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Small Homes Council—Building Research Council, University of Illinois at Urbana-Champaign

MODERNIZATION OF HYDRONIC SYSTEMS

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MODERNIZATION OF HYDRONIC SYSTEMS

Reasons for Conversion

Many reasons exist for converting or modernizing an existing residential heating system. In some cases, additional rooms have been added to the house and an increase in heating capacity is required. Or the old system may not provide satisfactory temperature control in the rooms. Sometimes changes are made to improve the appearance of the heating system. Many old systems are being modernized today in order to obtain the increased convenience and operating efficiency possible with more modern equipment.

The seasonal energy consumption of most old 1- and 2-pipe residential steam heating systems can be reduced by as much as 10% by converting the system to a modern forced-circulation, hot-water system. In this publication, guidelines will be presented for modernization of hydronic heating systems. The conversion of old steam and gravity hot-water systems to a modern two-pipe forced-circulation system requires an understanding of the originally installed system. For this purpose, a brief description of the common systems follows.

HYDRONIC SYSTEMS

A hydronic heating system consists of a boiler and fuel-burning unit, terminal units (usually baseboard, radiators, or convectors) located in the rooms to be heated, and piping for circulating the water or steam from the boiler to the terminal units and back.

Hydronic systems are of two basic types:

1. **Steam or Vapor.** The boiler of a steam heating system is filled with water only to the level recommended by the boiler manufacturer. Heat produced by the burning of fuel in the combustion space of the boiler is transferred to the water, causing it to be converted to steam under pressure. The steam passes through the piping of the heating system to the terminal units, where it condenses and gives off heat. The condensate is returned to the boiler, thus maintaining the water level within the boiler.
2. **Hot-Water.** The boiler, piping, and the terminal units of a hot-water heating system are entirely filled with hot water. Heat produced by the burning of fuel in the combustion space of the boiler is transferred to the water within the boiler. This heated water is circulated through the piping to the terminal units. The cooler water is circulated back to the boiler where it is re-heated and re-circulated through the system. This cycle is continued until the desired temperature is reached within the space being heated.

CLASSIFICATION OF STEAM OR VAPOR SYSTEMS

Many types of steam and vapor systems exist, but only the two most commonly used for residential heating will be described. These are the one-pipe and two-pipe steam heating systems.

One-pipe Steam System

In this system, a single main (pipe) serves the dual purpose of supplying steam to the terminal units and returning condensate from them. Ordinarily, only one pipe connection is made to each terminal unit and this pipe serves as both supply and return pipe. In some instances, separate supply and return connections are made to the terminal, but both are connected to the same main.

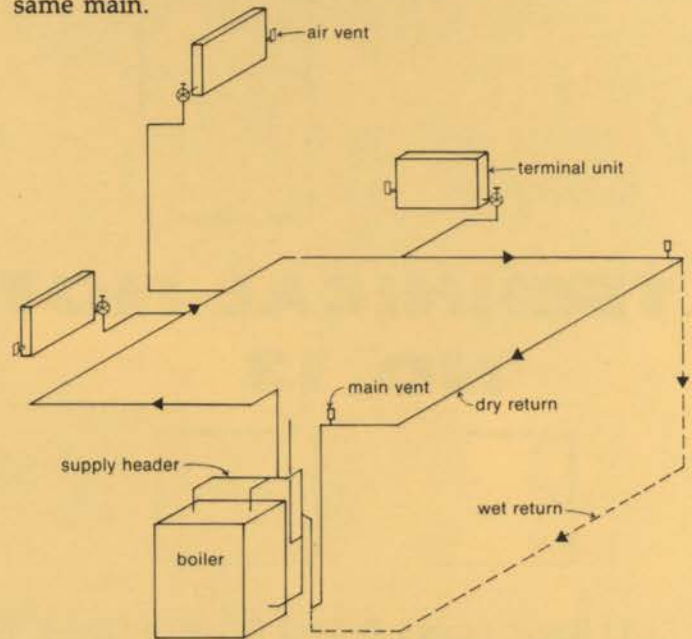


Figure 1. One-pipe heating system. Either a dry return or a wet return may be used independently.

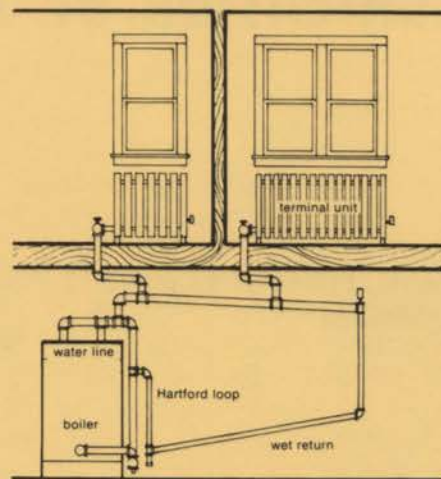


Figure 2. One-pipe steam system.

Figure 1 is a line diagram of this system, in which the components are shown in commonly accepted symbols. A more pictorial description of a one-pipe system is shown in Figure 2. The required slope in piping is exaggerated.

Two-Pipe Steam System

In this system, each terminal unit is provided with separate supply and return connections, and the steam and condensate flow in separate mains and branches. A pictorial description is given in Figure 3.

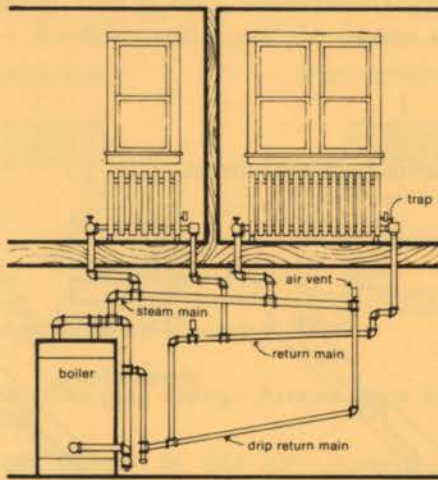


Figure 3. Two-pipe steam system.

CLASSIFICATION OF HOT-WATER SYSTEMS

Hot-water heating systems are of two basic types:

1. The **gravity** system in which the circulation of water through the system is caused by the difference in density of water in the supply and return sides of the system.
2. The **forced-circulation** system in which a circulator or pump is used to create the flow of water in the system.

Gravity Hot-Water System

In this system, the radiation is always located above the boiler. Large pipes are required to minimize friction losses of water flow. The essential elements of a gravity hot-water heating system consist of boiler in which the water is heated, fuel-burning equipment, terminal units for transferring heat from the water to the room air, a piping system between the boiler and the terminal units, an expansion tank, and air vents to remove unwanted air and gas from the system.

Gravity systems are usually two-pipe arrangements. These may be the direct-return arrangement, as shown in Figure 4, or the reverse-return arrangement shown in Figure 5. The latter piping is preferred,

since the total length of piping (supply and return) is about the same for each terminal unit, thus making the system easier to balance.

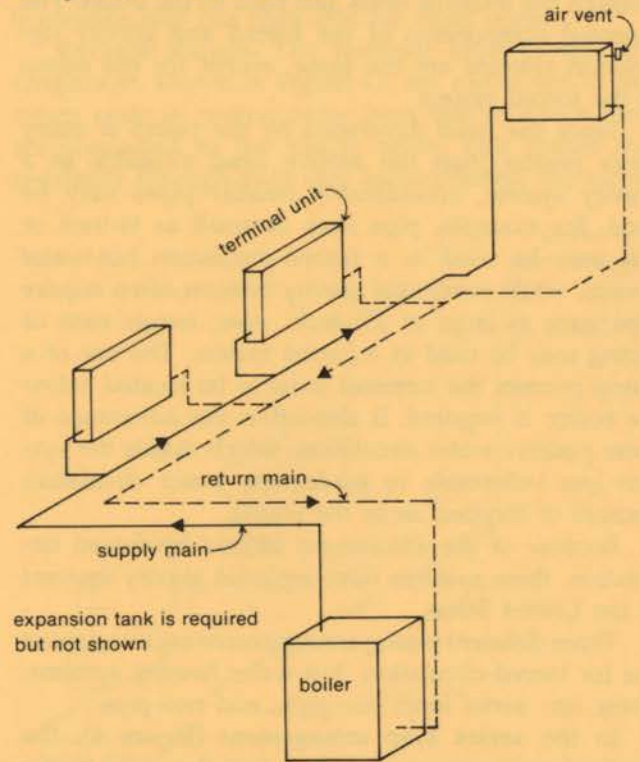


Figure 4. Circuit lengths differ for each terminal unit.

