LINHARDT'S

FIELD GUIDE TO

STEAM HEATING

Linhardt's Field Guide to Steam Heating

written and illustrated by Patrick Linhardt
cover illustration by Dick Keller

Dedicated to

**My Father,
Frank A. Linhardt**

A member of the greatest generation
Enlisted June 11, 1942
86th Air Depot Group
Headquarters Squadron
9th Air Force
Landed on Omaha Beach July 20, 1944
Discharged October 11, 1945

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Introduction

Welcome to the Field Guide to Steam Heating. The goal of this guide is to fix problems quickly and correctly the first time. If you want to solve a problem immediately, or don't like fish stories, skip to Chapter 1, "How to Use This Guide." That's where you'll learn how to use the features of this book, otherwise stick with the intro for the only "fish story" in this guide.

If you are still reading, relax and enjoy a little tale about three fishermen who set out to the North Channel of Lake Huron in search of King salmon, a delightful fish to eat, a tricky fish to find, and an exhilarating fish to catch. I am one of the three, a novice to the sport, but a fan of the taste of smoked, grilled, or baked salmon. The rest of the crew, Dan and Larry, are both avid sports fishermen and they were going to teach me to fish. We were all vacationing together at a compound of cabins with our wives, families, and dogs. Dan's boat, the "Winky," was docked no more than one hundred yards from the cabin where we slept in some of the most uncomfortable beds imaginable. Getting up before dawn to fish would be no problem, I couldn't sleep anyway.

The night before we had gone fishing with assorted family members and Ken, a colorful character who had grown up in the area and maintains a summer home on a private island nearby. In accordance with local custom, Ken had us make sacrifices to Manitou, the native spirit of hunters in the north woods. We sprinkled small amounts of beer and tobacco on the water as an offering to Manitou to help us in our hunt for salmon. I was rewarded that night with the magnificent sight of a bald eagle powerfully flying alongside the boat and landing gracefully on a tall pine tree along the shore. Ken and Kathy, Dan's wife, both landed big King salmon that night. Larry, Dan, and I were shut out.

It was a clear cool morning when the three of us set out to bring back many a fish to prove to our wives and families what great hunters and gatherers we were. The fishing hadn't been great so far, but this was the first time that just the three of us had set out together. We felt a decided shift in our luck that morning when we saw salmon jumping in a cove by the gravel point where the eagle had been seen. Excitedly, Dan told me to take the wheel, while he and Larry got the fishing gear ready as fast as they could. Dan pointed out the course for our first pass through the cove. When fishing for salmon, long lines are set on weighted down-riggers and trolled behind the boat. He showed me gauges and monitors on the dash and told me what to look for. The most important were the speed of the lure, the depth of the bottom, and the temperature of the water at the lure. The right combination of these caught fish, and we were there to catch fish.

On the First pass with me at the helm, Larry landed a beautiful, healthy 23 pounder. With that great start, I was now the “lucky helmsman.” Merle Haggard was moaning out one song after another on the tape deck as I swung the gear around for a second pass. All hell broke loose as soon as we eased back into the cove. Dan was all over the first line to go off. When the second fish struck 30 seconds later, Larry was right there. They both started yelling at me a minute later that another line had a “fish on.” Luckily we were heading into deep water, so I jumped away from the helm and grabbed the third line. It was a fisherman’s trifecta, every man with a fish on the line at the same time. Larry and Dan were busy landing their fish, while I was struggling with mine. I let him have a little too much slack and he jumped up and spit the hook out. The rookie lost one big fish on that pass, but Dan and Larry pulled in two nice ones. The cove was hot for hours, we didn’t leave until we limited out.

On the ride back to the dock, listening to the same Merle Haggard tape for the seventh time, I was thinking about a seminar I was going to teach using the classic book “The Lost Art of Steam Heating” by Dan Holohan. Each student would get a book and a highlighter, and I would show them how to use the book in the field. I knew the book well, because I’ve read it many times, used it to solve a multitude of problems, and recommended it to anyone interested in steam heat.

I was looking forward to sharing the book and my experience in the field. I was thinking of ways to do this when suddenly I realized how much salmon fishing is like steam heating. At that moment, I made a connection between the three keys to catching salmon that I had just learned from my friends, and a three step approach to steam heating that I could use to teach the technicians attending my seminar. Repairing a steam system is all about knowing how it works, just as catching a fish is all about knowing why they’ll strike a hook. On this day, I believe the spirit of Manitou guided us to the right spot on the lake. But once we were in the cove, we still had to follow the three guidelines of salmon fishing: water temperature at the lure, speed of the lure, and depth of the bottom.

The temperature of the water at the lure related, in my quirky mind at least, to getting the “steam up” in the piping. The speed of the lure related to getting the “air out” of the system. While the depth of the bottom related to getting the “water back” to the boiler. Maybe I had been out on the water too long, was sleep deprived from the back-breaking beds, or drank too many long neck Canadians, but somehow it was all making sense. Let me explain.

King salmon will school to feed on bait fish that like the water temperature at 48°F. We found the water gradient of the lake that day in that area was 45 to 50 feet. Without a school of fish, it's hard to get a strike on a lake the size of Huron. Without dry steam of the proper volume coming out of the boiler, good luck troubleshooting the system. You are chasing your tail my friend. I know, it happens all the time. "Steam Up," that's the place to start.

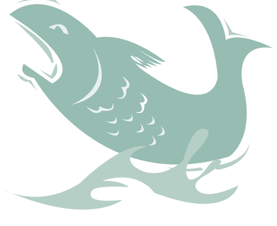
The speed of the lure causes its vibration to simulate the action of the bait fish the salmon feed on. If the lure is moving too fast or too slow, the salmon won't think it's food. You can't get a strike if the lure doesn't attract the fish. Venting the air out of the radiator is the only way to get steam in. Uneven heating, no heating, or hissing air vents are common complaints of the lady of the house. "Air Out" is essential to even steam heating.

