CHAPTER TWO

Steam Basics

Basic Theory of the Steam Cycle Simplified to Three Steps

The Path of Steam Up

- Steam is generated in the boiler.
- Steam rises up supply pipe to radiation.

The Path of Air Out

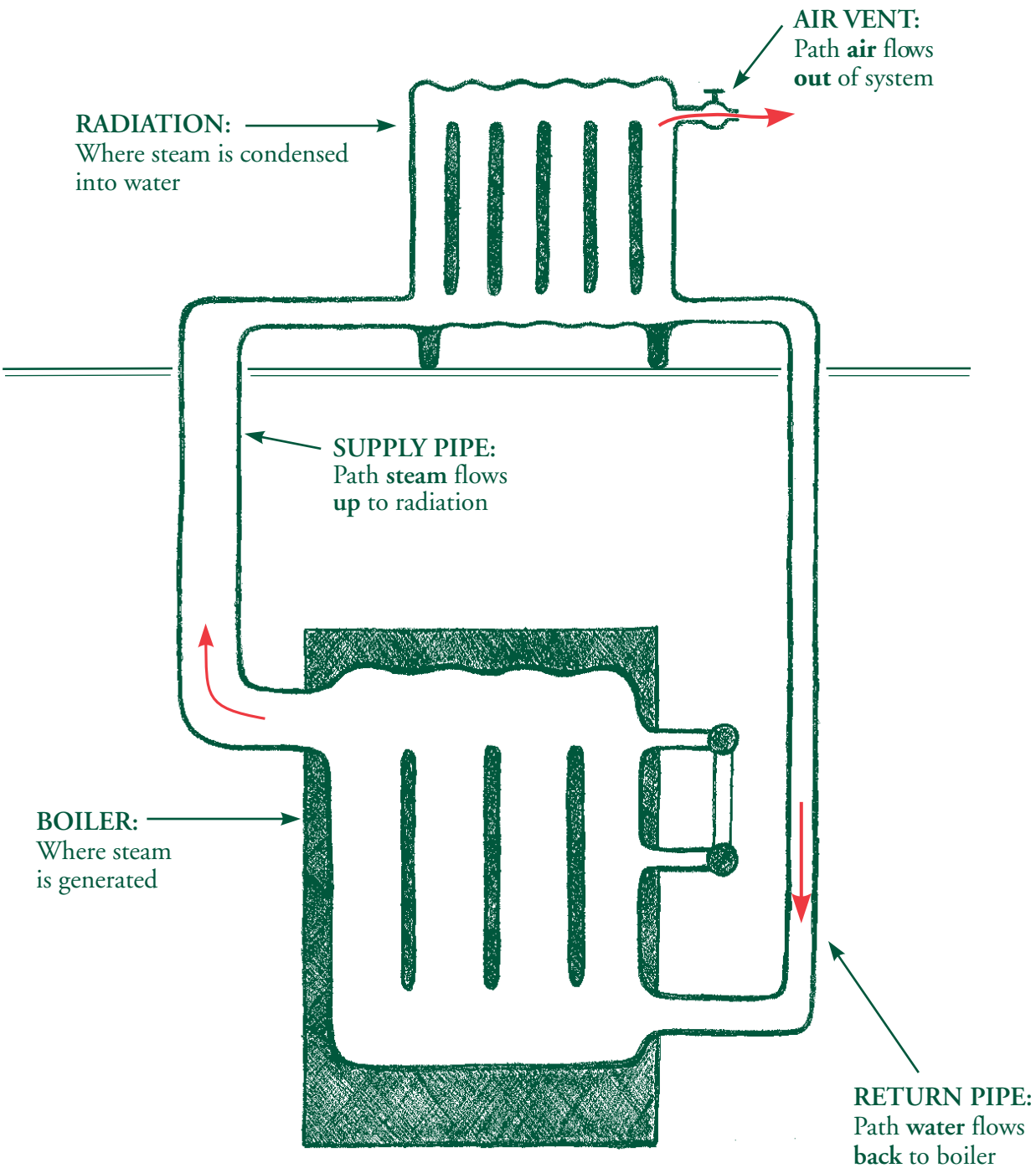
- Air is pushed out of the piping and radiation.
- Steam replaces the air in the piping and radiation.

The Path of Water Back

- Steam condenses to water in piping and radiation.
- Water flows back to the boiler through return line.

To troubleshoot, think of the paths that each step of the cycle must follow.

- Steam must rise up through the boiler, travel along the supply pipe, and enter the radiation to heat the room.
- Poor steam generation from a "dirty" boiler is the most common problem with ***steam up***.
- Air must pass through the piping and radiation to vent out of the system before steam can enter the radiation.
- Faulty, undersized, or missing air vents are the most common problems with ***air out***.
- Water must travel back to the boiler through the return line to continue the generation of steam.
- Improperly pitched supply mains, high steam pressures, or clogged wet returns are the most common problems with ***water back***.


AIR VENT:
Path **air** flows
out of system
RADIATION:
Where steam is condensed
into water
SUPPLY PIPE:
Path **steam** flows
up to radiation
BOILER:
Where steam
is generated
RETURN PIPE:
Path **water** flows
back to boiler

Basic Sequences of Operation

The diagrams on the opposite page are extremely simplified to easily show the flows of steam, air, and water.

- A manual air cock represents the radiator vent(s) in the system.
- One radiator represents all the radiators in the system.
- The supply piping is directly connected to the radiation without a header.
- The return line is directly connected to the boiler without a Hartford Loop.
- They do not represent how a steam system should be piped.

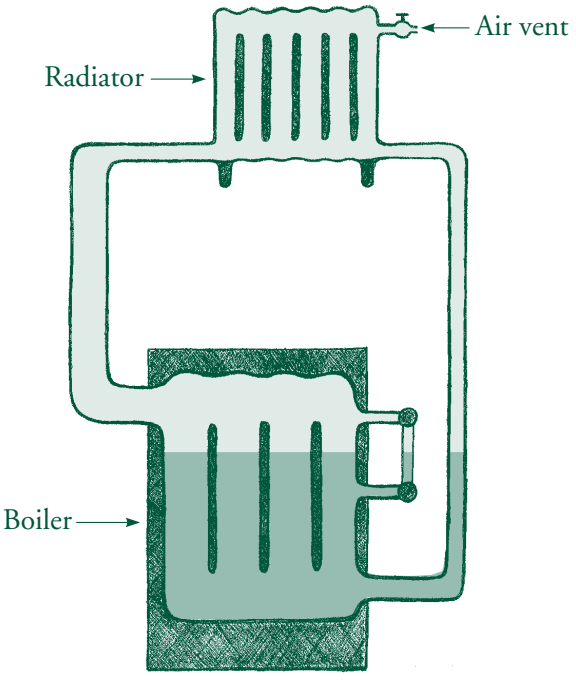
Fig. 1 System starts at rest with all water having returned to the boiler by gravity and the proper pitch of the pipes. Air fills the piping and radiation.

Fig. 2 Burner will fire to heat water to boiling point causing steam to release from water line.

Fig. 3 Steam builds up pressure inside boiler. Steam pressure will cause flow through piping to radiation with valve open. Higher steam pressure always moves to lower pressure outside piping/radiation. The steam pushes air through piping toward vent. Steam condenses on sides of supply pipes and flows back to boiler.

