CHAPTER THREE

Steam Up

Why the Production and Distribution of Steam Is Important

Any form of radiation cannot heat up to warm a room without a supply of steam.

- **Fig. 1** The boiler changes water to steam by adding approximately 1,000 BTUs of heat per pound of water.
- Steam forms as bubbles in the boiler water and then rises up to break the surface of the water.
- It is critical that the surface of the water is free of oil or grease in order to produce proper steam. Refer to page 34.

Steam is a gas that is lighter than air.

- While both are gases, steam and air do not mix and cannot occupy the same space.

Fig. 2 Steam moves through the system because the higher pressure of the steam goes to the lower pressure of the atmosphere or an induced vacuum.

- High pressure has to move to lower pressure by physical law.
- Any pressure in the boiler, as slight as an ounce, is greater than the pressure outside the boiler.
- Any pressure in the piping and radiator, as slight as an ounce, is greater than the pressure outside the piping and radiator.
- Movement or velocity of steam is a function of the volume of steam and the pipe size.

The ideal burner cycle during a "call for heat" is one that is not interrupted by a bouncing water line caused by a "dirty" boiler.

- Grease and oil on the water line will cause the water in the boiler to bounce up and down, causing the low water cut off to shut off the burner.
- When the generation of steam is interrupted, the flow of steam to the radiation is uneven.

Fig. 1

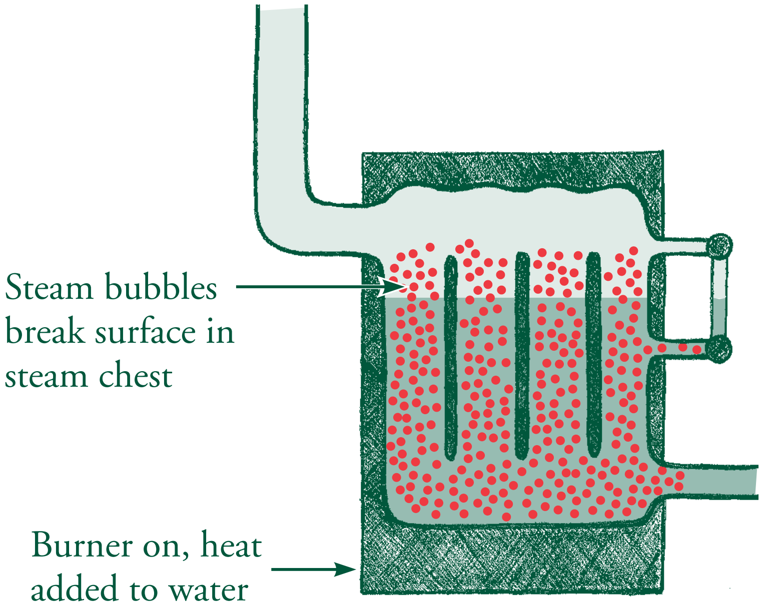
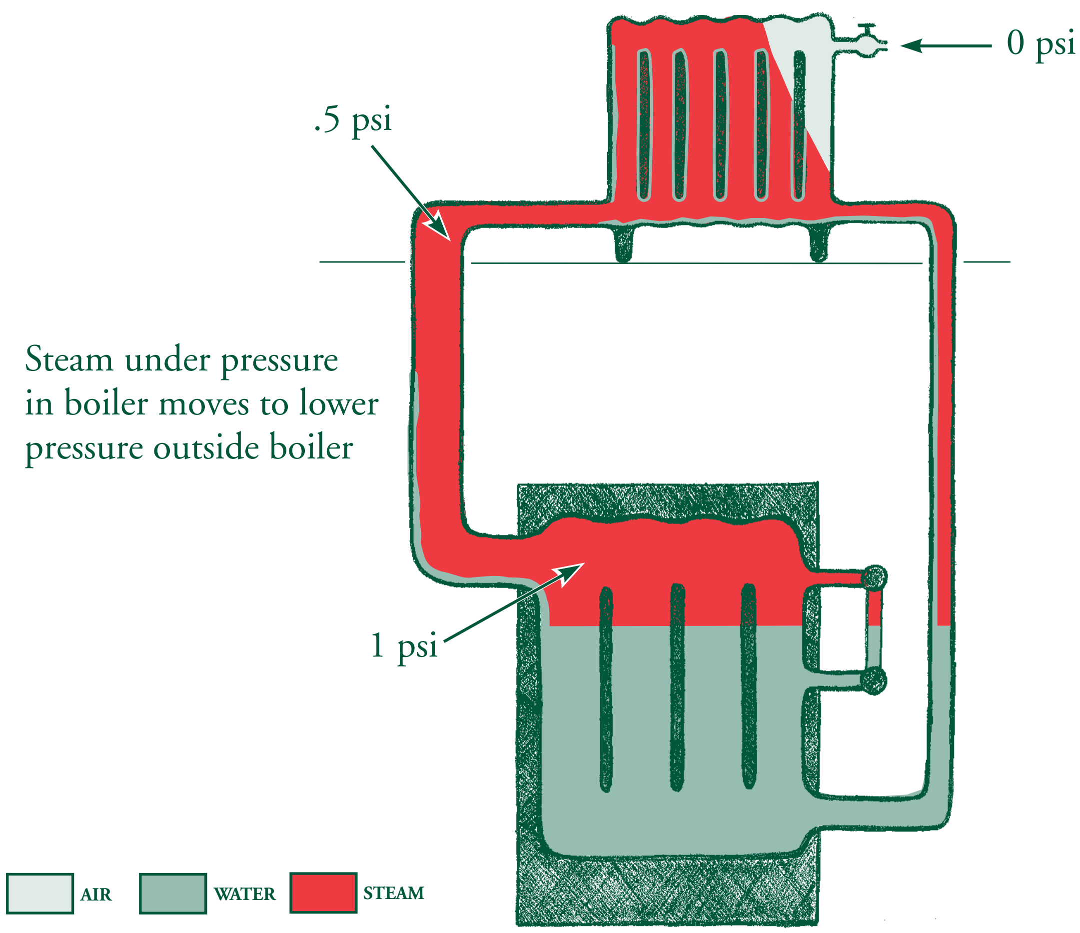

Steam bubbles break surface in steam chest
Burner on, heat added to water

Fig. 2


0 psi
.5 psi
Steam under pressure in boiler moves to lower pressure outside boiler
1 psi
AIR
WATER
STEAM

Follow the Path of Steam Through the System

We know why steam flows through the system, now let's follow it from the boiler to the radiation.

- **Fig. 1** Steam rises up through the boiler water to break free of the water line in the steam chest.
- **Fig. 1** Steam leaves the steam chest through the boiler supply outlet(s).
- **Fig. 2** The steam then flows up the supply riser(s), through the swing joints to the header.
- **Fig. 3** Steam flows out of the header to the supply main(s).
- **Fig. 3** Steam flows along the supply main to the takeoff.
- **Fig. 4** Steam flows through the takeoff to a run out.
- **Fig. 4** Steam flows through the horizontal run out to the vertical riser.
- **Fig. 4** Steam flows through the vertical riser to the radiation valve.
- **Fig. 4** If the valve is open, steam flows into the radiation.

All along this path, the steam has to warm the inside of the pipe.

- As steam moves out of the boiler, a portion of the steam volume is used heating the pipe it's flowing through.
- Uninsulated pipe will use a larger portion of the steam volume than insulated pipe.
- If asbestos insulation has been removed from piping, new insulation must be installed.
- It is strongly recommended that all supply piping, including the near boiler piping, be insulated.

As the steam moves through the piping it also experiences a pressure drop caused by the friction of the steam against the inside of the pipe.

- Steam leaving the boiler at one pound of pressure may experience as much as ½ pound of pressure drop from boiler outlet to the end of the main.
- The pressure drop is a function of the size of the pipe and the volume of steam flowing through it.
- The chart on page 160 shows the relationship of pipe size to pressure drop at different steam volumes.
- The oldtimers used charts like this when designing their systems.
- Use this chart to check existing piping or sizing new pipe during remodels.

Follow the Path of Steam Through the System

Fig. 1

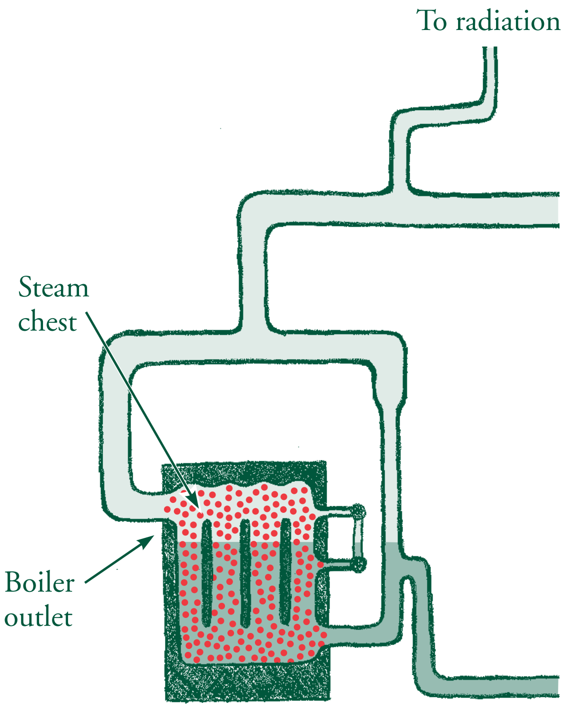


Fig. 2

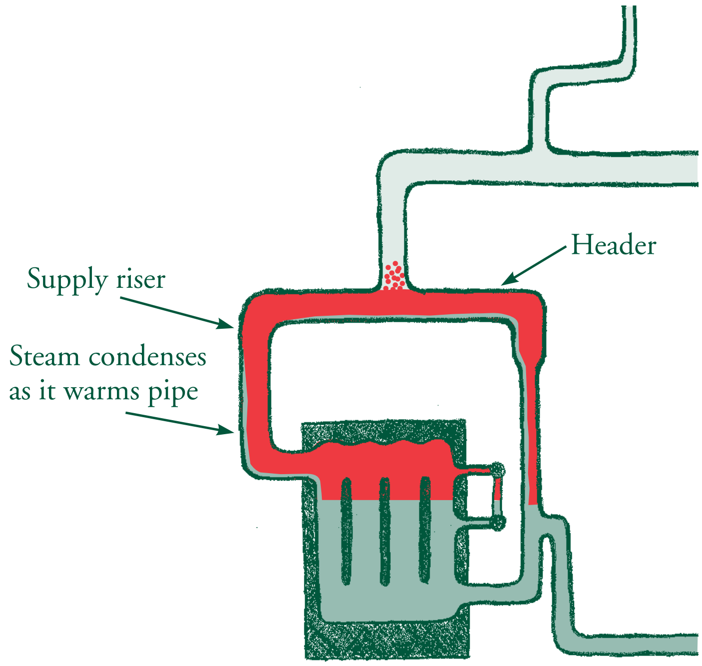


Fig. 3

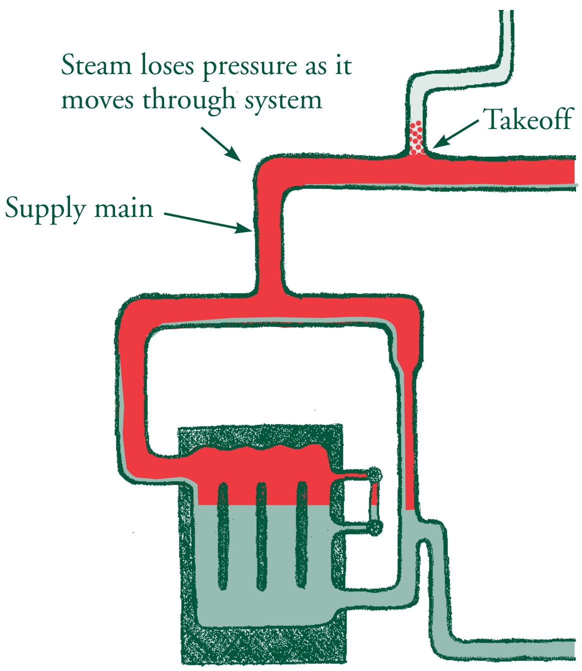
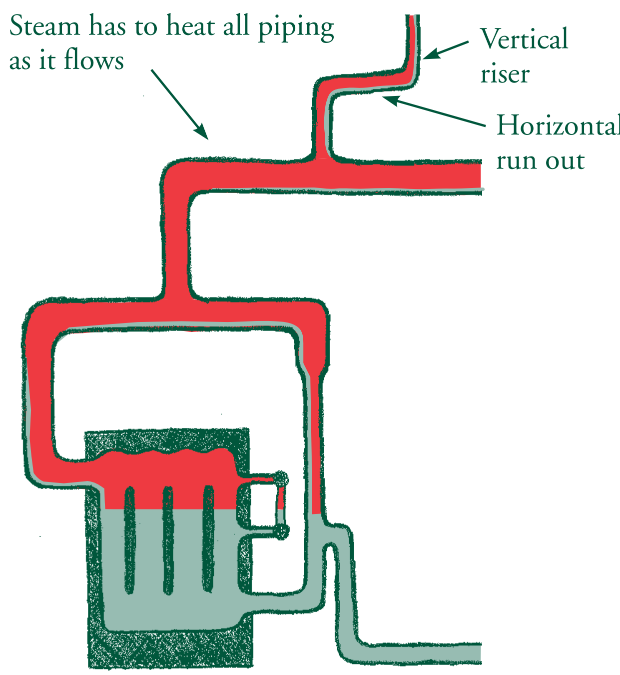


Fig. 4



AIR WATER STEAM

You Always Want a "Clean" Boiler

Fig. 1 Clean boiler water produces the best steam.

