A Practical Manual *of* Steam and Hot-Water Heating

A Practical Manual OF Steam and Hot-Water Heating

By

EDWARD RICHMOND PIERCE

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EDWARD RICHMOND PIERCE

AUTHOR'S PREFACE

For about a quarter of a century the writer of these pages has been connected with those who manufacture and sell boilers and radiators for steam and hot-water heating.

During this long period it has been his daily duty and privilege to answer the questions of architects, engineers, steam-fitters and house-owners in regard to every phase of the house-heating industry.

To do this with some degree of intelligence on his own part, and to keep in touch with the remarkable development of the science of heating through the efforts of heating engineers during this period, has compelled him to utilize every resource at his command and become a student of every phase of this somewhat complex subject.

His duties have compelled him to visit frequently every section of our country and to become acquainted with the heating requirements of each. Many times during these years he has been urged by friends to give some presentation of heating principles in book-form.

Experience has shown that in every doubtful problem, it was because some involved fundamental principle had not been fully understood. It has also demonstrated that the majority of those who do the practical work of measuring the buildings and erecting house-heating systems of steam or hot water require that the information they desire be given in simple terms of ordinary conversation, and not in scientific terms.

In the present work I have endeavored to bring out every fundamental principle involved in the science of heating in a manner to meet that need.

To a great number of authors who have preceded me I am indebted. There is scarcely a book published on the subject to whose author thanks are not due for some suggestion or fact. The list is too long for specific mention. To each, therefore, who in a way is quoted but is not given specific credit in the text, I now tender my thanks.

The agency system of sale that prevailed until within a few years in the heating industry, left as a legacy to those who must carry on the work of today questions for the manufacturer to solve as momentous as those that confront the architect, engineer and steam-fitter. The purport of these questions and the aid that the architect, the engineer, and those that carry out their plans can give to the heating industry by a more complete knowledge of the fundamental principles of the science, I have endeavored to make evident. When these factors have each a personal acquaintance with the principles which underlie the sciences of heating and ventilation, these contributors to public health and comfort will take their rightful position as among the greatest of practical sciences.

Though this book is written primarily for the everyday workman in the heating industry and therefore is without the usual formulas and scientific phrases, it is hoped that this simplicity of treatment will not prejudice the more technical student unfavorably. Many things are carefully explained herein for the first time, it is believed, in the history of heating literature.

October, 1911. E R Pierce

PUBLISHER'S PREFACE

In introducing this book to those interested in the heating industry, we have the satisfaction to know that we are offering to them a work unique in its construction and invaluable in its comprehensiveness of treatment. The opportunity of securing the service of a man as well fitted as Mr. Pierce to deal with the subject-matter is extremely rare. He was equipped for the task by years of acquaintance with all the ramifications of the heating-industry and because he has seen its evolution since its beginning. His intimate relations with users of the products throughout the country, his possession of practical and technical understanding, breadth of judgment and sympathetic interest, have given a personal element to his writings not to be found so distinctly in any other book on heating subjects.

For the past 25 years, Edward Richmond Pierce has been prominently identified with the heating industry. He commenced as a manufacturer of heating boilers and wrought-iron radiators in Maine. He next became the manager of the eastern branch of the Michigan Radiator & Mfg. Co., Detroit, Mich., with headquarters at Boston, Mass. Upon the formation of the American Radiator Co., he was appointed branch manager for New England and the Maritime Provinces. In a few years he was transferred to the middle western territory, with headquarters at Chicago. Later, this territory was enlarged to include most of the southern states east of the Mississippi River, the seat of direction being Detroit. With the opening of the Cincinnati branch of the American Radiator Co., the management of this was given to Mr. Pierce, with offices in that city. After resigning from this position, he spent some time on the Pacific Coast. In this manner, the reader will understand how great have been his opportunities to study heating conditions in varied climates and at various altitudes, with many different fuels. In each of the positions held by him, he has been consulted constantly by the leading engineers and architects of that territory.

The appearance of "A Practical Manual of Steam and

Hot-Water Heating" in serial form has aroused wide interest, not only among the users of heating apparatus but among the manufacturers themselves. Many of the leading manufacturers in the country are as anxious to secure an accurate definite basis of boiler-ratings as are the steam-fitters. But this will never be accomplished with the same degree of thoroughness as if it is brought about by the insistence of the steam-fitters themselves. It is to stimulate this desire that this manual is published. At the risk of being accused sometimes of repetition, the author has patiently drilled through every problem ordinarily met with in estimating and installing heating apparatus, under varying conditions. It has been done in the simplest language, so that there may be the least possible chance of misunderstanding. It has been well done, and will lay a foundation for the building-up of stable heating conditions throughout the United States.

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"Domestic Engineering" Cartoon on "False Boiler Ratings"—The Little Girl Who Was Lost

Whose Little Girl Are You?

A Practical Manual of Steam and Hot-Water Heating

SECTION 1.

It is believed that many facts connected with the heating of dwelling-houses by steam and hot water are not generally available to the greater mass of steam-fitters, plumbers, architects and owners. This is largely due to this information being locked up to a great extent in formulas, which many, possibly a majority, could not understand.

It will be the purpose of this book to clearly state the more important facts in simple form and entirely without algebraic designations, or formulas. Those who do not easily comprehend facts when expressed in the X. Y. Z. forms of the schools will have at their command by this means, not only the results of all the formulas, but the reasons for each step in the construction of a house-heating plant, whether steam or hot water be used as the heating medium.

It is hoped that the entire process, step by step, can be stated so simply and the reason for each step so clearly explained, that any steam-fitter, plumber, or mechanic, with a general knowledge of the use of the materials and tools of the trade can, by the aid of this series of articles proceed to measure up a house properly. Such measurement will be required in order to properly determine the loss of heat; the size of radiators needed to properly replace the heat lost; the proper sizes of piping to convey the heating medium at any selected gage-pressure in steam or temperature in hot-water heating; and the proper size and type of boiler to use.

It is a matter of common knowledge that there are a number of so-called systems or methods of constructing house-heating steam and hot-water plants.

But it is not generally known, apparently, that all these various systems are primarily based upon the observance of a few general laws; laws as certain in their action as the laws of attraction and repulsion.

There have been many books written and many rules given for students of heating problems, but most of these have been prepared to exploit some individual idea, or some one particular design, or type of construction, with the result that persons who have come into the possession of more than one authority, or writer's rules, usually find them so widely at variance on important points as to be bewildering.

Because of these well-known variations, thousands of splendid mechanics in the plumbing industry have been disinclined to take up the most desirable portion of their business, that of house-heating.

We believe that the reader, or student, who will, in these pages, carefully follow each step in the designing and construction of house-heating plants for steam or hot water, will have no difficulty in bringing all apparent differences of authorities to one common basis. When this is done, these differences will be reconciled, except in cases where, as in the foreign patented systems, an element is introduced which is beyond the explanatory scope of this present book; although when fully studied it will be found these systems in no way disagree from the fundamental laws explained herein.

With these few words of introduction we will start at once to discuss the necessary things to do and the reasons for doing them, preparatory to doing a steam or hot-water heating job in an ordinary residence building.

The form of procedure will be the same, whether the building be one that has been occupied for years, or is being prepared for first occupancy, and whether it is to be heated with steam or hot water.

CHIMNEYS.

The first thought and attention should be given to the chimney-flue construction when proposing to construct a steam or hot-water heating plant. Unless this is properly constructed, of ample size and height, time, money, patience and good reputation will be wasted if an attempt is made to connect up any one of the so-called systems to an inadequate chimney-flue.

In order that the student, or general reader, may understand what is meant by an inadequate chimney-flue, it will be necessary at this point to explain fully certain facts in relation to chimneys to be used for house-heating boilers.

The chimney-flue serves a double purpose. It must not only maintain a relatively steady draft, but it must also lift and discharge from its top the gases and smoke created by the fuel-combustion in the boiler.

Among heating engineers the strength of draft in a chimney-flue is measured by the number of inches of water required to equalize it.

For the benefit of those of our readers who are not familiar with the measuring devices used for this purpose, we illustrate and describe two draft-gages used extensively throughout the country.

The Péclet Draft-Gage.

It consists of a bottle A with a mouth-piece near the bottom, into which a tube, EB, is inserted with any convenient inclination. The upper end of the tube is bent upward, as at BK, and connected with a rubber tube, KC, leading to the chimney. The tube is fastened to a convenient support, and a level, D, is attached.

To use the instrument, first level it, note reading of

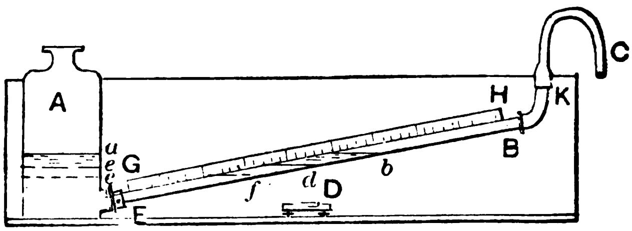


Fig. 1. The Peclet Draft-Gage.

scale, then attach it to the chimney, and take the reading, which will be, if the inclination is one to five, five times the difference of level in bottle and tube. The scale should be graduated to show differences of level in the bottle, and thus give the pressure directly in inches of water.

The Miller Draft-Gage.

This consists of two pieces of three-inch brass pipe connected by a half-inch pipe at bottom. One of the pipes is closed at the top and can be connected to the chimney by a small pipe with a valve as shown. The other piece of brass pipe is open and has a hook-gage reading to 1/1000 of an inch suspended in it. In preparing for a reading, the closed tube or leg is shut off from the chimney and opened to the atmosphere; the water then stands at the same height, aa, a^1a^1, in both legs. The closed leg is now shut off from the air and

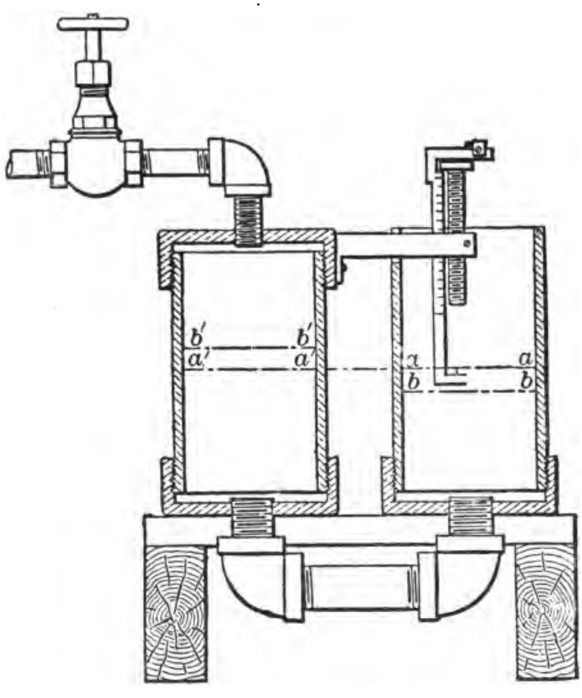


Fig. 2. The Miller Draft-Gage.

connection is made with chimney, whereupon the level falls to bb in the open leg and rises to b^1b^1 in the closed leg. As the two legs have exactly the same internal diameter, the fall ab is half the draft, measured in inches of water. The hook-gage is set to the level aa when it is connected to the chimney. The difference of the readings multiplied by 2 is the draft in in. of water. The reading by the hook-gage can readily give an accuracy of 1/1000 of an inch, which is sufficient for this purpose.

Hence it will be seen that a column of water 27.77 high is the equivalent of one-pound pressure per square inch of surface upon which it rests. It is usual to say 28 inches, and for ordinary computations this height of water-column is used. If a chimney-draft was balanced by a column of water one inch high, the draft strength would be 1-28 of a pound per square inch of area. This is not considered by power-boiler manufacturers enough draft for their product, for experience and experiment have demonstrated that to maintain combustion of the various coals at high-pressure steam-producing temperature, a minimum draft equivalent to a column of water one and one-quarter inches high is needed in big power plants and with some boiler construction even as high a pressure, or draft, as will balance two inches of water is required. Nearly all house-heating boiler-manufacturers of present time require that a chimney-draft shall equal the pressure of one fifteen-hundredths of an inch of water, although some require as much as two-tenths of an inch. But the chimney-flue must possess something more than draft.

It must have a sufficient area in square inches at the specified draft to permit the smoke and gases produced from a given quantity of fuel at varying rates of combustion to pass through the flue and be discharged from the top without excess of friction.

The varying conditions of atmospheric pressure, atmospheric temperature, humidity and other things tend to affect the specific item called draft, while the condition of the fire, the quality of the fuel, as well as the quantity of it, are constantly affecting the work the chimney is called upon to do in delivering freely from the chimney top the smoke and gases produced by the fire in the boiler.

Every boiler-manufacturer gives in his catalog the smoke-pipe size required for each boiler he manufactures. This smoke-pipe area represents the area in square inches, of free or frictionless area, which a chimney with not less than .15 in. of water-balancing draft must have to get satisfactory results from that particular boiler when a full charge of average fuel is to be used. Unless a chimney of at least that area is provided, even if the draft is perfect per square inch of sectional area, the volume necessary to pass through the flue in a given time will be restricted and the boiler will either fail to produce steam at all or it will do so in fitful spurts.

If a manufacturer furnishes a boiler with a smoke-hood eight inches in diameter, it will have an area of 50.265 sq. in., or practically 50¼ sq. in.

To attach such a boiler to a chimney with a sectional area of less than 50¼ sq. in. is to invite probable failure of the job, even if every other portion of it were perfect.

The height of a chimney adds to the draft as measured by the water-gage supposing only air, and lighter than air, gases are present. But the matter of friction must be considered when the whole work of the chimney in draft and smoke-delivery is considered.

Because of friction, one should never, under any conditions, accept a contract and garantee results where the chimney-flue, to which the boiler must be attached, is only four inches one way. Old buildings often present flues 4x8 or 4x12 or 4x16 in. If the owner will not furnish a round or square chimney of required area, it will be the part of wisdom for steam-heating contractors to decline the job.

SECTION II.

Having found a clear flue which in its smallest part is equal to, or exceeds the area required by the boiler it is intended to use as indicated by the smoke-collar on the boiler, the next thing is to look for possible objections to the proposed flue, either at the top or the bottom. Figs. 3, 4 and 5.

See if the chimney-top is lower than any projecting portion of the building, or even on a level with it; if any

Fig. 3.

nearby building towers above it; if trees grow so as to obstruct the draft when the wind is from certain directions. If everything outside is unobjectionable, look at the bottom of the chimney-flue, and make sure provision is made so that the bottom of the flue ends not more than 18 or 20 in. below the point where you intend to make the smoke-pipe connection. A good practice is to have a close-fitting slide-damper placed as many inches below the bottom of the smoke-pipe as the pipe is inches in diameter, and below this can be placed a clean-out door if the owner desires; but there should be no openings below the smoke-pipe opening. Next look for fireplace or stove-pipe openings into the chimney-flue above the smoke-pipe to the boiler-opening. If any are found they must be closed and sealed tight and in such a manner as to leave the chimney-flue smooth on the inside if possible. Lastly, make sure that the capstone of the chimney has opening sufficient for the required area.

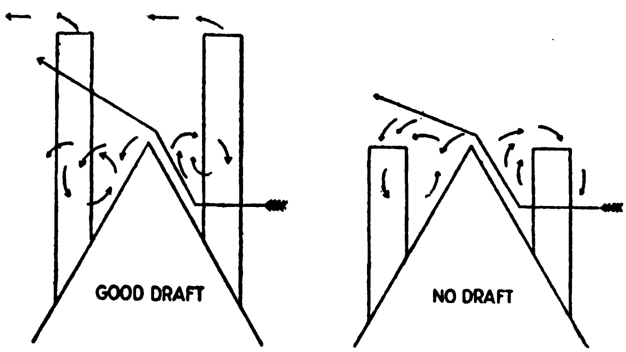


Fig. 4.

Owners often put on capstones with two or more openings, the combined area of which may be from 25 to 40 per cent only of the area of the chimney proper.

It is a very common experience to find an 8x12-in. chimney capped with a stone with two holes in it, each 5x6 in.; this at once reduces the delivery-area of the chimney from 96 sq. in. to 60 sq. in. Occasionally an 8x12-in. chimney will have a cap with two 4x6-in. holes, thereby cutting the delivery-area of the chimney down to 48 sq. in., or, of no more value than a 6x8-in. free area.

It should be remembered that a new chimney which has a large amount of moisture and which quickly absorbs a lot of heat from ascending gases will not have as vigorous a draft as when it is thoroughly dried out. On the other hand, do not assume that because a given flue has served for a hot-air furnace that it will answer for a steam or hot-water job to heat the same house. The conditions required for the operation of a steam-boiler or a hot-water boiler successfully may be very different from that required by the hot-air furnace.

The hot-air furnace may not have supplied warmth at one time to more than half the number of cubic feet of

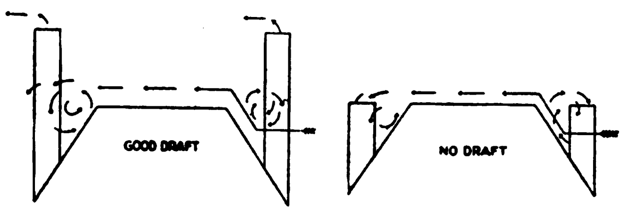


Fig. 5.

air that the steam or hot-water boiler is expected to heat all the time.

Table A gives the areas of circles—From this table it is easy to determine the free area in square inches a given boiler will require. For instance, a boiler which is cataloged to require a 10-in. smoke-pipe would require a chimney-area of not less than 78½ sq. in. and it is usual to use with such a boiler an 8x12-in. chimney-pipe, or a 10-in. round flue if the chimney is 45 ft. to 60 ft. high and a 12-in. round flue if the chimney is 20 or 30 ft. high. Boiler-manufacturers do not all use the same size smoke-flue on their boilers for the same rated capac-

TABLE A.
Areas of Circles.

Size	Area	Size	Area	Size	Area	Size	Area
⅛	0.0123	10	78.54	30	706.86	65	3318.3
¼	0.0491	½	86.59	31	754.76	66	3421.2
⅜	0.1104	11	95.03	32	804.24	67	3525.6
½	0.1963	½	103.86	33	855.30	68	3631.6
⅝	0.3067	12	113.09	34	907.92	69	3739.2
¾	0.4417	½	122.71	35	962.11	70	3848.4
⅞	0.6013	13	132.73	36	1017.8	71	3959.2
1	0.7854	½	143.13	37	1075.2	72	4071.5
⅛	0.9940	14	153 93	38	1134.1	73	4185.3
¼	1.227	½	165.13	39	1194.5	74	4300.8
⅜	1.484	15	176.71	40	1256.6	75	4417.8
½	1.767	½	188.69	41	1320.2	76	4536.4
⅝	2.073	16	201.06	42	1385.4	77	4656.0
¾	2 405	½	213.82	43	1452.2	78	4778.3
⅞	2.761	17	226.98	44	1520.5	79	4901.6
2	3 141	½	240.52	45	1590.4	80	5026.5
¼	3.976	18	254.46	46	1661.9	81	5153.0
½	4.908	½	268.80	47	1734.9	82	5281.0
¾	5.939	19	283 52	48	1809.5	83	5410.6
3	7.068	½	298.64	49	1885.7	84	5541.7
¼	8.295	20	314.16	50	1963 5	85	5674.5
½	9.621	½	330.06	51	2042.8	86	5808.8
¾	11.044	21	346.36	52	2123.7	87	5944.6
4	12.566	½	363 05	53	2206 1	88	6082 1
½	15.904	22	380.13	54	2290.2	89	6221.1
5	19.635	½	397.60	55	2375.8	90	6361.7
½	23.758	23	415.47	56	2463.0	91	6503.8
6	28.274	½	433.73	57	2551.7	92	6647.6
½	33.183	24	452.39	58	2642.0	93	6792.9
7	38.484	½	471.43	59	2733.9	94	6939.7
½	44.178	25	490.87	60	2827.4	95	7088 2
8	50.265	26	530.93	61	2922.4	96	7238.2
½	56.745	27	572 55	62	3019.0	97	7389.8
9	63.617	28	615.75	63	3117.2	98	7542.9
½	70.882	29	660.52	64	3216.9	99	7697.7

To find the circumference of a circle when diameter is given, multiply the given diameter by 3.1416.

To find the diameter of a circle when circumference is given, multiply the given circumference by .31831.

ity in square feet of radiation; therefore, no exact rule for chimney-size per hundred feet of radiation can be given, but in a general way Table B will be found sufficiently accurate.

When using Table A for ascertaining the chimney-area required, always select the area next larger in square-edged flues, unless the exact size is found. For example, if a boiler has a 9-in. smoke-pipe, Table A shows a 9-in. circle has an area of 63.6 sq. in., and you note an 8x8-in. chimney-flue has 64 sq. in. It would evidently not do to use an 8x8-in. flue, because in order

TABLE B.

Approximate sizes of Chimney-Flues for Steam and Hot-Water Heating in Residences and other Buildings.

Direct Radiation *		Size of Flue	
Steam in Square Feet	Water in Square Feet	Round	Square
250	400	8	8 x 8
300	500	8	8 x 8
400	700	8	8 x 8
500	850	10	8 x 12
600	1000	10	8 x 12
700	1200	10	8 x 12
800	1350	12	12 x 12
900	1500	12	12 x 12
1000	1700	12	12 x 12
1200	2100	12	12 x 12
1400	2400	14	12 x 16
1600	2700	14	12 x 16
1800	3000	14	12 x 16
2000	3400	14	12 x 16
2200	3700	16	16 x 16
3000	5100	16	16 x 16
3500	5900	18	16 x 20
5000	8500	18	16 x 20

* NOTE.—When a considerable amount of INDIRECT radiation is to be used, increased Boiler Capacity is necessary and in many cases such demands require a larger chimney flue for same number of square feet of radiation used.

to do it, you must reduce the manufacturer's required area for the proper working of his boiler from 9 to 8 in., or from 63.6 sq. in. to 50¼ sq. in. This means that the boiler as designed, has at this vital point been choked over 20 per cent—and it is certain that no machine, rated to do certain work when all its component parts are perfect, can reasonably be expected to do the same work, and equally well, when over 20 per cent of any one of its vital points of construction is taken away.

To Determine Amount of Heat-Loss From Rooms in Buildings—Measurements.

This question of the proper "figuring for radiation" is not an easy one to solve and the task is not made easier when the solution is to be attempted without resorting to algebra.

As a matter of fact there is no "hard and fast rule" applicable without change or modification to each and every condition.

The mere fact that two rooms are 15 ft. square and 10 ft. high, with a cubic content of 2,250 cu. ft. each, does not determine that there will be the same amount of heat required in each to maintain 70 deg. in each room when it is zero outside. If it did, the task of estimating the required amount of radiator-surface would be simple.

It requires no argument, or illustration, to demonstrate that if a given room shows a temperature of 70 deg. at one time of the day, and zero at another hour, that there has been a loss of 70 deg. of heat. It is also evident that if the doors, windows, or other openings have been tightly closed between the period when the room was at 70 deg. until it reached zero, that the heat must have in some way, passed through either walls, floors, ceiling or doors and windows, or, that each of them had contributed its proportion of the loss.

This much granted, the next step is to determine how much of the total loss each factor has contributed. Unless this can be determined with considerable exactness it would be the rankest sort of guesswork to attempt to "figure" for radiator-surface.

Fortunately, science and experiment have determined with considerable exactness the number of units of heat which a square foot of window-glass will permit to pass through it in a given length of time if one side of it is at 70 deg. F., and the other side has a temperature of zero. All the other factors, walls, doors, floors, ceilings —are found to be contributors to the total loss, each in its own proportion. As heat never passes from a cooler body to a warmer one, it follows that the colder the surrounding or connecting body the greater will be the loss in a given time from the warmer. Therefore not a single factor which goes to create the room will lose the same amount of heat under all conditions. Again it is not necessary to illustrate by argument that a brick wall 9 or 10 in. thick will not lose as much heat through a square foot of its surface under varying temperatures as would be lost through a square foot of window-glass.

The point to find out is how much of the total loss, each hour, does each factor furnish, and, having found this, the next step will be, how to so arrange the heating surface that it shall balance the hourly loss from all sources and thereby maintain the room at a steady temperature.

It would not seem necessary to advance an argument to demonstrate that a rule, for the proper proportioning of heating surface in a room, whose total loss of heat was created by losses through various factors, could only be made by carefully ascertaining the amount lost by each factor, and when this had been found that the proper rule for supplying this loss from a heated body would depend entirely upon the temperature of the heated body.

SECTION III.

Yet, simple as this proposition seems, the great mass of the steam-fitting trade of this country is trying to make a radiator at a temperature of a trifle over 200 deg. at its surface work satisfactorily, when the figures, upon which they base the surface, require a temperature 40 to 50 deg. higher by many of the rules.

Under present commercial ratings of boilers for both steam and water, the majority of rules in use, even those based upon correct measurements of wall and window surface, are but little better than the old "rule of thumb" guess-work ratio rules.

It is time that some of the simple facts be plainly set forth and the trade be shown how to figure radiation correctly at any required temperature of steam or water.

I realize that in attempting this it will be necessary to go over some ground that will seem almost trivial to many. The heating engineer, however, who gets out into the highways and by-ways, will appreciate how often and in what unexpected quarters he is asked to show customers how to measure a room. It is the purpose here to go into sufficient detail in all essential points to cover the questions that have been constantly presented to me by customers through the many years that have elapsed since I first began answering such questions. It is, first of all, necessary to measure the length, width, and height of each room, and multiply the length by the width and that sum by the height to secure the cubic contents of the room. Suppose we have a room 16 ft. long, 15 ft. wide and 11 ft. high. The length and width multiplied, $16 \times 15 = 240$; this multiplied by $11 = 2,640$ cu. ft.

We have agreed that the heat is lost through all factors composing the room. We have found the cubic con-

FORM

Measurements and figuring data from..........................
House of ....
Street No. ....
Telephone No. ....
R. F. D. No..

	Rough Sketch of Rooms
Name of Room and Temperature Required	
Compass location. Feet exposed wall. Prevailing wind. Elevation above sea.	
Kind of wall and condition.	
Size of room in Feet and inches.	
Number, size and kind of windows.	
Number, size and kind of Doors to outside air or Colder Rooms.	

A Useful Form of Measuring Up and

tents, but unless we find how many heat units are lost each hour through walls, windows, floors, ceilings and probable leakage, what good will the knowledge of cubic contents do? We must now look for exposed walls. By

AB.

......................t............................... Architect
Street ....
Town ....
County ....
State ....

or Floor in this Space.

Temperature Cold air.	
Square feet Exposed floor. Temperature of Cold side of floor.	
Square feet Exposed ceiling Roof or side of Bay window. Temperature of Cold side.	
General Remarks.	

Calculating on a Proposed Installation.

this is meant, walls exposed to the outside air, and also walls exposed to cold inside rooms. The fitter must never, for a moment, forget while measuring a room for heat-loss, that heat will always pass to a colder body with which it is in contact, and if one side of a room is to have on its outer side a cold room, note must be taken of it, just as surely as though the other side of the wall was surrounded by out-door air.

The fitter who is preparing to "measure up a house for heating," should first prepare a form upon which he can quickly and accurately place the data he requires, and without which he can only do a guesswork job.

A form, something like Form AB, answers very well, although some find more elaborate ones desirable, but for ordinary residence-work the one here given serves very well.

Care must be exercised with regard to floors. Many houses have cellars under a few rooms. Some, in the South and Middle West, have no cellars at all, the houses being built on piers. In all sections, rooms on the second floor will be found with the whole, or a portion, of a floor space over an open porch, and often with unusual wind-exposure. All such conditions must be met by extra radiation to supply the loss. Another very common condition, and one often overlooked, is the thin flat roof over a room which may have been added to an old house. Such a roof dissipates heat wonderfully as we shall discover later, when the measurements have been made and we begin to count up the heat-loss through each factor.

We now find the square feet of wall surface exposed to colder air than the room we are preparing to heat.

Suppose the room we used to illustrate the cubic-contents rule has one side 16x11 ft., and one end 15x11 ft. exposed to the out-door air. In addition, there are also four windows, each of which are 6 ft. 10 in. x 3 ft. 8 in, the first thing usually done is to get the gross square feet of exposed wall surface and from this deduct the window-opening. The end and side-wall lengths equal 16 + 15 = 31 ft.; the height is 11 ft.; then the total length, 31 ft. multiplied by the height, 11 ft. = 341 gross sq. ft. There are four windows, each 6 ft. 10 in. x 3 ft. 8 in., or 25 sq. ft.; then 25 × 4 = 100 sq. ft. of window. Deducting this from the gross wall surface and the real exposed wall is 341 — 100 = 241 sq. ft. real wall. The material of which the wall is constructed, and its condition is now to be noted.

There is not much difference in the loss of heat per square foot, between a well-built wooden wall, cross-boarded, well-papered and clapboarded, and a well-built hard brick house wall. Not nearly so much difference as often exists between two brick walls.

While we shall have to refer to this part of the subject again, it seems important to take up this matter of walls at some length right now, in order to explain the absolute necessity of securing data regarding them for future use.

It has not been called to the attention of the trade generally, I think, that a vast difference in loss of heat-averages, occurs in brick buildings of identical areas. I do not think it had occurred to anyone to investigate it until concrete-block houses began to be quite generally used. Occasionally some fitter would find himself in trouble with a brick-house-heating plant in wet, windy weather, and usually blamed the chimney or the fireman, or most anything except the real cause.

Recent investigations have shown that fine hard brick will rarely absorb over 5 per cent of their weight of water; good brick, not over 10 per cent; while many soft brick take up from 25 to 40 per cent of their weight of water. Improved methods of producing cheap brick have enabled contractors to secure good-appearing brick, with a ringing sound when struck, that will, notwithstanding their good appearance, absorb water like concrete.

When it is remembered that one heat-unit is the amount of heat required to raise one pound of water one degree of temperature and that that same amount of heat will raise five pounds of dry masonry one degree, the necessity of noting the quality of brick in walls becomes very evident to one who is to come under contract to furnish heat in all weathers. In some sections of the country, it is the habit to use fine hard brick of the best grade, for the front portion of buildings and cheap brick for the rear sides and end. It is usually this portion of the building where heating complaints originate in wet weather.

It is not unusual to find rooms finished close under the roof. These rooms should be measured with great care, especially the ceiling, when lathed and plastered close to the roof. Surface of this kind is especially affected by both wind and moisture.

If the building is of concrete, either block or poured, special attention should be then given to finding out if it has been water-proofed, and to what extent; also if plastered directly on the concrete, or if studded and lathed inside the concrete wall.

If studded, lathed and plastered, an increase of 15 per cent when the outside wall of concrete has not been water-proofed will usually be sufficient. If plastered directly on to the concrete, it will be found very difficult to provide sufficient radiation to keep the rooms both warm and dry in wet weather. An excess of about 60 per cent with some grades of concrete will not be too much allowance for wet weather, accompanied by high winds, while in dry weather, the same amount of radiation required for first-class brick walls is ample. Concrete which has been thoroughly water-proofed throughout its entire structure, or which has been water-proofed on all its surface inside and out in block construction, makes an ideal wall from a heating point of view. Just in proportion, however, that concrete absorbs water does it depart from the ideal.

The steam-fitter and owner should constantly bear in mind the fact that water is the greatest absorber of heat known. If a building is constructed of material that absorbs and holds large quantities of moisture, a corresponding excess of heat must be furnished during any period of excessive moisture.

SECTION IV.

Another important reason for noting down at time of measurement the kind and condition of outside wall of each room measured is that, very often the rooms, having porous walls, are on the side of the building most exposed to the winter winds, and moisture with wind in addition, unless especially provided against, will cause trouble for the steam-fitter.

The prevailing winter wind in a town may not be the prevailing wind direction at a given point in that town; thus, while the prevailing wind in the town might be Northwest; at a given point, because of conditions created by eddies, a room or a house may receive its winter wind from a point of compass somewhat different. The points of compass should always be included with the pencil sketch of floor plans of house, and they should always head the lists of measurements.

This sketch need not be finely drawn or in great detail, but should always be given. The contract may not be awarded at once; conditions of structure may be changed after your measurements; memory regarding the relative position of some room may fail; many things may arise that would make the rough sketch of great value. It takes but a moment to make it, and later, may save a long trip and hours of time. Never neglect the rough sketch even on the simplest jobs.

When measuring for square feet of window-opening or frame, special attention should be given to the manner in which the work of setting window-frame has been performed. A great many instances will be found where, if the finish boards were removed, an area equal to anywhere from one to three square feet of surface would exist where the only protection is the finish. Around these finish-boards, there will be a leakage of heat requiring careful attention. The leakage in a well-built house will usually equal twice its cubic contents per hour from the first-floor rooms, where the doors opening to outside usually are in excess of similar doors on second floor. Second-floor leakage is rarely less than the equal of the cubic contents once an hour. If, however, careless construction around doors and windows permits a still greater loss, some provision for radiator surface to offset the excess loss must be made.

From the foregoing, the absolute necessity of complete data as indicated will be readily understood, even at this very early stage of the proceedings. Later, when we come to figuring heat-losses, and selecting radiator surface, piping, and a suitable boiler, the value of this preliminary accuracy becomes startlingly apparent.

It should be distinctly understood that there is no "short-cut road" to successful steam-heating, and it is equally true that there is no mystic knowledge required. The whole proposition of house-heating is founded on a common-sense understanding of a very few natural laws. The very first of these is that, if two units of heat are taken from any larger number of units, two units added will make up for the original loss. The profession of steam and hot-water heating is not as yet an absolutely exact scientific profession in its application because of the varying conditions imposed. But it is scientific and exact when applied to an unvarying condition. The action of heat upon air, water and various substances has been ascertained from scientific theory and experiment, to be always the same under the same conditions. The more completely the conditions are ascertained under which heat may pass from a warmer to a colder condition, the more accurate can the provision for exactly supplying the needed heat to maintain the warmer body at a uniform temperature be made.

From the measurements of all the rooms to be heated we must be able to secure the following details as a base of further and final figuring.

The cubic contents of each room.

The square feet of real exposed wall.

The square feet of wall exposed to colder rooms.

The temperature of colder adjoining rooms (usually 32 degrees).

The square feet of window-openings.

The square feet of outside door-openings.

The square feet of floor exposed to outside air.

The square feet of floor exposed to cold cellar (usually 32 degrees).

The square feet of floor exposed to colder room (usually 32 degrees).

The square feet of ceiling exposed to colder room.

The square feet of ceiling exposed to outer air.

The kind and condition of walls.

.The direction of prevailing winter wind.

The relation of each room to point of compass.

The data of any other fact bearing upon probable loss of heat from any room which it is proposed to maintain at a steady temperature.

We are then ready to consider the probable loss of heat through each factor mentioned.

To Determine Amount of Heat-Loss From Rooms in Buildings—Effect of Altitude.

The cubic content of a room has long been the factor upon which guesswork rules have been hung. One man requires the use of one square foot of radiation for every 30 cu. ft. of air; another says you must use one square foot for 50 cu. ft. out of the total cubic content. A third man says you must use judgment (which is certainly sane and sagacious advice) and use one square foot to from 35 to 60 cu. ft. All sorts of rules have been advanced from time to time which, without question, were practical rules for a certain locality and a certain type of building, but which, under other conditions, would be without value. One noticeable omission in all "Rules of Thumb," as Professor Carpenter, of Cornell University, designates them, is that none of them state what pressure of steam is to be carried or what temperature the water in a hot-water job is supposed to attain.

If a room with 2,600 cu. ft. of contents is to be heated from a radiator based upon the ratio of 1 to 30, or, say, 87 sq. ft. by one man; and the same room is to be heated by another with a radiator based upon a ratio of 1 to 60, or, say, 44 sq. ft.; it is evident that the temperature of the steam in one radiator must be much lower than in the other.

Yet, each man might secure the same results in room temperature, the reason being that the first man might require a pressure at his boiler of 5 lb. per sq. in., and the second man would need approximately a 30-lb. pressure per sq. in. at his boiler. This one illustration is sufficient to show the absurdity of competing for steam-heating work when only 70 deg. in the room is required and the job is to go to lowest bidder, nothing whatever being said by owner or architect in regard to pressure to be carried.

But supposing it is stipulated that only 2-lb. pressure is to be carried at the boiler, which ratio rule would you select?

Again, suppose one has graduated from the ratio-rule class, and is using some rule based upon exposed wall and window surface—

Does he know what pressure he must carry to make the rule universal? Will the same rule that works perfectly in results when applied to a house in New York City, or Boston, give the same results when applied to a house built from the same plans, by the same builder, using throughout the same quality of material at Denver? A trial convinces that at zero outside, the rule that gives sufficient radiation to secure 70 deg. in a house in New York or Boston will not heat to 70 deg. a similar house in Denver, with the same gage-pressure.

There can never be a result without a cause. It is also evident that a rule that *does not meet all conditions is incomplete.* In order to clearly explain the cause of such varying results, we must investigate more fully. If we find that a ratio-rule that works out well in Boston fails utterly in Denver or Leadville, Colo., or in the "Land of the Sky," North Carolina, reasons for the discrepancy must be sought and found.

Those rules are worthless, not only because of difference of temperature in places named, but they do not work out in practice at the same outside and inside temperatures because of difference in altitude.

The steam that is produced at approximately 212 deg. F. temperature, is produced near sea-level under a barometric pressure equal to 29.905 in. of mercury, or as usually stated at 30 in. mercury-pressure. This just balances the weight or pressure of the atmosphere at sea-level.

As one ascends above the sea-level, this pressure or weight grows less and less and consequently steam is produced from water at a correspondingly lower temperature; in other words, it is not as hot.

The decrease in atmospheric pressure, as one rises above sea-level, is not exactly constant, as shown by the sinking mercury in the barometer, but approximately, the barometer-mercury sinks one inch for each 1,000 ft. above the sea-level.

The Encyclopedia Britannica, Vol. III, Page 387, gives the following table of the boiling temperature of pure water at different pressures of mercury:

TABLE C.

Temperature Fahr. at which Water Boils under varying Barometer Pressures.	Barometer Inches of Mercury
212	29.905
211	29.331
210	28.751
209	28.180
208	27.618

Temperature Fahr. at which Water Boils under varying Barometer Pressures.	Barometer Inches of Mercury
207	27.066
206	26.523
205	25.990
204	25.465
203	24.949
202	24.442
201	23.943
200	23.453

For practical purposes, in determining the amount of heat a square foot of radiator surface will emit at different altitudes with steam or hot water as the heating medium, it will do to assume that a decrease in the atmospheric pressure due to altitude equivalent to one-half inch of mercury occurs for every 500 ft. above sea-level, and a corresponding drop of one degree F. in the temperature of steam, or if you prefer, in the boiling point of water, or of the point of evaporation.

In other words, steam without pressure other than that of atmosphere is one degree F. hotter at sea-level than it is 500 ft. higher up. and at 1,000 ft. above sea-level, steam creates at 210 deg. F. This is, as will be seen by table C, within 154 thousandths of an inch of corrected mercury-height of barometer-pressure for 1,000 ft.

On this basis the boiling point of water, or the temperature of steam at various altitudes can be figured with sufficient accuracy for house-heating purposes as per table D.

TABLE D.

Feet above sea-level.	Boiling Point of Water or Point of Evaporation into Steam. Degree Fahr.
0	212
500	211
1,000	210
1,500	209
2,000	208
2,500	207
3,000	206
3,500	205
4,000	204
4,500	203
5,000	202
5,500	201
6,000	200
6,500	199
7,000	198
7,500	197
8,000	196
8,500	195
9,000	194
9,500	193
10,000	192

As the number of heat units given off or emitted per square foot per hour from effective radiator surface is determined by the difference of temperature between the surface of the radiator and the mean temperature of the surrounding air, it is very evident that the temperature of the heating medium at its point of evaporation becomes a most important factor in applying a ratio-rule or a rule with an unknown estimated pressure at its base.

At this point another most important fact comes in.

The steam in its circuit from boiler through radiators and piping back to boiler drops in temperature very materially. For this reason, only averages are considered for general heating deductions when determining radiator surface for house-heating. Unless such deductions are made serious errors are liable to occur.

By common consent the trade from every section of the country seems to have adopted as a basis in hot-water heating a drop of 20 deg. as being what may be safely considered the drop between the temperature of a hot-water job at the boiler and at the end of complete circuit. Thus if the water leaves boiler at 180 deg. F. they expect it to return to boiler at 160 deg. and they figure most of the radiation should have an average temperature of 170 deg. [$180° + 160° \div 2 = 170°$]. Curiously enough, the inevitable drop in temperature of the steam in a house-heating job seems to be pretty generally overlooked by the average steam-fitter. But it is there just the same, and now that definite pressures are being called for by manufacturers, owners and architects, it must be considered at all points.

Those American authorities who have written on heating have quite fully indicated this loss, but in giving out rules have usually covered it with a blanket under the guise of a factor of safety, but this factor, as will be often found upon analysis, is like many of the rules, only strictly applicable within a limited area of territory and of altitude.

SECTION V.

The following table, made up in part from personal experiment and in part from formulas, gives results that can probably be safely relied upon for house-heating as giving the average or mean temperature in radiators of cast-iron 3-column construction when the temperature at the boiler is as stated in Column A:

TABLE E.

A. Steam Temperature at Boiler Deg. F.	B. Altitude above sea-level In feet.	C. Average or Mean Temp. of Radiator Deg. F.
212	100	201
211	500	200
210	1,000	199
209	1,500	198
208	2,000	197.6
207	2,500	196.7
206	3,000	195.7
205	3,500	194
204	4,000	193.8
203	4,500	192.8
202	5,000	192
201	5,500	191
200	6,000	190
199	6,500	189
198	7,000	188
197	8,000	187
196	8,500	186
195	9,000	185
194	9,500	184
193	10,000	183

In figuring the heat emitted from cast-iron radiators, as will be more fully explained later, the temperature of the air, which is to be maintained at a given temperature to surround the radiator, is deducted from the average temperature of the heating medium in the radiator; and it is upon this difference that nearly all heating calculations, so far as house-heating is concerned, are based.

With this explanation it is easy to see what a difference altitude creates. There are towns in the United States much more than 10,000 ft. above sea-level, but such places can easily ascertain the boiling point of water at their altitudes, and they will find the average temperature of their heating medium will not be far from 95 per cent of the temperature at the boiler.

It will be interesting and also profitable at this time to consult a table of average temperatures at boiler under different gage-pressures, at approximately sea-level altitude and the average mean temperature of 3-col. cast-iron radiators when surrounded by air in room at 70 deg. and filled from boiler at stated pressure.

TABLE F.

Gage Pressure Lb. per sq. in.	Temp. at Boiler.	Average temp. in Radiator.	Surrounding Air 70 deg. F.
0	212°	201°	70°
1	215	204	"
2	219	208	"
3	222	211	"
4	224	213	"
5	227	216	"
10	239	227	"
15	249	237	"
20	258.7	246	"
25	266.7	254	"
30	273.9	260	"

It is to be understood that the above table is given as a *working basis* and no claim is made that it is prepared with laboratory exactness.

It will later be found valuable in determining what gage-pressure will be required to comply with many of the terms of quite recently published rules.

It will also prove to be of assistance in checking up old-time jobs where new boilers of modern ratings are to be put in in place of the original boilers. Furthermore, its use will be helpfully manifest in many ways as our study of cause and effect in heating problems extends.

This table is for sea-level pressures only. At higher altitudes the same relative difference exists that are shown between steam without pressure at sea-level and steam without pressure at different altitudes as shown in tables C and D of altitude-temperature. Page 29.

I have deemed it well to take this part of the heating problem up before going into the loss of heat from rooms for reasons that will naturally be suggested to the student, or reader, as the subject develops.

At this point it is also desirable to explain the heat unit and its relation to the heating problem. Many men seem to be afraid of the term heat-unit. They might as well be afraid of the term inch, when speaking of lineal measure, or of an ounce, or pound, when speaking of weight.

If you should weigh one pound of water when the thermometer shows its temperature to be 62 deg. F. and then apply heat to the water until the thermometer reveals one degree temperature-increase or 63 deg. F. and if, when you did this, you were at the sea-level and the water was open to the atmosphere, the amount of heat employed to raise that pound of water that one degree is called a British thermal unit. This is represented by the letters B. t. u., just as a lineal foot is represented by the letters, ft., gallon by gal., a degree of temperature by deg., pound by lb., and dollars by $.

The same amount of heat will always be required to raise a pound of pure water from 62 to 63 deg. at sea-level at atmospheric pressure. It is therefore a constant, something to be depended upon, and so it becomes the unit or one item by which all combinations of units of heat can be measured.

This unit of heat which raises one pound of water one degree will raise one pound of cast-iron 8 deg.; or it will raise one cubic foot of air from zero, about 50 deg. This unit of heat is used to fix what is known as the specific heat of bodies. Prof. Carpenter says: "Specific heat is the quantity of heat required to raise the temperature of a body one degree, expressed in percentage of that required to raise same amount of water one degree, or, in other words, with water considered as one. Thus, if one pound of iron in cooling eight degrees heats one pound of water one degree, its specific heat is $\frac{1}{8} = 0.125$."

The specific heat of air is 0.238. The weight of a cubic foot of air at zero is .0864 lb. If, therefore, we multiply the weight of one cubic foot of air, .0864 lb., by the specific heat, 0.238, we shall find what part of a heat unit, or B. t. u., is required to raise one cubic foot of air at sea-level one degree F.

Thus, $.0864 \times 0.238 = .0205632$ B. t. u.

To raise that cubic foot of air from zero to 70 deg. will require 70 times as much or 1.439 B. t. u. In practical use, 1.44 B. t. u., or 1.5, is sometimes used by heating engineers in estimating losses.

Now we can understand why heat is measured in B. t. u., and why, if a man intends to do good work, he desires to find how many units of heat are lost per hour that he may intelligently proceed to replace them.

If he works with cubic feet of air instead of units of heat he will in the end have to heat the air, therefore it is better to stick to B. t. u. from the start.

Heat has two values or qualities. One, we can describe by the word intensity, and the other by the word quantity. The intensity of heat is what we measure with the instrument we call thermometer. A less intense heat we may call zero, and a more intense heat we may call boiling point, but it is evident neither condition of intensity has any especial relation to quantity. A small quantity at zero, or at boiling intensity, has no different measure on the thermometer-measure of the same article than a great quantity.

The intensity of heat we designate temperature and in this country measure it with a Fahrenheit thermometer.

The quantity is measured by the number of heat units present in the body when it shows a certain intensity, or temperature.

Thus, a certain quantity of heat will be absorbed by one pound of water before it will show an increase of one degree of intensity. This gain is called one degree of temperature.

If the same amount of heat had been applied to one pound of iron the thermometer, instead of registering an increased intensity or temperature of one degree would register *eight degrees.*

It is evident from this fact that the amount of heat depends upon the temperature and *also upon the capacity of a given body to absorb heat without showing any increase of intensity that may be measured by a thermometer. It is very certain therefore that under every condition the nature of heat is different from temperature.*

The amount of heat which is absorbed by one pound of water before it registers an increase of intensity, or temperature, as this will hereafter be termed, of one degree is termed its "specific heat." Then, when at sea-level and under no pressure but that of atmosphere, which a column of mercury 30 in. high balances, the temperature reaches 212 deg., the entire pound, or other quantity of water, will continue to absorb heat without any increase of temperature until all the water has been evaporated into steam. But this steam, in cooling to a lower temperature than 212 deg., emits heat which it has stored or absorbed during the evaporating process when no increase in temperature was measured. So it is said no heat was lost, although during the process of evaporating the pound of water a large amount of heat had been applied to the water of which the thermometer was not sensible. This heat which the steam gives out in cooling is termed "latent heat."

It will be seen that at the beginning of the operation heat was absorbed in large quantity before the thermometer became sensible of it, and at the evaporating point a still greater quantity of heat was absorbed and carried by the steam of which the thermometer was not sensible.

This latter heat is, however, of importance, for it contains the value in heat units of the whole process of evaporation and has been shown to be of a total value above zero of approximately 966 B. t. u. The temperature of the steam, however, is only 212 deg. To get the total heat involved in the process from zero to 212 deg., it is evident we must add the B. t. u. of sensible heat and the B. t. u. in the latent heat, then 212+966=1,178 B. t. u. employed in the complete process from zero to evaporation.

The specific heat of water varies slightly at different temperatures. Therefore, the heat contained in one pound of water when evaporated from different temperature varies slightly; the sensible heat above zero increases with the increased intensity; and the latent heat grows somewhat less relatively.

At a temperature of 240 deg. in the water at point of evaporation, this temperature being secured by putting the water under pressure greater than that of atmosphere, the sensible heat above zero becomes equal to 241.31 B. t. u.; the latent heat 946 B. t. u.; total 1,187 B. t. u. A cubic foot of steam at 212 deg. weighs .0379 lb., while at 240 deg. it weighs .0634 lb. per cu. ft.

As pressure is increased the sensible heat increases and the difference between surrounding air of a stated temperature and the surface of a receptacle like a radiator holding the steam stored with latent heat becomes greater, and so more heat units will be emitted per square foot of surface. As these radiators are to supply the heat lost from a room, it is clear that the size of radiator required to supply a certain loss will be largely governed by the temperature or pressure of steam it contains. If then it is found that a square foot of such radiator will emit one and six-tenths B. t. u. for one degree of difference of temperature in one hour, and that the room is to be maintained at 70 deg., it being zero outside, the value of a square foot of radiation is easily found. If the radiator is filled with steam at 212 deg. the difference between room and radiator is 212—70=142 deg., and if each of these 142 deg. calls out from the radiator 1.6 B. t. u. latent heat, then 142×1.6=227 B. t. u. per sq. ft. per hr. If, on the other hand, the water had been under a pressure so that evaporation did not occur until a temperature of 240 deg. had been attained and the radiator is filled with steam at this pressure, then 240—70=170 deg. difference; 170×1.6=272 B. t. u. per sq. ft. per hr., or in round numbers 20 per cent difference in size of radiator required to emit same number B. t. u.

From the foregoing it is evident that in order to properly size radiators to give off the needed heat, the pressure under which the job is to work must be determined and the entire job must be proportioned to that pressure.

In order to do this, something different from ratio-rules will be needed and careful attention to all sources of loss and suitable provision to offset them must be made. The following table gives approximate values per square foot, per hour, of radiators at different temperatures.

It must be understood that Table FF is based on average conditions as they are found and is calculated for average cast-iron direct radiators. If wrought-iron pipe in single lengths had been taken instead of 3-column cast-iron, the B. t. u. per sq. ft. per hr. would be increased materially, especially at the higher temperatures. But as stated previously, this book is for those who do house-heating principally. Those who give their attention to large work already know how to work out the problem of heat-unit delivery from wrought-iron pipe used as radiators, and which gives a greater heat-emitting capacity than provided for in the present table at the higher temperatures.

TABLE FF.

Temperature of Room Throughout this Table, 70 deg. F.
Hot Water or Steam.

Boiler-Pressure Gage.	Steam in Boiler.	Radiator Deg. F.	B. t. u. per Sq. Ft. per Hr.*	Temp. Dif.** Deg. F.
....	110	100	48	30
....	120	110	64	40
....	125	115	72	45
....	130	120	80	50
....	135	125	88	55
....	140	130	96	60
....	145	135	104	65
....	150	140	112	70
....	155	145	120	75
....	160	150	128	80
....	165	155	136	85
....	170	160	144	90
....	175	165	152	95
....	180	170	165	100
....	185	180	182	110
....	200	190	198	120
....	210	200	215	130
....	212	201	216	131
2-lb.	219	208	220	138
4-lb.	224	212	227	142
5-lb.	227	215	232	145
6-lb.	229	219	238	149
7-lb.	233	222	243	152
8-lb.	234	224	246	154

*B. t. u. Emitted per Sq. Ft. per Hour from Average Direct Cast-Iron Radiator, 3-col. type.

**Difference Between Radiator and Room Deg. F.

10-lb.	239	227	251	157
15-lb.	250	239	270	169
20-lb.	257	249	295	179
25-lb.	267	258	310	188
30-lb.	275.7	266	333	196
35-lb.	280	274	347	204

Prof. Allen in "Notes on Heating and Ventilation," page 52, gives the value of 2-column cast-iron radiators per square foot per degree of difference as 1.455 for average from 80 to 100 deg. difference and 1.635 as average from 110 to 170 deg. difference between temperature of radiator and room.

J. H. Mills and Colonel Greene, of Boston, found from extended experiments with a 3-column cast-iron radiator, the heat-unit value per square foot per hour to average a trifle over 1.65. But in all of these tests, small radiators and short pipe-runs were used. In practical work where long runs of pipe and several radiators are used, 1.6 B. t. u. per square foot per hour is all that can safely be figured for 3-column radiators; 1.65 for 2-column, and 1.8 for single-column cast-iron radiators per degree of difference between heating medium in the radiator and air in room at 70 deg. up to 20-lb. pressure.

SECTION VI.

From the foregoing tables the great importance of altitude is seen when reference is made to Tables C and D. By comparison it will be seen that a rule calling for just steam temperature in radiator at sea-level would never work out for use at higher altitudes, because the steam would be less hot.