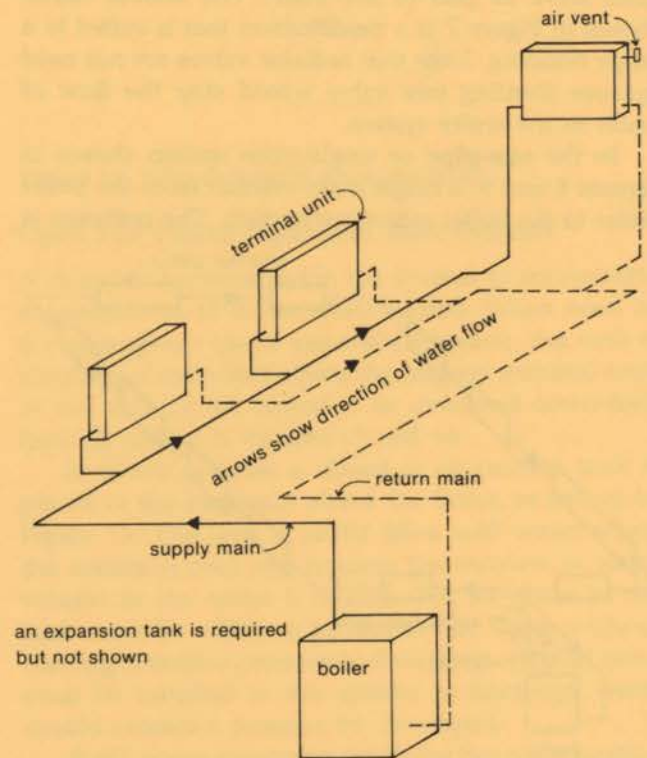


Figure 5. Circuit lengths are equalized.

Forced-Circulation Hot-Water System

In this system, a pump circulates water from the boiler through the terminal units and back to the boiler. The essential components of the forced and gravity circulation systems are the same, except for the pump in the forced system.

Since the head developed by the pump is many times greater than the motive head available in a gravity system, considerably smaller pipes may be used. For example, pipe sizes as small as 1/2-inch or less may be used in a forced-circulation hot-water system, while residential gravity systems often require pipe sizes as large as 2 1/2-inch. Also, longer runs of piping may be used in a forced system. The use of a pump permits the terminal units to be located below the boiler, if required. It also offers the advantage of more positive water circulation, which makes the system less vulnerable to inadequate water circulation because of trapped air in the piping.

Because of the advantages offered by forced circulation, these systems have replaced gravity systems in the United States.

Three different piping arrangements are in common use for forced-circulation, hot-water heating systems. These are: series loop; one-pipe; and two-pipe.

In the **series loop** arrangement (Figure 6), the terminal units are connected so that the entire water flow through the circuit passes serially through each terminal unit in the circuit. In this system, the terminal units serve as part of the main. The double circuit shown in Figure 7 is a modification that is suited to a larger building. Note that radiator valves are not used because shutting one valve would stop the flow of water in the entire system.

In the **one-pipe** or single-main system shown in Figures 8 and 9, a single main extends from the boiler outlet to the boiler return connection. The radiation is

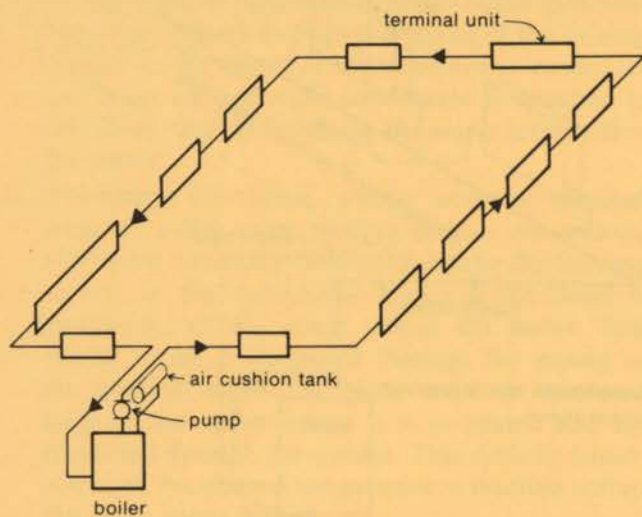


Figure 6. Series-loop, single-circuit.

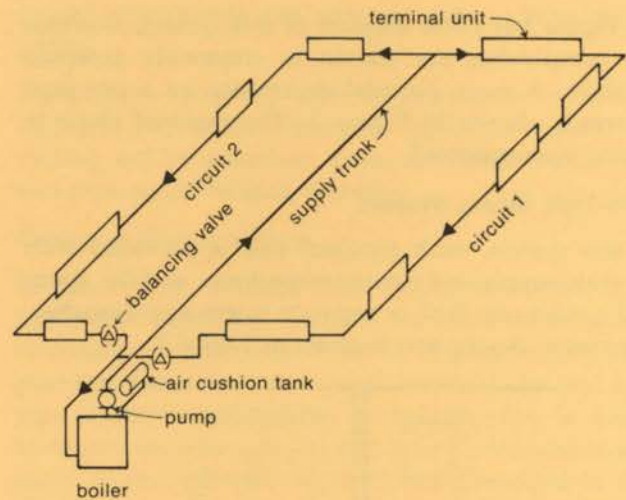


Figure 7. Series-loop, two-circuit.

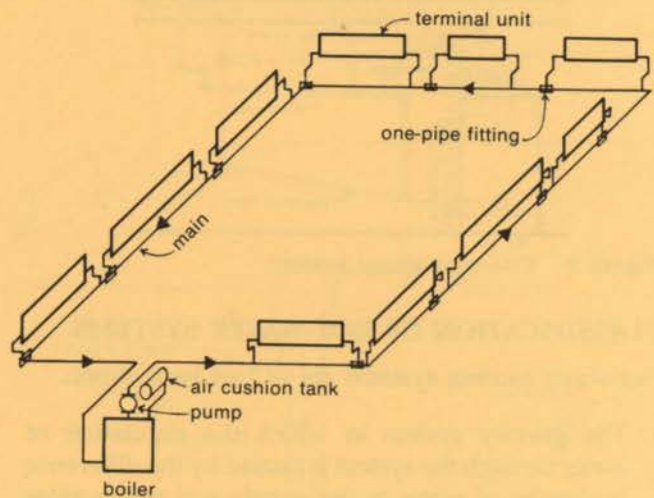


Figure 8. One-pipe, single-circuit.

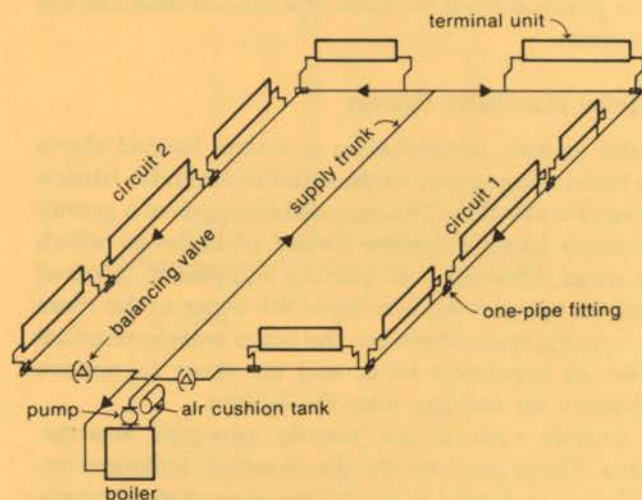


Figure 9. One-pipe, two-circuit.

connected to this single main by means of two smaller pipes called branches. When connecting these branches to the main, one of the standard tees is replaced by a *one-pipe fitting* (see Figure 10) to divert a portion of the water through the terminal branch circuit. These fittings are installed in the supply or return branch, whichever is recommended by the fittings' manufacturer.