- Water needs to be free of any oil or grease.
- Clean water surface required for proper release of steam from water.
- Clean boilers have steady water lines.
- Clean boilers have far fewer problems.

A "dirty" boiler can be the cause of a multitude of problems:

- Not enough heat throughout system.
- Uneven steam distribution.
- Water disappears from gauge glass causing nuisance low water shutdowns.
- Water gets carried over into steam mains causing water hammer and "wet" steam.
- Pressure in boiler builds up quickly, but steam doesn't circulate.
- Worst case, boiler cannot make any steam.

Fig. 2 To check if "dirty," with the boiler firing and making steam, check the gauge glass for water line condition.

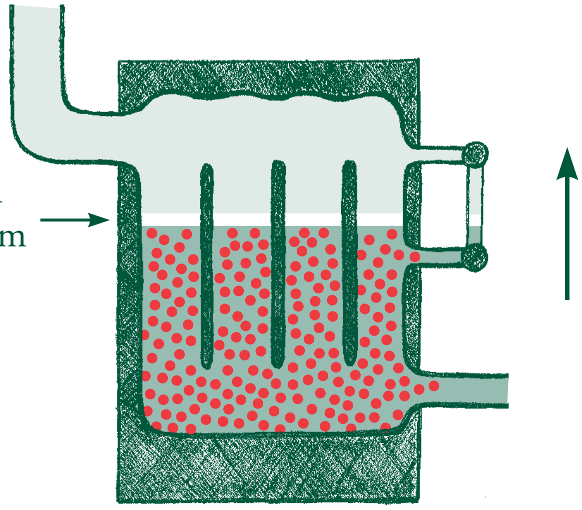
- A bouncing water line indicates a "dirty" boiler.
- Water running down the gauge glass from the top indicates a "dirty" boiler.
- Draw off some water into a pot, boil it on stove, and observe results. Steam should release from water evenly, with no foaming.

Fig. 3 The chemical balance of the boiler water can affect steam quality.

- Check the pH level of the boiler water.
- The pH should be from 7 to 8.5.
- High pH can cause foaming in the steam chest, boiler riser, and header resulting in poor steam production.
- Excess chemicals from mismanaged water treatment can cause poor steam quality.
- Use water treatment only when necessary, when directed at a specific problem, and when checked for effectiveness.

Fig. 1

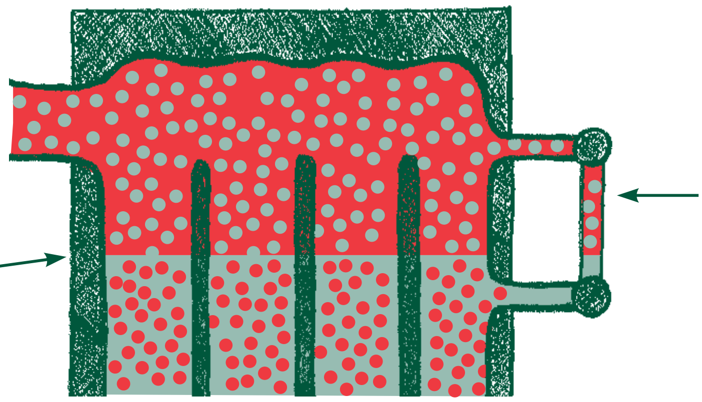
A layer of grease and oil on water line blocks steam from releasing from water



Steam flow blocked

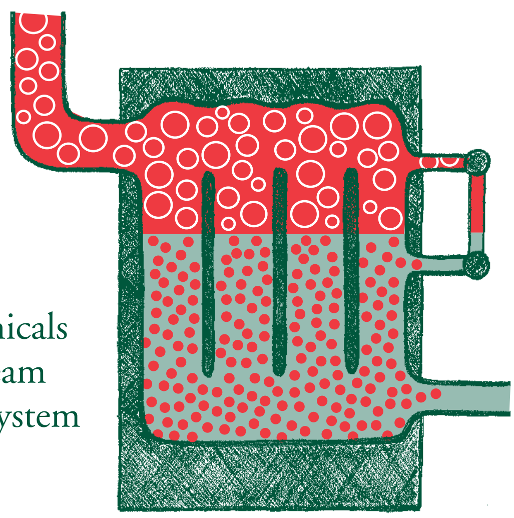
Fig. 2

Water line bounces as steam releases erratically from boiler water



Water running down gauge glass from top is visual indicator of dirty boiler and wet steam

Fig. 3



High pH or excess chemicals can cause foaming in steam chest resulting in poor system production

AIR WATER STEAM

Cleaning a Boiler

There are two methods to clean up a dirty boiler, chemical treatment or water line skimming.

- Both methods can be effective if properly done. See page 157 for detailed instructions
- There is no assurance that one skimming or one dose of chemicals will completely clean a boiler.
- Whatever method chosen will have to be repeated until system is clean.
- Never underestimate the importance of a clean boiler, one that can generate dry steam with a steady water line.

Suggested water line skimming (blowing off) techniques.

- **Fig. 1** Use as skim port, as large a tapping on side of boiler near or above normal water line and install 12″ nipple and gate valve.
- Adjust water feed to have boiler water flowing out nipple into 5 gallon bucket or go to drain at a very slow rate.
- Drive grease, oil, and other impurities to surface by heating boiler water to below steaming temperature.
- **Fig. 2** Too fast a flow rate or too small a tapping will force oil and grease back into the boiler. A slow flow rate and large opening will allow it to float out.

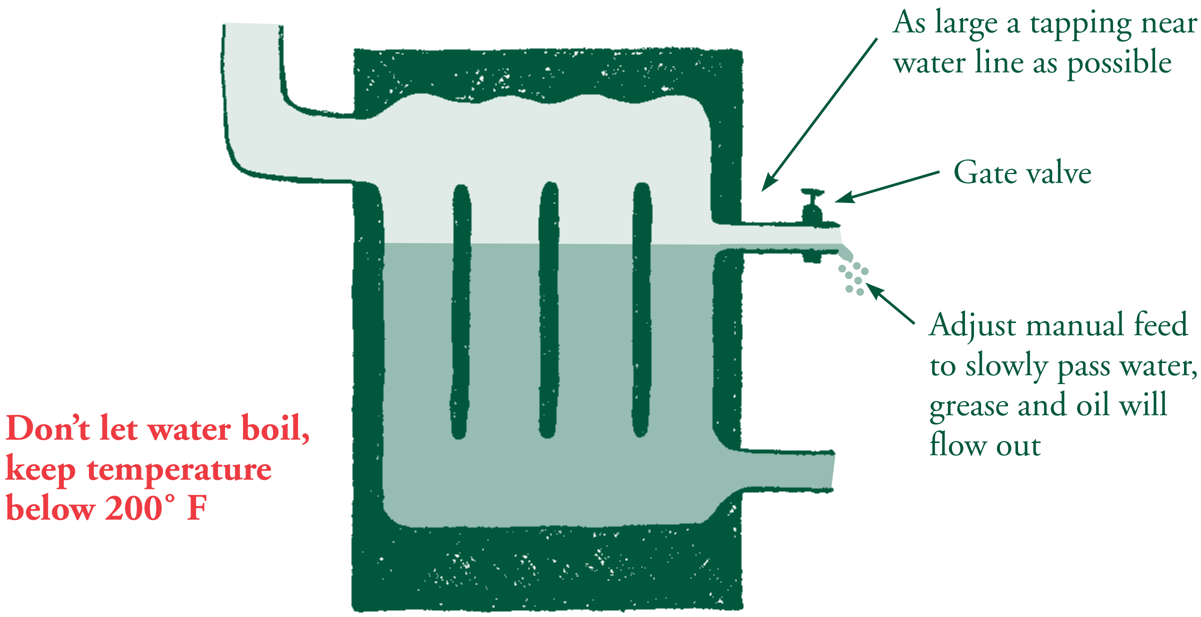
Chemical cleaning agents should be available at your local supply house.

- Cleaner should absorb grease and oil so it can be drained out of boiler.
- Always follow the directions and do not over apply. Too much left over chemical could cause symptoms of a dirty boiler.

An extremely dirty piping system may need to be cleaned by wasting the condensate to the drain until it runs clean.

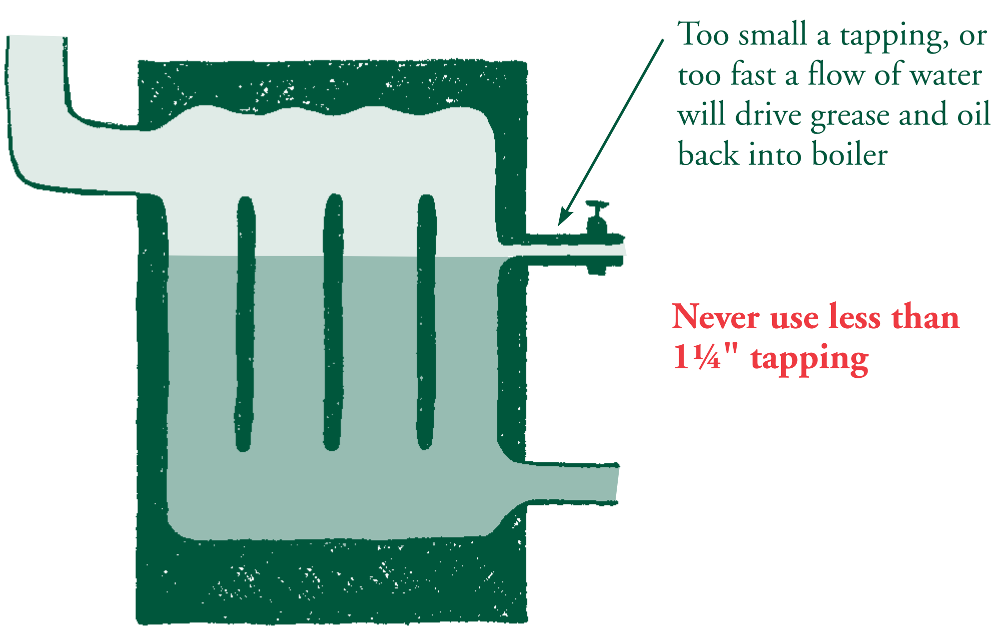
- Systems with return pumps (vacuum, condensate transfer, or boiler feed) should be checked for poor return water conditions.
- The wet return on gravity return systems should be checked for poor return water condition.

Fig. 1



Heat of burner drives grease and oil to water line

Fig. 2



AIR WATER STEAM

Water Line Position Affects Steam Chest Size

Importance of correct water line setting.
- Dry steam generated by boiler.
- Even heat distribution.
- Lower fuel bills.

Fig. 1 **With burner on and steam being generated, boiler water line in the gauge glass should be between one-quarter to one-half full.**
- Check specific boiler manufacturer's installation instructions, if possible, for recommended water line.

Fig. 1 **Water line level determines size of steam chest.**
- Properly sized steam chest gives steam enough space to release from water line.
- Properly sized steam chest results in normal fuel bills.

Fig. 2 **With water line set too high, generally above one half in the gauge glass, the steam chest doesn't have enough space for proper release of steam from the water line, resulting in wet steam.**
- Wet steam is steam with a high content of water causing it to give poor performance.
- A high boiler water line results in higher than normal fuel bills.

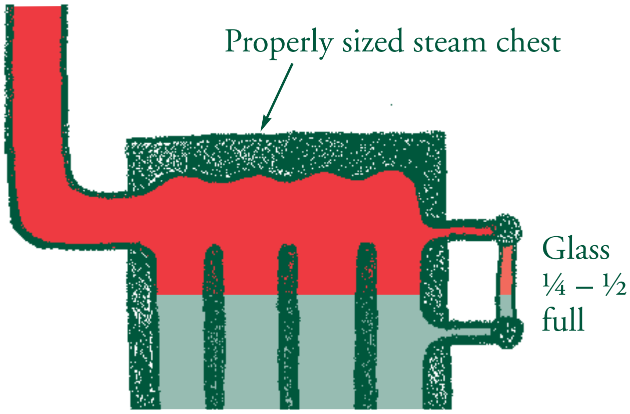
Fig. 3 **A flooded boiler has a full gauge glass and little or no steam chest.**
- The flooded boiler results in the highest fuel bills.
- The higher water level decreases the outlet area of the supply riser increasing steam velocity and causing wet steam.

Fig. 4 **A boiler with no water in the gauge glass, or water level below manufacturer's recommendations, will have an oversized steam chest.**
- The boiler will cycle on and off repeatedly by the LWCO (short cycle) causing poor steam circulation in the system.
- The chance of a boiler dry-fire (firing with little or no water in it) will be increased.
- Fuel bills will be higher because of the short cycling.

Water line can be adjusted by the position of the LWCO, direct feeder, boiler feed pump controller, or hand feed level.
- Set water line to boiler manufacturer's recommended level.
- ⊘ Don't raise water level to cover tankless heater.