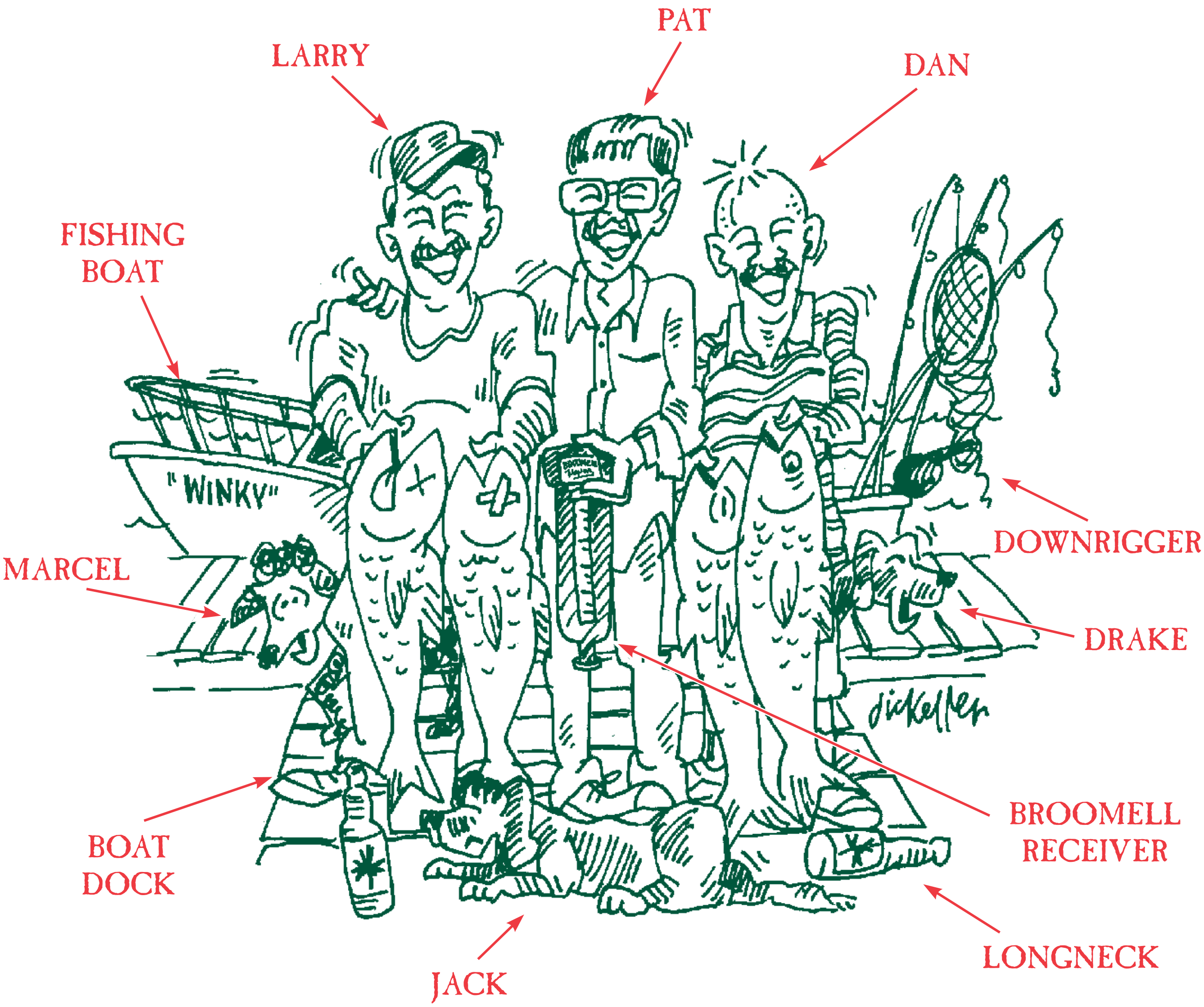
The depth of the bottom is critical to the condition of the fishing rigs. If the lures are set 45 feet down and they're running up onto ridges only 30 feet down, then the hooks are lost at the bottom. I've never heard of anyone catching a fish on a line without a hook. Without getting the water back to the boiler, you stop making steam. A dry-fired boiler might be more likely. Dry-fired boilers are a very expensive problem, heard of any lately? "Water Back" keeps the boiler going.

The day on the boat was all about threes. Three guys on a boat with three fish on three lines because they knew the three most important things about salmon fishing. If I could break down a complex subject like steam heating into the three most important, yet easy to identify groups, I could simplify my preparations for the class and make it easier for the techs in the class to understand. This seemed like a win-win situation to me. My new idea, Steam Up–Air Out–Water Back was what I was looking for.

Pulling up to the dock, we knew we had a great catch to show off to our families. We were plenty proud of that morning's haul, but I was also excited because I had devised a method to simplify steam heating in my upcoming seminar. Dan and Larry shared their knowledge of fishing with me, and now I'd like to share my knowledge of steam heating with you. I hope you enjoy using this guide as much as I've enjoyed putting it together.

Happy Fishing!





LARRY
PAT
DAN
FISHING BOAT
"WINKY"
MARCEL
DOWNRIGGER
DRAKE
BROOMELL RECEIVER
BOAT DOCK
JACK
LONGNECK

CHAPTER ONE

How to Use This Guide

The guide is arranged in an outline form for quick and easy reference.

- Main ideas on a topic are indicated by a light bulb.
- Details of that main idea follow below it and are indicated by a light switch.
- Common mistakes or pitfalls to avoid are indicated by a prohibited sign.

To simplify the technology of steam heating, it is divided into three paths.

- **STEAM UP** is the production and distribution of steam.
- **AIR OUT** is the removal of air from the piping and radiation.
- **WATER BACK** is the return of the condensed steam (water) to the boiler.

Steam Up, Air Out, Water Back are the basis of all steam heating systems.

- No matter how complex or simple, with modifications from original design or not, the system will break down into three paths.
- You can follow each path for any type of system.
- Once you know the paths, you can look for the problem or road blocks in the paths.
- Correcting that problem or clearing that roadblock will fix any job.

Explanations of the different types of steam heating systems are broken down into the simplest terms.

- The approach of the book is direct. Follow the paths.
- Identify the problem by looking at the system as three paths.
- Understand what is supposed to happen in each path.
- Find the trouble in a path and fix the problem.
- Always look at the problem with the three paths in mind, as the basis for your analysis.

The common terms of steam heating are defined and illustrated in Chapter 2 "Steam Basics" on pages 14 through 17.

- Refer to this glossary of common terms whenever you are not completely sure of any item or part.

Chapter 2 combines the three paths into easy to understand color diagrams labeled with the terms we will use in the guide.

- It is designed to familiarize the reader with the whole process using simplified diagrams and explanations.
- It is a good review for any level of experience.
- It is the foundation from which you can build a complete understanding of any system.

The troubleshooting guides in Chapter 6 are the quickest routes to solving 27 common problems.

- There is a listing of the most common problems found in the field.
- Each problem has a flow chart to help you locate the source of that problem and help you reach a solution.
- Steps of the flow chart are referenced back to chapter explanations in the main chapters.
- Review the explanations as you go through the chart.
- Don't skip the explanation, unless you are completely familiar with the path.

The three main chapters, Steam Up, Air Out, Water Back, explain each path in easy to reference outline form with color diagrams to help visualize the flow of steam, air, and water through the system.

- Each chapter is designed to familiarize the reader with the individual path in order to troubleshoot problems not included in this guide.
- With so many different types of systems experiencing varied levels of maintenance, questionable modifications and multiple boiler replacements through the years, you will have to understand the three paths because you never know what you'll find in somebody's basement.
- The chapter introductions will explain the importance of that subject and take you step by step through the sequence of flow in that path.

To begin troubleshooting in the field, start in the boiler room with the guide open on top of the boiler.

- Make sure the boiler will fire.
- This guide does not attempt to solve combustion or electrical problems.
- Start at Chapter 2 for basic theory or a quick refresher.

Check near boiler piping while in the boiler room.

- Refer to the manufacturer's instructions if left with boiler paperwork.
- Refer to pages 56 through 63 for piping sizes and fundamental near boiler piping arrangements.

Check the gauge glass while the boiler is firing.

- Note the level of the water line before the boiler starts to make steam.
- Refer to pages 38 and 39 for normal water line position.
- Observe the water line as the boiler makes steam.
- Refer to pages 34 and 35 to check for a "dirty" boiler.

Get out of the boiler room to observe the piping and follow the paths of the steam, air, and water through the system.

- Always find the end(s) of the steam main(s).
- Look at the piping connections at the end of the mains for vents and traps.
- Listen for the release of air out of the main vents.
- Look at the piping connections at the radiation to determine if it's a one or two pipe system.
- Look at the piping connections at the riser takeoffs.
- Use a level to determine pitch of piping. Make sure water flows in the right direction.

Now that you're familiar with the system, go to Chapter 6, the troubleshooting guide, to look for specific problems.

- Try to match the problem described by the homeowner or building manager to problems listed on page 125.
- Be careful with other's description of the problem. They can easily mislead you.

Go to Chapter 3 to work on non-specific problems, multiple symptom problems, or to improve the overall performance of the system.

- The production and distribution of the steam are fundamental to system performance.
- Always start with Steam Up when problems don't show up in the troubleshooting guide.