For instance, a house at New York, about 100 ft. above sea-level, requires according to tabular rule 500 sq, ft. to heat it to 70 deg. when it is zero outside, and with steam at 212 deg. at boiler. This would yield 216 B. t. u. per hr. per sq. ft. Then, 500×216=108,000 B. t. u. per hr. Supposing the same owner decides to duplicate the house on some of the hills of Pennsylvania 2,000 ft. above sea-level. His steam to be without pressure same as at New York, has only a temperature of 208 deg.; the average temperature of the radiator is only 197 deg. and the radiators emit but 203 B. t. u. per sq. ft. per hr. The 500 sq. ft. give out 500×203=101,500 B. t. u., a difference of 6,500 B. t. u. per hr., or over 6 per cent. If he had put in 533 sq. ft. instead of 500, the two jobs would have been practically the same if the wind pressure was the same, which it probably would not be. Wind pressure must surely be reckoned with in looking for heat loss.

When this question of altitude is considered, of what value are most of published rules, which have been calculated for sea-level use almost without exception, when altitudes, such as well-known cities, like Albuquerque, N. M.; Carson City, Nev.; Denver, Colo.; Butte, Mont.; Ogden, Utah; Pueblo, Colo., and many others, are reached, all of them about 5,000 ft. above sea-level? The troubles of the steam-fitter who attempts to follow sea-level rules of heating to the letter fairly overcome him in such altitudes.

Yet, it is just as easy to procure any desired result at one altitude as at another by sticking close to the B. t. u. measure. At first it may seem to be a little more trouble than a ratio-rule, but in the end it is not, as will be seen later. The steam-fitter must intelligently apply the thermal-unit loss under varying conditions encountered in detailed measurements, to enable him to suitably replace this loss by proportionate radiation. If he thus offsets the loss, item by item, he will be called back very seldom to the job on complaint of heating efficiency below the requirements of contract.

To Determine Amount of Heat Loss from Walls.

To the steam-fitter, who is preparing to heat a house by steam or hot-water radiation, it is especially important to know whether the whole building, or certain rooms in building, are to be closed off from heat supply during a portion of each day, or week, through the heating season.

The reason why it is important is hinted when specific heat is defined. The walls of a building, whether brick, stone, wood or concrete construction possess, as a mass, a certain specific heat-value.

In accordance with the definition of specific heat, the walls of a building absorb a certain amount of heat before the thermometer records it. This amount of heat, or some portion of it, the steam-fitter must provide from his boiler and the radiators, every time the walls drop from the established constant temperature of the rooms. This constant is usually 70 deg. inside. Experiment has shown that to offset the specific heat of walls when rooms are without heat through the night hours, a 30-per cent increase of radiator surface is demanded above that called for if rooms are kept heated day and night and if rooms or buildings are exposed on all sides.

If the building or room is only slightly exposed and heated during day only, 10 per cent will usually offset the loss. People who shut the heat off sleeping rooms every night, and want to leave a window open in addition, require from 20 to 40 per cent added for that particular room, according to the extent of wall exposure and the location of the room. If the room is on the north side of house or the side of prevailing winter wind then an addition of 40 per cent will not be excessive.

During daylight hours the loss of heat through the walls on the north side is greater per square foot than from the south side, but after midnight and before daylight, the loss is equal from all points if there is no wind, something that very rarely happens.

I am well aware that steam-fitters, as a whole, have neglected any special provision for extra radiation in rooms not steadily heated, but that does not annul the fact of the loss. Nature, when she created "specific heat," produced the condition; we know it is there. Why not meet it?

When a customer shuts the heat off a room and permits it to cool, the great quantity of heat in those walls is entirely dissipated and the boiler and radiators *must replace it each time the room is heated.* The effect is the same on the heating system as though the room had been increased in size. This will become quite clear if we recall that the amount of heat necessary to raise five pounds' weight of masonry one degree in temperature would raise 50 cu. ft. of air one degree. Estimate the weight of a wall and see what a quantity of air would be heated with this specific heat of walls. Put it in another way. Suppose a room to be 15x16x10 ft. with a total cubic content of 2,400 cu. ft. The amount of heat required to raise the walls one degree in temperature must be in a certain relation to the heat required to raise the cubic contents of air one degree. Right here we begin to find the advantage of a positive measure of the heat by B. t. u.

We have already seen that the specific heat of air is .238, that a cubic foot of it weighs .0864 lb., and that its specific heat is $.0864 \times .238 = .0205632$ B. t. u.

It will be seen that 50 cu. ft. of air would be raised one degree by one B. t. u. $.0205632 \times 50 = 1$.

The scientists who have investigated this subject tell us that the amount of heat required to raise one pound of water 1° will raise five pounds of common brickwork one degree. Builders compute that a cubic foot of common brickwork averages in weight 120 lb. If one solid wall, 16x10 ft., is exposed there would be 160 sq. ft., and if one foot thick, 160 cu. ft. by weight 120 lb. per cu. ft. = 19,200 lbs. If 50 cu. ft. of air in the room is raised one degree by one unit of heat it would require $2{,}400 \div 50 = 48$ B. t. u. to raise the cubic contents of the room one degree and $48 \times 70 =$ 3,360 units of heat to raise the air in the room from zero to 70 deg. F. If one heat unit will raise five pounds of masonry one degree and a wall exposed to outside air weighs 19,200 lb., then 19,200 ÷ 5 = 3,840 B. t. u. This amount must be furnished every time the wall cools down one degree. In other words, it would take, in case illustrated, more heat to raise the wall one degree than would heat the cubic contents in air from zero to 70 deg.

When a room is brought to 70 deg., however, and this temperature maintained for 12 hr. out of the 24, and then permitted to cool down from the outside, the loss will be slow and not all of the specific heat of the wall is dissipated in that time. But, if windows are opened so that the heat in the air in room is dissipated quickly, the loss in wall is greater, because the temperature is reduced from both inside and outside influences.

I have given this subject of the specific heat of walls a quite full discussion for the reason that it has not heretofore received the attention it deserves, especially, now that the craze for sleeping in rooms with the heat off and windows open is spreading so rapidly.

The same reasoning holds good for rooms or buildings heated only at long intervals, and then perhaps but for two or even less hours of steady occupancy when heated. Such rooms usually have great wall exposure compared to cubic contents, and it often requires from 24 to 48 hr. of continuous firing to supply the walls with their specific heat before the thermometer begins to show that the desired temperature has been attained by the air itself. If the heat is withdrawn only a few hours during the night, the loss from the constant is less and not so much of the heat absorbed by the walls will be dissipated as would be the case if a longer period of non-supply obtained.

The heat absorbed by walls in a hot summer day from the sun, and the cooling down of the same walls at night furnishes a good illustration of this action when entirely confined to natural force and law.

The effect of wind upon heated walls can be studied with profit during the hot summer days. The illustrations cited show the necessity of the fitter knowing as much as possible in regard to the continuance of hours of heat to be maintained per day, or the number of days per week that a continuous heat is to be maintained.

It is the habit of some house-owners to permit the heat to drop out entirely from some rooms for long periods. Others let the fire go out every night. These are conditions which may very materially affect the amount of radiation which should be provided and also the size of boiler to be selected.

The German government has had very exhaustive tests made of this phase of the heating question and as the result of their investigation, German engineers have decreed that an arbitrary addition to radiation shall be made, over and above other losses to be provided against, of 10 per cent when the heating is continued during the day only and closed off during the night; 30 per cent when rooms are heated during day and opened to outside air during night; 50 per cent when long periods of several days and nights prevail when building is without heat.

The loss of heat through average walls, per square foot of wall, is, of course, dependent upon the material of which it is constructed, the manner in which it is constructed, the temperature of the outside air and the temperature of inside air, and also to quite an extent to the force and velocity of the wind reaching outside surface of wall. Most elaborate algebraic formulas have been found necessary to express the loss of all kinds of building material, but for the needs of the "just every-day steam-fitter," making his estimates for average house-heating jobs, the average results of these investigations are all he requires. He is willing to let the intricate experiments go, if he can have access to the facts ascertained.

And it is perhaps well that that is his attitude if this book is to give its message without x. y. z. formulas.

One result of the investigations has been to demonstrate that in practice there is not a great amount of difference in the loss of heat from walls of residences, whether they are constructed of wood, brick, stone or concrete per square foot per hour, when the walls are dry, however much the material as a unit may vary in its capacity to conduct or absorb heat. This is accounted for by the manner of construction: for instance, a wooden wall boarded, papered and clapboarded on outside of studding and lathed and plastered inside of studding has a valuable air space the thickness of studs. Air is a poor conductor of heat.

A brick wall as usually built up for residences, with plaster often laid on to wall itself, will conduct as much and sometimes more heat from inside to outside as the wooden walls. Therefore, while at times there are occasional residence walls of brick or stone, so splendidly constructed as to require different percentages of loss per square foot than the average, such exceptions are so rare in this country that it is safe to go ahead on the basis that average loss will apply to any residence which, when measured, did not disclose the fact that exception should be made.

At this time no addition will be made for wind, but in the final summing-up for the purpose of a general rule for house-heating, the average loss per hour from wind will be added to both wall and window surface. A fair average for square foot of residence wall per hour loss in B. t. u. with zero temperature outside and 70 deg. inside, can be reckoned as 17 B. t. u. per sq. ft. per hour *in a dead calm.* Very thin walls will lose more, very thick walls less. As an approximate guide the following table based on brick walls, plastered on inside, air zero outside, 70 deg. inside, is given. It must be understood the loss here recorded is *when there is no wind.* The force or velocity of wind changes the whole proposition, but as walls often are situated so that no wind reaches them this table will be useful.

SECTION VII.

TABLE G.

Approximate loss of heat through walls when outside air is zero. Inside air 70 deg. per sq. ft. per hr. in B. t. u. Wall plastered on one side. No wind blowing Building continuously heated day and night.

Thickness of Wall.	B t. u. Per Sq. Ft. Per Deg. of Difference.	Outside Wall, B. t. u. Per Sq. Ft. Per. Hr.
1 Brick	0.357	25.
1½ "	0.286	20.
2 "	0.243	17.
2½ "	0.214	15.
3 "	0.186	13.

Inside walls often divide rooms with a difference of temperature on each side. Such walls require attention and the loss through them supplied by radiation to offset this loss. The following table gives a fairly accurate estimate of such loss per square foot of surface per hour:

TABLE H.

Approximate loss of heat through partition walls per square foot per hour at varying differences of temperature between rooms.

Temperature Warm Room.	Temperature Colder Room.	Loss Per Sq. Ft. Per Hr. B. t. u.
70 deg.	60 deg.	3.5
"	50 "	7.
"	40 "	10.
"	30 "	13.
"	20 "	17.
"	10 "	20.
"	0 "	23.

The foregoing tables cover walls of excellent construction. Many wooden houses are constructed very much thinner than those required to fill conditions called for by Tables G and H. Any estimate on wooden walls and balloon construction, as to loss per square foot, even without wind blowing, may fall far below the actual loss. I offer, however, the following as a fair estimate of what the loss in B. t. u. per square foot per hour may be from such construction, it being understood the walls are furred, lathed and plastered on the inside:

TABLE I.

Approximate loss of heat per hour in B. t. u. per square foot of outside wall of wooden buildings, balloon construction, zero outside, 70 deg. F. inside. Heat continuous day and night.

Construction of Building.	B. t. u. Loss from Exposed Walls Per Sq. Ft. Per Hr.
Crossboarded and Clapboarded.................	35.
Crossboarded, Thin Paper and Clapboarded.....	25.
Crossboarded, Double Papered and Clapboarded	18.

The loss of heat through windows next requires attention.

This particular branch of the heating problem has been much discussed and many long and hard words have been the result.

From some personal experiments and much study of the experiments of others, I conclude that it makes a considerable difference in the heat loss through glass whether the glass is wet or dry. It also makes a very marked difference how hard the wind is blowing when tests of loss through windows installed in a building are made, and some difference how high the window is, in comparison with total height of room.

Nearly every scientist who has experimented on loss of heat through glass has determined the loss per square foot per hour to be near one B. t. u. per degree of difference between the temperatures of the two sides.

Péclet, whose experiments and formulas are the real foundation of the modern science of heating, found very considerable difference in loss per square foot when room was 70 deg. inside and zero outside, when the windows were of different heights.

The following table reduced to B. t. u. from Péclet's data makes the point quite clear:

TABLE J.

Loss per square foot per hour from windows with 70 deg. difference in temperature.

	Ft. In.	Ft. in.	Ft. In.	Ft. In.	Ft. In.
Height of Windows..	3 3	6 7	10 0	13 3	16 3
Loss in B. t. u. per Deg. Diff. Temperature	0.98	0.945	0.93	0.92	0.91

The German scientists practically agree that the average window-loss is .97 B. t. u. per square foot per degree of difference per hour, and then comes the German government with the demand that windows be figured to lose 1.09 B. t. u. per degree of difference. This demand on the part of the German government seems to cast a doubt upon the correctness of .97 B. t. u. But add to .97 the increase because of average wind velocity, as will be fully illustrated in the discussion upon wind pressure, and it will be seen that the .97 has been accepted as correct. Assuming the average winter wind to be at rate of 18 ft. per sec., or 12.3 miles per hour, and allowing one per cent per mile velocity addition for loss from window because of this, and .97 + 12.3-10 per cent = 1.09, which is what the German government calls for. *In other words, they call for the loss from windows under average working conditions, not laboratory conditions.* It will at once be seen that the government is correct. In the tables on the loss of heat from walls and windows to be found later in the discussion, the various differences created by the wind will be considered quite fully.

TO DETERMINE AMOUNT OF HEAT-LOSS FROM ROOMS IN BUILDINGS.

Effect of Wind on Loss from Walls and Windows.

It requires no long argument to establish the fact that a room continually exposed to a strong wind will cool from a given temperature above that of outside air to that of outside much more quickly than one not so exposed, but otherwise under the same conditions. It is in order to understandingly figure for such additional loss that, when measuring the building, special note is made of the direction of prevailing winds.

It is a self-evident fact that the velocity of the wind varies many times in a day and the best that can be done is to work upon average conditions, and make special provision for conditions beyond the normal. It is also evident that such a very important factor cannot be overlooked in designing a heating plant.

The average velocity of the wind not only varies from day to day, but varies in different sections of the country, and even in different portions of quite small towns.

In years past, architects and owners have not been in the habit of specifying any special boiler-pressure, or temperature, contenting themselves with the general requirement of 70 deg. in room, or some specified room-temperature. But within a short time, architects and owners have been demanding that heating jobs shall give all sorts of temperatures in rooms and that they shall prevail when the temperature at boiler is not to exceed 180 deg. in a hot-water boiler, or 2-lb. gage pressure on a steam job, and a final settlement for the job is often refused unless the requirements both as to room and boiler temperatures are explicitly complied with.

Under these changed conditions it does not seem wise to overlook a factor which, if not provided for, may cause the expending of a considerable sum of money and many hours of time in adding sections to radiators in order to comply with contract-terms in rooms on north side of a building or at points especially swept by winter wind.

Here again the question of altitude presses upon our attention. This time not only the altitude above sea-level, but the altitude of the *radiator above the boiler,* which will affect the temperature of the steam or water in the radiator. This will be more fully discussed under the question of piping.

In regard to wind, a very serious discussion is demanded. The old rules are utterly valueless as a guide to the conscientious steam-fitter who wishes to do good work.

The books on the question as they affect the steamfitter are singularly silent on the question, and it is deemed well to discuss it quite freely at this time.

The Encyclopedia Brittanica, Vol. 16, page 157, sorts winds as "Polar or cold winds which blow from N. W., N., N. E., and E.; and Equatorial, or warm winds, as those from S. E., S., S. W. and W.," and states that the "polar or cold winds have a greater mean velocity of over one mile per hour than the equatorial winds."

As fitters often have occasion to figure for friends or others in a section remote from their own locality, in a general way it can be said that the prevailing winter winds in the United States and Alaska are as follows: Alaska, N. E.; New England States, N. W.; the Atlantic-Coast States, as far south as North Carolina, N. W.; South Carolina and farther south on coast, W. The great midland sweep of states from the Great-Lake region to western Texas, but east of the Rocky Mountains, present an irregular division of prevailing winter winds, which can be said to be caused by two great regions of high barometer-pressure, one in the southeast section, the other, and larger of the two, having its center near Utah.

Between these there is interposed a region of lower barometer-pressure, extending from northeastern Illinois to southwestern Texas. On the western line of this irregular line the prevailing winter winds seem to be from the northwest, but toward the eastern edge of it they become West, W. S. W., S. W., becoming N. W. as they reach the mountains of North Carolina.

Along the coast of the Gulf of Mexico and south of the irregular line mentioned the prevailing winter winds seem to be from the northeast.

The Pacific-Coast States and the territory west of the Rocky Mountains present a great many rather sudden changes in direction of prevailing winds; from N. at Fort Yuma, Cal., to nearly S. at other points. The variation is so marked, even within comparatively short distances, that local conditions should be ascertained before attempting to figure for Pacific-Coast heating jobs in regard to exposure to wind.

The following table shows something of the force of wind.

The descriptive names may not meet with the approval of my readers, but they can choose names to please. It is the feet per second and the miles per hour that does the heat-transporting act.

TABLE K.

Force, velocity and pressure in pounds per square foot of wind.

Perceptible Force.	Velocity Miles per hour.	Pressure in lb. per sq. ft. of Surface.
Just perceptible	2	.02
Gently pleasant	4	.08
Light breeze	10	.5
Fair breeze	12	.71
Good breeze	15	1.2
Stiff breeze	20-25	2.1-3
Strong breeze	30	4.5
High wind	35	6.
Very high wind	40	8.
Very strong wind	45	10.
Wind storm	50-55	12-15
Violent Storm	60-65	18-21
Gale	70-75	24-27
Hurricane	80	37.
Violent hurricane	100	49.

It is probable that the winter winds of the country over will average 12½ miles per hr., or 22 ft. per sec., with a pressure of perhaps 12 oz. per sq. ft. of exposed surface.

The Encyclopedia Britannica (Vol. XVI, p. 125), states that "the velocity of wind on the open sea is considerably in excess of that near land . . . 650 daily observations on the open sea give a mean hourly velocity of 17½ miles, whereas 552 observations near land give a velocity of only 12½ miles per hour."

The German engineers figure on a shade less than 12.5 miles, about 12.3 miles per hr. in the open country. In this country there are many sections where 15 or 20 miles an hr. would not be excessive.

Here again altitude cuts a very important part.

It is, of course, out of the question to prepare a table that shall be exact as an offset for wind-pressure, but a fairly safe average when the room is to be maintained at 70 deg. and outside temperature is 32 deg. or below is to increase the total loss in B. t. u. from all other sources from the wind-swept rooms from one to one and one-half per cent for each mile of wind-velocity. Thus, if a sheltered position s. reduced the average wind-velocity that it was not above 10 miles per hr., add 10 per cent; if so exposed, because of altitude or other cause, that the average wind was 15 to 20 miles per hr., add from 20 to 30 per cent.

SECTION VIII.

The discussion in regard to loss of heat from walls can be summed up as in Table L.

TABLE L.

Table Showing Probable Loss Per Sq. Ft. Per Hr. in B. t. u. from Average Well-Built Residence-Wall Surface When Rooms are at 70 Deg. F. Outside Air Zero. With various Wind Velocities. Rooms Not Over 12 ft. High and Continuous Heat Maintained Day and Night.

Loss in B. t. u. Per Sq. Ft. Per Hr.

Brick Wall, Furred and Plastered. Thickness of Wall.	No Wind	Wind Velocities 2 Miles Per Hr.	5 Miles Per Hr.	10 Miles Per Hr.
1 Brick	25.	25.5	26.25	27.50
2 Brick	17.	17.34	17.85	18.70
2½ Brick	15.	15.30	15.75	16.50
3 Brick	13.	13.26	13.65	14.30
3½ Brick	11.	11.02	11.55	12.10

	Average Winter Wind, 12½ Miles Per Hr.	Wind Velocities 15 Miles Per Hr.	20 Miles Per Hr.	30 Miles Per Hr.
1	28.12	28.75	30.00	32.50
2	19.12	19.55	20.40	22.10
2½	16.87	17.25	18.00	19.50
3	14.63	14.95	15.60	16.90
3½	12.38	12.65	13.20	14.30

To use this table, multiply total net square feet of exposed wall by factor representing wind-velocity required. For example—A wall equivalent to a 2-brick wall has, say, 125 sq. ft. of net exposed surface. We are required to estimate the probable loss per square foot per hour and total loss per hour, wind at average winter-velocity of 12½ miles per hour. Room 70 deg., outside air zero. Heat continuous.

Under 12½ miles we find probable loss per sq. ft. 19.12 B. t. u. Total net wall, 125 × 19.12 = 2390 B. t. u. per hour loss from the wall. The window loss will be found from Table M.

TABLE M.

Loss of Heat in B. t. u. from Window Surface Per. Sq. Ft. Per Hour, for Each Degree of Difference Between Temperature of Rooms, and Temperature of Outside Air, Varying Velocities of Wind. Room Not Over 12 Ft. High. Heat to be Continuous Day and Night.

Description of Glass	—Wind Velocities Per Hr.— No Wind.	Wind 2 Miles	Wind 5 Miles.
Single thick common.........	.97	.99	1.02
Double window..............	.45	.46	.47
Single skylight...............	1.09	1.11	1.14
Double skylight..............	.49	.50	.51

—Wind Velocities Per Hour— Wind 10 Miles.	Ave. Winter Wind 12½ Miles.	Wind 15 Miles.	Wind 20 Miles.
1.07	1.09	1.17	1.26
.50	.51	.54	.58
1.20	1.22	1.30	1.41
.54	.55	.59	.63

The use of this table is clear. If with an average wind of 12½ miles per hour one square foot of window loses 1.09 B. t. u. per degree of difference, then at 70 deg. difference the loss will be 1.09×70=76.30 per hour and 100 sq. ft. would lose 76.30×100= 7630 B. t. u. per hour.

The window surface is one of the great sources of heat-loss. As already explained, the scientists are fairly well agreed upon the loss in dead calm as .97 B. t. u. per sq. ft. per degree of difference. If the outside was zero and inside 70 deg., the difference would be 70; then .97 × 70 = 67.9 B. t. u. per hour per sq. ft. of window. If the window had 25 sq. ft. of surface, the total loss for the window "in a dead calm" would be 1697½ B. t. u., but with wind blowing this loss is increased as seen by Table M, calculating on an average winter rate of 12½ per cent to 1907½ B. t. u.

In order that those who do not care to take the time to make up a table of loss per square foot of window surface when the usual conditions required are called for, viz., zero outside, 70 deg. inside, wind normal, or, at an average of 12½ miles per hour, the following Table N will be of advantage.

Any other temperature than 70 deg. and any wind velocity other than the average, can easily be made use of by multiplying the required factor in Table M by required temperature. Desired the heat loss from a window when room is 60 deg. inside, outside 20 deg.; wind, 5 miles per hour. The factor per degree of difference by table is found under 5 miles to be 1.02 B. t. u. per sq. ft. The difference between 60 and 20 = 40. Then, 1.02 × 40 = 40 8-10 B. t. u. In practice this would be called 41.

TABLE N.

Showing probable loss per sq. ft. of surface of window per hour with air at zero outside, 70 deg. F. inside. Normal or average wind velocity of 12½ miles per hour.

Description of Window.	Av. Win. Wd. Vel. Per Hr.	Prob. Loss Per Sq. Ft. Per Hr.
Single thickness, common	12½ miles	76.3
Double window	"	35.7
Single skylight	"	85.4
Double skylight	"	38.5

It may be found useful to have a table giving in square feet and fractions thereof the area of the usual windows found in buildings, and for this purpose Table N-1 is given:

TABLE

Glass Surfaces

Areas in Square Feet and

Ft. In.	F. In. 1 8	Ft. In. 1 10	Ft. In. 2 0	Ft. In. 2 4	Ft. In. 2 6	Ft. In. 2 8
3 6............	5.81	6.42	7.	8.17	8.75	9.33
3 10............	6.36	7.03	7.67	8.94	9.58	10.22
4 2............	6.94	7.64	8.33	9.72	10.42	11.11
4 6............	7.50	8.25	9.	10.49	11.25	12.
4 10............	8.05	8.86	9.67	11.28	12.08	12.88
5 2............	8.61	9.47	10.33	12.05	12.92	13.77
5 6............	9.16	10.08	11.	12.83	13.75	14.66
5 10............	9.72	10.69	11.67	13.61	14.58	15.55
6 2............	10.27	11.30	12.33	14.39	15.42	16.44
6 6............	.....	11.91	13.	15.16	16.25	17.33
6 10............	.....	.....	13.67	15.94	17.08	18.22
7 2............	.....	.....	.....	16.72	17.92	19.11
7 6............	.....	.....	.....	.....	18.75	20.
7 10............	.....	.....	.....	.....	.....	20.88
8 2............	.....	.....	.....	.....	.....	.....
8 6............	.....	.....	.....	.....	.....	.....
8 10............	.....	.....	.....	.....	.....	.....

To find area, note where the height as given at the left side of table intersects with width as given at top. For example: The area of a 5 ft. 10 in. x 2 ft. 8 in. window is 15.55 sq. ft.

We now come to the consideration of the matter of leakage from rooms through other sources than walls and windows.

Doors naturally present a source of intermittent loss that can only be covered with some general factor of safety, but outside doors should be specially considered as certainly as windows.

N-1.

in Windows.

Fractions of a Foot.

Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
2 10	3	3 2	3 4	3 6	3 8	3 10	4 0
9.92	10.5	11.08	.....	.....	.....	.....	.....
10.86	11.5	12.14	12.78	.....	.....	.....	.....
11.80	12.5	13.19	13.89	14.58	.....	.....	.....
12.75	13.5	14.25	15.	15.75	16.50	.....	.....
13.69	14.5	15.30	16.11	16.92	17.72	18.52	.....
14.64	15.5	16.36	17.22	18.08	18.94	19.80	20.66
15.58	16.5	17.41	18.33	19.25	20.16	21.08	22.
16.52	17.5	18.47	19.44	20.42	21.38	22.36	23.33
17.47	18.5	19.52	20.55	21.58	22.60	23.63	24.66
18.41	19.5	20.58	21.66	22.75	23.83	24.91	26.
19.36	20.5	21.63	22.77	23.82	25.05	26.19	27.33
20.30	21.5	22.69	23.88	25.08	26.27	27.47	28.66
21.25	22.5	23.75	24.99	26.25	27.50	28.75	30.
22.19	23.5	24.80	26.11	27.46	28.72	30.02	31.33
23.13	24.5	25.85	27.22	28.58	29.94	31.30	32.66
.....	25.5	26.91	28.33	29.75	31.16	32.58	34.
.....	.....	27.97	29.44	30.92	32.38	33.86	35.33

It is the practice of some to consider doors which open directly to room as having same loss as windows, and it is not a bad practice. Yet some doors are hardly so productive of loss as that, and for quite careful estimators the losses shown in Table O have been found to be quite exact for the average machine-made doors. This table can be used also for tongued and grooved board walls if they are perfectly matched and tight.

TABLE O.

Probable loss per hour per degree difference of temperature from outside doors in B. t. u. per sq. ft. of surface:

Thickness.	Soft Wood.	Hard Wood.
½ in.	.58	.72
¾ in.	.49	.65
1 in.	.43	.60
1¼ in.	.38	.56
1½ in.	.35	.52
2 in.	.30	.45
2½ in.	.26	.41
3 in.	.23	.37

Glass in doors should be figureed with glass surface of room.

One very considerable source of leakage is found to be that from fireplaces.

This loss can be more nearly measured than from many of the minor sources, such as loose-fitting doors and windows, and semi-direct openings, such as arise from careless carpenter or mason work in fitting door and window frames. These are sometimes so badly fitted as to cause very serious heat-loss. Usually a careful "measurer-up" will discover such conditions and note them, but when figuring from plans it is always safe to put in a factor of safety for this and similar loss. This is usually covered in the times-per-hour provision made for change of air. Wooden and concrete houses quite often are so carelessly constructed in this respect that no mistake is made in allowing for three or even four changes per hour of total cubic contents of air.

Houses with a big reception-hall, which may also be the living room and usually with a big fireplace, is a room to call for most critical examination. The fireplace throat, even if it has a good damper, that can be closed, had best be considered as always open, and the rush of air through such an opening is large.

Such fireplaces often have an opening of full 144 sq. in., and it is of the utmost importance to find out about it.

Old houses with fireplaces in the rooms quite often have no provision for shutting off the fireplace draft except a loose-fitting front.

These fireplaces and other minor leaks, each perhaps small in itself, when all collected as one item, quite often produces a loss in B. t. u. per hour, several times the amount that would be required to maintain the cubic volume of air of the room itself at a given temperature, say, 70 deg. for an hour.

This can be illustrated by a very common condition found in residences. In a room, for example, 14x16x10 ft., containing 2,240 cu. ft., is found a fireplace with a throat, opening direct to a chimney, which is likely a 12x12-in. chimney or larger, and at least 30 ft. high. This fireplace throat may be 3x12, 4x12, or even 6x12 in.

When the temperature of the room is at 70 deg. F. and the external air is at 30 deg. F., the mean temperature of the chimney with the air from room going through it might be 50 deg., or 30 deg. in excess of outside air.

At this difference the 3x12 fireplace throat opening into chimney would discharge 66¼ cu. ft. of air per min. from the room to chimney, or 3,975 cu. ft. per hr. This gives 1,735 cu. ft. per hr. to be heated more than the cubic contents of room specified, or within 505 cu. ft. of twice the cubic contents.

If the chimney-throat was 6x12 in., the air moved under conditions named would be 132½ cu. ft. per min., or 7,950 cu. ft. per hr., nearly four times the cubic contents. Think of trying to solve a fireplace problem by any ratio-rule based upon cubic contents!

SECTION IX.

The Table P is given as showing the probable quantity of air, in cubic feet, passing through a flue having a sectional area of one square foot, like a 12x12 chimney, at various temperatures of difference and height.

TABLE P.

Showing probable amount of air discharged per minute in natural

Height of Flue in feet.	Excess of Temperature			
	5 deg.	10 deg.	15 deg.	20 deg.
20	108	153	188	217
25	121	171	210	242
30	133	188	230	265
40	153	217	265	306
50	171	242	297	342

It will be found easy to calculate fireplace loss approximately close from above table. The height of residence chimneys above fireplace rarely exceeds 30 ft. and the average temperature of flue, unless it receives warmth from some other flue in the stack, rarely exceeds 50 deg.

If some other flue, as the boiler-flue or kitchen-flue, is alongside the fireplace flue, the temperature of flue may be as high as 150 deg. at times above external air.

The cubic feet in table is per minute. To find hourly discharge multiply by 60. To find loss from fireplace throat, divide hourly loss by fractional portion of square foot corresponding to throat-opening. Suppose a fireplace throat to be 4x12 in.= 48.sq. in. Then 48/144 of hour loss under conditions existing as shown from use of table, would be the B. t. u. loss per hour from fireplace as already illustrated. Thus, with external air at 30 deg. and chimney 50 deg., the difference being 20 deg., the loss per sq. ft. is probably 265 cu. ft. per minute. An opening 3x12 in. equals 36 sq. in. and 36/144 of 265 =

TABLE P.

cu. ft. from a warm room through a 12x12-in. Chimney by draft.

of Air in Flue Above External Air.

25 deg.	30 deg.	40 deg.	50 deg.	100 deg.	150 deg.
242	265	306	342	...	...
271	297	342	383	541	663
297	325	375	419	593	726
342	375	431	484	684	838
383	419	484	541	765	937

66.25 per min.; 66.25 × 60 = 3,975 B. t. u. per hour as previously stated.

To still further emphasize the great importance of fireplace openings, compare the case of window-loss with the fireplace thus considered. A window under normal winter wind-velocity, when room was 70 deg. and zero outside, would cool 76.3 cu. ft. of air per hr. per sq. ft.; see Table N. As we find the fireplace loss to be 3,975 cu. ft. of air per hr. and the loss from a square foot of window to be 76.3, it follows that 3,975 ÷ 76.3 = 52 + sq. ft. of window, or about the equal of two windows, 3 ft. 4 in. × 7 ft. 10 in., or 26.11 sq. ft. each..

It may seem to the reader that with such a multiplicity of conditions under which heat is lost from a building that it would be a hopeless task to undertake to supply and maintain any regular temperature. But, on the other hand, the more accurately the known sources of 'loss are collected, the more certain does the contractor become of his ability to secure perfectly satisfactory results. And it might be said also the less inclined is he to rely upon "Rules of the Thumb" when figuring for radiator surface required.

If one should attempt to describe in detail all the various acts performed in dressing one's self in the morning to one who had never required clothing, it would probably seem to that one that mighty little time would be left after the dressing was completed for anything else.

It is certain that no rules can be given that will obviate the use of sound common sense at times. It is well to remember, nevertheless, that the more care given in the beginning to the simple details which have been described as necessary while measurements are being made and no material is being used except pencil and paper, the more certain will the fitter become as to the final net cost of the job when his garantee as to temperature has been filled and he is ready for final settlement with his client for the completed job.

With an acquaintance among steam-fitters extending from the Atlantic to the Pacific and from the Great Lakes to the Gulf of Mexico, I can state unequivocally that those men who are really making good money in their profession are:

Those who take the greatest amount of time and care to ascertain all probable sources of heat-loss from a given job before commencing to figure on it.

Those who exercise the greatest care in figuring the amount of surface needed in the radiators, to overcome each loss when it is apparent.

It is the men who use one or two short-cut rules to cover any sort of house-heating installation that comes to them, who are continually getting into trouble over their unsatisfactory jobs.

These "short-cut rule" men may get their bids in sooner than the careful fitter "who knows," but the finish of the job and collection in full from a satisfied client will, 9 cases out of 12, come first to the careful man "who knows."

There are some steam-fitters doing residence and small building work, in various sections of the country, who have no knowledge whatever of high-pressure sky-scraper heating jobs, but who do know how to figure a residence properly for any gage pressure required from 10 or 12 lb. less than atmosphere to 30 lb. above atmosphere. To these men, for they are few (may their number increase), a set of specifications calling for a half-dozen different temperatures in various separate rooms over a house, coupled with a boiler-gage pressure of specific amount, is no staggering proposition. It would be to the fitter who is trying to cover everything with a set of guesswork rules, or to the fitter who only has one rule, based to be sure upon wall exposure, glass exposure, and change of air in the rooms, but who has not the faintest idea whether the pressure called for by the specifications would agree with his rule or not.

There are thousands of steam-fitters in this country today, big concerns and little ones, who are continually attempting to fit a rule calling for 10-lb. pressure temperature in *radiator,* to a contract that calls for a 2-lb. pressure at *boiler.*

These are the people who are having trouble with the new boiler-ratings and who are sure radiators are much overrated by the manufacturers. These are the people to whom the careful detail of measurement and the bringing of all losses to the only basis of measurement of heat known, the B. t. u., or its foreign brother, the calorie, are either unknown or are considered by them as beyond their comprehension. As can be seen there is nothing mystic or unusual in bringing all losses thus far found to a B. t. u. basis. In fact, it is the proper method, and as the discussion proceeds it will be seen that it is the logical thing to do at every stage of the proceedings.

If the distance between two points is desired, one naturally measures it by feet or fraction thereof, and does not attempt to do it by getting a cubic foot of the intervening substance and guessing at it. Or, if it is desired to know how much water will be required to fill a cask that is leaking, so that it will just stay full, the most direct way is to measure the quantity leaked out in a given time, in order to find out how much in quantity must be replaced in a given time It would not be a logical or very successful way of going about the question of exactly replacing the leakage from the cask by finding its cubic contents and guessing that from 30 to 40 quarts or gallons per hour would about do.

It would be more logical to measure the loss per hour and, having fixed some degree of velocity or pressure at which you would pour the water back into the cask, say that it would require a certain quantity per hour to offset the leakage out of the cask. But if the movement, the velocity, or pressure of the returning water were changed from the condition fixed by the rule, either more or less water would be supplied than the balancing of leakage required. And that is what happens to the steam-fitter who attempts to fit a rule adapted to 10-lb. pressure-temperature in the radiator to a 2-lb. pressure at boiler condition. He does not get heat enough. If the reader has not grasped this thoroughly, refer to Section IV again.

Now that architects are generally calling for results with boiler-pressure stated in advance, and final settlement is to be made when the temperature demanded by contract is secured under conditions stated, and boiler-pressure required has not been exceeded, it will not do to overlook the many little sources of loss, the little leaks. If you do, when settling time comes you may be obliged to spend many times over, in adding sections to radiators and in other ways, what the cost to you would have been to have taken time to figure out these losses in the beginning.

It is much cheaper to pay one man for an hour or two of time in properly figuring a job, than to pay fitters and helpers for several hours' time for extra work and the manufacturer dollars for material that should have been provided in the beginning, if proper attention had been given to those wind-exposed rooms, or that floor with no cellar under it, or the fireplace that was overlooked, or some other bad loss of heat, of B. t. u.

It is very certain that if the total loss of heat under all conditions was the same, a simple ratio-rule would suffice to cover all conditions. It is evident such conditions do not apply. It is also very certain that if there was never any call for heating except for 10, 15 or 20-lb. pressure of steam at boiler, that one rule would answer for everything in steam-heating. But the fact is, architects and owners call for boiler-pressures varying from 2-lb. gage at boiler to 60-lb.

Any rule that cannot be made to supply the requirements of any condition of boiler-pressure, which may be called for in residence-heating, will hardly fill the requirements of the steam and hot-water fitters of today.

That a simple rule, easy to understand and apply, is obtainable, and is the logical outcome of the natural laws involved in heating by steam and hot-water when once those simple laws are understood, we are trying to demonstrate.

There are a few more minor losses of heat from a room that should not be overlooked, but often are by careless estimators. A very frequent source of trouble is second-floor rooms, whose floors also act principally as the ceiling for an open porch. Very often a half-inch hardwood porch-ceiling comes to be all there is between the chamber floor-boards and "all outdoors."

In these days of hardwood floors and no carpets, the protection to the room is slight from such a floor, and the heat-loss tremendous. Floors over cold cellars or over plain open space, must be considered. In the South and Middle West, quantities of fine houses have little cellar room. They are built on piers and stand just high enough above ground to be dry and permit a draft through between floor and ground.

It is with such conditions as these that considerable judgment must be exercised. No hard and fast set of ratio-losses can be fixed.

The best that can be done is to give an approximate average as a base upon which to work, and such an average is shown in Table Q.

TABLE Q.

Approximate loss of heat in B. t. u. per degree difference of temperature per sq. ft. of surface per hour from floors over cold-air-spaces:

Double-Boarded Floor.	No. Draft.	With Average Wind.	With Strong Wind.
1½ in. thick, open underneath..	.33	.25	.40
Floor double and sheathed on underside..................	.22	.25	.29
Lathed, and plastered with cement on underside.........	.18	.20	.24

Two hundred and twenty-four sq. ft. over an average porch exposure, would lose from its surface when room was 70 deg., outside air zero, from 5,488 B. t. u. to 3,136 B. t. u. per hour, loss calculated as follows: $.35 \times 70 \times 224 = 5{,}488$, or $.20 \times 70 \times 224 = 3.136$ B. t. u., according to conditions.

SECTION X.

It is interesting to note in this connection that a good wall of ordinary quality will lose but a trifle more per square foot per hour than that floor will when floor is in relatively same condition, having lath and plaster on one side of stud and wall or floor on other. See Table G and Table I.

Floors over cold cellars can usually be considered as having a cellar-temperature of 32 deg. F., and the difference between this and temperature of warm room should be taken in estimating loss. Thus, the cold air being without wind, the loss is taken from "No Draft" column. A double-boarded floor with no ceiling boards or lath and plaster counts by table as .33 per deg. of difference per sq. ft. of surface. Then, $70 - 32 = 38$; therefore 38 deg. $\times$ $.33 = 12\frac{1}{2}$ B. t. u. per sq. ft. per hr. A floor with 224 sq. ft. of surface would thus lose approximately $224 \times 12.5 =$ 2,800 B. t. u. loss..

TABLE R.

Showing approximate loss in B. t. u. per square foot per hour from warmer to colder rooms through ceilings or floors. Room heated day and night, not over 12 feet in height:

	Loss per sq. ft. per deg. of Differ.
Heated room having ordinary lath plaster ceiling, board floor on cold room above	.60

This .60 is taken when using the mean temperature of warm room and of cold room above.

As the air in the top of the room is some degrees warmer than average of the room, and also varies slightly according to height, a loss averaged from several tests has been used. The German authorities give the loss through a construction similar to our lath and plaster ceiling as .615. As stated in the commencement, it is not intended to fully cover the entire heating proposition at this time, but to cover quite fully, and endeavor to make clear the fundamental laws of heating.

The first lesson to learn is the use of the measure of heat, the thermal unit. Unless a steam-fitter has learned this so thoroughly that he can use it in ascertaining losses or gains in heat, as he would a foot-rule in measuring the length of a pipe, he can hardly expect any considerable accuracy in his heating undertakings.

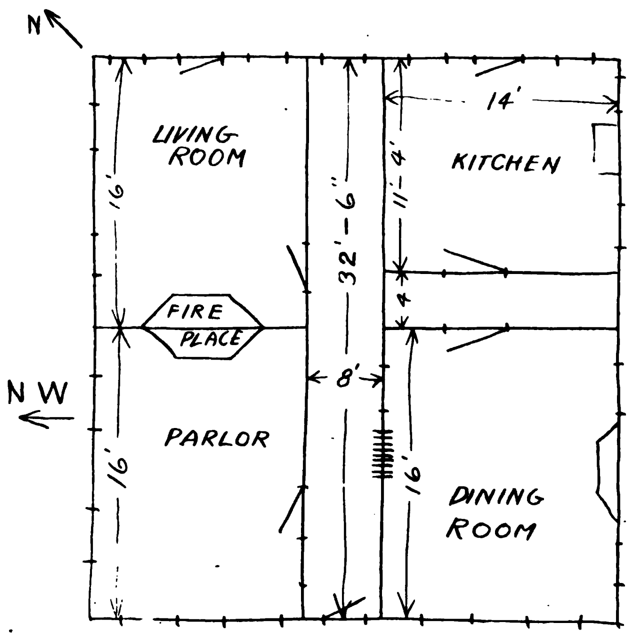
It is believed that any one of ordinary attainments who has carefully read to this point has become fairly familiar with this measure of heat, the British thermal unit.

We are now ready to apply what we have gathered in regard to loss of heat from rooms:

Let us suppose that we have a measurer's memorandum of a room on the northwest side of a house like the following before us, and proceed to apply to it the various things necessary to a complete understanding of how much heat. measured in B. t. u.. should certainly be provided to offset the loss.

FORM AB.

Measurements and figuring data from J. Plummer..............
....A. Bylder, Architect
House of J. Robertson..
Street—No. 146 ....
Telephone No.—1953 ....
R. F. D. No..
Street—Southport ....
Town—Springside ....
County—Wabash ....
State—Indiana ....



Name of Room and Temperature required	Living Room.* 70 deg. to zero.
Compass location. Prevailing wind. Elevation above sea.	N. E. 14x10. N. W. 16x10. N. N. W. 12 to 15 miles. 100 to 200 ft. above sea.
Kind of wall and condition.	Brick good.
Size of room in Feet and inches.	14x16x10 ft.
Number, size and kind of Windows.	Four. 6 ft. 6 in. b 2 ft. 8 in.**
Number, size and kind of Doors to outside air or Colder Rooms.	One. 7 ft. x 3 ft. x 2 in. Well fitted. Wind strips on sides and bottom.
Temperature, cold air.	Zero.

Square feet exposed floor. Temperature of cold side of floor.	8 x 12 ft. To cold cellar 32 deg. Nothing but 1½-in. floor.
Square feet Exposed ceiling X Roof or side of Bay Window. Temperature of cold side.	14 x 16 ft. To cold room above temperature 32 deg.
General Remarks.	*Has fire-place throat 3 x 12 in. Chimney 12 in. x 16 in. x 30 ft. **Well fitted except on N. W. next fire-place and opposite door. This leaks around finish.
Remarks on Unusual Conditions.	Cold cellar made to permit cold air to pass through it. Walls heavy to keep warmth from main cellar coming in. Cold cellar 32 deg. Rest of cellar 70 deg. Flue for heater, side of kitchen flue. Size 12 in. x 16 in. x 40 ft. Clear and smooth; no obstruction top or bottom.

We first find the cubic contents of room, 14x16x10 ft.; thus 14x16x10 = 2,240 cu. ft.

Gross exposed wall—14 + 16x10 = 300 sq. ft.

Window surface—	
6 ft. 6 in. x 2 ft. 8 in. x 4 ft. = 70 sq. ft.	70 sq. ft.
Oak door 3 x 7 ft. = 21 sq. ft.	21 sq. ft.
Net exposed wall 300—[70+21]=300—91	209 sq. ft.
Net exposed floor 8 x 12 ft. =	96 sq. ft.
Net exposed ceiling 14 x 16 ft. =	224 sq. ft.
Fire-place throat 3 x 12 in. = 36 sq. in.	.25 sq. ft.

As the memorandum states one window leaks around finish, and is also located opposite a door and near fire-place, it is evident some special judgment must be given to this. Ordinary leakage from a first-floor room is considered as twice the cubic contents per hour. This room is most unusual in its exposure, and this window must increase the leakage in an hour at least 25 per cent of the contents once, or .... 560 cu. ft.

Twice cubic contents for average leakage.... 4,480 cu. ft.

Total cubic feet of air-content to heat.... 5,040 cu. ft.

As 1.44 B. t. u. will raise 1 cu. ft. of air 70 deg. (Table T) it will require 5,040 x 1.44 = 7257 B. t. u. to raise contents and leakage to 70 deg. temperature required =

Contents and leakage loss =	7,257 B. t. u.
Net exposed wall [Table L] = 209 x 19.12 =	3,996 B. t. u.
Window loss [Tables M and N] 70 x 76.3 =	5,341 B. t. u.
Oak door [Table O] 21 x (.45 x 70) =	662 B. t. u.
Exposed floor [Table Q] 96 x (.35 x 38)	1,277 B. t. u.
Exposed ceiling [Table Q] 224 x 23 (70—32 x .60 = 23)	5,152 B. t. u.

Fire-place throat [Table P] 265 x 60 x 36/144 =	3,975 B. t. u.
Total estimated loss in B. t. u.	27,660 B. t. u.

No one would for a moment question that a room as above described would be a cold room, a very difficult room to guess at.

The amount of radiation required will depend entirely upon the temperature of hot water to be used or the temperature of the steam used, which is another way of saying what pressure. The range of size for radiator required to heat this room with steam is from 122 sq. ft. with 2-lb. pressure at boiler, to 65 sq. ft. at 60-lb. pressure at boiler, or from about 1 to 20 of cubic contents to 1 to 34.

But the amount that is left to guess-work in this case is small. This room had placed in it 100 sq. ft. of 2-column surface with guarantee of an average pressure at boiler of 15 lb. per sq. in., and numerous tests in dry weather were perfectly satisfactory. See rule for sizing direct radiators. In one test made during a heavy storm with wind estimated at 30 miles per hour, and outside air 5 deg. above zero, the room temperature fell off slightly to 65 deg., due, no doubt, to the fact that no provision was made for the extra wind-pressure beyond 12½ miles per hour, nor for the probably extra loss from walls and fire-place in such weather. The drop was not much and was easily provided for by a trifle more pressure at boiler. This extra loss is by tables found to equal about 2,500 B. t. u. This, if figured on at first, would have, without doubt, nearly or quite offset the difference, although the moisture and excess wind might have caused a slight increase over table averages.

SECTION XI.

RADIATOR-SURFACE REQUIRED TO OFFSET B. T. U. HEAT-LOSS.

As has been already stated, the difference in temperature between surface of radiator and temperature of room determines the number of heat-units emitted from radiators.

When the manufacturers fixed the rating of house-heating boilers for steam at 2-lb. pressure at boiler, they sounded the death-knell for nearly all the rules published prior to that time.

The heating contractor of today is called upon to do better work than ever, and is very largely called upon now to keep within the 2-lb. pressure-limit called for by the boiler ratings.

When discussing the specific and latent heat of steam this was explained to some extent. Table FF shows the varying measure of heat in B. t. u. which is determined by the different pressures. It is now time to extend the discussion to the radiating of these heat-units from the various forms of radiators styled Direct, Indirect, and Direct-Indirect.

The direct radiators are most in use. It is assumed that it is not necessary to go into detail regarding them here, as each manufacturer of steam and hot water radiators gives in his catalog full and generally elaborate descriptions.

The one thing none of them give in their catalog is the value of each style and type of radiator in B. t. u. per hour under different temperatures.

It is not the purpose to advertise any radiator manufactured here, but when the time comes, as it must, that radiators are sold by their garanteed delivery under given pressure, of B. t. u. per square foot per hour, the price per cataloged square foot of surface will materially drop for some manufacturers. A radiator rated in catalog at 5 sq. ft. per section, which will deliver 240 B. t. u. per hour when filled with steam at 212 deg. and setting in a temperature of 70 deg., is worth more money to steamfitter or owner than one rated at 5 sq. ft., which will only deliver 205 B. t. u. per hour when filled with steam at 212 deg. in same room. The former is worth at least 17 per cent more.

Today manufacturers ask about the same price for each representative pattern. All 38-in. two-column radiators are priced the same and so on through the list.

From what has already been said it can be seen that in dealing with this question and the present manner of rating nothing but averages can be given. Some manufacturers may claim the average given is low. It will simply be up to them to garantee that their goods will give more than the tables presented and then make their garantee good.

There is a difference between the value of single-column and two-column in value per square foot, and each additional thickness of mass or column decreases the value of the direct radiator per square foot of measured surface.

The B. t. u. emitted per square foot, as tabulated in this series, is based upon Standard Three-Column Radiators, as they have been found to average, unless otherwise stated. Some may do a little better, and some quite a bit less than the Table FF states as the probable value per square foot.

The simple rule for final sizing of radiator-surface for a given room is as follows, with 2-lb. boiler pressure, room 70 deg.

Rule for Sizing Direct Radiators, 2-lb. Pressure at Boiler.

Divide the total loss of heat from room in B. t. u. by 220 and result will show square feet of surface required.

Rule for Sizing Direct Radiators for Any Desired Pressure of Temperature at Boiler or in Radiator.

Divide total loss of heat of room in B. t. u. by the B. t. u. emitted per square foot of radiator-surface at the difference between room and radiator-temperature.

The B. t. u. emitted from radiators can be found by multiplying said difference by 2.5 for commercial pipe wall-coils; by 1.85 for cast-iron single-column, 1.65 for 2-column, 1.6 for most 3-column, 1.35 for 4-column cast-iron radiators.

The mean or average temperature of the radiators should be taken as 95 per cent of the temperature of steam at boiler. (Tables F and FF.)

To apply this rule, having 2-lb. pressure at boiler, the temperature of the steam is 219 deg., 95 per cent of that or 208 deg. will be the average temperature of steam in radiators; if the room is to be 70 deg., the difference is 138 deg. A 2-column radiator should emit $138 \times 1.65 = 228$ B. t. u. per sq. ft. per hour. A 3-column, $138 \times 1.6 = 220$ B. t. u. There are types of both two and three-column radiators offered for sale that will not give as good results as above; there may be others that will slightly exceed. I have tested 3-column radiators with rather flat tubes that only tested 1.4 or 193 B. t. u. per sq. ft. per hour. The fitter should require a B. t. u. garantee from the manufacturer of any cast-iron radiator, showing exactly what the heat emitted per sq. ft. per hour, at the pressure he will require, is garanteed to be. Then he will get what he pays for.

SIZING INDIRECT RADIATORS.

It is extremely difficult to secure satisfactory results from ordinary indirect surface when confined to the 2-lb. gage-pressure at which boilers are now rated, for the reason that the difference between the air entering the room from the radiator-stack and the room-temperature at 70 deg. is so small that the velocity of discharge is so reduced that it is very hard to get sufficient volume of warm air into a room. Again in using cast-iron extended-surface radiators, the air is splendidly heated and distributed, it is true, in its passage through the radiator, but the average temperature is thereby made lower.

If iron pipe is used the mass needed at such low temperature as 2 lb. at boiler deters one from getting results. In both cases the number of heat units delivered for room-heating purposes per square foot of radiator is less than would be delivered from same number of square feet of surface of direct radiators set up in the room to be heated.

To attempt to heat a room like that discussed for direct heating with indirect radiators and 2-lb. gage-pressure at boiler would probably end in some dissatisfaction on part of owner, unless he were willing to go to very considerable extra expense.

It is not well to attempt to place indirect heating for any room not provided with ventilating shaft to move the air sufficiently to secure a comparatively steady supply of warm air in motion. In fact, the attempt is likely to invite possible dissatisfaction or disappointment with indirect heating.

But as it is often required by house-owners who believe ordinary leakage sufficient for the purpose, the question should be discussed here.