Water Line Position Affects Steam Chest Size

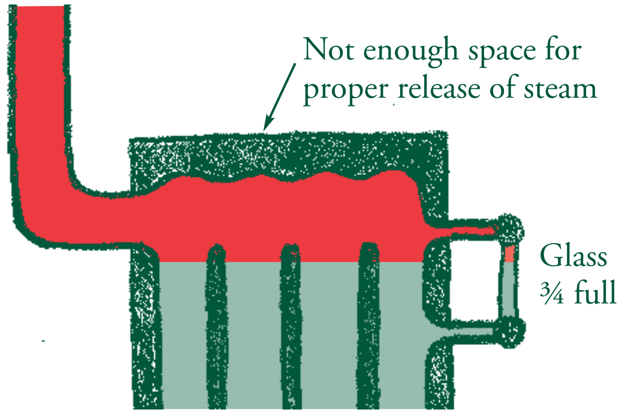
Fig. 1



NORMAL WATER LINES

NORMAL FUEL BILLS

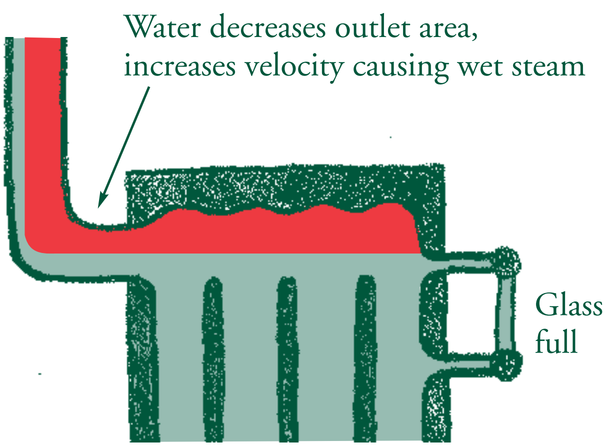
Fig. 2



WATER LINE TOO HIGH

HIGH FUEL BILLS

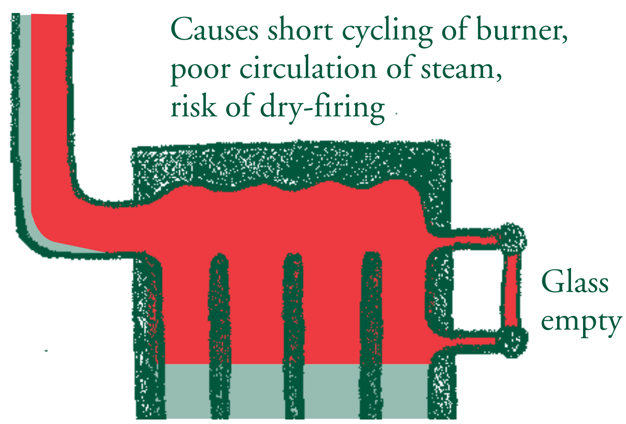
Fig. 3



FLOODED BOILER

VERY HIGH FUEL BILLS

Fig. 4



WATER LINE TOO LOW

HIGH FUEL BILLS

AIR WATER STEAM

Importance of Dry Steam

Steam with less than 2% water is considered dry steam.

- Dry steam heats better than wet steam.
- Dry steam does not contribute to water hammer problems.
- Dry steam moves through the piping system better than wet steam.
- The piping system was designed for dry steam, not wet steam.

Boilers manufactured in the early part of the 1900s used a very large steam chest (dome) to help dry out the steam.

- The steam chest was used to allow any water carried off the water line by the steam to separate and stay in the boiler.
- Early manufacturers also had more and larger outlet tappings than modern manufacturers.
- They insisted that all the outlet tappings were to be used at full size.

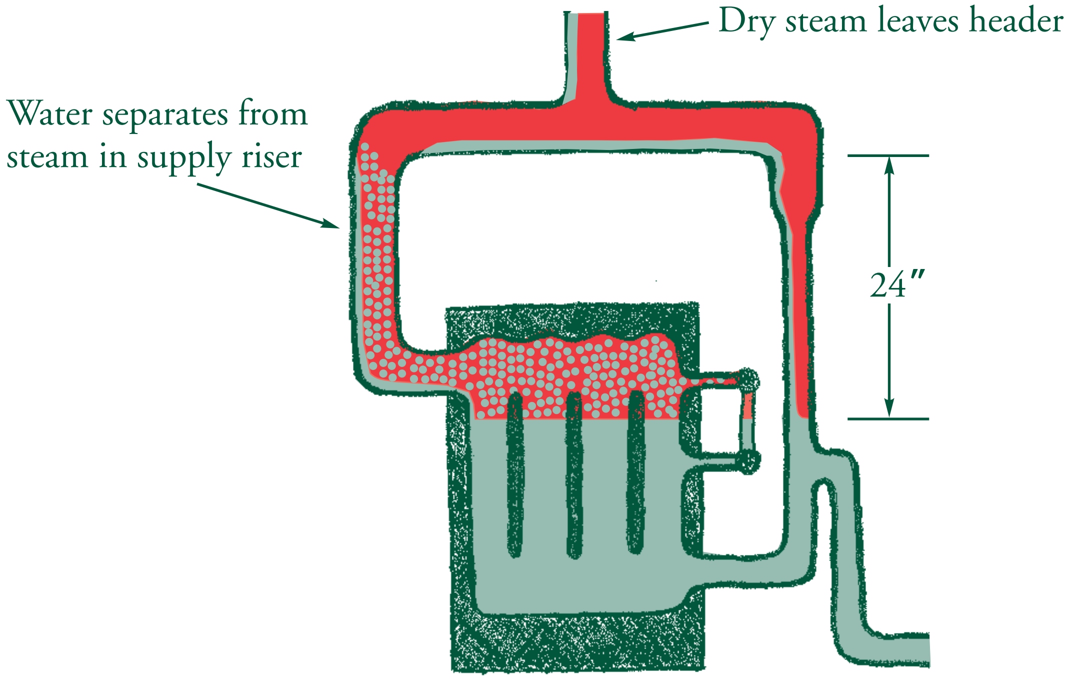
The purpose of the large steam chest and large outlet tappings was to keep the velocity of the steam flow out of the boiler to a minimum, sometimes allowing less than 10 feet per second (FPS).

- The slower the flow out of the boiler, the less water will be carried out of the boiler as wet steam.
- Boiler designers of old were quite concerned with the quality of the steam leaving the boiler. The drier the steam, the better.

Modern boiler manufacturers use a much smaller steam chest to increase efficiency and reduce initial cost.

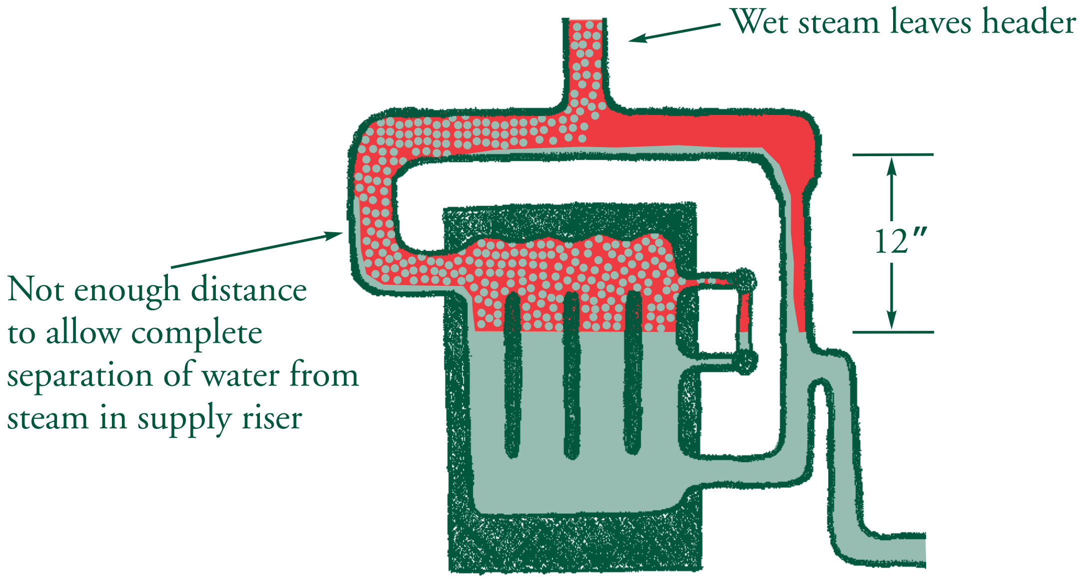
- Today's designers use the near boiler piping to produce dry steam.
- **Fig. 1** Modern boilers require a distance of at least 24 inches from the boiler water line to the steam header.
- Water will separate from the steam in this 24 inch vertical supply riser like it used to in the large steam chest.
- Any leftover water is then separated from the steam in the header.
- Don't use smaller than recommended piping. It can cause uneven heat, high fuel bills, and water hammer.
- **Fig. 2** If there is not enough distance between the water line and the header, wet steam can leave the header.

Fig. 1



DRY STEAM ASSURES GOOD CIRCULATION AND NORMAL FUEL BILLS

Fig. 2



WET STEAM CAUSES POOR CIRCULATION, WATER HAMMER, AND HIGH FUEL BILLS

AIR WATER STEAM

How Much Steam Pressure Is Necessary?

Low pressure steam heating systems generally work best at a steam pressure below 2 pounds.

- Most of the systems in operation today were designed to heat the building with a coal-fired boiler operating at a maximum of 2 pounds.
- Set the steam pressure control (pressuretrol) to cut in at ½ pound, and cut out at a maximum of 2 pounds.
- Some manufacturers designed vapor systems that could heat any size building with a maximum of 12 ounces of pressure.
- Set the vapor pressure control (vaporstat) to cut in at 4 ounces, and cut out at 12 ounces.

Fig. 1 The steam pressure produced at the boiler is reduced because of friction as it moves through the system.

- At start-up, steam condensing on the cold surface of the pipe keeps the pressure from rising.
- After the mains are warm, friction from the movement through the pipes reduces the steam pressure.
- The designers of old selected pipe sizes that kept that pressure drop consistent throughout the system.
- Most systems have a maximum pressure drop of ½ pound, from boiler to the end of the supply main.

Increasing the steam pressure above 2 pounds can cause problems.

- Higher steam pressure is more expensive to produce and maintain because it requires more fuel.
- Higher steam pressure can cause water hammer because condensate will back up to flood the supply mains in gravity return systems.
- Higher steam pressure can keep some one pipe radiator quick vents from cycling open to release air.

Some homeowners or building superintendents are reluctant to believe that a lower pressure setting will heat their system.

- Try working the pressure down slowly, as little as ½ pound at a time.
- The building should heat just as well if not better at the lower setting, with lower fuel bills as a bonus.

Fig. 2 The only reason to operate steam heating systems higher than 2 pounds is to lift condensate to overhead return lines on two pipe systems.

- 1 pound of steam pressure can effectively lift condensate 1 foot.
- When lifting condensate, install a swing check valve on the discharge side of the trap to keep water from flooding the radiation.

