A History of the Development of the Radiator

By ARA MARCUS DANIELS

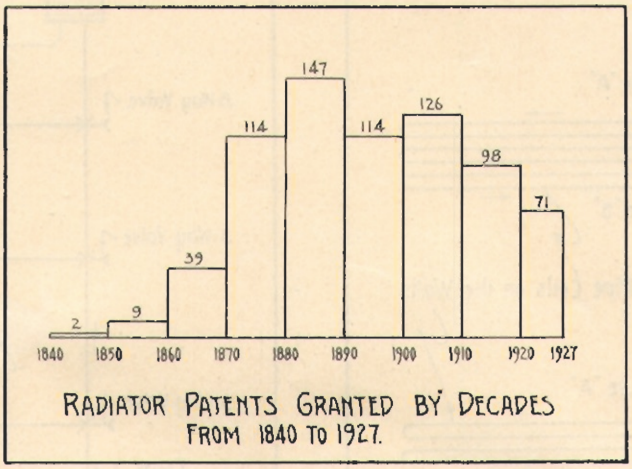


Fig. 1.—During the last eighty-seven years, no less than seven hundred and fifty patents applying to hot water and steam radiators have been granted

THE BIRTH of a useful idea, its gradual development into tangible form, the changes, modifications, alterations and elaborations accompanying its blossoming out into recognized popular usefulness and its ever present opportunity for still further advances in the art which it fostered, presents always an interesting field of research.

So it is with the practice of radiator heating. While this means of heating is at least seventy-five years old, the stages of development of the radiator to the familiar forms of today are appreciated by comparatively few, and the opportunities to improve and enhance are perhaps as great today as at any time throughout its development period.

Who can say when the first so-called "radiator" using hot water or steam, was installed in this country? Where can we look for some comprehensive picturization of the gradual unfolding of the idea that a receptacle for hot water or steam placed in a room would suffice to warm it to a comfortable degree for extremely low outside temperatures?

A search of the records of the United States Patent Bureau relating directly to the steam and hot water radiator as used in the application of steam and hot water heating to all types of structures would show a total of not less than seven hundred and fifty patents granted during the last eighty-seven years or an average of more than eight claims allowed per year. The chart of Fig. 1 illustrates the distribution of patents granted by decades from 1841 to the present.

The radiator has a history. To learn something of that early history, we must knock at the door of the hot water heating system. In 1837, Joseph Nason, who established the Nason Manufacturing Company in 1841, went to England and identified himself with a Mr. Perkins, the inventor of the Perkins' hot water system of heating, which at that time was well known and recognized throughout England. Mr. Nason superintended the erection and installation work in London and elsewhere.

This early system of warming buildings by means of hot water was really a closed system constructed almost exclusively of three-quarter inch piping. The boilers were of the box coil type being made in one continuous length without fittings, other than couplings, with all bends made in the pipes.

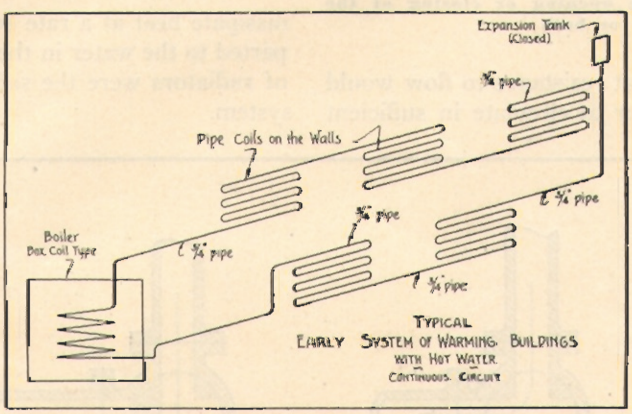


Fig. 2.—When hot water was first used as a heating medium for warming buildings, the system consisted almost exclusively of three-quarter inch piping. The boilers were of the box coil type with all fittings omitted, other than couplings. The expansion tank was seldom provided with an outlet. The coils located on the walls of the rooms represent the earliest type of hot water radiator and served as the only safety valve of these early systems

The radiating surface consisted of similar coils made without fittings and no valves were provided for regulating the circulation. There was an expansion tank near the top of the system, but it was seldom provided with a safety valve. Thus, the earliest hot-water radiators were coils carried about the sides of rooms (probably first used in greenhouses) in a very primitive manner. The circuit was continuous from the boiler, through the different rooms, and back to the boiler. Hence, the water from one coil passed in turn through each of the others in consecutive order, with the result that the water in each coil, after the first one served, was cooler than in that directly preceding it. See Fig. 2.

Obviously, it was soon found that pipes of large diam-

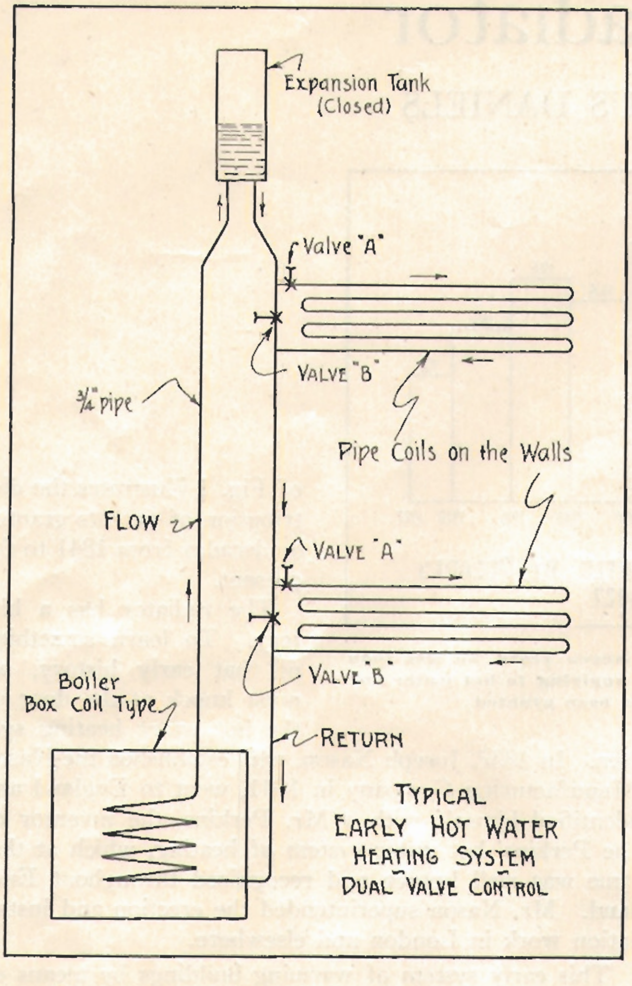


Fig. 3.—To permit separate control of the different coil radiators, two valves were next tried. While this solved the problem of control, the nuisance of handling two valves often resulted in trouble through the opening or closing of the wrong valve or both

eter were required in order that resistance to flow would be low enough to permit water to circulate in sufficient volume, to maintain a temperature in the last radiating surface served that would be high enough to assure heating service from that radiating surface. The bulk and appearance were objectionable features of this system, but the greatest objection was the fact that no part of the circuit could be interrupted without affecting the whole. Consequently, no valves were used and as it was a closed system, the radiating surface was the only element of safety. Hence the problem that faced the designers of these early systems was that of providing radiation having sufficient surface to