In the **two-pipe** system, one pipe or main carries heated water from the boiler to the terminal units and a second pipe or main carries the cooled water back to the boiler. Two types of two-pipe arrangements are in use — the direct return and the reverse return.

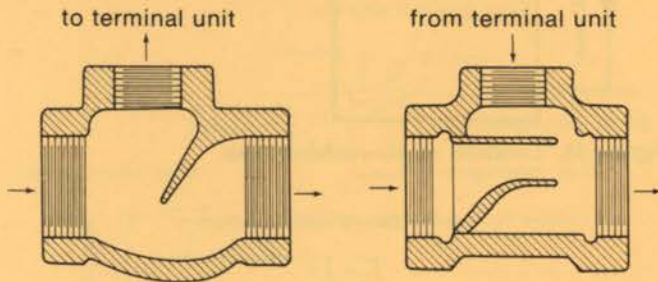


Figure 10. One-pipe fittings. Arrows show direction of water flow.

Direct Return. In this arrangement, shown in Figure 11, the terminal units are connected to the return main in the same order as they are connected to the supply main. Since the unit closest to the boiler

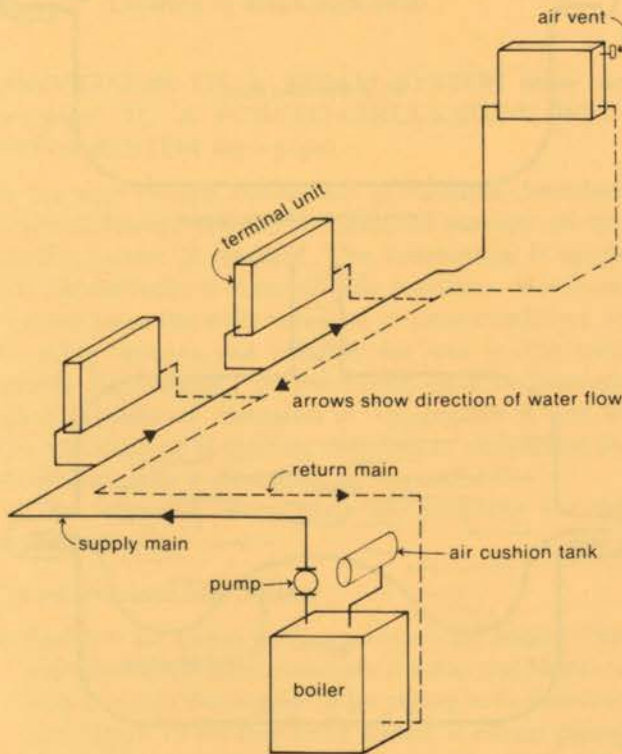


Figure 11. Circuit lengths differ for each terminal unit.

has the shortest supply and the shortest return, the resistance of the piping from the boiler supply tapping through this unit and back to the boiler return tapping is considerably less than that for other units.

Reverse Return. The terminal units in this arrangement, shown in Figure 12, are connected to the return main in reverse order from that in which they are connected to the supply main. This makes the resistance through each unit approximately the same.

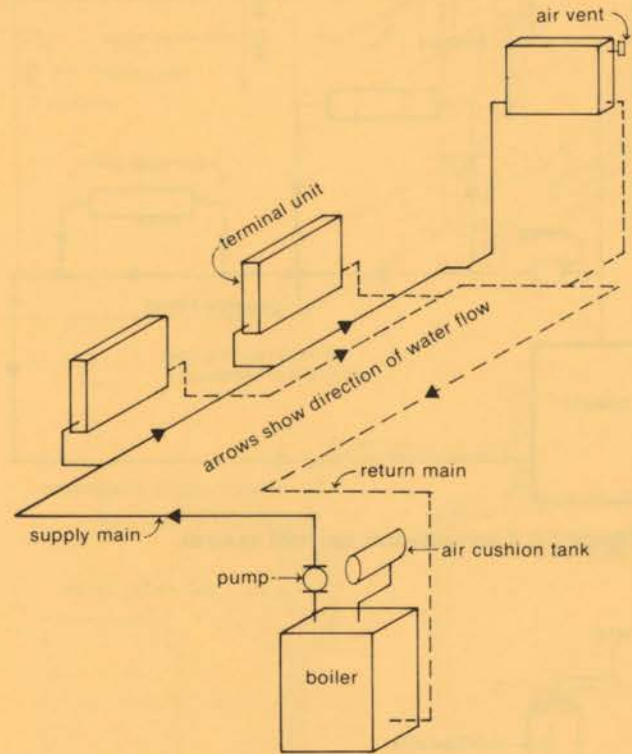


Figure 12. Circuit lengths are equalized.

Open and Closed Expansion Tank Systems

A chamber is connected in the system to accommodate the expansion of water when heated. When open to the atmosphere (as in some old systems), the tank is placed 3 or more feet above the highest terminal unit, or the main, if the system is an overhead down-feed type, as shown in Figures 13 and 14.

In newer systems, a closed or air-cushion tank is placed in the basement above the boiler, as shown in Figure 15. The tank is partly filled with water when the system is cold and receives the increase in water volume as the water is heated. The air space in the tank must be sufficient to receive the water without creating excessive pressure in the system. A *relief valve* must be installed in the system to discharge water should excessive pressure be developed.

A still newer expansion device for hot water heating systems is the diaphragm tank illustrated in Figure 16.

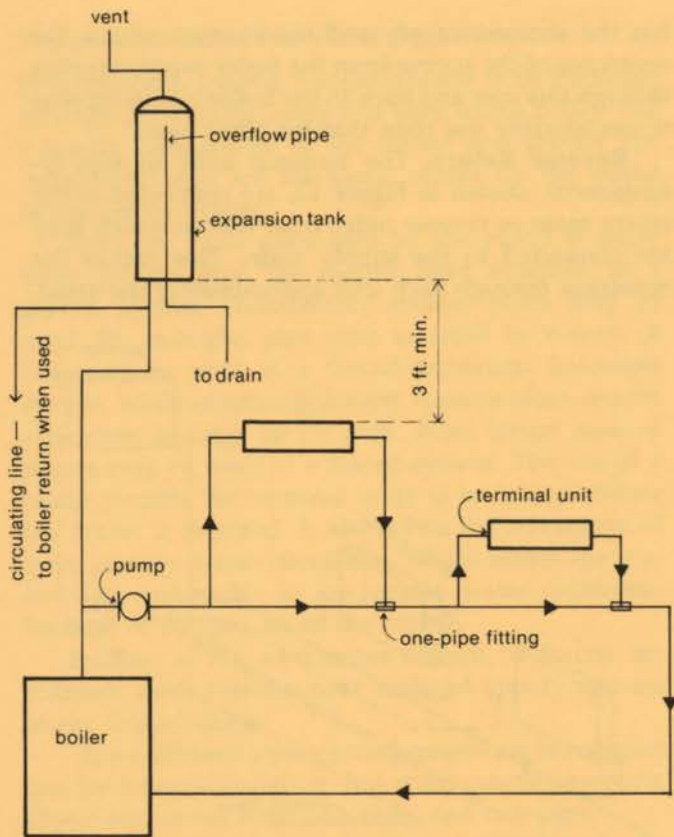


Figure 13. Conventional up-feed system.

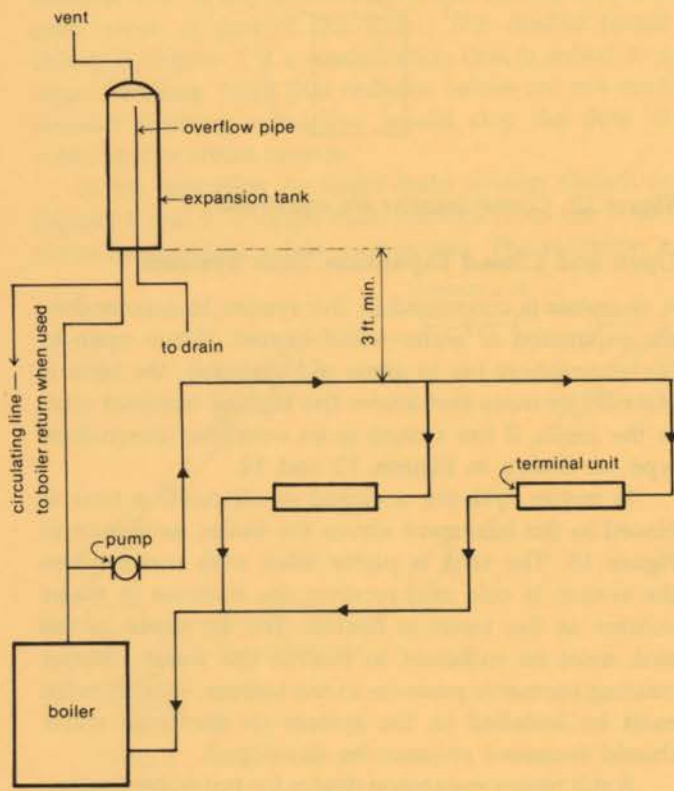


Figure 14. Down-feed system.