Fig. 1

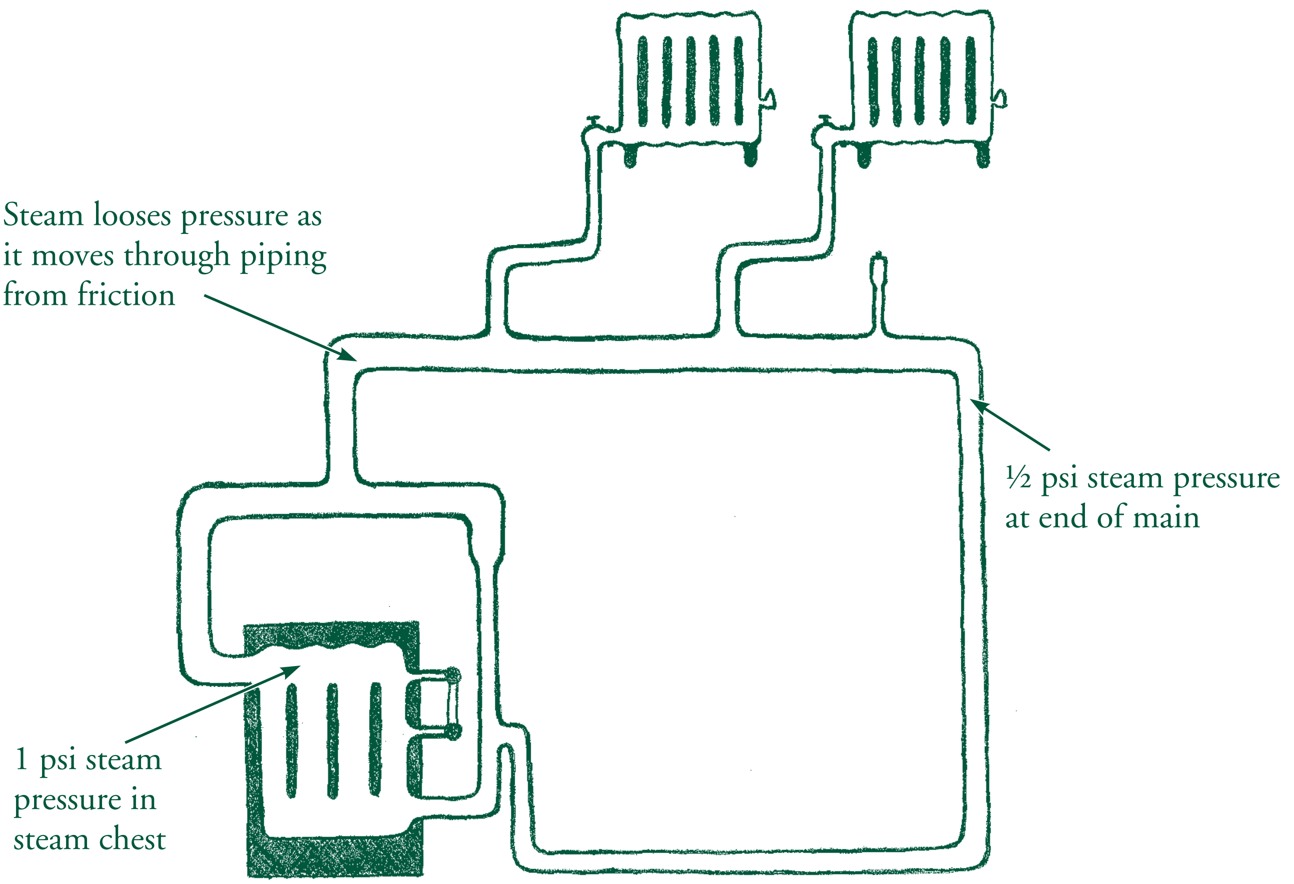
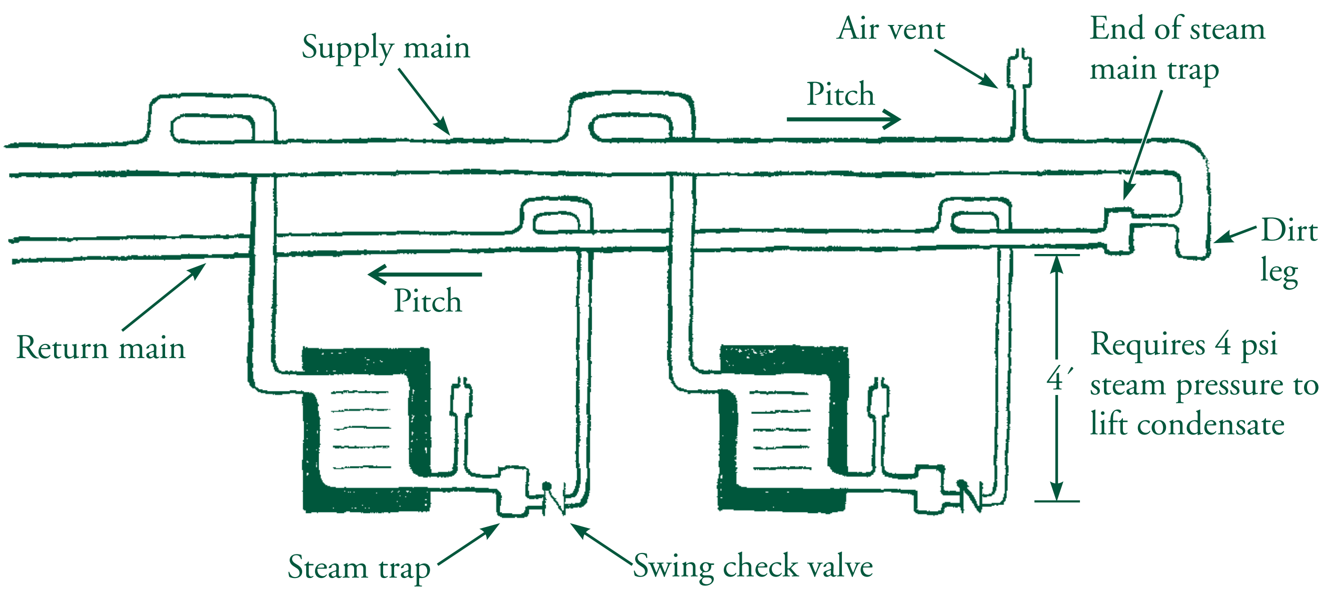

Steam looses pressure as it moves through piping from friction
½ psi steam pressure at end of main
1 psi steam pressure in steam chest

Fig. 2


Supply main
Air vent
End of steam main trap
Pitch
Dirt leg
Pitch
Return main
Requires 4 psi steam pressure to lift condensate
4′
Steam trap
Swing check valve

Types of Steam Distribution Systems

The ideal system of piping should allow steam to flow from the boiler to the radiation with a minimal loss in pressure at a velocity low enough to prevent conflict with the condensate, especially where they flow in opposite directions.

There are almost as many different types of steam systems as anyone can imagine.

- If you follow the principle of Steam Up, Air Out, Water Back, you can design any type system imaginable.
- Many manufacturers during the "Golden Age" of steam designed systems that were one of a kind.
- There were too many to try to list them all in this book, but they shared some characteristics that can be identified.
- Knowing what type steam distribution system you have on the job will help you fix it.

Fig. 1 In order for steam to flow throughout a piping system, it needs a clear path.

- Steam can move in any direction, up or down or horizontally.
- Steam and air cannot occupy the same space or blend with each other, so the air has to move ahead of the steam through the pipe toward an air vent.
- Steam and water can be in the same pipe if there is enough space for the volume of the steam.
- Steam will flow along the top of the pipe while water flows along the bottom.
- The steam and water can flow in the same direction or in opposite directions.

The flow of steam can be stopped by air (Fig. 2) or water (Fig. 3).

- All steam systems were designed to allow steam and water to flow together in the boiler riser, header, steam main, run outs, and risers.
- All steam systems were designed to vent the air from the supply mains and the radiation.

Pipe must always be sized for its function.

- How much steam is it carrying?
- How much water is it carrying?
- Is the water flowing in the same or opposite direction of the steam?

Fig. 1

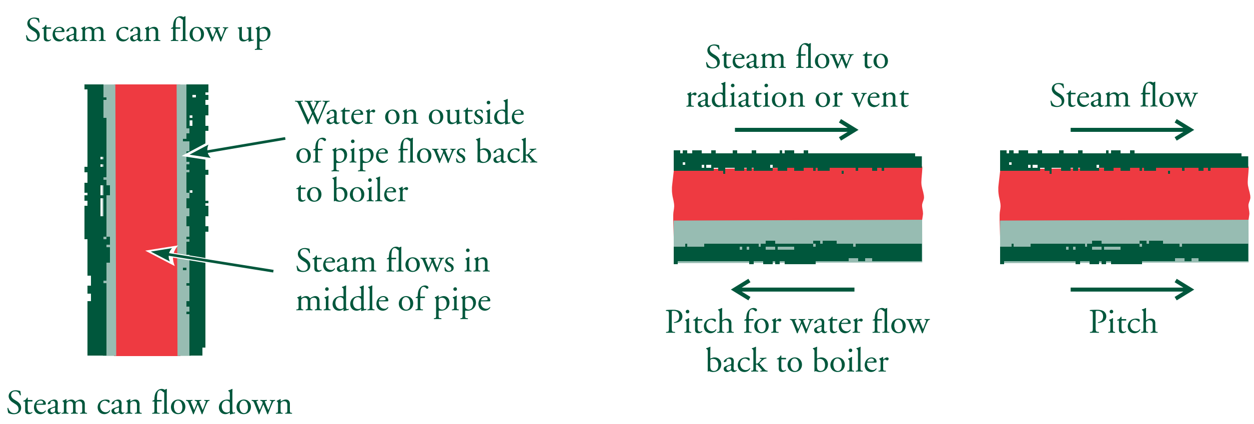


Fig. 2

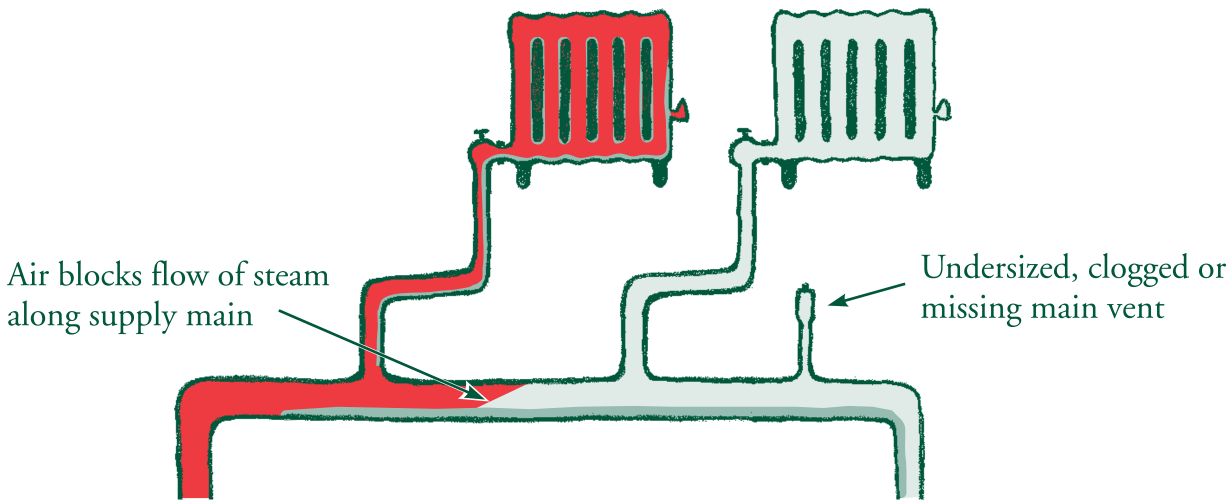
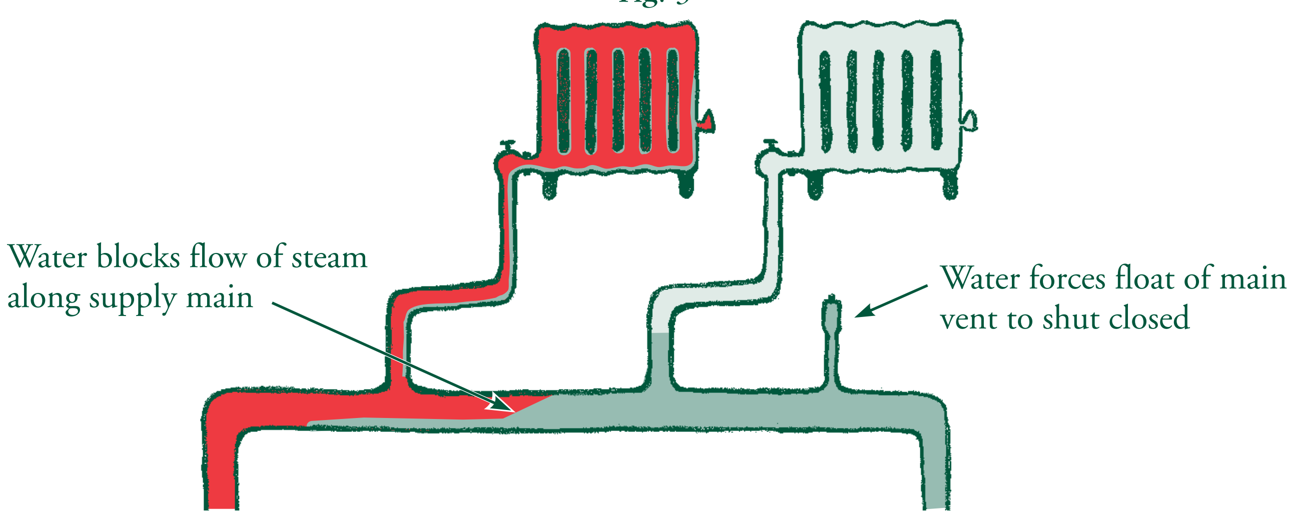


Fig. 3



One Pipe Steam

Fig. 1 One pipe steam systems will have one connection to the radiation where the steam flows in and the condensate flow out.

- The steam flows into the radiation and the condensate flows out through the same connection.
- The air in the radiation is typically vented with an automatic vent connected to the radiation, discharging air into the room.
- Some one pipe radiation is vented through an automatic vent that is connected to a vacuum line.
- The purpose of the vacuum line is to remove air more quickly for better economy, and more uniformly for even heating.

Fig. 2 With one pipe radiation systems, the steam must enter at the bottom of the radiation through a fully open, properly sized valve.

- Valve has to be completely open so that steam can flow into the radiator while condensate flows back.
- Partially closing the valve increases steam velocity and prevents some amount of water from leaving the radiator.
- The radiator has to be pitched from the vent end toward the valve end to drain condensate.
- Undersized or partially closed valves can cause water hammer in the radiator or spitting air vents.

Sometimes the valve disc will break off the stem or the stem will break.

- The disc will lodge in the supply piping to partially or completely block steam flow.
- Steam pressure may lift the disc off the seat to allow some steam in, but it will prevent water from leaving.
- Break the union, slide the radiator out of the way, and look into valve to verify disc will lift fully off seat by turning valve handle.

With one pipe systems, the steam, air, and condensate are flowing together in the supply main.

- Air is always pushed towards the end of the main(s) and radiators.
- Water can flow in the same direction or against the flow of steam.