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

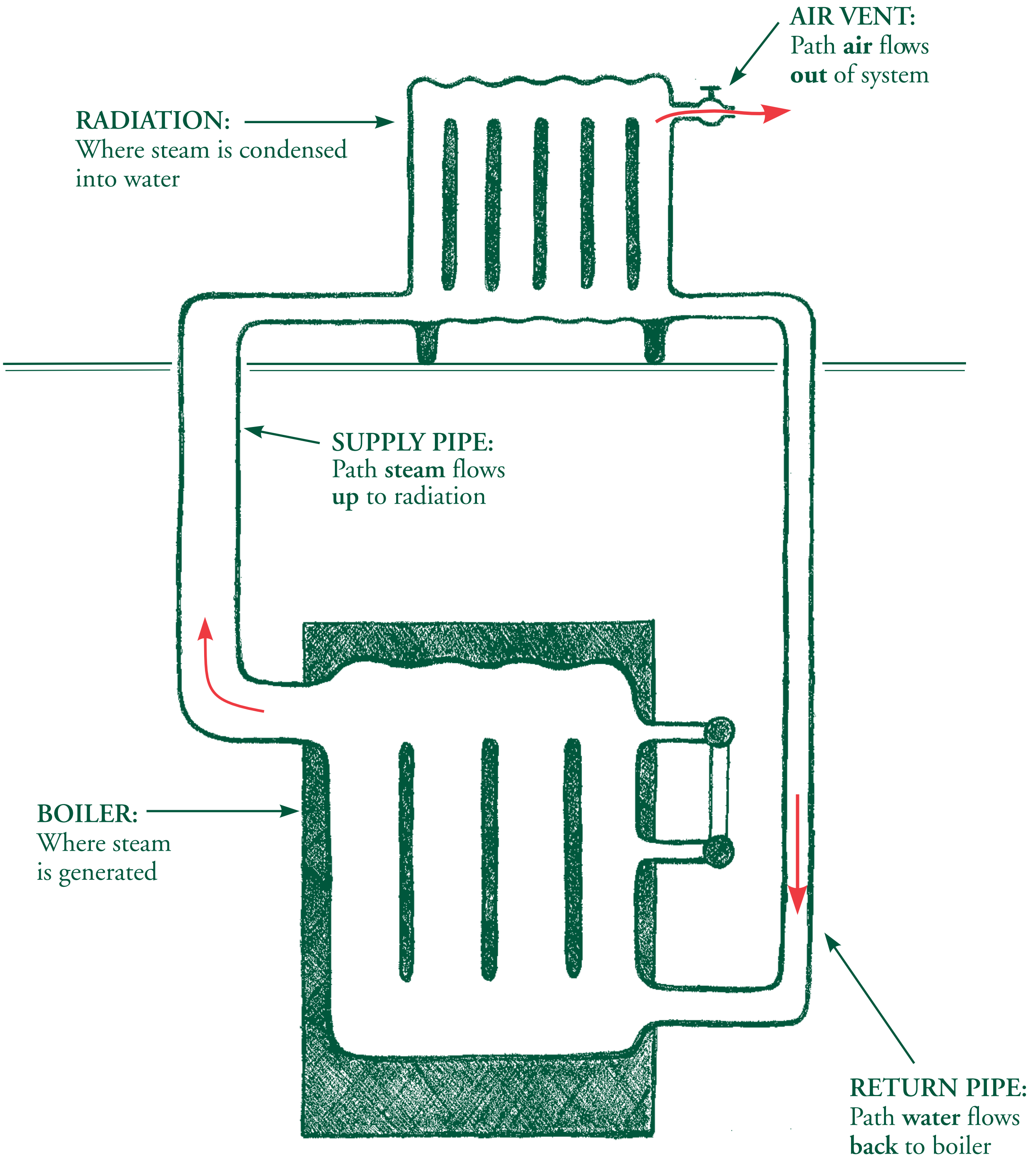
- Air is pushed out of the piping and radiation.
- Steam replaces the air in the piping and radiation.