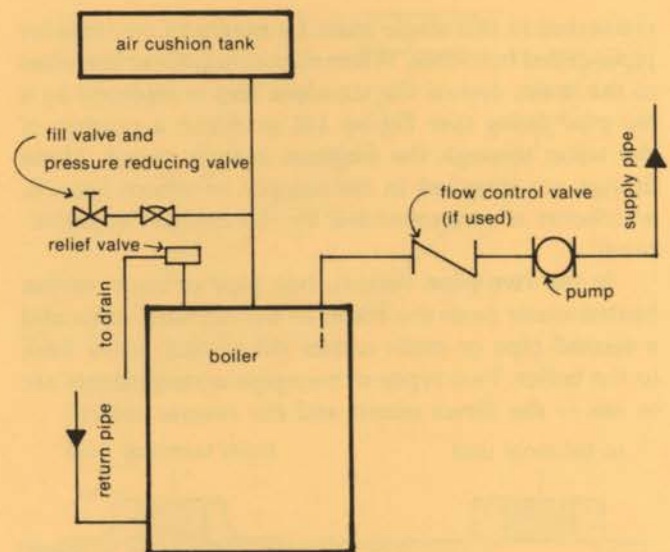


Figure 15. Location of air-cushion tank.

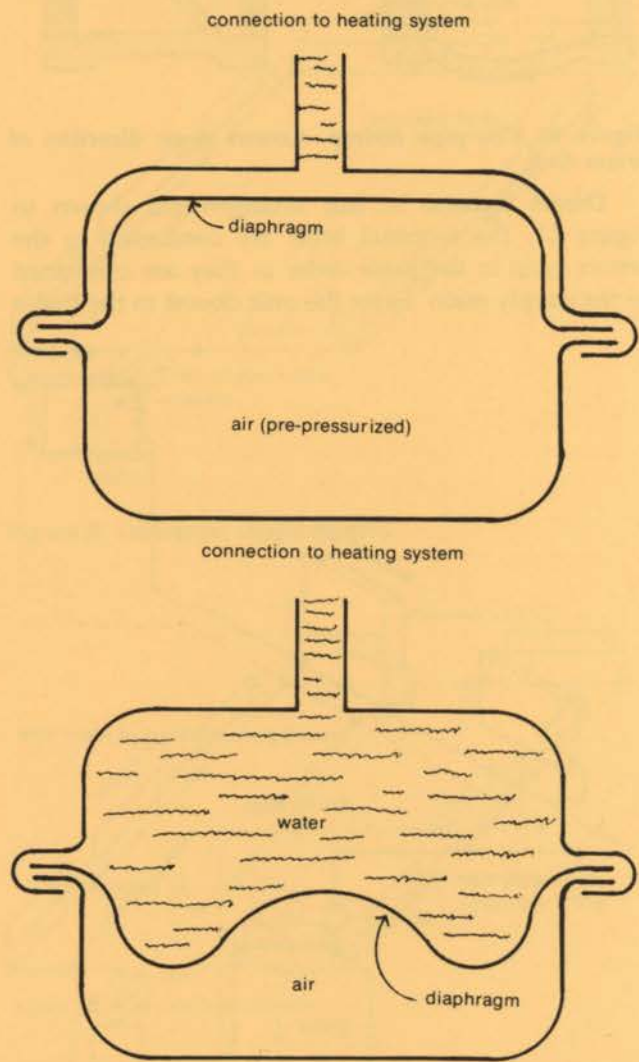


Figure 16. Diaphragm tank (a) at start of fill, and (b) system filled to normal working pressure.

- Add hot-water trim, consisting of combination pressure and water temperature gauge (altitude gauge), and ASME relief valve, as in Figure 19. The latter valve must be sized to the gross output of the boiler.
- The additions of pressure-reducing valve, check valve, and purge valve (Figure 19) are optional.
- Plug all unused openings in the boiler except the front supply tapping and the rear return tapping to be used for the converted hot-water system.

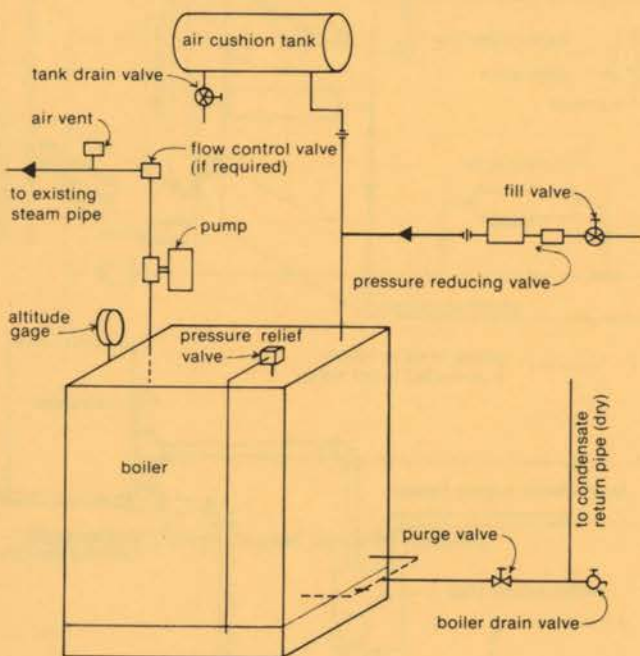


Figure 19. Piping details around hot-water boiler.

Main Piping

A procedure for checking sizing of existing pipe and determining the sizes of new piping is given in Appendix D.

- Remove all supply main piping between the last terminal unit supply and the boiler return. See Figures 20 and 22.
- If converting a two-pipe direct-return steam system (Figure 20) to a two-pipe, reverse-return hot-water system, all of the return piping of the steam system between the boiler and the first radiator must be removed. For convenience in draining, it is suggested that a drain valve be installed at (A), Figures 20 and 23. The return main from the last terminal unit (B in Figure 20) should be continued back to the boiler return. The pitch of the return piping from the steam system will make the high point occur at the boiler end. An air vent should be located at the high point of the return main. See Figure 23.

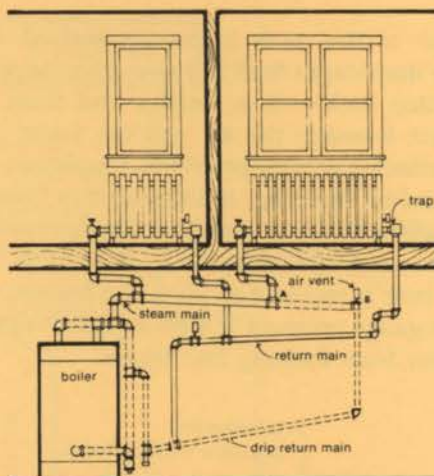


Figure 20. Piping to be removed when converting a two-pipe steam system to a two-pipe hot-water system.

- If converting a two-pipe, reverse-return steam system (not illustrated), all of the return piping back to the Hartford Loop or to the boiler return trap may be used in the two-pipe, reverse-return hot-water system. Extra air vents on the return main will not be required.
- When converting a one-pipe steam system to hot-water, all return piping must be installed new. The return main should be connected to the return tapping in the back section of the boiler, as in Figure 19.
- In practically all cases, the high point of the steam supply main will be at the boiler end. If this is the case, a manual air vent must be installed at this point. See Figure 19.