Fig. 1

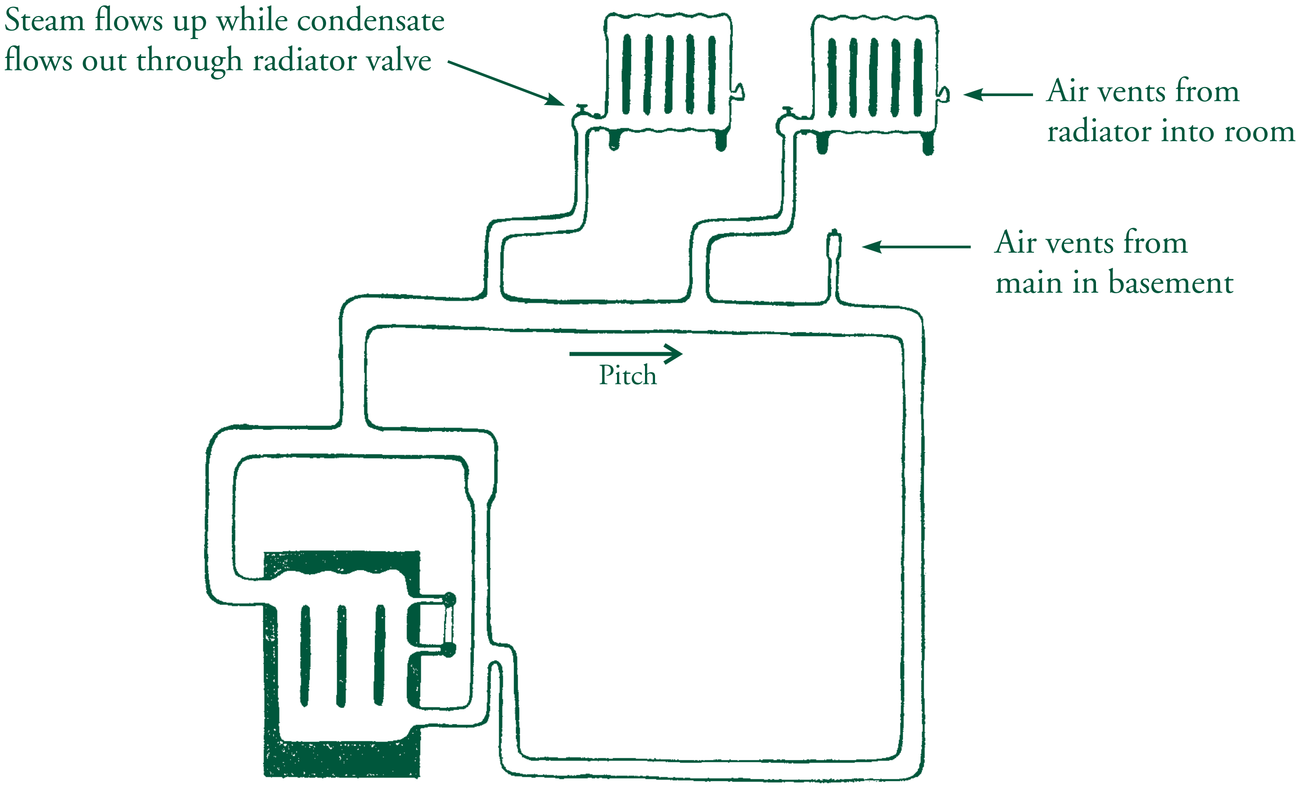
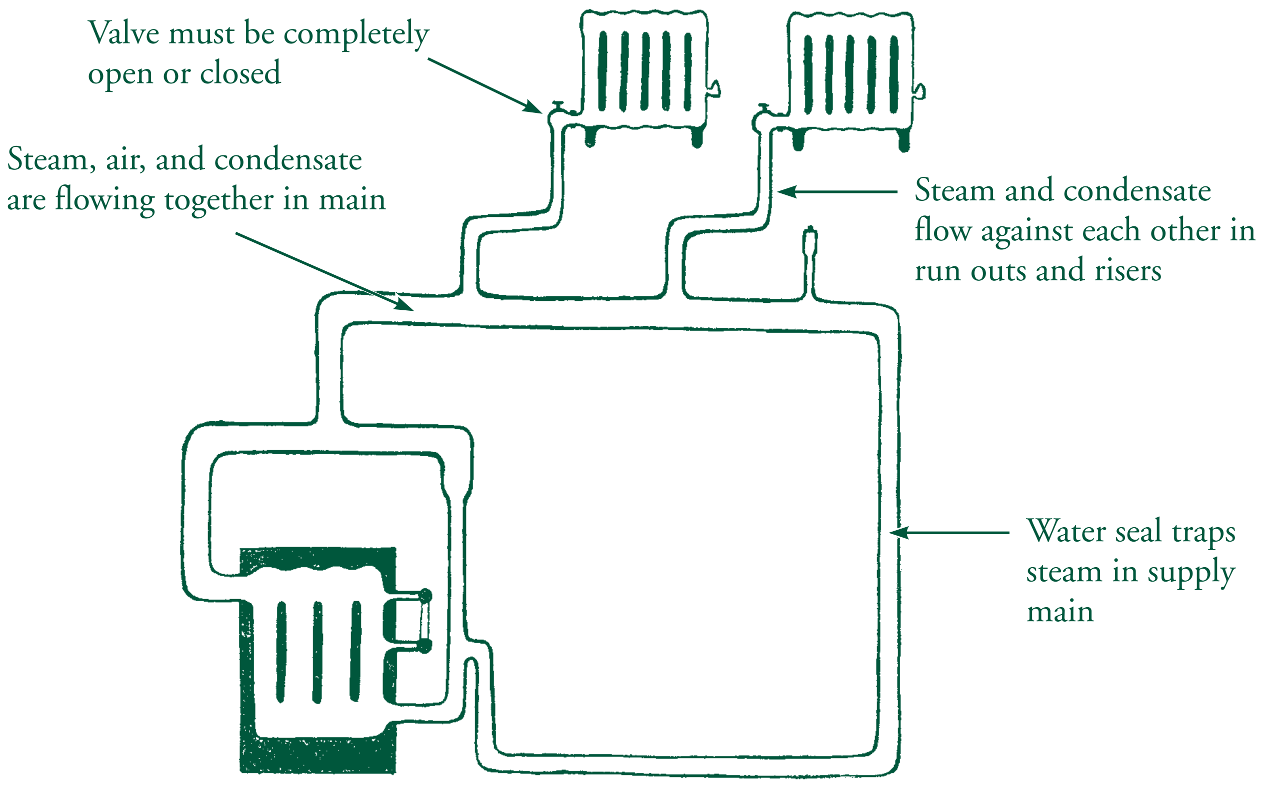

Steam flows up while condensate
flows out through radiator valve
Air vents from
radiator into room
Air vents from
main in basement
Pitch

Fig. 2


Valve must be completely
open or closed
Steam, air, and condensate
are flowing together in main
Steam and condensate
flow against each other in
run outs and risers
Water seal traps
steam in supply
main

Two Pipe Steam

Fig. 1 Two pipe steam systems will have one connection to the radiation through which the steam flows in and a second connection through which the air and condensate flow out.

- Two pipe systems can use many types of radiation: unit heaters, baseboard, cast iron radiators, fan coil units, etc.
- Two pipe systems can work on high pressure, low pressure, or vapor pressure (less than 1 pound).
- Two pipe systems can use water traps, thermostatic traps, F+T traps, bucket traps, or vapor devices on the return side of the radiation to keep steam in radiation and out of return lines.

Fig. 1 With two pipe radiator systems, steam enters at the top or the bottom of the radiator through a properly sized hand valve.

- Valve can be adjusted to any position, open or closed, to match heat requirements.
- Only steam passes through the valves, not condensate.

Fig. 2 With two pipe system, there is a separate return main for the air and the condensate.

- In the steam main, steam and the condensate from the supply piping only are flowing.
- In the return main, the air and the condensation from the radiation are flowing.

Fig. 2 A radiator trap or vapor device on the return end of the radiation keeps the steam in the radiation where it can give up its heat.

- The trap or vapor device passes the air and condensate to the return line.
- Pitch radiator toward steam trap or vapor device to drain condensate.

Steam must be kept out of the return lines.

- Steam in the return line can cause water hammer.
- Steam in the return line can stop steam flow to some radiators to cause uneven heating.
- If steam is getting past the radiator trap, repair or replace radiator trap immediately.

Fig. 1

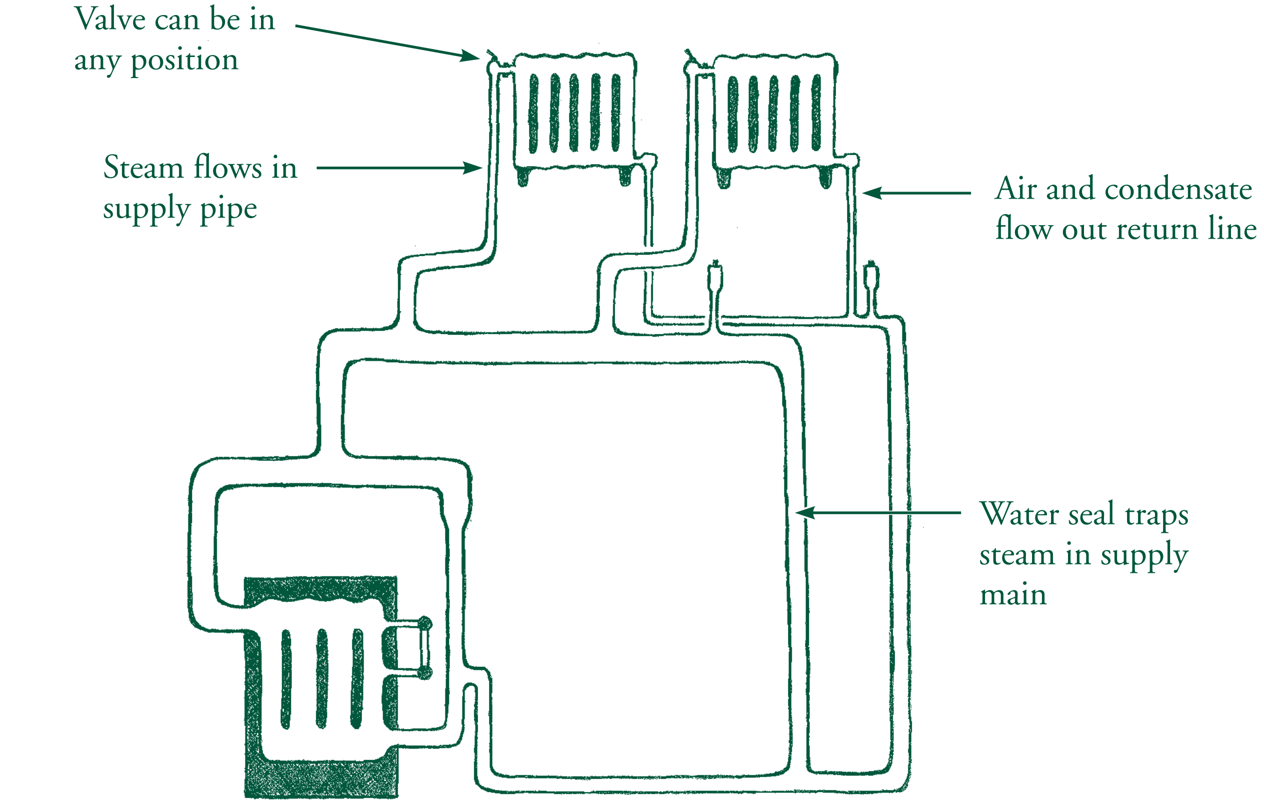
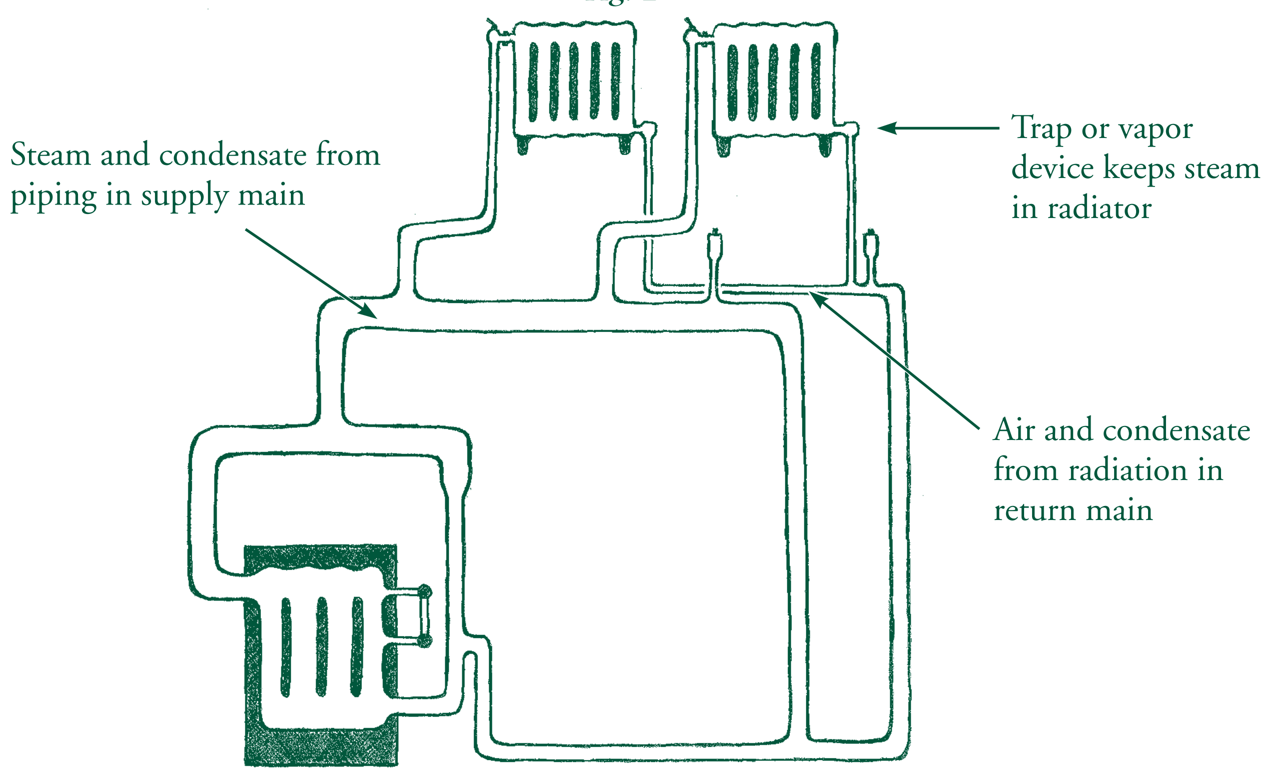

Valve can be in any position
Steam flows in supply pipe
Air and condensate flow out return line
Water seal traps steam in supply main

Fig. 2


Steam and condensate from piping in supply main
Trap or vapor device keeps steam in radiator
Air and condensate from radiation in return main

Two Pipe Metering Systems

Fig. 1 The practice of metering the flow of steam in a two pipe system at each radiator, with an orifice or an adjustable valve, is designed to provide even distribution of steam throughout the heating system and greater economy of operation.