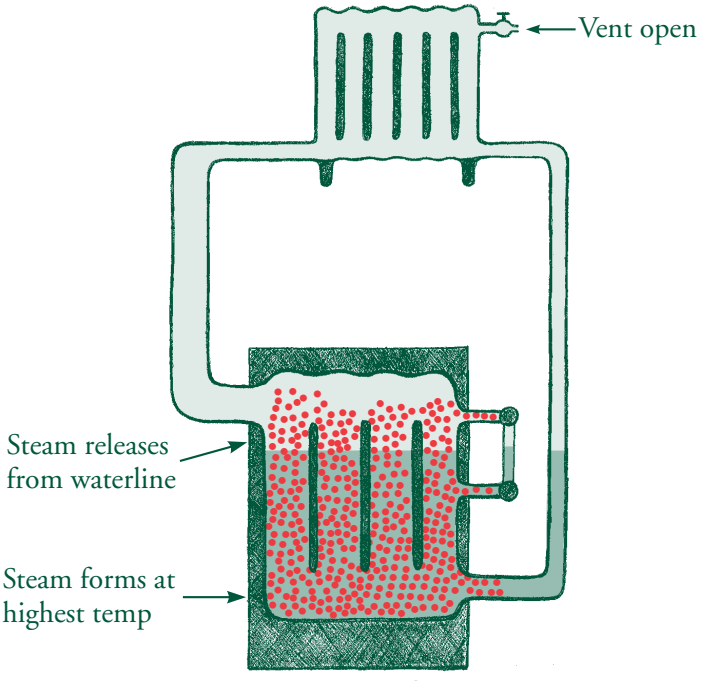
Fig. 4 Closed radiator vent valve causes steam to condense on cooler surfaces of radiation, turning back into water. Water flows back to the boiler through return line to be heated by burner to become steam again.

Fig. 1



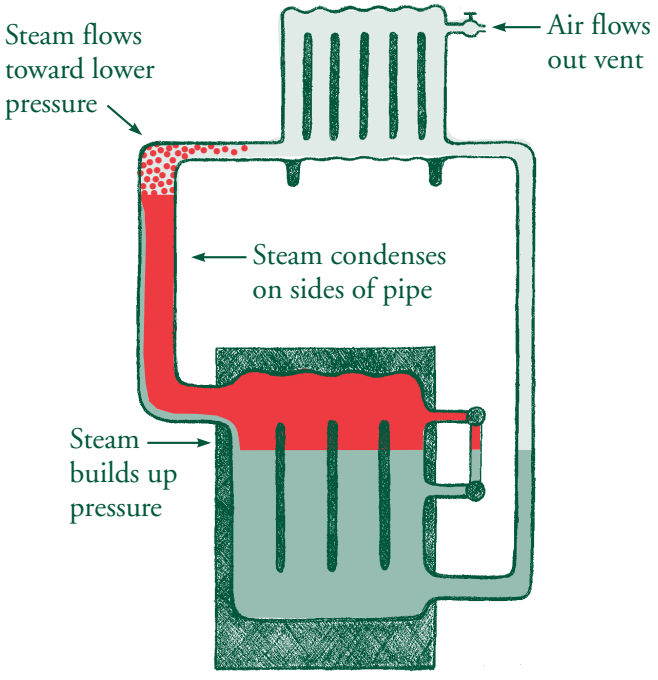
BURNER OFF

Fig. 2



BURNER ON

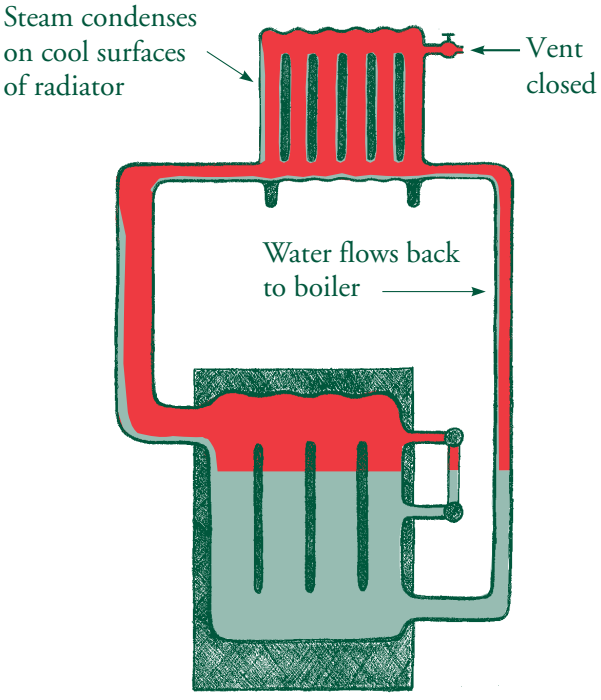
Fig. 3



BURNER ON

AIR WATER STEAM

Fig. 4



BURNER ON

Glossary of Common Terms

Boiler—generates steam by heating water to boiling point.

Boiler Riser(s)—supply piping directly off boiler carrying steam to header. There can be one or more risers depending on size and manufacturer of boiler. They can be taken from the side or the top of steam chest.

Condensate—water formed as steam gives up its heat.

Drip—piping connection to carry condensate to a return main.

Dry Return—return line on the two pipe system carrying air and water. Located above boiler water line.

End of Steam Main—portion of supply main piping after the last radiation takeoff where air is vented and condensate flows down to wet return.

Equalizer Line—connects header to return line to equalize pressure and drip condensate.

Gauge Glass—gives visual indication of boiler water line.

Gravity Return—water flows back into the boiler without a pump.

Hartford Loop—prevents boiler dry fires caused by leak in return line.

Header—accumulates steam for distribution; separates as much water as possible to assure dry steam.

Horizontal Run Out—distributes steam from takeoff to vertical riser.

Low Water Cut Off (LWCO)—safety device to shut off burner when boiler water line gets too low.