As indirect heating is accomplished usually by the use of extended-surface cast-iron indirect radiators, it is well to remember that all such radiators when cataloged by manufacturers very properly contain the entire surface-measurement of the material, extended as well as prime surface. Various manufacturers adopt different designs and arrangement of extended surface for their product, so that it is desirable always to ascertain, if possible from the manufacturer the garanteed value of his radiator in B. t. u. at the temperature you intend to use.

Failing to secure such information it will, as a rule, be safe to figure the radiator for B. t. u. as worth from 70 to 80 per cent of catalog-value. There are, however, so many conditions upon which the net value of indirect radiators depend that actual test under conditions similar to those to be erected seems to be the only safe proposition, unless the manufacturer can furnish and garantee the B. t. u. which will be emitted each hour under required conditions, per cataloged surface of his material.

The tables given on the value of indirects are made up from averages from the results obtained from ordinary extended-surface radiators and will be found approximately correct for the better grade of indirects. The contractor who is to use indirect surface cannot afford to use any except the very best. He may be able to pass through a job of direct heating with cheap direct radiators, but with indirect heating he requires every possible fraction of advantage to be gained from the most efficient goods.

In all jobs of indirect heating where only natural draft is used, even if a flue for ventilation is provided, there will be exceedingly variable results obtained, for the conditions affecting the flow of air through the radiators and ventilating shaft change many times per day, and occasionally per hour. .For instance, on a squally day the wind-velocity may run the range from an almost perfect calm to 20 or more miles per hour, within a single hour's time.

Indirect radiators furnish heat by conduction, therefore without forced circulation the velocity of air is low, and heating value less per square foot than with forced circulation.

Unfortunately, the tables mostly in use and the relative proportions given as between direct and indirect heating have, in this country at least, been based upon tests made when 60-lb. pressure was considered as within the range proper for house-heating. These pressures are given by Robt. Briggs as late as 1882 as being the base for the extensive tables he prepared. His tables are based on 10-lb. pressure in radiator and the use of 9.2 cu. ft. of steam per minute per 100 sq. ft. of radiating surface for direct heating, and from this as a base his tables are carried to 60-lb. pressure.

In 1895, when the Van Nostrand edition of Robt. Briggs' work with additions by Alfred R. Wolff was published, Mr. Wolff quotes Prof. C. A. Smith and the Dubuque Steam Supply Co., Dubuque, Ia., and gives a table which he says represents the results of the practice of these parties in indirect heating. This table gives 25 per cent as proper increase in surface of indirect over that which would be figured for direct heating.—Van Nostrand Science Series, No. 68, pages 117-118-119-121.

Later practice reduced the working-pressures of direct steam-heating and a new ratio was established between direct and indirect surface by various writers and 50 per cent increase was decided upon as about correct. In the 1900 Edition of Prof. Carpenter's book on "Heating and Ventilation," pages 205 and 216, data is given for direct radiation at 10-lb. pressure, and for indirect radiation at 212 deg. in radiator and the ratio fixed for the first floor, steam heat, as 66 2-3 per cent. Now that the practice has become based on 2-lb. pressure at boiler for direct heating, a new ratio becomes necessary and it will be found desirable to increase the indirect surface over that required for direct from 85 per cent to 100 per cent, according to net value of indirect surface used. The boiler manufacturers of the more conservative type give notice in their catalogs "that when indirect radiation is to be used not less than 75 per cent increase over direct radiation should be figured in determining the size of boiler required." As we can see when the matter is fully explained this 75 per cent increase is actually the least that can be used with safety. A larger percentage of increase is necessary on some makes of boilers. Personally, I would advise an increase of 100 per cent in order to cover all the conditions liable to develop, including the fuel quality and quantity.

The conditions under which indirect radiators do their work are so completely different from those of direct heating that the manner of determining the heating value of the surface is for convenience also somewhat changed.

SECTION XII.

To determine probable value of indirect radiator-surface of average cast-iron extended-surface radiators per square foot of catalog-surface per hour.

The indirect radiator heats by contact only and the heat given off is influenced by the velocity with which the air is moving over, or coming into contact with the heated surface of the radiator.

The detailed formula for determining the B. t. u. is too long for insertion here.

The constant factor is found to be 0.09825.

This is multiplied by the velocity at which the air is moving. It is found that at the low temperature of 2-lb. pressure at boiler that a velocity of 2 to 4.5 ft. per sec. is as much as is safe to figure on for average indirect work. To get indirect-radiator value, multiply 0.09825 by 3.25, average velocity, to 4.5 and that sum by 435 for 70 deg. in room and deduct 20 per cent for extended surface.

In order that the manner of getting the B. t. u. value of indirects may be carried out along the same lines observed for directs (see page 40 and Table FF), it may be explained that an indirect radiator heats the air by contact only; this air is then conveyed to the room which is to be heated, the air in the room itself not coming into direct contact with the radiator at all.

With direct-radiator heating, the air of the room is heated by direct contact and by radiation also, that is, by convection and radiation.

Because of this difference in method of heating it is evident that the direct radiator must be the more efficient per square foot.

We found the value of the direct 3-column radiator to be 1.6 B. t. u. per deg. of difference between the room and steam in the radiator.

We find by experiment that the indirect radiator must be figured to yield 0.805 B. t. u. per degree of difference between temperature of steam in radiator at 2-lb. at boiler and the temperature of room at 70 deg. F. for the best grade of indirect with air moving at an average of three and one-quarter feet per second.

There are indirects on the market that can not be figured higher than 0.696 per degree of difference between room and steam temperatures.

With 2-lb. pressure at boiler, good cast-iron indirects can be expected to yield 111 B. t. u. per sq. ft. per hour, although some types may not yield over 96 B. t. u. per sq. ft. per hour ($0.696 \times 138 = 96$). As the pressure increases, the value of the heating surface increases the same as with direct surface.

As the pressure increases the velocity may also increase to some extent. But in house-heating it is not usually wise to allow for a greater velocity than four and one-half feet per second.

The B. t. u. emitted by average indirect radiators per square foot per hour with an average velocity of 3.25 ft. per sec. in moving air is approximately as follows at different pressures.

TABLE S.

Probable number B. t. u. emitted per sq. ft. per hour from average cast-iron indirect radiators. Boiler pressure 2-lb. to 15-lb. Temperature room, 70 deg.. Velocity, 2 ft.

per sec. to 4.5 *per sec. For residence work, average* 3.25 *ft. per sec.*

Lb. Pressure at Boiler.	Difference Temperature Between Room and Radiator.	B. t. u. Per Deg. Difference in Temperature.	B. t. u. Value Per Sq. Ft. Per Hr.
2 lb.	138	.805	111
5 lb.	145	.814	118
10 lb.	157	.828	130
12 lb.	162	.834	135
15 lb.	168	.839	141

It is not the intention to take up ventilation in this work. This is a subject intimately connected with heating, to be sure, but is also an independent branch of the work not usually undertaken by house-heating steam-fitters except upon specially prepared specifications.

But as occasion might arise where the residence-heating steam-fitter might find it desirable to figure out for himself other velocities than that given in Table S it is thought well to explain that table more fully. When the constant 0.09825 is multiplied by the given velocity of 3.25 ft. per sec. (this being the average) the result is .319. This multiplied by the number of heat units emitted from the radiator to the moving air, 435 B. t. u. per hour at the temperature of 138 deg. difference between the room and the surface of the radiator, gives the room-heating value of the prime surface of the radiator. But, as 20 per cent of the average cast-iron indirect radiator as cataloged is extended surface, it is necessary to deduct that much from the cataloged surface and to save error it is well to do so at this point. The process is in full $0.09825 \times 3.25 = .319 \times 435 = 139 - 20$ per cent $=$ 111 B. t. u.

The same method should be employed for other velocities and pressures. Table SS shows the heat units emitted to the incoming air per hour at different temperatures within the range of present practice in indirect house-heating by the radiators.

TABLE SS.

Pressure at Boiler.	Temperature of Radiator.	Difference Between Room and Radiator	Heat Units Emitted to Moving Air Per Sq. Ft. Per Hr.
2 lb.	208	138	435
5 lb.	215	145	462
10 lb.	227	157	510
12 lb.	232	162	530
15 lb.	238	168	554

At 5 ft. per sec. velocity and 15-lb. pressure we would have $0.09825 \times 5 = .491$. This multiplied by the B. t. u. emitted from the radiator to the moving air at 15-lb. pressure $= .491 \times 554 = 272$ B. t. u. for prime surface. Deduct the 20 per cent for extended surface cataloged and you have the value of the radiator per square foot at 5-ft. velocity per sec. in moving air as 238 B. t. u. as against 141 B. t. u. when air has 3.25 ft. per sec. velocity. This illustration serves to show very vividly how difficult it is to get satisfactory results from simple gravity systems of indirect heating.

It is, however, at times necessary to know how much heat in B. t. u. is necessary to raise one cubic foot of air to a certain point.

The specific heat of air, 0.238, multiplied by the weight of a cubic foot of air, .0864, will give the amount required to raise one cubic foot one degree. This amount multiplied by the number of degrees to be raised will show the total. Thus $.238 \times .0864 = .02056 +$ this $\times$

by 70 = 1.4392 + B. t. u. required to raise one cubic foot of air from zero to 70 deg.

The weight of air changes slightly as it increases above zero. Therefore, at other minimum temperatures than zero, the decimal of weight per cubic foot changes. The following Table T shows the values of all temperatures usually required in house-heating and domestic water-heating operations.

TABLE T.

B. t. u. Required for Heating Air.

This table specifies the units of heat required to heat one cubic foot of air at different temperatures.

Extern'l Temp.	Temperature of Air in Room									
	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°
-40°	1.802	2.027	2.252	2.479	2.703	2.928	3.154	3.379	3.604	3.829
-30°	1.540	1.760	1.980	2.200	2.420	2.640	2.860	3.080	3.300	3.520
-20°	1.290	1.505	1.720	1.935	2.150	2.365	2.580	2.795	3.010	3.225
-10°	1.051	1.262	1.473	1.684	1.892	2.102	2.311	2.522	2.732	2.943
0°	0.822	1.028	1.234	1.439	1.645	1.851	2.056	2.262	2.467	2.673
10°	0.604	0.805	1.007	1.208	1.409	1.611	1.812	2.013	2.215	2.416
20°	0.393	0.590	0.787	0.984	1.181	1.378	1.575	1.771	1.968	2.165
30°	0.192	0.385	0.578	0.770	0.963	1.155	1.345	1.540	1.733	1.925
40°	0.000	0.188	0.376	0.564	0.752	0.940	1.128	1.316	1.504	1.692
50°	0.000	0.000	0.184	0.367	0.551	0.735	0.918	1.102	1.286	1.470
60°	0.000	0.000	0.000	0.179	0.359	0.538	0.718	0.897	1.077	1.256
70°	0.000	0.000	0.000	0.000	0.175	0.350	0.525	0.700	0.875	1.049

Above tables from F. Schumann's "Manual of Heating and Ventilation."

The use of the above table is adapted to many purposes in heating problems.

It is often required to know how many B. t. u. will be required to raise a given number of cubic feet of air from zero to 70 deg. or some other temperature.

Let us suppose it is required to know how many B. t. u. would be needed to raise 2,800 cu. ft. of air from 20 below zero to 80 deg. above. Under 80 deg. and opposite minus 20 deg. we note that it will require 2.150 B. t. u. to raise one cubic foot of air from minus 20 deg. to 80 deg. above, then, $2800 \times 2.150 = 6020$ B. t. u. per hour. Or, if it is desired to know how many cubic feet of air 1303 B. t u. would heat from 20 below to 80 above, divide the 1303 by 2.150; or from zero to 70, divide 1303 by 1.439.

A great variety of occasions will occur when this table will be found of value.

From time to time there is a call for direct-indirect radiators.

This type of radiator is probably the least understood as to its requirements and limitations of any type in ordinary use.

While it is not intended to take up ventilation, it is necessary to give a little instruction regarding direct-indirect radiator use, as this form is the most difficult to handle with some degree of success of all the natural-draft systems. Yet, when well proportioned, it is a very effective system within its limits.

The various designs of the numerous manufacturers are so startlingly unlike in the amount of cold air admitted per square foot of rated surface, that until the time arrives that each manufacturer states the average quantity of air which will pass, or will give the exact free area for air to pass, through his product per section attached to cold-air box, any general rule for handling direct-indirect radiators and ventilators will be the rankest kind of guess-work.

Some have guessed 25 per cent additional, but they were using at least 15-lb. gage-pressure and some particular make of radiator that allowed a small amount of air to pass through it.

Some say 50 per cent more than for straight direct radiators. These again are correct for certain particular types of direct-indirect. With 2-lb. pressure at boiler and the average cheap direct-indirect, it is probable that from 35 to 50 per cent more than would be required for two or three-column direct radiators is not far from correct. There is at the present time but one direct-indirect radiator on the market, which, as cataloged, is worthy any serious attention.

FIGURING FOR DIRECT-INDIRECT RADIATION.

In figuring for direct-indirect, ascertain the cubic feet of air the radiator you desire to use will average to deliver per hour to room. Multiply this by 1.4 or 1.5 to get number B. t. u. required to heat the incoming air to temperature of room, or 70 deg. (See Table T opposite O and under 70.) This amount is what will have to be added to the amount of direct radiating surface required.

The matter is simple as soon as the number of cubic feet of air the radiator will permit to pass through it per hour can be decided.

The amount of air which may be expected to pass through 144 sq. in. of flue is given in Table U.

TABLE U.

Cubic feet of air which may be expected to pass through a flue 144 square inches in area in one hour with a velocity of three and one-half feet per second:

Height of Flue in Ft.	Excess of temperature in flue above colder air.					
	20 deg.	30 deg.	50 deg.	100 deg.	138 deg.	150 deg.
1	2880	3540	4560	6840	7620	7980
5	6540	8040	10020	14520	17040	17880
10	9180	11200	14520	20520	24000	25140

SECTION XIII.

We have now canvassed the question of direct steam-heating, indirect steam-heating, and direct-indirect steam-heating, and rules and sample illustrations have been given for practically every process indicated.

In each case we have found the result depended finally upon two principal factors.

First, the total loss of heat from the room expressed in B. t. u., and second, by the difference between the temperature of the steam in the radiators and the air surrounding the radiator. This difference determined the number of B. t. u. each square foot of radiating surface should yield.

We have found that it always requires the same amount of heat to raise a cubic foot of air one degree at the same height above sea-level. That it requires 70 times as much to raise the air 70 deg. That it always requires the same amount of heat at sea-level to raise one pound of water one degree and that this amount of heat is the unit of heat-measure, or the B. t. u., which has been accepted as the base upon which all heat problems are worked out with accuracy.

We have found that the total loss of heat at any altitude is susceptible to measurement by the unit of heat, as readily as distance is measured in feet, or weight in pounds, or temperature in degrees.

We have found the loss of heat through various substances as glass, brick, wood, iron, and the like, varies with the substance. It varies also with the velocity with which the air in contact with the substance passes over it, and this holds true whether the moving air is charged with a high or low degree of temperature.

We have found that if the total amount of heat-loss is ascertained, that an equal amount is required to be supplied to produce an equilibrium and thereby maintain a room at any predetermined point of temperature.

We have seen that all these things are controlled by strict natural laws easily applied.

We have found that steam at 2-lb. pressure at sea-level is not as hot when measured by thermometer-degrees as is steam at 30 to 60-lb. pressure at same level, and that the steam produced at a higher altitude is not as hot when measured by the thermometer as at sea-level.

From the foregoing summary of what has been investigated and explained, it is evident that one or two simple rules can be made that for ordinary use would cover the required procedure for direct heating by radiating surface placed in the room to be heated, providing some one selected steam-temperature is considered, and it is also plain that the only change necessary to make the rule apply to any gage-pressure is to change whatever number of heat-units is required to raise one cubic foot of air from the minimum to the maximum.

The fact that steam-heating boilers for residences and small buildings are now rated as to capacity on a basis of 2-lb. gage-pressure at the boiler, seems to demand that any rule for practical and general use by the trade should be stated in terms that accord with boiler-ratings.

The various detailed processes can be summed up then in the following rules for average conditions. When special conditions of floor-exposure or ceiling or roof-exposure are present the reader who has followed the discussion to this point will know instantly the course to pursue to find out how many additional units are needed to offset abnormal conditions.

General rules for heating residences in zero weather to 70 deg. with average wind-conditions when steam-gage pressure at boiler is at 2-lb.

Rule 1—Multiply the cubic contents of up-stairs rooms or twice the cubic contents of down-stairs rooms by 1.5 to find necessary heat-units for supplying cubic contents and leakage.

Rule 2—Multiply the square feet of net wall exposure by 19 or 20 to get B. t. u. heat-loss from walls.

Rule 3—Multiply the total square feet of window-surface by 76.3 to find needed heat-units to supply loss from windows.

Rule 4—Multiply square feet of exposed floors by 23 to find loss of heat from this source. Multiply total square feet of exposed ceiling by 23 if cold room above, or by 42 if exposed directly to the outer air.

Rule 5—To obtain the radiating surface for direct steam-heating with 2-lb. pressure at the boiler, divide the sum of losses found by Rules 1, 2, 3, 4 by 220.

Rule 6—To obtain the radiating surface for direct hot-water heating with water at boiler at 180 deg., divide the sum of losses found by Rules 1, 2, 3, 4 by 160.

Rule 7—To ascertain square feet of radiation required for any temperature of hot-water or steam, divide the sum of heat-units found by adding results of Rules 1, 2, 3, and 4 by number of heat-units emitted per hour per square foot of radiating surface at temperature or pressure selected and the result will be the square feet of radiation required at selected temperature.

These rules can be condensed when a steam-pressure of 2-lb. at boiler is desired, or 180 deg. at boiler, for hot-water heating, into a very simple form. Thus:

Condensed rule for heating with direct radiation in zero weather to 70 deg. 2-lb. steam-pressure at boiler, or 180 deg. at boiler for hot water.

Divide sum total of heat-units required to offset loss from walls, windows, exposed floors, ceilings and leakage by 220 for steam heat, or by 160 for hot-water heat.

The great degree of exactness possible to obtain by the processes detailed cannot, it is believed, be obtained by any rule now in general use among the trade.

As it is often necessary to figure for other steam-pressures than 2-lb. at boiler or 180 deg. at boiler for hot-water, a list of divisors for use at other pressures and temperatures is herewith given. These are for use with average cast-iron radiator-surfaces.

TABLE V.

Steam-Gage at Boiler.	Divisor.
2-lb.	220
5-lb.	232
10-lb.	251
12-lb.	259
15-lb.	284
20-lb.	297
25-lb.	324
30-lb.	380

Hot Water Temp. at Boiler Degrees.	
210	206
200	192
190	176
180	160
170	145
160	131

Rule for Direct-Indirects.

To the amount of direct radiator surface required, add in direct-indirects sufficient to offset the total incoming air through the indirect surface. Usually about 30 per cent of 2-column and from 40 to 50 per cent with 3-column radiators.

Rule for Indirect Heating.

Divide the total loss in heat units as found by Rules 1, 2, 3 and 4 by 111. For divisors for other pressures than 2-lb. see Table S.

Generally, in hot-water heating, where economy of fuel and easy control are desired, the divisor for 170 deg. at boiler will be found very desirable. At this temperature somewhat more radiation is required, it is true, but, on the other hand, in medium weather a much lower temperature in radiators is needed and the house does not become overheated in the warm part of day as is quite liable to be the case where a high temperature in the water is needed to offset the colder hours of the early morning. It is often found in those sections where quite warm hours occur during the middle of the day that if water is raised to a high temperature in the morning that it does not cool down sufficiently to prevent overheating during those warm hours.

This will be corrected by figuring the whole job at a lower temperature. There is also the advantage of quicker response when called upon for more heat.

Architects often desire to know what temperature of water or steam-pressure a contractor proposes to compel his client to carry. By the aid of these rules and divisors the approximate pressure or temperature is very easily found.

A contractor who has figured by these rules can almost instantly tell what pressure or temperature a competitor who proposes a different quantity of radiation must furnish to the radiators.

Thus a contractor by these rules has figured a house to be heated by steam at 2-lb. at boiler and proposes 440 sq. ft. of surface. A competitor proposes to do the job using 341 sq. ft. and another proposes to do the job using 372 sq. ft. The average owner at once jumps to the conclusion that the man who wants to put in 440 sq. ft. of surface is wildly off, because the other two are only 31 sq. ft. apart, and they both garantee their proposal.

Examining the matter, let us assume that the man who offered 440 sq. ft. figured on 2-lb. at boiler. Then he figured 220 B. t. u. per hour per square foot. Therefore $440 \times 220 = 96.800$ B. t. u. to be furnished per hour.

One competitor proposes 372 sq. ft., then $96.800 \div 372$ will show how many B. t. u. per hour each square foot must emit to do the required work. The division shows 260 B. t. u. The other man proposed 341 sq. ft.; division in same manner shows 284 B. t. u. A glance at the table given above and it is seen that

440 sq. ft. called for 220 B. t. u. or 2-lb. pressure.
372 sq. ft. called for 260 B. t. u. or 12-lb. pressure.
341 sq. ft. called for 284 B. t. u. or 15-lb. pressure.

There is no question that either of the three will heat the house equally well, but the amount of fuel and care required to produce results required will be vastly different.

The owner who "knows" will very quickly decide that the man who is widely off is the man with the one hundred feet less radiating-surface. He will realize that when he begins to "kick" because of big fuel bills that the 341 sq. ft. man is the one who is apt to meet his protests with the remark that "If you expect to keep warm in cold weather you must expect to burn fuel," or words to that effect.

When it is so easy to "know" it will soon become out of fashion to guess.

We have said that with 2-lb. pressure at boiler, 100 per cent should be added for indirects to the direct surface required. This is very close to what very careful figuring will develop, as will be seen by comparing Table S with the table of heat (FF) emitted from direct-radiators. Direct-indirect radiators require an increase of from 35 to 50 per cent above the amount required for direct.

SECTION XIV.

Piping to Steam-Radiators.

To those who desire to carefully construct a steam-heating job, the last thing in "laying out the job" will be the selection of boiler size, as it is plain to be seen that the boiler must be big enough to supply easily all heat-losses from all sources, and a very important source is piping.

It is common practice to guess at the surface in piping. Some will guess that piping will equal 10 per cent of direct radiator-surface; others 20 or 25 per cent. It is rare that pipe surface is "guessed" to be over 25 per cent of total radiating-surface. Yet it often exceeds 50 per cent on small jobs where there are many fittings used, elbows, tees and the like.

The discussion in regard to different pressures and their effect upon size of radiating surface has developed the fact that the higher the pressure carried the smaller the radiator surface required.

To a marked degree this rule holds true with piping also. The usual piping formulas in use were developed when 15 to 30, or even 60-lb. pressure was in general use for house-heating. As we develop the facts in regard to proper size of pipes for steam-heating this fact becomes very distinct and important.

The first thing to determine in regard to piping is the system to be adopted: Whether 2-pipe or single pipe circuit; single pipe and relief; one pipe overhead or some modification.

Each of these systems is good, and each is especially well adapted to some special class of work. We will

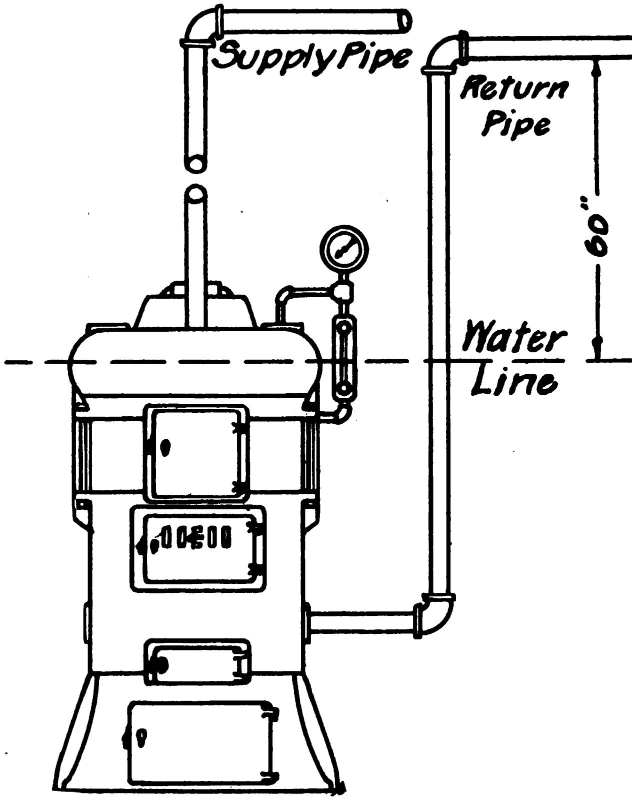


Fig. 6.

take them up in order named. In each system there is one thing to be carefully safe-guarded and that is the so-called water-line of boiler.

Unless this is reasonably steady under the various pressures required, dissatisfaction develops at once.

As this water-line is a constant source of anxiety to

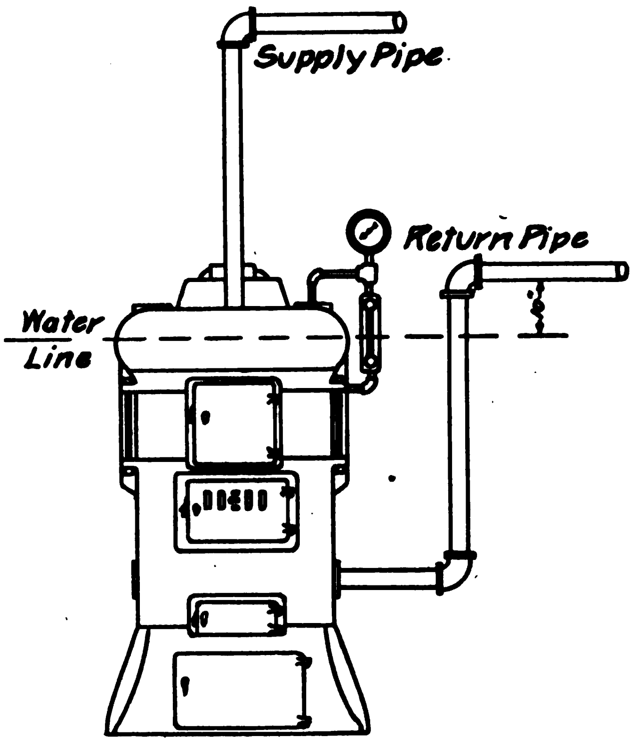


Fig. 7.

many, if not all fitters, and is present with every system mentioned, it is probably best to begin to explain piping systems by an explanation of why piping develops the unsteady water-line.

There is no house-heating boiler on the market that will not maintain a steady water-line under usual conditions of firing if the openings provided for the steam to escape are attached to pipes discharging steam and condensation to the atmosphere, the supply of water in boiler being fed automatically as steam is evaporated. With a connection of this kind there would be required continued and excessive firing to develop a condition where water in the gage-glass would seriously drop below an average point. This would demonstrate there was nothing in the manufacture of the boiler that of itself produced this condition so often found with house-boilers. If now, the various openings from the steam-chamber of boiler are connected up to the return-openings provided by the manufacturer at the bottom of his boiler and when the 2, 5 or 10-lb. pressure is developed, the water in the gage-glass begins to fluctuate or even leave the glass completely, any sane person would conclude that something about the piping caused the effect. There can be no effect without first a cause; there can be no cause without an effect. The first thing to find out then is if any natural law has been violated that has produced the unsteady water-line.

The pipes being connected as per Fig. 6, the line of water-gage is steady as when discharging to outer air.

Connect as in Fig. 7 and at 5-lb. pressure on gage the water-line becomes unsteady and with the accession of a little more pressure nearly or quite disappears from sight.

Connect as in Fig. 8 and the water line begins to trouble before gage shows pressure.

Now for the cause. When the pipes have been so connected that all circuits are complete, the system is simply like a hollow circular tube somewhat crooked in its contour.

If in a tube, shaped as Fig. 9, water stands at A and

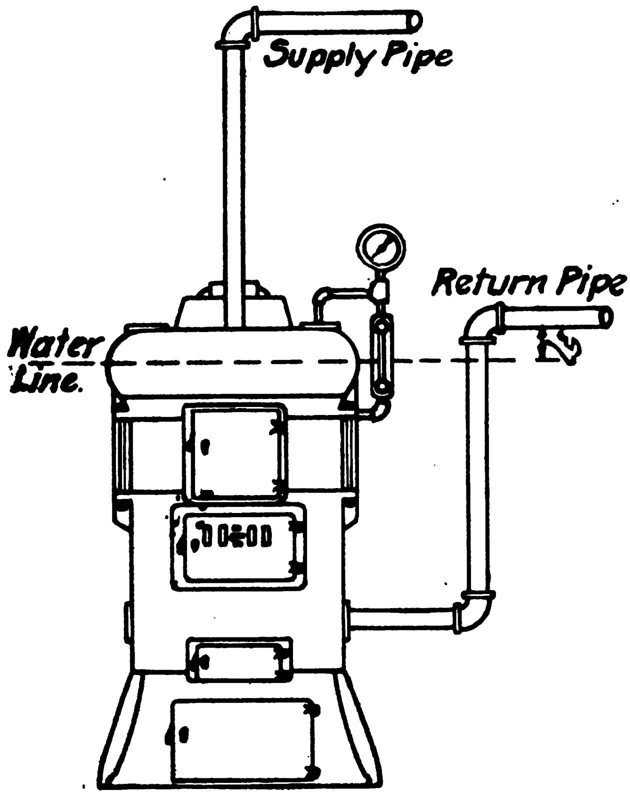


Fig. 8.

B it will remain in each side perfectly even and level. You have a steady water-line.

But apply a small pressure at A and the water will no longer be at a level with either A or B. A new line is established for A and B. (Fig. 10.) The position of the new line will be determined by the amount of pressure applied at point A. Whatever the pressure may be the water will advance above B (Fig. 9), if the tube is high enough to balance A plus weight or pressure.

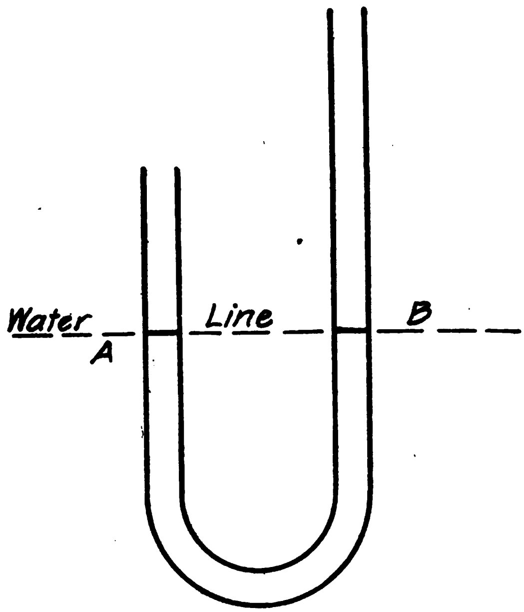


Fig. 9

If the water at B now receives a pressure somewhat less than is being exerted at A a new position will be assumed by the water in both arms of tube. This new position will be determined by the difference in the pressure at A and B.

If, when in piping a steam-heating job, the piping is so placed that the difference in pressure between the pressure on the water in the boiler which is represented in Fig. 10 at A and that on the return water-pipe of B is considerable, the water will leave the boiler water-gage glass.

This must now be illustrated by known facts. A column of water 28 in. high exerts a square-inch pressure of approximately one pound. Always keep this in mind when preparing to lay out a steam job of piping.

It is your purpose to carry a certain pound-pressure at the boiler on the job. Let us say as illustrating the idea, one pound. Then if you have one-pound pressure on the boiler, that is equivalent to 28 in. once, or a column of water 28 in. high, it is evident that if you intend to return the water of condensation into the boiler that *somehow you must provide for a greater pressure* than that in the boiler, or one pound.

This must be done in the pipe which drops from the supply-pipe end of circuit. Assuming then that the piping was so small that when the circuit reached the drop-pipe, there was ¼-lb. pressure of steam, the water would stand 21-in. higher in the drop-pipe than in the boiler. In other words, the two lines would equalize at a point 21 in. higher on one side than the water in boiler because the pressure of ¼-lb. at end of return equals 7-in. of water and $21 + 7 = 28$-in. or one-pound pressure. In order to get a greater pressure than just an equilibrium, this standpipe or drop from circuit must be more than 21 in. above the water-line of boiler. This is so that in addition to the pressure of ¼-lb. which equalizes, there may gather a body or column of water of condensation of a couple of ounces possibly. This then means four inches more length at least in that return drop, or a total of 25 in. that the supply-piping must stand at its lowest point above the water-line of boiler when the drop to below water-line of boiler is made.

The secret of steady water-line in its last analysis is found to be absolutely in this.

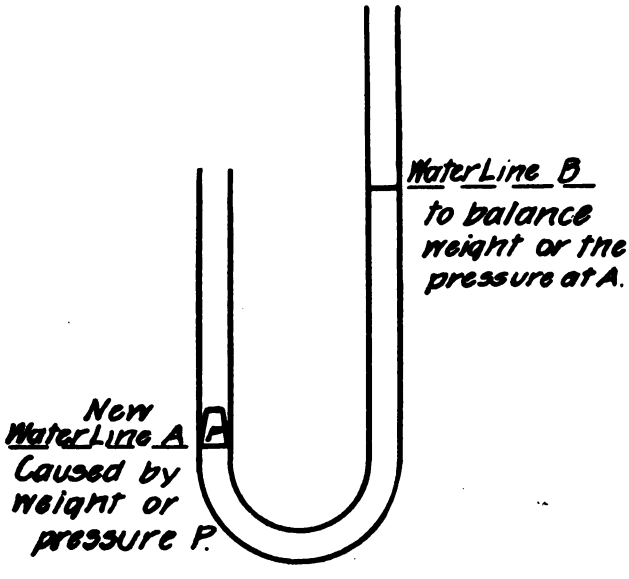


Fig. 10.

No matter how many things seem to cause unsteady water-lines to the extent of the water leaving the boiler when finally chased down to absolute cause, it will always develop that the prime effect of the cause, whatever it seemed to be, was to bring a greater pressure on the water in the boiler than was present in the return-pipe drop connection at boiler.

The secret of good piping lies in the science of so adjusting the piping that the point of equalization shall be at a point where an ample excess of pressure can be provided by a steady upright column of water in the drop-line.

Here is where the great difference among fitters as to pipe sizes originate. One adjusts his pipes so as to require great velocity of steam and thereby requiring a very high space between his supply-pipe return-end, and the water-line of boiler.

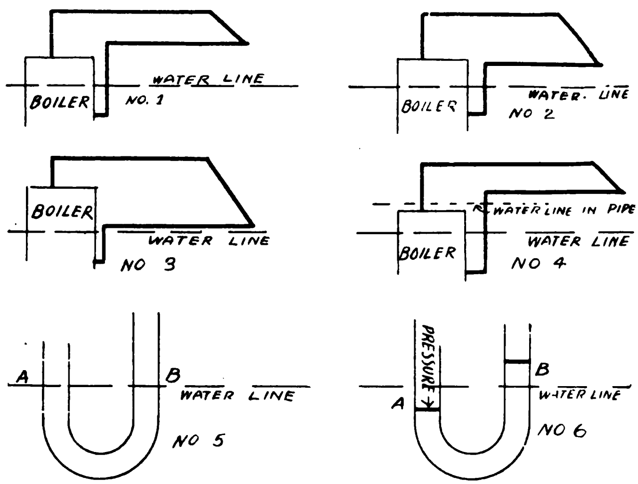
Another requires a less velocity to the steam, consequently his volume per minute is delivered with less loss of pressure and he can work nearer the water-line of the boiler. A third may work on a velocity of 20 or 25 ft. per second and his pressure-loss is slight.

Still another may so increase the size of his pipe that the loss of pressure is merely a trifle of an ounce. This one can work on a distance above water-line, for his return, of six or less inches and still have a steady water-line. The first one might require five or six feet drop in order to hold a steady line, but he would use small pipe.

The craze for using small pipe by men who do not know how to calculate velocity and delivery-volume of steam, has cost boiler manufacturers many thousands of dollars in trying to fix up a job so it would present a steady water-line. This happened when the only trouble was with the foolish piping which some contractor had used on the job. Nine cases out of ten if it is suggested to the fitter that the trouble is in the piping he flies into a rage and begins to tell about his great experience, usually winding up by saying "he is no theory man, he is practical."

Notwithstanding all his practical knowledge and experience, which may be very great, the moment he pipes a job so that it will not carry a steady water-line and failing to fix it himself, calls upon the manufacturer to "fix his boiler," Mr. Practical Man has acknowledged he does not know either the practice or theory which produces steady water-lines.

There is a natural law involved and no living man can



A Condensed Study of the Water-Line Question.

evade it or get around it. A false water-line may be created in the piping and a steady line on boiler-gage attained, but that simply proves that the law can not be evaded. It can be fairly stated that if a cast-iron steam-boiler is so constructed that it will carry a steady water-line under 2-lb. pressure in the factory or anywhere on earth at one time, it will continue to do so for all time so far as that type of boiler is concerned. If it will carry a steady line when the piping is laid out properly in one place, any boiler cast from same patterns will continue to carry a steady water-line so long as the piping is properly adjusted as to size, velocity of steam and volume to be delivered to end of main, to the distance above the water-line. If this distance is less than it should be, or, if it is just enough for equalization, an unsteady water-line will result, and that whether the man, who laid it out and put it in, is the best engineer on earth or the poorest.

It is, therefore, evident that in order to lay out the piping for a steam job it is still necessary to "know" instead of guess, fully as much so as in figuring radiation. But unfortunately for all concerned, the wildest guessing contest in the whole heating business is the sizing of pipes by the steam-fitting men, who blindly follow a book-rule they have picked up somewhere. They have not the faintest idea as to what velocity the steam will have to assume to supply the demand they have made on it, nor where the return must drop below the water-level of the boiler in order that the water-line may remain satisfactorily steady.

SECTION XV.

The problem is not a difficult one to solve for the man .who is willing to use his thinking outfit for a short while. It is a question that really should be presented in algebraic form, but, as in the beginning, I promised to explain these things clearly without algebra, I will attempt to explain this piping question so clearly that any intelligent workman can understand and apply the theory.

Don't get nervous over that word theory. No man ever accomplished anything out of the regular line of endeavor unless in some way some theory, conscious or unconscious, anticipated the accomplishment. The theory may have been wrong, but the mind-action preceded the accomplishment, right or wrong. After a successful accomplishment of an idea, the whole working-out process will be tabulated into a series of facts, and this series of facts will become the theory upon which all can proceed with certainty that the theory practically applied will produce satisfactory results. A man not knowing the theory upon which the work should progress may at some point deviate from the true theory and produce very unsatisfactory results.

Piping for steam is really the development of one of Nature's laws. From what has been said it is evident that if pressure in the pipes becomes much reduced by the time the steam has completed its circuit that the pressure must be restored and some added to it before the water of condensation can enter the boiler. Our first inquiry then is to see what causes loss of pressure and if more than one thing contributes to the loss.

The steam, in its passage through the pipes and radiators is constantly giving up to the surrounding air the latent heat-units it contains. As these heat-units depart, something of measure and strength goes out of the steam. Its bulk decreases and its heat decreases, and therefore in corresponding measure its pressure. As this continues the time comes when the expansive force, or pressure, has all been absorbed and nothing remains but water without pressure. Another item is friction, every atom of pressure or strength exercised in overcoming friction leaves just so much less strength or pressure in the steam to continue along the journey. The size of the pipe then must exercise a powerful influence for friction, elbows, tees, couplings, bends, valves—all these fittings take strength out of the steam in its effort to get by these resisting items. They all help reduce the strength with which the steam started out from the boiler. Nature has in this respect no different law for steam when it is doing work than it has for you. If you start out strong and vigorous to get to a certain point by a certain time, to accomplish a certain task of work, but on your way have, instead of smooth, level roads, ravines and swamps to fight your way through, huge boulders to climb over, long detours instead of straight lines of road, you find yourself exhausted with exertion long before your proposed destination is reached. You have no strength left for performing your proposed task or work.

Nature has decreed that if steam has quantities of fittings to overcome, in its journey, and undue friction to remove, in addition to giving out its heat to rooms, that its strength or pressure, as we term it, in steam, shall rapidly decrease.

Now this decrease in pressure can be measured with considerable accuracy in advance. When a compact little house-job has a great many fittings within close distance of each other, a pipe-size that might be perfectly proper on another job with same amount of radiation, may be not at all the proper size for that job. The velocity of the steam in the pipes increases the friction and consequently reduces pressure. Professor Carpenter, of Cornell University, in his book on "Heating and Ventilating Buildings," states that, "the friction in a pipe when steam is moving at a velocity of 100 ft. per sec. causes a reduction in pressure of 1½-lb. in 100 ft.; a velocity of 50 ft. a sec. causes about ¼ as much, and a velocity of 25 ft. about 1-16 as much."

According to this data, steam moving at a velocity of 100 ft. per sec., with an initial pressure of 2 lb. or the equivalent of 56 in. of water head, will at the end of the flow through 100 ft. of straight pipe only have a pressure of the equivalent of a 14-in. head of water. It will be seen that with 56-in. as initial-head and a 14-in. head at the end of run that the equalization point would be 42 in. above the water-line of boiler. To this 42 in. must be added about 4 in. more to hold the water of condensation in order to create in that drop-pipe the necessary extra pressure on the return-pipe to put water into the boiler. (See Section XIV. Piping to Steam Radiators.)

Reduce the velocity by increasing the size of the pipe so that a large volume of steam can move on its way doing all the work the first did as to heating, but not so much strength spent in overcoming friction, using the same initial head of 2 lb. or 56 in. of water, and at the end of the 100 ft. the slower moving, but larger volume of force arrives with a strength, or pressure left, equal to a head of water of 45½ in. or a difference of 10½ in. between head and heel. With this velocity then, a difference of 14½ or 15 in. between water-line of boiler and return-end of supply would answer perfectly.

Increase the size again so that the velocity shall be 25 ft. or less per sec. with same head of 56 in. of water and the other end of the 100 ft. of straight pipe is reached with nearly all the pressure or strength with which it started. The loss is only about 2½-in. of head. The point of equalization is now so close that a distance of five or six inches would produce a steady water-line.

The question is very frequently asked why it is engineers differ so widely as to pipe-sizes. I think the question fully answered in the above discussion, but I will here give a definite illustration.

Mr. A makes a lay-out for a small job of steam-heating with total radiation of 200 sq. ft. He figures that the job should be a 2-pipe job with a 2-in. supply pipe and a ¾-in. return.

Mr. B figures the same job and calls for a 1¼-in. supply and a ¾-in return.

Mr. C figures for a 1-in. supply and a ¾-in. return. All of them require a boiler pressure of 10 lb.

Which of the three is in error?

Supposing each to be a competent engineer all the way through, neither of them can be said to be in actual error.

Mr. A is figuring on exceedingly slow velocity in order to get his main down close to water-line of boiler and still hold a steady water-line.

Mr. B is figuring on a much higher velocity to the steam and expects to drop below the water-line of the boiler when 18 or 20 in. above it.

Mr. C is figuring on a very high velocity to the steam and expects to drop below the water-line of the boiler when the return end of his main is at least 46 to 48 in. above the water-line of the boiler.

SECTION XVI.

All of these jobs would work nicely and probably give satisfaction, but the man who knew the most or paid the most attention to detail of his office work had the low bid. The total weight of steam delivered to the radiators would not materially differ in either case, but the amount of extra steam required for overcoming friction would, in a large job, show in the fuel account.

From the foregoing it will, I think, be perfectly clear how different engineers may differ very materially in pipe sizes for a given job. They are simply working out different theories and different pressures.

There is one thing not to be overlooked. These very small pipes calling for high velocities are not productive of much value to the house-owner in mild weather from the vapor of steam. It has vitality or strength enough to work its way very slowly through the larger pipes, but the small pipe is very difficult for it.

Now that house-heating boilers are rated at 2-lb. pressure at boiler, it should be explained how to figure out the sizes that should answer for certain velocities. In attempting to explain this without algebra. I shall limit the explanation to jobs based on 2-lb. pressure at boiler and the use of average quality of cast-iron radiators rated for 4 or 5 sq. ft. per section.

We have seen that the average radiator above described at a pressure of 2-lb. at boiler gives out on an average 220 B. t. u. per sq. ft. per hr. when it is zero outside and the room is at 70 deg. (Table FF). It has been shown that the total B. t. u. which a job must be supplied with, through the pipes, will equal the total square feet of radiation multiplied by 220 B. t. u. given off by one square foot equal total B. t. u.

To supply this total amount of heat in B. t. u. a certain number of pounds of steam must be supplied each hour. To deliver this required number of pounds of steam through a pipe of one size will certainly require a certain velocity per second; through a larger pipe, another velocity, and so on. Therefore, the velocity of the steam must depend upon the area of the pipe to quite an extent.

In making comparisons with various tables of the properties of steam as given by different writers it will soon be noticed that there is some considerable difference, especially in the figures for weight and volume; this is caused by the fact that that portion of the table is derived from experiment with some and from formulae in other cases.

The tables most in use in this country are those of Porter, Clarke, Buel, Derry and Peabody. There is no considerable difference between these authorities in the important items of temperature, total heat, latent heat, as given in their various tabulations. Therefore, so far as house-heating estimates are concerned, almost any table of steam properties can be used with safety. In the following table the gage-pressure is followed by the absolute pressure so that the difference can be seen at a glance. This is because in some sections of the country architects generally call for absolute pressure instead of gage-pressure.

TABLE W

Table of the properties of steam from

Vacuum Inches of Mercury.	Absolute Pressure lb. Per Sq. In.	Temperature Fahrenheit.	Total Heat Above 32 in Water.
29.74	.089	32	0
29.19	.359	70	38
28.90	.502	80	48
28.00	.943	100	68
27.88	1.	102	70
25.85	2.	126	94
23.83	3.	141.6	110
21.78	4.	153	122
17.70	6.	170	139
13.63	8.	183	152
9.56	10.	193	162
5.49	12.	202	171
1.41	14.	210	179
Atmospheric Pressure.			
	14.7	212	180.9
Gage-Pressure in Lb.			
1 "	15.7	215	184
2 "	16.7	219	188
3 "	17.7	222	191
4 "	18.7	224	193
5 "	19.7	227	196
6 "	20.7	230	199
8 "	22.7	235	204
10 "	24.7	239	208.5
12 "	26.7	244	213
15 "	29.7	249.6	219
20 "	34.7	258.7	228
25 "	39.7	266.7	236.5
30 "	44.7	273.9	243.9

TABLE W.

29.7 in. of vacuum to 30 lb. gage-pressure.

Total Heat Above 32 in Steam	Latent Heat In Heat Units, Steam.	Volume 1-Lb. Steam. Cu. Ft. in	Weight Ft. Steam. of 1 Cu.
1091.7	1091.7	3333.3	.00030
1103.3	1065.3	875.61	.00115
1106.3	1058.3	635.80	.00158
1112.4	1044.4	349.7	.00286
1113.1	1043.0	334.23	.00299
1120.5	1026.0	173.23	.00577
1125	1015.3	118	.00848
1129	1007	90	.01112
1134	995	61	.01631
1138	986	47	.02140
1141	979	38	.02641
1144	973	32	.03136
1146	967	28	.03625
1146.6	965.7	26.36	.03794
1148	963	24	.04110
1149	961	23	.04325
1150	958	22	.04592
1150.5	956	21	.04831
1151	955	20	.05070
1152	953	19	.05237
1153	949	17.5	.05711
1155	946	17	.06183
1156	943	15	.06651
1158	939.2	13.61	.07350
1160.8	932.5	11.76	.08507
1163.3	926.8	10.35	.09653
1165.5	921.6	9.27	.1079

In this, as in most heating problems, the question must be brought to some definite standard from which to work. In this pipe question the standard is 100 ft. in length of straight pipe.

In order to get this before us clearly, suppose we find out how small a pipe can be used to supply 760 sq. ft. of 3-col. cast-iron radiation with steam at 25 ft. velocity per sec., 2-lb. pressure at boiler. At this pressure each square foot of radiating surface will emit 220 B. t. u. per hr., $760 \times 220 = 167{,}200$ B. t. u. per hr. From Table W on "Properties of Steam" we note one pound of steam gives up 966 B. t. u. in process of condensation. (Actual 965.7. Commonly called 966.)

We must furnish 167,200 B. t. u. per hr. One-pound steam furnishes 966; then $167{,}200 \div 966$ shows that we must deliver 173 lb. steam per hr. From the same table we learn that one pound of steam at that temperature makes 26.4 cu. ft. Therefore 173 lb., multiplied by $26.4 = 4{,}567$ cu. ft. per hr. to be delivered. There are 3,600 sec. per. hr.; then $4{,}567 \div 3{,}600 = 1.27$ cu. ft. per sec. We desire a velocity of 25 ft. per sec., therefore we divide 1.27 by 25 to find the area in square feet. Thus $1.27 \div 25 = 0.05$ of a square foot needed in the pipe, 144 sq. in. $\times\ 0.05 = 7.2$ sq. in. in area. The Table of "Area of Circles," Table A, shows that a 3-in. pipe with an area of 7.068 could be used, although if it was a question of close fit for steady water-line, a 3½-in. pipe would be required.

Supposing 50 ft. velocity to be required. Then 1.27 $\div\ 50 = 0.0254$ sq. ft. 144 sq. in. $\times\ 0.0254 = 3.66$ sq. in., a 2½-in. pipe being the nearest commercial size. Supposing 110 ft. per sec. to be required. Then 1.27

$\div$ 110 = 0.0115 sq. ft. 144 sq. in. $\times$ .0115 = 1.66 or a 1½-in. pipe.

All of this is for 2-pipe direct-heating. If single pipe work is to be used an area equal to supply and return of 2-pipe work must be used.

To illustrate this, the 25-ft. velocity called for 7.2 sq. in. Multiply this by 1.5 (or area of supply and return pipes in 2-pipe work). Then, $7.2 \times 1.5 = 10.8$. The nearest commercial size is a 4-in. pipe, which would be required for single-pipe work at 25-ft. velocity. At 50-ft. velocity, a 3-in. pipe would be needed and at 110-ft. velocity a 2-in. pipe.

These high velocities should not be attempted on house-heating. With 2 to 5-lb. pressure a velocity of from 25 to 50 ft. per sec. is as high as should be attempted.

If indirect is to be used, double the area in square inches of 2-pipe direct requirements.

Many fitters who have not had the opportunity to study into this question of relation to water-line of boiler and velocity, often erect jobs with pipe so arranged that a drop of at least 30 to 40 in. is required to equalize, and yet they will not have, sometimes, half of that.

Of course, the water "goes out" of gage-glass before a pound of steam is registered and a great howl goes up about the boiler. Yet the trouble was not in the boiler. This book is being written that those who will may take a few moments to multiply, add, subtract, and divide figures and figure out for themselves where the trouble is, or else do better, and figure out in advance what piping will be right in a given case, thus saving themselves many hours of hard work and perhaps many troublesome hours with an irate owner.

It is exceedingly doubtful if any boiler-manufacturer ever sent out a steam-boiler which would not maintain a steady water-line if the piping had been properly adjusted to the conditions in which it was set.

Friction in fittings causing decrease in pressure seems to be very generally overlooked by the average steam-fitter. He probably has about his office a "List of Pipe-Sizes for Steam and Hot-Water Heating," and this is rather blindly followed under any and all conditions. Fortunately, these lists of sizes are for the most part comparatively safe for housework, but often fail on very compact jobs with many radiators and on the other extreme of very long runs of pipe with many elbows.

SECTION XVII.

It must be remembered, or, at least always should be remembered, that those "Lists of Pipe-Sizes" nearly all have a note attached, or a statement is made, that for over 100 ft. in length the size is to be increased a certain amount.

TABLE X.

Table for the Capacity of Steam-Pipes 100 Ft. in Length with Separate Returns.

By A. R. Wolff.

		—2-lb. Pressure—		—5-lb. Pressure—	
Diam. Supply in Ins.	Diam. Return Ins.	Total Heat Transmitted B. T. U.	Radiating Surface Sq. Ft.	Total Heat Transmitted B. T. U.	Radiating Surface Sq. Ft.
1	1	9,000	36	15,000	60
1¼	1	18,000	72	30,000	120
1½	1¼	30,000	120	50,000	200
2	1½	70,000	280	120,000	480
2½	2	132,000	528	220,000	880
3	2½	225,000	900	375,000	1,500
3½	2½	330,000	1,320	550,000	2,200
4	3	480,000	1,920	800,000	3,200
4½	3	690,000	2,760	1,150,000	4,600
5	3½	930,000	3,720	1,550,000	6,200
6	3½	1,500,000	6,000	2,500,000	10,000
7	4	2,250,000	9,000	3,750,000	15,000
8	4	3,200,000	12,800	5,400,000	21,600
9	4½	4,450,000	17,800	7,500,000	30,000
10	5	5,800,000	23,200	9,750,000	39,000
12	6	9,250,000	37,000	15,500,000	62,000
14	7	13,500,000	54,000	23,000,000	92,000
16	8	19,000,000	76,000	32,500,000	130,000

Table X, the most accurate of these lists, is that of Prof. R. C. Carpenter and A. R. Wolff, but they insert the following notes: Note No. 1—"This table is computed for straight pipes with *water level in return 6 in. above that in boiler.* In case there are bends or obstructions *consider the length of pipe increased* as follows: Right angle elbow, 40 diameters; globe-valve, 125 diameters; entrance to tee, 60 diameters." The italics are put in by the writer of this book. This note No. 1 is under Professor Carpenter's single-pipe steam table, in which a 3-in. main is given for 1,000 sq. ft. of steam at 10-lb. initial pressure.