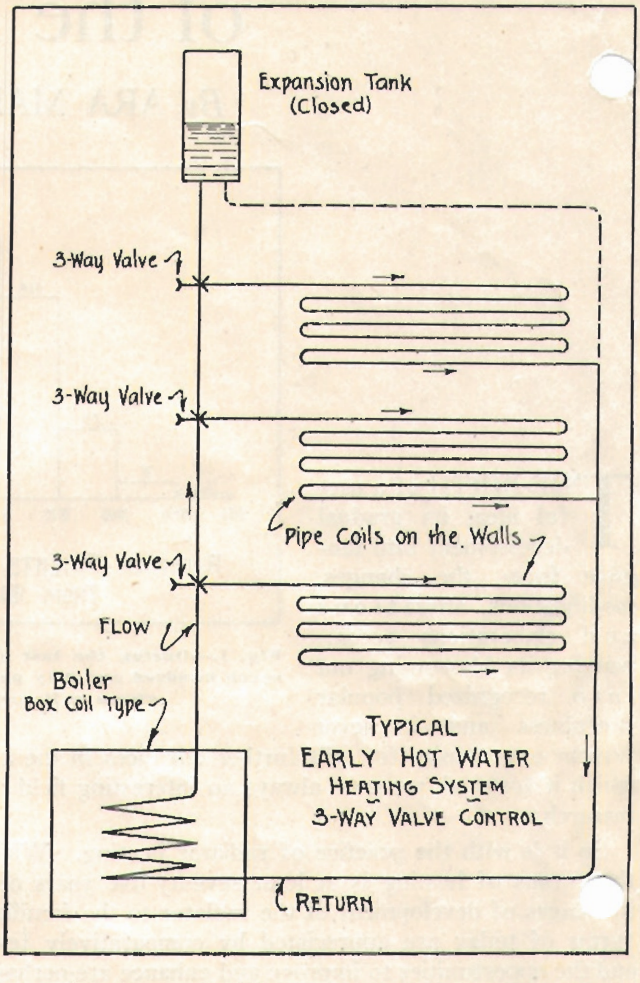


Fig. 4.—Replacement of the two control valves shown in Fig. 3 with a single 3-way valve served to eliminate the troubles caused often by the personal equation

dissipate heat at a rate equal to or in excess of that imparted to the water in the boiler. Thus, these early types of radiators were the safety valves of the entire heating system.

Earliest Application of the Hot Water Radiator Valve

The next development was to provide a system built on the principle shown in Fig. 3. Two valves were provided for each radiating surface, as shown at A and B in Fig. 3, so that by closing A and opening B, the particular surface could be cut out with positive circulation still maintained. We have here what might be consid-

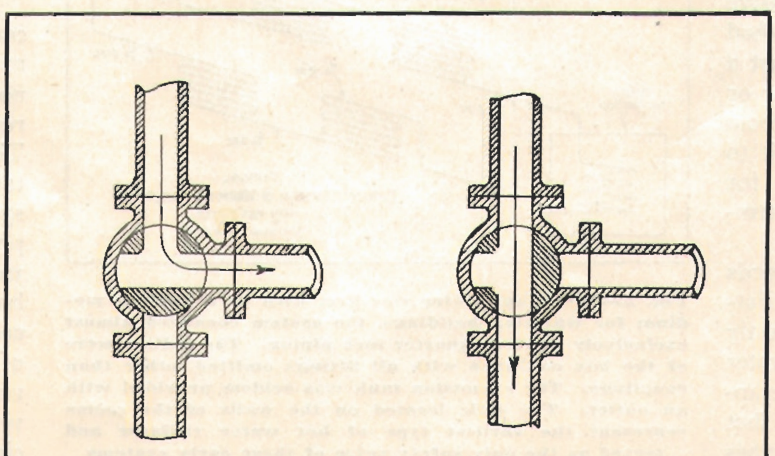
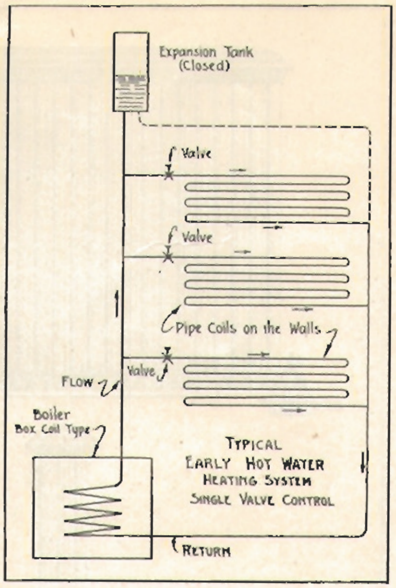


Fig. 5.—Illustrating the interior construction of this early type of hot water radiator control valve

Fig. 6.—Piping the system as shown here served to contradict the idea that a continuous circuit was essential to circulation, permitted the use of a single straight-wa· ·lve and proved tha· ·art of the flow would pass through the radiating coil and still maintain a circulation through the flow and return mains



ered the earliest application of the hot water radiator valve.

While this arrangement solved the problem of control

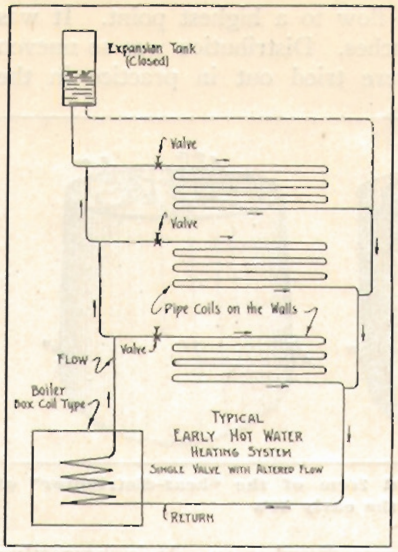
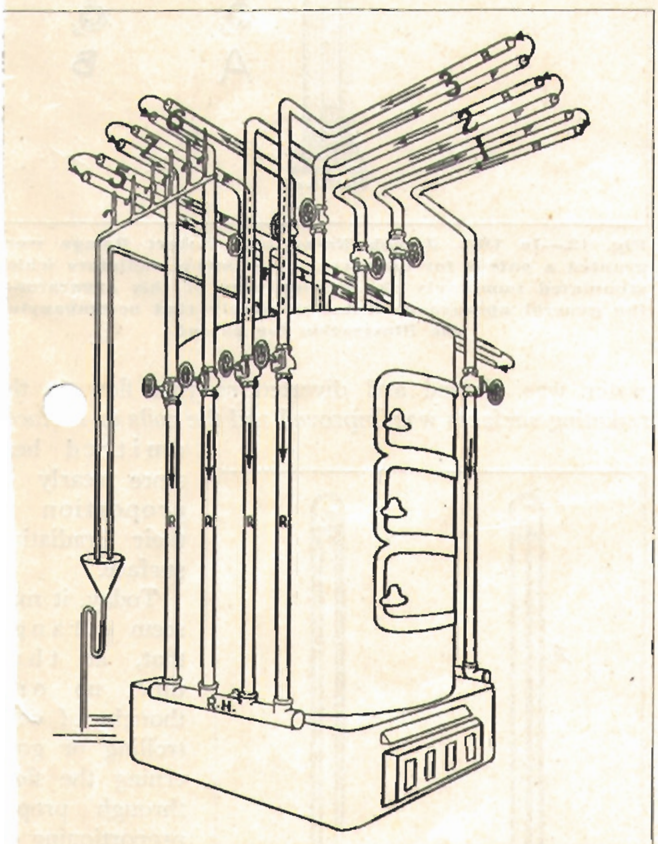


Fig. 7.—To assure more even distribution of flow, resistance due to change of direction of flow was introduced resulting in improved heating service



ig. 8.—Piping for hot water heating systems in these early mes was treated much as plumbers treated circuits for do·eatic water supply in the best work. Each flow and return ·ne was valved at the boiler with a small "draw-off" line for emptying the circuit

·f water to respective radiating ·urfaces, so long as valves A and 3 were closed and opened prop·rly, yet, so often, one valve was ·pened without closing the other ·r vice versa, that circulation was ·nti·· stopped with resultant ·rou·.. So, to correct this condi·ion, one three-way valve was used ·o replace the two valves, and in-

stalled as shown in Fig. 4. The operation of the valves is illustrated in detail in Fig. 5. The large pipes of the same size throughout the system were still used.