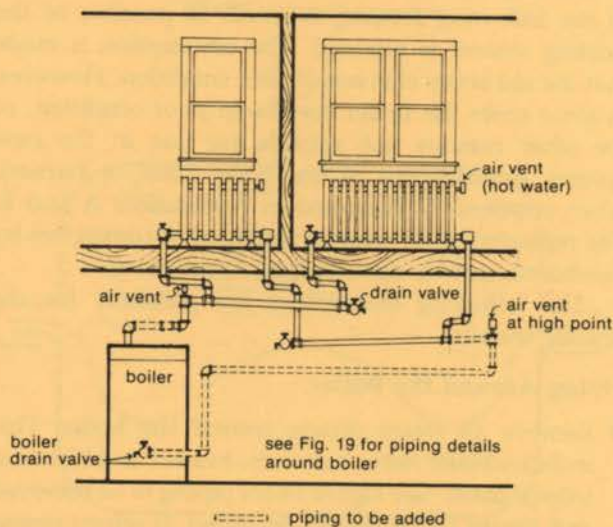


Figure 21. Piping to be added when converting a two-pipe steam system to a two-pipe hot-water system.

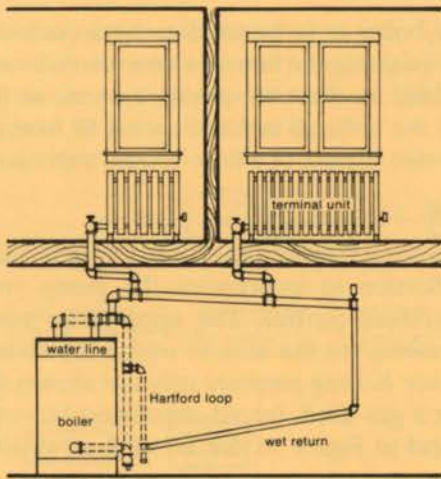


Figure 22. Piping to be removed when converting a one-pipe steam system to a two-pipe hot-water system.

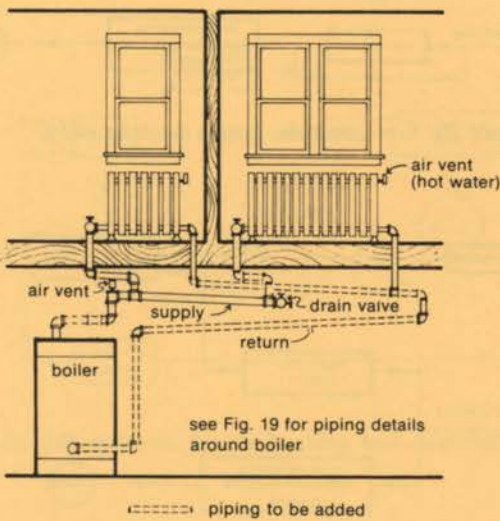


Figure 23. Piping to be added when converting a one-pipe steam system to a two-pipe hot-water system.

- Add a drain valve in the supply main just downstream of the last terminal unit take-off. See Figures 21 and 23.
- If the steam system consisted of *multiple circuits*, the circuit supply mains will be joined together in a header or trunk main. The connections may be retained in the hot-water system. The trunk main should be connected to the front boiler supply tapping as shown in Figure 19.
- If the steam system consisted of multiple circuits and the return circuit mains are connected together, as illustrated in Figure 24, it will be necessary to remove all piping from the points X to the boiler and join the returns together, as illustrated in Figure 25.

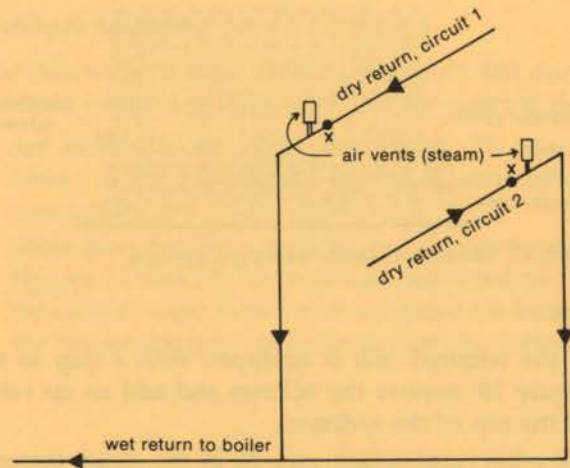


Figure 24. Junction of return circuit mains, steam.

Air Vents

- All air vents designed for use on steam systems must be removed.
- If the terminal unit is a radiator, the air vent (steam) will be located low on the end section, as in Figure 27. After this vent has been removed, plug this opening in the radiator.
- If there is no 1/8-inch tapping at the top of the return radiator end section, drill and tap the top radiator plug to receive an air vent designed for use on hot-water systems. See Figure 26.
- If the terminal unit is a convector or baseboard unit, the new air vent may be installed in the same location as was the vent designed for use on steam systems.

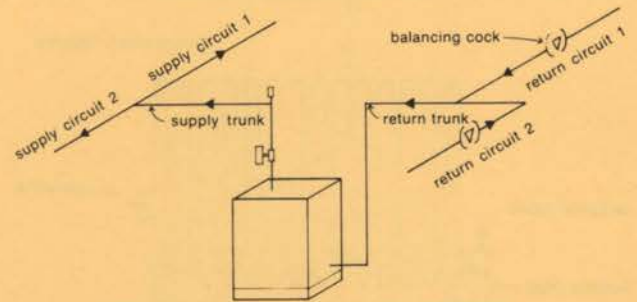


Figure 25. Junction of circuit mains, hot-water.

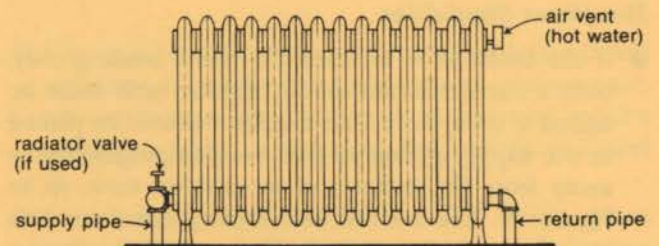


Figure 26. Hot-water radiator.

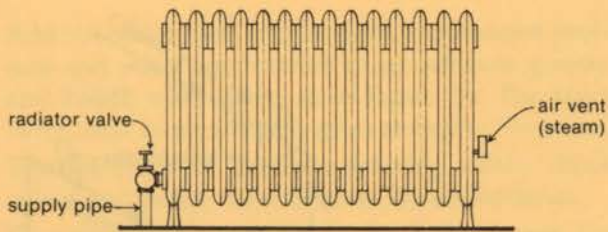


Figure 27. Steam radiator, one-pipe system.

Traps

- If the terminal unit is equipped with a trap as in Figure 28, remove the bellows and add an air vent at the top of the radiator.
- All other traps which may be in the steam system should be removed completely.

Terminal Units

- Some old-style steam radiators, Figure 29, were provided with only the bottom nipple connection between sections. Radiators of this type should be replaced when the system is being converted to hot-water.

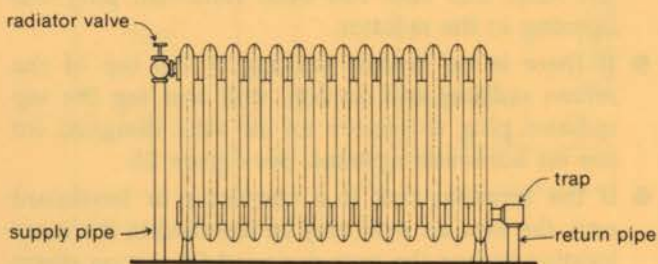


Figure 28. Steam radiator, two-pipe system.

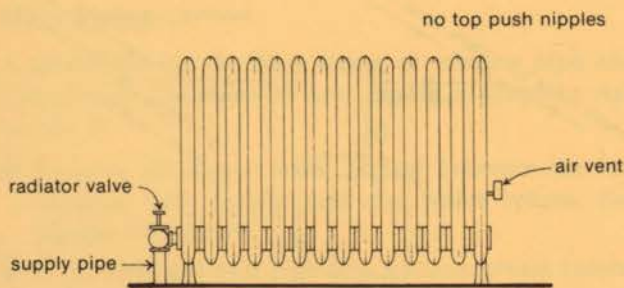


Figure 29. Old-style steam radiator.