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

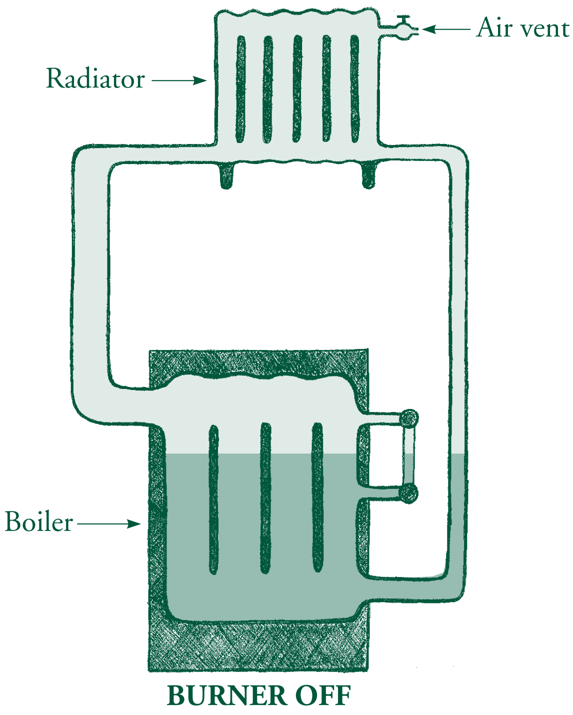


Fig. 2

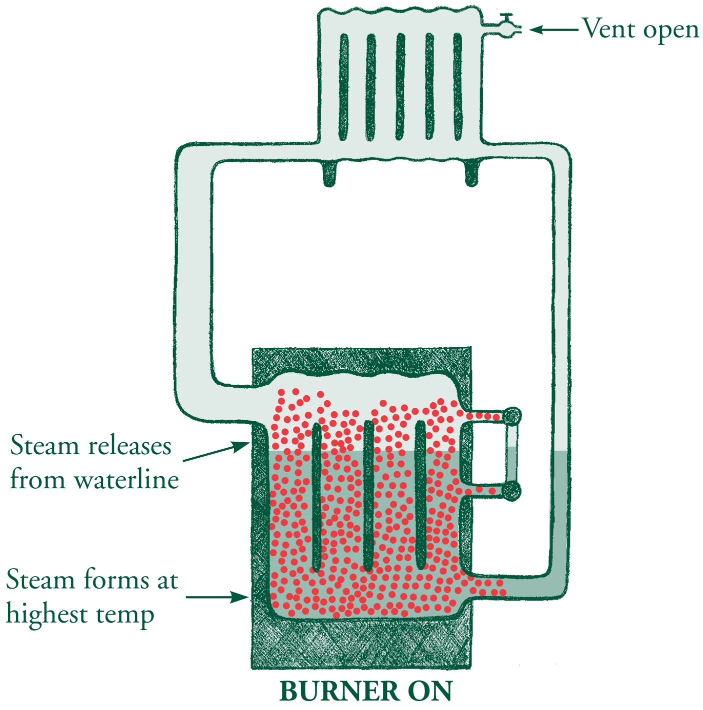


Fig. 3

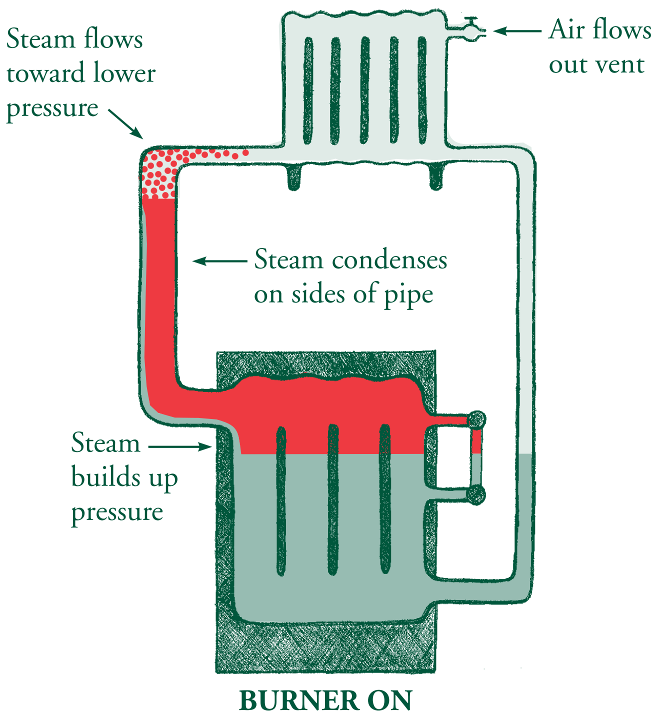
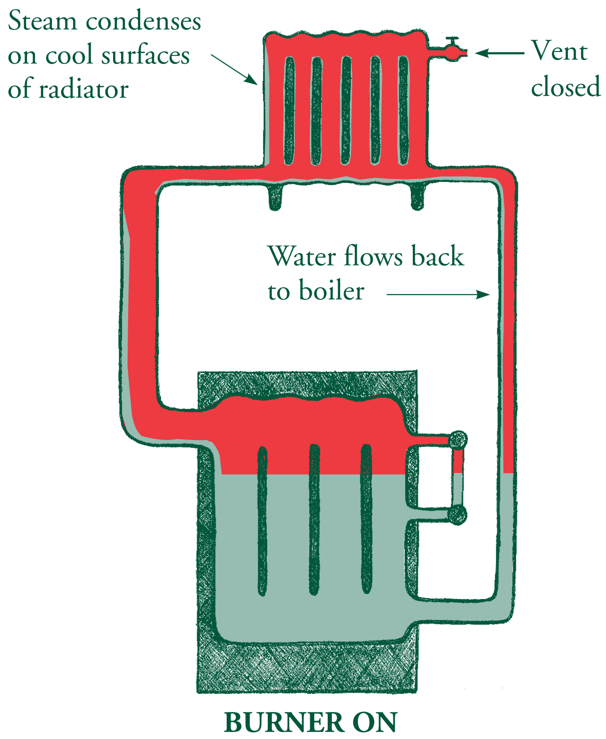


Fig. 4



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.

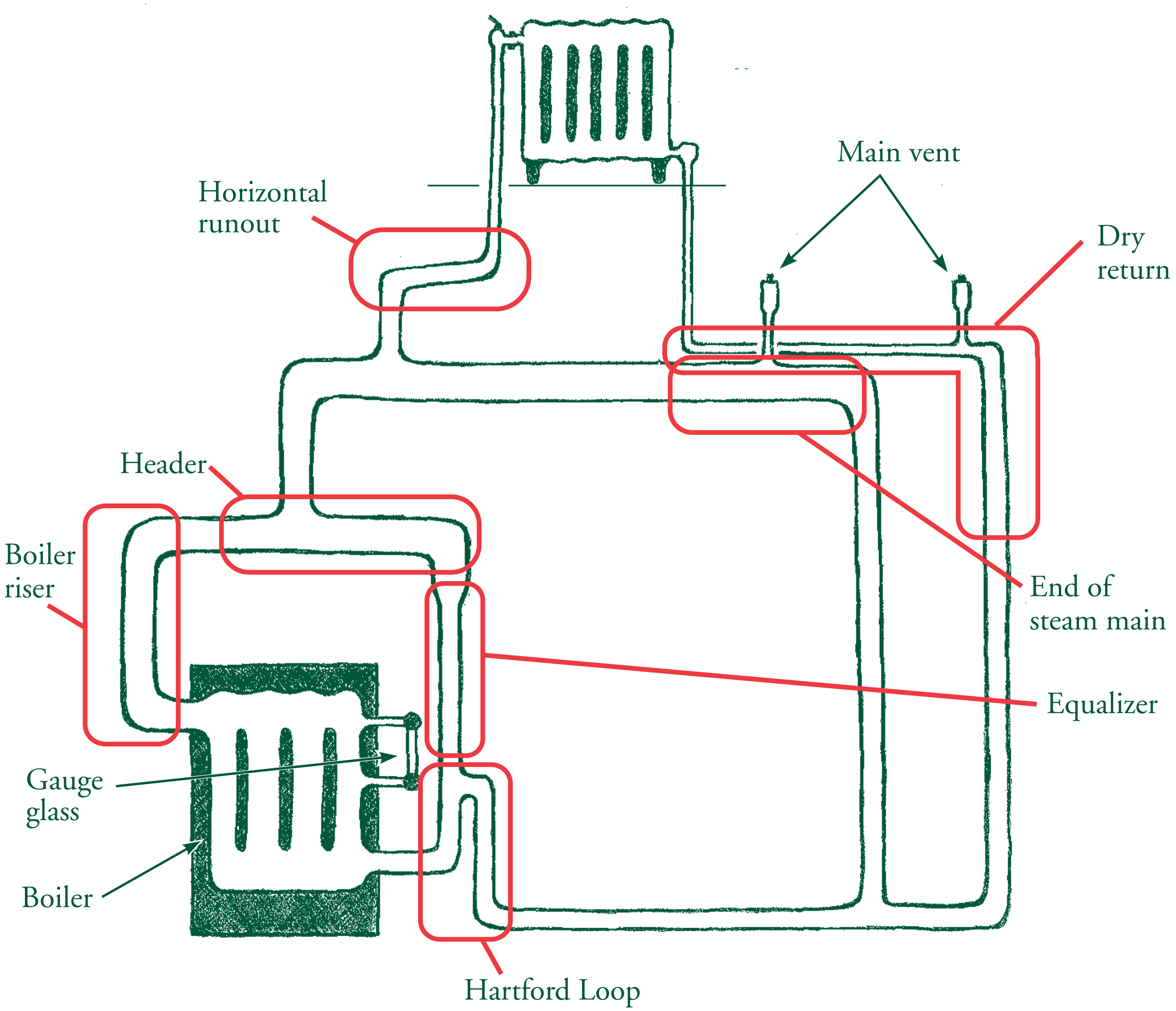
Main Vent—designed to be open at the presence of air, to close at the presence of steam and water. Vents air from supply or return main.

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.