It was decided that a continuous circuit was not essential to circulation. On this theory, the radiating surface was connected to the piping system as shown, typically, in Fig. 6. Here, a single valve was used on each radiating surface. Part of the flow circulated through the heating surface or coil when the valve was partly or wide open, while the main circuit was maintained through the main supply pipe to the tank and thence through the return pipe to the boiler.

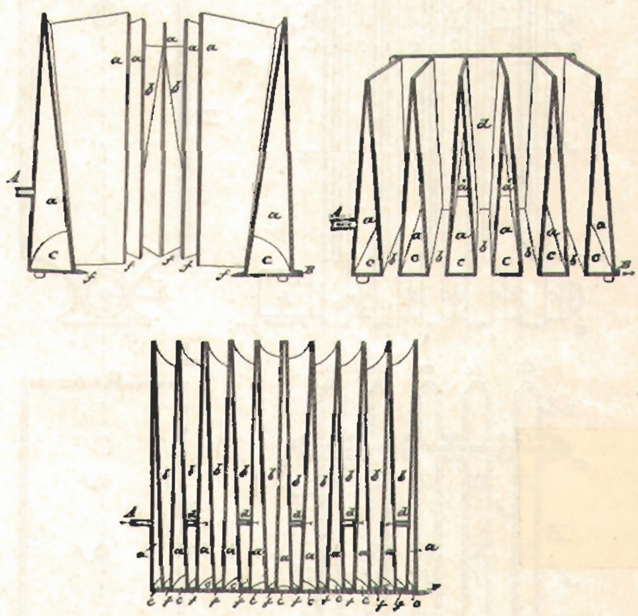


Fig. 9.—The earliest idea for a steam or hot water radiator designated "The Temperative Heat-Distributor." It represents a crude form of the radiator of a later period

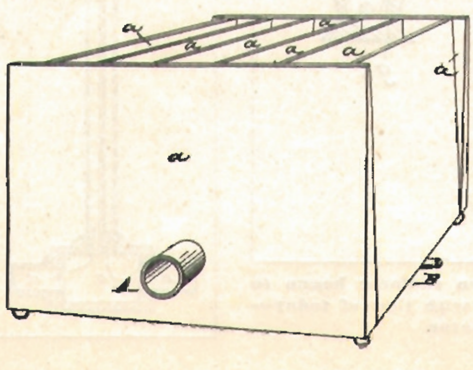


Fig. 10.—"The Heat Distributor" of the early 50's in box form

Under these conditions, radiating surfaces at different elevations above the boiler, delivered different quantities of heat for the same surface. The upper coils or surfaces were warmer than the lower coils. The tendency of the hot water was, and is, to flow to a highest point. It was passing the lower branches. Distribution was so uneven that various ideas were tried out in practice in the

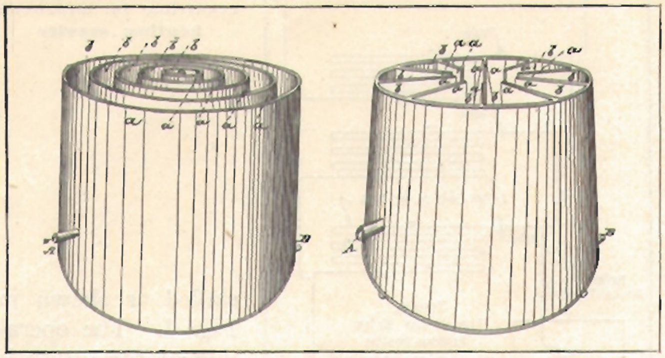


Fig. 11.—The cylindrical form of the "heat-distributor" of the early 50's

effort to produce uniform distribution. It is interesting to note that change in pipe sizes was not considered, the old idea prevailing always that large pipes of the same size should be used throughout the system.

Finally, the plan of introducing resistance by changing the direction of flow was tried. The piping arrangement shown in Fig. 7 was employed. Thus, the current of hot

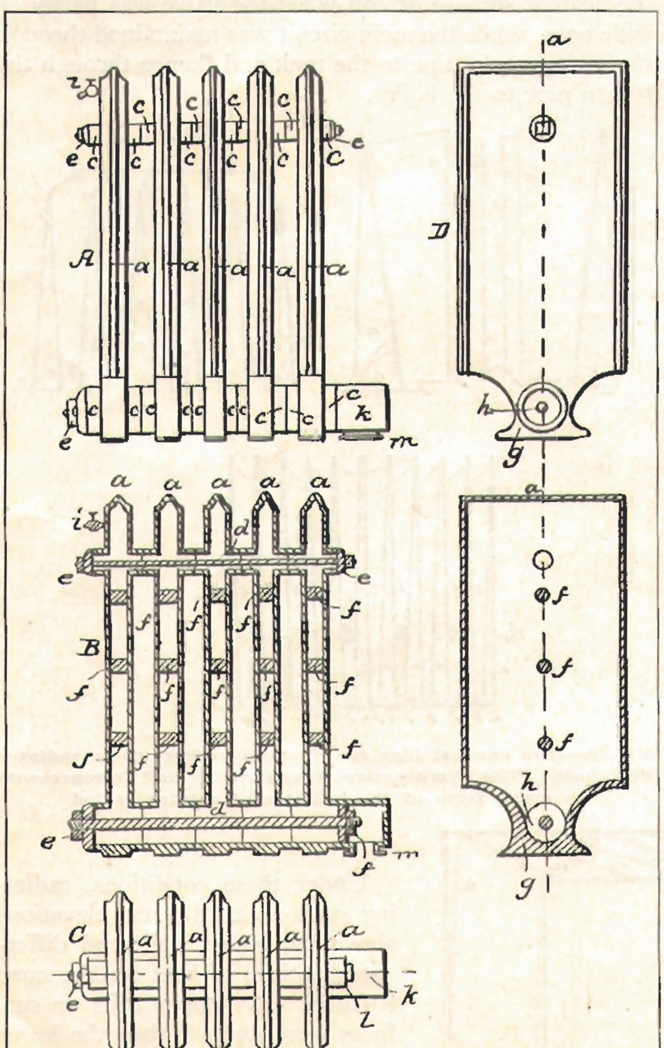


Fig. 12.—About 1860, the steam cast-iron radiator began to take form by which it may be identified with that of today—a crude five-section radiator