Note No. 2 is under A. R. Wolff's table for 2-pipe steam and reads as follows: "For pipes of greater length than 100 ft., multiply results in above table by the square root of 100 divided by the length." *In all cases the length is to be taken as the equivalent length in straight pipe of the pipe, elbows and valves* as previously given."

"In above table each square foot of radiating surface is assumed to transmit 250 heat-units per hour."

"For other lengths multiply above results by following factors: Length of pipe

in. ft.	200	300	400	500	600	700	800	900	1,000
Factor	0.71	0.58	0.5	0.45	0.41	0.38	0.35	0.33	0.32

"For example, the capacity of a pipe 8 in. in diameter and 800 ft. long would be 0.35 of 12,800 sq. ft. of radiating surface = 4,480 sq. ft."

From above it will be noted that supposing an 8-in. main 155 ft. long had on it 6 ells, 8 tees, 2 globe-valves, its length should be considered as 800 ft. of straight pipe and only 4,480 sq. ft. 2-pipe radiation at 2-lb. pressure attached.

How many fitters follow this advice?

Mr. Wolff gives a 3-in. pipe 100 ft. long to carry on 2-pipe work at 2-lb. pressure 900 sq. ft. or at 5-lb. pressure 1,500 sq. ft.

Now you and I know of jobs, probably, where 1,200 to 1,500 ft. of surface have been run on a 3-in. main. I have known numerous cases where trouble with water-line developed and solely because of the fact that the great number of fittings so decreased the pressure at end of supply main that the straight drop from supply-pipe to water-line of boiler was some inches less than it should have been. Now to illustrate this. Suppose there was full 1,500 sq. ft. on 3-in. main. That there were 6 right-angle elbows, 10 tees, 2 globe-valves, and the main was 88 ft. long. According to note No. 1, each elbow should be counted as increasing the length of the pipe 40 diameters. Then, as the diameter is 3 in. $40 \times 3 = 120$ in. or the equal of 10 ft. of straight pipe. There are six of them, so these increase the friction equal to 60 ft. straight pipe. The 10 tees$=10 \times 60=600$ diameters, 600×3 in.$=1,800$ in.$\div 12$ in.$=150$ ft.; 2 globe-valves$=125$ diameters each, then $125 \times 2=250$ diameters$\times 3$ in.$=750$ in.$\div 12$ in.$=62$ ft. Instead of 88 ft. of pipe to figure on, we have $88+60+150+62=360$ ft. of pipe. Now, according to note No. 2, if pipe was 300 ft. long the factor of .58 was to be used, if 400 ft., .50. To find our factor we get the average of the two, or the 350 ft. factor, by adding $.58+.50=1.08$ and dividing by $2=.54$, the proper factor.

We now multiply 1,500 sq. ft. which could be carried on **100 straight feet of pipe by .54 and find that only 810 ft. should have been put on that 3-in. main under conditions of water-line intended by Mr. Wolff** when the table was made. Of course, this is a most unusual condition of fittings, but something similar can be found in most every town where there are a dozen jobs of this size.

A fairly accurate guide for pipe-sizes can be found in following table for small installations say of 2,000 sq. ft. or less.

TABLE Y.

To Find Pipe-Size Suitable for Varying Distances Between Supply or

Probable Decrease in Pressure of Steam in Ounces or Pounds on Ordinary House-Heating Job.	Distance from Water-line of Boiler up to Main Supply-Pipe Return-End. Inches.
1 oz. = 1/16 lb.	4
2 oz. = 1/8 lb.	6
4 oz. = 1/4 lb.	10 to 12
8 oz. = 1/2 lb.	16 to 18
12 oz. = 3/4 lb.	23 to 25
16 oz. = 1 lb.	32 to 33
24 oz. = 1 1/2 lb.	46 to 48

As in most small jobs the areas will not come out exactly in correspondence with areas of commercial pipe, always take the next larger area which will fit to commercial-size pipe.

In using Table Y, it will be found to be a convenient guide to water-lines. Assume a very low cellar and a job requiring 500 sq. ft. of surface. How near to water-line can the return or lowest end of supply-pipe be run and have job work with steady water-line and what size pipe will probably be required for single-pipe circuit?

We have 500 sq. ft. of surface. Then, by Table Y, $5 \times 1.4 = 7$ sq. in. of area or a 3-in. main, see Table A, and the return end can be within 4 in. of water-line. But if there is plenty of room and a pressure of 5 lb.

can be carried or more upon occasion, a very small pipe can be made to work by carrying it very high above water-line of boiler at return-end, say 48 in., the supply-pipe starting the circuit of 100 ft. at, say 60 in. above water-line of boiler. The table says under

TABLE Y.

Water-Line of Boiler and Farthest Point from Boiler of Steam-Main.

To Find Area of Steam-Main in Square Inches, Multiply Each 100 Sq. Ft. of Radiating Surface. One-Pipe.	Two-Pipe.	Probable Steam Pressure Required at Boiler.
1.4	.9	½ lb. to 1 lb.
1.35	.9	1 lb. to 2 lb.
1.03	.68	2 lb. to 3 lb.
.63	.46	3 lb. to 5 lb.
.56	.38	5 lb. to 10 lb.
.45	.32	
.43	.31	

these conditions the 500 ft. of heating surface multiplied by .43 will give the size that can be made to work, 5×.43=2.15 sq. in. But the area of a 2-in. pipe will have to be taken because 2.15 is the very smallest that it will do to use and no commercial-size pipe will answer to a 2.15 sq. inch area.

From what has been said it will be seen that no steamfitter is warranted in attempting to guess out a job. No man with sufficient intelligence to be in the business at all, but that is able to lay out a rough pencil or chalk diagram of the proposed job. From this he is able to count up the elbows, tees and the like as well as measure the actual length of pipe, fittings included. He can then easily determine whether he has more than 100 ft. in length of pipe supposing the ells and tees were all in straight pipe. If he has, he would increase the size of pipe beyond table by at least one commercial size. If he needed a 2-in. pipe for 100 ft. on an area of 2.960 sq. in. on 100 ft., and when fittings were added he had 200 ft., he would use a 2½-in. pipe, as that is the next larger commercial size. Another way to put it would be that under the additional loss of pressure caused by these fittings he could not carry so much surface on a 4-in. difference between water-line and lowest point of his supply-pipe.

Under the old practice less attention was given to these questions than is forced upon the fitter by the new.

SECTION XVIII.

The discussion on pipe sizes for two-pipe work and single-pipe work applies also to all types of steam-work. An overhead steam-job is sized for velocity the same as any other. There is only one unfailing, never-to-be-forgotten rule connected with overhead work that if overlooked will usually cause the water to leave the boiler, viz.: No drop-pipe must be stopped until it is below the water-line level of boiler.

A secondary circuit can be run half way between top supply and boiler or one can be run on several floors if all drop-pipes are carried to basement and enter main return pipe *below the water-level of boiler.*

Probably the overhead system is the peer of all heating systems where conditions permit or compel its use.

If the cellar is so low that a circuit cannot be completed and secure a steady water-line, then the overhead system is all valuable, providing always that every drop-pipe is carried below the water-line of boiler. If there is one single pipe that the fitter fails to get into this wet return below water-level, trouble will probably develop for him all right, and will continue until the piping is fixed so that the lower end of that drop-pipe is below the water-level of the boiler.

It is not necessary for the purposes of this book to go into minute details of description of pipe-fitting. That is every-day practice for those who are in the business.

In Section XVII we gave Mr. Wolff's table for two-pipe work. Table Z gives the sizes calculated by Prof. Carpenter, for single pipe work, as shown in his book, "Heating and Ventilating Buildings."

TABLE Z.

Internal Diameters of Steam-Mains for a
Steam pressure 10 lb. above atmosphere.
Steam pressure 0.5 lb. above atmosphere,

	Length of Steam-Main in Feet.		
Radiating Surface Sq. Ft.	20	40	80
	Diameter of Pipe in Inches.		
20	0.5	0.5	0.6
40	0.6	0.7	0.8
60	0.7	0.8	0.9
80	0.8	0.9	1.0
100	0.9	1.0	1.2
200	1.1	1.3	1.5
300	1.3	1.5	1.8
400	1.5	1.7	2.0
500	1.6	1.9	2.2
600	1.8	2.0	2.4
800	2.0	2.3	2.6
1,000	2.2	2.5	2.9
1,400	2.5	2.8	3.3
1,800	2.7	3.2	3.6
2,000	2.9	3.3	3.8
3,000	3.4	3.9	4.4
4,000	3.8	4.3	5.0
6,000	4.1	4.7	5.4
8,000	4.4	5.0	5.8
10,000	4.7	5.3	6.1

The above table Z is computed by formulas for diameter in inches in which head=318.6 (of water);

quantity of steam discharged per minute=9.2 cu. ft. for 100 sq. ft. radiating surface.

The table is computed for straight pipes with water-level in returns 6 ins. above that in boiler. For other

TABLE Z.

Single-Pipe System of Heating by Direct Radiation.
frictional resistance 6 in. of water-column.
frictional resistance 12 in. of water-column.

Length of Steam-Main in Feet.					
100	200	300	400	600	1,000
Diameter of Pipe in Inches.					
0.6	0.7	0.8	0.8	0.9	1.2
0.8	1.0	1.0	1.1	1.2	1.6
1.0	1.1	1.2	1.3	1.4	1.8
1.1	1.2	1.4	1.5	1.6	2.1
1.2	1.4	1.5	1.6	1.7	2.3
1.6	1.8	1.9	2.0	2.2	2.9
1.8	2.1	2.3	2.4	2.6	3.5
2.0	2.4	2.6	2.7	3.0	4.0
2.2	2.6	2.8	3.0	3.2	4.2
2.5	2.8	3.0	3.2	3.5	4.5
2.7	3.2	3.4	3.6	3.9	5.0
3.0	3.4	3.7	3.9	4.3	5.5
3.4	3.9	4.2	4.5	4.9	6.5
3.8	4.4	4.7	5.0	5.4	7.0
3.9	4.5	4.9	5.2	5.6	7.2
4.6	5.3	5.8	6.1	6.6	8.5
5.2	6.0	6.5	6.8	7.5	9.7
5.7	6.5	7.1	7.4	8.2	10.5
6.0	7.0	7.5	7.9	8.7	11.3
6.4	7.4	8.0	8.4	9.2	11.9

resistances and steam-pressures, multiply the diameters as given above by following factors:

to the actual measured length, or serious error in the area required will surely arise.

If the pipe is uncovered its radiating surface must be ascertained and figured as direct radiation (see Table EZ). When the length exceeds 100 ft., with the equivalent length of the fittings added, the results found by Table Y should be multiplied by one of the following factors given in Table AZ. Column A expresses lengths from 175 ft. to 1,000 ft. Col. 2 shows the percentage of area to be added to the area found by Table Y in order that the decrease in pressure shall remain the same as that found for 100 ft. by Table Y. Column 3 shows what percentage of radiation found by Table Y the increased length of piping will carry and still maintain the distance between water line of boiler and lowest point of main pipe intended or indicated by Table Y.

To the man who desires to do good work in steam-heating houses, no more important tables will be presented than these in regard to the sizing of pipes. The use of the tables is as follows:

Assuming that on a simple job as illustrated by Fig. 12, the total amount of the required radiation, including surface of the main itself, is found to be 345 sq. ft., and the cellar is found to be so low that from point x on the bottom of the main, to the water line of the boiler selected to use, only 4 inches can be secured. It is desired to know what size main to use if a single pipe-circuit job is put in, also what size pipe will be required for a two-pipe job.

From Table Y we learn that for only 4 inches drop, each 100 ft., and fraction of 100 ft. of radiation, must be multiplied by 1.45 to find the area of pipe necessary for a one-pipe job, and for a two-pipe job the total radiation should be multiplied by 0.97 to get the correct area for 100 ft. of straight pipe.

We look at the sketch and notice that on a single-pipe circuit there are 9 elbows above water-line of boiler, and 6 tees. We may also find the actual measured length of the proposed circuit to be, say, 92 ft. It is evident that in this case fittings must cut considerable of a figure. We first find out what size of pipe would be required to carry the 345 sq. ft. of radiation if the pipe had no fittings and was perfectly straight. We therefore multiply the 300 ft. and the 45/100 ft. by 1.45 to get the area of main for single-pipe circuit $3.45 \times 1.45 = 5$ sq. in. The nearest commercial-size pipe of this area is a 2½-in. pipe. But this is for 100 ft. of straight pipe. See Table A. Page 12.

We must find out how many feet of straight pipe these fittings will equal and add it to the 92 ft. of measured length in the lay-out. Each 2½-in. elbow is the equivalent of 8 ft. 2 in. of 2½-in. pipe and each tee of 12 ft. 6 in. Then the 9 elbows are equivalent to 73½ and the 6 tees to 75 ft. more. The total length then that must be taken into account is $92+73+75=$ 240 ft. Table AZ states that the area in the pipe must be increased 35 per cent to carry 240 ft. of length and provide same drop as for 100 ft. length. 35 per cent of 5 is 1.75; then $5+1.75=6.75$ sq. in. area that must be provided. This area requires that a 3-in. pipe be used if a steady water-line is to be maintained.

If the height of the cellar would permit a distance of 18 in. between point x and the water-line of boiler, instead of multiplying by the factor 1.45 the radiation should be multiplied by 0.68. From Table CZ it will be found that the fittings are equivalent to a length of 125 ft. of pipe to be added to the 92 ft. of measured length, or a total length of 217 ft. The area found to be needed by Table Y for 345 sq. ft. of radiation with

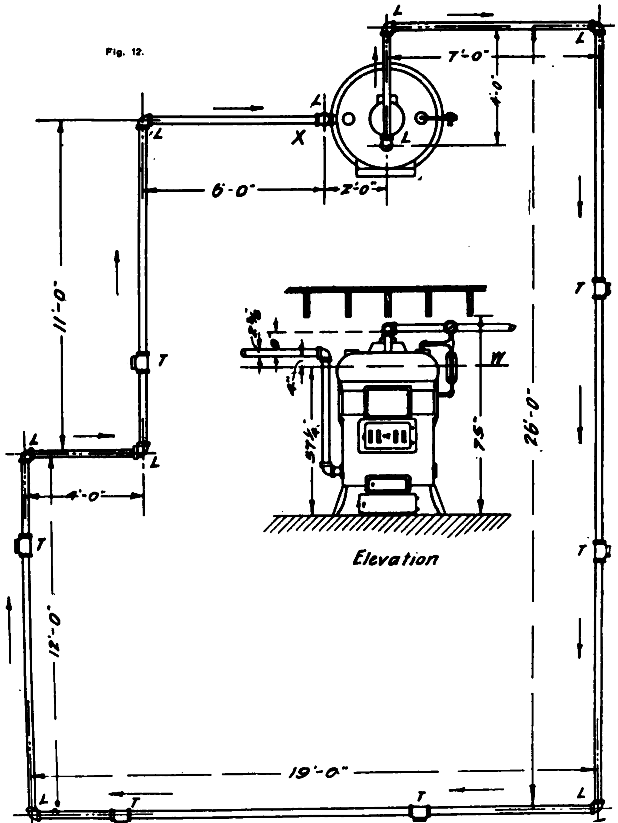


Fig. 12.

an 18-in. drop is 2.346 sq. in. Table AZ gives the increase in area necessary to equalize 220 ft. in length with 100 ft. as 0.33 per cent. When this percentage is added we have the required area as 3.12 sq. in. or the area of a 2-in. pipe. In the same manner we would find the area that should be used if the head-room permitted the main to have a drop of 4 ft. It will be found to require 1½-in. pipe for the main if a 48-in. drop can be had. A main pipe should never be used of less area than a 1½-in. pipe.

These illustrations very clearly show that it is of the utmost importance to the fitter that he should know what distance can be secured between the low point of the proposed main and the water-line of the boiler to be selected. In fact, an intelligent selection of the piping layout, or of a properly proportioned steam-boiler cannot be made without this information.

The importance of reaming the ends of every pipe can be seen in the light of this discussion. For instance, the burr which is often left when pipe is cut not only produces a considerable amount of friction, but produces an actual reduction in the available area of the pipe itself.

SECTION XIX.

In order to bring out this close connection between the low point of main and the water-line of boiler, and the size of main that can be used; the necessity also of knowing the velocity at which the steam is to move, before selecting the pipe-size for the main, or the

TABLE BZ.

Number of Ft. of Radiation Main May Carry by the Rule.

Size Pipe.	Monroe.	J. L. Mott.	Cleveland.
2 in.	300	200	400
2½ "	500	400	625
3 "	750	700	962
3½ "	1,075	1,060	1,225
4 "	1,400	1,590	1,600
4½ "	1,900	2,272	2,025
5 "	2,400	3,120	2,500
6 "	4,000	5,440	3,600
7 "	5,500	8,550	4,900
8 "	7,000	12,556	6,400
10 "	12,000	25,300	10,000

make or type of boiler to be used, a summary of the illustration just given will be useful.

We have found that, in this one selected case, three sizes of pipe can be used. But each requires a different distance between low point of main and the water-line of boiler. Thus:

Can use 3-in. pipe and have 4-in. drop.

Can use 2-in. pipe and have 18-in. drop.

Can use 1½-in. pipe and have 48-in. drop.

The tremendous import of the point brought out, and its value to the trade can be seen by the most casual inspection of the following Table BZ, which gives the pipe sizes suggested by nine well-known authorities, or in use in certain localities by a number of high-class fitters. These nine have been selected in order that practically every section of the country where considerable work in steam-heating is done may have a fairly representative showing. The selection includes the following authorities and local city-practices—William Monroe; J. L. Mott; W. J. Baldwin; John H. Mills; Norman Whitelaw; C. B. Thompson, in "Plumbers' Trade Journal"; a Cleveland, O., Rule; a Chicago, Ill., Rule; a St. Louis, Mo., Rule.

TABLE BZ.

Number of Ft. of Radiation Main May Carry by the Rule.

Baldwin.	Chicago.	Mills.	Whitelaw.	St. Louis.	C. B. Thompson.
.....	350	500	360	300	590
314	460	750	560	500	1,240
706	675	1,000	800	900	1,900
962	850	1,250	1,000	1,450	2,500
1,250	1,100	1,500	1,400	2,000	3,900
1,590	1,350	2,000	1,800	2,500	4,000
1,963	2,000	3,000	2,200	3,000	6,900
2,827	3,600	4,000	3,300	4,500	10,000
3,848	5,000	5,500	.....	7,000	13,500
5,026	6,500	7,000	.....	12,000	19,500
7,854	9,800	10,000	.....	16,000	31,000

For a more extended list see "Sizes of Flow and Return Steam Mains," published by "Domestic Engineering" in 1909.

"Domestic Engineering" Cartoon on "The Intricacies of Boiler-Rating" No. IX.

The Steam-Fitter's Choice Will He Make the Lighthouse?

The Steam-Fitter's Choice. Will He Make the Lighthouse?

After looking over this list, which one would be chosen for a job where the utmost drop to be obtained between water line of boiler and low point of main circuit was seven inches? A decision would be fully as much of a guess as any of the old guess-work rules for selecting radiation.

The differences shown in the above table is a very marked example to show the need of instruction to the trade in general in the use of piping.

The reader who has followed the discussion to this point can readily understand that no one would be justified in stating that either of the nine rules is in error all the way through.

That some radical changes in velocities occur in nearly every column is perfectly evident. It may seem that the radiation provided for a 3-in. main in Col. 2, if correct, must prove that the 1,900 ft. permitted by Col. 9 for same size of pipe is badly off. But, as has been shown, the question of velocity to a very considerable extent determines the size of pipe needed to deliver a given number of pounds of steam to a given point in a stated period of time. Then, again, as has been shown, the pressure at the boiler has a bearing. Before condemning Col. 9 as certainly wrong, let us analyze both and see if possibly each is not correct.

Assuming that the steam in each case is to reach the radiators at a pressure that shall average 212 deg. F. in the radiators, and that the radiators shall emit in both cases 227 b. t. u. per sq. ft., the temperature of the room being at 70 deg. (212—70=142. 142 ×1.6=227 B. t. u.), let us examine both suggestions.

Under these conditions the 700 ft. will call for 158,-900 B. t. u. per hour, or about 165 lb. of steam, each pound of which will fill 26.4 cu. ft. per hour or 1.21 cu. ft. of area per second. With a speed of 25 ft. per second, the area required to furnish the needed steam is found in 3-in. pipe.

The 1,900 ft. upon the same statement of conditions

TABLE CZ.

Length of straight pipe which equals the friction of various fittings. Actual diameters of pipe taken for this table.

Size of Pipe Fitting in Inches.	Each Tee Equal to Straight Pipe Ft.	In.
½	3	2
¾	4	2
1	5	2
1¼	6	10
1½	8	..
2	10	4
2½	12	4
3	15	4
3½	17	8
4	20	2
4½	22	6
5	25	2
6	30	4
7	35	2
8	39	11
9	45	..
10	50	..
12	60	..

will emit 431,300 B. t. u. per hour, requiring 447 lb. of steam per hour, or 3.25 cu. ft. per second. With a velocity of a trifle over 66 ft. per second, a 3-in. pipe would be sufficiently large, providing that the total friction did not exceed that on a pipe 100 ft. long and without elbows, tees, or other friction-creating items. For a complete method of figuring out these velocities Section XV of this series will repay the reader's careful study.

TABLE CZ.

Length of straight pipe which equals the friction of various fittings. Actual diameters of pipe taken for this table.

Each Elbow Equal to Straight Pipe.		Each Coupling Equal to Straight Pipe.		Each Valve Equal to Straight Pipe.	
Ft.	In.	Ft.	In.	Ft.	In.
2	2	1	1	3	2
2	8	1	4	4	2
3	6	1	9	5	2
4	7	2	3½	6	10
5	5	2	7½	8	..
6	11	3	5½	10	4
8	2	4	1	12	4
10	2	5	1	15	4
11	9½	5	10	17	8
13	5	6	7	20	2
15	..	7	6	22	6
16	10	8	5	25	2
20	2	10	1	30	4
23	5	11	8	35	2
26	8	13	4	39	11
30	..	15	..	45	..
33	4	17	..	50	..
40	..	20	..	60	..

But if the total length of pipe, including the friction of the fittings, exceeds 100 ft., how will you proceed if the drop is 7 in., for instance? With the conditions named, how are you to tell the distance needed between water-line of boiler and drop point of piping? There is nothing plainly stated in the tables that gives the slightest clue to these points which are of vital importance to the fitter who intends to do good work intelligently and not by guess.

Now take these same assumed conditions and the same amounts of radiation and see what can be done with them by the aid of Table Y, using the same 700 and 1,900 ft. of radiation and securing a 3-in. pipe.

For a two-pipe job, we find that the 7 hundreds multiplied by the factor .90 calls for a 3-in. pipe as nearest commercial size. The 19 hundreds if multiplied by the factor .32 also calls for a 3-in. pipe. But the Table Y also tells something more about the case. It tells that with the 3-in. pipe for the 700 ft. one can, if needed, bring the lowest point of the main to within from 6 to 9 in. of the water line of boiler. If, however, the 3-in. pipe is used for the 1,900 ft. of radiation, there must be at least 33 in. between the two points mentioned. There is nothing stated in the tables usually found in trade catalogs to guide one in these things. If one needs to use a single-pipe circuit, Table Y furnishes all the needed data for the proper size. Table Y and Table AZ will practically answer every question that will arise in regard to steam-mains in any house-heating job.

By the aid of these two tables it is possible to reconcile all the apparently wild suggestions for pipe-sizes that are published from time to time in the trade magazines.

It is hoped that this dicussion may help to make clear to my readers this hitherto perplexing question. The one thing never to be forgotten in studying this pipe-question, is that the standard of pipe-sizing is 100 ft. of straight-pipe friction. If fittings are used, the length of pipe which the fittings equal in friction must be added. As perhaps some who may use this book may not have the time or inclination to figure out for themselves the values in straight pipe of the various fittings most often used in steam fitting, Table CZ is given for their benefit.

The importance of this table to any steam-fitter in the exceedingly vital matter of correct piping must be apparent to the most casual reader.

It seems rather strange, however, that although the first one of the American writers on the subject of steam heating called attention to this matter of friction in the pipes, and as early as about 1870 such allowances were in use by the best grade of engineers in Boston and New York, the working steam-fitter of that day seems to have had little or no knowledge of the matter. And for that reason, perhaps, the knowledge does not seem to be at all general to this day.

Section XX.

The first steam-heating of buildings to be applied in this country originated with the firm of Walworth & Nason of Boston, Mass. The first building in America to be steam-heated, using small wrought-iron pipe to convey the steam, was the building in Boston then known as the Eastern Exchange Hotel. This was completed about 1845 or only 65 years ago at this writing. The early heating of the rooms was accomplished entirely by means of pipe-coils. Later, various forms of cast-iron radiators came into use. The names given to these as generally applied by the trades-people clearly indicates their appearance. There were the "Ox-bow," the "Wash-board," the "Bars," and others in cast-iron. A very popular radiator in some sections of New England at that time was built of sheet-iron. This radiator was bolted in such a way that the steam passed up and down quite in the same manner that it passes in a hot-water radiator of today. In general appearance this radiator resembled a bed-mattress, and was usually called the "mattress radiator" by the trade.

It was not until 1862 that the Nason radiator made its appearance. This radiator was built of pipes screwed into a cast-iron base and so adjusted that each pipe and the base for it contained exactly one square foot of superficial surface. This radiator was the first to be constructed on strictly scientific lines and I think it can be fairly stated that all radiator-ratings in use today in this country are primarily based upon the Nason radiator. The ratings of radiators will be explained more fully in a later chapter. The great thinkers and engineers of those early days who gave their lives to the development of the heating industry, comprised many notable men, some of whom are herewith enumerated:

Joseph Nason, who with J. J. Walworth, created the firm of Walworth & Nason, afterwards merged into the great manufacturing concern known as The Walworth Manufacturing Co.

Miles Greenwood, of Cincinnati, who invented the arrangement of a nest or coil of upright pipes connected by return bends.

Thomas Tasker, of Philadelphia, known as the first to introduce the closed system returning the water of condensation to the boiler. Professor Mapes, of New York, who invented the first reliable steam-trap.

Mr. Gold, of Connecticut, whose invention of the Gold-pin radiator changed the steam-heating practice of the entire trade in many respects. Robert Briggs, who "established the characteristic shapes and dimensions universally adopted for the globe-valves and for the fittings or couplings of the tubes."

Of this brilliant and capable group of men the only one to place in print any considerable amount of the great fund of knowledge he had gained by study and experience is Robert Briggs. In the "Proceedings of the Institution of Civil Engineers" are to be found many things presented by him. About 1882 some of these papers were collected and published by D. Van Nostrand Co., of New York.

Mr. Briggs became associated with Walworth and Nason in 1846 and therefore can be clearly called the most competent authority possible, to decide as to the friction-demands of the fittings which are still made upon the "characteristic shapes and dimensions" established by him.

It is from the data furnished by Mr. Briggs that the Table CZ has been compiled. It seems probable to the writer that one of the reasons that the trade at large has not become conversant with the tremendous effect for trouble that the friction of fittings may have on a given job, is because the few authorities who have given the matter attention have quite generally led up to it through formulae that the average working steam-fitter did not fully comprehend. Another reason possibly is that the great majority of the steam-fitters of the present day have secured their notions as to the detail of the work from trade catalogs, traveling salesmen who might or might not have some engineering skill, and to a very large degree from the "lay-outs" which different manufacturers of boilers or radiators were, until within a very few years, prone to furnish to the purchasers of their material.

Naturally, if the manufacturer or his engineer understood all about the effect of fittings on pipe sizes he did not explain the thing to the customer, rarely saying anything more than that "the pipe sizes as given must not be changed, or any changes made in the connections without consultation with the one who furnished the plans."

From 1862 to about 1892, the practice of furnishing piping plans to any one who would buy boilers was the universal habit in this country. In this way men who were totally incompetent for the work came in time to the doing of the plan-making work for some of the manufacturers. That the results were not more disastrous than they often proved is a matter of wonder to some of those who look back upon those days from the standpoint of present knowledge.

It is with full knowledge of those days in mind that the writer is giving so much space to this subject of pipe and fittings. It is not to be wondered at, I think, that the trade at large is not familiar with this most important thing in regard to piping, when one looks up the trade-papers for the past 30 years and finds what a very small amount of information given in plain English and clearly stated can be found in them, information as to piping resistance and the like.

In 1906, a gentleman from Montevideo, Minn., addressed a letter to "Domestic Engineering" asking for information as to pipe-sizes. Thirty of the best fitters and engineers in the country answered the inquiry.

Not one of them gave out figures that in all respects agreed with any other one! It would be totally impossible to find out from any or all of these 30 answers how to bring all these conflicting sizes to one common basis and from that base to find the velocity required by each, the probable drop in pressure in order to locate height of main above the water-line, or what percentage to add for fittings. It is perfectly evident from the replies that some of the writers had these things in mind, but no one seemed inclined to explain them. Out of the 30, one only gave a statement of the results in pipe-sizes required to supply 25 lb. steam through 100 ft. of pipe at four different velocities. *But this one gave no hint of the needed increase in pipe size if the fittings taken off the main increased the friction to equal another* 100 *ft. if same drop or distance between main and water-line was to obtain.*

Four lay stress upon velocity, but give nothing to enlighten the inquirer as how to determine in advance what the probable velocity will be in any given case. Four others pay considerable attention to pressure at boiler, but give no adequate advice in regard to how this may affect the size of the main pipe. One writer giye a comprehensive list of pipe sizes suggested by a number of authorities, some of which are made use of in Table BZ, in connection with others in the present discussion, but fails to reconcile the differences between the figures beyond showing the great differences in velocities. One, only, states the back-pressure, saying "that his tables are calculated on 12-in. back-pressure." One gives a fine description of the relative value of drop-distances, but does not explain how these distances are to be obtained by the fitter. One gives Wolf's table of factors for decreasing the radiation for increased length of main, but fails to mention fittings in any way. Out of the 30 answers, only 3 make special mention of the importance of the friction of fittings, and of these, one goes a little farther than the rest, and embodies his explanation in a sentence of 14 words. After placing fittings as the third important factor out of six mentioned he disposes of it thus: "If a number of fittings are on the pipe I allow somewhat larger sizes." Of the other two who specially refer to fittings one says very truthfully. "Every bend and angle produces friction." He refrains from giving the Montevideo, Minn., man, or others, any specific information as to the method of finding out how much this friction might be or how to provide for it in the pipe.

That this matter of pipe for mains is considered of paramount importance is shown by the appointment by the American Society of Heating & Ventilating Engineers in 1906 of a very able committee to secure data from members of the society upon standard sizes of steam and return-mains." This committee made its final report, it is said, in 1907. In concluding their report this committee said: "In regard to the recommendation of a 'standard', their investigations have led them to the conclusion that the use of such a velocity as will require a difference in pressure of not more than one ounce to 100 ft. in *straight pipe* to maintain it, represents, as near as they can at the present time ascertain, the best average practice in proportioning the sizes of steam and return-mains." This committee prepared a table of the highest, lowest and average sizes, from the data received by them from the members of the society. From this table, which is only partially reproduced here, just one size will be taken to illustrate the danger of taking any table, which is ready-made, as a guide in selecting a main for house-heating.

FROM THE REPORT OF COMMITTEE OF THE SOCIETY OF HEATING AND VENTILATING ENGINEERS.

TABLE DZ.

"Maximum amount of radiation permitted on low-pressure steam-main in plants of moderate size, or those not having over 100 ft. of main."

Condensed from an article in "Domestic Engineering."

Size Pipe.	Highest.	Lowest.	Average.
1 in.	100	40	59
1¼ "	125	75	94
1½ "	250	126	171
2 "	400	286	335
2½ "	700	500	594
3 "	1280	800	994
3½ "	1600	1100	1407
4 "	2560	1500	1971

The average in above table is said to have been made up from all the data supplied to the committee, and probably is the fairest presentation of the average practice of the highest type of steam-fitters in this country in 1906 that can be procured.

Assume one of these new types of houses patterned somewhat after the bungalow of the far west, which calls for 8 radiators having a total of 332 sq. ft. all on one floor. Mr. Fitter looks at the Society's table and finding that it gives a leeway between high and low of 114 ft., with an average about what his job calls for, decides to use a 2-in. main for a two-pipe lay-out. He finds that the total run of pipe will measure 70 ft. As this is 30 ft. less than the length upon which the table is said to be based, he feels very confident that the job will be perfect, and will not show a greater decrease in pressure than one ounce.

When the time comes to put it up, he decides to make sure that no trouble with water-line being unsteady shall occur, and so he runs the pipe full size for the entire 70 ft. The cellar is none too deep, and he finds he has not a large drop, but this does not seem dangerous, considering that 30 ft. In time the job is tested out. Then begins trouble for Mr. Fitter, and Mr. Boiler-maker, and Mr. Owner. By the time a 2-lb. pressure shows on the boiler-gage the water-line is jumping furiously. The reason is not hard to find for the man who has at his command tables, Y, AZ, and CZ. From table CZ he finds that the eight 2-in. tees on the main require 82 ft. 8 in. of straight 2-in. pipe to equal their friction. The 9 elbows require 62 ft. more, so that he has a total length of 215 ft. instead of 70 ft. to reduce pressure. By table AZ he finds that with 220 ft. in length he can only carry 67 per cent of either amount given in the Society's table and maintain the "standard" loss.

This means then that his method of piping, while giving all the relief possible, still has produced such a loss in pressure by fitting-friction that, under the highest estimate of any fitter reporting to the committee, not over 268 sq. ft., could have been used and maintain the "standard" pressure, while the average of them, whose practice he thought he was taking, would only use 224 sq. ft., on 220 ft. length of straight pipe, or its equivalent in friction.

If the fitter had started his job from Table Y, and when he had it sketched out roughly, so that he could count up the fittings on the main, had added to the first measured length the equivalent length as found by Table AZ, he would have soon found that in order to maintain the "standard" pressure at return end of piping that he must increase the area of the main 33 per cent. With this much added the Society's rule in this case would have been correct.

Neglect on the part of the fitter to count the heating surface contained in the surface of the piping is an almost universal habit among fitters who do not give their entire time to the business, and with some who do, I regret to state. This neglect often causes serious trouble to the man who was so foolish as to neglect to take into his figuring probable loss from this source. For instance, in the case just illustrated, without taking the loss from this source into the account at all, we found that the 2-in. pipe was overloaded 107 sq. ft. But in order to get the full amount of the trouble that would be coming to the fitter, we must add, to the 332 ft. of radiation he had put in, the 117 sq. ft. of heating-surface which the pipe itself contained. With this added the simple fact is that the fitter was trying to maintain "standard" pressure for 449 sq. ft. of surface, on 215 ft. of 2-in. pipe-friction! This being over 10 per cent more radiation than the table prepared by the committee of the Society of Heating and Ventilating Engineers claimed to be the highest permissible to be carried by a 2-in. pipe for 100 ft. The number of square feet of surface which the measured length of any given size of pipe in common use will contain can be figured from Table EZ. This table also shows the actual internal area of the different sizes of pipe. In cases where very close figuring for water-line is required, this table can be

TABLE EZ.

Table of Important Dimensions of Steam-Pipe in Steam-Heating.

Normal Diameter.	Length of Pipe in Ft. Per Sq. Ft. of External Surface.	Actual Internal Area in Sq. In.
½ in.	4 ft. 6 in.	.3048
¾ "	3 " 8 "	.5333
1 "	3 " 0 "	.8626
1¼ "	2 " 4 "	1.496
1½ "	2 " 0 "	2.038
2 "	1 " 8 "	3.356
2½ "	1 " 4 "	4.784
3 "	1 " 0 "	7.388
3½ "	0 " 11 "	9.887
4 "	0 " 10 "	12.730
4½ "	0 " 9 "	15.961
5 "	0 " 8 "	19.990
6 "	0 " 7 "	28.888
7 "	0 " 6 "	38.738
8 "	0 " 5½ "	50.04
9 "	0 " 4½ "	62.73
10 "	0 " 4 "	78.839
12 "	0 " 3½ "	113.098
14 "	0 " 3 "	159.485

used in the place of Table A, of the area of circles. As a matter of fact, the actual area of most sizes of pipe is a shade larger than the area given for a circle of the stated size. There is one notable exception to this, and that is on the 2½-in. size.

It will be noticed that the internal area of pipes do not fully agree with the area of circles as given in Table A. This is because the actual internal area of steam-pipe is not in exact accord with the nominal area. A 2½-in. circle by Table A has an area of 4,908 sq. in., while a 2½-in. steam-pipe by Table EZ is found to have an area of a trifle less. But on nearly all sizes the actual pipe-size internally is a little larger than that given in Table A. Table EZ is given here because there often come places where it is of the utmost importance to the fitter to use the smallest pipe possible and hold the desired velocity. Probably error in the use of 2½-in. pipe is more general than on any other size, for the reason that it is not in excess of area in sq. in. as is the case with most other sizes. Again, the average fitter seems to have a great aversion to reaming the ends, and when this is not attended to the area of the pipe is considerably decreased, often to such an extent that the effective area of the 2½-in. pipe, instead of being 4.784 sq. in., is found to be not above 3½ sq. in., a deficiency large enough to upset completely any very close figuring on a water-line proposition for instance. What has been said in regard to 2½in. pipe is equally true of all sizes of pipe in the matter of reaming the end of pipe to be used in steam-fitting.

SECTION XXI.

Leaving the full discussion of piping methods to be taken up later, we are now ready to select a boiler for our steam-job.

We are able to determine how many B. t. u. must be furnished per hour. The boilers are all rated on a basis of 2-lb. pressure at boiler.

Suppose we have found we require 500 ft. of radiation in the rooms. Should we put in a boiler rated for 500 ft.?

Most assuredly not. Why? In the first place, the piping, covered or uncovered, will use up a large quantity of B. t. u. that the boiler will produce, and so, of course, those do not get to the radiator at all. At the very lowest estimate this demand will equal one-quarter of the boiler capacity at 2-lb. pressure. The piping often exceeds on small jobs, in radiating surface and heat-loss from friction full 40 per cent of direct radiating surface. Carefully measure up all piping, risers, radiator-valves and all surface connected to any job you ever did with 500 ft. or less direct radiation and add to this the loss by reason of friction and see if the statement that 25 per cent is the very smallest that can be allowed for piping, as draft on boilers at 2-lb. pressure is not very conservative.

It was different when 15 to 60-lb. at boiler was in vogue. Now, as we are dealing with a proposition mighty close to hot-water conditions and friction eats up a big percentage of our available B. t. u.

Then there is the difference in fuel from year to year to be considered; the probability that it will sometimes be colder than just zero, in which case more heat will be demanded; then again, while the boiler is rated to carry a certain number of feet at 2-lb. pressure, how long at a time will it carry it? Look catalogs over and see how many make this apparent.

These boilers may be rated, for all you know, on a 6-hour firing basis, or more or less, or perhaps a careful measuring up and testing of boiler would show an 8 or even 9-hour carrying capacity for 500 sq. ft. at 2-lb. pressure. Assume first an 8-hour basis. Then if your client fixes his fire at 9 p. m., he must be up at 5 a. m. next day to attend to it, if the steam is to be supplied at the time most needed. Will he do it? Hardly. It is more likely to be 7 a. m. the next morning. If so, then two hours, or 25 per cent of the rated value of the boiler, has been demanded by the radiators, when there was no garantee on the part of the manufacturer to supply it. The item of extra demand from piping being 25 per cent and the almost certain demand from owner of a longer supply than 8 hours, equalling, usually, at least 10 hours, or 25 per cent more, demonstrates the necessity of an arbitrary increase in boiler-capacity over stated amount of radiation required on job of at least 50 per cent. A job requiring 500 sq. ft. of steam-radiators figured on 2-lb. pressure basis should have at least a boiler rated at 750 sq. ft. capacity.

As will be seen, this is not because the boiler is incorrectly rated but for reasons entirely outside of the special item of radiators in the rooms.

Many men want their boilers so that they can hold fire 12 hours at pressure-producing point. That is 50 per cent of itself beyond the rated capacity of boiler under selected conditions of 8-hour run and 100 per cent beyond the rated capacity of a boiler rated on a 6-hour firing basis. *In both cases the additional tax from piping and friction must still be added.*

The steamfitter should inquire into the desires of his client as to length of time between firing dates and figure accordingly. Then he must know from the manufacturer just the number of hours the boiler he intends to use will supply steam at 2-lb. pressure and have sufficient fuel left in good condition to start a fresh lot of fuel without materially diminishing steam pressure.

With this information he can select a boiler with a reasonable sense of security.

Boiler manufacturers are now selling their product on the practical basis of an average temperature in the radiators, of steam at 212 deg. or less. The 2-lb. pressure is a factor of safety against all sorts of possible mistakes on the part of party installing the boiler.

It is up to the steam-fitter to meet the present conditions by having a clear understanding of the fundamental principles governing the medium he is attempting to harness and control, viz., steam.

The question of selection of a boiler for any house-heating job should be approached by the steam-fitter without prejudice, and, so far as is possible, without preconceived notions in favor of any special type of boiler. Because some job or jobs have turned out well or badly with a given type or make of boiler in use is no certain sign that it will be the very best thing to put on the job in hand, or that it should not receive proper consideration.

In fact it may develop that the manufacturer who produced the boiler or boilers that were satisfactory on the previous jobs does not even actually make the best boiler in every respect for the present condition.

It should be the aim of every steam-fitter to put the very best boiler to procure on to each job he undertakes, and in order to do this he must candidly consider all the conditions surrounding each job. He is very liable to find that the height of water-line on one make of boiler is such that if he uses that boiler, he will be obliged to use a size larger pipe on the main circuit than he would require if he used a boiler of another manufacturer who produced a type with a lower water-line. Quite often the size of the smokehood on small-sized cast-iron boilers becomes a deciding feature. It is running a greater risk than any steam-fitter can well afford, to put a boiler on to a job which has a smoke-hood calling for a smoke-pipe larger than the face of the chimney provided by the owner. Another condition which should have a very great influence in the decision is the strength of the draft. There is a very great difference in the various types of boilers in this item of draft. In fact, there is often quite a difference between boilers of the same type but different capacity, as produced by the same manufacturer. Because of these constantly varying conditions it is up to the fitter to have some personal knowledge of what each type of boiler will do under given conditions.

This does not mean that he must know from personal experiment what each boiler manufactured will do. That is quite manifestly impossible. If, however, he will carefully examine the cast-iron boilers on the market he will soon discover that they, in reality, are covered by three distinct types. The vertical sectional (Fig. 13). The horizontal sectional (Fig. 14). The single casting (Fig. 15). Each of these types have a multitude of variation in detail of construction as produced by the various manufacturers, but it would be a bold claim to make that any type, or any one variety of a given type, would always be the best choice that could be made for all conditions that present themselves to the heating contractor.

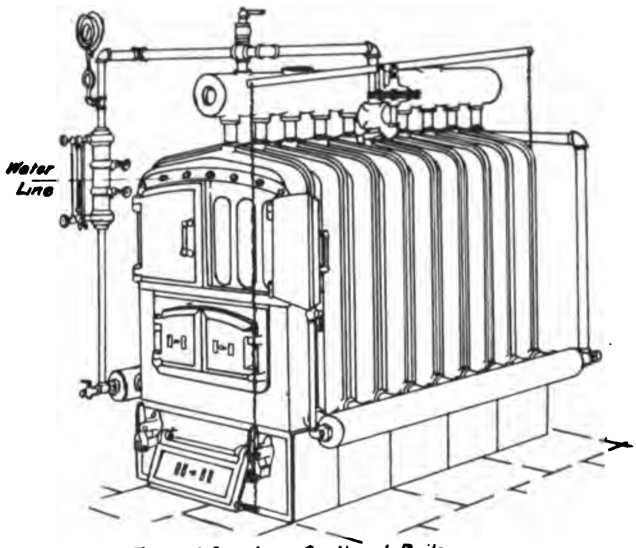
Only a very limited experience in the installing of residence-heating plants is needed to demonstrate that a certain make or type of cast-iron boilers will, under apparently similar conditions furnish widely varying results.

That two owners, using the same size and type of boiler from the same factory and installed under similar conditions, secure different results is partly due to the difference due to the human element involved is undoubtedly true, but this difference in men is not great enough to account for the wide difference in results obtained.

A not unusual condition to find is that of the so-called twin house in which the same system is put into each, and yet the results are measurably different, even when cared for by the same person.

This is particularly true of the smaller sizes of vertical, sectional types. This is because of the greater effect of slight differences in draft upon the small vertical, sectional construction.

For small jobs the round, horizontal sectional will



Common Type of Cast-Iron Sectional Boiler.

Fig. 13.

generally be found to be more even in its work under similar conditions.

There is, however, considerable choice in these round sectional boilers, especially when the chimney draft is not all that it should be. When the draft is known to be somewhat weak a round type with the most direct draft will be found the most effective.

On the other hand, when the draft provided for a small job is excessively strong, a sectional of vertical construction, with small ports and long fire-travel, is the more likely to give satisfactory results.

As a general thing, it will be found that on jobs, which require not to exceed 800 sq. ft. of radiation, that the most practical boiler to use will be some type of the round horizontal sectional patterns. Steam-boilers of the round type with grates of more than 30-in. diameter seem to have rather gone out of fashion within a few years, yet often it would be decidedly to the advantage of both the owner and the fitter if, instead of a vertical sectional, a large, round horizontal sectional boiler had been used.

As a general statement, based upon an experience covering practically the entire heating-territory of the United States, I would say that for either steam or hot-water heating, jobs requiring less than 1,000 sq. ft. of radiation for steam, or 1,650 sq. ft. for hot-water, the round, horizontal, sectional boiler has proven itself to be more even in its performance, and more economical, in fuel consumption, than have the small-sized vertical sectional types. That they have given way to the vertical sectional is a proof of the selling ability of the manufacturers and I am inclined to say of the lack of knowledge of heating-surfaces and their value on the part of the public.

This statement leads up to the discussion of the value of heating-surface in the different types of cast-iron boilers.

The very first thing to do is to emancipate yourself from all attempts to measure house-heating boilers by the same rules one would apply to power-boilers.

SECTION XXII.

It may be well to state here as concisely as possible the accepted terms of rating power-boilers in order to show how entirely different the conditions of rating really are.

House-heating contractors are often asked by those who have not looked into the matter at how many horse-power a given cast-iron house-heating boiler is rated.

It would seem that this, then, will be a good point to begin the explanation of why the modern heating-boiler is not rated in terms of power-boilers or by horse-power.

"The term horse-power has two meanings when applied by engineers: First, an absolute unit or measure of the rate of work done in a given period of time."

This unit of time has been accepted as one minute; and the measure of work has been accepted as that necessary to raise 33,000 lb. one foot, or 33,000 foot-lb.

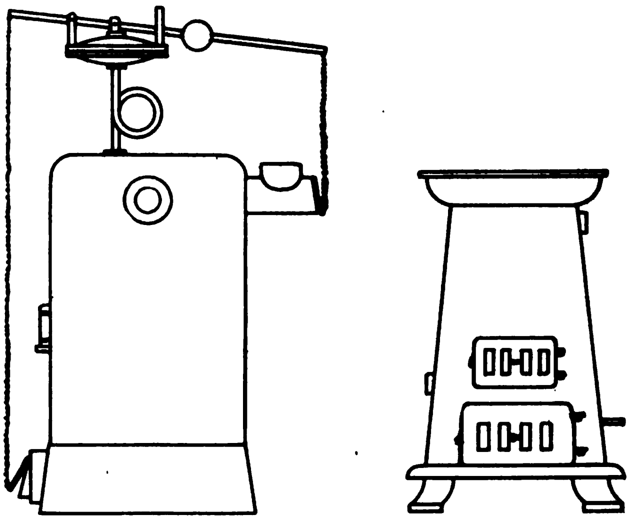
"When the work done, the conversion of water into steam, cannot be expressed in foot-pounds of available energy, the usual value given to the term horse-power is the evaporation of 30 lb. of water having a temperature of 100 deg. F. into steam at 70-lb. pressure above the atmosphere."

The term horse-power was first used by James Watt as a means of comparison. He concluded that a good London draught-horse could exert sufficient energy or power to raise 33,000 lb. one foot above the ground in one minute and he therefore decided that, if the energy or power exerted by such a horse was equalled by the energy or power developed by steam evaporated from 30 lb. of water at some stated pressure, that energy should be termed a horse-power. It will be seen that the unit of time and the unit of energy to be exerted in

Fig. 14.

the unit of time are simply terms of comparison which have been accepted by common consent as a guide or measure.

"The second definition of the term horse-power is an approximate measure of the size, capacity, value or rating of a boiler, engine, water-wheel or other source or conveyor of energy, by which measure it can be described, bought, sold, advertised and so forth. No definite value can be given to this measure, which varies largely with local custom or individual opinion of the makers and users of machinery. The nearest approach to uniformity which can be arrived at in the term horse-power used in this sense, is to say that a



Common Types of Cast-Iron Single Casting Boilers.
Fig. 15.

boiler, engine, water-wheel, or other machine, rated at a certain horse-power, should be capable of steadily developing that horse-power for a long period of time under ordinary conditions of use and practice, leaving to local custom, to the judgment of the buyer or seller, to written contracts of purchase and sale, or to legal decisions upon each contract, the interpretation of what is meant by the term "ordinary conditions of use and practice." (Trans. A. S. M. E., Vol. 7, page 226.)

When the Centennial Exhibition was held, the question of testing power-boilers was very carefully considered and the judges concluded to define a horse-power for commercial tests to be the evaporation of 30 lb. of water per hr. from feed-water of 100 deg. temperature F. into steam at 70-lb. pressure per sq. in. above atmosphere. These conditions were considered as representing fairly the practice in this country of the users of power-boilers.

It will be observed that this calls for the use of 1110.2 B. t. u. to evaporate one pound water.

The unit of power proposed for this country therefore is the development of 33,305 heat units per hour. This unit has been accepted by the engineering societies of the country as the proper base of comparison for power-boilers.

In order to clearly understand the very considerable difference in the manner of rating we must explain the unit of evaporation as it is called. Professor W. Kent defines it as follows: "It is the custom to reduce results of boiler-tests to the common standard of weight of water evaporated by the unit weight of the combustible portion of the fuel, the evaporation being considered to have taken place at mean atmospheric pressure, and at the temperature due to that pressure, the feed-water being also assumed to have been supplied at that temperature. This is, in technical language, said to be the equivalent evaporation from and at the boiling point at atmospheric pressure, or "from and at 212 deg. F."

This unit of evaporation as described by Prof. Kent is equivalent to the development of 965.7 B. t. u. or as commonly stated 966 B. t. u. The measure for comparing the "duty of power-boilers" is the number of pounds of water evaporated per pound of combustible, the evapora-

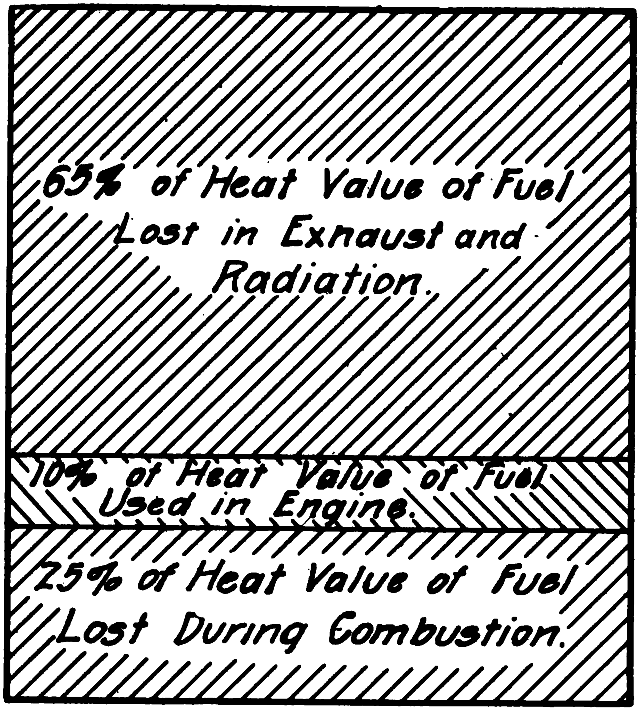


Fig. 16.

tion being reduced to the standard of "from and at 212 deg. F.; that is, it is the equivalent evaporation from water at a temperature of 212 deg. F. into steam of the same temperature.