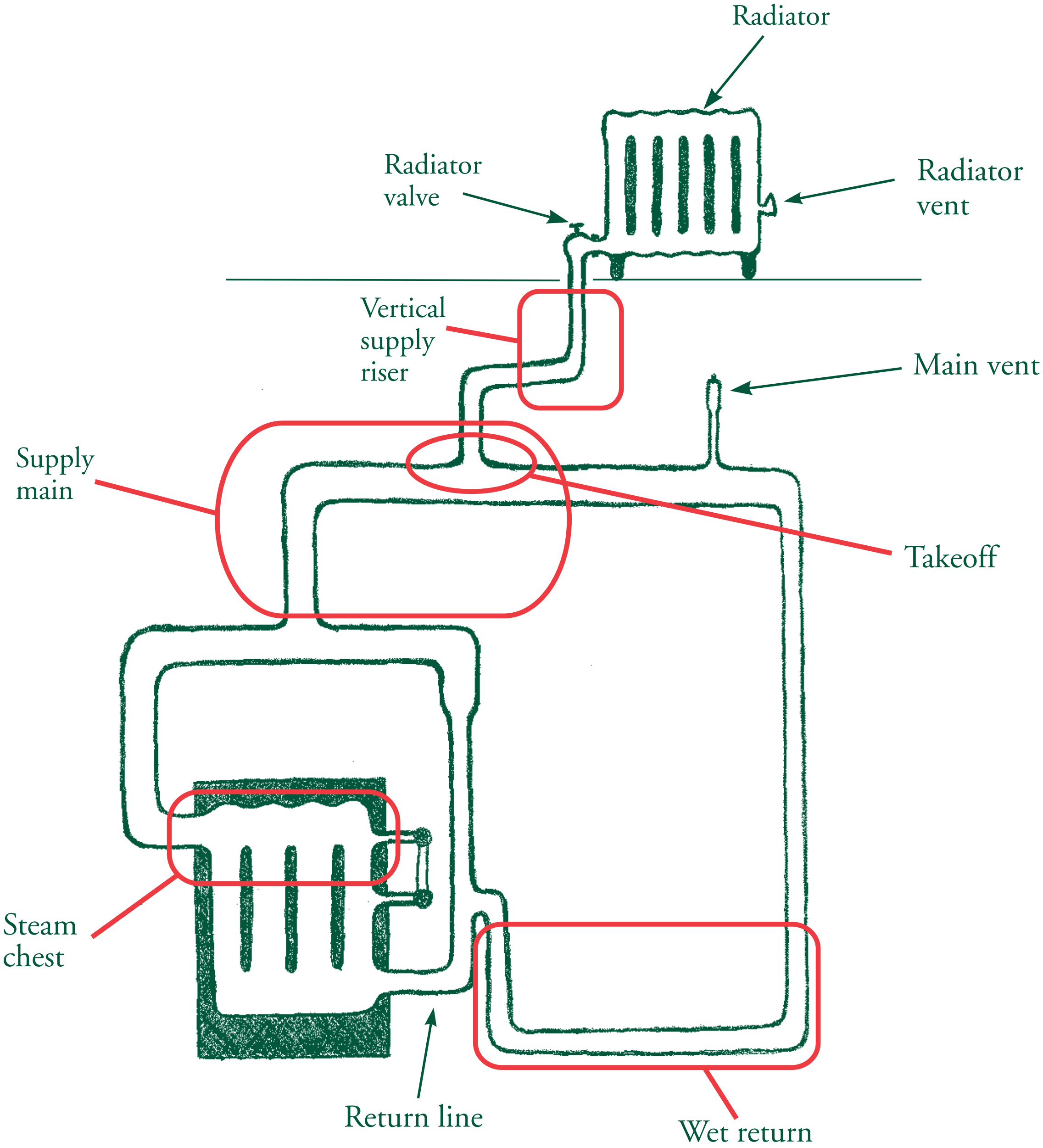
Two Pipe Steam—steam system where steam flows into radiation while condensate and air flows out of radiation through two separate pipes.

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

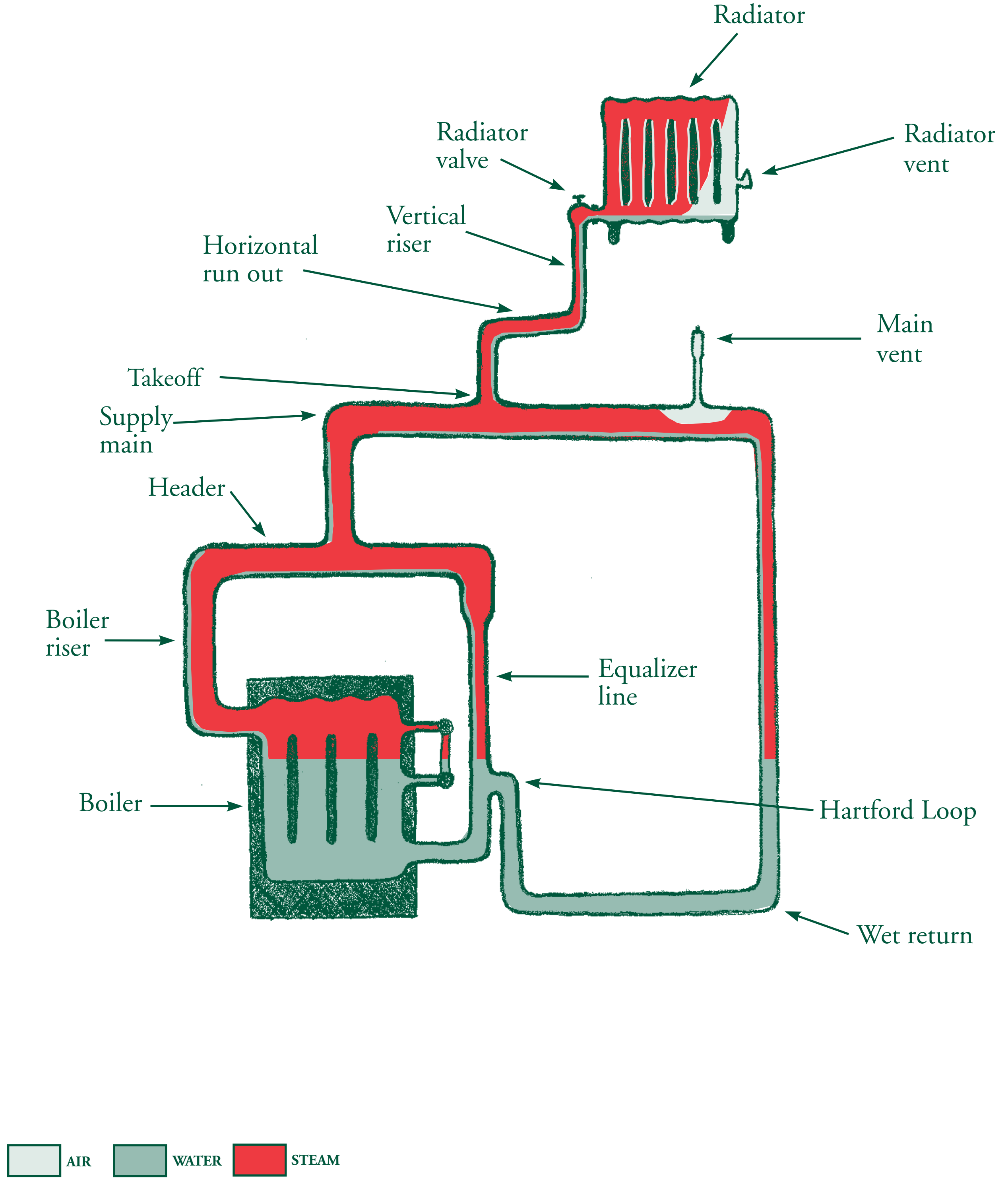
Sequence of the flows through the system.