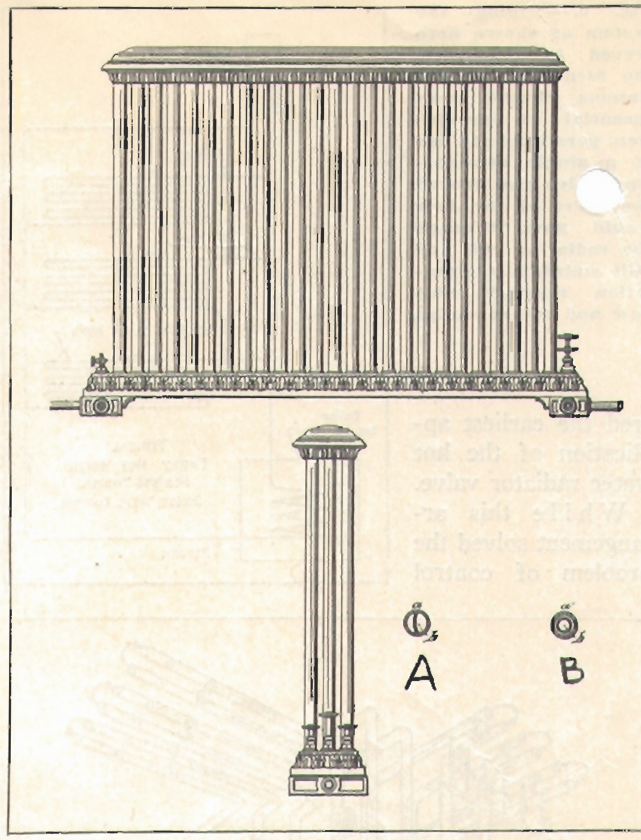
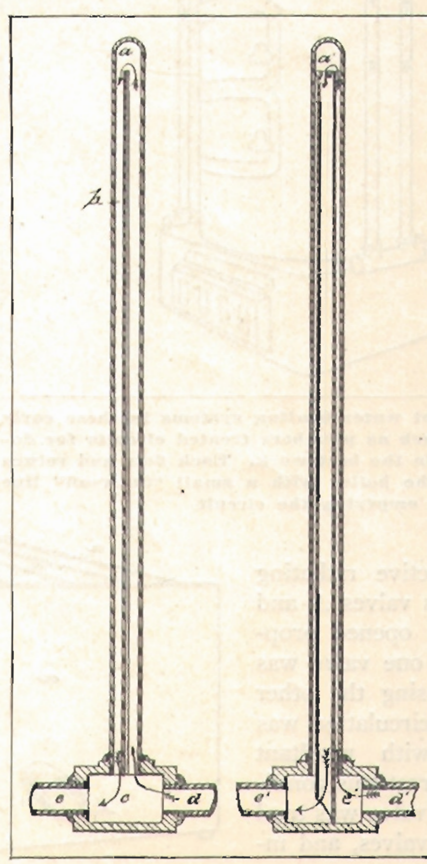


Fig. 13.—In 1862, Joseph Nason and Robert Briggs wer granted a patent for improvement of steam radiators whic stimulated immensely the manufacture of this apparatus— the general appearance followed closely that accompanyin the illustration for patent

water was divided and diverted so that flow to th radiating surfaces was improved and the coils or s rface emitted hea more nearly i proportion t their radiatin surface.



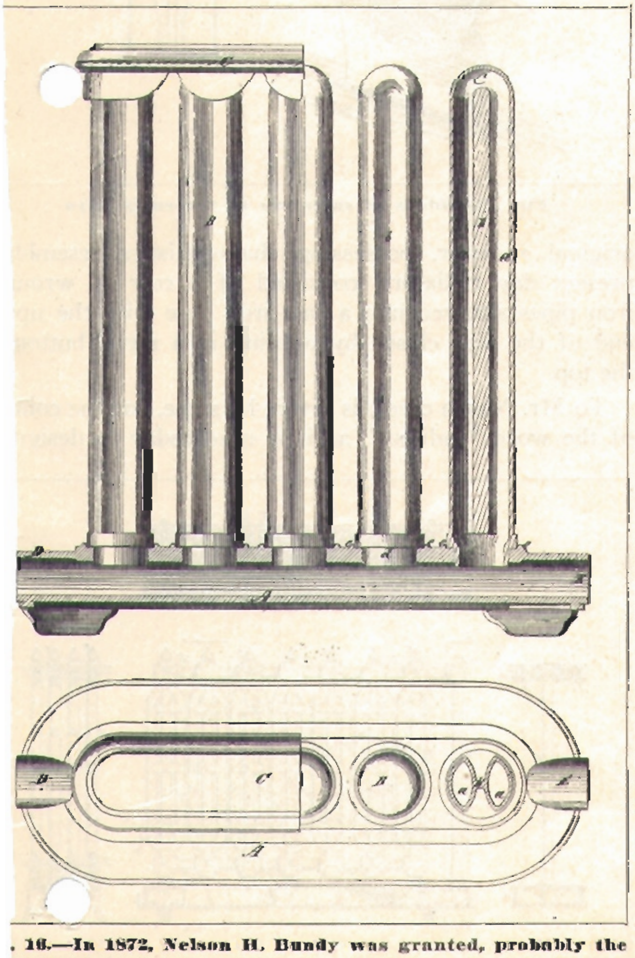
Today, it ma seem strang that, at tha time, no on thought of co trolling or go erning the flo through prop proportioning pipe sizes, b when it is rea ized that the were available i those days com paratively fe

Fig. 14.—The Na son and Brigg patent relate primarily to th construction the tu —th diaphra "h was claimed mos essential for mor efficient operatio

ifferent sizes of pipe, the impracticability of so doing is ppreciated.

ig. 15.—The Nason "Standard" wrought-iron welded tube diator with 4 rows of tubes built in 8 sizes equipped with one inlet. In use during the 60's and 70's

Thus, we look to the principle of hot water heating r our earliest forms of radiators and we realize that these radiators of the coil type persisted so long because of the prevailing general idea that continuity of the current of water should not be interfered with under any circumstances.



. 16.—In 1872, Nelson H. Bundy was granted, probably the t patent on the loop tube whereby independent devices as in the Nason patent were eliminated

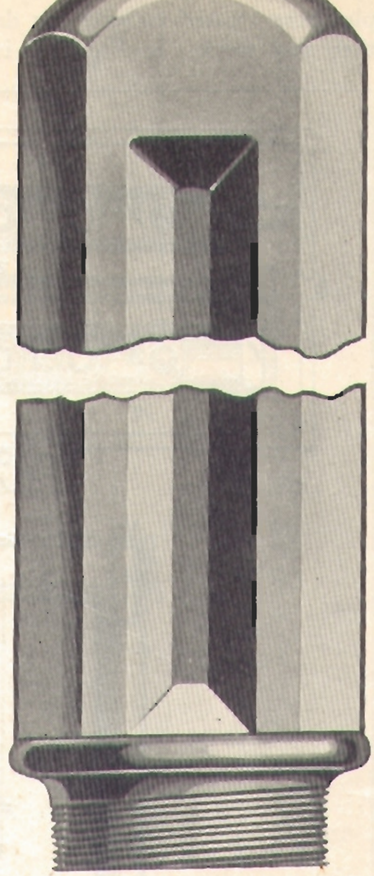


Fig. 17.—Cross section and outward appearance of the Bundy-Tompkins steam and hot water direct radiator loop

One of the earliest hot water installations employing these coil radiators made in this country was handled by Mr. Nason above mentioned. It was installed to warm the counting room of the Middlesex Mill in Lowell, Mass., about 1841.

For this work, practically all pipe used was imported from England for the job.

It is interesting, in passing, to observe as the art progressed, that

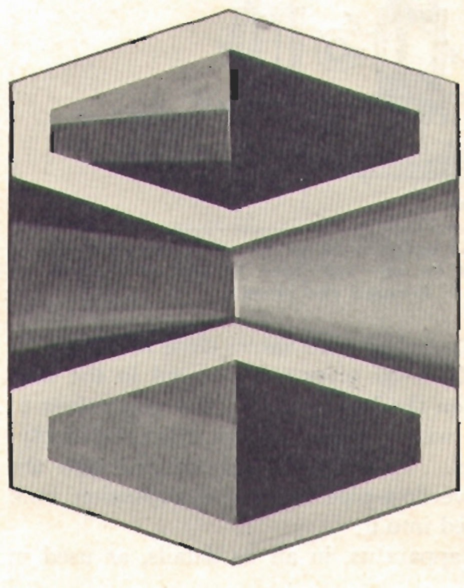


Fig. 18.—Radiator loops as built in three types of radiators used during the 80's and 90's. These loop sections were used in steam and water radiators. The standard section was patterned so that every 12 in. of lineal length represented one sq. ft. of heating surface, full measurement. The steam radiators had one-half sq. ft. of surface per loop in the base and hot water radiators had the same total in both base and upper circulating chamber making one sq. ft. per loop. The enlarged and extended sections contained 20 per cent more surface than the standard section; the extended, however, occupied less floor space than the enlarged