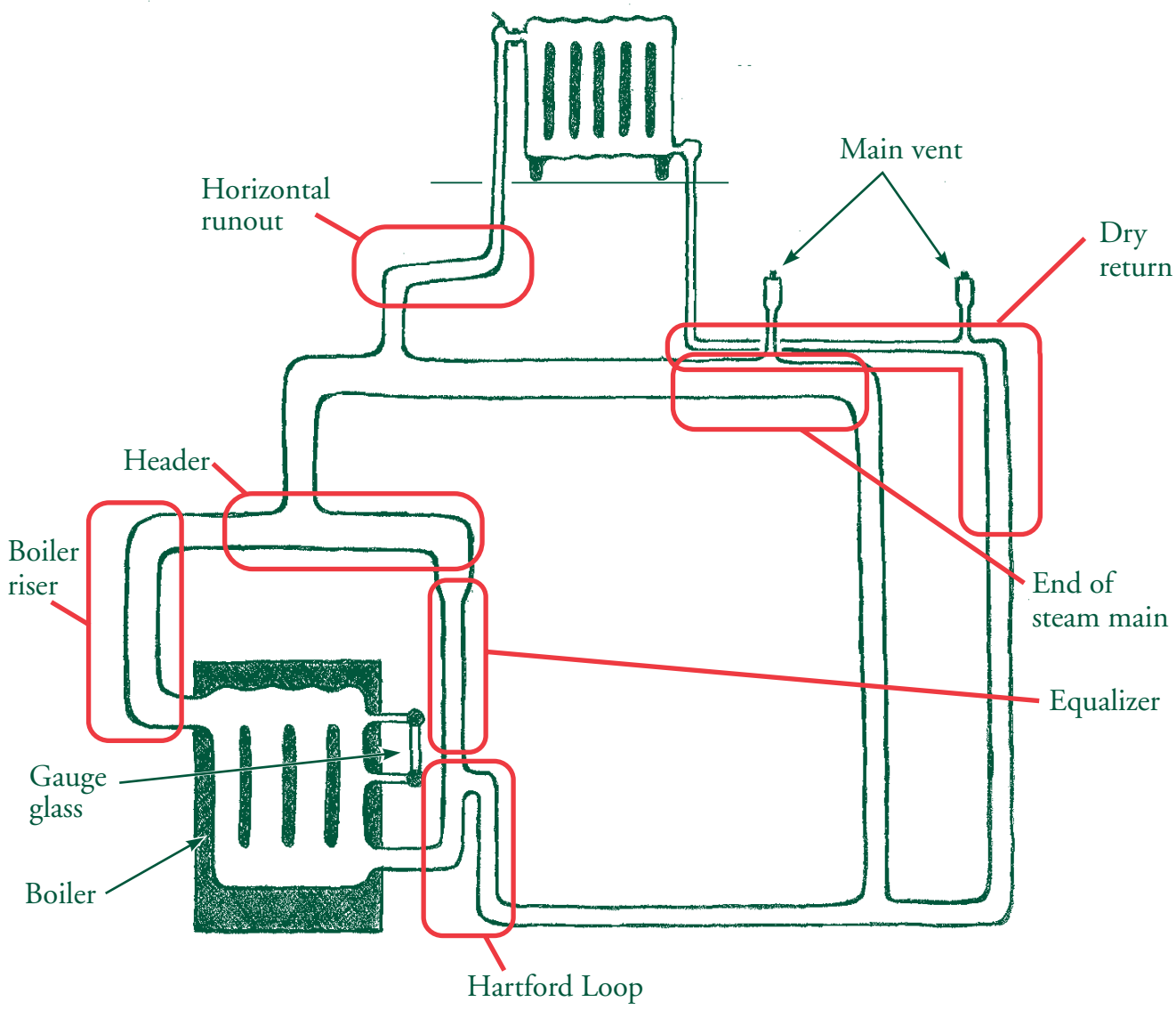
Main Vent—designed to be open at the presence of air, to close at the presence of steam and water. Vents air from supply or return main.

One Pipe Steam—steam system with steam flowing into the radiation and condensate flowing out of the radiation through the same pipe.

Pitch—tilt of pipe in one direction to direct flow of condensate.

Pressure Control—pressure sensing safety device to shut off burner when steam pressure gets too high.

Simplified Two Pipe System



Glossary of Common Terms, continued

Pumped Return—water is pumped back into the boiler by a pump on a boiler feed, condensate, or vacuum unit.

Radiation—any kind of device to allow steam to give up its heat. Examples: cast iron radiator, unit heater, convector, baseboard, bare piping, pipe coils, etc.

Radiator Valve—located at inlet of cast iron radiator. Must be completely open or closed on one pipe steam. Can be any position for two pipe steam.

Radiator Vent—designed to be open at the presence of air, to close at the presence of steam or water.

Return Line—the pipe that condensate flows through to boiler, by gravity or pump.

Return Riser—on two pipe steam, carries water and air to dry return.

Steam—the gas created by heating water to its boiling point.

Steam Chest—portion of boiler above the water line where steam separates from boiler water.

Steam Pressure—operating pressure for steam system, typically 2 pounds or less.

Supply Main—carries the steam away from the header to the takeoffs to radiation.

Takeoff—connects main to horizontal runout.

Trap—device to stop the flow of steam and pass condensate and air.

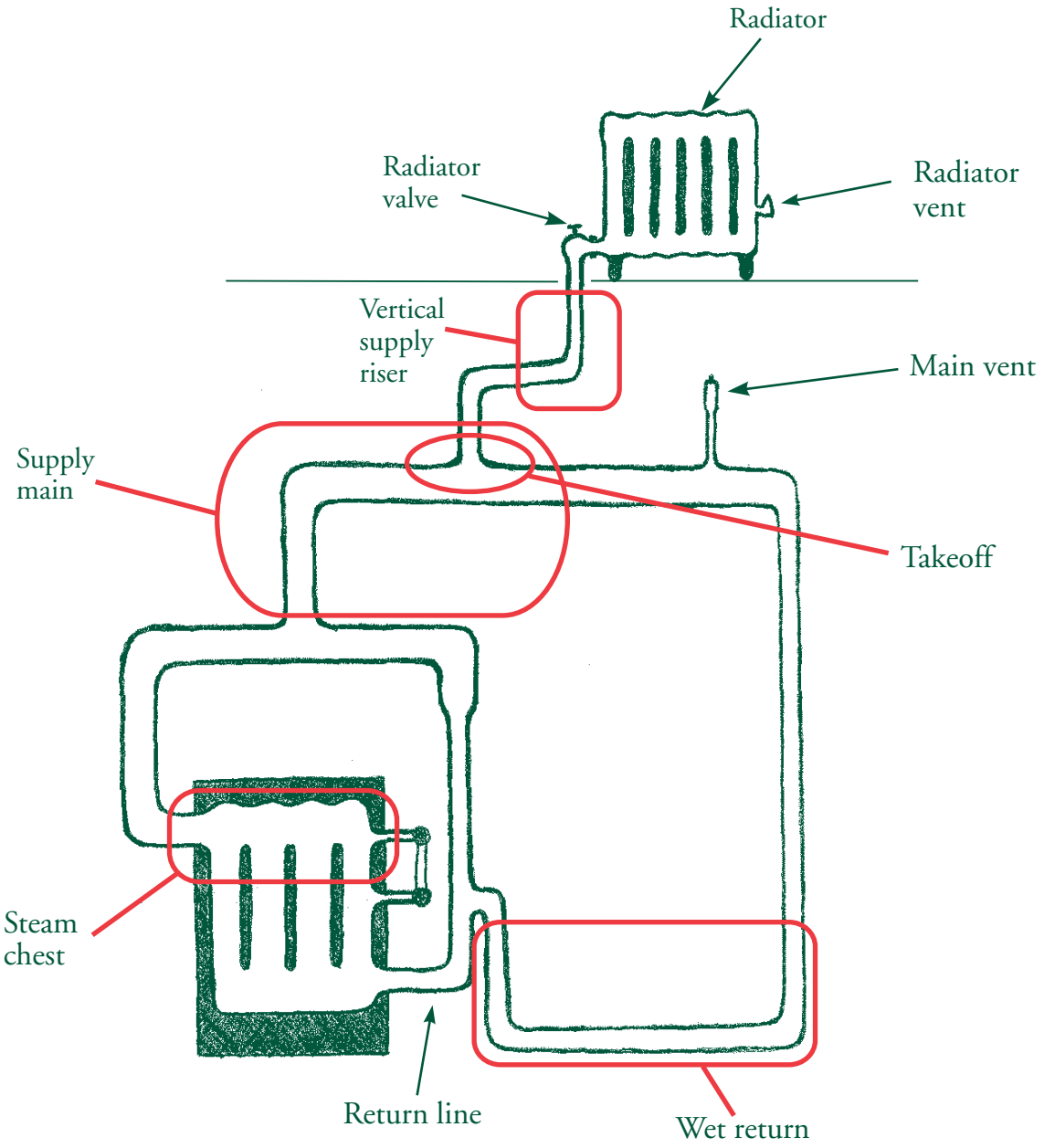
Two Pipe Steam—steam system where steam flows into radiation while condensate and air flows out of radiation through two separate pipes.

