Ends of Mains

B connection, a connection used whenever a reduction occurs in the size of the mains in order to relieve the air at the point of reduction. The D connection, Fig. 8, is employed whenever a branch is taken supplying a riser to upper floors. The A connection, Fig. 9, is used when branches supply a first floor radiator or a first floor radiator and riser to upper floor, in which event the branch for the riser is taken from the branch to first floor, from its side or by the use of a D connection.

How should risers be connected on the ends of mains?

Fig. 10 shows one method of connecting risers on the ends of mains. Fig. 11 shows another method. Note that the return from upper radiator is connected into the side of the main return.

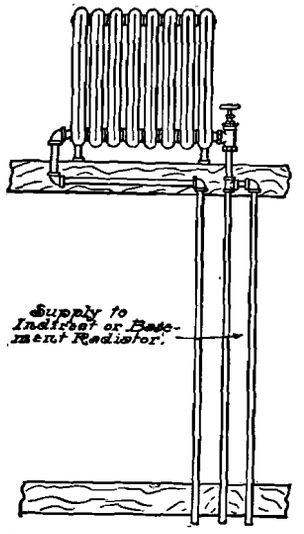


Fig. 12—Connections for Securing Good Circulation in Basement Radiators

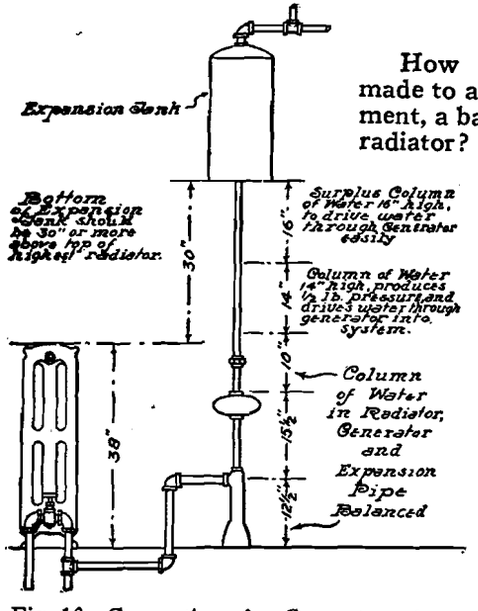


Fig. 13—Connections for Generator when Located on a Second or Higher Floor

How should a connection be made to an indirect radiator in basement, a basement ceiling coil or wall radiator?

When it is necessary to supply an indirect radiator in the basement or a basement ceiling coil or wall radiator, the connection to the same should be taken from a riser at the top of the first floor, in order that the difference in the weight of water, or specific gravity, will cause a positive circulation through the radiator in basement. Fig. 12 shows the method.

Why should all pipe ends be carefully reamed?

It is of vital importance that the ends of all pipe be thoroughly reamed to remove the bur and prevent the lodgment of sediment. The bur made by the cutter wheel frequently lessens the area of the pipe at least 25%, and therefore should be removed.

What methods are employed in connecting the generator to the heating system?

The generator may be connected on the expansion line between the return of the top radiator and the tank, or the expansion line may be run to the basement and the generator connected into the return line at the base of the boiler, and the expansion line in turn connected into the top of the generator. This latter method is preferable to the other. Fig. 13 shows the method of connecting the generator at the top of the system and Fig. 14 shows the method of connecting the generator at the boiler.

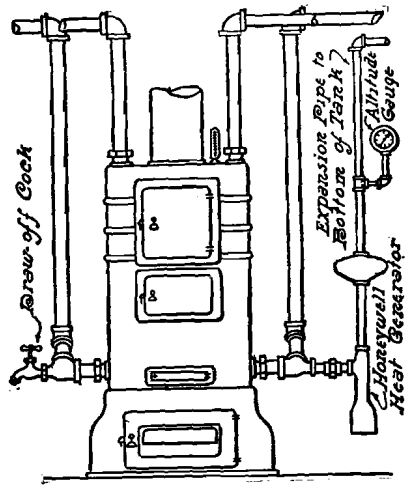


Fig. 14—Connections for Generator with Altitude Gauge and Draw-off Cock

CHAPTER XXV

PIPE FITTING IN CONNECTION WITH REFRIGERATING PLANTS

Is there much work for the steamfitter, in connection with refrigeration?

There is much work in connection with refrigerating plants, whether large or small, which the steamfitter is qualified to do. This work is in his line, and he will find that it can be made a paying specialty. There are certain things peculiar to this work, however, which he should know, and the writer has thought it a wise plan to add a short chapter on the subject, taking up briefly those features which seem to be of special practical importance, and giving concisely a general idea of the apparatus of a refrigerating plant.

What are the special features of a refrigerating plant?