"The measure of the capacity of a power-boiler is the amount of boiler-horse-power developed, a horse-power being defined as the evaporation of 30 lb. of water per hour from 100 deg. F. into steam at 70-lb. pressure or 34½ lb. per hour from and at 212 deg. F."

The measure of relative rapidity of steaming of power-boilers is the number of pounds of water evaporated per hour per square foot of heating-surface. The measure of relative rapidity of combustion of fuel in power-boiler-furnaces is the number of pounds of coal burned per hour per square foot of grate-surface. (Kent, page 678.)

These extracts from the highest American authorities as to what constitutes a horse-power, in a power-boiler value, is ample to show the futility of attempting to apply "horse-power" data to the present ratings of cast-iron steam-boilers.

The power-boiler begins to rate for horse-power when the steam has a gage pressure of 70 lb. The maximum rating of the cast-iron, house-heating boiler is only 2 lb. at the boiler. The power-boiler is to evaporate 30 lb. of water into steam of 316 deg. F. temperature in one hour, in order to develop one unit or one horse-power, while the cast-iron, house-heating boiler is rated to evaporate approximately 34½ lb. of water into steam of 212 F. in same time.

The power-boiler is supposed to deliver its steam to an engine where a portion of its heat and power is used by the engine and a much larger portion in the shape of latent heat is thrown off in the exhaust. This exhaust represents a great fuel consumption, how great can be easily considered when we consider the fact that the exhaust from an ordinary electric-light plant is usually sufficient to heat the houses lighted. The house-heating boiler is supposed to use all the steam produced in it for the sole purpose of heating.

Figure 16 will give an idea of this fuel-consumption loss when the exhaust steam from a power-boiler is not untilized in heating and also shows very clearly why boilers which are to be used exclusively for heating are not rated in terms used to describe power-boilers.

Almost without exception, persons who are accustomed to high-pressure boilers seem to think they must determine low-pressure house-heating plants by high-pressure terms and conditions. They forget, or perhaps do not know, that the horse-power unit has a temperature of 316 deg., while the house-boiler unit has a temperature of only 212 deg. F.

Almost never does a client who is acquainted with high-pressure work fail to ask the dealer in house-heating boilers what horsepower the boiler under discussion will develop. If the dealer or steam-fitter answers that he does not know, in nine cases out of ten, he loses the prospective customer. Or, if the dealer states that house-heating boilers are sold on an evaporation basis, not on horse-power ratings, the customer immediately states that there is no difference, and wants to know what the size of the grate is in the boiler under consideration.

Some patience on the part of the dealer is usually called for at this stage of the negotiations, especially if, as is often the case, the dealer is not expert in power-work.

SECTION XXIII.

I am taking up this side of the boiler question at this point because it has so often come to my knowledge that the sale of a really proper house-heating boiler has been lost to some steamfitter on small house-work, because he could not translate into power-terms the cast-iron, heating-boiler ratings.

The man who immediately wants to know the horse-power of a modern house-heating boiler is usually a very intelligent person, one who can be shown, and who is capable of understanding any clear explanation. But he is also, usually, one who has a lot of ideas perfectly applicable to power-work with a working pressure of anywhere from 30 to 100 lb. pressure per sq. in. These ideas must be translated into the modern practice of heating with the boiler pressure not above 2 lb. and the maintenance of that pressure for 8 or 10 hours or even 12 hours on one firing.

In the process of this translation many things, of course, are sure to arise that can not be taken up in detail here, but the more frequent things concern only a few points. The careful reader of these pages will probably be able to fully explain most any question that will come up. The matter of grate-surface, fire-surface, ratio of heating to grate-surface, heating-surface per horse-power, pounds of water evaporated per square foot of heating-surface, pounds of fuel per square foot of grate per hour—all these are questions almost sure to be asked and if answered without carefully explaining the different view the house-heating man takes of the value of each from that taken by the power-man, the steam-fitter is pretty certain to have some rather sarcastic remarks addressed to him.

All these questions are important and are all proper ones to ask, the difficulty with them being that they have a somewhat different aspect when applied to house-heating boilers than when applied to the power-boilers. Readers will, of course, understand that the foregoing remarks are supposed to apply to small house-heating boilers only. In jobs of sufficient size to require power-boilers for mechanical purposes, the exhaust would be probably utilized and in selecting such a boiler the conditions necessary to produce the most economy in power would be sought, in the same manner that in a small job where the boiler is to be used for heating only, conditions should be sought that will give the most economy in heat.

High-pressure engineers quite frequently use data approximately as follows:

1 sq. ft. of heating-surface will evaporate 2 lb. water per hr.

1 horse-power equals 30 lb. water evaporated.

15 sq. ft. of heating-surface equals 1 horse-power.

1 horse-power will supply 100 sq. ft. of radiation.

1 sq. ft. of heating surface will supply 7 sq. ft. of radiation.

1 sq. ft. of radiation will condense .03 lb. steam per hr.

It will be at once evident that these conditions cannot apply to a boiler which is rated at its maximum at 2 lb. The average cast-iron steam boiler for heating purposes under average working conditions will evaporate from 2 to 6 lb. of water per hr. per sq. ft. of heating surface. Possibly a grand total average of all the boilers now in use would be below rather than over 4 lb. per hour. Then, as has been shown, 34.5 lb. of water evaporated from and at 212 deg. F. equal 1 horse-power. The common use of 3-column radiators on all house-heating jobs create an entirely new condition from which to figure the condensation per hour, and it is only under most exceptional conditions that the condensation from these radiators will reach even that from 0.25 lb. of steam per hour. But as something must be taken as a basis upon which to work from, the manufacturers seem to have tacitly accepted 0.25 lb. of steam condensed as expressing the condensing power of cast-iron radiators per sq. ft. per hour when considering the evaporative power of cast-iron boilers. Under these conditions, altogether different results will be obtained from those which the high-pressure data would produce. The statement of present ratings for cast-iron heating-boilers could be fairly presented, perhaps, by data something like the following:

1st. 34.5 lb. of water evaporated from and at 212 deg. F. equals 1 horse-power.

2nd. One square foot of heating surface in the ordinary cast-iron heating boiler will evaporate from 2 to 6 lb. of water per hour, from and at 212 deg. F.

3rd. One square foot of cast-iron radiation will condense from 1/5 to ¼ lb. of steam per hour in air of 70 deg. with pressure at the boiler at 2 lb.

From the foregoing it is evident that the condensation of the radiators per hour, per square foot of surface, practically determines the so-called horse-power capacity of the boiler to which it is attached. It is also evident that the heating surface of the boiler itself cannot be taken as a certain guide to its capacity to carry a given number of feet of radiation.

The old notion that 1 horse-power would only carry 100 sq. ft. of radiation falls to the ground badly crippled in the examination.

The high-pressure 100-ft. notion is developed in this way. With 70-lb. pressure at boiler the evaporation of 30 lb. of water equals 1 horse-power. At this difference of temperature between the steam and 70 deg. F. in the room 0.3 lb. of steam will be condensed per hour per square foot of surface in the radiator. Then the 30 lb. steam divided by the 0.3 lb. which 1 sq. ft. condenses equals the 100 sq. ft. required to evaporate the 30 lb. steam at 70-lb. pressure at boiler.

It has been shown that with 2 lb. at boiler there must be condensed 34.5 lb. of water to equal 1 horse-power; that the 30 lb. of water evaporated for a horse-power is at the temperature of steam at 70-lb. pressure, while the 34.5 lb. must be evaporated into steam at a lower temperature by about 100 deg. F. If the condensation per hour per square foot of radiation is only 1/5 lb., then with a condensation of 34.5 lb. per hour, the boiler would supply a heating surface of 172.5 sq. ft. per horse-power. Thus 34.5 divided by 1/5 equals 172.5 to be placed in the rooms. If the radiators were so efficient that they condensed 1/3 lb. of steam per sq. ft. per hour, then 1 horse-power would only require 103.5 sq. ft. of radiation per horse-power.

The following table FZ will show very clearly the varying amounts of radiation that one so-called horse-power will "carry" at different rates of condensation:

If any reader should ever find radiators so excellent that they will condense more than 1/3 lb. of steam per hour, or be so unfortunate as to purchase some that will condense less than 1/5 lb. per hour (there have been such in the market) he can get the number of square feet of surface that will be required to equal 1 horse-power by finding the evaporation per square foot per hour and divide the 34.5 lb. steam required for 1 horse-power by the ascertained evaporation. Thus; Suppose that some one has produced a radiator that will condense ½ lb. steam per square foot per hour: 34.5 divided by ½ equals 69 sq. ft. that 1 horse-power would "carry." Or, assume that the radiator was so poor that it would not condense more than 1/6 lb. per sq. ft. per hour: then 34.5 divided by 1/6 equals 207 sq. ft. radiator surface required to condense 1 horse-power in 1 hour.

As previously stated, the boiler manufacturers have practically accepted as the basis for rating their boilers a condensing power of ¼ lb. of steam per hour per sq. ft. of radiation.

By taking this as the rule to apply to all cast-iron heating boilers, quite a few of the talking points of the average boiler salesman can be compared and checked against his catalog.

The first point to ascertain is the evaporative power of the boiler under consideration per square foot of its heating surface. The salesman may claim that the boiler he is trying to sell has an evaporating power of 6 to 8 lb. of water per hour, per square foot of the heating surface in the boiler.

You desire a small boiler of say, 500 sq. ft. rated capacity. You recall that the rating of all cast-iron steam boilers is on the basis of ¼ lb. steam per sq. ft.; then the 500-lb. boiler you require must deliver 125 lb. steam per hour. If this boiler can evaporate 8 lb. water per square foot of heating surface then the boiler can only have 15.6 sq. ft. of heating surface. ($125 \div 8 = 15.6$) If the sales agent is correct, then it must be necessary to drive the fire at a very high temperature. Only a few of the catalogs publish the producer's claim as to square feet of heating surface in his goods, and none of them as yet state the number of hours that the rating they do

TABLE FZ.

Pounds of Water Evaporated per Sq. Ft. Heating Surface per Hr.	Sq. Ft. Heating Surface in the Boiler to 1 H. P.	Sq. Ft. of Radiators Condensing 1/5 lb. Steam to 1 sq. ft. Boiler Surface.
2	17.25	10.00
2½	13.80	12.50
3	11.50	15.00
3½	9.85	17.50
4	8.625	20.00
4½	7.66	22.50
5	6.90	25.00
5½	6.275	27.50
6	5.75	30.00

give can be sustained. Among the few published claims for fire surface in boilers rated for 500 sq. ft. steam, I find the range to be from 24¼ to 84 sq. ft. Or from 5.15 lb. to 1½ lb. of water condensed per sq. ft. heating surface per hour, but I find no catalog which states the stack-temperature that was maintained when the rating was fixed, or the pounds of fuel burned per hour during the test. Yet these are all things of importance that the purchaser is entitled to know: things of the utmost importance to the steam-fitter who has to garantee the working of the job, and the heat that it will produce. If the chimney to which the boiler is to be attached has not sufficient draft to maintain a stack-temperature of 600 deg. it would be useless to put on that job a boiler that must develop that stack-temperature in order to maintain its rating.

The boiler may be, and probably is, correctly rated. In fact it may have developed a power considerably in excess of the catalog-rating under the 600-deg. stack-temperature.

TABLE F Z.

Sq. Ft. of Radiators Condensing ¼ lb. to 1 sq. ft. Boiler Surface.	Sq. Ft. of Radiators Condensing 1/3 lb. to 1 sq. ft. Boiler Surface.	Sq. Ft. Boiler Will "Carry" per H. P. Lb. 1/5	Lb. 1/4	Lb. 1/3
8	6.00	172	138	103
10	7.50	172	138	103
12	9.00	172	138	103
14	10.50	172	138	103
16	12.00	172	138	103
18	13.50	172	138	103
20	15.00	172	138	103
22	16.50	172	138	103
24	18.00	172	138	103

But this same boiler, working at a stack-temperature of 350 deg. may not, probably will not, develop a power to evaporate more water than will supply 375 sq. ft. of radiation with steam.

The highest authorities obtainable all agree that the point of greatest fuel-economy in power-boiler construction is that which is so constructed that each square foot of heating surface will develop from 2 to 4 lb. of steam per square foot of heating surface per hour with a stack-temperature from 450 to 500 deg. F. in the stack-gases. As has been demonstrated, the house-heating boiler works under a much lower pressure and has to evaporate 34.5 lb. of water per hour at 2-lb. pressure at the boiler instead of 30 lb. at 70 lb. pressure as does the power-boiler.

SECTION XXIV.

This difference, coupled with the long interval between firing dates, has developed the fact that for house-heating boilers a stack-temperature of from 300 to 450 deg. F. is within the range of reasonable requirement for either the producer or the owner. If, however, the firing period is to be extended to 12 hours, or from 6 to 7 at night, to 6 or 7 in the morning, then a constant stack-temperature of 450 deg. would be found to be high for practical use.

Owing to the fact that the catalogs of nearly every cast-iron heating boiler manufacturer fail to give anything in the way of definite information regarding the fire surface, the stack-temperature required to secure the evaporation claimed per square foot of heating surface, the total evaporative capacity secured when the tests were made, the pounds of coal that the fire-pot holds, when what is considered by the manufacturer as the proper amount for a full charge is to be put in, or the pounds of coal burned per hour during the test, there is but little, apparently, that the steam-fitter or owner has to guide him in selecting a boiler.

About all that the average catalog of heating boilers gives out, that can be easily made available for the purpose of determining whether a given boiler is in reality a suitable one to put on a certain job or not, is the grate size, the height of water-line, diameter of smoke-pipe, total height and width, and the claimed radiation-capacity, or rating. Each and every manufacturer will claim that his goods are "conservatively" rated. "That the rating is based on the assumption that hard coal is to be used for fuel," "that the steam ratings are based on a standard of two (2) pounds pressure at the boiler, and the water-ratings at a temperature of 180 deg. F. as it leaves the boiler."

It has been said by one writer that the manner of figuring for radiating surface under the old ratio-rules might be called "rules of thumb." We have seen that the usual manner of fixing pipe-sizes is a guessing contest. What can be said of the way the boiler ratings are stated?

No man is warranted in saying the rating on any house-heating boiler is not correct. There is not a boiler rating published that is not a conservative rating at *some* stack temperature, and yielding a certain amount of condensation per square foot of grate and heating surface per hour. The fact is that, if all the ratings were brought to one common basis there would be many surprises among the fitters of this country.

It is not an unheard-of thing that the castings made from one set of boiler patterns are assembled and sold under different names, and that the rating given under each name is different from that of the same castings under another name.

The selling agent who is disposing of each product is willing to garantee that the rating on his particular name of boiler is very conservative and based on 2-lb. pressure at boiler. He is perfectly willing to go farther and garantee that the boiler will "hold its rating providing it is fired *with suitable fuel and given sufficient draft.*" But not one of them states the time in hours that he expects his particular boiler to "carry" its load.

Like many of the apparent puzzles in the heating business, the solution is simple when the full facts are known.

Bearing in mind that at this time the most of the catalogs are giving out but little, if any, information in regard to ratings, it may be of interest to study this steam boiler-rating question from just the available data given out with most of the ratings, aided by the almost unquestioned fact that the average condensation of water per pound of anthracite coal is 8½ lb.

The first thing to find out is whether the total capacity of a given boiler to evaporate water is practically constant at all stack-temperatures.

For the purpose of this illustration let us take a steam-boiler having a catalog rating of 500 sq. ft. The grate size may be given as 432 sq. in. or 3 sq. ft. The catalog does not usually give anything definite as to size of the fire-pot, or the amount of coal in pounds considered as a full charge, therefore we must get at it approximately.

The catalog most certainly will not state, as it should, the number of pounds of coal burned per hour per square foot of grate surface when the rate was fixed. Nor will it state, as it should, the pounds of hard coal considered by the manufacturer as being the fire-pot capacity.

A catalog, giving the stack-temperature during the test, or the number of hours the boiler is supposed to run on one charge of fuel and maintain its rating, has not as yet been published, so far as I have knowledge of catalogs.

Each of these things must be made clear, however, if boiler-ratings are to be of any more value to the steam-fitter than that of a guide to a blind guess as to what the "garanteed rating" may possibly mean.

If the reader will follow closely at this time he will find the reasons, or at least some of them, why all of these things should appear in the description of every boiler as surely as the height of the water line, or any item the producers now give out. Having only the grate surface to start with, but with every desire to be perfectly fair to the manufacturer, let us find out, if we can, what this 500-ft. rating may mean.

Probably no one producer would object to having his boiler figured as burning 8 lb. coal per hour, per square foot of grate as the base of getting at the full capacity of it. His catalog says the grate in this boiler has 3 sq. ft. of surface. Then the boiler, when "sufficient draft and good hard coal is used," will burn 24 lb. coal per hour during the test. As there is absolutely no way of finding out positively the square feet of heating or fire surface from the modern catalogs, with two or three notable exceptions, let us assume that this boiler has the average heating surface shown to be in these, namely, 54 sq. ft. In order to find out the full evaporative power of the boiler it is evident that we must first find the pounds of coal that the grate will burn per hour, and multiply that amount by the pounds of water that the coal will evaporate. The catalog fails to state the evaporative value of the coal used at time boiler was rated, therefore we will use the average evaporative power of 8½ lb. of water to the pound of coal.

Twenty-four pounds of coal then yields 204 lb. of steam. The 54 sq. ft. heating surface has an evaporative value of 3.78 lb. per ft. per pound of coal burned. To get the full value of the boiler, multiply the total heating surface by the value of one foot of it ($54 \times 3.78 = 204$ lb.) and divide that sum by the total pounds of coal the boiler will consume in one hour, or 24 lb. The full evaporative power of the boiler then is 8.5 lb. steam for each pound of coal when 24 lb. are consumed in one hour. But suppose a slower combustion, a lower stack-temperature, causing only 20 lb. of coal to be burned per hour. The showing as to *total* boiler capacity will not be materially changed, for each pound of coal yields 8½ lb. evaporation whether it is burned with a stack-temperature of 700 deg. or at 300 deg. It is not at this point that the stack-temperature becomes vital. But to clear the point as to the total evaporative power of the boiler under consideration. The 20 lb. of coal will evaporate $20 \times 8\frac{1}{2} = 170$ lb. water per hour. $170 \div 54 = 3.15$ lb. per square foot of heating surface or a full value of 8.5 lb. $(54 \times 3.15 = 170 \div 20 = 8.5)$. At a still slower combustion, say, 4 lb. per square foot of grate per hour, the full value of the heating power remains practically the same. The 12 lb. coal burned yield 102 lb. evaporation; the heating surface is worth only 1.9 per foot or a full value of 102 lb. per hour. This, divided by the total coal burned, or 12 lb., shows the full power of the boiler to be the same as in the previous cases mentioned, or 8.5 lb.

This shows that the rate of combustion, within reasonable limits, *does not affect the total evaporating power* of the boiler.

What, then, is the use of the stack-temperature at time of rating being in the catalog? If the rating-question stopped at the point of finding the total capacity of a boiler to condense water, there would be no need of it, but, as we shall see, the whole rating-question does not end with the finding out the size of grate, the square feet of heating surface, and the pounds of coal burned per hour per square foot of grate.

It is very needful that the engineer, or the steam-fitter, shall know how many hours the boiler will continue to convert water into steam on one full load of coal. He must know as to the rate of combustion required, in order to determine whether the chimney provided by the owner is capable of furnishing the required stack-temperature, and he needs to know how many pounds of coal the fire-pot will hold, in order that he may intelligently use the boiler under conditions that vary from those selected by the manufacturer in rating the boiler.

Having found that the boiler has a possible power of condensing 8.5 lb. water per sq. ft. of heating surface per hour, and that there are 54 sq. ft. in the boiler, the information is of no particular value unless the pounds of coal the fire-pot will contain is also known.

It is certain that if 24 lb. of coal are needed to carry the rating one hour, it will require eight times as much to continue the work for eight hours. But where is the boiler catalog that plainly states the capacity of the fire-pot in pounds of coal of any boiler listed?

In the case we are considering, the fire-pot should hold not less than 240 lb. as a full charge, for an 8-hr. run at full capacity would use 192 lb. and no boiler should burn up over 4-5 of its total fire-pot capacity during the time it is to keep up steam without new fuel being added. At least 1-5 of the coal will be needed to start the new fuel-charge into combustion.

We will therefore consider that there are 192 lb. of hard coal to be used in making the tests and that the test is to be made for 6 different stack-temperatures, or rates of combustion, from 750 deg. F. to 250 deg. F., inclusive.

The data we have accumulated in regard to this boiler can now be tabulated as follows:

Size of grate .... 3 sq. ft.
Total heating surface .... 54 sq. ft.
Total lb. hard coal fire-pot will hold.........240 lb.
Total lb. to be burned each test, 4-5 total.....192 lb.

When the boiler-catalogs give these items and also the hours the boiler is expected to remain its rating, and at what stack-temperature, or rate of combustion, the steam-fitter or the engineer will be able to determine for himself the conservatism of the catalog-rating.

SECTION XXV.

The importance of having all these items in a catalog is clearly shown in Table GZ, which shows the results of an 8-hr. test based on the foregoing data, each item showing the results from each of the 6 different rates of combustion.

The rather startling differences in the various "conservative' ratings which the same boiler will afford when rated under different rates of combustion (all of them within the possible range of good chimneys) indicates very sharply why great care should be exercised in the selecting of a boiler, to ascertain the condition of the chimney first. (See Sections I and II in this work. These sections will prove of great value in the consideration of chimney-values.) The strength of the draft may compel the use of a boiler rated with a stack-temperature of only 250 or 300 deg. if a satisfactory job is to be secured; or, the draft may be so strong that one rated under a stack-temperature of 600 or even 800 deg. F. should be used. It is true that the same boiler might be used in either case, as shown by table GZ. But an intelligent fitter would not put a boiler rated to carry 500 sq. ft. radiation under a stack-temperature of 550 deg. on to a chimney that would not develop a stack-temperature above 225 or 250 deg. for that boiler, and expect it to carry its rating. There is one other thing than can be developed from Table GZ. Item 10 shows the total capacity of the boiler to be 1,632 lb. of steam. If this was all to be condensed in 6 hours there must be 272 lb. condensed per hour, requiring a rating of 1,088 sq. ft. radiation, with no allowance for "conservatism."

TABLE GZ.

Showing the different ratings the same boiler will require to comply with the evaporation secured at various rates of combustion and stack temperature.

Item	1—Stack temperature, deg. F	750
"	2—Grate size, sq. ft	3
"	3—Total heating surface, sq. ft	54
"	4—Fuel to be burned, 4-5 total	192
"	5—Fuel burned in 1 hour, lb	24
"	6—Fuel burned per sq. ft. grate in 1 hour (Item 5 ÷ Item 2)	8
"	7—Lb. water 1 lb. coal evaporates	8.5
"	8—Evaporation per hour per sq. ft. of heating surface. Lb. $\frac{\text{Item 5} \times \text{Item 7}}{\text{Item 3}}$	3.78
"	9—Evaporation possible from total heating and grate surface $\frac{\text{Item 3} \times \text{Item 8}}{\text{Item 5}}$	8.5
"	10—Total lb. boiler can evaporate from the full quantity of fuel to be used in test (Item 4 × Item 9)	1632
"	11—Total evaporative power of boiler developed in 1 hour from fuel burned in 1 hour (Item 5 × Item 9)	204
"	12—Total radiator-rating possible, based on each sq. ft. radiator condensing ¼ lb. steam per hour (Item 11 ÷ 0.25)	816
"	13—"Conservative" catalog-rating if 15 per cent is deducted from the test-showing, as a factor of safety	694

If Item 10 is divided by the hours the boiler is to be run without attention, the gross rating of the boiler for that number of hours will be the result. Table HZ

TABLE GZ.

Showing the different ratings the same boiler will require to comply with the evaporation secured at various rates of combustion and stack temperature.

650	550	450	350	250
3	3	3	3	3
54	54	54	54	54
192	192	192	192	192
21.6	19.2	16.8	14.4	12
7.2	6.4	5.6	4.8	4
8.5	8.5	8.5	8.5	8.5
3.4	3.2	2.64	2.27	1.88
8.5	8.5	8.5	8.5	8.5
1632	1632	1632	1632	1632
183	163	142	122	102
732	652	568	488	408
622	554	483	415	347

shows another set of ratings based on the data developed by Table GZ, Item 10.

From the facts developed in Tables GZ and HZ in regard to the ratings possible to be given any steam-boiler, and the vital importance of stack-temperature in the working out of a rating, as well as the number of hours run when the rating was established—Does the average catalog leave the engineer or the steam-fitter

TABLE HZ.

Showing the Gross Radiator-ratings Required to Condense Periods, when the Total Capacity of the Boiler from 2 lb. Also "Conservative"

Number of Hours to Maintain the Rating.	Pounds of Steam to be Condensed Each Hour.
6	272
7	233
8	204
9	181
10	163
11	148
12	136
13	129
14	116
15	109
16	102

with anything but a wild guess as to what the rating may, or may not, mean? It should also be stated that these tables only contemplate an evaporation of 8½ lb. water per lb. coal and 3.78 lb. evaporation per sq. ft. heating surface. A given manufacturer may claim to evaporate 6, or 4, or 2, or 1½ lb. water per sq. ft. of heating surface. The value of that surface represented in radiator surface condensing ¼ lb. steam per hour would be, if the evaporation is 6 lb. per sq. ft. heating surface, 24 sq. ft. of radiator surface.

If the evaporation is 4 lb. the radiator capacity is 16 sq. ft. per sq. ft. heating surface. If the evaporation is 2 lb. the radiator capacity is 8 sq. ft. If the evaporation is 1½ lb. per sq. ft. heating surface the radiator capacity is 6 sq. ft. Therefore the capacity of a boiler claimed by the manufacturer to contain 100 sq. ft. of heating surface

TABLE H Z.

the Steam Produced by a Boiler for Different Hourly
One Full Charge of Fuel is 1,632 lb. Gage-Pressure
Catalog-Ratings for Same.

Total Sq. Ft. Radiator Surface Condensing ¼ lb. Steam per Sq. Ft. to Condense the Amount.	"Conservative" Catalog Rate, 85% of Total.
1088	925
932	792
816	694
724	615
652	554
592	503
544	462
516	439
464	395
436	370
408	347

may be entitled to a rating of 2,400 sq| ft. of radiating surface; it may not be entitled to over 600 sq. ft. rating, or an evaporative value of 1½ lb. per square foot of heating surface, or it may be at any point between.

The present method of cataloging house-heating boilers does not enable one to come much nearer the real facts regarding the goods than a rough guess. If you guess correctly, you are satisfied. If you guess wrong, somebody suffers; usually the owner and contractor; once in a great while the manufacturer.

It may be claimed that as the catalogs all give the grate size, the guess cannot be far wrong as to the correctness of the catalog rating. I am not raising the question of the correctness of the ratings. I will concede that there is not one boiler on the market today that is not correctly rated. But how is it rated, at what rate of combustion, or for how many hours' run without attention, or at what stack-temperature must it be run? All these vital points must be guessed at, until the manufacturers see fit to give out the items.

To illustrate this point. One boiler that has been on the market for a long time has a catalog rating of 500 sq. ft. The catalog says the boiler has 2¾ sq. ft. grate, and 84 sq. ft. of fire surface. The catalog of another equally popular boiler with a rating of 504 sq. ft. claims 3.6 sq. ft. grate. One very popular boiler now on the market and rated at 550 sq. ft. for steam is claimed to have 3.2 sq. ft. grate and 41 sq. ft. of heating surface, while still another cataloged at 700 sq. ft. steam-radiator capacity has a grate surface of 3 sq. ft. and 45 sq. ft. of heating surface!

It will not require a long study of Tables GZ and HZ, and the text which explains them, to realize that the present catalog-method regarding boiler data is like Carlyle's definition of axioms. "Words! Words! High air-castles cunningly built of words; the words well bedded in good logic-mortar; wherein, however, no knowledge will come to lodge." Each of the boilers just mentioned is manufactured by a prominent concern of high standing. The East, West and Middle-West are represented in the four boilers mentioned.

If a contractor has to furnish a client a steam-job and the requirements are that he shall supply steam continuously from 6 p. m. to 8 a. m. the next day for an average amount of 300 sq. ft. of radiation, will the data given as to either of these boilers give the contractor the slightest assistance in selecting the boiler? Suppose an examination of the proposed flue shows a weak, sluggish draft, so that only a very low stack-temperature can be secured, which boiler should he select, having only the usual catalog ratings to guide him? Here are 4 boilers, each with practically the same grate surface relative to the claimed heating surface, each produced by very reputable concerns, yet none of them now give, nor have they ever given, in their catalogs, the data which can enable any one to make an intelligent selection in a case of this sort. Undoubtedly the reason for this condition lies in the fact that it is only within a very few years that the manufacturers of boilers gave up the practice of making the plans for all the jobs into which their product entered, and it was not thought to be good business policy to let the public know all about their goods. Each manufacturer stood behind his own goods with his personal garantee that the rating was a correct one, and each felt that that was all that the public need to ask. Under the old methods they may have been justified in taking that position. But now that they have thrown the burden of the garantee of the working of the boiler, and the job, on to the engineer or the steam-fitter, these latter have a just claim to be furnished *all the facts* in relation to the ratings of the boilers offered for sale.

SECTION XXVI.

Until this is done, the whole heating fraternity must continue to trust to luck in selecting a boiler, or else enter into a long and often fruitless correspondence with the producers of heating boilers. Because of the new conditions, established by the manufacturers themselves when they established the new ratings, the rules for the figuring for radiation, which were applicable to the old ratings, become useless for the man who desires to do reliable work. In fact, the change practically forces every man in the business to get busy and learn the inside working, the why, and wherefore of boiler rating, in order to protect himself. It is quite certain that there are boilers on the market that the manufacturers thereof do not care to state in their catalogs the basis of their rating in full, or even to give out enough information to be of much value to the average buyer. But when the manufacturers adopted the new ratings in 1903 they also forced upon themselves, and the trade, the present situation.

The new conditions compel the engineer and the steam-fitter to study the heating question from a point of view new to many, if not to all of them. The boiler-rating no longer is large enough to cover the piping and all sorts of shortcomings. *The burden of selection and garantee no longer rests upon the manufacturer. He has, therefore, no longer the moral right to withhold from the men whom he has forced to take the responsibility, all the essential facts in regard to the goods produced.*

If a boiler requires a stack-temperature of 700 deg. F. in order to deliver its rating, the man who is to put that boiler into a job and must garantee its performance, certainly is entitled to know of such an important condition. If, on the other hand, the boiler requires a low stack-temperature, but the fire-pot will only carry fuel for a 6-hour run at its rating, the man who has the burden of making the job hold steam for perhaps 10 hours, should know that the rating is for 6 hours, and also on what kind of stack-temperature the rating is based.

The manufacturers have transferred the most of the responsibility; they should now transfer *all the facts* in regard to the rating of the boilers they produce.

While considerable information in regard to boiler-ratings has already been developed in this discussion, it is evident that—

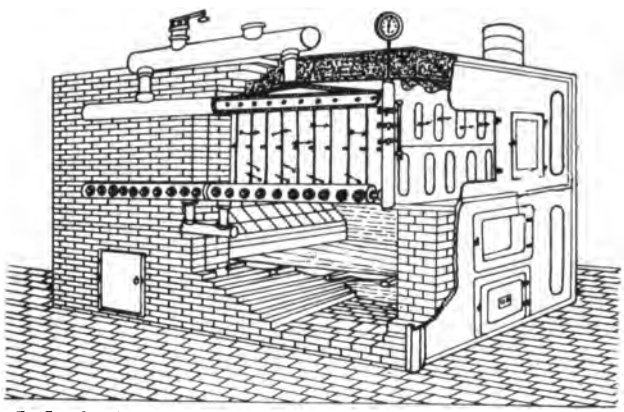
When two boilers with nearly 4 sq. ft. of grate surface and full 84 sq. ft. of claimed heating surface are rated for 500 ft. of steam-radiation—

And another boiler, made by a manufacturer as honest and reliable as the makers of the two mentioned, rates a boiler with only 3 sq. ft. of grate and about 40 claimed sq. ft. of heating surface to carry 500 sq. ft. of steam-radiation—

While another, whose standing and reputation is the equal of either of the others, gives a rating of 700 sq. ft. to a boiler with a grate of 3¼ sq. ft. and a claimed heating surface of 45 sq. ft. —

There must be other things to consider than the simple question of grate and heating surface that the boiler salesmen mostly talk about. But it will be well to examine into this matter of grate and heating surface in order to more fully explain the necessity for one producer to put 84 sq. ft. heating surface into a boiler rated for 500 sq. ft., while another can get the same results with about one-half the amount.

There has been much less change in the construction of house-heating boilers from cast-iron, between those of the earliest types and the very latest, than many fitters think. In Fig. 17 is shown the "Brayton Cast-Iron Sectional Steam-Boiler," which was the first steam-



The First Cast-Iron Vertical Section Heating Boiler with Parts Bolted Together. "The Brayton," Erected in Providence, R.I., in 1864 by George B. Brayton.

Fig. 17.

heating boiler made of cast-iron with its sections bolted together after the modern fashion. This boiler was a good many years in getting recognition from the public. It was first designed as a power-boiler in 1849, and the shape of the cast-iron heating surface has never been materially changed to this day. With the necessary changes to adapt it to heating a building, such as the brick-setting, and the other minor changes such as would be made today in fitting a locomotive-boiler for house-heating purposes (for the original boiler was mounted on a locomotive) Mr. Brayton attempted to use the boiler for heating buildings, but he met with tremendous opposition. The wrought-iron boiler-manufacturers fought him at every step. The public were slow to believe that the cast-iron surfaces could be safe. Mr. Brayton, however, had the courage born of knowledge and conviction, coupled with an indomitable desire to prove the correctness of his theory that cast-iron was the cheapest and safest material for heating boilers. It was not until 1863 or 1864 that Mr. Brayton secured a contract to put one of his large cast-iron boilers into a building in a city of some size. At this time, he entered into a contract to place one of his boilers into a large building located in one of the principal streets of the city of Providence, R. I. The proposition created a tremendous discussion in the city. The wrought-iron boiler-men insisted that the boiler if put in operation would be a menace to life and property. Finally, the city authorities appointed "a special committee of scientists to investigate the character of the new construction in order that the safety of the citizens should be protected." When the committee met, Mr. Brayton suggested to them "that, in order to show them the entire safety of the boiler he proposed to heat the boiler red-hot from the absence of water and then to cool it down to its regular conditions of action, by pumping cold water," asserting that it could be done without danger. The committee rather objected to this, but proceeded to give the boiler a most thorough testing, and finally reported so strongly in favor of the boiler that the city authorities granted a permit for its use at any point within the city limits.

In 1865 the Massachusetts Mechanics' Association, at the American Institute Fair, awarded to this boiler the highest award it could bestow.

The public were not yet convinced that a cast-iron steam boiler was safe, for at this time it must be remembered that 60-lb. pressure was the usual, and 125 lb. to 200 lb. not unusual as the pressure carried on steam-boilers. The heating of buildings with steam had not yet become common.

In 1868 the Brayton boiler was tested by the then ablest associated body of scientists in the country—The Committee of Science and Arts of the Franklin Institute of Pennsylvania. The report of the committee on this Brayton boiler is in many ways a remarkable production. After Mr. Brayton had established the safety of his boiler he sold the patents he held on it and the patterns for making the castings to the Exeter Machine Works, of Exeter, N. H., who changed its name to the "Exeter" boiler. Under this name the boiler has had an enviable sale and record in New England, New York, and Pennsylvania as a power-boiler and as a heating boiler, especially on blower-systems of heating. The "Exeter" was entered in the International Exhibition held at Philadelphia, Pa., in 1876, and again at the Chicago exposition, or World's Columbian Exposition in 1893. In each case this original type of cast-iron boiler made a most creditable showing. The history of this typical boiler would not be complete without a short extract from the official report of a committee of the Franklin Institute of the State of Pennsylvania, to whom the Exeter Machine Works sent one of their boilers for examination as to its safety from explosions. Remember that the Exeter and the Brayton boiler are the same in construction. The committee said in part: "The Exeter Sectional Boiler comes very near to it, if it does not solve the difficult problem of uniting small compartments composing a boiler of considerable size, and at the same time provide for the free escape of steam without lifting the water. Many sectional boilers are so constructed in combining their parts as to cause the steam generated in the lower portion of the apparatus to force its way in zigzag courses through a whole neighborhood of narrow passages or through a number of long, comparatively small, and nearly horizontal tubes, into which it is quite impossible for the water to promptly follow, as it should do in order to maintain perfect circulation, and take up all the transmitted heat before effecting its escape. In many cases these upper sections are alike subjected to the direct action of fire, and become, under a moderate supply of steam, highly heated, rendering them liable to fracture, without increase of pressure from sudden changes in the height of the water.

"The water in the 'Exeter' section exists in vertical masses, about 3¼ in. square and 28 in. high, a form favorable to the ready liberation of the steam to and from the surface of the water, and securing at the same time prompt circulation and supply of water to the heated surfaces of the boiler."

That portion of the above report which refers to the construction of water-ways in boilers has not lost any of its force, or truth, in the years that have passed since 1870. Perhaps, at this time there are some, so-called, new boilers on the market that provide a splendid example of the type of construction that "causes steam to zigzag its way through passages that the water cannot promptly follow."

SECTION XXVII.

I am giving this condensed history of the first successful construction of a cast-iron vertical-section boiler, with the sections bolted together, because, in its general idea of construction, only a very few manufacturers have improved upon it, except in some detail of waterways or other interior arrangement.

Until a very recent period, practically every producer of cast-iron boilers retained the idea of the separately-connected steam-dome, and the so-called mud-drums, as first produced in the Brayton boiler.

Another reason is that Brayton has never received the full credit for which his devotion to the principle that cast-iron was safer than wrought-iron for house-heating boilers entitles him. Some recent writers, in fact, have given the credit to Samuel Gold, who produced the second type. This is only an improvement of the Brayton boiler. (See Fig. 29, page 330.) Samuel Gold was not granted a patent on the Gold boiler until the summer of 1869, or four years after the Brayton boiler had received the highest award that the Massachusetts Mechanics' Association could bestow. But this fact should not dim in the slightest the honor that rightfully belongs to Samuel Gold.* To the writer's mind, it does not appear that those who have preceded him as writers on this subject have given, as a rule, to Samuel Gold the commanding place in the early history of the steam-heating that is his rightfully. From a business point of view, Mr. Gold was very fortunate in the selection of

*Further analysis of Mr. Gold's original patent is presented on pages 329 and 330.

his manufacturing sales-agent. He selected H. B. Smith & Co., Westfield, Mass., who decided to push the boiler, in conjunction with the Gold pin-radiator, as being the most suitable for house-heating work. That they were

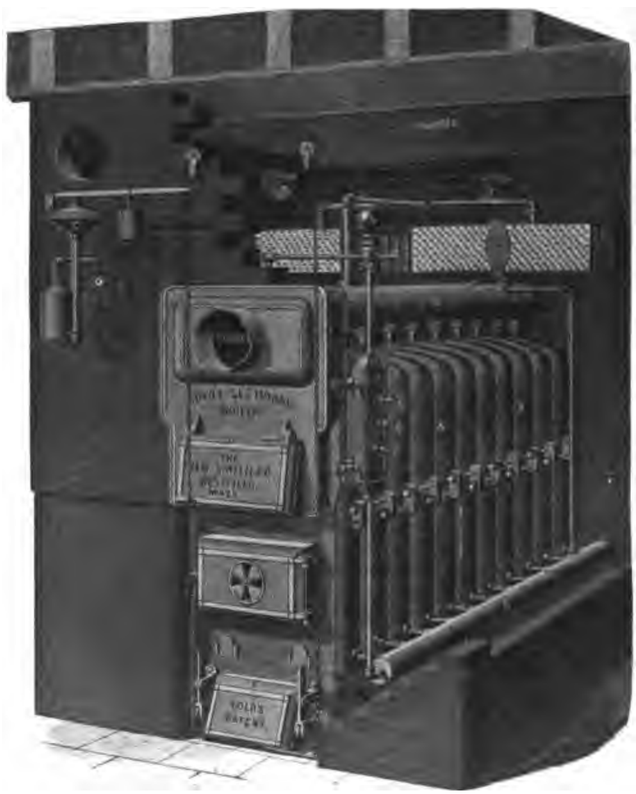


Fig. 18. Gold's Sectional Boiler.

correct in their judgment is evidenced by the great popularity of the combination and the further fact that its introduction as a low-pressure steam-heating system with indirect cast-iron radiators, not only caught the public fancy, but practically changed the entire heating methods

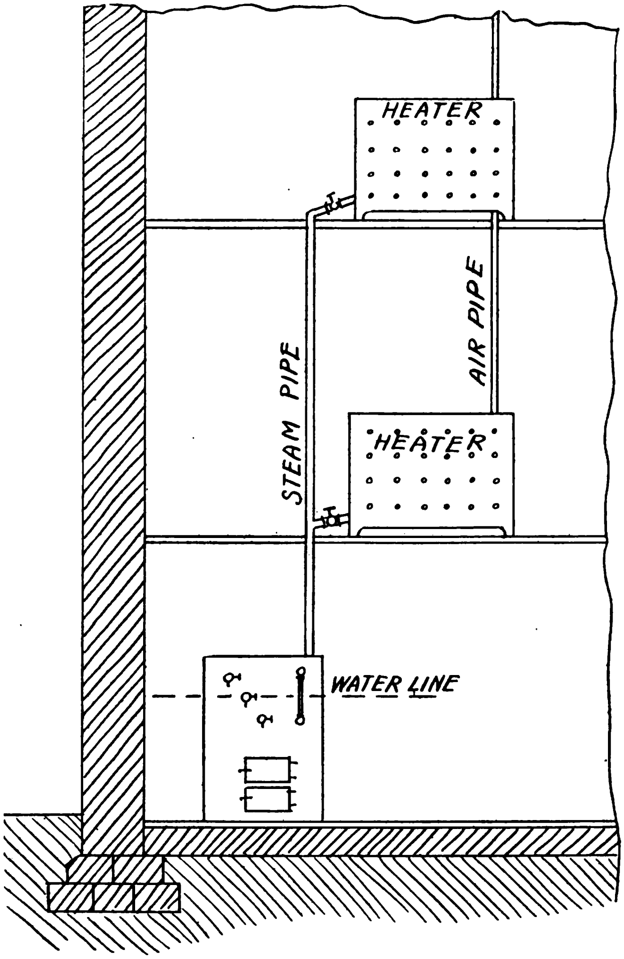


Fig. 19. First Single-Pipe Steam System Used in Low-Pressure Work.

of the whole country. But it was H. B. Smith & Co. that stood in the lime-light of public knowledge of the

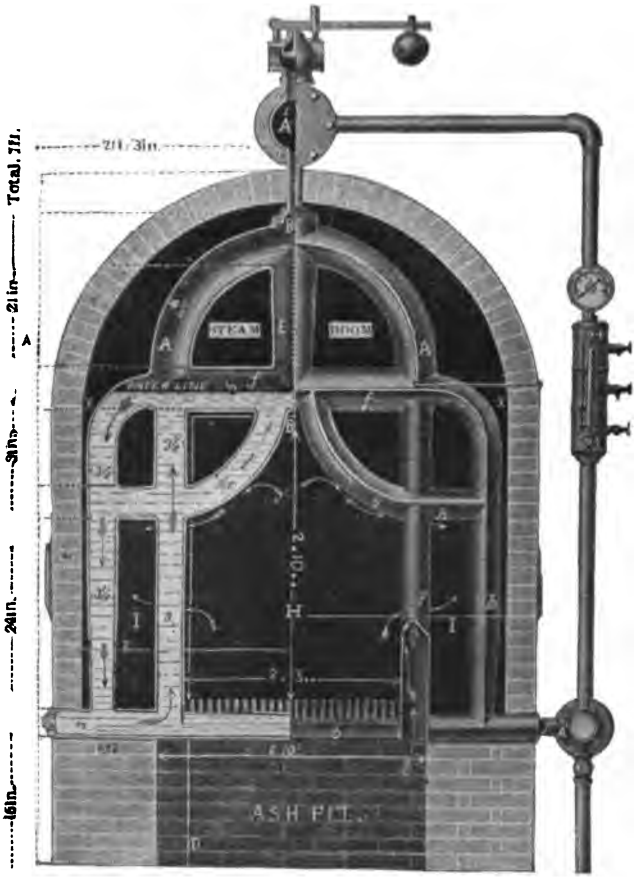


Fig. 20. Mill's Original Safety Boiler.

Gold boiler and the Gold pin-radiator, and not Samuel Gold, the inventor.

No one can, or would even try, to detract in the slightest degree from the glory of achievement due to J. J. Walworth and Joseph Nason, as the first engineers to demonstrate the use of steam as a practical means of heating. But as a historical statement, we must not lose sight of the fact that, notwithstanding that Walworth and Nason were without question the originators of the process of heating buildings by steam, Samuel

Fig. 23. The Harrison Boiler.

Gold was the first inventor, in this country at least, to devise a safe and practical steam-heating apparatus for small buildings and homes, that could be operated without a special engineer, and with perfect safety, as the only pressure generated was that caused by the friction in the pipes. This apparatus was first placed before the public in either 1856 or 1857 in a very limited way. In

1859 Gold's system of steam-heating began to attract attention. The radiators were made of sheet-iron riveted. Each radiator was fed by one pipe which was carried to the highest radiator on the circuit, the condensa-

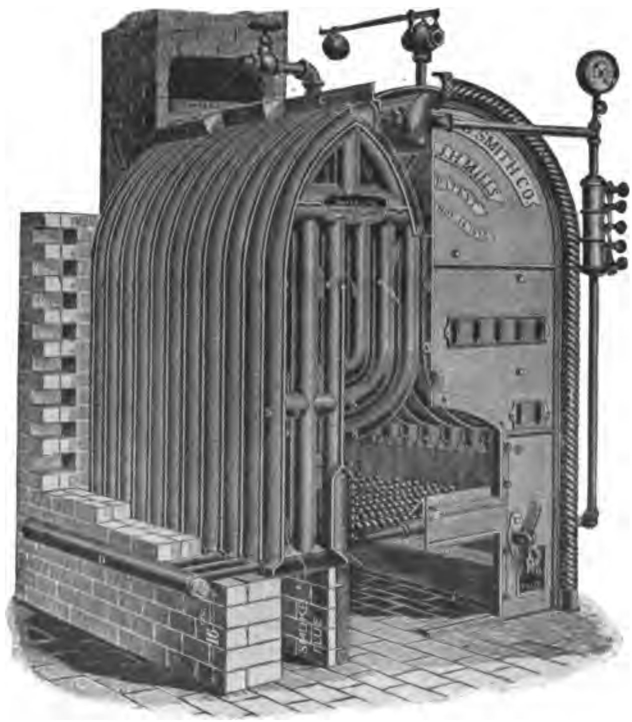


Fig. 21. Mill's Improved Boiler.

tion flowing back to the boiler automatically. A pipe, called an air-pipe, was connected to the end opposite the end at which the steam entered the radiator, in such manner that the steam not condensed in the radiator continued on to the outer air. Fig. 19 gives the idea.

This was not only the first *practical* and safe steam-heating apparatus, for low, or non-pressure house-heating work, but was the first single-pipe steam-system, so far as I have discovered, to be used in low-pressure work.

The use of sheet-iron radiators was furiously attacked by the manufacturers of the several types of cast-iron

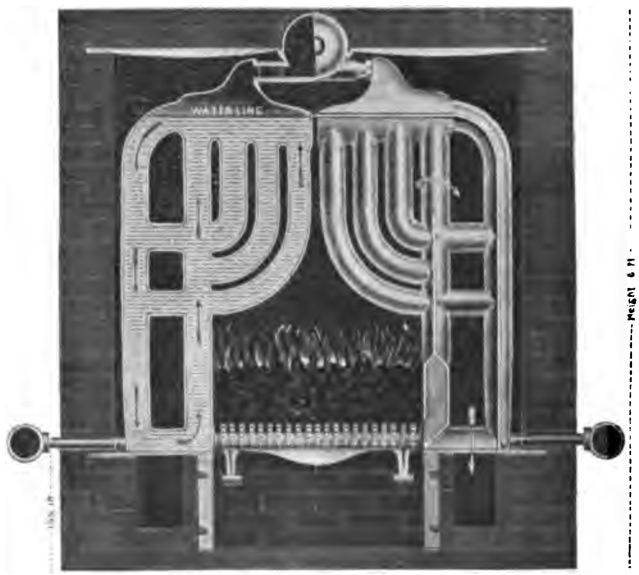


Fig. 22. Mill's Twin Section Boiler.

radiators, or heaters, as they were then called, on the one hand; and by the wrought-iron pipe-men on the other. The high-pressure steam-men also brought all their forces of ridicule to bear upon the apparatus. Mr. Gold, however, kept at his task and kept on investigating. He quickly saw the value of T. T. Tasker's apparatus for returning the water of condensation to the boiler in a closed apparatus, and evidently studied Brayton's boiler with care. While the public had accepted his non-pressure system with considerable satisfaction, the great bulk of the sheet-iron surface placed in the rooms caused a prolonged wail of protest from the artistic architect, and from the housewife who had "some special thing to put right where that hideous great heating thing had to go." The cry rose loud from these quarters to "get those unsightly radiators away." In 1862 the Nason pipe-radiator was put on the market. These were an improvement, but having gained this much the cry still went up that some one should find a way to heat homes with steam at a moderate expense, but without the use of direct radiators in the rooms. When Samuel Gold brought out the improved Gold system, which included the new cast-iron boiler and the cast-iron indirect radiator, known as the Gold pin-radiator, in 1869, the question seemed to have been solved.

It is a fair statement to say that the real beginning of the general use of steam for heating dwelling-houses should date from the introduction of the Gold system. Fig. 18 is an illustration of the improved Gold boiler with the pin-radiators placed in the hot-air chamber.

In 1872, the Mills boiler was brought out. This boiler was constructed under the patents obtained by the late John H. Mills, of Boston, who was also the patentee of the Mills overhead system of steam and water-heating. The Mills boiler presents the first radical change from the idea of construction that Brayton established in his boiler which, as stated, is now known and sold as the "Exeter," and which under that name held its own at the World's Fair at Philadelphia and also at the great Exposition at Chicago, in each case entering the competition for high-pressure boilers. This point must not be overlooked. The Mills boiler was also designed as a high-pressure boiler. Mr. Mills, in his book on "Warming and Ventilation of Buildings," reproduces several letters from users of his boilers wherein the pressure is stated at various pressures from 60 to 165 lb., the average being about 100 lb.

Figs. 20 and 21 show the original and the improved form of Mills' boilers. It will be well to study the Brayton or Exeter, the Gold, and the Mills boilers with great care. With one exception they represent the whole field of vertical sectional boiler-making in cast-iron designs. There are a host of variations in the construction of the water-ways and of the smoke and gas-travel; various, and sometimes unintelligent, grouping of alleged heating surfaces. This is very evident to any one who is in possession of any considerable number of the boiler-catalogs of different manufacturers for the past 20 or 30 years. But in them all, with the exception of two or three which have come out within the last decade, there is no essential change from the three distinctive types first produced as the Brayton or Exeter, the Gold, and the Mills. Every vertical-sectional, cast-iron boiler produced in this country from 1864 when Brayton forced the city of Providence to permit the use of his cast-iron boiler within its limits, down to the latest line of boilers are copies of the idea of Brayton, nearly all using the external steam-dome and the so-called mud-drum, and the connecting of each section as a separate boiler. Some of the latest lines have the internal connection used by Gold in his first boiler made of cast-iron.

For some reason, not easily discovered, the cast-iron boiler-manufacturers have never taken up, as their model, the Harrison boiler. This boiler was invented by an American engineer of great ability, Joseph Harrison, Jr., and is today, in many of its features, the nearest perfect as a steam-producing generator of unquestioned safety that is produced from cast-iron. It was first exhibited in England and won the highest award possible to its class in the International Exhibition at London in 1862. The invention of this boiler secured for Mr. Harrison the highest honors it is possible to award to an engineer in this country, namely, the awarding of both the silver and gold Rumford medals by the American Academy of Arts and Sciences. This distinction did not come to him because of his having designed an 11-ton engine for the Reading Railroad in 1840, or for building the St. Petersburg and Moscow Railroad, or for designing the great bridge over the river Neva. For none of these great feats of engineering skill could he have received these medals of distinction. It was for the production of a safety steam-boiler, that was safe, that he was given the medals that classed him as a benefactor of the human race; as a man whose service to the world at large entitled him to be classed with Sir Humphrey Davy, Michael Faraday, John Tyndall, John B. Erricson, George H. Corliss and other inventors and discoverers of world-wide fame.

The strange thing about the production of steam-boilers is that the wrought-iron boiler men, who try to produce safety boilers have, to a great extent, adopted the ideas developed by Harrison in his cast-iron boiler. Boilers of the Babcock & Wilcox and Abendroth & Root, and to some extent the Heine type, all follow the lines laid down by Harrison in his cast-iron boiler, while the cast-iron boilers produced for house-heating have followed the ideas of Samuel Gold who, as we have seen, took his design from the boiler of George B. Brayton. It is not the duty of the writer of the present series to consider, at this time, the reasons for such an outcome, although they are of interest to any student of the development of either the power-boiler, or the low-pressure, house-heating type of cast-iron boilers.