Vertical Supply Riser—distributes steam from horizontal run-out to radiation.

Water Line—water level in boiler. Under steaming conditions, it should be steady.

Wet Return—return line on one or two pipe system carrying water located below boiler water line.

Simplified One Pipe System



Simplified One Pipe Steam

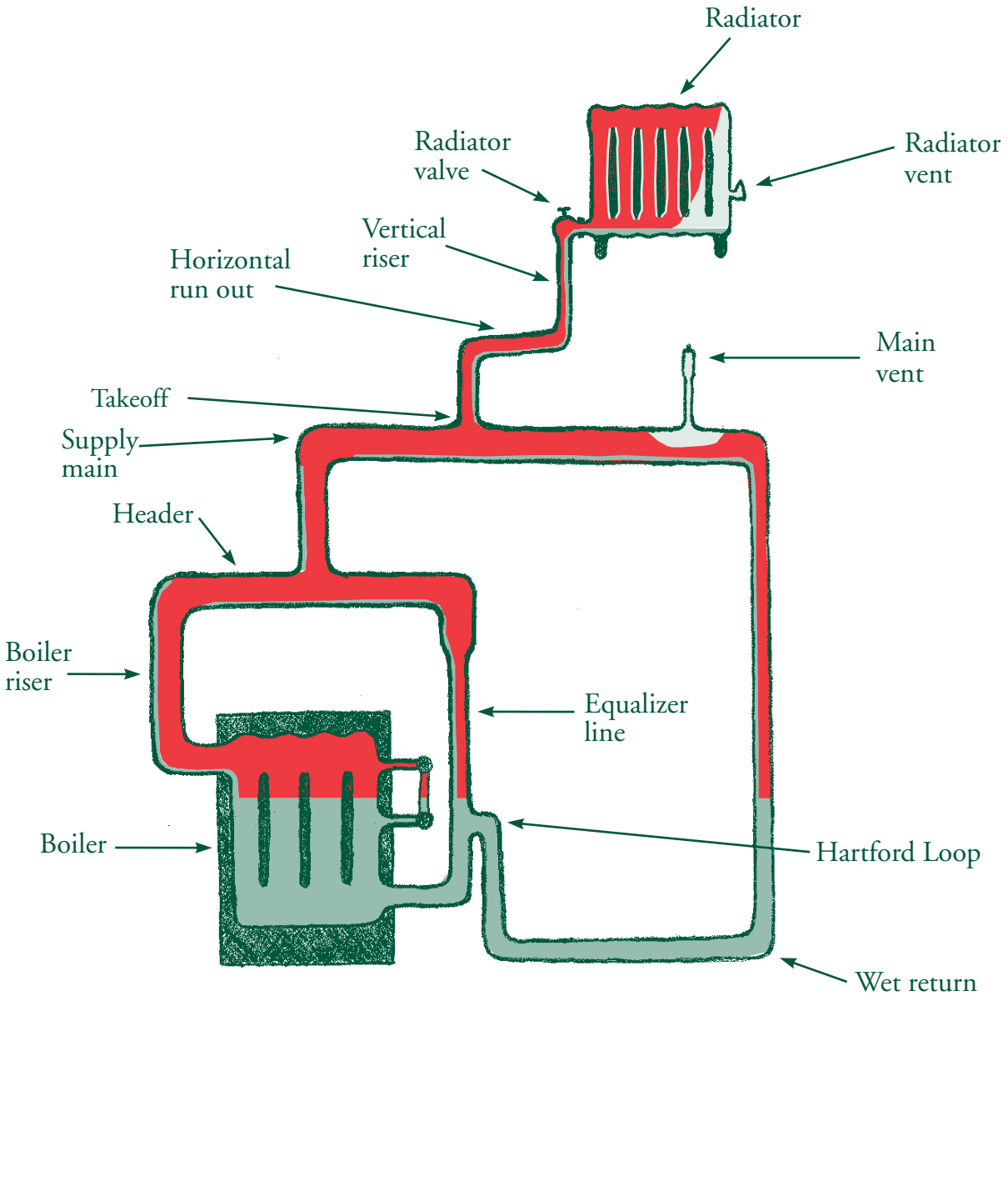
Sequence of the flows through the system.

1. Steam pressure generated in boiler, moves through boiler riser, header, supply main, takeoff, horizontal run out, vertical riser, and radiator valve, to lower pressure in radiator with vent open.
2. Condensate from boiler riser flows back to boiler against steam flowing out of boiler.
3. Condensate from header returns to the boiler through the equalizer line.
4. Air in supply main is vented to basement through main vent.
5. Steam turns to condensate as it gives up its heat to the cooler surfaces of the radiator.
6. Air in radiator is vented to room through radiator vent.
7. Condensate slides down the sides of the radiator and leaves the radiator through the radiator valve.
8. Condensate from radiator returns to the boiler through the vertical riser, horizontal run out, takeoff, supply main, wet return, and Hartford Loop.

All the paths must be properly sized and pitched for proper operation.

- Refer to pages 56 and 57 for the details of the near boiler piping.
- Refer to pages 62 and 63 for checking the size of the existing near boiler piping.
- Refer to page 54 and 55 for information on supply mains, run outs and risers.

Simplified One Pipe System at Mid-Cycle



One Pipe Radiator—A Look Inside

Fig. 1 With the system off, radiator is full of air.

- Air must be removed from radiator before steam can flow into radiator.

Fig. 2 Steam rises up through vertical riser and through radiator valve.

- Radiator valve must be properly sized and wide open to allow steam to flow up while water flows back down. See page 55 for sizing chart.
- Radiator vent should be located on opposite end of radiator valve.

Fig. 3 Steam is lighter than air, so it will go to the top of the radiator first.

- Air is being pushed toward the end and the vent.
- Vent tapping is located one third up from bottom of radiator to decrease chance of spitting water from vent.

Fig. 4 Steam condenses on cooler surfaces of radiator, forming water that slides down inner surface of radiator to bottom of radiator.

- Radiator must be pitched toward radiator valve to prevent water from pooling in bottom of radiator.
- Radiator vent is open at presence of air to allow air to flow out of radiator.

Fig. 5 Radiator vent closes at presence of steam to prevent steam from flowing out of radiator vent.