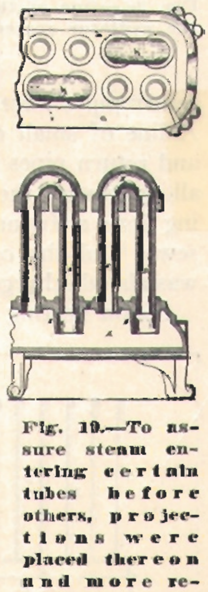


Fig. 19.—To assure steam entering certain tubes before others, projections were placed thereon and more responsive heating of the radiator was claimed—mostly a dream of the patentee

the hot water circuits, in these better and improved systems, were treated in very much the same way as plumbers treated circuits for domestic water supply in their best work. In Fig. 8, it is seen that the flow and

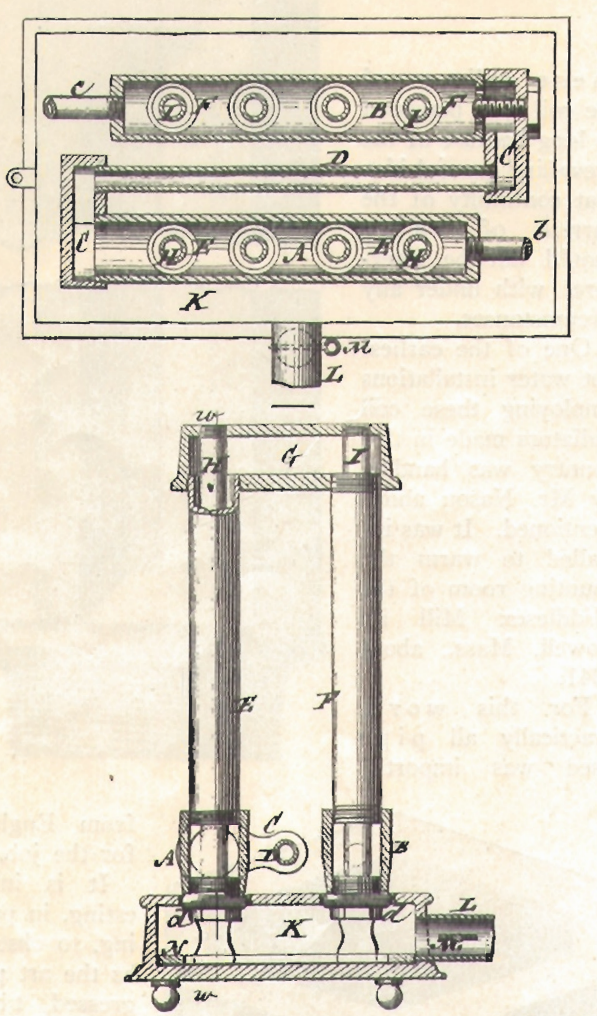


Fig. 20.—One of the early types of direct-indirect radiator—the radiator rested on an "air" base K, and air passed up through the tubes

return pipes were supplied with valves close to the boiler. A line of small draw-off pipes were placed in the flow and return pipes on the house side of the stop valves to allow drawing the water from a line or circuit and emptying into a funnel. The funnel was trapped into the sewer and the overflow-pipe from the expansion tank was also discharged into it.

Steam heating apparatus, in all its details, as used in

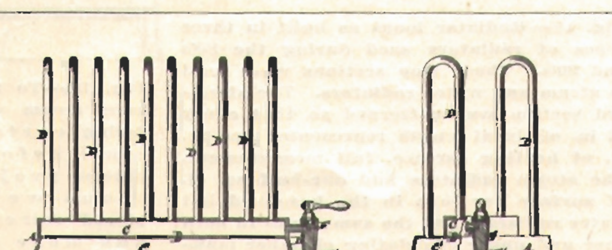


Fig. 21.—Another type of the radiator showing separate steam and water chambers

America, is peculiarly American, and its origin is properly credited, so far as the writer is informed, to Joseph Nason. The radiator probably owes its birth to the use of the tapering thread on the ends of the pipe. The

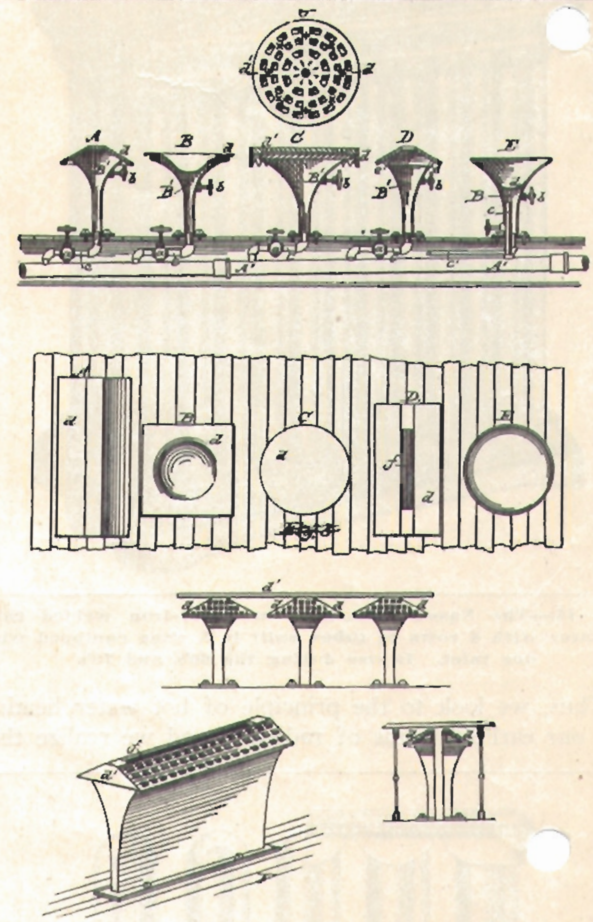


Fig. 22.—Ideas of radiators of the early days

original radiator, possessing characteristics resembli present day radiators, consisted of a row of wrou iron pipes screwed into a cast iron base with the up end of the pipe closed by welding in a metal button the top.

To Mr. Nason credit is given, by some, for the coin of the word "radiator" as it is used today to design

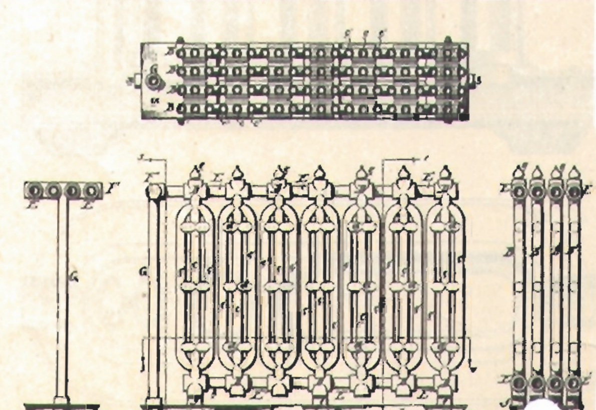


Fig. 23.—Other ideas of radiators of the early days

that part of the hot water or steam heating system by which structures are warmed through standing direct radiation. Unquestionably, Mr. Nason may be considered the father, if not the grandfather of our present systems of warming buildings as the art is practiced today. Much of his time was spent, also in the development of fittings, valves, etc., used in such work, for he took out patents for cast-iron fittings, malleable fittings, tapered joints, screwed and flanged valves, the angle