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

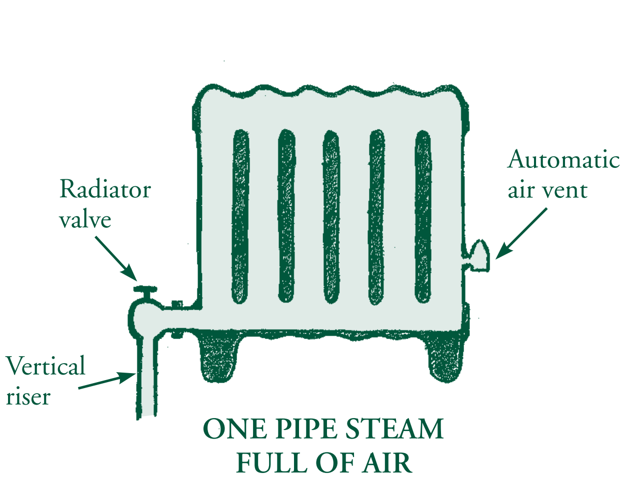


Fig. 2

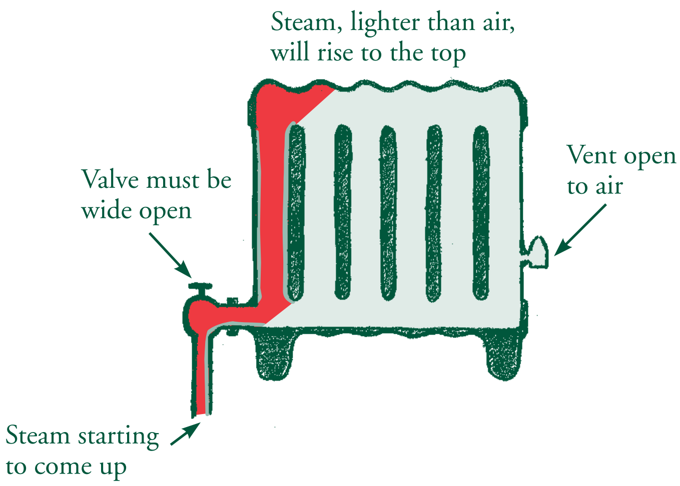


Fig. 3

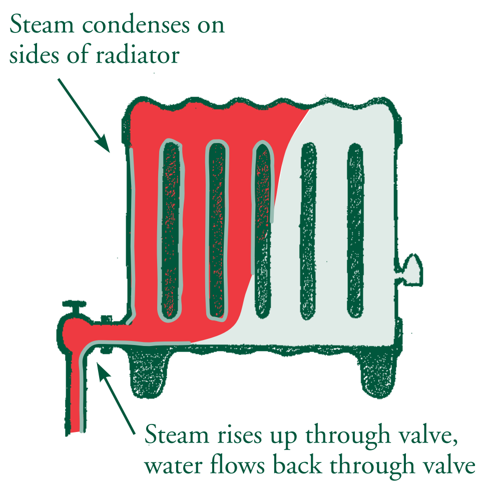


Fig. 4

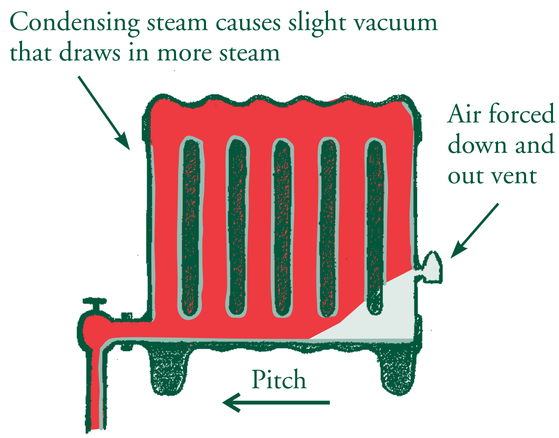


Fig. 5

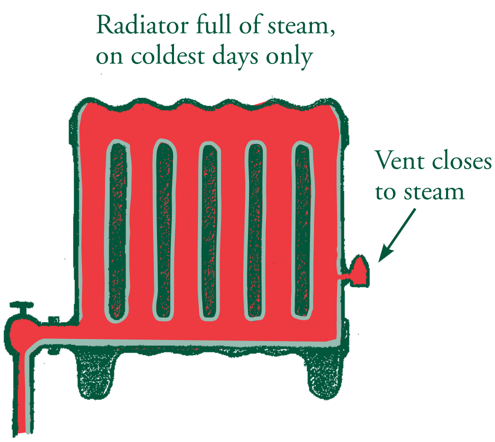
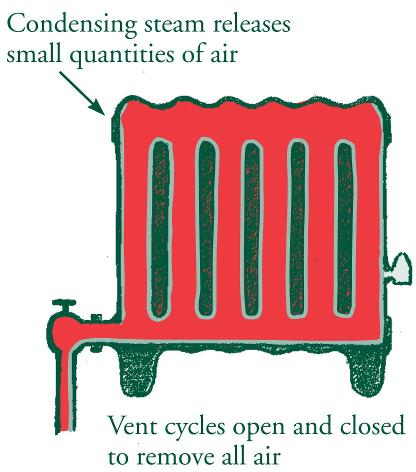


Fig. 6



Simplified Two Pipe Steam

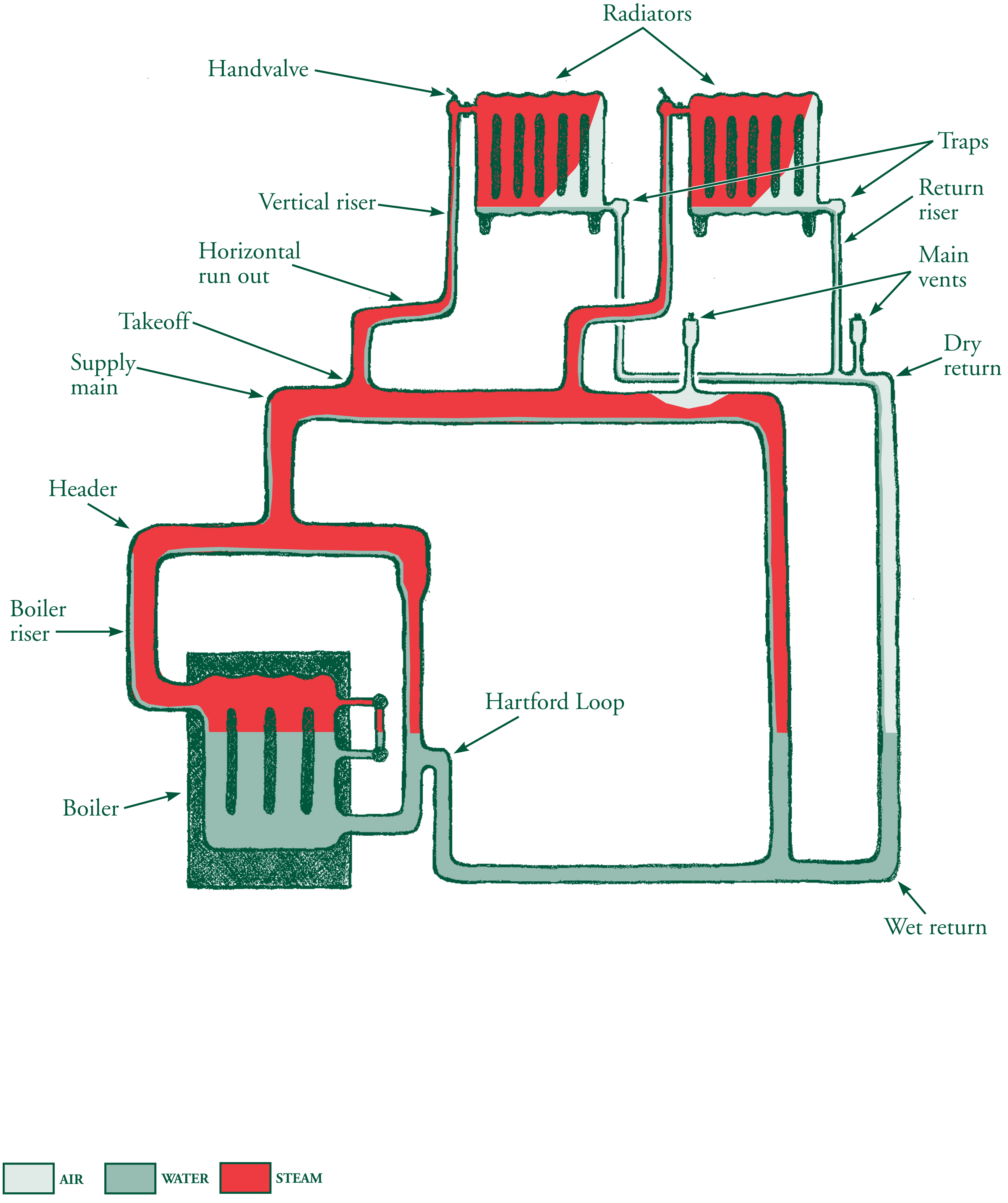
Sequence of the flows through the system.