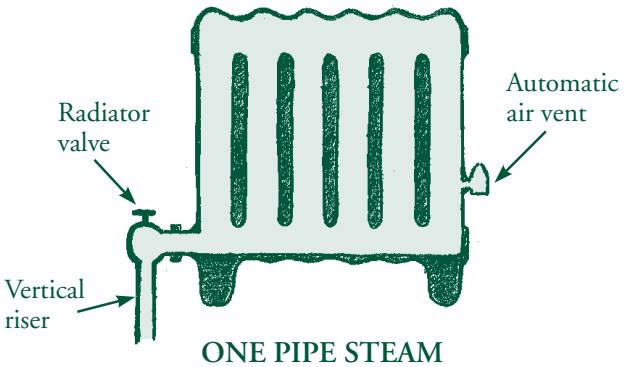
- Radiator vent also closes at presence of water to prevent water from flowing out of radiator vent.
- Radiator fills completely with steam only on long boiler run cycles, like the coldest days of the year, or coming out of a night set-back period.

Fig. 6 Radiator vent cycles open and closed to remove the air in radiator at start of cycle and the air released by the steam as it condenses in the radiator.

- As steam condenses, it gives up a small quantity of air.

One Pipe Radiator—A Look Inside

Fig. 1



ONE PIPE STEAM FULL OF AIR

Fig. 2

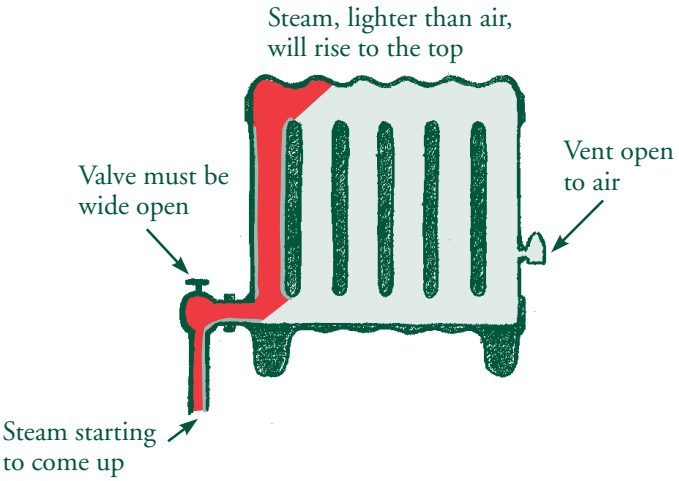


Fig. 3

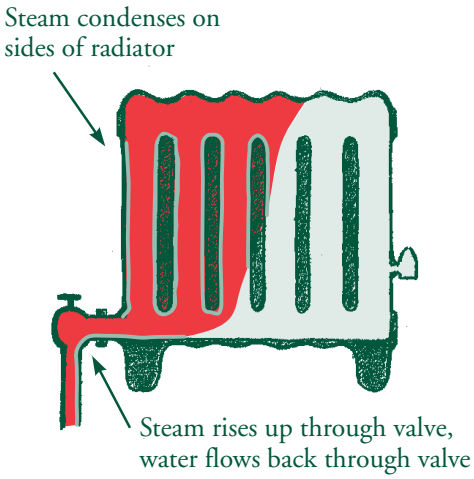


Fig. 4

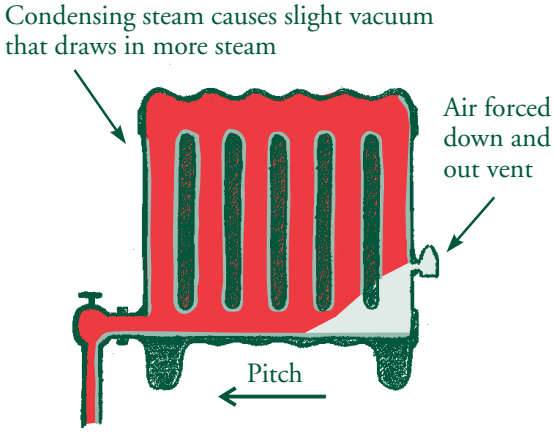
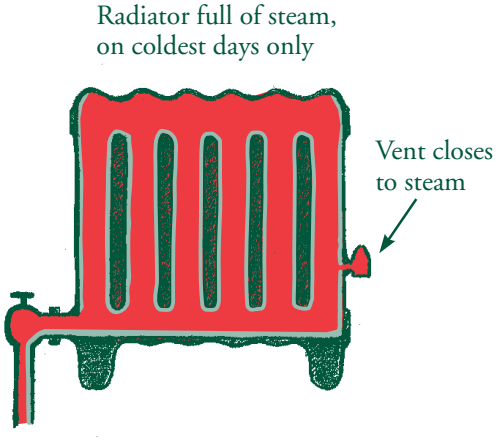
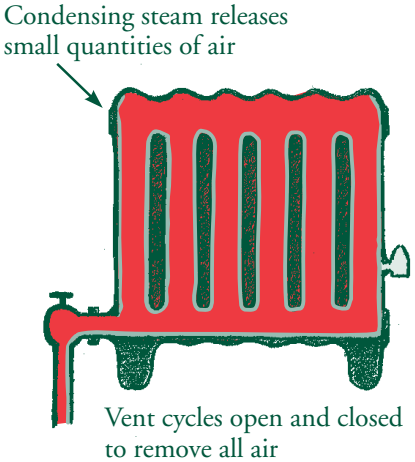


Fig. 5



AIR WATER STEAM

Fig. 6



Simplified Two Pipe Steam

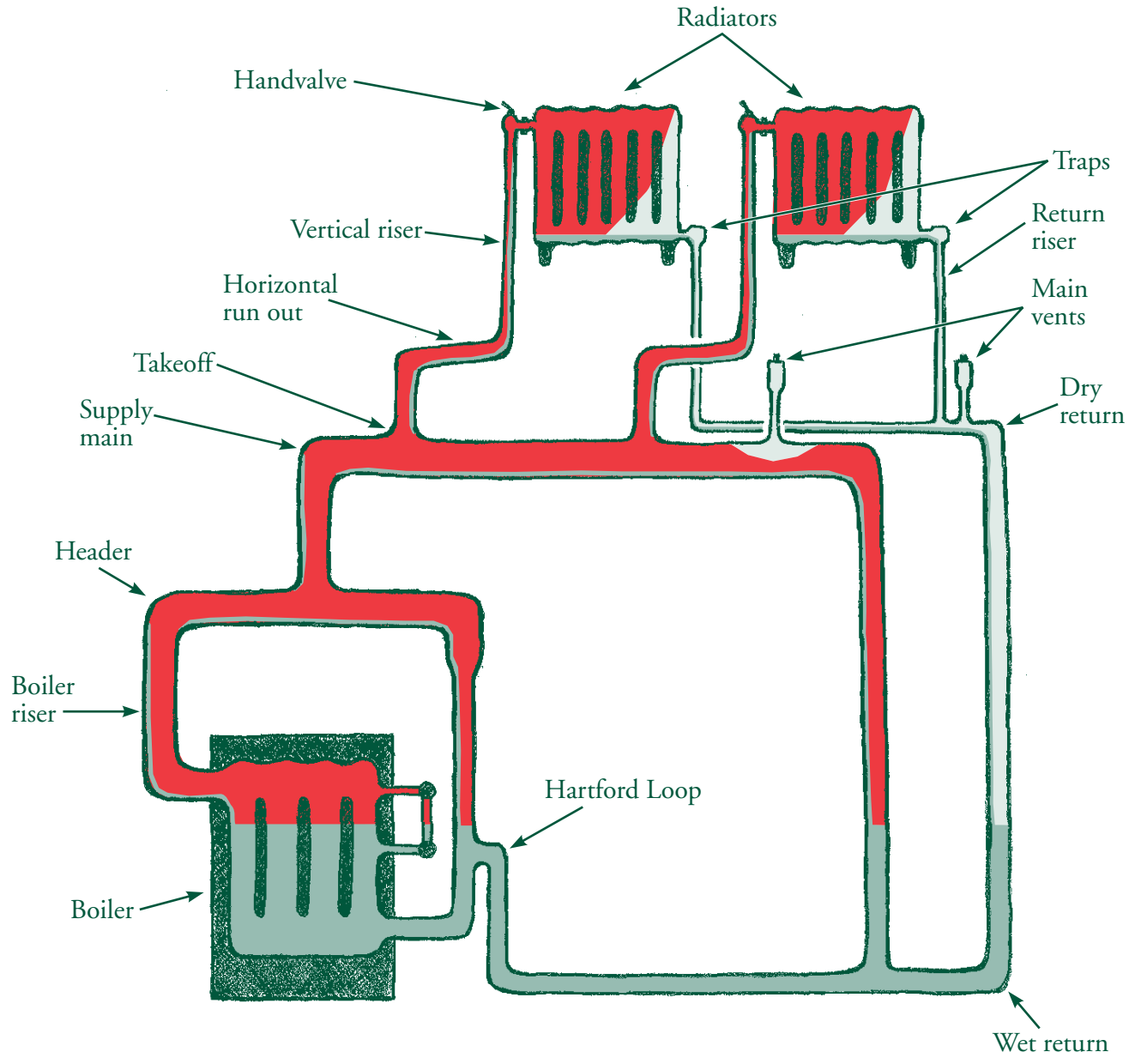
Sequence of the flows through the system.