Hot-Water Specialties

- If the boiler is to be used for home heating only, both a circulator and an air-cushion tank must be added to the system. The circulator should be placed in the supply piping so that the pumping action is away from the boiler and air-cushion tank, as in Figure 19. The method of selecting circulator size is explained in Appendix D. The method of selecting the air-cushion tank size is given in Appendix E.

- If the boiler is to be used to heat domestic water as well as heat the house, a flow-control valve must be added to the new piping system, as in Figure 19. If the boiler is not to be used to heat domestic hot water, the use of a flow-control valve is optional.

Controls

- The existing thermostatic control system will require modification to incorporate the pump and water temperature control. The appropriate control arrangements for the case in which the boiler is used for house heating purposes only are shown in Figure 30 for a gas-fired, forced-circulation hot-water system and in Figure 31 for an oil-fired system.

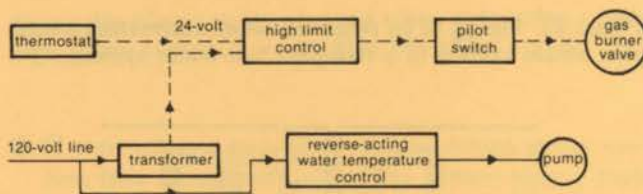


Figure 30. Gas controls, house heating only.

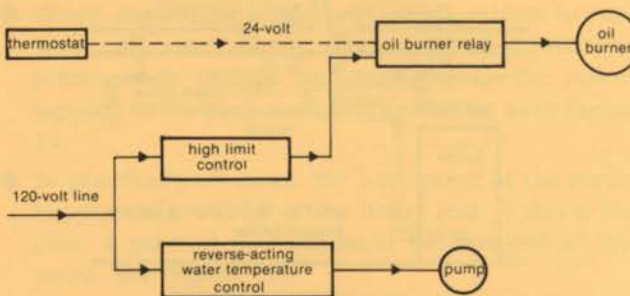


Figure 31. Oil controls, house heating only.

The operating sequence of the controls shown in Figures 30 and 31 is as follows:

1. The thermostat controls only the burner.
2. If the boiler water temperature reaches the high-limit control setting, the burner is shut off. When the boiler water temperature drops approximately 20°F, the high-limit control allows the burner to start again. The high-limit control setting should be 240°F.
3. The circulator operates continuously unless the boiler water temperature drops to approximately 110°F, in which case the reverse-acting water temperature control shuts off. A rise in water temperature again starts the circulator. For this control arrangement, the reverse-acting control must be located in the boiler or the supply main in close proximity to the boiler.

The control arrangements for the case in which the boiler is used for both heating and for supplying domestic hot water are shown in Figure 32 for a gas-fired burner and in Figure 33 for an oil-fired burner.

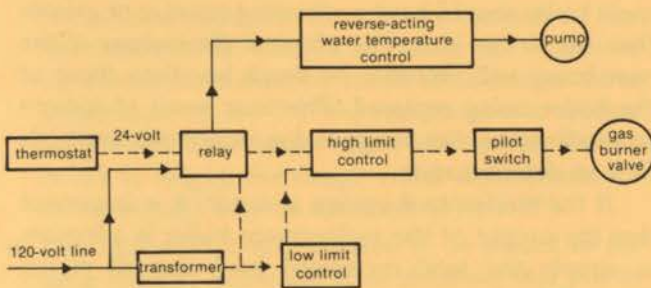


Figure 32. Gas controls, house heating and domestic hot water.

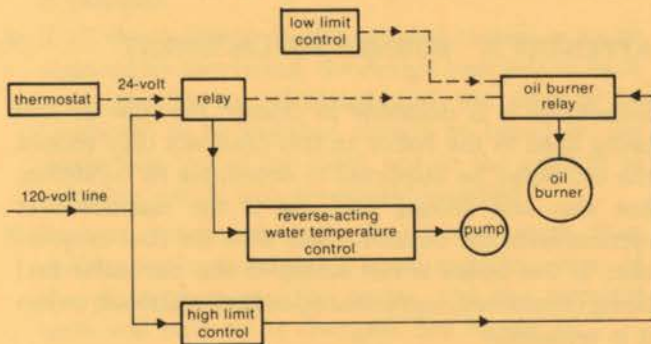


Figure 33. Oil controls, house heating and domestic hot water.

The operating sequence of the controls shown in Figures 32 and 33 is as follows:

1. The thermostat, through the relay, controls both the circulator and the burner.
2. If the boiler water temperature reaches the high-limit control setting, the burner is shut off, leaving the circulator in operation. When the boiler water temperature drops approximately 20°F, the high-limit control allows the burner to start again. The high-limit control setting should be 240°F.
3. When heat is not required for the house, the thermostat shuts off the burner and circulator. The low-limit control then will start only the burner to maintain boiler water temperature for the indirect water heater.
4. If the indirect water heater is the tankless type, the reverse-acting water temperature control stops the circulator whenever the boiler water temperature is too low for satisfactory tankless heater operation.

Optional Changes

The following changes are not mandatory, but may be made to improve performance and for convenience:

- An automatic fill valve (see Figure 19) may be added to the new piping system to automatically maintain proper system pressure.
- Some manufacturers provide special equipment (see Figures 34 and 35) for removing entrained air from the system water. When such equipment is installed, the manufacturer's instructions must be followed.

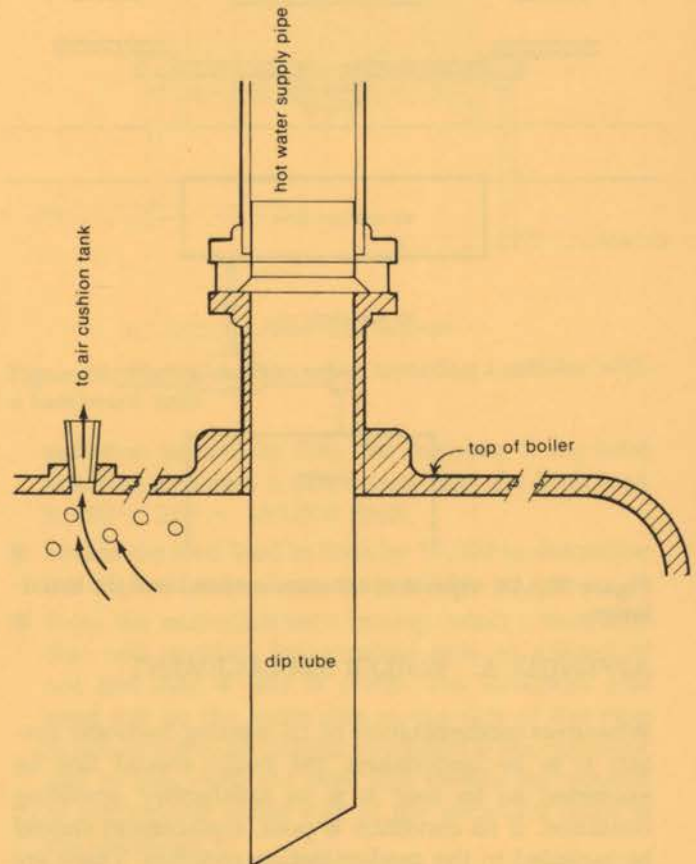


Figure 34. Dip-tube installation.

- Old-style radiators may be replaced with baseboard radiators to improve appearance and performance, and to increase the living space. This may require piping changes, as described in Appendices C and D.
- Square-head cocks may be installed in the return side of each radiator circuit to assist in balancing the water flow rates.