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



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.

Fig. 1

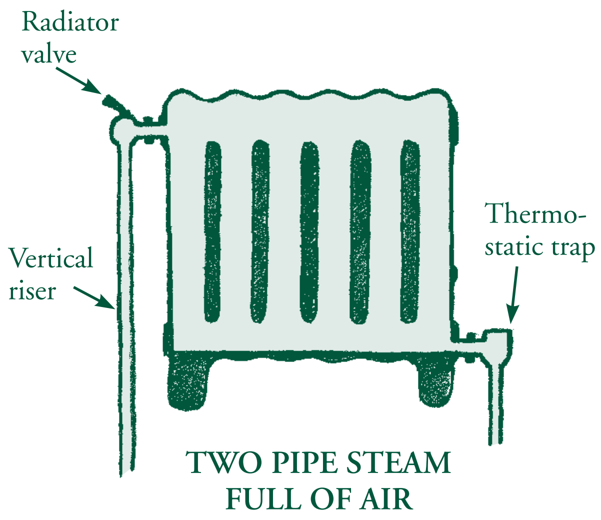


Fig. 2

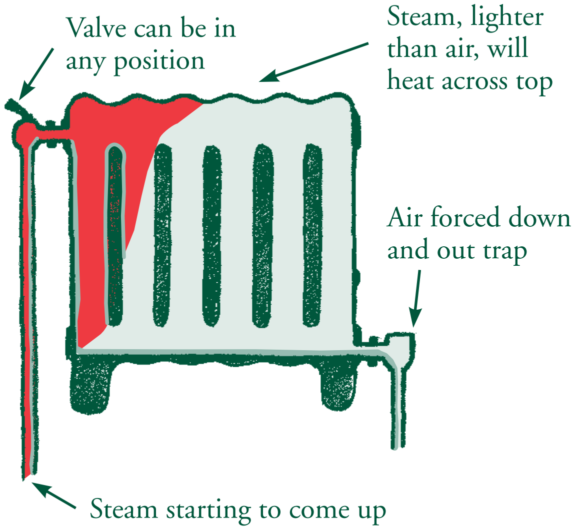


Fig. 3

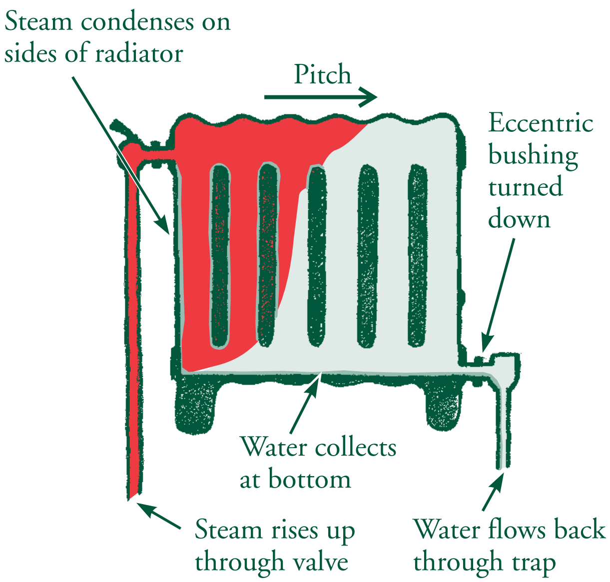


Fig. 4

Condensing steam causes slight vacuum that draws in more steam

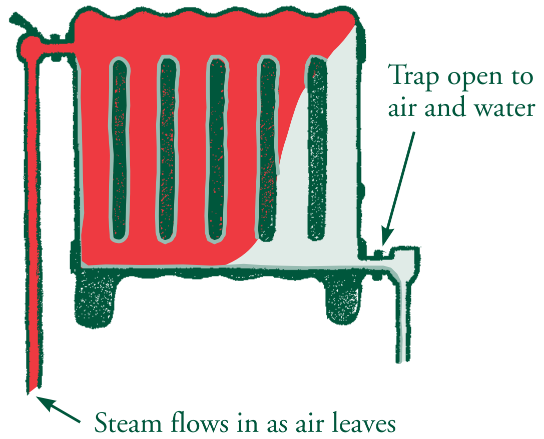


Fig. 5

Radiator full of steam, on coldest days only

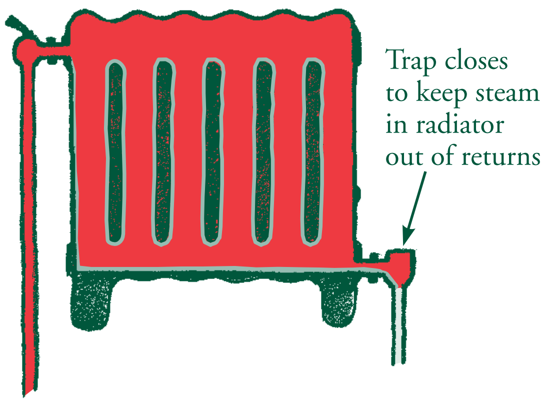
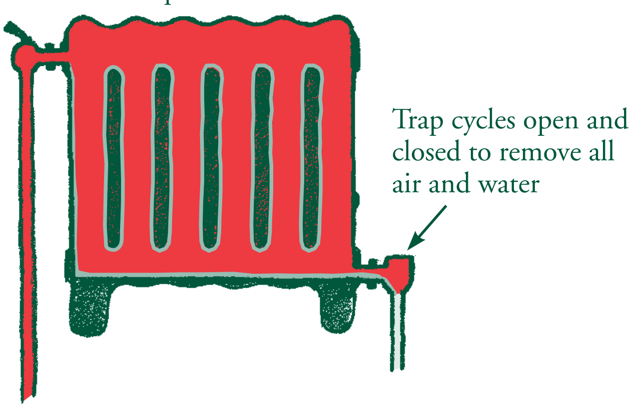


Fig. 6

Condensing steam releases small quantities of air



AIR WATER STEAM

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.

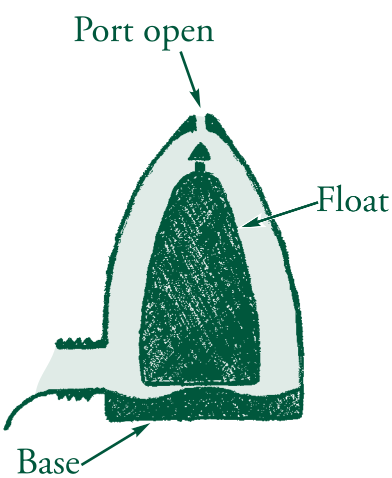
Fig. 5 With steam at vent, port is closed to keep steam in piping.

- 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.

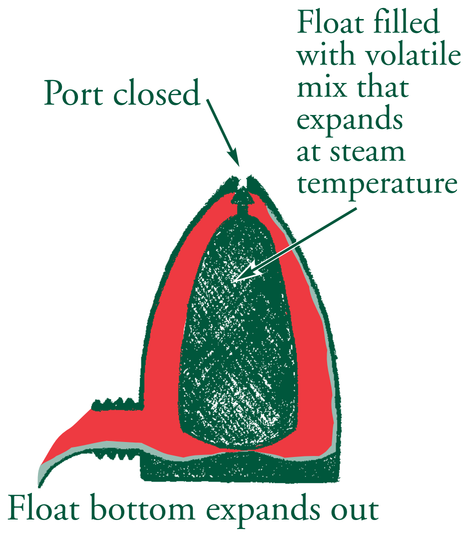
- Float rises up with the water to drive pin up into port.