1. Steam pressure generated in boiler moves through boiler riser, header, supply main, takeoff, horizontal run out, vertical riser, and radiator valve, to lower pressure in radiator with trap and main vent on dry return open.
2. Condensate from boiler riser flows back to boiler against steam flowing out of boiler.
3. Condensate from header returns to the boiler through the equalizer line.
4. Air in supply main is vented to basement through main vent at end of supply main.
5. Steam turns to condensate as it gives up its heat to the cooler surfaces of the radiator.
6. Air in radiator passes through open trap to vent through main vent on dry return.
7. Condensate slides down the sides of the radiator and leaves the radiator through the trap.
8. Condensate flows from radiator to the boiler through the return riser, dry return, wet return, and Hartford Loop.

All the paths must be properly sized and pitched for proper operation.

- Refer to pages 56 and 57 for the details of the near boiler piping.
- Refer to pages 62 and 63 for checking the size of existing near boiler piping.
- Refer to pages 54 and 55 for information on supply mains, horizontal runouts, and vertical risers.

Simplified Two Pipe System at Mid-Cycle



AIR WATER STEAM

Two Pipe Radiator—A Look Inside

Fig. 1 With the system off, radiator is full of air.

- Air must be removed from radiator before steam can flow into radiator.

Fig. 2 Steam rises up through vertical riser and through radiator valve.

- Radiator valve can be open to any position to proportion the flow of steam entering the radiator.
- Since steam is lighter than air, radiator valve is usually located at the top, to allow steam entering the radiator to force air down and towards trap.

Fig. 3 Steam condenses on cooler surfaces of radiator, forming water (called condensate) that slides down inner surface of radiator to bottom of radiator.

- Radiator must be pitched toward trap to prevent condensate from pooling in bottom of radiator.
- Trap is connected to bottom of radiator with an eccentric bushing turned down to prevent any pooling of water in bottom of radiator.

Fig. 4 Trap is open at presence of air or water to allow them to flow out of radiator, allowing steam to flow in.

- Condensing steam causes a slight vacuum to increase steam flow into radiator.

Fig. 5 Trap closes at presence of steam to prevent steam from entering return lines.

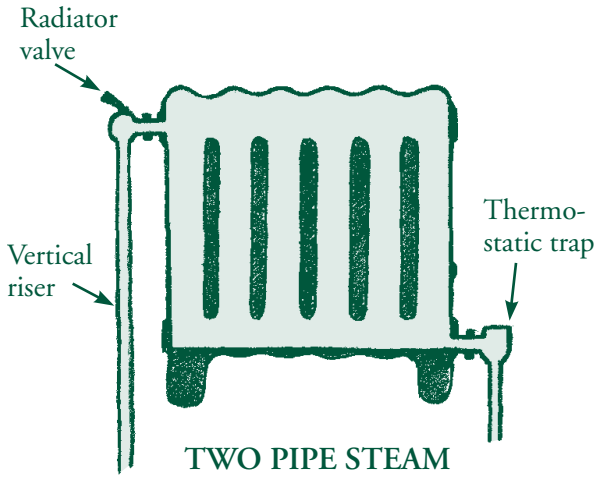
- Steam in return lines can cause water hammer and uneven heating.
- Radiator fills completely with steam only on long boiler run cycles, like the coldest days of the year or coming out of a night set-back period.

Fig. 6 Trap cycles open and closed to remove air in radiator at start of cycle and air released by the steam as it condenses in the radiator.

- Trap also cycles open and closed to remove water in radiator formed as the steam condenses in the radiator.