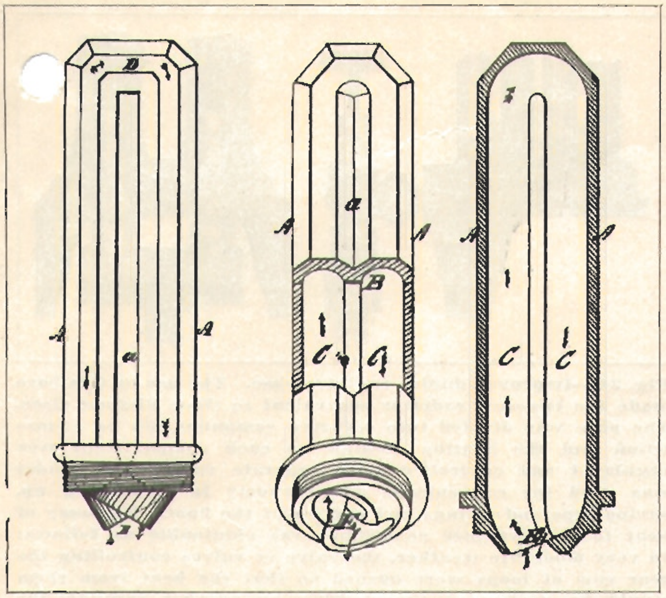


Fig. 24.—The prototype of the two-column radiator—about 1875 to 1880

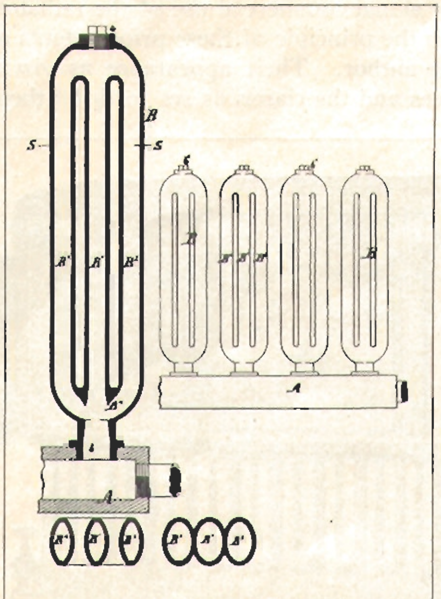


Fig. 25.—The prototype of the three-column radiator—about 1875 to 1880

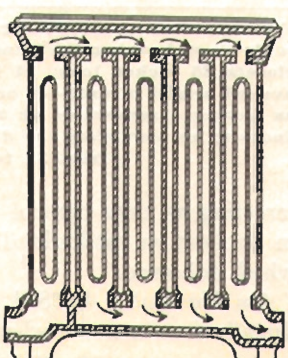
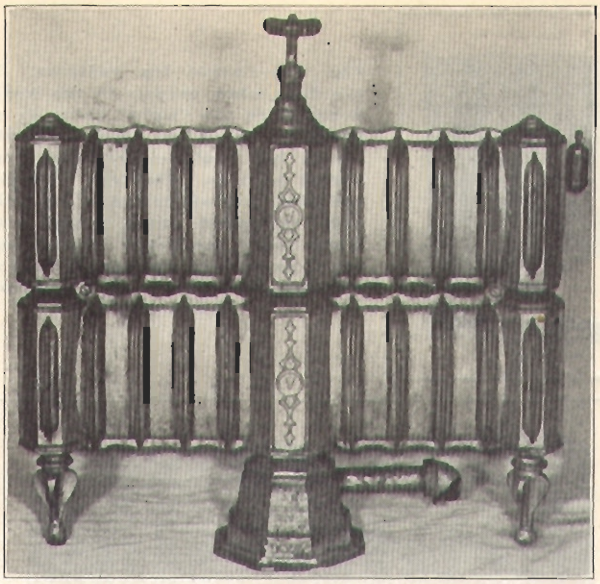
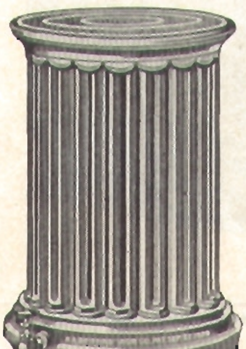


Fig. 26. — The "Bundy-Tompkins" hot water radiator as first constructed. The partition at left was introduced to turn the water into the head and prevent its passing from inlet to outlet. This partition was found later to be unnecessary



Courtesy Richmond Radiator Co.

Fig. 27.—An ornamental type of one of the "old boys." With the radiator valve cast directly into the radiator, it presented a unique appearance. The particular radiator shown was installed in a Chicago building in the late 60's or early 70's



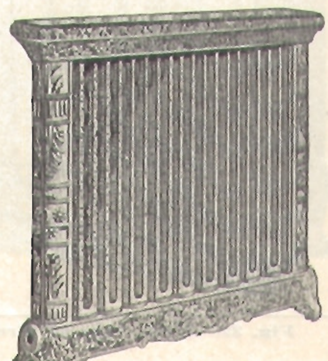


Fig. 28.—Circular radiators, popular types of long ago. The circular radiator was built in 36 and 42 in. heights with base diameters varying from 17¼ to 36 in. with heating surface ranging from 35 sq. ft. to 306 sq. ft. for the high type and 30 to 252 sq. ft. for the low type

Fig. 29.—Renaissance direct radiator, decorated pattern. This single row radiator was built in three heights, 24½, 31 and 37 inches, of the standard width

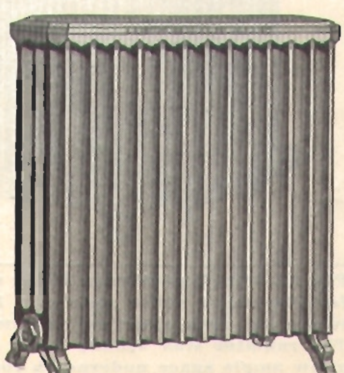


Fig. 30.—Triumph direct radiator. This radiator was built only as the three-column type with circulation up the central and down the two outside legs. The sections were of parabolic form. It was furnished with top as shown. The sections were connected by 2-in. nipples, cut from extra heavy oil well tubing to give large area as compared with 1½-in. nipples cut from ordinary steam pipe. It was built in a 30-in. height with 5½ sq. ft. of surface per section 8 in. wide

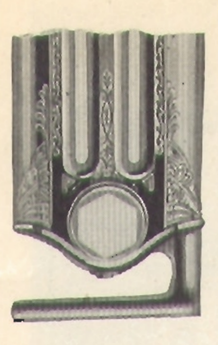


Fig. 31.—Carpet leg radiator. In the days when carpets to the washboard were the "right" thing in all properly furnished structures, the carpet leg radiator served a very useful purpose. The legs were detachable and so designed that the radiator would stand alone, even when not connected. Their use added greatly to the convenience of cleaning and fitting of the carpet thereunder

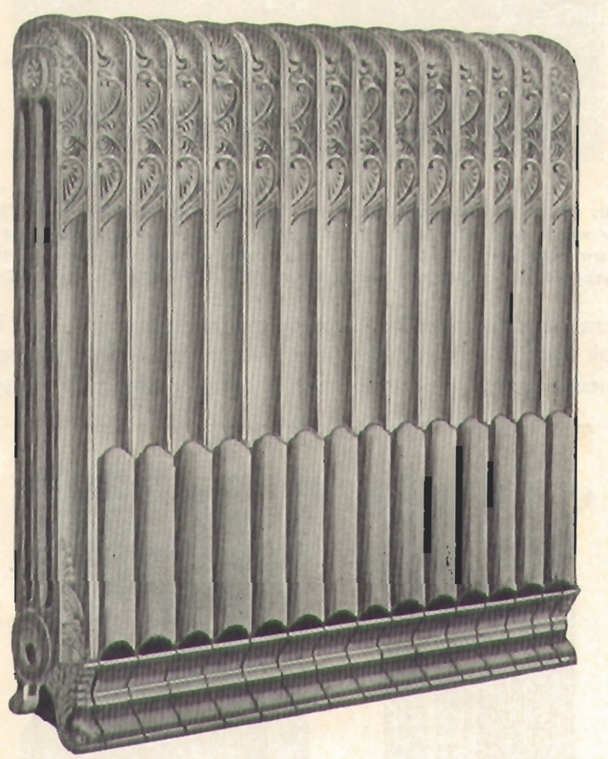


Fig. 32.—Early type of direct-indirect radiator

valve, globe valve, stop cock as well as for much of the machinery needed for their manufacture.