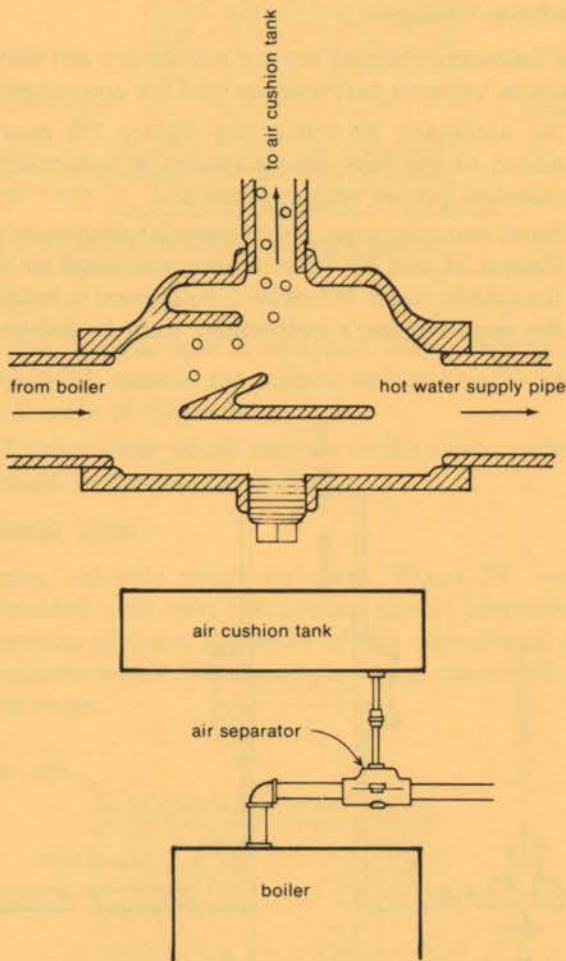


Figure 35. Air separator, (a) cross section, and (b) installation.

APPENDIX A: BOILER REPLACEMENT

Whenever modernization of an existing hydronic system is to be undertaken, the boiler should first be examined to be sure it is in satisfactory operating condition. If its condition is poor, replacement should be included in the modernization program. There are two procedures which may be followed in selecting a replacement boiler. If it is known that the boiler being replaced had adequate capacity, and the *gross* output of the old boiler is available, it may be replaced by a new boiler having the same gross output. While this procedure will ensure the selection of a replacement boiler of adequate capacity, it may also result in the selection of a boiler larger than actually needed, as systems installed many years ago were frequently oversized.

If the modernized system is hot-water, and it is desired to make the most economical choice of size for the replacement boiler, the load should be recalculated just as though it was a new installation. The actual *design* heat loss of the building should be used

for load determination, not the amount of installed radiation. (Detailed instructions for calculation of design heat loss are given in I=B=R Guide 21, *Heat Loss Calculations*, published by the Hydronics Institute, 35 Russo Place, Berkeley Heights, NJ 07922.) The replacement boiler should have a *net* rating equal to or greater than the *design* load. The physical dimensions of the new boiler will probably be much less than those of the boiler being replaced. This is a result of today's more efficient boiler design and more accurate methods of load determination.

If the modernized system is steam, it is important that the output of the replacement boiler is adequate to supply the total connected load and all piping losses. Therefore, in selecting a replacement boiler for a steam system, it is necessary to determine the sum of the ratings of all terminal units to determine the required *net* rating of the replacement boiler. If the steam boiler selected has insufficient capacity, high seasonal fuel consumption may be expected.

APPENDIX B: BURNER REPLACEMENT

Sometimes it is desirable to change the type of fuel being used in the boiler. In this case, not only should the old boiler be inspected to determine its condition, but also one should find out if the manufacturer recommends the boiler for use with the fuel in question. If the boiler is not suited to the particular fuel being considered, inefficient operation will result unless it is replaced.

If the boiler is in satisfactory condition and the manufacturer recommends it for the fuel being considered, there is no need to replace the boiler even when the burner is to be changed. The boiler manufacturer should be able to supply information as to the type and size of burner which should be used, along with installation instructions. These instructions should be carefully followed.

If the condition of the boiler is unsatisfactory or the boiler is not adaptable to the fuel in question, it will be necessary to replace both the boiler and the burner. In this case, one should select a boiler specifically designed to use the fuel in question, and the size of the boiler should be determined by the procedures given in Appendix A.

APPENDIX C: REPLACING OLD-STYLE RADIATION WITH BASEBOARD

The following guidelines should be followed to ensure satisfactory results in replacing existing radiators with baseboard radiation units:

- If only part of the old-style radiation is to be replaced with baseboard, the output of the base-

board must be equal to that of the old-style radiation that it is to replace.

Catalog ratings of baseboard contain a 15% effective heat allowance (for its favored location near the floor) which is not included in the ratings of cast-iron radiators. In order to compensate for this difference in method of rating, the output of the baseboard should be based on a design water temperature of 200°F. If the baseboard is to replace front-outlet convectors which do not exceed 26 inches in height, the design water temperature for the baseboard may be assumed to be 215°F.

- The baseboard is not required to be placed in the same location as the old-style radiation that it is to replace. For best results, baseboard units should be located along outside walls of the room
- It is not necessary to replace all of the radiation. A mixture of old-style and baseboard radiation is feasible. Often, only the radiation in the living room is changed.
- If all the radiation in the original system is to be replaced by baseboard, the design heat loss of each room should be calculated and the amount of baseboard to be installed should be based on the *design heat loss* of the room, not on the amount of radiation which was previously installed.
- Because baseboard units are much longer than radiators or convectors of equal capacity, some of the piping between the mains and the terminal units will have to be changed. See Figure 36.
- All new piping between the baseboard and the mains should be of the same size as the piping used for the terminal unit being replaced. This is especially true where only a part of the old-style radiation is being replaced.
- If the pipe size is larger than the supply and return connections to the baseboard, the reduction in pipe size should be made as close to the baseboard as possible.
- All new piping not replacing pipe from the old system, for example, the return-side piping when converting a one-pipe steam system to hot-water, should be sized in accordance with Appendix D.
- The manufacturer's instructions for installation of the baseboard should be followed.

APPENDIX D: SELECTION OF CIRCULATOR (PUMP AND PIPE SIZING METHOD)

The steps required for the selection of the circulator (also referred to as a pump) are as follows:

- Determine the Btuh load on the old circuits and main by multiplying the square feet of attached

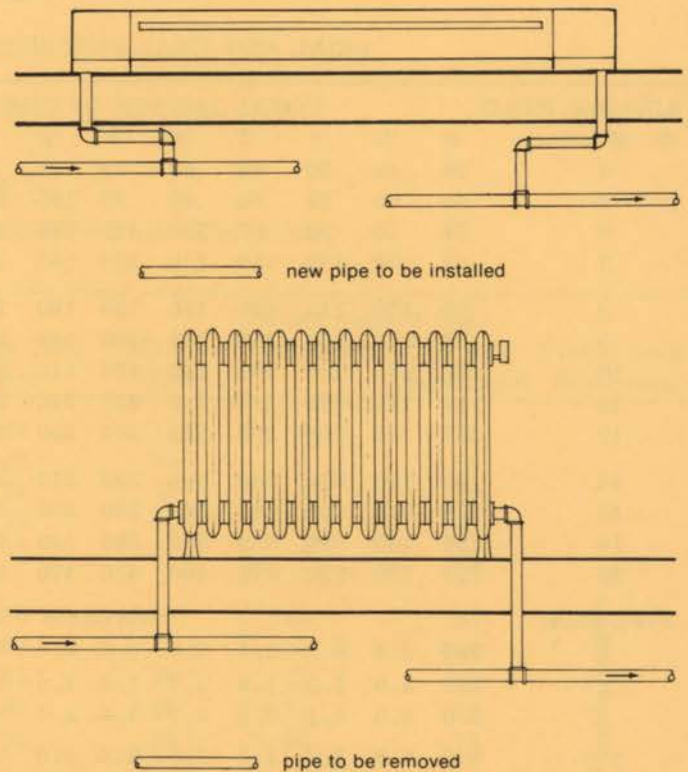


Figure 36. Piping changes when replacing a radiator with a baseboard unit.

radiation (steam) by 240. For example, if the total attached radiation is 800 square feet, the Btuh load is $800 \times 240 = 192,000$ Btuh.

- Divide the total load in Btuh by 10,000 to determine the required rate of water circulation in gpm.
- From the manufacturer's catalog, select a circulator that will circulate the required gpm at a head of not less than 4 feet of water. The circulator size need not be the same size as the size of the pipe in which it is to be located. However, if the circulator size is less, then the pipe size should be reduced to correspond to the size of the circulator close to the circulator.
- The sizes of the existing steam piping will probably be more than adequate to handle the water quantity to be circulated. However, pipe sizes should be checked, using an accepted pipe-sizing procedure. (An accurate, yet simple, pipe-sizing procedure is described in detail in I=B=R Installation Guide 200, which may be obtained from The Hydronics Institute, 35 Russo Place, Berkeley Heights, NJ 07922.) If any section of pipe is found to be too small, either that section should be replaced with a pipe of the proper size or a circulator that can develop a higher pump head should be selected.
- The data in Table 1 may be used to check the size of existing pipe and to determine the proper size for all new piping required.