Two Pipe Radiator—A Look Inside

Fig. 1



TWO PIPE STEAM FULL OF AIR

Fig. 2

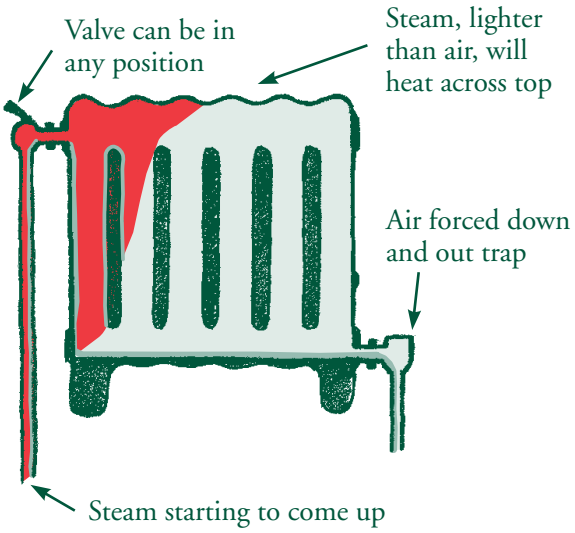


Fig. 3

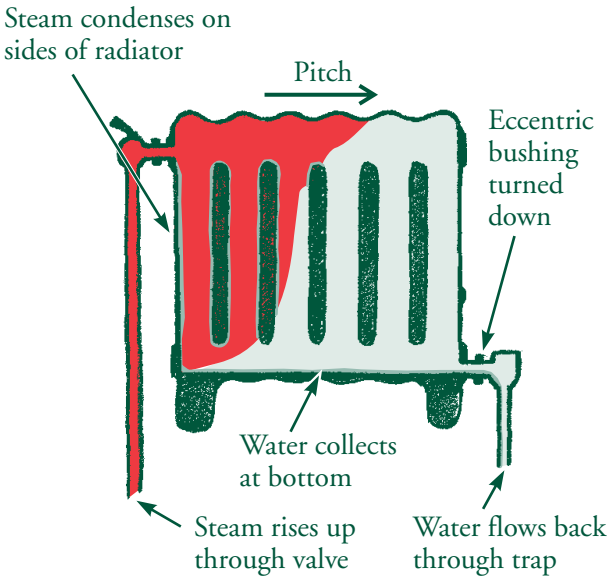


Fig. 4

Condensing steam causes slight vacuum that draws in more steam

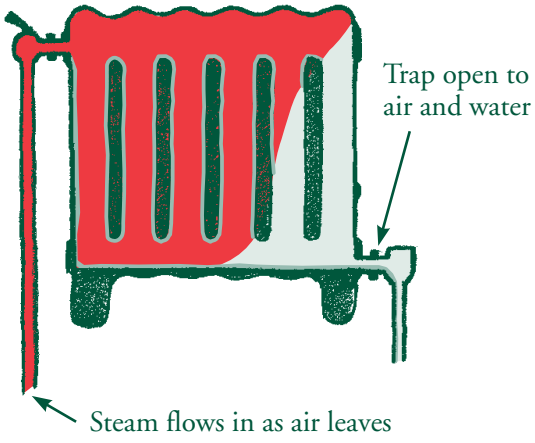


Fig. 5

Radiator full of steam, on coldest days only

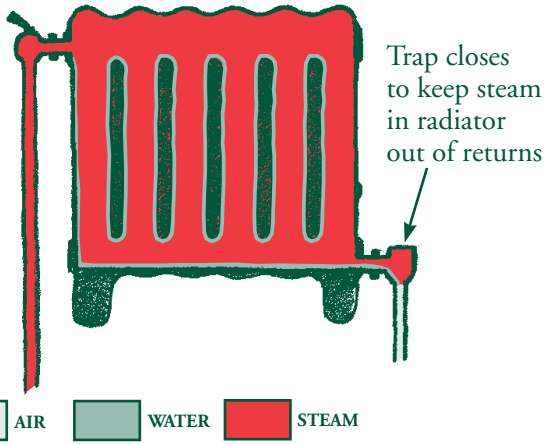
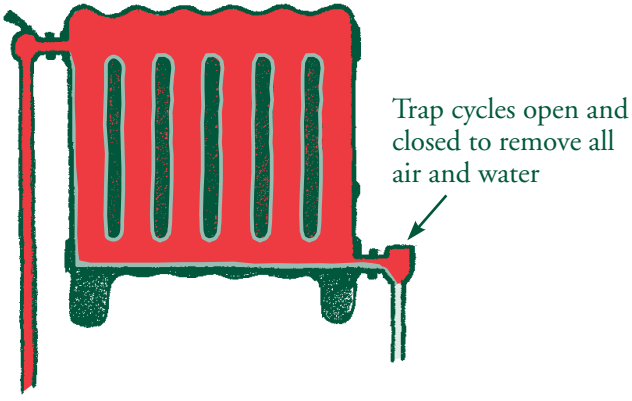


Fig. 6

Condensing steam releases small quantities of air



Simplified Air Vent Theory

One pipe steam radiator vent

Fig. 1 With no steam at vent, port is open for air to pass out of radiator.

Float rests on the base.

Fig. 2 With steam at vent, port is closed to keep steam in radiator.

- Float bottom expands out to drive pin up into port.
- Float is filled with volatile mix that expands at steam temperature, contracts when it cools.

Fig. 3 With water at vent, port is closed to keep water from leaking on the floor.

- Float rises up with the water to drive pin up into port.

Main vent

Fig. 4 With no steam at vent, port is open for air to pass out of piping.

- Float rests on the base.

Fig. 5 With steam at vent, port is closed to keep steam in piping.

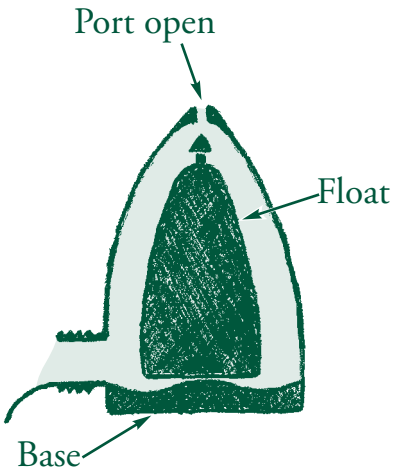
- Float bottom expands out to drive pin up into port.
- Float is filled with volatile mix that expands at steam temperature, contracts when it cools.

Fig. 6 With water at vent, port is closed to keep water from leaving piping.

- Float rises up with the water to drive pin up into port.