A few patents, however, relating to radiators and radiating surfaces were issued prior to those on which the Nason Manufacturing Company built its radiator business during the years from 1862 forward. No records of the actual commercial use of the radiators manufactured on the principle of these prior patents are available to the author. Their appearance as visualized by the patentees and the claims as set forth by them are interesting as they present early ideas which, while crude in application, undoubtedly stimulated the developments which followed.

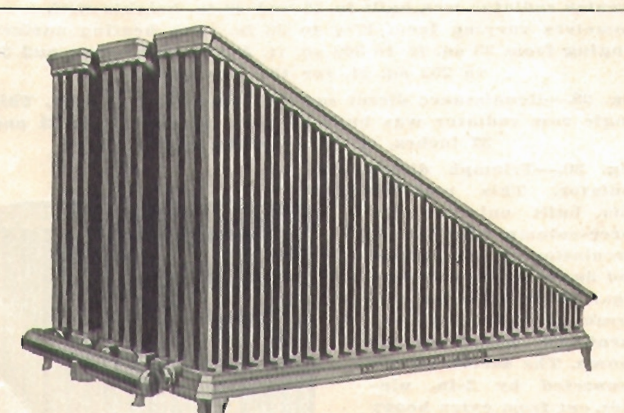


Fig. 33.—Duplex stairway direct radiator. A type of radiation for placement under stairways in hotels, halls, lobbies, etc., where this floor space not otherwise usable might be utilized. The radiator was usually built on a high leg base so as to allow ample space underneath for air to pass up through and between the loops

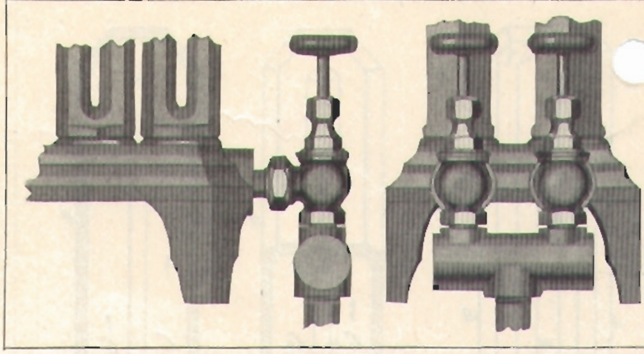


Fig. 34.—Improved duplex radiator base. The use of this base made the two-row radiator equivalent to three distinct sizes. The base was divided into separate compartments by a partition and the heating medium to each compartment was regulated and controlled by a separate valve. The leader was used for convenience and economy in connecting up, saving pipe and fittings and cutting of the floor. Economy of heat to suit weather conditions was obtainable as follows: In very moderate weather, the valve or valves controlling the rear row of loops were opened so that the heat from them would be moderated considerably by passing through the front row of loops, which were not in use; in fairly cold weather, the valve or valves controlling the front row of loops were opened, leaving the rear row idle and thus a more direct and unimpeded heat supply with resultant higher temperatures resulted; in extremely cold weather, all valves were opened so that the entire radiating surface was active

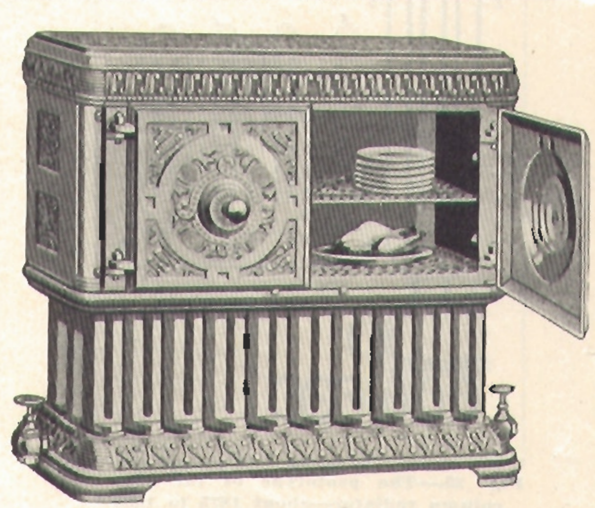


Fig. 35.—Hot closet dining room steam direct radiator. A radiator embodying the Bundy loop. This type was built with closets 35 inches long, 14 inches wide, and 18 inches high; overall height of unit—36 or 42 inches. They were advertised as having a removable or adjustable shelf with amply large doors to accommodate the dishes. The heating surface varied from 33 to 70 sq. ft. each

On November 4, 1851, a patent was granted to K. K. Ingalls for "a new and useful arrangement, for heating

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A History of the Development of the Radiator

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-d ventilating public and private buildings—by the use ..efly of steam or hot water" and which was "denominated" by the patentee as "The temperative heat-distributor."

The principle of this apparatus is illustrated as Fig. 9. It consisted essentially of a series of chambers, an inlet pipe for steam or hot water and a pipe for carrying away the condensed steam or cooled water. It is apparent that it represents a crude form of the steam radiator of a little later period.

These "heat distributors" were claimed to be constructible of "tin, copper, cast or wrought iron, or of any material known to furnish a good radiating surface." They were constructed of rectangular box form, Fig. 10, and it was claimed that the principle might be applied to a cylindrical form, Fig. 11. They were placed directly in the room to be warmed and thus presented an early type of direct hot water or steam radiator. Small legs are shown in the illustrations of Figs. 10 and 11. These legs raised the apparatus from the floor so that air might pass under and into the spaces between the heating sections and as it was warmed pass upward and out the top. Ventilation was assured by connecting an outside air duct directly to the underside of the radiator. In this particular patent, much stress was laid on the advantages of the tapering form of the radiating surfaces, but these claims were not borne out in practice.

About ten years later, June 12, 1860, a patent for a ..eam radiator was granted to A. P. Pitkin and herein the radiator, as we know it, begins to take on more definite form. Considerable trouble had been experienced through the bursting of connections due to unequal expansion or from permitting pressures within that were excessive for the material or manner in which it was used.

In describing his invention, this inventor recognized many requirements of radiator design which were passed on as the art progressed. In Fig. 12 the drawings accompanying this request for patent illustrate a cluster of five radiators. The patentee claimed improvement in steam radiators by "making a perpendicular radiator of one piece of metal with the two sides cast or made together, having intermediate connections to support the plates." He recognized the need of providing against unequal expansion or excessive pressure, of preventing collapsing when bolting the sections together, of assuring free entrance for the air between sections, for providing a ready means for collection of the condensed steam, and provision for relieving air from the radiator.

This radiator certainly possessed advantages over its predecessors in that it offered more economical construction through its manufacture without seam or joint; its compactness and hence relatively large amount of radiating surface for space occupied; its simplicity; its ready means of extension and the improved entrance for the air at . bottom, between sections.

On March 11, 1862, a patent for improvement in steam radiators was granted to Joseph Nason and Robert Briggs. The general appearance of this radiator is illustrated as

Fig. 13. The claims applied primarily to the construction of the tubes of steam radiators.

The radiating tube of this improved Nason radiator is shown in Fig. 14, and consisted of the tube *a*, a diaphragm *b*, a steam-pedestal *c*, an inlet-pipe *d*, and an outlet-pipe *e*. In Fig. 14, the diaphragm *b* extends from the bot[illegible] of the tube *a* nearly to its top. This diaphragm was made of sheet-iron or other suitable material and of such width that when curved slightly and pushed into the tube, it would remain securely in place by friction contact.