- Fig. 2 Orifices and adjustable valves have three functions.
  - Establish a steam condition (pressure) in the system piping for even distribution.
  - Govern the flow of steam into each radiator in proportion to its output requirement.
  - Give controlled steam distribution under partial filling operation (mild weather)

Valve may have an internal feature built in or an orifice plate installed to balance the steam flow in the whole system.

- With valve wide open, only the required amount of steam will be admitted to the radiator, therefore all steam will be condensed before leaving radiator.

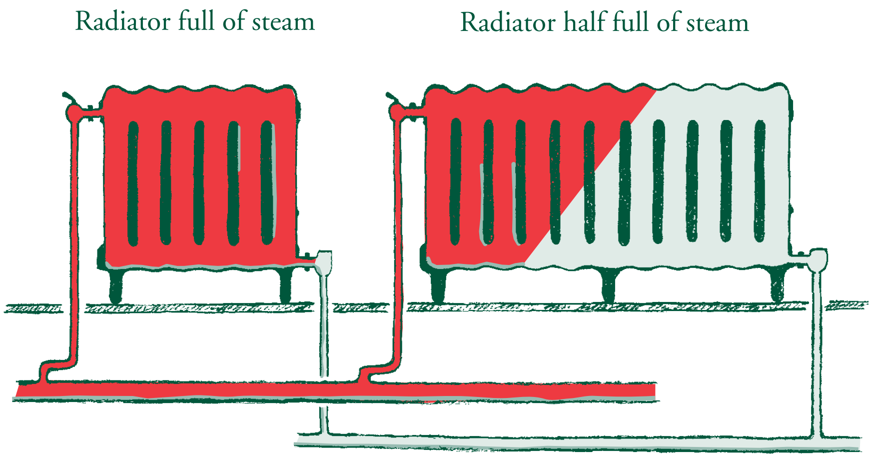
If you replace adjustable valve or remove orifice plate on vapor system, replace vapor device on return side of radiator with a thermostatic steam trap.

- Fig. 3 Removal of orifices or valves can allow steam to enter return lines, where it's not supposed to be, which causes uneven heating and water hammer.

Adjustable valves and orifices were designed to match the quantity of steam allowed into the radiator with the heat output of the radiator.

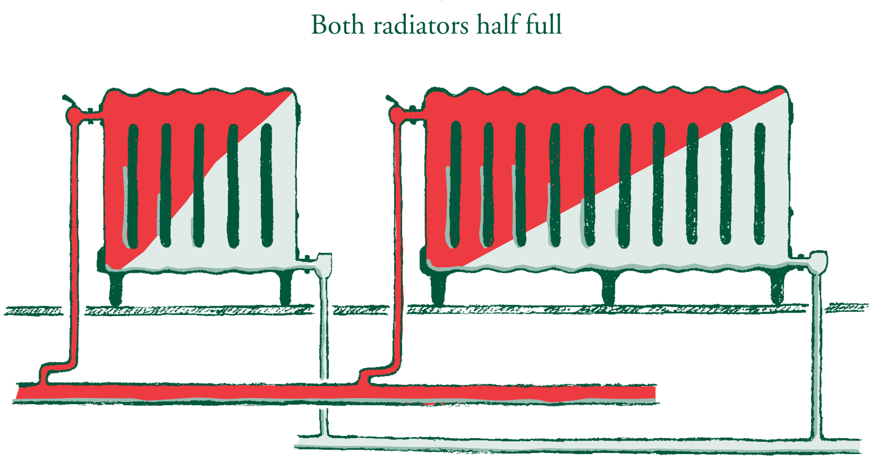
- In the past, valves could be accurately adjusted internally on the job to match actual conditions.
- Orifices were sized by engineers, generally not adjustable.
- Modern radiator valves do not have an internal adjustable feature.
- Thermostatic radiator valves are a good replacement for adjustable valves or orifices.

Fig. 1



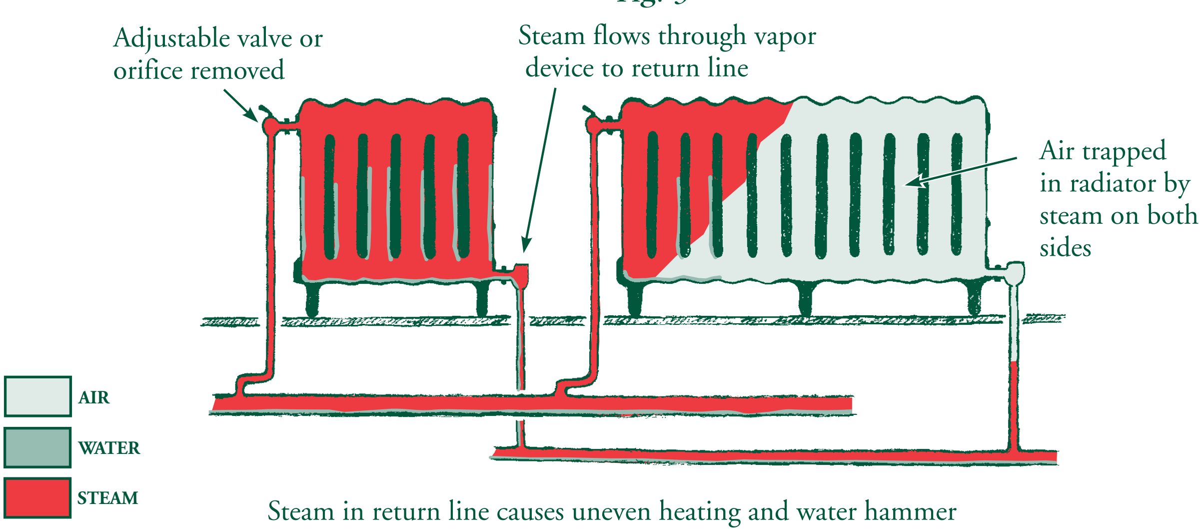
If the first radiator valve is wide open, steam flow will favor it to cause uneven heating

Fig. 2



When orifices or adjustable valves were installed to match the radiator output, a steam distribution balance can be achieved

Fig. 3



Steam in return line causes uneven heating and water hammer

Parallel/Counter Flow and Up Flow/Down Flow

The steam supply main and takeoffs for both one and two pipe systems can be parallel flow or counter flow.

- Fig. 1 Parallel flow means the pipe is pitched so that the steam and condensate in the pipe are flowing in the same direction.
- Fig. 2 Counter flow means the pipe is pitched so that the steam is flowing in one direction while the condensate is flowing in the opposite direction.
- In either system, steam flows along the top of the pipe while condensate flows at the bottom.

The pipe must be sized large enough to have room for both flows.

- Counter flow piping is always sized at least 1 pipe size larger than the parallel flow for the same volume of steam.
- The chart on page 160 and 161 can be used to check existing pipe size.

Steam mains can be located in the basement or in the attic.

- Steam systems with the mains at the bottom are called up-flow.
- Steam systems with the mains at the top are called down-flow.

Fig. 3 Down-flow systems with the boiler in the basement have a vertical supply riser from the boiler to the attic called the express main.

- The express main is a counter flow riser. Steam is traveling up while any condensate formed at start-up flows down, typically to a separate drip connection.
- The steam risers that distribute steam down the sides of the building to the radiation are parallel flow risers. Both the steam and the condensate are flowing down.

Fig. 4 Up-flow systems can have steam mains that are either parallel flow or counter flow.

- Some systems have both parallel flow or counter flow mains.
- Check the pitch of the pipe and the flow of the condensate and steam to determine parallel or counter flow.
- The steam risers that distribute steam up the sides of the building to the radiation are counter flow risers. Steam is flowing up, while condensate is flowing down.

Fig. 1

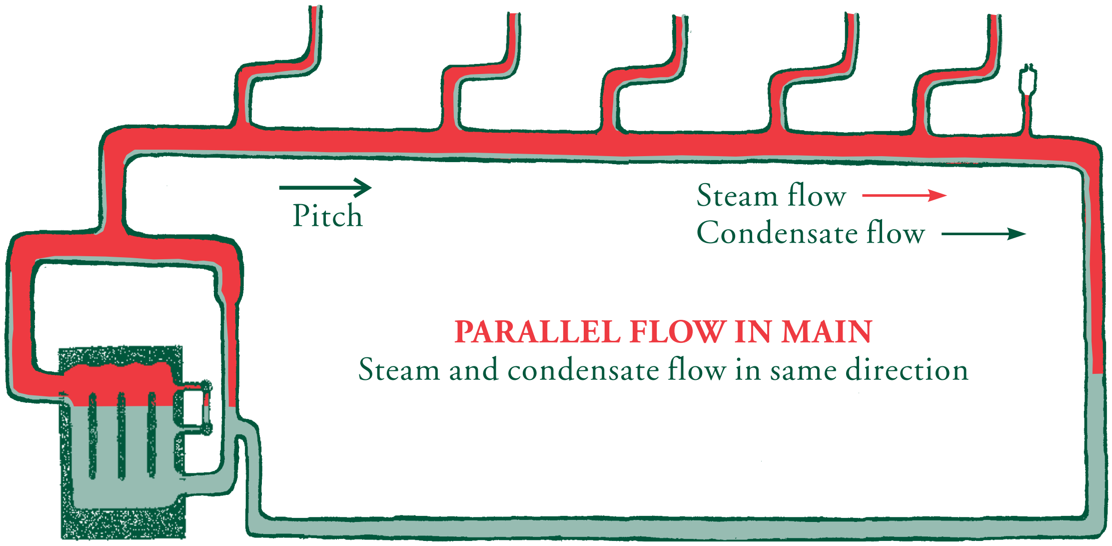


Fig. 2

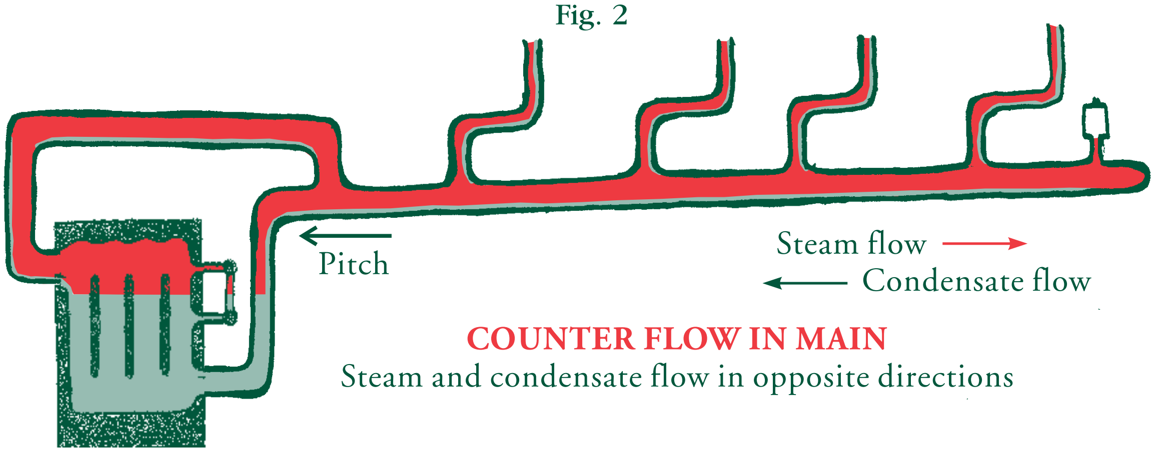


Fig. 3

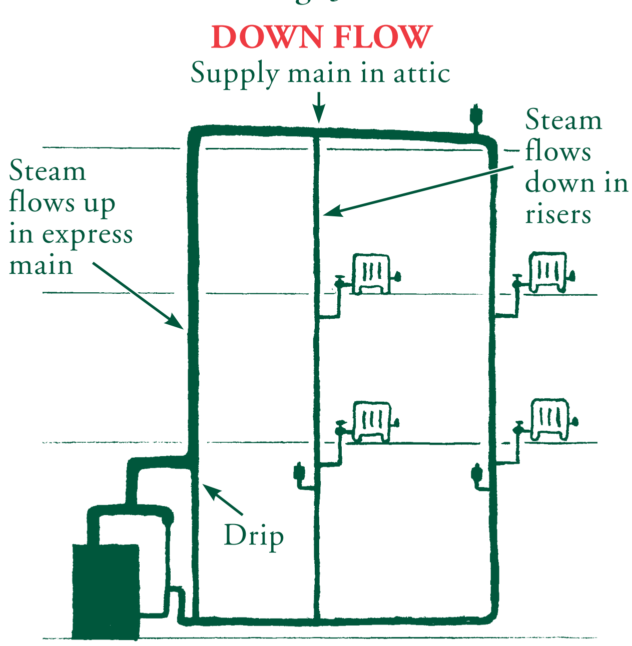
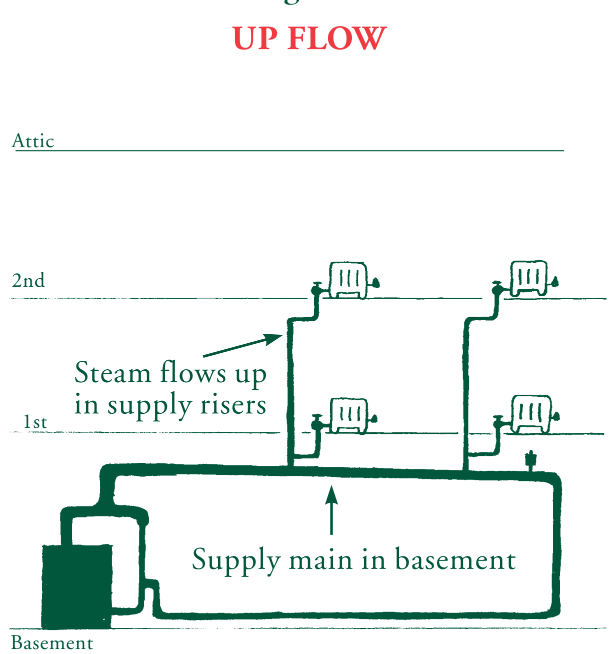


Fig. 4



Sizing Steam Supply Mains, Run Outs, and Risers

All pipe sizing starts with knowing how much radiation is connected to supply line.