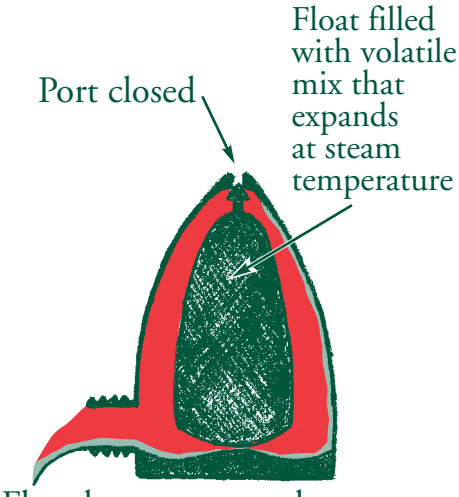
Simplified Air Vent Theory

Fig. 1



AIR

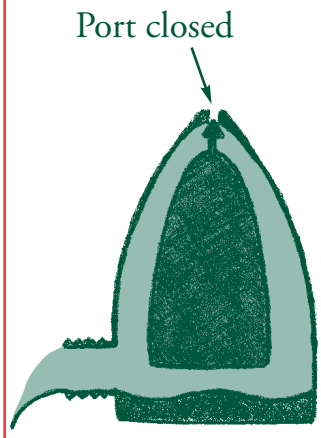
Fig. 2



Float bottom expands out

STEAM

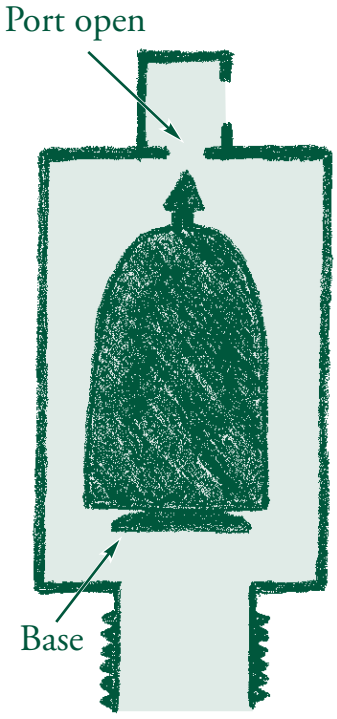
Fig. 3



Float rises with water

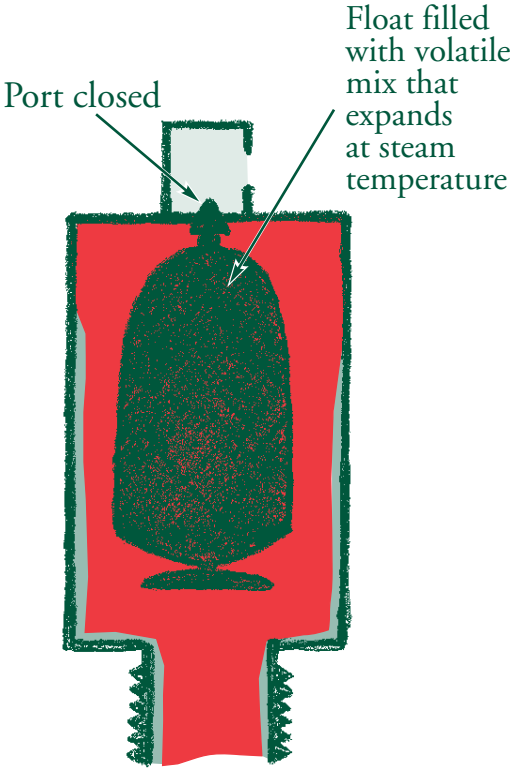
WATER

Fig. 4



AIR

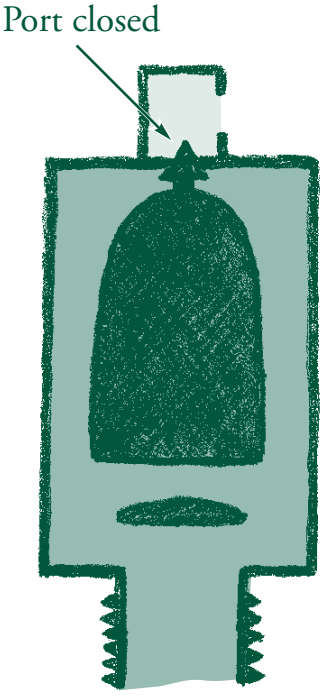
Fig. 5



Float bottom expands out

STEAM

Fig. 6



Float rises with water

WATER

AIR WATER STEAM

Simplified Steam Trap Theory

All types of traps have in common the purpose of stopping the flow of steam at some point in the steam system.

- A water trap at the end of the supply main will keep steam in the distribution piping and out of the wet return.
- A thermostatic trap at a radiator will keep steam in the radiator, to condense to water while giving up its heat to the room.
- A float + thermostatic trap (F+T) at the end of a supply main will keep the steam in the distribution piping and out of a return line that is connected to a boiler feed unit, condensate unit or vacuum unit.

Water traps pass only condensate; air cannot pass through the water.

- **Fig. 1** Air is normally vented above the water trap with a main vent.
- **Fig. 2** Water seals the steam in the supply main at the balance point of the vertical pipe. See pages 90 and 96.
- Condensate from system flows back through wet return.

Thermostatic traps pass both air and condensate; normally used at end of radiator or above end of steam main on some two pipe systems.

- **Fig. 3** Thermostatic traps are open when air is at the trap during start up.
- **Fig. 4** The thermostatic element in the trap is filled with a volatile mix that expands at steam pressure to drive pin into seat to close.
- **Fig. 5** Condensate collects in trap to cool volatile mix causing the element to contract the pin and open trap.

Float and thermostatic (F+T) traps pass both air and condensate; normally used on large radiation and at the end of the supply main.

- **Fig. 6** F+T trap are open to vent air at system start up.
- **Fig. 7** The thermostatic element in the F+T trap is filled with a volatile mix that expands at steam temperature to drive pin into seat to close.
- **Fig. 8** As the water level in the float chamber rises with the returning condensate, the float rises to lift the pin from the seat to allow water to pass through trap.

Simplified Steam Trap Theory

Fig. 1

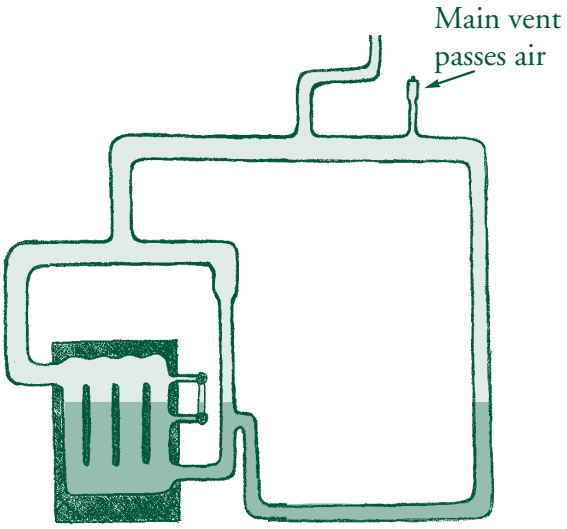


Fig. 2

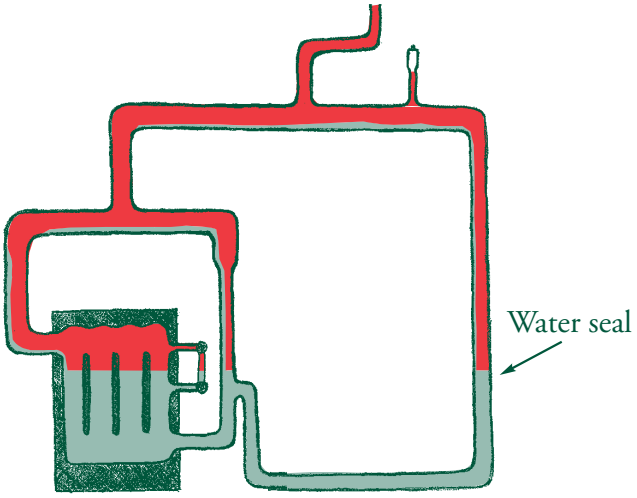


Fig. 3

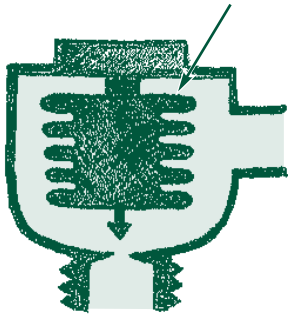


Fig. 4

Fig. 5

Fig. 6

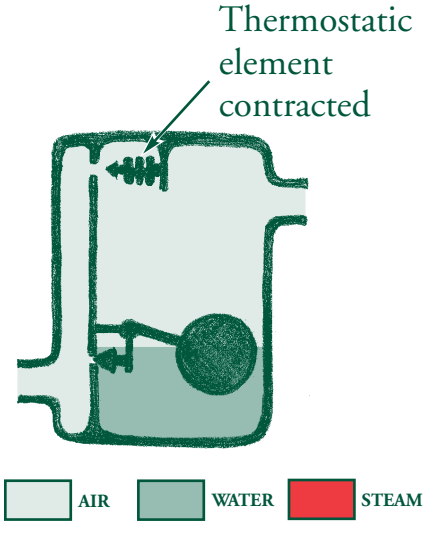


Fig. 7

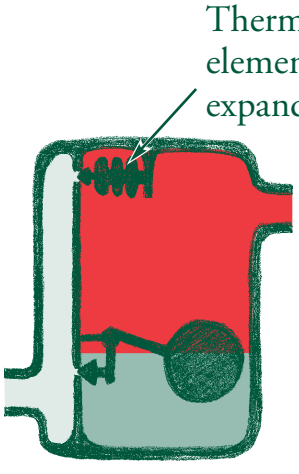


Fig. 8