There are six distinct features in mechanical refrigeration—the compressor, condenser, receiver, expansion valve, expansion coils, and the gas used in the system.

What is the purpose of the compressor, and how is it driven?

The compressor may be any form or variety of pump suitable for pumping the gas to be used. Some are made with inclosed crank cases, with a stuffing box on the shaft, while others have stuffing boxes on each cylinder, similar to a steam engine. They are generally driven either by steam or electricity, and sometimes by a gas engine.

What is the purpose of the condenser and what is its construction?

The condenser is a series of pipes arranged in columns, through which the gas is pumped by the compressor, and condensed into liquid form. The condenser is sometimes cooled by a thin sheet of water falling down over the pipes. Such a condenser is known as an atmospheric condenser. Condensers are also made of two pipes, one inside the other, suitable fittings being provided at the ends, so that the cooling water may flow through the inner pipe, while the gas passes through the space

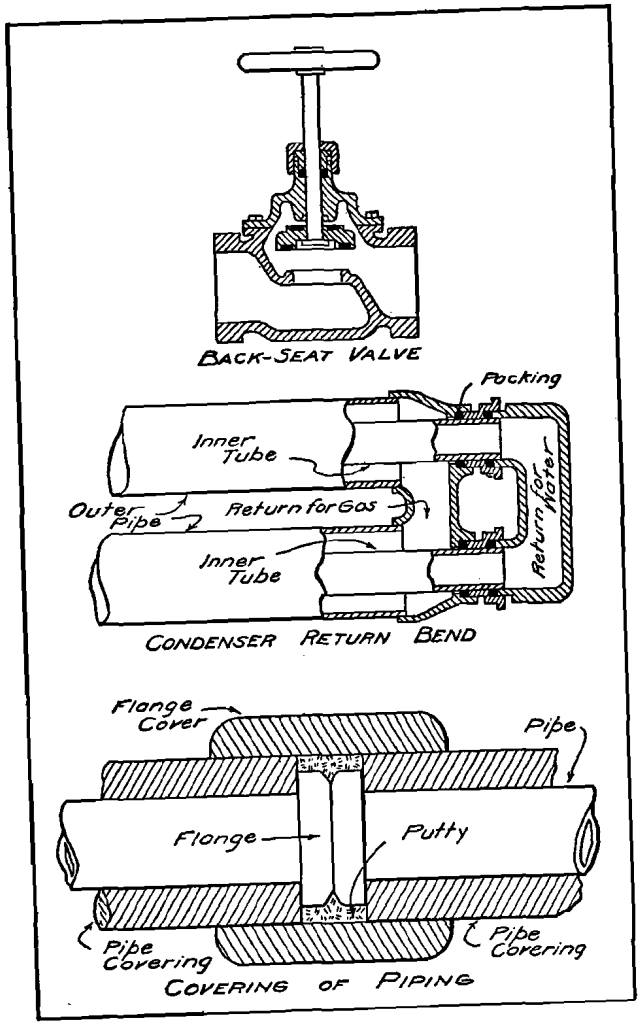


Fig. 2

CHAPTER XXVI

THEORY

What is atmospheric pressure?

It is the pressure exerted by the atmosphere upon one square inch of surface, or in other words, it is the weight of a column of air one square inch in cross section. At the sea level this column of air, that is, the earth's atmosphere, is about 45 miles deep, and exerts a pressure of about 15 pounds per square inch.

Why is atmospheric pressure less at the top of a mountain than at sea level?

For the reason that at the top of an elevation, the depth of the atmosphere is necessarily less than at lower points.

How is the boiling point of water affected by atmospheric pressure?

The temperature at which a liquid boils, rises as the atmospheric pressure increases. Therefore water will boil at a lower temperature at the top of a mountain than at its base.

Explain the action of expansion and contraction.

When heat is applied to a metallic body, the particles of which the body is composed increase in size, and the body itself naturally occupies a larger space than before. This is the action of expansion.

When the body cools, the opposite action takes place, and the body contracts. If heat is applied beyond a certain amount, varying with each metal, expansion becomes so great that the particles will no longer hold together, and the body is transformed into the liquid state. Expansion and contraction apply to many substances besides metals, such as air, water, etc.

How does the expansion of water differ from that of other substances?

As stated above, substances in general continue to expand as long as heat is applied, and contract as long as the heat is lessened. Water is heaviest at 39.2 degrees, and when heated above, or cooled below this point, it expands.

If this were not so, at the freezing point the coldest water would be at the bottom, and the formation of ice would begin at the bottom of rivers and ponds, the entire body of water finally becoming a solid mass of ice.

Does heated air and water rise or fall, and why?

Heated air and water rise because their particles are more expanded, and therefore lighter than the colder particles.

How does this principle find application in heating?