- Refer to charts on page 162, 163, and 164 to calculate individual pieces of radiation.
- Add up individual pieces of radiation.
- The capacity of the pipe has to exceed the calculated load of the radiation.

Estimate loads if exact totals are not possible.

- Example: If boiler size is 1,000 sq. ft. and there are 2 supply mains (one for the front of the house and one for the back of the house), use 500 sq. ft. as estimate for each main.

Supply mains, run outs, and risers are sized differently for one pipe and two pipe systems.

- One pipe supply mains, run outs, and risers carry steam and the condensate from the radiation and the piping. They will be larger than for two pipe.
- Two pipe supply mains, run outs, and risers carry steam and the condensate from the piping only. They will be smaller than for one pipe.
- If mains are counter flow, use one pipe size larger than parallel flow.
- Refer to chart on opposite page for sizing info.

On one pipe, run outs and risers can drain condensate away from the main if they are pitched and piped to drip connections.

- The use of drips allows for smaller pipe sizes for run outs.

For parallel flow, the pitch of the supply main should be 1 inch in 20 feet away from the boiler to the end of the main.

For counter flow, the pitch of the supply main should be 1 inch in 10 feet away from the end of the main to the boiler.

- The pipe size of the run out should be one pipe size larger than the riser to slow the steam's velocity.

One Pipe Steam Supply Piping
Capacity in Sq. Ft.

Pipe Size	Mains			Horizontal Run Out		Vertical Riser	Radiator Valve
	100´	200´	400´	Not Dripped	Dripped		
1	—	—	—	26	65	42	26
1¼	—	—	—	62	140	78	62
1½	—	—	—	70	220	152	100
2	400	300	—	100	430	295	200
2½	600	500	300	160	675	475	—
3	1,000	800	500	250	—	850	—
4	2,400	2,000	1,500	—	—	—	—
5	4,500	3,500	3,000	—	—	—	—
6	7,500	6,000	5,000	—	—	—	—
8	12,000	8,000	7,000	—	—	—	—

Steam and water flowing in same direction in main.
Use next pipe size up when steam and water flow in opposite directions in main.

Two Pipe Steam Supply Piping
Capacity in Sq/ Ft.

Pipe Size	Mains			Horizontal Run Out	Vertical Riser	Radiator Valve
	100´	200´	400´			
½	—	—	—	—	24	24
¾	80	50	—	24	74	74
1	140	100	68	74	148	148
1¼	300	210	140	148	200	200
1½	450	320	220	200	380	380
2	900	640	430	390	—	—
2½	1,500	1,000	680	—	—	—
3	2,500	1,800	1,250	—	—	—
4	5,000	3,600	2,500	—	—	—
5	9,600	6,500	4,500	—	—	—
6	15,000	11,000	7,500	—	—	—
8	32,000	22,000	15,000	—	—	—

Steam and water flowing in same direction in main.
Use next pipe size up when steam and water flow in opposite directions in main.

Near Boiler Piping

Fig. 1 The near boiler piping consists of the boiler supply outlet, supply riser, header, equalizer, Hartford Loop, and return line.

- The most important of these for the purpose of steam flow are the boiler supply outlet, supply riser, and the header.
- Boilers may require a single supply outlet and riser or multiple supply outlets and risers depending on capacity and boiler design.

Changes in boiler design through the years have affected the near boiler supply piping.

- The steam chest has gotten smaller and the number and size of the supply outlets has been reduced.
- The piping is now used to help "dry out" the steam.

The header and supply riser are now used for separating any leftover water from the steam.

- The header should be at least 24˝ above the water line so water can separate in the supply riser.
- The header should be pitched toward the equalizer to drain the water.
- Water flows down equalizer while dry steam flows up supply riser.
- The header pipe size should never be reduced on the horizontal. Make the pipe size reduction from the header to the equalizer in the vertical position.

The steam flow in the header should always be in the same direction.

- **Fig. 2** Multiple supply risers should combine before supply main is taken off.
- ⃠ **Fig. 3** Don't crash steam flow from two risers into one supply outlet located between the risers. It can cause wet steam and water hammer.
- ⃠ **Fig. 4** Don't use a "Bullhead" tee, when flow is from branch of tee into run of tee.

Fig. 1

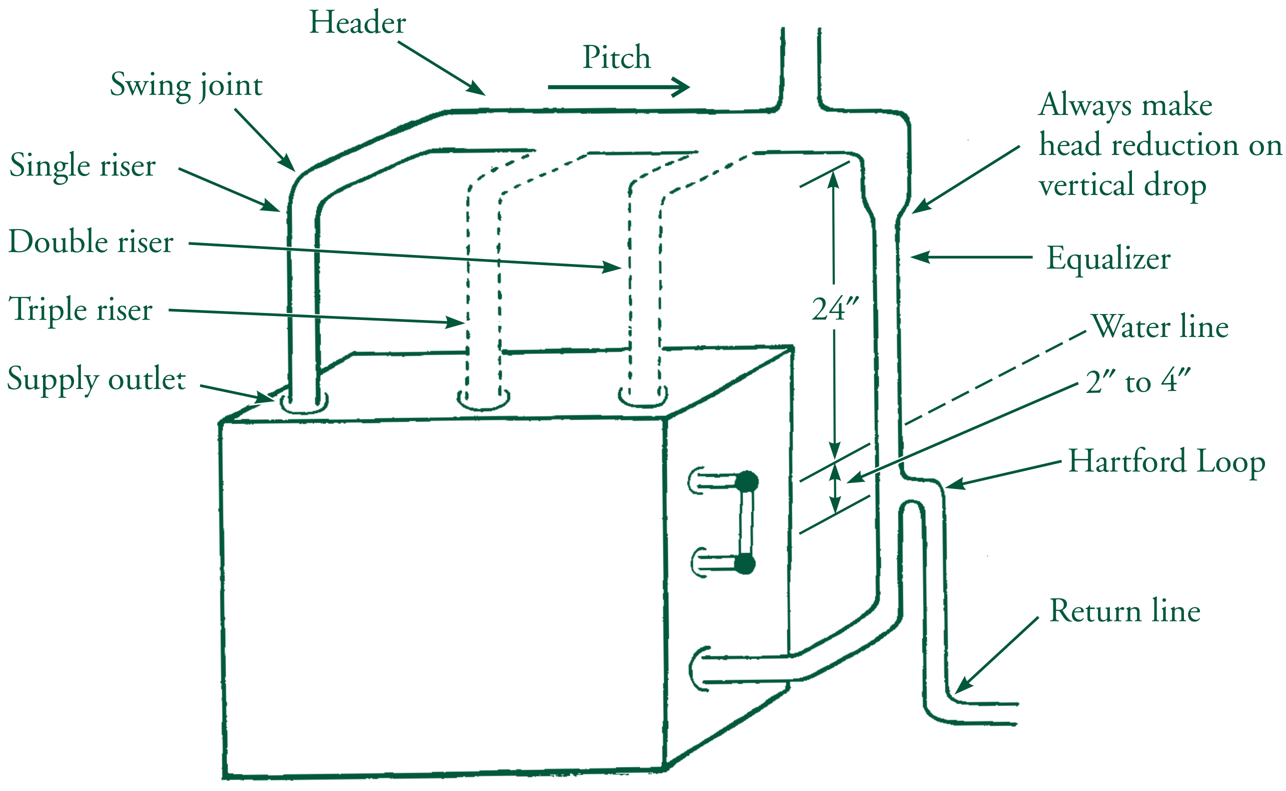


Fig. 2

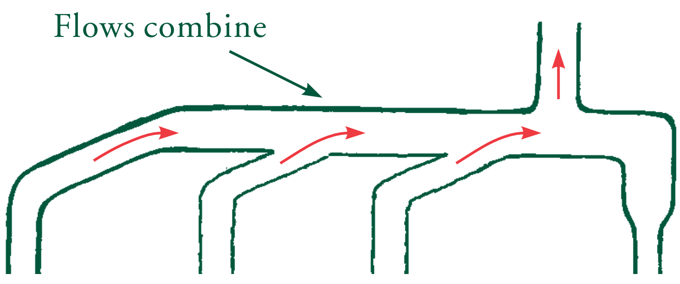


Fig. 3

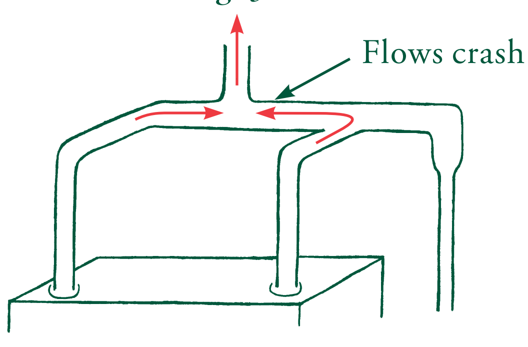
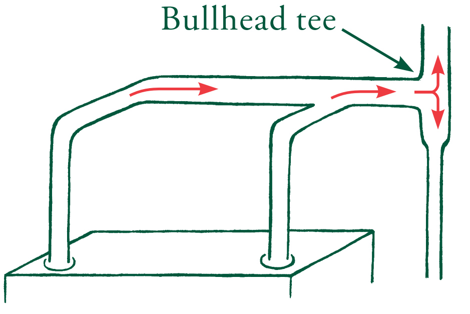


Fig. 4



Steam Velocity at Boiler

Boiler manufacturers will have a chart in their installation guide with suggested minimum pipe sizes.

- The outlet velocity of most modern boilers, if minimum pipe sizes are used, can be over 40 fps.
- The higher the velocity, the more water will be carried out and up.
- Larger than minimum pipe sizes give positive results.
- Using a 3″ supply riser instead of a suggested 2″ supply riser can cut the outlet velocity of the steam flow in half.

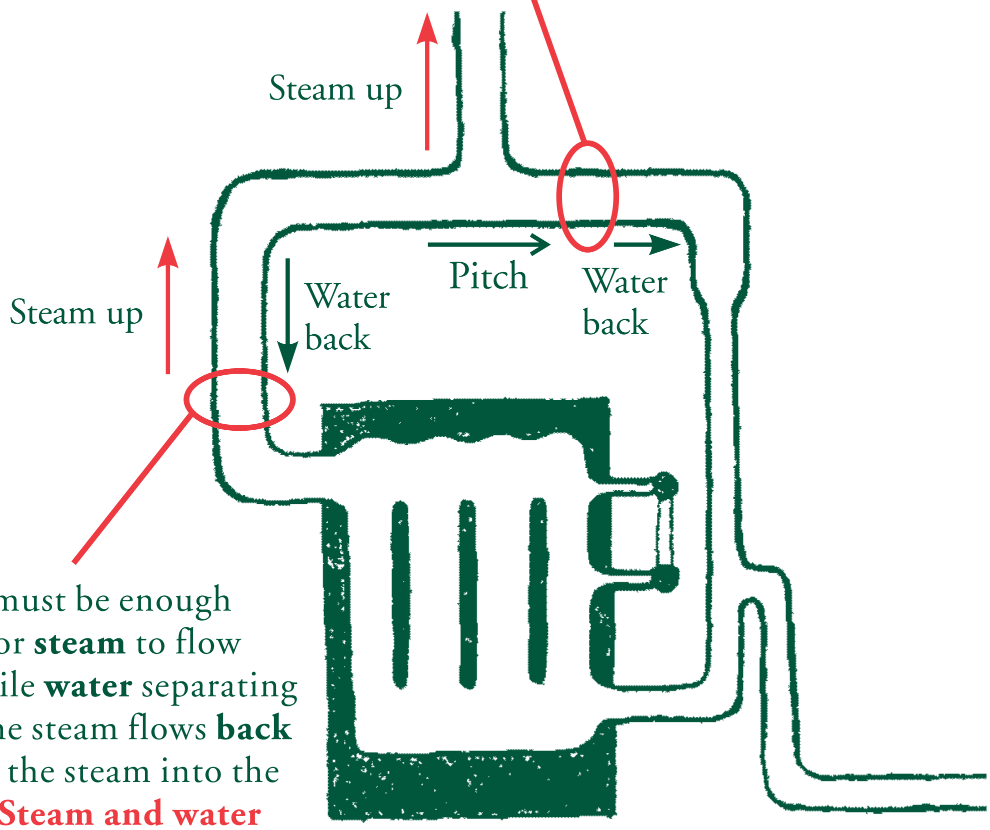
The velocity of steam flow out of the boiler is critical.