SECTION XXVIII.

I have stated the general facts connected with the adoption of the distinctive types concisely in order to give the reader a clear understanding of how the present types of boiler came into prominence, and also to show that it is not necessary for an engineer or a steam-fitter to have had an actual personal experience with a boiler designed as an improvement of either type, in order to have some knowledge of its value when any such variation of the type is offered to him for use on a given job. But in order for him to pass an intelligent judgment on the type, he should possess some knowledge of the value of direct and indirect fire-surface. Whenever a large amount of flue-surface is presented, he must have some understanding of the amount of friction these flues produce and the draft required to offset it. He must also know something as to the proportionate relation of grate to fire-surface and heating surface that experience and experiment have shown must obtain in order to secure the best results.

It is of course impossible to tell the real value of any cast-iron boiler except by actual test. But there are enough things that are universal and that in a greater or less degree must be found in any one of the types, either round or so-called square, to enable one to determine quite well the probable value of any cast-iron boiler, if the party offering it for sale will state in definite terms those points upon which we have shown that the steam-fitter or engineer is clearly entitled to be enlightened.

The very first thing to find out is the fire-pot capacity in pounds of hard coal. There is, so far as the writer's personal observation extends, no boiler-catalog that states this all-important fact in a clear manner. Some manufacturers give out enough data as to the size of the fire-pot to enable a capable mathematical professor to secure an approximate basis for guesswork as to the fuel capacity, but that is about all that can be secured from the average catalog.

The most complete catalog I have seen gives out in a very roundabout way the information required to check up any statement that a salesman for the product of the factory might make. But to find what the fire-pot of any boiler listed in this catalog would probably hold in pounds of coal, from the catalog itself, would probably be an impossible task to many, if not a majority, of the salesmen who are calling on the trade today in this country. The proportion of architects and members of the trade upon whom these salesmen call who could, or would, quickly or easily find and figure out for themselves, the fire-pot capacity is even less.

In this best catalog, in order to find the coal-capacity of any one of the listed boilers a long hunt is needed. In the printed matter giving the grate-area in square inches, is given the square feet in the fire-pot, but *not the cubic contents.* An item in the text indicates that additional measurements can be found in another portion of the book. A careful series of line-drawings indicate various important features of construction and on another page the inches applying. From these it is possible to get the distance from the top or bottom of the grate to the center of the feed-door, which is certainly as high as any house-owner will be liable to feed his boiler at any one firing. Assuming, then, that this is the producer's idea of the fire-pot capacity, we proceed to multiply the square inches in the grate or fire-pot, as given in one place, by these new-found figures, on the assumption that the new-found measure is the maximum height of the fire-pot, in order to get the cubic inches supposed to be in the space indicated on the line-drawing. This gives us a measure that may be correct, or may be quite incorrect. But it is at least a measure that enables one to make a fair guess as to the capacity of the various boilers as shown by these drawings, to hold coal. But now comes a new difficulty. What kind and size of coal was used in the testing of the boiler? Is the weight of a cubic foot of coal to be taken as the weight of a cubic foot of solid coal, or of broken, or of egg, or of stove, or of chestnut, or of pea? They all vary in their weight per cubic foot of space, according to leading authorities. Just to show how completely one is up against another guessing contest in this boiler-catalog matter, the moment one tries to solve the published ratings of house-heating boilers, the following table of the pounds of coal required to fill one cubic foot of space is given, also the cubic feet required for a ton of 2,240 lb. and for 2,000 lb. The great difference in the B. t. u. given off by different grades of hard coal is *well known, and manufacturers have apparently agreed that good coal should be considered to develop* 14,500 *B. t. u. per lb. under laboratory conditions. Now they should agree upon the pounds of hard coal to be considered as a cubic foot when used in the fire-pots of heating boilers.*

This table discloses a difference of nearly 30 per cent in the claimed weights of one average cubic foot of hard coal. Supposing a fire-pot of 3 cubic feet in capacity. If figured on the basis of 64.7 lb., the full load is 194 lb. If taken on the basis of 50 lb. to the cubic foot, then the full load is only 150 lb. A difference certainly large enough in a small boiler to cause serious trouble to a man who must garantee his job to maintain fire and hold steam for a certain number of hours. When

TABLE JZ.

Mine or Authority	Average Lbs. in 1 Cu. Ft.	Average Cu. Ft. in 2240 Lb. Ton	Average Cu. Ft. in 2000 Lb. Ton
Average Wilkesbarre	64.7	34.6	31.0
Hard Lehigh	61.9	36.2	32.4
Average Schuylkill W. A.	59.9	37.5	33.4
Shamokin	58.2	38.5	34.4
Lorberry	56.4	39.8	35.5
According to Haswell. Average all hard coal	56.7	39.5	35.3
According to Heine. Average all hard coal	53.4	42.0	37.5
C. E. Houghtaling Average all Lehigh..	56.0	40.0	37.7
Amer. Radiator Catalog. Average all hard coal, as about	50.0	44.8	40.0

considering the ratings of cast-iron boilers, it should not be overlooked that the difference in weight between the various commercial sizes required to fill one cubic foot of space is large, although not as great as has been disclosed in the different hard coal mined from the best hard-coal mines.

Take the Wilkesbarre mine as an illustration. "According to measurements made with Wilkesbarre anthracite coal from the Wyoming valley, it requires 32.2 cu. ft .of lump, 33.9 cu. ft. broken, 34.5 cu. ft. egg, 34.8 cu. ft. of stove, 35.7 cu. ft. of chestnut, and 36.7 cu. ft. of pea, to make one ton of coal of 2,240 lb." (Records of American Charcoal Iron-Workers, Vol. 3.)

This means, then, that 1 cu. ft. of Wilkesbarre lump will weigh 69.6 lb.; 1 cu. ft. of broken, 66.07 lb.; 1 cu. ft. of egg, 64.92 lb.; 1 cu. ft. of stove, 64.37 lb.; 1 cu. ft. of chestnut, 62.74 lb.; 1 cu. ft. of pea, 61.04 lb.

It will be seen from these figures that there are substantial reasons why the boiler-catalogs, under the present conditions as previously described, should state the capacity of fire-pots, as certainly as they should state the heating surface, height of water-line, or grate-surface.

Having the grate-surface, and the cubic capacity of fire-pot when full, the next thing of commanding importance, but not usually given in catalogs, is the matter of heating surface.

This is one thing over which the manufacturers will honestly differ with each other, and members of the trade hold more or less vigorous opinions as to the value of the heating surface not in direct contact with the fire. There are also many members of the trade who have quite positive opinions to the effect that it is impossible to get too much heating surface in a boiler. It is not the purpose of these articles to enter into an argument for or against any special type of heating boiler, or of the ideas of any special producer in regard to the manner of placing heating surface. Rather is it to state, as clearly as I can, the facts derived from a great number of tests made by others, and by the writer, and leave the individual, who is to purchase, install and garantee the working of any particular boiler, to make such application of the data as his judgment dictates. As has already been stated there is no one type of boiler made in cast-iron that is absolutely best to use for any and all jobs. It is the intention in these articles to so present the essential facts in regard to the rating and working of the cast-iron heating boiler that any intelligent and thoughtful architect, engineer, or steam-fitter can, from ascertained data, determine from facts, instead of guess or prejudice, the particular boiler best fitted to do the required work under given conditions.

The basic ideas embodied by Brayton and Harrison, in their original boilers, in regard to heating surface in the cast-iron boiler, have never been discredited, and remain to this day as the form of structure of most of the boilers produced from cast iron in the vertical types.

The use of the wrought-iron boilers almost entirely for heating as well as power-purposes from the time Walworth and Nason first pointed the way to the use of steam for house heating, up to 1863, and to a very considerable extent to this writing, has probably had much to do with the fact that but a very small amount of data has been accumulated and published in regard to the heating surfaces of the cast-iron boilers. The further fact, already mentioned, that almost without exception the cast-iron boiler manufacturers sold their product either through agents or direct to the consumer, in either case furnishing the "lay-out" from 1863 until within a very few years (indeed, some of the smaller manufacturers are yet doing so) has made it a very easy thing to keep this sort of information from the public. In some cases it would be about the last thing that the manufacturer would care to have stated in regard to the product, if he were to come into competition with a boiler claiming to have three or four times the heating surface he was claiming for his own production.

SECTION XXIX.

It is within the memory of a large number of the trade that a prominent wholesale house in this country published, as illustrating the wonderful heat-extracting power of the heating surface in a cast-iron, house-heating boiler they were offering, a picture or cartoon, in which the boiler was shown as being run with a roaring fire in it, while perched on the smoke-pipe was a buxom, naked baby, tagged "Just Comfortable!"

It is perhaps needless to say that that especial boiler was being praised up to an expectant, but ignorant public, because of its alleged heating surface and the wonderful arrangement of its flue surface, coupled with quite extravagant claims in regard to the coal-saving effected.

That a cartoon of this sort could be sent out by a strong and reputable selling agent, as a business-getter for his boiler, indicates how little the average person uses his reasoning powers, and also to what extent the public has considered the requirements of one feature of the matter of producing steam to be converted into energy; namely, heating surface in a wrought-iron boiler, to the almost total exclusion of other contributing features.

There are some things, usual in the care of and in the running of boilers used for power-purposes, that are not usual in the care of, or in the running of cast-iron house heating boilers. For instance, it is not expected that a fireman shall be in constant attendance on a residence-heating plant, or that mechanical stokers will be used, or that the boiler shall be blown off with frequency, or that a feed-water heater shall be installed. Such things as these belong to the care of boilers that are used to create steam that is to be stored in the boiler under considerable pressure and then delivered to an engine for its heat-energy to be reduced to mechanical power.

With the pressure at the boiler limited to 2 lb., it is evident that the steam produced is not to be used for mechanical power. It is also evident that no great amount of the steam created can be stored without creating a greater pressure than the stipulated 2 lb. At the very first, then, it will be seen that a condition entirely different from that demanded for a power-boiler is presented. The fire is not to be fed so often, yet constant steam is to be delivered for 8, 10 or 12 hours from one firing.

Ordinary common sense will at once recognize that a larger fire-pot capacity relative to the heating surface should be provided. How much larger depends upon the number of hours that the steam is to be constantly furnished at the 2-lb. pressure, and the evaporative value of the fuel to be used. Given a coal of the theoretical value of 15,000 B. t. u. and each pound may evaporate in practice 8.5 lb. water, but given a coal that has a theoretical value of 10,000 B. t. u. and the very best that can be expected in evaporation of water may be 4.5 lb. to the pound of coal. As a practical proposition the difference in size of fire-pot required to hold an 8-hour supply of fuel for a run of 8 hours in a house-heating boiler, using these two coals is as one to two. If it required 100 lb. of the best coal to produce the steam it would require practically 200 lb. of the poorer grade. And this without considering the question of heating surface at all. As has been shown, ***the total heat that a boiler can in time develop from the fuel, and the hourly capacity of that boiler are widely different propositions,*** but in either case the evaporative value of the fuel determines the size of the fire-pot needed to hold the fuel required.

With the power-boiler the difference in the evaporation power of the coal can be covered by the labor of the fireman and more frequent firings. The selection of a suitable boiler for a given house-job must therefore be governed to some extent by the kind of coal that the prospective customer intends to use, and the number of hours it is required to hold steam with one firing of fuel.

Most heating catalogs contain a table showing the heating and evaporative power of different coal. An examination of any of these catalogs will disclose that there is a very considerable difference between the coal mined in the east and that from the western portion of the country.

It necessarily follows that a corresponding difference in the size of the fire-pot must obtain in order to get the same results from one full load of fuel.

It will be found that not only are there very considerable differences in the heating value of a pound of different coals, but there are also as great differences in the number of pounds required to fill a given space, in the western as in the eastern coals.

A bushel of bituminous coal in Pennsylvania is 76 lb. In Indiana, 70 lb. In Ohio, Kentucky, Illinois, Missouri, and several other southern and western states, 80 lb. are required for a bushel of bituminous coal.

A discussion of the process of combustion is not needed at this time perhaps, but it may be well to explain in a few words the use of the tables of the heating and evaporating power of coals that are given in many of the boiler-catalogs.

The different manner in which these tables are given out by various boiler-makers quite clearly indicate that it is not intended by some of them that the tables are to be used in connection with the question of the sizes of the fire-pot they are putting into their particular product, but rather as a foil when the rating of their boiler happens to be questioned in some soft-coal territory.

A table of this sort, to be of real assistance to the fitter, should give the average moisture, ash and volatile matter contained in each pound of a given coal. A table to be of real value as an aid in selecting a cast-iron house-heating boiler should give these in order that the fitter may find out the probable space that he must have provided in the fire-pot for holding the total bulk of the fuel he intends to use on a given job.

The "combustible" in a coal, is that portion that will burn. In each pound there is a varying quantity of earth, ash, water, sulphur, and nitrogen which are of little or no value as fuel. In the various kinds of coal the ash and moisture constitute quite a percentage of the total weight. In good coal the portion of what is called the fixed carbon constitutes the largest percentage of the weight, and from it comes the largest percentage of the heat. In all coal there is some pitch, tar, naptha, and gases which combine to produce what is called the volatile matter in some tables, and hydro-carbon in others. It is the proportion of fixed carbon and of hy-

"Domestic Engineering" Cartoon on "The Intricacies of Boiler Rating."—No. XIX.

"Domestic Engineering" Pilot-Boat to the Rescue.

"Domestic Engineering" Pilot-Boat to the Rescue.

dro-carbon in a coal that fixes its quality as hard, anthracite, bituminous, or the intervening grades.

Coal containing from 86 to 100 per cent of fixed carbon and not to exceed 12.5 per cent of hydro-carbon, or volatile matter, is sold as anthracite coal in various sections of the country. Strictly hard, dry, anthracite-coal should contain not less than 92 per cent fixed carbon and not over 7.66 per cent of volatile or hydro-carbon matter. Coal, that shows less fixed carbon and more in volatile matter, should properly come under the head of either semi-anthracite, semi-bituminous, or bituminous. The dividing line between the coals is slightly at variance as given by the most careful writers. The classification as given in the Babcock & Wilcox catalog "Steam" seems to be an average of several. It is as follows:

	Fixed Carbon, per cent of combustible.	Volatile Matter, per cent of Combustible.
Anthracite	100 to 92	0 to 8
Semi-anthracite	92 to 87	8 to 13
Semi-bituminous	87 to 75	13 to 25
Bituminous	75 to 50	25 to 50
Lignite	below 50	over 50

Simply stating the heating value of the coal from a given mine, unless the moisture, ash, and volatile matters are also given, does not give the man who must select a cast-iron boiler, or any boiler, for a heating job that is to be fired only at intervals of 6 or 8 or more hours anything definite upon which to work.

A table saying simply that a certain coal has a heating value of 10,000 B. t. u. per lb. is interesting as a statement of fact, but of what use will it be in deciding as to the cubic content of the fire-pot that is to carry coal enough to furnish steam steadily for 10 hours? The ash in coals varies from less than 2 per cent to 34 per cent, or more of the bulk; the moisture from almost 1 per cent to over 17 per cent; and no one expects to get heat, to any great extent, from ash or moisture. Shall we assume that these tables are giving the B. t. u. in a lb. of combustible? If so, then one must guess at the amount of ash and moisture And why not? The cast-iron boiler manufacturers compel the fitter to guess at many of the most important things connected with the selection of a boiler so far as any information is to be found in their present catalogs. That is, most of them do. Another guess cannot leave the poor fitter much worse off.

But if the 10,000 B. t. u. represents the heat in a pound of the coal as it comes from the mine, what else does it contain? Is the ash, for instance, 10 or 30 per cent of the pound? How much fixed carbon is in that pound of coal? How can one find out from the statement how many pounds of that coal it will take to fill the fire-pot of any boiler?

When a table gives the moisture, ash, fixed carbon, and the evaporative power of one pound of the coal, dry and free from ash, you can seem to get at something to base a reasonable guess upon. I am not claiming that a positive certaintv can be secured, but a basis can be laid that will enable one to place a factor of safety with a fair prospect of securing a boiler that would give satisfaction with the coal to be used. To make this quite clear, take as an illustration two jobs, each of which is to furnish 125 lb. of steam per hour for 8 hours with one firing. One is to use a high grade of anthracite coal. The other an Ohio coal of average quality. How many cubic feet of space will be theoretically required to hold enough of each coal to probably produce the steam?

This, as will be seen, does not touch the question of the heating surface or any of the things which go to make efficiency in a boiler. We can take those up later; what we want now is to find out something about fire-pot capacity required for these two coals in order tc know how to select a proper boiler fire-pot for each, so far as that one feature is concerned. Hunting up a catalog that tells the whole of the story of an analysis, we may find that the anthracite coal is listed as having 3.42 per cent moisture, 4.38 per cent volatile matter, 83.27 per cent fixed carbon, 8.20 per cent ash, and 14,900 B. t. u. per pound of combustible. Taking this data and deducting the moisture 3.42 per cent and the ash 8.20 per cent or 11.62 per cent of the pound which has no heating value, we find that only about 88 per cent (100—11.62 per cent=88.38 per cent) of this coal as it enters the furnace is combustible, or 13,112 B. t. u. (14900 × .88 = 13112).

All of this 88 per cent is not available, for at least 25 per cent of the combustible in hard coal and from 35 to 50 per cent of the total combustible in bituminous coal is required to supply the loss through imperfect combustion, radiation from the boiler itself and the chimney-draft, and often other losses. It is usual to consider the sum of these losses from the best of anthracite coal as 25 per cent of the net combustible. Making this allowance for coal we are considering, we have left for the production of steam 9,834 B. t. u. from each pound of the coal. As 996 B. t. u. are required to produce one pound of steam from and at 212 deg. F, it follows that each pound of this coal should produce a trifle over 10 lb. of steam (9834 ÷ 966 = 10.1). We have to provide for 125 lb. of steam each hour for eight consecutive hours with one firing of coal, or for 1,000 pounds of steam. To supply this, with no extra allowance for extra waste or for renewal, will demand the supply of 100 lb. of this quality of coal.

SECTION XXX.

Turning to table J Z we find that it will require anywhere from 50 to 65 lb. of anthracite coal to fill 1 cu. ft. of space. At 60 lb., which is about the average weight claimed by the mines as the weight of a cubic foot, the 100 lb. required will occupy 1.2-3 cu. ft. of space. If we use the average of weight given by the outside authorities given in that table, or 54 lb., it will require 1.85 cu. ft. If we use the lowest average weight as given in the table is will require 2 cu. ft. These are for an 8-hour run. If the run is to be for 6 hours a smaller space would be required, and if for 10 or 12 hours more cubic space must be provided.

Now let us examine the other boiler for which an Ohio coal is to be used for fuel. The conditions are to be the same, an 8-hour run with one firing. We may find that the Ohio coal has the following data given as to its value: Moisture, 5 per cent; volatile matter, 35.65 per cent.; fixed carbon, 53.15 per cent.; ash, 9.1 per per cent; and the heating value of 1 lb. of combustible, 14,200 B. t. u. The ash and moisture equal 14 per cent of each pound; therefore, the coal as it would enter the furnace contains only 86 per cent of a pound of combustible, or 12,212 B. t. u. Owing to the high percentage of hydro-carbon, or volatile matter, present in this coal, and which is very difficult to keep in a state of combustion in actual practice, experiment has demonstrated that a much larger loss of the theoretical value in B. t. u. is sustained from coal with a large percentage of hydro-carbons than occurs in the anthracite coal. In fact, it is so difficult to keep the coal in such a state of perfect combustion as will ignite all these gases before they pass to the chimney, that the losses through imperfect combustion, radiation from the boiler itself, the chimney-draft and other losses are in actual tests on working jobs never less than 35 per cent and they sometimes reach over 50 per cent, when the volatile matter is in a high ratio to the fixed carbon. The figures given for the coal we are considering indicate that under good working conditions that instead of the 25 per cent that we allowed for these losses in the hard-coal boiler-case, that we should allow in this case at least 40 per cent for them. We have 12,212 B. t. u. from which to take this 40 per cent, leaving us for steam-production 7,327 B. t. u. Dividing this by the heat units required to produce one pound of steam 966 B. t. u. and we have the steam value of the coal at 7.6 lb. per pound of coal. To produce the 1,000 lb. of steam required to run for 8 hours, we must burn 132 lb. of this coal in the 8 hours. A cubic foot will weigh 53 lb., although one catalog gives the average weight of soft coal as 40 lb. At 53 lb. per cu. ft., the boiler which is to use this Ohio coal must furnish 2.5 cu. ft. to just contain the coal for an 8-hour fire, with no allowance for extra waste or renewal. The boiler that was to use hard coal we found must have 1.2-3 cu. ft. of space. The difference in space required for the hard coal and that required for the soft coal used for the illustration is practically 51 per cent.

It may be argued that in making this illustration that I have used extremes of hard and soft coal-values, but a closer examination of the combustible value will disclose that the hard-coal sample was held at 14,900 B. t. u. per pound of combustible and the soft coal at 14,200 B. t. u.

Many people confound the semi-anthracite coals with the bituminous coals. There are also many who say that soft coal cannot be used in house-heating boilers because they will not hold steam long enough for an 8 or 10-hour run. In this they are in error.

Given a suitable chimney and sufficient draft, with a fire-pot large enough to hold the quantity of fuel required, soft coal can be used with as much certainty of satisfaction as can anthracite, providing care is taken to keep the boiler-surfaces and the stack free from the accumulations of soot.

This soot is in reality largely composed of the volatile matter, or the hydro-carbons, of the coal which did not become ignited. Kent, page 620, says: "If mixed on their first issuing from amongst the burning carbon with a large quantity of hot air, these inflammable gases are completely burned with a transparent blue flame, producing carbonic acid and steam. When mixed with cold air they are apt to be chilled and pass off unburned. When raised to a red heat, or thereabouts, before being mixed with a sufficient quantity of air for perfect combustion, they disengage carbon in fine powder and pass to the condition partly of marsh gas and partly of free hydrogen; and the higher the temperature, the greater the proportion of carbon thus disengaged. If the disengaged carbon is cooled below the temperature of ignition before coming in contact with oxygen, it constitutes, while floating in the gas, smoke, and when deposited on solid bodies, soot."

As stated, many people, including a number of boiler-manufacturers, confound the semi-bituminous with the bituminous coal.

Just to show the difference, so far as boiler selection is concerned, let us take, as an illustration, a sample from Pocahontas, Va., and one of the New River, W. Va., mines and compare the cubic space required for an 8-hour run with the results we have already found necessary for anthracite and real soft coal.

Take Pocahontas first. The proximate analysis show that this coal has 1 per cent moisture, 21 per cent volatil matter, 74.39 per cent fixed carbon, 3.03 per cent ash; heating value per pound of combustible, 15,700 B. t. u.

The ash and moisture equals 4.3 per cent of each pound of coal as it enters the furnace, therefore only 95.7 per cent of the total is combustible, or 15,025 B. t. u., which are available for all purposes. This coal having 22.5 per cent of volatile matter in its combustible will lose more by means of imperfect combustion and chimney-draft than would anthracite, while the other losses would without doubt be fully as large. From the results derived from many experiments it has been found that under the most favorable conditions that these losses average for the very best grade of semi-bituminous coal at least 35 per cent of the total available B. t. u. in each pound. In this case then it would mean 35 per cent of 15,025 B. t. u., or 5,259 B. t. u. As it takes 966 B. t. u. to create 1 lb. steam from and at 212 deg., it follows that this coal will produce 10 lb. of steam per pound of coal. Therefore, to produce the 1,000 lb. in 8 hours with one firing, space for 100 lb. of it must be provided. This being a West Virginia coal, it will average to weigh about 50 lb. and rarely exceeding 53 lb. At 50 lb. to the cubic foot, it will require two cubic feet of space to hold the fuel for the 8-hour run, with no allowance for waste or refiring.

The New River coal is listed as follows: Moisture, 0.85 per cent; volatile matter, 17.88 per cent; fixed carbon, 77.64 per cent; ash, 3.36 per cent; heating value per pound of combustible, 15,800 B. t. u.

The ash and moisture constitute only 4.21 per cent of the total 15,800 B. t. u., therefore the coal as it enters the furnace has a theoretical value of 15,135 B. t. u. Of this, at least 25 per cent is lost, leaving 9,837 B. t. u. for steam, or a trifle over 10 lb. of steam to the pound of coal as it enters the furnace. This coal then, like the Pocahontas, will require a fire-pot space about one-quarter larger than strictly anthracite coal will require. But the instant that your customer indicates that he proposes to use soft coal for fuel it becomes to the steam fitter a most important question as to what coal he means, *and he cannot intelligently select a suitable house-heating boiler until he finds out.*

As we have seen, if he means to use a high-grade *semi-bituminous* coal like the last two mentioned, a boiler capacity increased 25 per cent will answer. But if he is to use the best of the Ohio coals he will be wise to provide for an increase of 50 per cent. For some of the western coal weighing from 50 to 54 lb. per cubic foot the available value of the coal as burned in the furnace is not over 5 lb. of steam per pound of the fuel as it enters the furnace. This simply means that if that is the coal to be used, and the fitter is to garantee that the boiler he is to furnish will, when that coal is used, maintain steam steadily for 8, 9, 10 or more hours with one firing, then the fitter must provide a holding capacity for the boiler at least double that which would be required for a high-grade hard coal. These illustrations show the need of the manufacturer clearly stating in his catalog the cubic contents of the fire-pot, the pounds of hard coal he considers as a full firing, and the proximate net value per pound of the testing coal and the hours the full load is supposed to carry its rating.

It is presumed that my readers will understand that the various illustrations given are to show the method by which a person can arrive at a fair basis of judgment in regard to the space that will be certainly required to hold the amount of coal called for according to the constantly varying demands of his customers as to hours of firing, the use of different kinds of coal, and the like. The factor of safety that should be used in each case has been left to the judgment of the engineer or steamfitter who is to garantee the job. It will also, I trust be fully and clearly understood that in all cases the value of a pound of the *combustible* is to be taken instead of the value of the pound of coal as given in many catalogs.

It will be found that the value of the pound of combustible in the coal from a given section of country will vary but slightly, but that the heating value of individual coal-products within the section may show wide differences. Thus, almost the entire anthracite-coal-region in Pennsylvania produces coal which shows the heating value of the pound of combustible to be 14,900 B. t. u., but mines that are almost side by side may show decidedly sharp and important differences in ash, moisture and volatile matter. Enough to make, in some cases, the fire-pot of one make of boiler the point of selection as against another. In the semi-bituminous and bituminous coals the heating value *per pound of combustible* is found to be remarkably even over extended areas.

In the strictly bituminous coal this is very pronounced, and the steam-fitter who neglects to investigate it will, if he is doing any considerable heating business, surely get into trouble at times on account of that neglect.

For instance, the Ohio soft coal is almost certain to show a heating value of 14,500 B. t. u. per pound of *combustible*—that is, the part that burns. But the coal from an individual mine in Ohio might show that 1 lb. of its coal, as it came from the dealer ready to go into the furnace, did not have one-half that heating value per pound, while the coal from a mine quite near it, in the same condition, might show that it had 20 or 25 per cent more heating value as it entered the furnace.

This, naturally, means that the steam-fitter could, if he desired, use a boiler with a smaller fire-pot on the latter job than would be safe to use on the first, although the heating value of the *pound of combustible* might be the same for each coal.

The manufacturer no longer makes the plans or garantees the working of heating jobs. He has thrown the burden on the steam-fitter. The sooner the fitter gets next to this rating and fuel-proposition, the better it will be for him individually and the trade collectively.

Before leaving this part of the heating question, it should be stated that there is considerable variation in the ash of coal, according to its size. The most of the analyses used for the illustrations just given were taken from tables published by the Babcock & Wilcox Co. of New York. The ash, as given, is evidently the result of laboratory-conditions, and is considerably less than will actually prevail in the ordinary run of practice. But, as has been said, the illustrations are given that the reader may understand how to get at a practical working basis from which to start.

In regard to the ash developed from the different sizes of a lot of coal taken from one hard-coal mine, the increase of ash as the size became smaller was considerable.

From the Egg size the ash was......... 5.7 per cent
From the Stove size the ash was........10.00 per cent
From the Chestnut size the ash was.....12.6 per cent
From the Pea size the ash was..........14.6 per cent

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It is probable that there is no great difference among the various tables that have been prepared as to the heating value in B. t. u. per pound of combustible, however much they may vary as to ash, moisture, fixed carbon and the rest. These variations come from individual or special samples usually. What the fitter needs to do is to get from the dealers in the territory he covers the complete analyses of the coal handled therein. From these he can make his own deductions as to the size of firepot that will be required for different coal, always starting from the value given in B. t. u. for one pound of combustible, and deducting for ash according to the size of coal to be used. Allowance should be made for a larger percentage of ash in small sizes than for the large. There should always be a liberal factor of safety added to the theoretical space as determined from the published analysis.

In the matter of grates for boilers there is no reason why any of the grates now on the market should not be taken, if the firepot and other important things are suitable to the work to be done.

The matter of fire or heating surface is not by any means a settled question. It is only within a very short time that any real data on the value of the various items that go to make up the cast-iron heating boilers has been presented by independent investigators. In fact, the only attempt at standardizing seems to have been the fixing of the relative temperature that a hot-water boiler should show, as the correct temperature of water at the boiler, to secure a rating for radiation with 65 per cent increase over that given for the same construction and size of steam-boiler when rated for steam at 2 lb. at the boiler; and the rating of steam-boilers as carrying 2-lb. pressure at the boiler.

From the individual tests that have been made on nearly every type of cast-iron heating boilers, it is quite well demonstrated that, in a general way, the same law that governs the value of heating surface in tubular boilers obtains with equal force when considering the cast-iron surface.

But the roughness of the flues, in the cast-iron construction, tends to develop somewhat larger losses because of the quick accumulation of soot when soft coal is used as fuel, particularly when there is an excess of indirect flue surface. The tendency of this surface to collect ash when anthracite coal is used seems also to be more pronounced in the cast-iron flue.

The tests of the United States Geological Survey at St. Louis, Mo., and of the Engineering Experiment Station of the University of Illinois as published in bulletin No. 366 of U. S. G. S., and bulletin No. 31, of the University of Illinois, February, 1909, are practically the first attempts, by outside engineers of high standing, to test cast-iron house-heating boilers on a somewhat prolonged basis.

These tests are far from complete, they having been made to determine the heating value of various fuels when burned in the cast-iron house-heating boiler. The tests, however, disclose incidentally many things beside the coal-value that are of importance to the student of the heating question as it relates to the house-heating problem.

In order to emphasize what has already been said in regard to the general lack of information in the trade of proper data upon which to base anything like an accurate estimate of the various estimates and claims of the different manufacturers, I quote a few paragraphs from the bulletin No. 31 of the University of Illinois, dated Feb. 22, 1909.

"Page 9.—On account of the small amount of available information relative to a satisfactory method for conducting house-heating boiler tests, one of the principal purposes in conducting these tests was to obtain information that would assist in developing such a method. Fuel-tests with house-heating boilers will of necessity be similar, in many respects, to the tests made in connection with power-boilers."

"Page 11.—In the case of a house-heating boiler, the question relative to capacity which is of importance, is how many square feet of radiation can be served through comparatively long periods of time without attention, except at the time of firing. It is generally desired to know how many square feet of radiation can be served through a period of from six to eight hours without attention during that time. The same amount of fuel consumed within a short time should serve more radiating surface per hour than when burned during a longer period of time. The one-hour period as employed in defining a horse-power, and as used in rating power-boilers, is not satisfactory for comparative purposes in connection with house-heating boiler-work. In this kind of work, then, in order that information relative to capacity may have the greatest usefulness, it should be based upon the evaporation which can be obtained during a period of from six to eight hours without attention, rather than upon the evaporation obtained in one hour with whatever attention may be required. Thus a boiler rated at 1,000 sq. ft. should be capable of serving that amount of radiation for a period of at least six hours without attention during that time.

"Page 12.—The lack of a satisfactory method of making tests, *or of one generally accepted as such was apparent.* Under these circumstances it was deemed advisable to make a series of tests according to the American Society of Mechanical Engineers' code for conducting boiler-trials.

"Page 14.—Societies and individuals interested in this kind of work have from time to time reported tests, or discussed methods for making such tests, but apparently without making definite recommendations that have been found satisfactory for the guidance of others, or that have been adopted generally enough to make comparisons possible or of value. The number of tests of this kind which have been reported is surprisingly small as compared with the number of tests conducted upon power-boilers. Probably the greatest amount of work in this line has been done by the manufacturers of heating apparatus. The results of their investigations are, however, either not available, or are applicable to particular makes."

When a great university, as recently as 1909, finds itself utterly unable to find, even among the house-heating boiler-manufacturers of this country, a method of testing cast-iron heating boilers that was even in general use among themselves, it is not a matter of great surprise that the trade have up to the present time no general knowledge of the important points that they should investigate when selecting a boiler. The time has now come, however, when the intelligent engineer and steamfitter must, in justice to himself, require from the manufacturer the data already indicated in this discussion, and those of the trade who are in the fair way to secure work upon a larger scale than residence-heating, will naturally require considerable data in addition.

The authorities at the University of Illinois were justified in taking the code of the A. S. M. E. fuel-tests for power-boilers as the guide for testing cast-iron boilers for house-heating. In this they only followed the example which the United States engineers set two or three years previously when making similar tests at St. Louis, Mo.

Undoubtedly one of the chief reasons that neither of these parties found any satisfactory rule among the cast-iron boiler manufacturers of the country was the fact that nearly every boiler on the market from 1860 to, within perhaps ten years, or 1900, which was made of cast iron, was some sort of an attempt to improve upon the Brayton boiler; if not that, then the Mills or Gold, in the vertical sectional type, while in the round horizontal sectional type, the boilers without an exception, were either direct copies of foreign boilers without variation, or were adaptations of the upright tubular boiler of the high-pressure type. In a majority of cases the manufacture of the house-heating boilers, especially of the cast-iron ones, was entered into by some foundryman who saw a chance to increase his output of castings by slightly changing his patterns from those of some type of boiler within his knowledge that was giving a fair degree of satisfaction. When it came to rating the boiler, the foundryman, with characteristic American confidence, determined that, if the model that he had chosen to improve upon had a given rating, then he could safely rate his production at the same, or a trifle more, according to the disposition of the manufacturer.

That a test along the plain, simple lines indicated in tables GZ and HZ, pages 188 to 191, was made prior to 1900 is very doubtful. It is also a well-known fact that the results of any tests made by any of the boiler manufacturers who cater to the house-heating trade have never been given out in a form that would enable one to promptly and easily determine the value of the boiler when placed under conditions that varied from those under which the manufacturer may have placed his boiler and secured what he was pleased to call its rating. Another reason why the manufacturers have never had a simple straightforward rule for the testing of cast-iron heating boilers is the fact already stated that their product was almost universally sold through agencies. As a rule, only one make of boiler would be allowed to one agent. The manufacturer usually made all the plans, and decided what size of boiler should go on a given job. There was no pinning the job down to a 2-lb. pressure-at-the-boiler proposition. If a job would not give out heat enough with 2-lb. at gage, "fire a little harder and carry more pressure. The boiler is safe; burn a little fuel."

There is not a man in the trade today who can remember back ten years who will say the statement just made is overdrawn. But when the trade at large had become somewhat acquainted with the general practice of steam-heating for residences, and the public were getting particular as to the pressure to be carried, and the amount of coal to be burned, the manufacturers decided that the modern practice had developed to a point where steam-jobs were being installed at times, and probably could always be installed in residences, and give satisfaction if only 2-lb. pressure was carried at the boiler.

This was a condition of economy and safety for the house-owner much to be desired. It would also, it was thought, simplify boiler-ratings by bringing all boilers to the same standard of 2 lb. at the boiler on all house-heating boilers. A few of the larger producers began to rate on this basis, and in a short time the manufacturers as a body had adopted the new rating. Practically coincident with this move, came the almost universal cessation on the part of the large producers of drawing plans for, or the laying out of house-heating jobs. These steps which have been taken by the boiler manufacturers within a very short period of time: i. e., doing away with the agency system, stopping plan-making, and adopting a definite stated pressure as a basis of rating: have had the effect of calling the attention of the United States Departmental Officers and engineers to the question.

The first thing that they found out was, that there was no actual standard in effect which governed the rating of cast-iron heating boilers such as were used in residences. The next thing was, that of those manufacturers who pretended to have a system of scientific rating, no two of them were alike, or agreed in full with each other as to the value of things upon which they did agree as being important.

Power-boiler data, at the time of the Centennial Exhibition at Philadelphia, was found to be in this same guess-work sort of a condition, and it became necessary to formulate a code for testing power-boilers. This code, with certain corrections and additions, became what is now known as the Testing Code of the A. S. M. E. for Power Boilers.

There is no great exhibition being projected to require the making of a code for testing house-heating boilers, but there is a still more important reason that requires such a code, and that it shall be settled upon quickly, and correctly, and above all simply. *And that reason is that, with the taking of the successive steps just referred to, the steamfitter and the engineer have had all the burden of performance thrown on to them.* The manufacturer is out from that. It is no longer a question for a few boiler producers. It is a vital matter concerning the pocket-book of every house-heating contractor in the entire country.

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I do not claim that the data I have shown as absolutely necessary to be given out by every boiler-producer, in addition to the little that they now do give out, is all that should be covered when a Testing Code for House-heating Boilers is finally prepared. Far from it. But I do think that until a suitable code, that all can agree upon can be produced, that every steam-fitter and engineer is, for his own protection, in duty bound to find out for himself, in some way, every fact covered by tables GZ and HZ of this series. And in addition, as much data in regard to the firepot size, and other things yet to be taken up fully, as he may require for his personal protection.

In the matter of the value of the various sections of the heating surface in a cast-iron boiler, the boiler men are not, as yet, a unit. A very exhaustive series of tests covering nearly every type of boiler and its variations now on the market has been made by individuals, and to a slight extent the results have been divulged, and the tests are quite fully in accord with the published tests that have been promulgated as to the value of the heating surfaces of power-boilers.

In order to give the tests that have been made on the different boilers it would be necessary to fill a space equal to more than that used in the average magazine in 10 years of publication. It will be impossible to give even a summary of the items shown by Table GZ that every boiler catalog should give in detail for any of the prominent cast-iron lines now on the market, for the reason that there is not one single line that is not full of variations. There is not a boiler catalog covering a line of cast-iron boilers that is fully consistent with itself all the way through. The stack-temperatures are found to vary all the way from the 200 deg. F. to the 800 deg. F. in temperature in order to produce the catalog-rating for an eight-hour run on some lines, while on another line, there may not be a stack-temperature in the whole list that will run outside of the recognized points of greatest economy for boilers of this class, namely: from about 350 to 450 deg. F. One of the most important features disclosed in my personal study of boiler ratings is the different rates of combustion that is often required in one line of boilers to secure the necessary amount of steam to supply the rating for any definite number of hours. A certain line of quite popular boilers have three boilers cataloged in one line rated to carry 1,050, 1,250 and 1,400 sq. ft. of radiating surface on a certain size of grate. Another line with precisely the same grate and about the same fire surface is cataloged at 850, 950 and 1,050 sq. ft. One other popular line with the same grate surface and almost the same heating surface is cataloged 1,300, 1,425 and 1,550 sq. ft. These three examples are not, as is sometimes the case, all cast from the same patterns, except the doors, but are distinctly different in the arrangement of the sections. In each case, however, when tests are made of the three there is developed a great difference in the stack-temperature required to develop from the fuel the necessary amount of steam to sustain the catalog-rating for an eight-hour period. These are typical boilers selected from widely separated sections of the country. Tests on these show that there is no change whatever in the grate surface or size of fire-pot in order to secure the increased rating. The only difference made in either of them is the increasing of the indirect heating surface. A short study of Tables GZ, HZ and J Z, in connection with these ratings should enable any one to see what was done to produce those ratings from the same amount of coal held by the same firepot on the same sized grate. It is hardly necessary to state that the stack-temperature on the three ratings varied over 300 deg. between the highest rating and the lowest if an eight-hour run was maintained on each boiler.

It must not be taken from the foregoing that on a round type of boiler that two or three different ratings may not be legitimately given to a given size of grate and firepot. This phase of the question has been admirably stated in a publication recently produced for private distribution, as follows: "Boilers that have a moderate quantity of heating surface and a short fire travel will operate when attached to a flue that would be wholly inadequate to the requirements of a boiler with the much-vaunted long-fire travel." The reason for this is that the draft in the chimney flue is caused by the difference in the temperature of the column of air in the chimney and the temperature of the external air; and the boiler with the short-fire travel delivers the gases to the chimney at a high temperature, which lightens the column of air in the chimney, causing the heavier outside air to take its place, thereby creating the necessary draft. Because of this variation in the chimney intensity, it is possible to arrange boilers with a varying number of sections as in the round type. But the statement that there must be an ideal number of sections which should be placed between firepot and dome of all round boilers is misleading, for such an ideal can never be realized owing to the *wide difference in the intensity of chimney drafts.* It has been demonstrated by actual tests that the addition of a limited number of sections above the firepot increases proportionately the value of the heating surface in the fire-pot and a relative increase in the power derived from the fuel, thereby allowing a proportionate increase in the rating of the boiler (which has the additional sections) over one having fewer sections, even though the grate and fuel capacity are alike in both boilers. It must therefore *always rest with the heating contractor to select the boiler which will suit the chimney conditions.*"

But how can the heating contractor intelligently select from any catalog now in use? What has just been quoted in regard to round boilers, is equally applicable to every kind and shape of vertical sectional boilers, whether cast-iron or tubular.

This manual was commenced with a discussion of chimneys, for the reason that the chimney and its quality of draft and volume absolutely dominates the question as to the exact kind of a boiler best to put in for most satisfactory results.

The quality of the draft and the volume of it will first be looked at to determine the question of stack-temperature that can be selected to the greatest advantage in the matter of combustion. The range may be anywhere from 250 deg. F. to as high as 800, or, even in some known cases, over 1,000 deg. F.

The usual range, however, on jobs installed in places where the altitude is under 1,000 ft. above the sea level, for house-heating is in the vicinity of 350 to 450 deg. F. in the stack and, with the exception of chimneys that develop most unusual draft and volume combined, the cases where a boiler requiring a higher stack-temperature than that covered by those figures can be used with satisfaction to steamfitter and owner alike are quite rare.

It will not require a very long hunt on the part of the steamfitter, however, to find boilers that in order to maintain the catalog-rating will have to show at least 700 to 900 deg. stack-temperature.

Grant that we have considered the draft, the volume, and the general condition of the chimney; the kind of coal that is to be burned, which will determine the B. t. u. available per pound; decided as to the number of hours that the job is to run without attention; we then require a firepot with sufficient cubic contents to not only hold the quantity of the coal that is to be used in the selected time, but that will also hold a good-sized surplus in order to provide for a sufficient amount of fuel for rekindling. It should provide for an hour or two additional run in an emergency, or when the outside temperature is several degrees below the zero or other selected winter temperature. This firepot chosen, the question of the kind and amount of heating surface to be placed above the firepot can be taken into the account.

As has been stated, this is a point over which there seems to be an honest difference of opinion among the manufacturers, and among the trade as well.

The writer of this series has, in the past, been favored with the views of nearly all the most prominent producers of cast-iron boilers in this country, and has had the pleasure of meeting some of the largest producers of France, England and Canada, who have also expressed their views on this question of heating surface. I can only say that as the net result of all these interviews, or talks, that the cases where the opinion advanced had been based upon the results of experiments upon a large number of boilers produced by other manufacturers than themselves, were very rare. And in these few cases the experiments were in only two or three instances extended to boiler construction that differed materially from that produced by the investigator. With the exception of a very few, the position taken in regard to the matter of heating surfaces can be summarized in the statement that all surface which in any way can transmit heat from the flame or the gases of the coal to the water in the boiler is to be considered as heating surface in that boiler. In only an occasional instance has the producer suggested that there should be allowance made for difference in effectiveness in this surface.

Within the past few years this question of effectiveness of surface has received some little attention from a few of the thinkers connected with the industry of heating houses with steam or hot water.

That the matter is not fully appreciated by either the architects, or the trade at large, is evidenced by the numerous heating specifications that come to the trade calling for boilers with a certain size of grate and a stated gross amount of heating surface, but not one word as to the distribution of that surface. Not a word as to whether it is to be placed 50 per cent direct and 50 indirect, or 25 indirect and 75 per cent direct, or in some other combination. I do not recall this ever having been stated in one of this sort of specifications.

It is not necessary to discuss the question as to whether the surface exposed directly to the flame is not more valuable than that not so exposed and usually called the flue-surface. But, it is of importance, to carefully examine the relative value of the two in the common house-heating boiler.

SECTION XXXIII.

I recently saw the specifications for the heating of a certain building by steam. They were drawn by an architect who prides himself upon the entire completeness of his specifications. In this case the demand was for the use of a cast-iron boiler having a grate-area of not less than 9.25 sq. ft. and the heating surface to be not less than 220 sq. ft. The intent and design of these specifications was, probably, to secure a certain boiler which he did not care to name in specific terms. But it developed that there were a number of cast-iron boilers that had the required size of grate, while only two or three manufacturers claimed to have the required 220 or more sq. ft. of heating surface attached to that size of grate. It soon developed that no two of the manufacturers who had boilers with the required grate-area, claimed the same amount of heating surface for their boilers. The strange thing to the steam-fitter, who was making inquiry from the different firms, was that the manufacturer, who claimed the largest amount of heating surface in connection with the correct size of grate, made the smallest claim for rating. The steam-fitter and the architect at once jumped to the conclusion that that particular boiler must be, by all means, the best and most conservatively rated of any of the product of manufacturers of whom they had made inquiry. This particular boiler was installed. Because of its supposed conservative rating, the owner of the building decided to add to the original proposition two rooms, making the total square feet of cast-iron radiation on the job 885 sq. ft.; in addition to this there was the draft of the piping, a portion of which was well covered.

To a suggestion that was made to the fitter that possibly he was rather crowding the boiler, and that when the job came to the test of zero weather and rough wind that he would have trouble in store for himself, he replied, with great confidence, "that he was not a bit worried on that score." He based his confidence on the following statistics.

He had received answers to his questions from nine concerns. Not all of them had given him their figures as to heating surface. But all had replied as to grate-surface, and the difference between the largest and smallest grate-surface was found to be not over 1-3 sq. ft. and the concern with the very smallest area of grate had a rating among the largest. The boiler they had selected had a grate-area of 1,350 sq. in.; claimed heating surface, 222 sq. ft.; rating claimed, 1,350 sq. ft. for steam. The list of ratings run as follows: 1,350 sq. ft., 1,350 sq. ft., 1,450 sq. ft., 1,700 sq. ft., 1,800 sq. ft., 1,850 sq. ft., 1,950 sq. ft., 2,100 sq. ft., 2.150 sq. ft.

"We have found an eastern boiler that has a grate 8 sq. in. smaller and with a rating of 1,350 sq. ft.; they claim to have two square feet more heating surface, but as the freight would be more, we took the one nearer home, rated for 1,350 sq. ft."

"One concern, that has one of the big ratings, wrote us that their boiler only had 106 sq. ft. of heating surface, but that they would garantee the rating they put on their boiler."

"If a concern as big as that one can garantee such a rating as they put on to 106 sq. ft. of heating surface, we don't think we need to fret when we have a boiler which a first-class concern tells us in writing has over double that amount of heating surface and it is willing to garantee that the boiler is correctly rated."

When that job was completed, and utterly failed to give satisfaction, the surprise of the architect and steam-fitting firm was certainly intense. After a large amount of money, relatively speaking, had been expended in the attempt to get satisfactory results, the producers of the boiler finally installed another of their boilers which carried a catalog rating of 2,150 sq. ft. for steam, and the job worked fairly well. If the architect and the heating firm had fully understood the value of the position of heating surface, they would have examined very carefully the position, in the boiler, of all of that 222 sq. ft. of claimed heating surface. It is not for the writer to dispute the correctness of the manufacturers' measure of heating surface, but I can say that in order to secure that amount of surface he had to measure some portions of that boiler that it is not usual to consider as heating surface.

The experience of the people quoted in this case can hardly be considered as very unusual. Every section of the country can produce numerous instances of a similar nature, but perhaps not so extreme. There were errors in the piping of this job that tended to demand more of the boiler than is usual in small jobs of this kind. There is no claim made by the writer that this boiler was incorrectly rated. On the contrary, its rating could be established for a very short run. But not for eight hours. Nor am I disposed to say that the majority of the steam-fitters of the country hold the same view that was held by the firm I have quoted in regard to house-heating boiler surface, but that a large number do so hold is unquestioned.

Some of the highest authorities on heating and ventilation give out what seems to be substantially the same idea, unless they are very carefully read and understood. For instance: "The International Correspondence Schools Plumbers' and Fitters' Pocketbook," on page 124, states that "In ordinary forms of house-heating boilers, from 1,800 to 2,400 B. t. u. are absorbed per sq. ft. of heating surface per hour, and since 1 sq. ft. of direct steam radiating surface requires from 250 to 330 B. t. u. per hour, say an approximate average of 300 B. t. u. per hour, it is evident that 1 sq. ft. of boiler-heating surface will generate enough steam to supply from 6 to 10 ft. of radiating surface. In other words, a vertical sectional boiler, having 180 sq. ft. of heating surface, will supply sufficient steam for 1,080 to 1,800 sq. ft. of direct radiation, including all losses due to condensation in the transmission of the steam through the supply-piping."

Even so careful a writer as Prof. Allen, in his "Notes on Heating and Ventilation," says: "In purchasing a boiler specify the number of square feet of heating surface the boiler should contain."

Both of these authorities, if fully and carefully read, make these extracts clear, but read as most of the trade look through a book, and the same idea is absorbed that was presented by the members of the firm I quoted. In fact, in the course of a series of talks with this firm, both of the quotations just given were presented in justification of their belief that the boiler with 222 sq. ft. of alleged heating surface could be depended upon to handle all contingencies, if a boiler with only 106 sq. ft. of heating surface could be warranted by a reputable concern to carry a big percentage more surface than the 1,350 sq. ft., credited to the 220 sq. ft. of claimed heating surface in the boiler they had ordered for this job.

One great difficulty in the study of the house-heating boiler is that nearly all the books, that are available to the average steam-fitter, fail to make clear the difference in the matter of handling the ratings of the ordinary cast-iron house-heating boiler and the power boiler. In addition to this, is the fact that but very few competent writers have taken up this side of the question since the manufacturers changed the manner of rating so that cast-iron boilers for steam state their ratings based on a pressure not to exceed 2 lb. at the boiler.

Another reason is, that, practically all those who have taken up the heating question, have taken it up from the standpoint of the big engineer and steam-fitter and the architect of the big building, whose calculations are made to accord with the construction of the tubular boiler, and who only considers the use of the cast-iron house-heating boiler at long intervals, if at all.

The power-boiler has, for the past 60 years, received about all the attention of the scientists and mechanics who catered to large work. Even as late as 1908, two years previous to the present writing, William J. Baldwin, one of the very best of the American writers, published the 16th edition of his work on heating, having revised the former editions and brought the 16th to "harmonize with modern practice." He says in the preface to this last edition that "So far as the (1st) work related to the principles of steam-heating, where the water of condensation is returned by gravitation to the boiler, there could be little change in the book. To bring it down to modern practice in the use of steam by other methods, a general revision was necessary. Therefore the whole former book is superseded by one whose date and practice harmonize. I therefore endeavor to give some facts relating to the principles of modern steam-fitting, which, since the writing of my first book (1878) has risen to the dignity of a branch of engineering science that may be known as domestic engineering, and which includes substantially all that goes to make up the engineering plant of a modern city building, except the electric light and elevator system, which do not properly belong to the subject."

I have quoted thus freely from Mr. Baldwin's preface to his new book for two reasons. First, because Mr. Baldwin was a good engineer when he wrote his first book in 1878 and is a better one in 1908.

Second, because Mr. Baldwin in the preface quoted, and in the text of his most excellent book, most fully substantiates the fact that the competent writers have not taken up carefully this matter of cast-iron boiler-ratings and their construction, and the relation of the heating surface, to the ratings as now given out in the catalogs of cast-iron steam and water boilers.

As a matter of fact, even in this revised edition of 1908, Mr. Baldwin in giving the requirements for house-heating boilers confines himself entirely to the detail of tubular boilers, and simply gives the names and description in the briefest possible terms of 8 or 9 of the most widely known cast-iron boilers.

The 20,000 men in this country who do house-heating, using cast-iron boilers almost entirely in their work, can get much that is of the utmost importance to them from this, and other recent books by men of experience. So far as I have observed, however, there has as yet been no detailed information that will give them the practical information in regard to cast-iron boilers, such as they use in their work, that is given in all the books in regard to the power-boilers, which most of them seldom are called upon to place.

To make the attempt to give this information to this army of workers, as fully and clearly as possible, is the object of these essays.