Mr. Nason recognized the necessity of air removal as a function of effective warming with steam, and hence based his claim on the fact that the interior diaphragm provided means for establishing and maintaining an inward current of steam and an outward current of air on opposite sides of the diaphragm.

A modification of the application of the principle is illustrated at B, Fig. 14, where the interior tube *b′* extends from the lower part of the pedestal *c′* nearly to the top of the radiating tube *a′*. It was claimed that when steam was admitted to the pedestal *c′*, that it would flow upward and fill the tube *a′* while the air, being heavier, would flow down the interior tube *b′* and thence into the pedestal and into the outlet pipe.

In 1861, this type of radiator with the cast base, the tubes and baffle plate began to be installed in each room to be warmed just as present direct radiator practice. It was provided with a grill top and each tube was guaranteed to have one square foot of radiating surface which simplified calculation.

In the illustration of Fig. 13, separate control valves are shown for each row of tubes. The assembled rad[illegible]or as placed on the market is illustrated in Fig. 15 as a 4-row type with one inlet. This type was known as Nason's standard pattern wrought iron welded tube radiator. Nason also made the "Improved" vertical wrought iron welded tube radiator. This type was made in 1-, 2-, 3- and 4-row patterns. Somewhat later, in the early 80's, there was added Nason's duplex pattern radiator which contained 8 rows of 24 tubes each. Its overall dimensions were 4 feet, 5½ inches by 24½ inches and as each tube contained 1 sq. ft. of surface, it presented 192 sq. ft. of radiating surface.

The rows of tubes were arranged in groups of two so as to permit air to pass up through openings in the base and thus allow the interior tubes to function nearly as efficiently as those on the exterior. These radiators were carried in stock, either plain or bronzed, and immediate delivery could be obtained.

Improvements in steam radiator design were constantly being made through filing of various patent claims but perhaps the most noteworthy advance in design was covered in the claim of Nelson H. Bundy under date of July 30, 1872, when he was granted a patent on improvement in tubes for steam radiators. This patent was among the first, if not the first, to be granted on the loop tube. It was indeed a forward step for it not only improved circulation for the radiator but materially increased the radiating surface.

Fig. 16 illustrates the construction of this Bundy tube while Figs. 17 and 18 illustrate the commercial development of the idea. It provided for the circulation of steam through upright radiator pipes without the introduction of any independent device or pipe. The radiator tube or pipe was cast with separate passages *aa* for its entire length, with the passages connected at the ends. A cast web, *b*, separated the passages. Thus, the passages were given an ellipsoidal shape and the area of radiating surface for a given diameter of radiator tube or pipe increased considerably. The upper ends of the pipes could be covered with a top as shown in Fig. 16.

The idea as presented through the Bundy patent seemed to provoke a desire to make more positive the circulation through the tnbe and we find a number of ideas advanced for the accomplishment of this end. Fig. 19 illustrates a construction for the base such that a projection on certain of the tubes would assure steam entering those pipes having these projections before it entered those without projections and thereby serve to drive the air quickly from the pipes with the result that a more rapid and quicker steam circulation was established and a more responsive heating of the radiator was obtained.

Another proposed plan for improving and assuring circulation is shown as Fig. 20. To say that it was cumbersome would be putting it mildly. Here the steam was admitted at *b*, to the base steam pipe *A*, to which the radiator tubes *E* and *F* were connected. The other base steam pipe *B* was similarly constructed and connected to *A* by means of the connecting pipe *D* through which water of condensation was carried. The steam entered at *b*, passed along the horizontal pipe *A*, up the vertical tubes E and along the hollow upper connection manifold *G*, down the vertical tubes *F* and along the horizontal pipe *B* to the ontlet *C*.

The water of condensation, collecting in pipe *A* from the tubes *E* passed through connecting pipe *D* and the hollow sections *CC* to pipe *B* and there combining with condensation from tubes *F*, passed to outlet *c*.

This radiator, as proposed, presented one of the ea..y types of direct-indirect radiator for it was built with an air base *K* on or in which the radiator rested. The tubes *H* and *I*, Fig. 25, were air pipes into which air from the outside was admitted through an inlet *L*, Fig. 20, with valve control. Or, by means of ports in the base, circulation of inside air was provided for.

While the principle illustrated in Figs. 20 and 21 shows the trend in radiator design and consideration, the author is not informed as to any practical use of the patent.

Fig. 21 shows another idea where the base was divided into an upper and lower chamber and there was proposed, the use of a two-way cock, for admitting steam and drawing water of condensation. Nor did this ever receive commercial consideration so far as the writer is informed.

Other ideas of radiators from the inventive mind are shown as Figs. 22 and 23.

The prototype of the column radiator made its appearance between 1875 and 1880. Figs. 24 and 25 illustrate, respectively, a two- and a three-column type. The underlying principle of that shown as Fig. 24 was a spiral twist given the channels of the tubes to provide an auger-like aperture which, it was claimed, would assist in the quick removal of condensation.

The radiator illustrated in Fig. 25 claimed distinct improvement in circulation through providing two or more descending arms having a large amount of radiating surface to insure rapid condensation of the steam, and a central arm or channel directly in the path of the entering steam so as to assure positive entrance thereinto and rapid flow to the top of the radiator. Special construction at the inlet of the central tube was used to insure the steam entering.

While the vertical tube, wrought-iron radiator and the loop type radiator were designed and built for steam, it was not long before it was applied to hot water radiators as well. Early in the history of this type such a radiator was produced by Bartlett, Hayward & Co. The top of their radiator consisted of a hollow, cast-iron casing into which tubes were screwed, exactly as they were screwed into the base of the Nason steam radiator. The free ends of the pipes were left open and passed through corresponding holes in the upper side of the radiator base and there expanded, similar to the expanding of boiler tubes. The bottom of the base was then attached with screws and a copper or other suitable gasket used to make a tight joint.

Tests with these radiators showed that, when the radiator was relieved of air, bottom connections could be used on both ends with practically equally good water circulation and heat emission, which contradicted the idea that the supply should always be made at the top.

To the A. A. Griffing Iron Co. (Samuel D. Tompkins, an officer of the company) has been credited the joining of cast-iron loops with a hollow top casting and of making the first cast-iron loop hot-water radiator.

In the construction of Bundy-Tompkins hot water radiator the loops were screwed into the base exactly as for a steam radiator. The cap or top was cast hollow, with a series of tapped openings through it. The upper opening was made large enough to permit passing short brass nipples used for joining the head of the loops with the lower holes. These lower holes and those in the heads of the loops were tapped in one operation so they coincided in taper and thread register. The short threaded taper tube or nipple, which was made of brass and had a square hole in it for a wrench, was then forced into the hole and into the head of the loop after which the hole was closed by means of a hollow plug. Then an entablature was placed over the whole to cover the plugs and present a pleasing radiator appearance.

The radiator as first constructed is shown in section as Fig. 26. Note the partition at *a* which was introduced at first as necessary to turn the water into the head of the radiator and prevent its passing through the radiator from inlet to outlet.

This was no other than evidence of the prevalence of the old idea that a continuous current was necessary for circulation. The added resistance caused by the abrupt turn to force the water upward through the end tubes of the radiators and their nipples as noted by arrows, Fig. 26, before it reached the other tubes was high, so workmen often punched out the division *a* with the result that circulation was improved, better heating resulted and the division *a* was eventually omitted entirely.

Through the 80's and 90's and early in the 20th century, cast-iron radiator design passed through various stages of decoration and application. Examples of many of the types in use during that period are illustrated by Figs. 27 to 35 with descriptive notes of their characteristics.