- The vertical portion of the supply riser has the flow of steam and the flow of condensate going in opposite directions.
- The slow velocity of the steam flow allows the condensate to flow back into boiler and not get picked up by the steam to create wet steam.
- Higher velocities are allowed in the horizontal supply mains when the steam and the condensate flow in the same direction.

Slowing the velocity of the steam flow out of the boiler has many advantages.

- Less water carried out of boiler results in a more stable water line and less short cycling.
- Slow velocity steam at the boiler creates the driest steam and best heat distribution.
- Slower velocity at the boiler lowers the fuel usage.

Header must be sized large enough to allow any water to separate from steam before flowing up supply main, assuring dry steam. **Steam and water flowing in same direction.**



There must be enough space for **steam** to flow **up**, while **water** separating from the steam flows **back** against the steam into the boiler. **Steam and water flowing in opposite direction.**

The more space, the slower the velocity, the drier the steam, the better it heats, **the lower the fuel bill.**

Calculating Velocity at Boiler

To calculate the steam velocity at start up use this simplified equation.

- Pounds per hour divided by the internal area of pipe in square inches equals velocity of steam at one pound of pressure.
- The chart on opposite page gives pounds per hour of common boiler sizes and internal area of common pipe sizes
- Example: Boiler size: 1,000,000 BTU's input with single riser.

  Pipe size: 6´´ area 28.89 sq. inches

$$\frac{834}{28.89} = 28.8 \text{ fps}$$

Changing to a 4´´ pipe = 12.73 sq. inches

$$\frac{834}{12.7} = 65.5\text{fps}$$

- The exit velocity of 28.8 fps with the 6´´ pipe would produce dry steam.
- The exit velocity of 65.5 fps with the 4´´ pipe would produce wet steam.
- Don't use smaller than recommended pipe sizes on outlet of boiler, even if it matches the existing supply main.
- Near boiler piping velocities over 60 fps can create wet steam.

Equation based on 1# steam.

- Velocity changes with steam pressure. Velocity slows as pressure rises.
- Use low pressure to calculate velocity for start-up of steam cycle.

Pounds per Hour	Gas Input	Oil Input	Gross Output	EDR	Horsepower
63	75,000	0.5	60,000	215	2
84	100,000	0.7	80,000	285	2.5
104	125,000	0.9	100,000	355	3
125	150,000	1.1	120,000	425	3.6
146	175,000	1.3	140,000	496	4.2
167	200,000	1.4	160,000	567	4.8
209	250,000	1.8	200,000	708	6.1
250	300,000	2.1	240,000	850	7.2
292	350,000	2.5	280,000	992	8.5
334	400,000	2.9	320,000	1,133	9.7
375	450,000	3.2	360,000	1,275	10.9
417	500,000	3.6	400,000	1,417	12.1
500	600,000	4.3	480,000	1,700	14.5
584	700,000	5	560,000	1,983	16.9
667	800,000	5.7	640,000	2,267	19.3
751	900,000	6.4	720,000	2,550	21.6
834	1,000,000	7	800,000	2,833	24.2
1251	1,500,000	10.7	1,200,000	4,250	36.3
1668	2,000,000	14.3	1.600.000	5,667	48.3
2085	2,500,000	17.9	2,000,000	7,083	60.4
2502	3,000,000	21.4	2,400,000	8,500	72.5

Example: 500,000 BTU Input with 4" Single Riser

$$\frac{\text{417 Pounds per Hour}}{\text{12.73 Square Inches}} = \text{32.76 Feet per Second}$$

Pipe Size in Inches	Internal Area in Square Inches		
	Single Riser	Double Riser	Triple Riser
1¼	1.5	3	4.5
1½	2.04	4.08	6.12
2	3.36	6.72	10.08
2½	4.78	9.56	14.34
3	7.39	14.78	22.17
3½	9.89	19.78	29.67
4	12.73	25.46	38.19
5	19.99	39.98	59.97
6	28.89	57.78	86.67
8	51.15	102.3	
10	81.55		
12	114.8		

Checking Velocity of Near Boiler Piping

The chart on the opposite page is designed to check existing near boiler piping for proper steam velocity.

- The oldtimers used boiler exit velocities as low as 10 fps to assure dry steam and a steady waterline.
- Modern boiler manufacturers use boiler exit velocities between 30-60 fps, requiring the near boiler piping to assure dry steam.

The chart is calculated for velocities of 25 fps or 50 fps.

- I recommend using the 25 fps column for driest steam and lowest fuel bills.
- Low steam velocity in the near boiler piping creates the best steam performance.
- Not exceeding the 50 fps by using the pipe size shown will keep you out of trouble.
- Piping that is one pipe size smaller than shown in the 50 fps column may require changing.

Example: Boiler size: 500,000 BTU's input. Using a single riser.

- At 25 fps, recommended pipe size is 5″.
- At 50 fps, acceptable pipe size is 4″.
- Using 3″ is not recommended because of the high velocity in the near boiler piping it would produce.

The water line setting (page 38) and the condition of the water (page 34) also affect velocity of the steam in the near boiler piping.

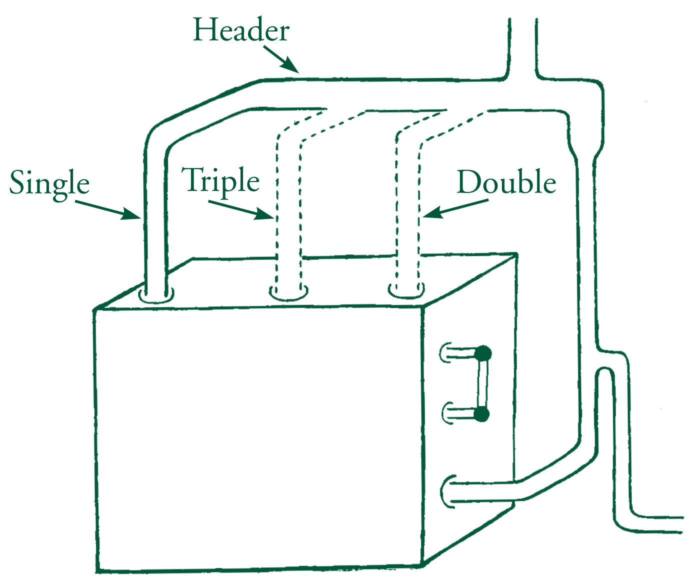
- Make sure the boiler water is clean and the water line is not set too high.

With high near-boiler piping steam velocities come problems such as water hammer, wet steam, poor steam distribution, and high fuel bills.

- Don't use smaller than recommended pipe around boiler to save yourself money; you'll give it back and more in call backs.

Near Boiler Piping/Velocity Relationships

Gas Input BTUs	Oil Input GPF	Pounds per Hour	Pipe Sizes: Single Risers 25 FPS	Single Risers 50 FPS	Double Risers 25 FPS	Double Risers 50 FPS	Triple Risers 25 FPS	Triple Risers 50 FPS	Header 25 FPS	Header 50 FPS
75,000	0.5	63	2	1¼					2	1¼
100,000	0.7	84	2½	1½	1½	1¼			2½	1½
125,000	0.9	104	2½	1½	2	1¼			2½	1½
150,000	1.1	125	3	2	2	1¼			3	2
175,000	1.3	146	3	2	2	1¼			3	2
200,000	1.4	167	3	2	2	1½			3	2
250,000	1.8	209	4	2½	2½	2			4	2½
300,000	2.1	250	4	3	3	2			4	3
350,000	2.5	292	4	3	3	2			4	3
400,000	2.9	334	5	3	3	2			5	3
450,000	3.2	375	5	3	3	2½			5	3
500,000	3.6	417	5	4	4	2½			5	4
600,000	4.3	500	5	4	4	3			5	4
700,000	5.0	584	6	4	4	3			6	4
800,000	5.7	667	6	5	5	3			6	5
900,000	6.4	751	6	5	5	3			6	5
1,000,000	7.0	834		5	5	4	4	3	8	5
1,500,000	10.7	1,251		6	6	4	5	4	10	6
2,000,000	14.3	1,668				5	5	4	10	8
2,500,000	17.9	2,085				6	6	5	12	8
3,000,000	21.4	2,502				6		5	12	8



Boiler Sizing—Why Size Matters

Boiler sizing has an effect on the steam system.

- **Fig. 1** If the boiler is too small, the system will not fully heat and will cause high fuel bills.
- If the boiler is too large, the boiler will short cycle and cause high fuel bills.

The boiler size should be matched to the installed radiation.

- The heat loss of the building should not be used.
- **Fig. 2** The steam output of the boiler has to be able to fill the existing pipe and the installed radiation.
- Measure all the radiation in the building. See pages 162, 163, and 164 for calculating the radiation.
- Piping that does not have any insulation is radiation. See page 164 for chart to size. The extra load has to be added to the building load.
- Unusual piping arrangements, longer than normal supply mains, or piping that runs through un-conditioned space, can increase radiation load and boiler size.
- The boiler's net rating must exceed the total calculated load for the radiation and piping.
- An undersized boiler cannot produce enough steam volume to fill the system.

Burner firing rate should also match the radiation load.

- An underfired burner cannot fully and evenly heat the building.
- An overfired burner can cause an unsteady water line, excess steam velocities, wet steam, and high fuel bills.

Always make sure that there is enough combustion air available for the boiler/burner firing rate.

- Not enough combustion air can cause poor firing, short cycling, high fuel bills.
- Check local code or boiler manufacturer's instructions for combustion air requirements.

Fig. 1

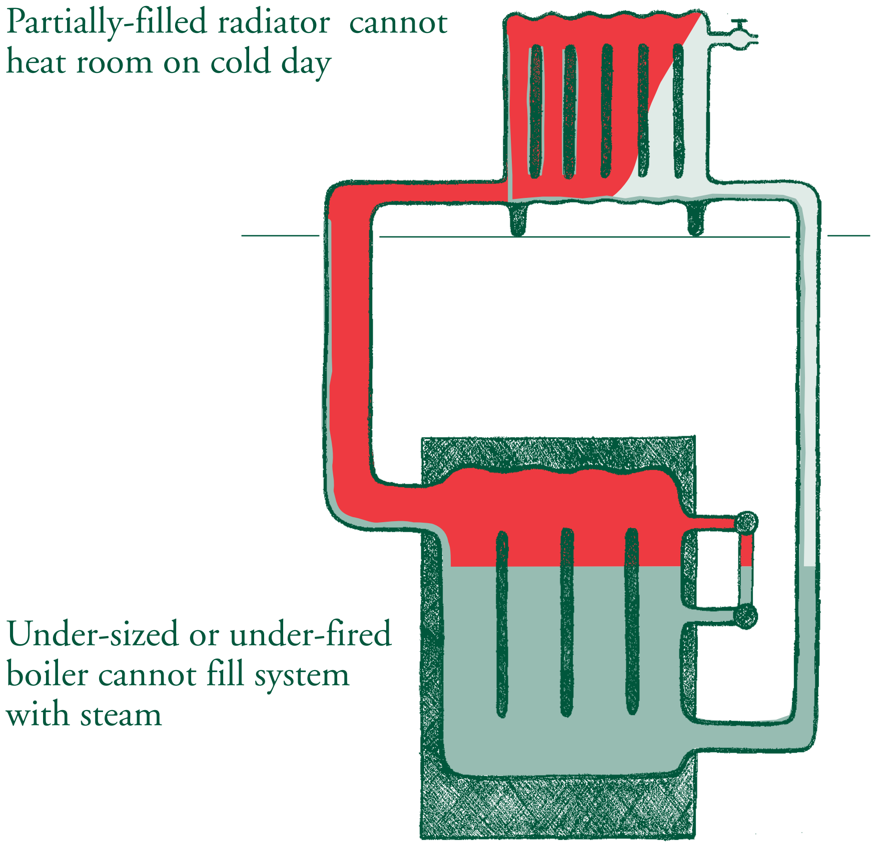
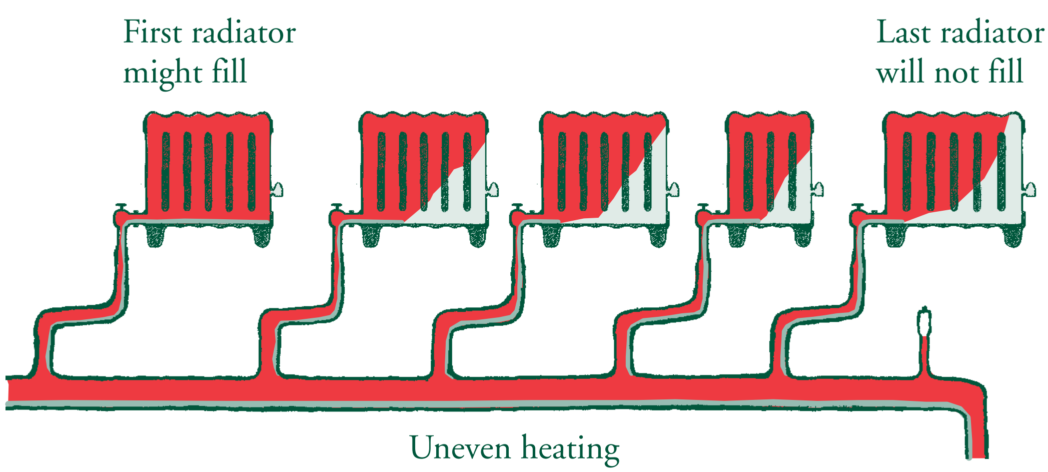


Fig. 2



AIR WATER STEAM