In regard to this matter of cast-iron boiler-surface, it should be stated at the very outset that the last word which shall fully determine the exact law of the transmission of heat to water through metal plates has not yet been spoken.

Scientists have made many experiments which seem to point toward the truth of the statement that "The evaporative action of different portions of the heating surface of a steam-boiler point to the general law that the quantity of heat transmission per degree of difference of temperature is practically uniform for various differences of temperature," but there is much to be ascertained in regard to the question before laboratory exactness as to the law can be stated.

For the practical purpose of deciding as to the heating value of surface in a cast-iron boiler, the assumption that the evaporative action is uniform per degree of difference is a safe base from which to make calculations. At this point we come up against an almost blank wall so far as positive claims of the boiler-makers are concerned. If any of them have published to the trade in general anything on this point, it has not been seen by the writer of this book.

There have been some statements, made privately, giving the results of tests made on a certain line of boilers that would seem to indicate that the law, as generally accepted, may be considered correct as to the transmission, but that, in so far as cast-iron boilers are concerned, there is a larger loss in what may be termed the unaccounted-for units than is usual with brick-set tubular boilers.

SECTION XXXIV.

Before taking up this important matter of position of heating surface in detail, it may be well to quote from two or three of the best known authorities on heating boilers.

W. J. Baldwin in his new book says, on page 57: "A square foot of surface in a firebox of ordinary construction has 2½ to 4 times the value of the same area of average tube surface, but they should not convey the idea that by increasing surface near or in the firebox and decreasing the tube surface near or in the direction of the chimney in a three-fold proportion to the increase in the firepot, that they can evaporate as much water with the increased surfaces. Makers of cast-iron boilers often make this claim. When a firebox or furnace is large enough for proper combustion, its surface is then receiving all the radiant heat there is. By increasing the surface directly exposed to the action of the fire (beyond the required chamber for combustion) it will be necessary to have the surface of the firebox as a whole more remote from the fire, and the radiant heat from any source has its effect decreased *directly as the surface which absorbs it.*"

Professor Carpenter, in his book on "Heating and Ventilating," says: "That part of the heating surface which is close to the fire and receives directly the radiant heat is much more effective than that which is heated by contact with hot gases only; but it will be found that considerable indirect heating surface will in every case be required in order to prevent excessive waste of heat in the chimney."

Alfred G. King, in his book, "Practical Steam and Hot Water Heating and Ventilation," 1908 edition, says: "Direct-surface is more effective than flue-surface, the proportion being about 3 to 1. 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 into the chimney, and a large number of heat-units from the fuel consumed is therefore wasted."

Nearly every book of modern date, which takes up this boiler question, will have a general statement of the tenor of those just quoted. But these are as direct and definite as any I have noticed in any of the recent publications. Probably no reader of this series of articles will dispute the correctness of the general statement, but I think it quite probable that there are numbers of my readers who, like the man from Missouri, desire to be shown more definitely the real value of these surfaces and the bearing that they really have on the capacity of a boiler.

But, as in many other things in the heating business, they find themselves left by most writers to guess as best they can what the starting point in the transmission of heat through the fire-pot heating surface may be and then to guess again as to whether the flue-surface in a given boiler is worth 2½, or 3, or 4, or some other times less than the fire-pot surface. It is rather strange that this most important feature of the cast-iron boiler has been so universally side-stepped by all of the later and best writers. That something definite is needed is apparent to every one. As we proceed to discuss this feature of the cast-iron heating boiler, the positive necessity of a precise statement from every boiler-manufacturer as to the exact number of square feet of each kind of heating surface in his various boilers in his catalogs will be so clear that no careful buyer will again purchase a boiler until such data is not only furnished, but the correctness of the figures garanteed. There are today but few of the boilers which are offered for sale that have the actual surface claimed by the manufacturers. I do not recall one single instance of a catalog that gives what the manufacturer claims to be the direct and the indirect surface for heating in his product.

Now that the burden of selection and garantee of the boiler has been thrown onto the steam-fitter and the engineer by the manufacturer, the discussion that follows will clearly show, I believe, that not one single manufacturer of cast-iron boilers at this time gives out to the public the most vital point of information in regard to his product that he has to give. The reason will also be made somewhat obvious by an illustration from an actual transaction. A clear and practical rule for getting at the real value of these surfaces will also be developed by the discussion.

There are but few reliable records of the value of boiler-surfaces in this matter of transmission, through the heating surfaces, of the heat to the water in the boiler, and expressed in B. t. u. per degree of difference per square foot of surface per hour.

The largest transmission per square foot per hour mentioned by any reliable author is that given by Prof. Kent in his manual for engineers, 1910 edition. It is there stated that in a locomotive-boiler, where radiant heat was brought into play, that 17 units of heat were transmitted through the plates of the fire-box per degree of difference of temperature per square foot per hour.

It should be remembered that there is a vast difference between the transmission of heat through iron to water and the transmission of heat from steam or water through iron surface to water, or the transmission of heat from steam or water to air through iron surfaces.

TABLE KZ.

Temp. of water in boiler, Degs. Fahr.	200	200	200	200	200
Temp. of gases in boiler, Degs. Fahr.	1200	1100	1000	900	800
Degrees of difference in Temp.	1000	900	800	700	600
B. t. u. transmitted per sq. ft. surface per degree of difference per sq. ft. per hour	10	9	8	7	6
Total B. t. u. transmitted per sq. ft. per hour	10000	8100	6400	4900	3600
Sq. ft. of steam-radiation carried by 1 sq. ft. heating surface	41.66	33.75	26.66	20.41	15.00

From the heated water on one side of an iron-plate there may be transmitted 400 or even 600 B. t. u. per sq. ft. of surface, per degree of difference, to colder water on the other side of the plate. But the quantity of heat that the water will transmit to air through the same plate will be from less than one unit to possibly five under the most favorable conditions.

For instance, the average house-heating radiator rarely transmits 2 B. t. u. per degree of difference of temperature between the water or steam in the radiator and the air of the room. This point must not be overlooked when considering the manufacturer's claim as to the heating surface in a given boiler.

From all the available data at my command I am persuaded that the cast-iron heating boilers now on the market are usually tested when the fire-pot gases approximate a temperature of 1,200 deg. F. Some of them, because of the grouping of their surfaces, producing unusual flue-surfaces, have to secure a higher temperature

TABLE KZ.

200	200	200	200	200	200	200	200	200	200
700	600	500	400	350	300	250	240	230	220
500	400	350	300	150	100	50	40	30	20
5	4	3	2	1.5	1	0.5	0.4	0.3	0.2
2500	1600	900	400	225	100	25	16	9	4
10.41	6.60	3.75	1.66	.938	.416	.105	.066	.038	.017

than that in order to develop their catalog-rating; others, because of deficient flue-surface, can develop their rating at a somewhat lower temperature than 1,200 deg.

The general law that the heat transmitted per degree of difference of temperature is practically uniform for the various temperatures reached in testing boilers, when applied to the house-heating boiler-surfaces, throws a flood of light on to this rating question, and, if intelligently applied, will go far to prove the correctness of my statement that there is no single line of boilers in the market today that can furnish the absolutely best boiler to put on every job.

Apply the law to the two boilers already mentioned in this discussion.

The manufacturers of each made claim as to heating surface as follows, the data having been obtained only after considerable correspondence. One claimed 220 sq. ft. of total heating surface, divided as follows: Direct surface, 30 sq. ft.; indirect surface, 190 sq. ft.; stack-temperature when tested about 220 deg., catalog rating, 1,350 sq. ft. steam. This boiler we will call Boiler A. The other, or Boiler B, claimed to have 106 sq. ft. of total heating surface, divided into 43 sq. ft. direct surface, and 63 sq. ft. indirect surface. Stack-temperature, when tested, about 400 deg. Catalog-rating, 1,950 sq. ft., steam radiation.

While experiment has shown that a locomotive-boiler-plate, in the fire-box, transmitted 17 B. t. u. per degree of difference of temperature, the tests on cast-iron house-heating boilers show that, at a temperature of 1,200 deg. in the fire-box, and with the circulating water in the boiler at about 200 deg., that there is transmitted 10 B. t. u. per degree of difference of temperature. This difference being approximately 1,000 deg., we can conclude that there is one unit of heat transmitted for each 100 deg. of difference. This conclusion is verified by the results obtained from a multitude of tests. It is an easy matter to construct a table from this data of the B. t. u. transmitted per degree of difference of temperature between the heated gases and the water over the fire-pot surface, and the temperature of the flue-gases and the water as it circulated in the boiler.

The ratio of the heat in the fire-pot section and the beginning of the flue-surface is as 12 to 8. If the fire-pot gases have a temperature of 1,200 deg., the beginning of the flue-surface will show a temperature of about 800 deg. The difference between the water in the boiler, as it circulates, and the temperature of the gases, is therefore 1,000 deg. for the fire-surface, and 600 deg. at the beginning of the flue-surface.

The person who desires to make an intelligent choice of a boiler for a given condition will find table K Z one of the highest importance to him. For convenience of demonstration I have taken the temperature of the water, as it circulates, to be 200 deg. in the boiler, but any other temperature can be taken as well, as the relative values will remain the same. That is to say, those within the range of house-heating temperatures.

The column that shows the number of square feet of steam-radiation condensing ¼ lb. steam per hour that each square foot of the heating surface will carry, is especially startling, when considered in the light that many manufacturers have desired us to look at their boilers, viz., the great amount of flue-surface that they have contrived to get into their product.

SECTION XXXV.

In case radiation of a greater condensing capacity is to be used, or that of a smaller value, the needed correction can easily be made by dividing the total B. t. u. transmitted per square foot per hour from the required heating surface, by the number of B. t. u. that the required radiating surface will condense per square foot per hour. Thus, if a pipe condensing 3 B. t. u. per degree of difference was to be used in a room which is to be kept at 70 deg. F., the total heat transmitted by the boiler heating surface at a given temperature would be divided by 450 B. t. u. in order to find the number of square feet of surface that one square foot of the heating surface would carry. As the boilers are all rated at 2-lb. pressure at the boiler, the utmost temperature that the steam could have in the radiators would be 220 deg. Then 220 — 70 = 150 deg. diff., 150 × 3 = 450 B. t. u. If this radiation was used, the fire-pot surface would carry 22 sq. ft.; the flue-surface according to its value. The absurdity of the popular notion that a very low stack-temperature is needed for best results is made quite manifest by this table.

Now let us examine the boilers A and B in the light of facts, instead of guess-work, and perhaps we can find out why the boiler with the big heating surface fell down in performance when put to the test of severe weather.

Boiler A was claimed to have 220 sq. ft. of heating surface, 30 ft. of which were in the fire-pot. Taking a fire-pot temperature of 1,200 deg. as the probable testing temperature, we find by Table K Z that a square foot of heating surface will transmit 10,000 B. t. u. per hour. Then, 10,000 $\times$ 30 = 300,000 B. t. u. that will be transmitted by the direct surface. The beginning of the flue-surface will have a temperature of 800 deg.; the temperature of the water, as it circulates, is 200 deg., the difference being 600 deg. The stack-temperature they claimed to be 220 deg. at the test. Therefore, the difference at that point would be 20 deg. and the average temperature of the flue-gases would be 510 deg. With the water, as it circulates, at 200 deg., the average difference of the water-temperature in the boiler and the average flue-temperature will be 310 deg. This means that the surface will transmit on an average 3.1 B. t. u. per degree of difference, or a total of 182,500 B. t. u. The total transmitted then is 482,500 B. t. u. It will not do to figure on the whole of this reaching the radiators, because many experiments have demonstrated that there is always a loss not accounted for at the radiators. This loss may be fairly fixed at about 15 per cent. Deducting this loss, which cannot reach the radiators or piping, and the total number of heat-units that can be relied upon to reach the radiators and piping attached to this boiler is 410,125 B. t. u. As one foot of standard cast-iron radiation has been generally accepted by the manufacturers of cast-iron boilers to emit 240 B. t. u. under the usual conditions of house-heating, we divide the 410,125 by 240, and find that the gross capacity of the boiler is for 1,708 sq. ft. cast-iron radiators.

The producer of this boiler called particular attention to his claim that his catalog-rating was only 80 per cent of the gross capacity. In order, then, to test the catalog-rating we must deduct the factor of safety that he claims.

The net capacity of the boiler for catalog-purposes is in round numbers, 1,366 sq. ft. This being 16 sq. ft. more than the catalog calls for, we must conclude that the rating is correct and conservative, under the conditions named.

We will now examine boiler B in the same manner. This boiler is claimed by the manufacturer to have the same size of grate as boiler A. The claim for total heating surface, however, is for an amount less than one-half that claimed for boiler A and very differently distributed. Boiler B is claimed to have 106 sq. ft. of total heating surface; 63 sq. ft. in the fire-pot surface, as direct surface; and 43 sq. ft. of flue-surface, which is indirect surface. Using the same temperatures that were taken by boiler A, we arrive at the following data: 63 sq. ft. transmitting 10,000 B. t. u. per ft. yields 630,000 B. t. u. The stack-temperature established by the producer, of boiler B, was 400 deg. Deduct the temperature of the water, as it circulates, or 200 deg., and we have the temperature-difference at the stack-end of the flue-surface. The fire-pot end of the flue is, of course, the same as in boiler A, or 800 deg., the difference, 600 deg., being the same as in boiler A. The average difference of the temperature in boiler B flue-surface is 400 deg., yielding 4 B. t. u. per square foot of surface per degree of difference. The flue-surface of boiler B yields $43 \times 4 \times 400 = 68{,}800$ B. t. u. per hour. The total B. t. u. transmitted = 698,800. The same loss, or unaccounted-for units by pipe and radiators, must always be deducted, viz., 15 per cent. There are then 59,980 B. t. u. available as the gross capacity of the boiler B. We must take the same factor of safety that we used for boiler A, or 20 per cent of the gross, leaving 80 per cent of the 2,478 sq. ft. gross capacity for the catalog-rating. The catalog-rating of boiler B is 1,950 sq. ft. Then, 80 per cent of 2,478 is 1,982. It is evident that boiler B is even more conservatively rated than the boiler A, when the fire-pot gases are at 1,200 deg. F.

It is certain that no house-owner will maintain a permanent temperature of 1,200 deg. in the fire-pot of his heating boiler, therefore an examination of these two boilers at a lower fire-pot temperature may be of interest.

Suppose we take for the trial a rather moderate fire-pot temperature of about 900 deg. The temperature of the water, as it circulates, must remain the same, or at about 200 deg. The beginning of the flue-surface will be at about 2-3 of the fire-pot temperature, or at 600 deg. The stack-temperature of each boiler, we will assume, to be in perfect proportion with the fire-pot gases when at 1,200 deg., or 165 deg. for boiler A and 300 deg. for boiler B. The difference will be, for boiler A, 700 deg. for the fire-pot direct surface and 400 for the fire-box end of the flue-surface; but, at the stack-end of the flue, the temperature will be below that of the water as it circulates. The average temperature of the flue-surface of the boiler A, because of this, will not be above 382 deg., from which must be deducted the temperature of the water as it circulates, or 200 deg. So that the average difference will be 182 deg.

At this temperature, one average square foot of boiler A's flue-surface transmits 1.82 B. t. u. per degree of difference per hour. Applying this data to boiler A, we have the following: The 30 sq. ft. of direct surface at 700 deg. difference will transmit 147,000 B. t. u. ($4,900 \times 30 = 147,000$—See Table K Z). The 190 sq. ft. of flue-surface will transmit 62,935 B. t. u. ($1.82 \times 182 =$

331.24; 331.24 × 190 = 62,935). The total transmission is therefore 209,943 B. t. u. per hour. Fifteen per cent of this will not be accounted for through the piping and radiators, therefore we have for actual use 178,451 B. t. u. As each square foot of radiator is to emit 240 B. t. u. per square foot per hour, the boiler can only carry 743 sq. ft. gross, when a moderate fire is used.

Boiler B under the same conditions will show results from its surface as follows: The 63 sq. ft. direct surface will transmit 308,700 B. t. u. per hour. The 43 sq. ft. of flue-surface will transmit 26,875 B. t. u. per hour, a total of 335,575 B. t. u. per hour. Fifteen per cent of this is useless, therefore the gross transmission that is available is only 285,239 B. t. u., or enough to carry 1,188 sq. ft. It will be seen that the boiler A under a less powerful fire loses in a larger proportion than does boiler B.

It should be understood, however, that in the cases where the stack-temperature falls below that of the water as it circulates in the boiler, it is not usual to find the transmission from the flue-surface to be in equal proportion with the cases where the stack-temperature is above the temperature of the circulating water. The friction in the flue-surface and the cooling of the water at the stack-end of the flue often create conditions that reduce the value of the flue-surface greatly out of proportion to the figured transmission, and never, so far as I have observed, to the advantage of the boiler.

There is a tendency on the part of some manufacturers to rather overdo the matter of putting in a large quantity of direct heating surface and cutting down the flue-surface. The steam-fitter will find himself about as badly off in one case as in the other. The proportion of flue-surface to direct surface is one for experiment, to quite an extent, in all cast-iron boilers. It is reasonably certain, however, that any combination of surfaces, which results in having a direct surface more than double the flue-surface in square feet, will be difficult to control. While, on the other hand, a cast-iron boiler with a flue-surface more than double the direct surface will require a powerful draft to secure the required results.

This side of the question can be well illustrated by testing two boilers. Suppose one boiler to have 60 sq. ft. of direct surface and 30 sq. ft. of flue-surface. The other boiler to have 30 sq. ft. direct surface and 60 sq. ft. of flue-surface. Both boilers have 90 sq. ft. of heating surface, but the heating value of the two boilers, when tested with the gases in the fire-pot at 1,200 deg. F. and stack-temperature the same for each, say 400 deg., will be greatly different. The total transmission from the first one will be 648,000 B. t. u. per hour. From the second one 396,000 B. t. u. per hour. Deducting the 15 per cent loss, not accounted for from the piping and radiation, and the gross capacity of the first boiler for steam-rating is 2,295 sq. ft., and the gross capacity of the second boiler will be 1,402 sq. ft., a difference of over 61 per cent in the working out of two boilers, each having 90 sq. ft. of heating surface.

In the light of the facts disclosed in the discussions of the factor of combustion as shown in Tables G Z and H Z; the matter of fire-pot size as shown in Table J Z and its bearing on the time factor; the necessity of knowing the exact amount of direct heating surface, and the total amount of flue-surface as just shown by illustration; of what material value to the steam-fitter, to the engineer, to the house-owner, or to the student, are the various data in the ordinary catalog of cast-iron boilers for house heating? If the manufacturers have seen fit to throw the burden of selection and garantee upon the steam-fitter or engineer, why should not the steam-fitter and engineer demand from the producers of boilers, the explicit information that these discussions have developed it is necessary for them to have in order that they may make an intelligent choice of a boiler for the particular heating job they may have in hand?

The question of heating with hot water as the medium for distributing the heat instead of steam naturally comes up for discussion at this point.

SECTION XXXVI.

There have been long arguments prepared by various authors to show the great superiority of water over steam as a heating medium. It is not my purpose to present an argument in terms either for or against either method.

It should not be overlooked by the trade, however, that when the manufacturers changed the basis of rating steam-boilers, and thereby changed the whole problem of steam-heating, that they at the same time changed the rating basis of the hot-water heating boiler and in so doing they spoiled many of the arguments as to the great superiority of water over steam as a heating medium, when each system is planned and executed by equally competent workmen.

With 2-lb. pressure at the boiler, we have seen that it is not to be expected that the temperature of the steam in the radiators will be above 208 deg. F. (See Tables F and F F). This is a temperature very easily produced in any open-tank hot-water job where the tank has an elevation of 15 ft. or more above the boiler. The production of the vacuum-valve and a regulator that will work promptly below atmospheric pressure have developed an entirely new condition in steam-heating that advocates of hot-water heating must very carefully contemplate before they advance the old stock arguments in regard to hot-water heating.

Under these changed conditions it will not be long before the great buying public will demand of the hot-water heating fraternity that it should give the promptness and certainty of action, which is developed by steam working under less than atmospheric pressure, in the hot-water jobs which they intend to install, and at the same time maintain a fuel-account not in excess of the steam-job as it is presented in a first-class steam-job working under pressure at, or below, that of the atmosphere.

This may sound strangely to the fitter who has not taken the time to keep himself posted on the new developments in this heating problem. If any one of my readers has an abiding faith within his mind cells that the possibilities of steam entirely supplanting the hot-water heating plant for household, or home-heating, are great, and that the beginning has already commenced, that reader is probably well started on the road of ultimate success in the house-heating business.

It is reasonably certain that during the ten years from 1895 to 1905, of the house-heating in this country, where either steam or hot-water heat was used, fully 80 per cent was water.

This must not be construed to mean that 80 per cent of all the heating in this country during those years was by hot-water, for that would be far from the fact. But of the homes, the houses of from 5 to 12, or 15 rooms, the proportion of hot-water heating to steam was fully 80 per cent. Of the steam jobs, only a very small percentage, during those years, were constructed on the vacuum or even on the vapor-system.

So little did the plumbing and heating fraternity know in 1894 in regard to these systems as applied to the small house-heating jobs that one of the trade journals printed a series of articles on the vapor and vacuum-systems as applied to house-heating. Even these articles did not seem to rise to a full comprehension of the magnitude of the question they were presenting. Some time later a writer in the same journal ventured the prediction that "it would not be long before practically every heating job would be a vacuum, a vapor or an accelerated hot-water system." In the six years that have passed since this writer made his prediction there has been a greater gain in the installation of vapor, and so-called vacuum-steam systems for house-heating, than was made in the entire heating industry so far as it relates to steam and hot-water heating in the 30 years following the introduction of steam-heating by Walworth and Nason.

The tremendous strides made by the hot-water men in the past 15 years in this country has, perhaps, been only exceeded in the mechanical professions by the electric-lighting men, in so far as household development is concerned.

It is comparatively easy to determine the age, or beginning, of steam-heating. There was a patent issued June 12, 1835, in this country for a device for "warming buildings by radiated and steam-heat" to Robert Rogers, of South Berwick, Maine. The patent office building was burned in 1836 and all the drawings and papers connected with the Rogers patent for steam-heating were destroyed. It is thought that Rogers died in 1836. This patent was issued at least seven years before Walworth and Nason did their first job. In fact, this patent was granted before Mr. Nason went to England to study under the other great American, Angier Perkins, who invented a steam-cannon which this country refused to buy, but which Perkins sold to the English government, but upon such terms that he was practically obliged to remain forever in England. He soon turned his attention to heating and, strangely enough, to hot-water heating instead of steam. The Perkins sealed-pipe system was the outcome of his invention, which he patented in this country as well as in England.

There was no great amount of steam-heating at that time in England, but hot water was in quite general use. That he should have turned his attention to hot water as his medium for heat is even more unexplainable when we consider the fact that some steam-heating had been practiced in England before 1800, and the process patented. Thomas Tredgold, in his book on "Principles of Warming and Ventilating," published in 1836, states that "Col. William Cook first suggested the idea of employing steam as a means of distributing heat in 1745." An English patent was issued to John Hoyle, of Halifax, in 1791, for a process of heating by steam. This is undoubtedly the first recognition of the use of steam as a heating medium in modern times.

The beginning of hot-water heating is lost in the mists of ages. The first official record, which I have been able to locate, as to the earliest use of hot water as a heating medium, is in one of the Special Reports to the United States Secretary of the Treasury, from China, in 1851. This particular report was made at the request of the U. S. Government, by Dr. D. J. McGowan, who was sent to China to make an investigation and report to the United States Government in regard to early Chinese inventions of record. Among others he reported the invention of a water-clock by the Duke Chau, who was a philosopher and inventor, who lived before Confucius. The Chinese records describe the clock as being attached to a furnace which heated water which surrounded the water-clock and kept it at even temperature during the winter months. This same inventor is claimed to have invented a compass which was in use as early as 2,634 years before the Christian era, or some 4,500 years ago. Therefore the first official record for hot-water heating by the aid of a furnace refers to a time which must be fixed as corresponding with the Chinese claim for the compass. Dr. McGowan in his report does not fix the time directly, but he states that the same man who invented the furnace and connected it with the water-clock to keep it from freezing, is also given official credit for inventing the compass. The Encyclopedia Britannica, Vol. 6, page 226, states that "the earliest references to the use of the compass are to be found in Chinese history, from which we learn how, in the 64th year of his reign, Emperor Ho-ang-ti (2634 B. C.) used a chariot equipped with a compass."

For the benefit of those who have scruples about accepting this date because it refers to a time previous to the date of the Biblical flood, suppose we take the statement as Dr. McGowan put it, "that Duke Chau was a philosopher and inventor who lived before Confucius." Well, Confucius was born 550 years before Christ, so in any way one looks at the matter the first official report of hot-water heating carries with it evidences of a very respectable age. So old, in fact, that when some enthusiastic old fitter tells you confidentially that he helped install the first hot-water job ever constructed, you are entitled to the belief that he is mistaken. Other references to the use of hot water as a heating medium can be found in the writings of numerous early authors. Perhaps the most complete descriptions are to be found in the works of the elder Pliny, Publius Papinius Statius, and Lucius Anneus Seneca; each of these three describes with considerable detail the method of heating water contained in pipes, one end of which was passed through a fire, and show that this method was practiced long before the Christian era commenced.

The descriptions are so clear that there have been made drawings of the methods used. With hardly an exception the plan follows the lines of many constructions in use today in this country. The piping used in those old days was made of brass instead of iron. In fact, it appears that in a period of over 2,000 years, we have practically added nothing to the knowledge of heating bathing pools by hot-water circulation. And judging from the description of the heating arrangements in a private house owned by a Roman aristocrat, as given by Ausonius about the year 350 A. D., the average hot-water job of today has but little improvement to show for the nearly 1,600 years that have elapsed between that day and this. The use of hot water circulated through pipes for heating appears to have been discovered, used, dropped from use only to be rediscovered, several times since its first expression some thousands of years ago. And yet, it is only within a period covered by the last half-century that anything approaching scientific investigation and application of what we, today, term scientific methods, has been attempted.

To a very great extent investigation has been directed to problems in steam-heating. And to a very great extent to the problems that apply to big installations, operated under heavy pressures.

One reason that the scientific investigation of hot-water heating has not been more fully attempted can probably be attributed to the fact that hot-water as a heating medium rarely, if ever, makes any noise or disturbance of any kind, however badly treated. It does its best, however poor its setting. With steam it is different. The moment the steam job finds itself in anything but conditions of perfect satisfaction it begins to "speak for itself in no uncertain tones." It will "squeal" on the incompetent that constructed it. It will hammer and knock in a most exasperating manner, something that the quiet hot-water job never does, and yet the hot-water as a heating medium responds even more emphatically to proper environment in the cost of maintenance.

The present demand that steam boilers shall maintain the heat in the radiators with a pressure at the boiler of not to exceed 2 lb. compels the fitter to produce a job for steam carrying less pressure at the boiler than does any open-tank hot-water job where the expansion-tank is 10 ft. above the boiler.

A head of water of 1 ft. is equal to 0.4331 lb. pressure per sq. in. If the water in the expansion tank is 5 ft. above the boiler the pressure at the boiler will be 2.165 lb., or nearly 1-6 of a pound greater pressure than the steam-job is to carry. As the majority of residence-jobs will average to have the expansion-tank at least 20 to 25 ft. above the boiler, the pressure at the boiler is from 8.66 to 10.83 lb., or from 4 to 5 times that of the steam-job. This natural pressure, due to the head or elevation of the expansion tank, is frequently increased by the use of one or another of the patent devices for sealing the job for another 10-lb. pressure, thus presenting the curious condition of having an alleged hot-water open-tank system working under a boiler-pressure that is practically prohibited in modern house-heating with steam. These are things the hot-water contractor must seriously consider. The new steam practice without the aid of appliances for strictly vapor-heating, or any of the various so-called vacuum-accessories, produces results that in economy of fuel, or ease of care and attention, often are more favorable than many hot-water jobs.

If it is needed for the steam-fitter to remodel his ideas and practice, because of the new conditions created by the change in the rating of steam-boilers (and it certainly is), it is still more important that the hot-water fitter and engineer gets busy with the new problems which the new fashion of rating water-boilers has forced to the front. The old rules are as much out of place in the practice of hot-water heating as they are for steam and for the same reasons.

SECTION XXXVII.

With the advent of gages and regulators and graduated valves that will work with absolute accuracy on steam-jobs which are producing the steam below the atmospheric pressure, the supremacy of water-heat over steam is seriously threatened at least, and if the hot-water man expects to hold his place in the race he will need to stop just guessing, and get down to solid *knowing* the hot-water heating business.

To be a first-class hot-water heating man today requires a better and more complete knowledge of the science of heating than is required for steam-fitting. That this is true is shown by the almost universal failure of mechanics who do steam-fitting fairly well, to do equally good hot-water heating.

In those sections of the country where the heating season is very long, some artificial heat being required at times during 7 or 8 months of the year, hot water will remain somewhat a favorite on account of its evenness of heat. But even there, unless the hot-water men keep pace with the advances being made in steam-heating for small residences, they will certainly find themselves distanced in the race for contracts.

Twenty years ago a writer on heating said: "Heating apparatus of all kinds—hot water, hot steam, or hot air—are not necessarily a success or a failure *because belonging to either system,* but really and simply because they have had more or less brains engrafted and transferred into them by the designer and engineer. Establish any rational standard of construction, operation and result for either system, and then compare the failures of each to reach such a standard, and I do not know on whose shoulders—the steam, the water, or the hot-air furnace men—the sword would fall with the greatest force."

This rather drastic comment is even more applicable today than it was 20 years ago, for the percentage of men who try to do each kind of heating is larger than then, and the proportion that are trying to fit old-time rules and styles to the new ratings, is so great that probably never in the history of the steam and water-heating business has the amount of unintelligent work been greater than during the past few years, since the change of ratings.

The many failures have had the influence, however, of calling the attention of the trade to the fact that more care must be given to the little things now than in the past.

Strangely enough, the greatest factor in the development of the desire to do better work in hot-water heating was the introduction of the various forms of the so-called heat generators.

The trade had been taught that in hot-water heating that there is but one element present after the apparatus is once filled with water and put to work. The water fills all spaces, and closes them against the entrance of the air-element. That in the water-job the motive power is not pressure obtained from the boiler as in the steam-job, but that it comes from the difference in the weight of the colder and the hotter water in the pipes, and many of the smaller fitters really professed to believe that a temperature above the boiling-point of 212 deg. could not be attained in an open-tank system, and often questioned the accuracy of the thermometers sent for use at the boiler.

Everything that we have discussed in relation to the figuring for heating by steam is applied in the same way for hot-water heating. Even more care should be exercised in the examination of the chimney conditions than might be needed for a steam-job. The area in square inches of the proposed chimney for a hot-water installation is of the utmost importance. Especial care should be exercised to make certain that the area of the smallest place in the chimney is well in excess of the area of the smoke-opening called for by the manufacturer of the proposed boiler. There should be a more careful examination of this chimney proposition when a hot-water boiler is to be used than for a steam-boiler, and the area must never be less than the area of the smoke-flue provided for the hot-water boiler to be used.

It is impossible to state this detail of the installation of a hot-water boiler too strongly. A careful study of tables GZ, HZ and KZ, in the light of the fact that all hot-water boilers are now rated on the basis of a temperature at the boiler of only 180 deg. F., will disclose abundant reason for the emphatic insistence, on the part of the hot-water fitter, that the owner shall furnish a chimney of ample size and quality of draft.

Water being the greatest absorber of heat known, and as one great source of circulation in the ordinary house-heating job is the difference in the weight of the hot and colder water in the circulating pipes, and as the temperature fixed by the new ratings is so low, 180 deg., it becomes a matter of the utmost concern to the fitter, who must garantee the job, that the draft for the boiler shall be of the best, and that the volume of it shall be ample, in order that a constant combustion at this very low temperature shall be secured.

It is one thing to have just draft enough to produce the disintegration of coal at a low temperature, and quite another to have coal burn at a low temperature, although the net number of pounds of coal passed through the furnace may be practically the same for each condition. In order to produce actual combustion of the coal the chimney must not only have a strong draft per square inch of its area, but it must have an area, free and clear, equal or in excess of the area provided by the manufacturer of the boiler for the passage from the boiler of the smoke, coal gases and the air needed for good combustion of the coal. Every word said in the opening chapters of this series in regard to the chimney for a steam-boiler applies with equal force to the hot-water boiler.

Unless the chimney-conditions are right as the starting point for the hot-water job, it is downright foolishness to attempt to produce a thoroughly good hot-water job.

The hot-water fitter must go over identically the same methods for securing the loss of heat from the rooms that the steam-fitter is obliged to use. Until the questions of selecting the boiler and sizing the pipes present themselves for decision, the various steps of the steam-heating men and of the hot-water heating men are, or should be, identically the same.

But with the method of selecting the boiler certain differences in the manner of deciding what is best for the individual job begins to show.

It may be well to state them side by side so that they can be seen at a glance.

Steam System.

To select a steam-boiler the fitter must consider the following:

1. The height of water line.
2. The pressure he can carry at boiler.
3. The pressure required at the end of the supply-line where the drop is made below the water-line.
4. The grade of the piping.
5. The kind of coal to be used.
6. The number of hours heat is to be furnished with one firing.
7. The size of fire-pot required to meet the required conditions.

Hot-water System.

To select a hot-water boiler the fitter must consider the following:

(1) The height of the boiler.
(2) The grade of the piping.
(3) The kind of coal to be used.
(4) The number of hours heat is to be furnished with one firing.
(5) The size of fire-pot required to meet the conditions.
(6) The proportions of direct and indirect-heating surface in boiler best adapted to the chimney-draft.
(7) The stack-temperature required to produce manufacturers' rating.

8. The proportion of direct-heating surface to indirect in the boiler best adapted to the chimney-draft.

9. The stack-temperature required to produce the manufacturers' rating.

10. The area of the smoke, gases and air-opening at boiler.

(8) The area of the smoke, gases and air-opening at boiler.

SECTION XXXVIII.

The two things that the steam-fitter must consider with care when he is to select a boiler, that the hot-water fitter is not required to consider particularly, are, pressure at the boiler and pressure at the point where the point of equalization occurs in the piping. The new ratings having brought the maximum temperatures of the two heating mediums within 40 deg. Fahr. of each other, the hot-water man who is required to show a saving in fuel as compared with the steam job of same size, needs to know the positive value of each and every step in the construction of a hot-water apparatus.

The first thing he must consider, with even more care than the steam job requires, will be the boiler. While he does not have to figure primarily on boiler pressure, as shown on a gage affixed to the boiler, we shall find that height of the water in the boiler, as well as the quantity of water that the boiler contains, may be of commanding importance for an individual installation.

In order to make this clear it will be necessary to study the principles involved in the circulation of hot-water which is heated at one point and then circulated through pipes back to the point of heating, to be heated again to the higher temperature, that the circulation may continue.

In a general way, almost every one has an idea, which is more or less correct, in regard to what produces the circulation in a hot-water job. But it is important that the exact view of the question, upon which the statements that will follow in regard to hot-water heating are based, shall be fully set forth at this time in order that no confusion of ideas shall occur. The necessity of this will be all the more apparent when the fitter comes to consider the question as to whether or not he will add to his piping any one of the so-called "heat-generators," "heat-retainers," "circulation-accelerators," and other descriptively-named patented articles, which from time to time appear on the market. The first thing, then, is to get a clear idea of what produces the circulation of the water in an ordinary heating job, and then to examine into the things that either retard or improve the circulation of the water as a heating medium.

The foundation of the theory of hot-water circulation in pipes is based upon three facts: First, the fact that one cubic foot of water at the temperature, or point of its greatest density, or at 39.2 deg. Fahr., weighs at the sea-level nearly 62½ lb. (62.425), while a cubic foot of water at 212 deg. weighs not quite 60 lb. (59.844 lb.) (Encyclopedia Britannica, Vol. 12, page 480; Subject, Hydromechanics). There will be found slight variations in tables presented by different authors as to the weight of one cubic foot of water at different degrees of temperature, but the change from the table KZ is so slight that it does not affect the results of the needed calculations for a small heating apparatus and need not be considered as of moment in the present discussion.

The second fact is that if heat is applied when water is at its point of greatest density at the sea-level, the water soon begins to expand, to occupy more space than it did at 39.2 deg. temperature. In other words, the mass of water is actually bigger than it was before the heat was applied and it keeps on growing larger in its mass, or

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TABLE KZ.

Weight of 1 cubic foot of water at the various temperatures usually found within the range of house heating by hot water.

Temp. of Water, Deg. Fahr.	Wt. in Lb. of 1 Cu. Ft. Water at this Temp.	Relative Volume.
40	62.42	1.00001
50	62.41	1.00025
60	62.37	1.00083
70	62.31	1.00196
80	62.23	1.00334
90	62.13	1.00497
100	62.02	1.01491
110	61.89	1.00901
120	61.74	1.00748
130	61.56	1.01409
140	61.37	1.01678
145	61.28	1.01828
150	61.18	1.01983
155	61.08	1.02145
160	60.98	1.02309
165	60.87	1.02480
170	60.77	1.02656
175	60.66	1.02836
180	60.55	1.03024
185	60.44	1.03213
190	60.32	1.03414
200	60.07	1.03820
212	59.76	1.04332
220	59.64	
230	59.38	
250	58.81	
270	58.21	
300	57.25	

The above table has been prepared by taking items from a number of different authorities who gave the formula used in preparing their tables, and is believed to be sufficiently accurate for the work to which it should be applied. No one should attempt to seal a job to a pressure of 65 lb. actual or 50 lb. gage pressure, which is about what 300 degrees temp. would mean. The table has been carried to that point because among some of the cut-throat-sell-them-cheaper concerns the size of piping sent out with the material, as well as the size of the radiators used, indicate that that pressure is intended.

expanding, until it reaches its limit of expansion at 212 deg. if it is not confined in a closed apparatus. When the water is confined in a closed apparatus in such a manner that the water at no point is in contact with the atmosphere, the pressure that can be exerted by the continued application of heat is bounded only by the strength of the material that composes the envelope.

The third fact is that when water is at its point of greatest density at the sea-level, or at about 40 deg. Fahr., it is also at its point of greatest compressibility. This fact is of the utmost importance to the heating profession. This last fact is at the very bottom of the whole hot-water heating problem. No man who intends to do hot-water heating has any right to overlook this tremendous fact in nature for one single moment when he is considering the question of the piping outfit for a given job.

One cubic foot of water at the sea-level at its point of greatest density has been compressed by the strength of Nature into the smallest compass that it can occupy. If the pressure of a column of water a mile in height should be applied to it the amount that it could be compressed would not be enough to permit the addition of another half-pint of liquid into the cubic foot that was under pressure. It was compressed to the limit when it just filled the cubic foot of space at the sea-level at 39.2 deg. Fahr. and atmospheric pressure only applied. So little, in fact, has this matter of the utter impossibility of compressing water into a smaller compass by pressure, and the constant expansion in bulk, or mass, under the application of heat been understood among the trade that it is a very common thing for the fitter engaged in the hot-water heating business to tell the prospective customer that the difference in weight between the hot and cold water produces the circulation. While this difference in weight is one of the things that tends to produce the circulation it is far from the only thing or the most important thing in the phenomenon of circulating water through pipes for heating purposes.

SECTION XXXIX.

I will try to make this clear with the aid of Fig. 24 and Table KZ. We will assume that Fig. 24 represents a receptacle B which may be called a boiler, and tubes or pipes P connected to the top and bottom of the receptacle B, and also open to the air at point T. The lower portion of the receptacle B does not contain water but is arranged to maintain fire. We will assume that the distance from E^1 to E^2 is 34 ft. and from the point at G at the bottom of receptacle B to the T on the tube P is also 34 ft. The tube or pipe may be of any size, but for our illustration we will call it a 3-in. pipe. From Table LZ we learn that one foot in length of 3-in. pipe will contain .38 of a gal. of water and that 19.5 ft. in length will contain one cubic foot of water which will weigh when at its point of greatest density 62.425 lb.

The importance to the hot-water heating man of this statement as to the weight of a cubic foot of water at its point of greatest density has not usually been brought forward by the writers on hot-water heating. Why it has been so slightly mentioned is another of the many strange things to be encountered when looking up this heating problem in so far as it is related to hot-water heating. When a receptacle contains one cubic foot of water at the sea-level, of the temperature 39.2 deg. Fahr., practically the most water that can be pressed into one cubic foot of space is in that receptacle. If a pressure equal to that of a column of water 5,000 feet high should be placed on it, the water could not be compressed enough to increase the weight to 63 lb. or enough to add one gill more water. It is because of this fact, the impossibility of compressing water more than it is compressed by Nature at atmospheric pressure, that one pound of distilled water at the sea-level and at its point of greatest density is used for obtaining the British thermal units that we talk about so frequently.

For the same reason the specific gravity of anything is determined by comparison with water at the sea-level when at a given temperature.

It is probable that this attribute of water is also the cause of its being the greatest absorber of heat known. At simply atmospheric pressure of 14.7 lb. at the sea-level, water will always absorb exactly the same quantity of heat in producing the same condition. If open to the air it will burst the bond of atmospheric pressure at a temperature of 212 deg. Fahr. Confine the water in a closed receptacle and continue to apply heat and the water will continue to absorb it until the pressure of the expanding of the incompressible water will burst the bond that holds it. In this, water is in no way different from what we call steam in its action under similar conditions, except that its weight and density per cubic foot of space is much greater than steam.

One feature of the process of heating water in a boiler or heating system that is of the greatest moment to the hot-water fitter is that each additional foot in height that a body of water contains between the bottom and the top of the column that is exposed to the air at the top, increases the pressure at the bottom of the column, and the temperature of the water at the bottom will always be higher when heat is applied to the bottom than it can possibly be at the top where it comes into contact with the air.

It is probable that the circulation in an open-tank system of water-heating is due more to this cause than to the difference in the weight of the ascending and descending columns of water, and that the difference in weight is of much less consequence than the difference in power needed to expand one cubic inch of water at the top of

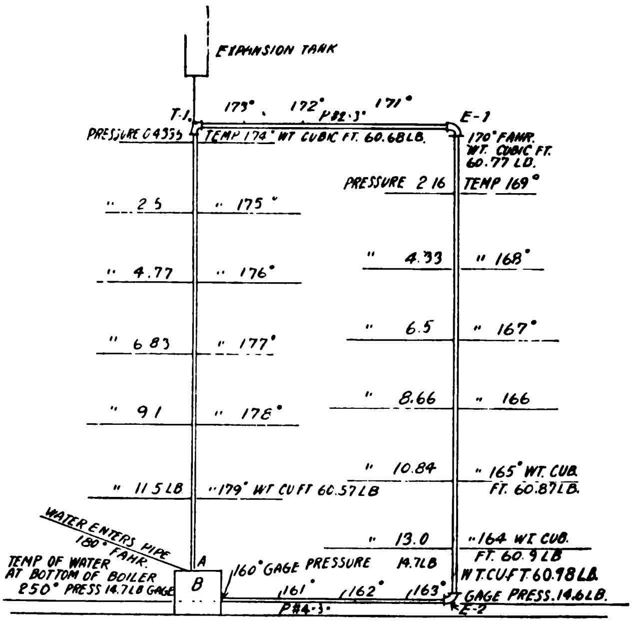

Fig. 24.

the column, where it is in contact with no pressure greater than the atmosphere, and the power needed to expand one cubic inch of the water at the bottom of the column, where the pressure in an average house job may easily be produced from 30 to 40 lb. per sq. in. greater than at the top.

In Fig. 24 the tube P is to be considered as being 34 ft. from the bottom of elbow E2 to the bottom of elbow E1. At the top of the pipe P1 a tee permits the water in the pipe to come into contact with the atmosphere by means of the extension of the pipe 1 to the expansion tank.

As a column of water one foot high exerts a pressure of .4335 lb. per sq. in. at its base when at the temperature of 40 deg. at the sea-level, it follows that the pressure at the bottom of a column 34 ft. high will be 14.7 lb. above that exercised by the atmosphere on the top of the column.

When heat is applied to the receptacle B circulation does not start instantly, as is sometimes stated, any more than circulation starts instantly in a pan of water set over a fire on a stove. The depth of the water in the pan creates a certain pressure at the bottom of the pan on the particles which constitute the element we call water, and the more depth the greater pressure. This pressure determines the length of time which, under a specified temperature of heat, will be required before circulation of the particles will actually begin.

In a hot-water heating apparatus the water will not begin to circulate until some particle of the water has absorbed heat enough to overcome whatever pressure rests upon it. As cold water cannot be further compressed it follows that no particle of water can rise until it overcomes whatever pressure rests on it.

SECTION XL.

In Fig. 24 the pressure on the bottom of the system is that due to a column of water 34 ft. high or 14.7 lb. above atmosphere, to which must be added the pressure of the atmosphere, or 14.7 lb. more, therefore, each particle of water at the bottom before it can start up from the bottom must reach a temperature of at least 250 deg. Fahr., as it is only at that temperature that a pressure of that amount is equalized. When one particle has absorbed that much heat it will have the power to overcome the pressure on it and to rise up in the receptacle because it has increased in strength, and although it now possesses the power to shoot straight to the top of the column if unobstructed, it does not do so. The first obstruction to its progress up is the fact that as soon as it finds itself under a less pressure it immediately expands itself in size, and in doing this parts with some of its acquired heat to the particles with which it comes into contact. As soon as it has parted with so much power that it is equal in size and strength to the particles with which it is in contact, and can no longer overcome the pressure put on it by the height of water above it, it will either remain in a nearly stationary position until it receives more heat by contact with other rising particles, or it will drop towards the bottom again and remain there until it receives the necessary heat to give it the power to overcome the pressure on it and to rise toward the top again. It is this action that keeps the water circulating. The difference in the weight between the warmer and cooler water in the flow pipes is a secondary movement which is produced by, and from, the first cause just explained.

Let us investigate this matter a bit with the aid of Fig. 24. We will suppose that the system is filled with water when it has a temperature of 62 deg. Fahr., when each cubic foot will weigh 62.355 lb. From Table LZ it is seen that each lineal foot of 3-in. pipe will hold 0.051 of a cubic foot of water. The 34-ft. pipe will hold 1.73 cubic feet. One cubic foot of water measures or contains 7.4805 gals. One gallon of water weighs 8.3356 lb. The total weight of the water in the upright 34-ft. columns E1—E2, will be 107 1-3 ($7.4805 \times 8.3356 \times 1.73 =$ 107 1-3.)

Assuming the total length of the horizontal pipes to be 36 ft. the total length of all the 3-in. pipe suggested by Fig. 24 will be 102 ft. (32+36+34), and the pipe alone will hold over 5 cubic feet of water, weighing 324 lb., *all of which must be put into motion to produce circulation*, and in addition to the water which the pipe will hold there is an additional quantity in the receptacle or boiler itself that must be made to move.

If we apply heat to the receptacle B for a sufficient length of time and in sufficient amount the temperature of all the water in the system will become raised to any desired temperature below 212 deg. at any point in the system, if applied under conditions usually found in the average house-heating job. To accomplish this, however, all that weight of water must be moved up and down and over a great many times, and something more than the difference in the weight of the rising and falling columns of water in pipes P1 and P3 will enter into the process.

As boilers for hot-water heating are now rated as being capable of heating to 180 deg. the usual amount of water held in a heating system with the amount of radiating surface each boiler is rated to carry, commencing at the point where the pipe is attached to the boiler (a, on Fig. 24), and to return to the boiler at 160 deg., perhaps

TABLE LZ.

Showing the quantity of water held in one lineal foot of pounds and ounces. The length in feet of each size of pipe the cubic feet held in one lineal foot of each size of pipe at

Size of Pipe, Diameter in In.	Gallons in 1-Ft. Length.	Weight in 1-Ft. Length Lb.	Oz.
1	0.045	0	6
1¼	0.077	0	10
1½	0.105	0	14
2	0.174	1	7
2½	0.249	2	1
3	0.384	3	3
3½	0.514	4	5
4	0.661	5	8
4½	0.829	6	15
5	1.062	8	10
6	1.489	12	8
7	1.998	16	12
8	2.596	21	11
9	3.259	27	3
10	4.095	34	2
11	4.937	41	2
12	5.875	49	0

it will be well to examine into this difference of weight proposition from those temperatures. Especially so, as we have already seen that the actual pressure on the crown-sheet of a hot-water boiler before there is any heat applied is several times greater than the new ratings for steam boilers permit for a steam job.

With the simple lines of Fig. 24 to aid us we arrive at the following fact: That the water contained in first foot of pipe attached to the top of the boiler weighs .02 lb. less than the water in the last foot of pipe which is connected to the boiler as the return.

TABLE L. Z.

pipe in gallons, quarts, pints and gills. Also the weight in that will be required to hold 1 cubic foot of water. Also 40 degrees Fahr. and at sea level.

Length in Lin. Ft. Required to Hold 1 Cu. Ft. of Water.	Quantity Held, Gal.	Qt.	Pt.	Gill.	Cu. Ft. in 1 Lin. Ft. Length.
167	0	0	0	1½	0.006
96¼	0	0	0	2½	0.011
70⅔	0	0	0	3½	0.014
43	0	0	1	1½	0.023
30	0	1	0	0	0.034
19.5	0	1	1	0¼	0.051
14.5	0	2	0	0½	0.068
11.33	0	2	1	1⅛	0.088
9	0	3	0	2½	0.111
7	1	0	0	2	0.136
5	1	1	1	3 5/7	0.199
3.75	2	0	0	0	0.267
2.88	2	2	0	1 5/7	0.347
2.29	3	1	0	0 5/7	0.436
1.83	4	0	0	3	0.547
1.52	4	3	1	2	0.659
1.27	5	3	1	0	0.785

One foot in length of a 3-in. pipe holds 2.97 lb. water of 180 deg. temperature. The same length and size of pipe holds 2.99 lb. of water of 160 deg. temperature, a difference of .02 lb. The equivalent of .01 lb. is 70 grains. The total difference, then, in practically 3 lb. of water at 180 deg. and 160 deg. is 140 grains. As 437½ grains equal one ounce, the difference in the weight of these three first and last pounds is less than one-third of an ounce. If we are to take the statement usually handed out by the hot-water fitters in regard to what causes the water to circulate, we must conclude that .01 lb. weight in a hot-water apparatus is many hundred times more effective than anywhere else on earth. Four inches of the 3-in. pipe will hold 1 lb. of water, and the last pound is the heaviest and has the greatest velocity of any pound of water in the system and, therefore, is the propelling power that moves the whole mass according to the proposition that is usually advanced by fitters as being the cause or power which circulates the water in the heating pipes.

The absurdity of the proposition is evident the moment that any person takes the time to examine it as we have in this case. That over 300 lb. of water will, or can, be elevated over 30 ft. and forced through more than 100 ft. in length of 3-in. pipe with elbows to turn in the distance by a pressure of less than 50 grains to the pound, is hardly probable.

It is time that the advocates of hot-water heating get down to practical facts in regard to the circulation of water in this very excellent method of heating, and they will certainly have to do so if they expect to hold their own in the competition which is arising from the vapor-steam, vacuum, non-pressure steam and other similar projects of the steam men who are giving thought to the development of their business.

SECTION XLI.

The plain fact of the matter of the circulation of hot-water through the pipes in an open-tank system can be fairly stated by saying that the same heat that expands water until it breaks into the steam which is driven by the pressure generated in the process through the pipes, when applied to pipes that are first filled with cold water which at some high point in the system is permitted to come into contact with the atmosphere pressure, expands the water nearly one-quarter of its bulk between the temperature points of 40 and 212 deg. And as water is not compressible to any extent, this expansion presents a moving force to the particles of water which eventually lifts them to the point of highest elevation, at which point each particle finds itself against the slight pressure created by the height of the column of expanded water in the pipe to the open air, which may be connected with the main pipe at that point. The particles of water in the main pipe itself have less power of resistance against the now slightly expanded water than is offered by the weight of water in the so-called expansion-tank, and the warm water follows the path of least resistance to the pipes that drop to the boiler; and here the careful observer finds that in the ordinary hot-water job when running at its rated capacity of 180 deg., at the boiler, 160 deg., at the return, if he is to have proper circulation he must have a static or head-pressure greater at the foot of his return pipe than he has in the top of the boiler. In this there is no difference between steam and water jobs. It is at this point, and at this point only, that the difference in the weight of the ascending and descending columns of water cuts the greatest figure in the general question of hot-water circulation.

In a gravity steam job the only way that the water is returned to the boiler is by having the pressure of the return water at the point where it enters the boiler greater than the pressure of the steam on the water in the boiler. The difference in the average steam job of house-heating is 2 ounces per sq. in. greater at the bottom of the return pipe than the pressure on the bottom of the crown-sheet of the boiler.

In a well-proportioned hot-water job the difference in the pressure between the water on the crown-sheet of the boiler and on the bottom of the drop-pipe at the point where the pipe for the return enters the boiler, when the apparatus is working at the rated temperature of 180 deg. at the boiler, varies in accordance with the height of the ascending column of water and the length of the descending column coupled with the average temperature difference of the descending and ascending columns of water.