TABLE 1

TRIAL AND FINAL PIPE SIZING-HEAD PRESSURE TABLE

AVAILABLE HEAD ft. of water	TOTAL LENGTH OF CIRCUIT (AS MEASURED ON PIPING LAYOUT)																	
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
4	35	45	50	60	65	70	75	80	90	100	110	130	150	180	220	290	400	620
5	45	60	65	70	80	90	100	100	120	130	140	160	190	230	290	360	510	790
6	55	70	80	90	100	110	120	130	140	160	180	200	240	290	350	450	620	950
7	65	90	100	110	120	130	140	150	170	190	210	240	290	340	420	540	730	1120
8	75	100	110	130	140	150	160	180	200	220	250	290	330	400	490	620	850	
9	85	110	130	150	160	170	190	200	230	250	290	330	380	450	560	710	950	
10	100	130	140	170	180	190	210	230	260	290	320	370	430	510	620	790	1060	
11	110	140	160	190	200	220	240	260	290	320	360	410	480	570	690	880	1170	
12	120	160	180	200	220	240	260	290	320	350	400	450	530	620	760	960		
14	150	190	210	250	260	290	310	340	380	420	470	540	620	730	900	1120		
16	170	220	250	290	310	330	360	400	440	490	550	620	720	850	1020			
18	190	250	290	330	350	380	420	450	500	560	620	710	830	950	1150			
20	220	290	320	370	400	430	470	510	560	620	700	790	910	1060				

PIPE SIZE	GALLON PER MINUTE CAPACITIES																	
	$\frac{5}{8}$ " *	$\frac{1}{2}$ "	$\frac{3}{4}$ "	1 "	1 $\frac{1}{4}$ "	1 $\frac{1}{2}$ "	2 "	2 $\frac{1}{2}$ "										
$\frac{5}{8}$ " *	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.2
$\frac{1}{2}$ "	2.3	2.0	1.9	1.8	1.7	1.7	1.6	1.5	1.5	1.4	1.3	1.2	1.2	1.1	0.9	0.8	0.7	0.6
$\frac{3}{4}$ "	5.0	4.3	4.1	3.8	3.7	3.6	3.4	3.2	3.1	2.9	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.3
1 "	9.6	8.3	7.7	7.3	7.0	6.8	6.5	6.3	5.9	5.7	5.5	5.0	4.6	4.3	3.8	3.4	2.9	2.3
1 $\frac{1}{4}$ "		18	17	16	15.5	15	14.5	14.0	13.0	12.0	11.5	11.0	9.7	9.0	8.3	7.3	6.3	4.8
1 $\frac{1}{2}$ "		27	25	24	23	22	21	20	19	18	17	16	15	13	12	11	9.3	7.5
2 "						42	40	39	38	36	34	32	29	27	24	21	18	14
2 $\frac{1}{2}$ "									60	57	54	52	47	44	38	32	29	24

* $\frac{5}{8}$ " Copper Tubing only

NOTE: Do not go beyond the maximum or below the minimum figures shown in the table.

Single pump — Enter the upper portion of the table at the head pressure of the pump selected. Read across to the figure closest to the total length of the longest circuit. Read down to the lower portion of the table to the gpm figure equal to or greater than the gpm required for the circuit. Read to the left-hand column to determine the pipe size required. Staying in the same column established by the circuit with the longest total length, repeat the last step for the gpm requirements of the other circuits and the trunk.

Multiple pumps — Enter the upper portion of the table at the head pressure of the pump selected. Read across to the figure closest to the total length of the longest circuit served by the pump. Read down to the lower portion of the table to the gpm figure equal to or greater than the gpm required for the circuit. Read to the left-hand column to determine the pipe size required. For a two-pipe circuit, size all pipe in the circuit from the same column in the table established by the circuit with the longest total length. Size the trunk and any common piping using the total gpm of the system, the lowest head pressure of the pumps selected, and the longest total length of circuit.

APPENDIX E: SELECTION OF COMPRESSION TANK

1. The size of the compression tank depends upon the quantity of water in the entire system, consisting of the boiler, the terminal units, and the piping. The first two of the three items, namely the water contained in the boiler and the terminal units, can be determined from Table 2.
2. The third item, the quantity of water in the piping system, depends upon the size of the piping system that is in place. It is necessary to determine not

only the diameters of the piping in the system, but also the length of pipe of each diameter. The quantity of water required to fill one foot of steel pipe or copper tubing is given in Table 3.

3. Add the three volumes determined in steps 1 and 2 to obtain the total water content of the system.
4. Choose the appropriate air-cushion or diaphragm tank selection factor from Table 4.
5. Multiply the total water content of the system (step 3) by the tank selection factor (step 4) to obtain the minimum tank capacity.

TABLE 2
WATER CONTENT OF BOILERS AND TERMINAL UNITS

Net Btuh Rating in 1000 Btuh	Water content Gal.			Water content Gal.				
	Conventional Boiler	Flash Boiler	Rad. Output in 1000 Btuh*	Large Tube Rad.	Thin Tube Rad.	Convector	Cast Iron Baseboard	Finned Tube Baseboard
50	12	5	50	24	13	6	20	
60	14	6	60	29	14	7	23	
70	17	7	70	33	16	7	27	
80	20	8	80	38	19	8	32	
90	22	9	90	43	21	9	36	
100	25	9	100	48	23	10	38	
125	30	11	125	59	32	15	49	
150	36	13	150	71	40	18	59	
175	42	15	175	83	46	21	69	
200	48	16	200	95	53	24	79	
250	60		250	118	67	30	98	
300	70		300	143	80	36	118	
350	84		350	166	92	41	138	
400	95		400	190	106	48	157	
450	107		450	214	119	53	177	
500	120		500	237	131	59	196	
600	140		600	285	159	71	236	
700	160		700	332	190	83	275	
800	190		800	380	209	95	314	
900	210		900	427	238	107	353	
1000	235		1000	475	266	118	397	
2000	480		2000	950	531	237	784	
3000	720		3000	1430	795	356	1180	
4000	960		4000	1900	1060	466	1570	
8000	1200		8000	3800	2125	950	3140	
12000	3000		12000	5700	3190	1430	4720	
16000	3700		16000	7600	4300	1900	6280	

consider as part of piping system

*Based on 240 Btuh per square foot heat emission rate.

TABLE 3

VOLUME OF WATER IN STANDARD PIPE AND TUBE

Nominal Pipe Size Inches	Standard Steel Pipe			Type I. Copper Tube	
	Schedule No.	Inside Dia Inches	Gallons per Lin Ft	Inside Dia Inches	Gallons per Lin Ft
3/8				0.430	0.0075
1/2	40	0.622	0.0157	0.545	0.0121
5/8				0.666	0.0181
3/4	40	0.824	0.0277	0.785	0.0251
1	40	1.049	0.0449	1.025	0.0442
1 1/4	40	1.380	0.0779	1.265	0.0653
1 1/2	40	1.610	0.106	1.505	0.0924
2	40	2.067	0.174	1.985	0.161
2 1/2	40	2.469	0.249	2.465	0.248
3	40	3.068	0.384	2.945	0.354
3 1/2	40	3.548	0.514	3.425	0.479
4	40	4.026	0.661	3.905	0.622

TABLE 4

AIR CUSHION TANK CAPACITY

Initial or fill, pressure psig	Altitude	Max. height of system above gage ft	Air cushion tank capacity in gallons per gallon of water in system	Diaphragm tank pre- pressurized to 6 psig
4	9	0	0.11	0.10
6	14	5	0.14	0.10
8	18	9	0.16	0.12
10	23	14	0.19	0.14
12	28	19	0.23	0.16
14	32	23	0.28	0.19
16	37	28	0.34	0.24
18	41	32	0.43	0.30
20	46	37	0.54	0.39
22	51	42	0.71	0.50
24	55	46	1.00	0.72

This table is based on a final pressure of 30 psig at the boiler or low point in the system, and an initial fill temperature of 60°F.