In the circulation of air and water.

What is a vacuum?

A vacuum is a portion of space from which the air has been entirely exhausted.

What is evaporation?

It is the slow passage of a liquid into the form of vapor.

What causes increase the rate of evaporation?

Increase of temperature, increased exposure of surface, and the passage of air currents over the surface.

What is condensation?

Condensation is the passage of a vapor into the liquid state, and is the reverse of evaporation.

What are the laws governing the pressure of liquids?

1—Pressure exerted upon a liquid is transmitted undiminished in all directions, and acts with the same force on all surfaces, and at right angles to those surfaces.
2—The pressure at each level of a liquid is proportional to its depth.
3—With different liquids and the same depth, pressure is proportional to the density of the liquid.
4—The pressure is the same at all points on any given level of a liquid.

What is buoyancy of a liquid?

The pressure of the upper layers of a body of liquid on the lower layers causes the latter to exert an equal reactive upward force. This force is called buoyancy.

Does the pressure of a liquid depend upon the shape of the vessel containing it?

It does not.

What is fluid friction?

In flowing over any surface, for instance the sides of a pipe, a fluid meets with more or less resistance from the surface. This resistance is called friction.

What are the laws which govern the friction of fluids?

1—Friction does not depend in the least on the pressure of the fluid upon the surface over which it is flowing.
2—Friction is proportional to the area of the surface.
3—At a low velocity (not more than one inch per second for water) friction increases with the velocity of the liquid.
4—Friction increases with the roughness of the surface.
5—Friction increases with the density of the liquid.

Is the friction of water greater in small or in large pipes, and why?

Friction is greater comparatively, in small pipes, for a greater proportion of the water comes in contact with the sides of the pipe than in the case of the large pipe. For this reason mains on heating apparatus should be generous in size.

How do the compressibility of air and water compare?

Air is extremely compressible, while water is almost incompressible.

Of what is water composed, and what are the proportions?

Water is composed of two parts of hydrogen, and one part of oxygen.

Will water absorb gases, and under what conditions is absorption greatest?

Water will absorb gases, and to the greatest extent when the pressure of the gas upon the water is greatest, and when the temperature is the lowest, for the elastic force of gas is then less.

Of what is air composed, and in what proportions?

Air is composed of about one-fifth oxygen and four-fifths nitrogen, with a small amount of carbonic acid gas.

Describe the principle of circulation.

To illustrate, we will expose a piece of ice to heat. The ice is composed of innumerable small particles, each one in constant motion.

As the ice is heated, these particles begin to expand, and their vibrations increase in rapidity, finally to such an extent that

the particles will no longer hold together, but separate from the solid mass, and become water.

As the heat continues, expansion still continues, each heated particle striving to rise, which of course forces the colder particles to fall and fill the vacant space.

Up to this point the action has been just what takes place in the circulation of hot water.

At last, however, the water becomes so heated that expansion becomes stronger than atmospheric pressure, the particles escape from the mass of water, and being lighter now than the air itself, pass off in the form of steam. Being lighter than the air they of course rise, and here again we have circulation, that is, the circulation of steam. These principles underly all circulation work, both hot water, steam and hot air.

What is the elastic force of steam?

The elastic force of steam is equal to the pressure under which it is generated. If generated under a pressure of 15 pounds, its elastic force when free will be 15 pounds.

Explain the action of the syphon.

The syphon consists primarily of a bent tube, one arm being longer than the other. The syphon transfers liquids from a higher to a lower level. In order to start the syphon the air in the long arm must first be exhausted. As soon as this vacuum is formed, atmospheric pressure forces the water up the short arm, and into the long arm, through which it passes out.

This action continues, unless broken by other means, until the short arm no longer dips into the water.

How may the action of the syphon be destroyed?

By bringing air into the crown of the syphon.

CHAPTER XXVII

MISCELLANEOUS INFORMATION

At what temperature does water boil?

At the sea level, water boils at 212 degrees.

At what temperature does water boil in vacuum?

At 98 degrees.

What is the weight of a gallon of water?

8 1/3 pounds.

What are the cubic contents of a gallon of water?

231 cubic inches.

What is the weight of a cubic foot of water?

62½ pounds.

How many gallons does a cubic foot of water contain?

A cubic foot of water contains 1728 cubic inches, or 7½ gallons.

What is the expansion of water in freezing?

About one-tenth of its volume.

What is the expansion of water in boiling?

About one-twentieth of its volume.

What is the expansion of water in changing to steam?

In changing to steam water expands 1700 times its volume. Approximately 1 cubic inch of water produces 1 cubic foot of steam.

At what temperature does water occupy the least space?

At 39 degrees.

What is the pressure of a column of water?

A column of water 27.67 inches in height produces 1 pound