When the water contained in the system indicated by Fig. 24 is all of the same temperature there will be no circulation. It would make no difference whether the temperature of all the water was 40 deg. or 180 deg., the result would be the same, because so long as the temperature of the entire mass remains the same, the pressure at every point of the system bears the same proportionate relation to every other point. As soon as additional heat is applied to the bottom of receptacle B (which will represent the crown-sheet of a boiler the lowest part of the water in which is under the same head-pressure as the water in the bottom of the pipe P-4 when all the water is of the same temperature), the water immediately over the fire begins to absorb the increased heat and continues to absorb it until the expanding particles of water have received power enough to overcome the head-pressure on that bottom layer, if I can use such an expression in regard to water. These particles will in every case reach a temperature equal to the temperature of steam at the same pressure. In the case of Fig. 24 we have taken the height to be 34 ft. from crown-sheet to the top of pipe P-2. This height represents a pressure of 14.7 lb. due to the static head, or height of the column of water.

From table M-2, or any table of the properties of steam, one will find that this represents a pressure equal to that of the same amount as the atmosphere. In other words, of the atmosphere itself and another, or gage pressure, two atmospheres or an absolute pressure of 29.3 lb. The temperature of these particles at the moment of their overcoming the total pressure upon them will be, therefore, the same as that of steam at the same pressure, or 250 deg.

The weight of one cubic inch of these expanded particles would be 236 grains, while the weight of one cubic inch of the water in the return pipe at the point of its connecting with the boiler would be in accordance with the temperature of the whole body of water at the time the heat is applied, provided that there is no circulation yet in actual progress.

If that temperature be 62 deg., then the weight of one cubic inch will be 259 grains and the difference in the weight of one cubic inch is 23 grains, or about one-nineteenth of one ounce. This difference constantly diminishes as the contents of the two pipes approach each other in temperature. With the water in the supply pipe at 180 deg. at the boiler and 160 deg. at the return, the difference in the weight of one cubic inch will be about one-fortieth of an ounce as compared with the very bottom of the boiler, and about one-two-hundred-and-eighteenths of an ounce if compared with the weight of a cubic inch of water as it enters the supply pipe at 180 deg. If we compare the weight of one cubic foot of water at 180 deg. with the weight of a cubic foot at 160 deg. we find the difference to be .43 lb. or a trifle less than 7 ounces. .01 of a lb. equals 70 grains. 437.5 grains in one ounce. We find that the weight of the water in 1 ft. of 3-in. pipe at 180 deg. will be 2.97 lb. and at 160 deg. will be 2.99 lb., a difference of .02 of a lb., or less than one-third of an ounce.

From the foregoing it is evident that there must be something besides the difference in the weight of the two columns of water that produces the circulation in a hot-water job. It will hardly be a competent reply to say that the height of the fall of the return water furnishes the motive power, it seems to me, although that is usually the offhand statement. If the pipe containing the water is tightly sealed, and heat is applied to the pipe at its lowest point, the pressure which would be created would be equal at every part, but the expansion of the particles of water would constantly grow less as they receded from the point where the heat was applied. To a great extent, it is this expanding and contracting of the particles of the water that gives action or circulation to the water in the heating system, whether the system be an open-tank or a sealed system. The terrific force that can be developed by the constant application of heat to water in a sealed pipe is well known. At this point please bear in mind that water at about 40 deg. is compressed to a point almost beyond the power of man to compress farther its particles. Apply heat in sufficient quantity and the particles increase in bulk, and of necessity crowd or press those that have not increased in bulk the same degree. The greater the pressure on the particles to which the heat is applied, the greater the quantity of heat that must be applied to cause expansion and circulation.

The amount of heat that will raise the temperature of a cubic foot of water from 40 deg. to 212 deg. will expand it to nearly 1.25 cu. ft. in size if exposed to the air. In gallons this means that approximately 8 gal. of water will swell to about 10 gal. The enormous power that is generated in this process and which is the prime cause of the circulation will be understood better, perhaps, if we notice what happens to 100 ft. in length of the iron-pipe that contains the water. Starting the heat when the water is at 40 deg. and continuing it until the whole body of water is at 212 deg., we find that the 100 ft. of iron pipe has been stretched in length about one and one-quarter inch. That is the power that produces the circulation, aided by the difference in weight.

TABLE MZ.

Velocity of water in pipes in feet per hour when the radiator at various temperatures, from 161 degrees to 180 dicated, no allowance

Water enters	161	165
Water leaves	160	160
Difference.	1	5

Drop of Return in Feet.	Feet Flow per Hour.	Feet Flow per Hour.
1	370	868
5	824	1,936
10	1,166	2,740
15	1,429	3,358
20	1,653	3,744
25	1,843	4,334
30	2,003	4,752
35	2,192	5,112
40	2,336	5,472
45	2,477	5,796
50	2,610	6,120

While this table is made with the return water as of 160 degrees there will be but a very slight difference at other temperatures usually required in hot water heating. For instance, if the entering water is at 220 degs. and the water as it leaves the radiator is at 210 degs. the difference in feet of flow per hour is only about 200 feet with no allowance for friction. To illustrate this and at the same time explain the method of producing the Table M Z: The weight of one cubic foot of water at 220 deg. is 59.64 lb. and a cubic foot at 210 weighs 59.82 lb. A difference of 18/100 of one pound.

Without an allowance for friction the velocity of drop per foot as produced by gravity is 32.16 feet, but it has

TABLE MZ.

water leaves the radiator at 160 degrees and enters the degrees, when the return drop is from 1 to 50 feet as in- being made for friction.

170	175	180
160	160	160
10	15	20
Feet Flow per Hour.	Feet Flow per Hour.	Feet Flow per Hour.
1,199	1,444	1,714
2,678	3,308	3,816
3,744	4,536	5,436
4,644	5,724	6,624
5,364	6,588	7,668
5,976	7,416	8,568
6,552	8,100	9,396
6,804	8,748	10,152
7,488	9,324	10,836
8,028	9,900	11,520
8,460	10,440	12,132

the same to overcome in the rising column, therefore the two columns equal 32.16×2=64.32. The distance dropped is to be 10 feet; then 64.32×10=643.20. The difference in weight is .18 lb. more 643.20×.18=115.7760. This must be divided by the total weight of one cubic foot of each column for both move at the same time. 59.82+ 59.64=119.46 and the square root of the quotient from this division will be the velocity per second without any allowance for friction. (115.7760÷119.46=0.969, the square root of which is 0.984—ft. per second; 3600 seconds to the hour. .984×3600=3542. feet per hour without allowance for friction. Table N Z under the difference of 10 deg. with the return water at 160 deg. gives the flow as 3744, a difference of 202 ft. in an hour, so small that it would not be of consequence.

Having found the velocity in feet that the water will move, the next thing is to find the cubic feet of water that will be required to supply various conditions that may arise. The manner of finding this out is clearly shown in Table N Z.

TABLE N Z.

Showing the cubic feet of water required per hour per square foot of radiating surface at different temperatures and at different rates of loss as the water passes through the radiating surface.

Item									
1	Temperature of water.	140	150	160	170	180	190	200	210
2	Weight per cu. ft. at above temperature.	61.37	61.18	60.90	60.77	60.55	60.32	60.07	59.82
3	Temperature of room.	70	70	70	70	70	70	70	70
4	Dif. bet. temp. water and air in room.	70	80	90	100	110	120	130	140
5	B.t.u. emitted per hour per sq. ft. of radiator per deg. diff.	1.4	1.45	1.45	1.5	1.5	1.5	1.6	1.6
6	Total B.t.u. per sq. ft. per hour. (Item 4xItem 5.)	98	116	130	150	165	180	208	224
7	Lb. water cooled 1 deg. Fahr. in producing 1 B.t.u.	1	1	1	1	1	1	1	1
8	Lb. water required to be supplied to each sq. ft. per hour if cooled 5 degs. passing through radiator. (Item 6 ÷ Item 8.) thus (98 ÷ 5 = 19.6.)	19.6	23.2	26.	30.	33.	36.	41.6	44.
9	Lb. when cooled 10 deg. in passing. (Item 6 ÷ Item 9.)	9.8	11.6	13.	15.	16.5	18.	20.8	22.
10	Lb. when cooled 15 deg. in passing.	6.5	7.7	8.6	10.	11.	12.	13.8	14.9
11	Lb. when cooled 20 deg. in passing.	4.9	5.8	6.5	7.5	8.25	9.	10.4	11.2
12	Cu. ft. required per sq. ft. per hour if cooled 5 deg. in circuit. (Item 9÷Item 2) thus, (19.6 ÷ 61.37 = 0.319.)	0.319	0.379	0.426	0.493	0.545	0.597	0.692	0.749
13	Cu. ft. required if cooled 10 deg. in circuit. (Item 9÷ Item 2) thus, (9.8 ÷ 61.37 = 0.159)	0.159	0.189	0.213	0.246	0.273	0.298	0.343	0.374
14	Cu. ft. required if cooled 15 deg. in circuit. (Item 10÷Item 2.)	0.106	0.126	0.142	0.164	0.182	0.199	0.230	0.249
15	Cu. ft. required if cooled 20 deg. in circuit. (Item 11÷Item 2.)	0.079	0.096	0.107	0.123	0.137	0.150	0.173	0.187

SECTION XLII.

But what gets the water into the boiler against the combined head-pressure and heat-pressure at the crown-sheet?

As previously stated, the process is exactly the same as with the steam boiler. In the hot-water boiler there is an area of surface exposed to the action of the heat very much greater than the area of the connecting pipes that circulate the water after it is heated. Because of this the total quantity of water that is actually expanded enough to rise to some considerable distance higher than the highest point in the boiler cannot all get through the pipe opening, with the result that a forced circulation is set up in the boiler which sends the water into the pipe as it starts on the circuit in much the same manner that water is sent out of a hose nozzle. As soon as a complete circulation is established the weight of all the water in the boiler itself is lighter per cubic foot than the pressure due to head at the top of the boiler where the circulating pipe commences, and as it cannot get out of the boiler a pressure is created artificially that at least equalizes the static head at that point, and as the heat in the water increases, this expansion, or pressure, extends higher in the pipe of an overhead system, or farther in the main of a circuit system, very much as happens with a steam job. This crowding of particles and loss of strength as they get away from the boiler is in every way similar to the action of steam.

The net result of this is that, while the total depth of

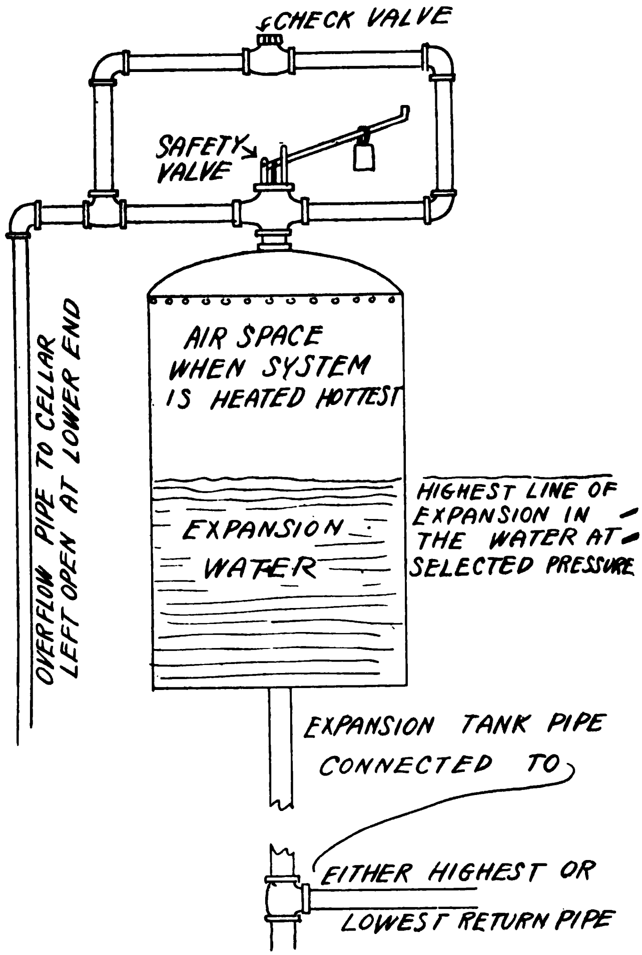

Fig. 25.

water is the same in the supply and return as indicated in Fig. 24, the pressure equalizes at some point higher than the top of the boiler, thus making the unequalized portion of the return pipe longer than the supply, sometimes by several feet.

Assuming that the loss of 20 deg., from 180 to 160, is absolutely uniform per lineal foot for an apparatus as

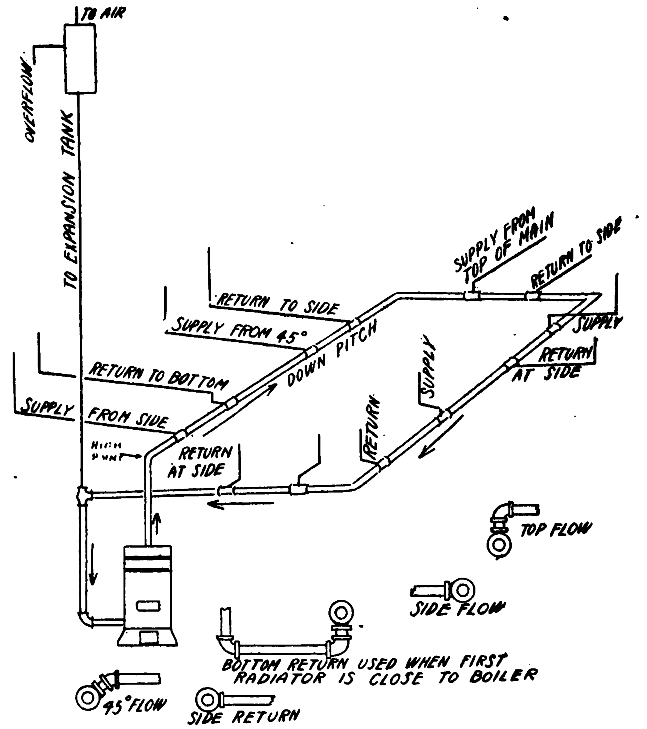

Fig. 27.

indicated in Fig. 24, the point of average temperature would be at E-2. At 170 deg. the water has an expansion or pressure force to exert against the down column of about .25 lb. per sq. in., which added to the longer fall in the return pipe produces the extra pressure needed to keep the water continually flowing into the boiler through the return until such time as the heat in the boiler growing less fails to expand the water sufficiently to overcome the static head. When that time arrives there will still be some particles of water receiving sufficient heat to expand slightly for a time but they will be robbed of their heat by the other particles in the boiler before they force themselves out of the boiler and soon the active movement of the particles ceases.

Here is where the hot-water system gets its greatest gain over gravity steam jobs. The gravity steam job having but a comparatively small quantity of water to raise to 212 deg., gets heat to the radiators in an effective quantity sooner than can usually be secured from hot-water, but the steam has nothing but the latent heat of the steam to give out, 966 B. t. u. per lb. of steam. When the heat in the boiler of the steam-job falls below the point where the water in the boiler can be maintained at 212 deg., the heat from the radiators ceases as quickly as it started.

With the water job it is different. The water not only has a large bulk from which to deliver heat, but it continues to receive the heat from the fire and deliver it to the radiators to the extent of at least 100 deg. of temperature after the steam-point ceases. This refers of course to the open-tank systems for water, and gravity systems for steam.

With any sort of a sealed-tank system of hot-water the case is somewhat different. Given an overhead, or attic-circuit water-system sealed to 25 lb. pressure at its highest point, and pipes, smaller than would be used for a gravity steam job limited to 2 lb. at boiler, can be used.

The radiators would be smaller than would be required for the steam job. Reserving 20 per cent of the usable

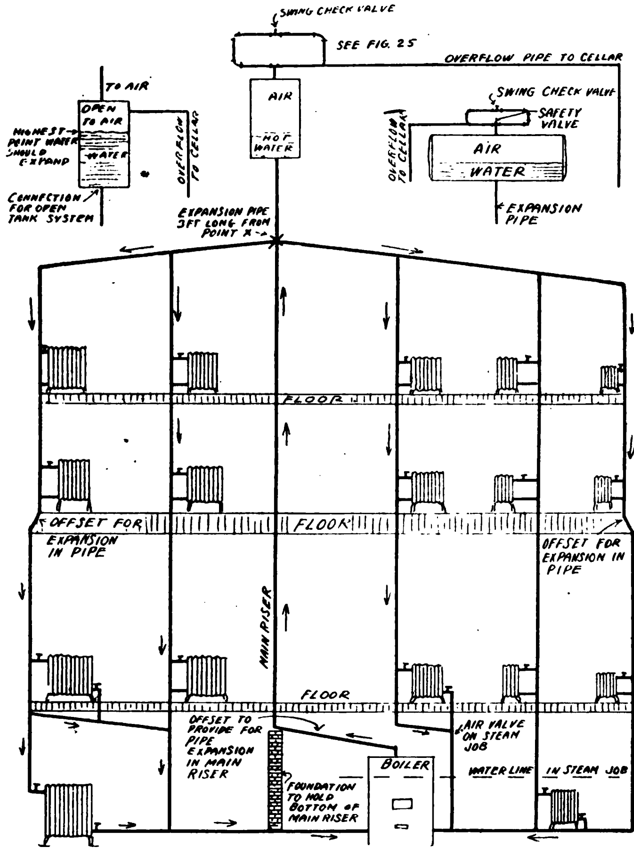

Fig. 26.

pressure for emergencies, the radiation can be figured on the basis of 20 lb. pressure or at a temperature difference of 190 deg., but all the heat of the fire above about 100 deg. will be delivered from the radiators to the room.

All the patent heat-generators, so-called intensifiers, and the like that have come on the market within the past few years are nothing but carefully prepared seals operating at anywhere from 10 lb. to 30 lb. pressure. A well-adjusted weight safety valve set as per Fig. 25 is a safer and more sensible attachment than some of these patent seals now on the market. The weighted safety valve has also the compensating feature that you can know exactly what pressure you are sealing in the boiler.

If you are going into the sealed hot-water business, and within reasonable limits, there should be no great objection to it, keep the regulation of the pressure within your own control.

The overhead hot-water system as indicated in Fig. 26 is undoubtedly the best theoretically for either open-tank or sealed jobs. Next to that I would say turn the overhead system into the cellar. You will then have a single-main pipe-system, on the whole the most practical for either steam or water heating for ordinary house-work. This is shown in Fig. 27. The old-fashioned manifold system, where each riser was connected with the boiler, is not used to any great extent at this time, but there often arise conditions where its use is a matter of good practice. This is quite often the case where indirect radiators for a hot-water job are required. In most instances it will be better to feed the indirect stack from a simple circuit directly from and to the boiler rather than to attempt to take it from the main circuit that is to supply the direct radiators on the floors above.

Piping for hot-water heating, and piping properly, is a careful and should be a painstaking piece of work.

Water cannot be compressed as steam or air may be at one place and allowed to expand in another through the vagaries of piping and secure for the fitter the best results.

SECTION XLIII.

In hot-water heating, because of the non-compressibility of the water, and in the open-tank systems of the very slow velocity of the water through the pipes, the fitter who cares for his reputation as an engineer, or who has a pride in giving to his clients the best possible equipment for his heating-plant, will be exceedingly careful in the selection of the pipe-sizes.

The craze for small pipe that has swept over the country in regard to steam-work seems to have been growing in favor with the cut-price-get-a-job-at-low-price men in the hot-water heating-business. Hundreds of water-heating men have badly crippled the effectiveness of their work from a senseless selection of pipe-sizes.

Consider what the heat which emanates from a hot-water radiator is derived from. We have seen that water is a fluid which is practically compressed to the limit when we start with it. We also know that in order to have the radiator deliver one heat-unit, 1 lb. of water must be cooled 1 deg. Fahr. It follows, then, as the simplest sort of reasoning, that if the fitter desires to have one square foot of hot-water radiator surface yield any given number of heat-units per hour, it will be necessary to supply that square foot of surface with a certain number of pounds of water per hour at the temperature required.

For instance, with water at 180 deg. at the boiler and 160 deg. at the return, the average temperature is 170 deg. If the room is at 70 deg. the difference is 100 deg.

Given a three-column radiator delivering to the room 1.5 B. t. u. per degree of difference per square foot per hour, or 150 B. t. u. or 1 deg. from 150 lb. of water. Assuming that the water enters the radiator at 170 deg. and leaves it at 160 deg., the radiator surface has taken as an average 1/15 of the heat that it is designed that it shall take from the water in one hour; and to complete the requirements, the same amount of water at the same temperature must flow through that same radiator 15 times in one hour. And in order to accomplish that, it is certain that a definite pressure and a definite quantity of water-flow must be maintained. To obtain this there must be a definite relation between the size of the pipe, the friction incurred, the velocity attained, the quantity of water delivered, and the loss that is to occur in the passage through the system. In an open-tank system the velocity under the most favorable conditions must be low, but there will be a variety of velocities in the ordinary house-job.

The height that a radiator sets above the boiler has a very great bearing on the velocity of the water through it and, of course, this in turn has a bearing on the size of pipe that will be required to deliver the needed pounds of water to furnish the 150 B. t. u. per hour. Table MZ gives the number of feet per minute which the water will move in a properly piped hot-water open-tank system.

Table N Z makes no provision for friction in the pipes. Having found the cubic feet of water to be moved per hour at an accepted loss of temperature as shown in Table N Z Items 12 to 15, inclusive, and the velocity that the water must assume to produce that loss (Table M Z), it is evident that if the total number of feet of radiating surface on a job is multiplied by the loss from one square foot and the sum thus found is divided by the hourly velocity, the area that will be required in the pipe will be disclosed. But this will not provide for the friction, as these tables only show the theoretical movement of the water in the pipes.

The fitter for hot-water who is to give his client the best results possible will give this matter of friction the most careful attention. In laying out the job the fitter will use the least possible number of elbows and other friction-producing fittings. In the long run it will be found that the use of the patent fittings, like the O. S. fittings, on risers and other suitable places, the Eureka fittings for the main supply pipe, or the Phelps combination fitting, are decidedly better than the regular fittings, and will tend to produce better results in the circulation and also reduce the net cost of the work.

Labor, at present prices, is decidedly more expensive than the difference in the price of these patent fittings and the price of the common ones. In addition the fittings mentioned, and others that may be not so well known, present a smoother surface to the water and also to the eye.

In most cases where the piping, including the addition to be made because of fittings (see Section XVIII) does not exceed in measured length 100 feet, the pipe-sizes found by the use of the tables will protect the friction if the next size larger pipe of commercial rating be used.

There are almost as many combinations of pipe sizes available for hot water as we found for steam and they are each governed by the same rule. The velocity, the volume, or cubic feet to be moved in a given time, the heat given off from one square foot of heating surface per hour, all enter into the size of pipe to be selected.

Suppose we have 1200 square feet of heating surface in a hot water job, and that the average length of the return pipes above the top of the boiler is found to be 10 feet. We have a great variety of pipe-sizes that can be used, any one of which will be correct for certain conditions. It is the duty of the fitter to decide upon the condition, and then to have the knowledge and understanding to comply with the selected condition in the size of pipe used.

The most of the open tank water jobs are figured for pipe-size on the assumption that the emitted heat from the radiator will reduce the temperature of the water in passing through the radiator about 10 degrees and that the average height of the return piping will be 10 feet. Some authorities use a loss of 8 degrees, others figure the loss at 12 degrees and, of course, each has a different set of pipe-sizes from the other, just as we found to be true in steam heating.

With 1200 square feet of radiation surface and the water to be figured at 170 degrees average in the radiators, we would first note from Table N Z that each square foot of surface required for a drop of 10 deg. 0.246 cubic feet, then 1200 sq. ft. will require 295.200 (1200×0.246). From Table M Z we note that the velocity with a drop of 10 degrees is 3744 ft. per hour, so we divide the total cubic feet of water required by the total velocity to find the area that will be required 295.200÷3744=0.078. As there are 144 square inches in one square foot we multiply 0.078 by 144 and find the area required, without provision for friction, to be 11.23 square inches. The nearest commercial size pipe larger is that of a 4-in. pipe. If we use a loss of 5 degrees we will find we must use a 6-in. pipe. If we use a drop of 7 degrees in passing through the radiator, a 5-in. pipe, and so on through a long list. It seems useless to attempt to furnish a general set of pipe-sizes for hot water, as every job should be figured for its individual condition. I have clearly shown how to do the figuring. It is better that each fitter make his list for his locality.

From this table it is evident that a radiator that is 20 ft. higher than the boiler will circulate more water through it than one that is 5 ft. above the boiler, if fed from the same size of pipe. If the water in its passage through the radiator at each height delivers the same relative proportion of heat per sq. ft. per lb. of water passing through it, it is clear that a smaller pipe which will deliver a less number of pounds of water per minute or hour to the upper radiator should be used.

Perhaps this increased velocity of the water in sections of a heating-system will be more clearly understood from an illustration and drawing. The experience and observation of any mature person entitles him to know that a weight falling through space increases its velocity as it descends. The longer the fall the greater the velocity attained. Water in the pipes of a heating-apparatus is no exception to the law.

In Fig. 28 the fall from the radiator 1 is comparatively slow because of the short distance that the return water has to fall. In radiator 2, the supply-pipe is of the same height, but the drop is three times as long for the return water and therefore the movement will be quicker. *In hot-water heating it is the velocity of the movement of the return water that determines the speed of the circulation.* Neglect of this fact on the part of fitters often creates a condition where the movement of the water almost ceases.

Bear in mind that the average radiator holds about 1 lb. of water to the sq. ft. of surface, and that while the total loss of heat between the first supply and the re-

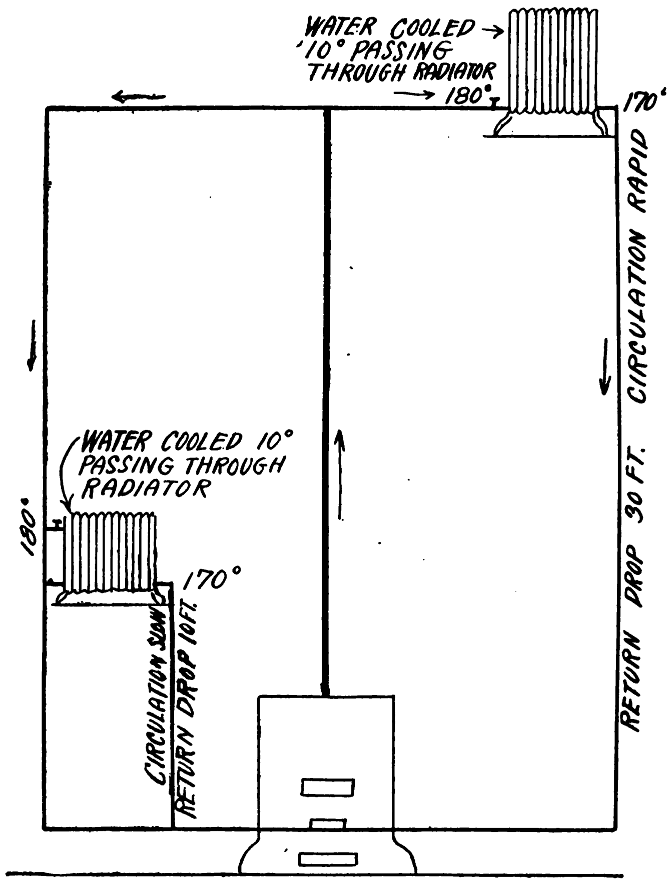

Fig. 28.

turn end of the piping from all causes may be as much as 20 deg., the average difference between the supply end and return end of a radiator is seldom over from 5 deg. to 10 deg. This fact calls for the exercise of some judgment on the part of the fitter when locating the radiators on a job. A radiator near to the boiler, with a long drop to the return, if fed full would circulate so fast that the difference between supply and return would be so slight, even in a very large radiator, that it could be safely figured to give off 170 B. t. u. per hour per sq. ft. of 3-col. surface, when the same radiator located just as near the boiler, so far as its supply pipe was concerned, but with the return-pipe only 3 or 4 ft. from the level of the top of the boiler, would have a circulation so slow that 140 B. t. u. per hour per sq. ft. might be all it would emit.

It is doubtful if for house work there is at this time anything known for artificial heating that is the equal of hot-water arranged to work evenly at an average temperature of about 150 deg. in the radiators, when it is 70 deg. in the room and zero out of doors.

SECTION XLIV.

On some pipe-lines a deficiency in the length of drop at the radiators the farthest from the boiler causes a very slow and unsatisfactory circulation. The remedy is evident. While the demands for accuracy are greater in the erection of the hot-water system than in the gravity steam, there are many things about the water-heating that appeal with commanding force to the home-owner. Now that steam-heating is practical at below atmospheric pressure, so that the temperature of the radiators is no greater than in hot-water heating, with the fuel expense even less than with most hot-water systems, the hot-water heating men will either have to learn to do better and much more careful work when installing open-tank water-heating, or find themselves slowly pushed out of the race.

In piping for the expansion-tank there is a great difference in the practice in different sections of the country. Personally I would advise that the bottom of the expansion-tank never be less than 30 in. above the top of the highest radiator, and, when practical to do so, I should connect the tank as shown on Fig. 27. The higher the expansion-tank above the highest radiator the better. If a water-job is to be sealed, and a safety valve attached to the tank, the utmost care must be taken to provide sufficient space in the tank that there may be a generous air-cushion in the top of the tank. This air-cushion should equal about one-half of the total inside capacity of the tank when the water has attained its normal expansion for the pressure it is intended to carry.

In selecting a boiler for any sealed job, the manufacturer should be told that the boiler is to be so used and a certificate of hydraulic test to at least 200 lb. per sq. in. should be furnished. This pressure is not above that at which many boilers are regularly tested, but it is well to have a certificate of inspection and test from the boiler manufacturer even when the job is to be sealed to the extent of the 10 lb. that the majority of the patent-seals claim to give. When the patent-seal is attached to the return-pipe near the boiler in the cellar with a direct connection from the top of the seal to the expansion-tank in the attic, the fitter should always request that the manufacturer of the boiler he intends to use should specially test it to 200 lb. per sq. in. and furnish a written certificate to that effect. The total seal when set in this way is sometimes very heavy, and it is but fair that the manufacturer of the boiler to be used on the system should know that a pressure in excess of the open-tank system is to be used.

In piping for the sealed system, the same question in regard to the number of pounds of water at the higher temperature that must be used comes up for solution. The velocity of the water in a system sealed to 10 lb. will be much more rapid than in the open-tank system, and if sealed to 25 lb. will be more rapid than at 10 lb. These differences can be stated in this way: If in an open-tank system, a 1-in. pipe will supply 40 sq. ft. of hot-water radiators, the same pipe will supply 60 sq. ft. with all other pipes properly proportioned to a 10-lb. seal, or from 112 to 125 sq. ft. and under some conditions as much as 200 sq. ft. can be successfully filled from an inch pipe when the seal is at 25 lb.

Whatever the pressure carried on a hot-water job, one stubborn fact is always present. To secure the delivery of 1 B. t. u. from a square foot of radiating surface 1 lb. of water must be cooled 1 deg. Fahr., and therefore the number of times the water must pass through a given radiator in a given time will be conditional upon the number of degrees of loss there is in the temperature at each passage.

The usual loss when the open-tank system is properly proportioned and under average conditions is about 5 deg. when the water enters the radiator at 180 deg. and the air of the room surrounding it is at 70 deg. This is a higher temperature than is usual for the average in an open-tank system, but might be secured. Taking the average jobs the country over, and the difference is perhaps 10 deg., which, of course, means a slower circulation. The average radiator will hold just about 1 lb. of water to the sq. ft. of rated surface, that is the 2 and 3-column goods, and their capacity for radiating heat is approximately 1.5 B. t. u. per degree of difference per hour below 170 deg., or 1.6 above 180 deg. See Table FF, Section V. With the average temperature of the water passing through the radiator at 170 deg. and the temperature of the room at 70 deg., the difference is 100 deg.; this multiplied by the 1.5 equals 150 B. t. u. per hour. If there is the cooling of 5 deg. from 1 sq. ft. in the one circuit through the radiator, each pound of water must pass through the surface 30 times in one hour. If the loss is 10 deg., the circuit must be made 15 times per hour, and the pipe-size must be larger to supply the water. Under the conditions named, 70 deg. in the room and 170 deg. average in the heating medium, it is very doubtful if a loss of over 15 deg. between the entering and leaving temperatures is often found in well-proportioned work. At this point it is well to recall the fact that with a difference of 15 deg., that with the water entering at 170 deg. and leaving at 155 deg., the average is 162 deg., or a loss in efficiency of nearly 10 per cent. The difference when the water averages 170 deg. is 100 deg. between water and room, the radiator emitting 150 B. t. u. per sq. ft. per hour. Let the water enter at 170 deg. and leave 15 deg. lower, and the average is only 162; the room being at 70 deg. the difference is 92 deg. and the radiating value per sq ft. drops to 138 B. t. u. per sq. ft. per hour ($92 \times 1.5 = 138$). This is a condition to be considered when the job is being laid out for the workmen.

The farther away from the boiler the radiator receives its supply of water, the lower will be the entering temperature as a rule, and also the slower the natural circulation. Fitters who use the so-called two-pipe circuit and who reduce the pipe every so many hundred feet of radiator surface, need to be very careful, as they near the last radiator taken off, to provide not only an ample size in the supply-pipe but to provide for a generous drop for the return-pipe.

Because of this feature it will be found in hot-water piping that the overhead system is best whenever it can be used, as the difference in temperature of the entering water can be more easily estimated and the drop is certain to be the most rapid at the place where it is the most needed.

Next to this come the single main circuit in the cellar with the supply-pipe for the radiator starting from the side of the main circuit-pipe when near the boiler and the return entering the bottom of the same circuit-pipe farther along. As the distance from the boiler increases in this sort of connection there is no reduction in the size of the main-pipe of the circuit and as the pitch of the pipe is all the way down from the boiler, the last radiator taken off will have a slightly increased drop-pipe over the next preceding radiator on the same floor. After getting some distance from boiler the radiator supply-pipe is taken from top of main. There is one other important feature to the credit of this single-pipe main circuit and that is that all elements which go to accelerate the flow are united in the one pipe. The circulation is more positive than in any other cellar-circuit system. The fact that this type of piping provides a continual circulation of the water in the cellar-pipes if every radiator on the job is shut off, is of as much value in this construction as in the overhead system. Some fitters claim that the circulation is the quicker in the cellar single-pipe because it averages to require less feet of pipe in the total, and therefore less friction.

From what has been developed in regard to hot-water heating it is evident that there is always, even in the so-called non-pressure, or open-tank system, a greater pressure to the sq. in. in the hot-water boiler than exists at the steam boiler under present ratings. When the expansion-tank is several feet above the top of the highest radiator, say 10 ft., and tank connection is made to the return-pipe of this radiator, there will be over 4-lb. pressure on the circulating water at the point where the tank-connection is made. The difference between the steam gravity job at 2 lb. at the boiler and the usual hot-water job so far as pressure on the crown-sheet of the boiler is concerned is all in favor of the steam.

In the matter of selecting the boiler for the hot-water system all the things that enter into the question of selection for steam enter into the careful selection for water heating, namely: The size of the fire-pot (see section **34**). The kind of coal to be used (see section **28**). The number of hours to be run with one firing (see section 25). The division of the fire-surface (see sections 33, 34, 35). The stack temperature required to produce the rating, is of even greater importance to the man who is to select a water-boiler than it is to the steam-fitter (see section **25**.)

The manner of selecting a hot-water boiler from the B. t. u. transmitted is in no manner different than with the steam-boiler. The only difference is in the divisor. With steam there is a tacit agreement on the part of the manufacturers to consider 240 B. t. u. per sq. ft. per hour as the value of radiation, but it is different with water, and it may be found that the majority of the manufacturers are still rating their boilers on the percentage basis, 65 per cent more for water than their steam-rating for a given boiler. It will be necessary, then, for the hot-water fitter to exercise the responsibility that the manufacturer has so freely thrown upon him and select a radiator value to please himself.

We will assume that the fitter is not desirous of wild-cat fame, but wishes to give his client the safest, easiest to handle and most economical sort of a heating job.

This would mean that a room temperature of 70 deg. is to be secured at zero weather with the average temperature of the water flowing through the pipes at from 150 to 160 deg., the difference being only 80 or 90 deg. As the radiator has a heating value of 1.5 B. t. u. per deg. of difference, the divisor would be either 120 or 135 B. t. u. in the place of the 240 B. t. u. used for steam. (150 —70 or 160—70×1.5=120 or 135).

In case of closeness on the part of owner, perhaps one of the kind that stands up very straight and declares "that the man who puts in the lowest bid and will warrant the job to heat will get the contract," the fitter who is so crazy to get a job that he will put in a bid for such an undertaking, might figure to get the expansion-tank 10 or 15 ft. above the top of the highest radiator, and to connect it with the return close to the boiler, and the pressure thus attained will enable him to figure safely that the average temperature in the radiators will be 210 to 215 deg. Suppose he takes 210, the room at 70, difference 140; $140 \times 1.5 = 210$ B. t. u. for his divisor. In the same manner if he desired to seal the job either with one of the patent "heat-generators" or with one of his own, he would decide as to the temperature that the proposed seal would permit, from this deduct the room temperature, and multiply the sum thus found by the radiator value of 1.5 to 1.6 to find the B. t. u. which each sq. ft. of radiator will emit, and this will be the divisor instead of 240, as for steam.

Nearly every day some honest well-meaning fitter loses a job to some house-wrecking concern which apparently undersells him. It is usually because the fitter, knowing only one way to figure a hot-water job, neglects to find out that a wrought-iron shell, made to stand the pressure that some high-sounding named seal will put on the job, is to be used for the wildcat boiler, and that the piping can, from its size, only deliver sufficient water to the radiators BECAUSE of this pressure, which must produce quick circulation. After it is too late, he wakes up to the fact that he could have sold what the customer actually bought at the same price and have made a bigger percentage than he ever dared to put on a legitimate open-tank system of the only kind he knew anything about.

If the fitter desires to test the rating of any hot-water boiler on the basis of 180 deg. at the boiler, he will consider the average temperature as 170 deg. for the flowing-water, which gives him just 100 deg. difference, and a divisor of 150 B. t. u.

SECTION XLV.

This leads us to the matter of radiators. The first radiators were crude indeed. Of course the first radiating surface was pipe coils of 1-in. pipe. Much of the confusion in the trade today in regard to radiator ratings has developed from lack of information in regard to the early history of the heating-business and of radiators in particular. The first recorded patent for a heating-radiator accompanied with a description that is now available, was granted to Anthony Hitchings in 1848. There was a patent granted 12 or 13 years before this to Robert Rogers of South Berwick, Me., but all trace of what form his system of steam-heating assumed was destroyed by the Patent Office fire of 1836.

The illustration, Fig. 29, of the original Gold boiler, as produced by H. B. Smith & Co., is very interesting, in that it shows that Gold's idea in the first place was not to use the header and return, or mud-drums, but to provide for an internal circulation.

It is probable that the troubles that come to the manufacturers because of the diffculties of maintaining tight joints with the rubber gaskets, when the boilers were used at the high pressure used in those days, led to the production of the header and return-drums in order that a screw-nipple construction might be employed and thus get rid of the troublesome rubber gasket.

This connection became practically universal; and as years of use accustomed the fitters to this header-connection, in time many of them came to think that there was something of special circulating merit in the device.

That, with the improved mechanical facilities of the present day, manufacturers should go back to the original Gold idea of an internal circulation without the use of the cumbersome outside connection, is a striking proof of the vitality and correctness of Samuel Gold's original idea as to the proper construction of a cast-iron heating-boiler.

Fig. 30 will be interesting as showing the first American patent for a system of hot-water heating. The chief

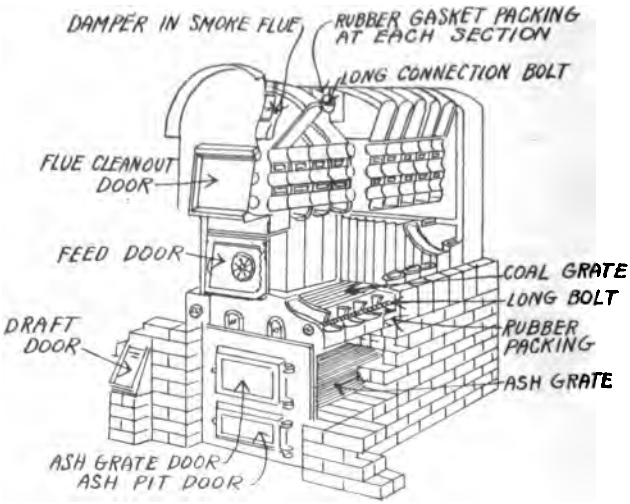

Fig. 29.

feature of the outcome of Hitching's patent seems to have been that it compelled fitters to use pipe for radiating the heat in steam and water-heating systems, or buy of Hitchings.

In order that the manner of rating radiators shall be clearly understoood. it will be necessary to trace, very briefly, the evolution of pipe-coils into pipe-radiators and the rise of the cast-iron radiator as a competitor.

It would undoubtedly be interesting to many to have the whole history given, but to do that would be to write a book. I personally believe that such a book from a

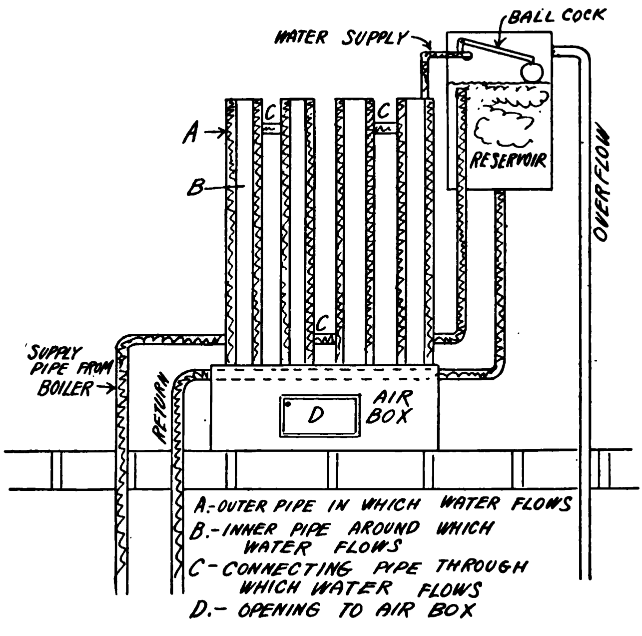

Fig. 30.

competent writer would be of great interest and value to the trade and the public.

The first radiating surface used was mostly of cast-iron pipe. A little later gun-barrels were used for this purpose to such an extent that the secretary of the United States treasury called attention to it in one of his reports to congress, in which he mentioned the beginning of a wrought-pipe industry in this country.

The first variation from a single pipe around the wall was what was called the "flat-coil." This was either pipe or gun-barrels from 30 to 48 in. long, screwed into return-bends. This was followed by what was known as "two-section coils," which were simply two "flat-coils" fastened up side by side with a "chuck-spacer" to fix the distance between them. Following this came what were known as "manifold-coils," the pipes being 3 or 4 pipes wide. The "box-coil" came into use for indirect work, taking its name because it was boxed close into its place in the cellar. There were several other designs of pipe-construction which were used in a horizontal position, and the name for which was as significant to the trade as the "box-coil," and about as unintelligible to the fitter of to-day; as, for instance, the difference between a "flat-coil" and a "wall-coil," although there was a marked difference.

The fitters of those days made many attempts between 1848 and 1862 to produce vertical radiators from pipe, but with slight success, and it was not until 1862 that the problem was solved.

In March, 1863, there was issued to Mason and Briggs a patent for a steam radiator composed of vertical tubes screwed into a horizontal cast-iron base, the tubes having an inner-tube, or a diaphragm, which served to prevent the steam from compressing the air and thus preventing the circulation of either the steam or the air. It is rather curious to find these two greatest of American steam-engineers adopting for the first successful vertical-pipe radiator the inner tube shown in the patent granted to Hitchings in 1848 for a hot-water radiator. It is also notable that while Hitchings' patent did not expire until 1865, or for three years, that Nason and Briggs considered Hitchings could use his radiator as a steam-radiator.

Within the few years immediately following 1862, the Walworth radiator and one or two other pipe-radiators received Patent-Office protection because of some novelty in the manner of construction.

In this way, from 1862 to 1879, the vertical-pipe wrought-iron radiator business fell into the hands of concerns of great capital and great business ability. These were the men who had the inventive power and the business capacity to make the steam-heating development in this country in those 17 years one of the business marvels of the 19th century. After the close of the Civil War the heating-business began to attrract the attention of the manufacturers of cast-iron.

Nason and Briggs, in putting their radiator on the market, arranged its surface in such manner that each wrought-iron pipe and its proportionate part of the cast-iron base and top should present exactly one sq. ft. of surface to the air.

Their first patterns were for single-pipes only, and about 30 in. in height. The demand for less extended radiators, when quite large surfaces were required, led to the making of 2-section, and later to 3 and 4-section radiators. But each section was figured to present exactly one sq. ft. of surface. Do not overlook the supreme importance of this fact. It is the key that will unlock for us the methods adopted by the cast-iron men when they got into the radiator game.

The production of radiator surface in absolute units of one sq. ft. immediately led to the adoption of the following method in ordering radiators. Suppose a fitter wanted 24 sq. ft. of surface in each of four radiators, and sent in an order for four standard height steam radiators, one 1x24, one 2x12 one 3x8 and one 4x6. There would be shipped to him four radiators, each of which actually contained 24 sq. ft. of heating-surface, but he would very soon find out that the 1x24 would heat more air than the 2x12, and that would heat the same amount of air hotter than the 3x8, and that in turn more than the 4x6. In this respect there was no difference between the vertical pipes "bunched" and the "wall-coils" 'bunched." The usual howl of "overrated" went up from those fitters who were so "practical" that they never needed to study or even read the "fool stuff that the book men get out."

Mr. Nason gave out the results of a few tests made by him as follows: From single horizontal 1-in. pipe, 64 ft. in length, and filled with steam at 228 deg. temperature, the air in the room being at 70 deg., he found the pipe emitted 447 B. t. u. per sq. ft. per hour. His test on a 1x24 Nason and Briggs wrought-iron radiator showed that under the same conditions the value was 390 B. t. u. per sq. ft. per hour. Under the same conditions he found that a 2x24 Nason and Briggs radiator only emitted 309 B. t. u. per sq. ft. per hour, and a 3x16 emitted at the rate of 278 B. t. u. per sq. ft. per hour. Mr. Nason endeavored to make it clear to those who wished to know that there was a material difference in the heating-value of 24 sq. ft. of 1-in. pipe surface as a radiator of heat, caused by the position in which it was placed, horizontal or vertical, and, again, it made a more pronounced difference if the surface was massed in close parallel rows.

As the result of the discussion at that time, different wrought-iron radiator manufacturers produced radiators which they warranted to contain 1 sq. ft. to each pipe, but some there were who endeavored to furnish for each single section of pipe, cast-iron base and top, which constituted the radiator, enough additional surface beyond that in the Nason and Briggs wrought-iron radiator so that a 1x24 section, for intance should emit 447 B. t. u. per sq. ft. per hour under standard conditions as they then existed. This had the effect of making these radiators more than 30 in. high.

After the close of the war between the states, the possibilities of the heating-business began to impress itself on the foundrymen of the east. They very soon became a factor of importance in the boiler part of the trade, but in order to get the radiator business into their hands something would have to be originated that could compete with the wrought-iron radiators in efficiency, appearance, and durability.

The popular width in the wrought-iron radiator was the 2-column. The first cast-iron radiator to catch the popular fancy was the "Bundy" radiator. This was brought out in 1869 and was the invention of Nelson H. Bundy, of the firm of Bundy & Healy, of New York. With some minor changes from the original "Bundy" the radiators manufactured by the late A. A. Griffing Company of Jersey City, N. J., was the same as this first real competitor of the wrought-iron radiators. The original patterns of the "Bundy" are owned now, and have been for many years, by the Walker & Pratt Mfg. Co., of Boston, Mass.

In order to secure the same number of heat-units per sq. ft. rated surface in a 2-col. cast-iron radiator that would be emitted from some larger unit in the 2-col. wrought-iron radiator, it was found that by making the cast-iron radiator a little higher, each section could be made to have the same value in B. t. u. emitted as a 2x2 wrought-iron standard radiator of the Nason and Briggs type.

This fixed the standard for 2-col. cast-iron radiators as 4 sq. ft. per section, and *height would vary according to width.* When in the course of time other foundrymen dipped into the making of radiators, they followed the precedent of the "Bundy" and professed to make their 2-col. radiators to emit the same number of heat-units per section as a 2x2 wrought-iron pipe-radiator of the standard of the Nason and Briggs type, and as a result 2-col. cast-iron radiators, rated at 4 sq. ft. per section, ranged from 34 to 39 in. in height.

The growth of the radiator business among the foundrymen soon led them to produce 3 and 4-col. radiators. It is at this point that the confusion arises in the minds of those who are not conversant with the methods which the cast-iron men used in rating their goods. When the matter of rating the 3 and 4-col. cast-iron radiators came up, they were fashioned so that each section should emit a certain number of heat-units relative to the wrought-iron goods of a 3 or 4-col. That is, one section of the cast-iron radiator should equal a definite number of sections of "bunched" wrought-iron pipe sections. The 3-col. radiator proved to be a troublesome proposition. In order to get the efficiency of 6 Nason pipes in a casting of the same height that had been established for 2-col. cast-iron radiators of 4 sq. ft. to the section, a radiator of undue width presented itself. It was thought that the height had already been raised as much as the public would stand, and finally the matter was solved by taking a 3x5 wrought-iron radiator containing 15 sq. ft. as the standard from which to create the competing cast-iron sections. In this way it became possible to produce a 3-col. cast-iron radiator that would emit under the then standard conditions of steam in radiator at 228 deg., air in room at 70 deg., 4,170 B. t. u. for 15 ft. of the massed or bunched surface, this being the same that a 3x5, or 15 sq. ft. of 3-col. wrought-iron pipe radiator emitted under same condition, viz.: 278 B. t. u. per sq. ft. of surface at temperature difference of 158 deg.

Probably there has been more notice taken of the size of the cast-iron 4-col. radiator in connection with its rating of 8 sq. ft. than of any other pattern. To most of the trade this 8-ft. rating has seemed like highway robbery. But when measured against a 4-col. pipe mass, it is the one pattern of all the cast-iron goods that is the most conservatively rated.

The great trouble with the cast-iron radiator proposition is that the trade has been fooled into buying the goods by the square foot of alleged surface, instead of buying what they themselves are called upon to sell, British thermal units of heat. When the trade gets around to the point of vantage which enables them to buy radiators on the basis of the number of heat-units given off under the new standard conditions, imposed by the new rating placed upon boilers, instead of buying sc many square feet of cast-iron, trusting to luck and guessing that the job will come out all right, as they now do, they will require of the radiator manufacturer a garanteed statement of the heat-units that each pattern of radiator will emit when placed under the standard conditions that the manufacturers themselves have created. And why should radiators be sold upon any other basis? It is heat-units that you are obliged to furnish when you contract to heat a building. Why then should you purchase square feet of iron without the slightest intimation of a garantee as to its capacity for delivering the heat you have contracted to furnish with "not to exceed 2 lb. pressure at the boiler" for your steam job, or with the thermometer not above 180 deg. at the boiler in the hot-water job?

From those who have followed me from the time we commenced with the chimney to this last question, I believe that there will be but one reply.

When the steam-fitters, the hot-water fitters, the architects and the engineers on whom the burden of selection and garantee has been thrown by the manufacturers, call for heat-unit values from the manufacturers as the only standard upon which business will be done, scientific heating will have commenced.

To give the common-school fitters of the country an idea of the fundamental principles of the science that they are practicing in their daily work, has been my aim, rather than to present a series of hard and fast rules, which, from the very nature of the heating-problem, could only serve to confuse those who had some insight into heating-problems as stated by others.

To furnish plain, even if at times long, explanations for each of the more important items which enter into the design and erection of a steam or hot-water heating-apparatus, to the end that any intelligent workman may, by the aid of the tables and explanations, be able to reconcile most, if not all, of the differences that the publishing of numbers of individual rules has created, has seemed to me to be the helpful thing to bring to the American architects and workmen in the steam and hot-water heating lines.

When these workmen have once grasped the fundamental facts which govern the heating-problems, it will not be necessary to furnish cut and dried rules for them. They have the capacity to work out, each for himself, a better working-plan for each individual contract than can be furnished ready-made.

To the man who desires to be reasonably well prepared to construct intelligently either steam or hot-water house-heating jobs, it is believed the plain reasons for each step which have been detailed in the discussion here ending will prove of value. But sound common-sense, applied to each job as it comes, is as much needed as the knowledge of rules. King David instructed Solomon, whom we are told became the wisest of men, as follows:

"Get wisdom, get understanding. Forget it not. Wisdom is the principal thing; therefore get wisdom, but with all thy wisdom get understanding." The advice is said to have worked out well when accepted by Solomon. Think it over.