Fig. 1



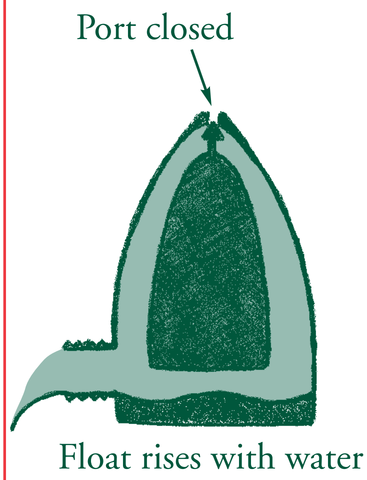
AIR

Fig. 2



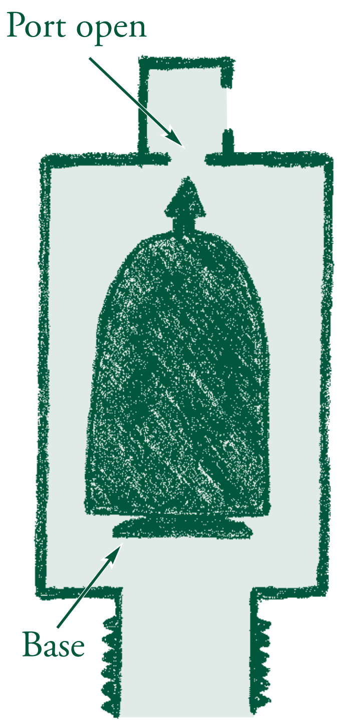
STEAM

Fig. 3



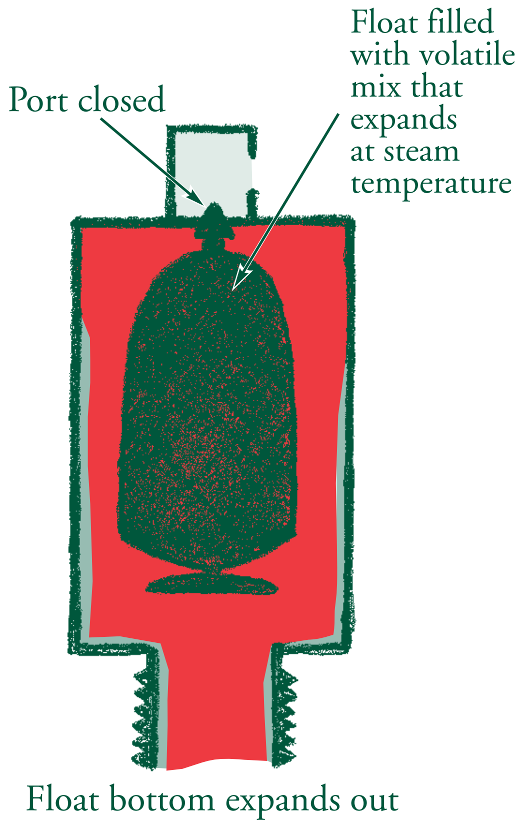
WATER

Fig. 4



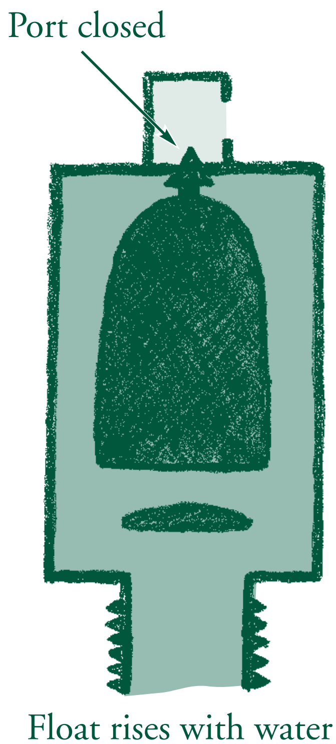
AIR

Fig. 5



STEAM

Fig. 6



WATER

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.

Fig. 1

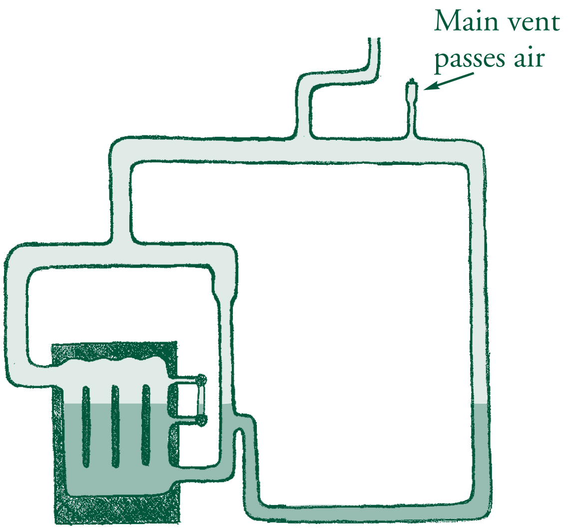


Fig. 2

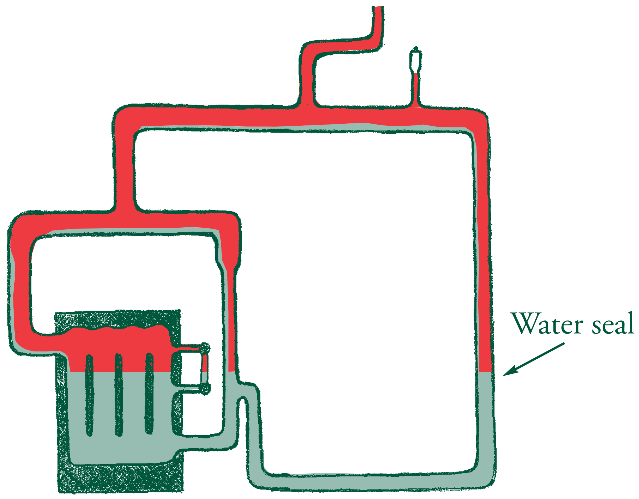


Fig. 3

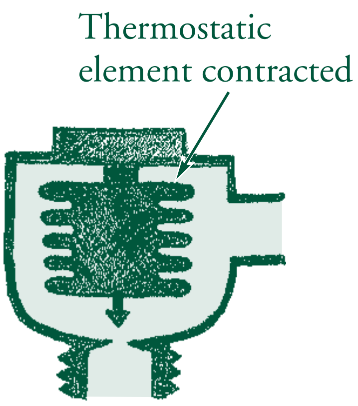


Fig. 4

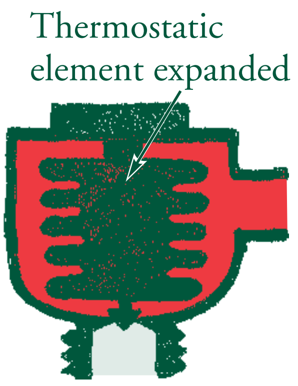


Fig. 5

Fig. 6

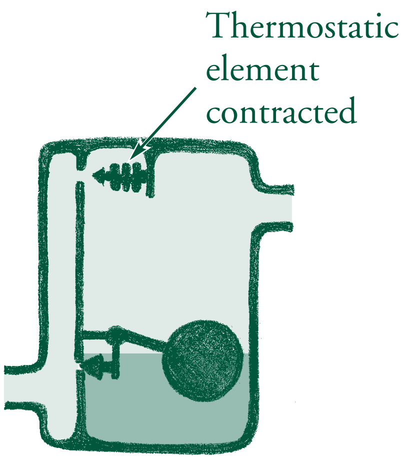


Fig. 7

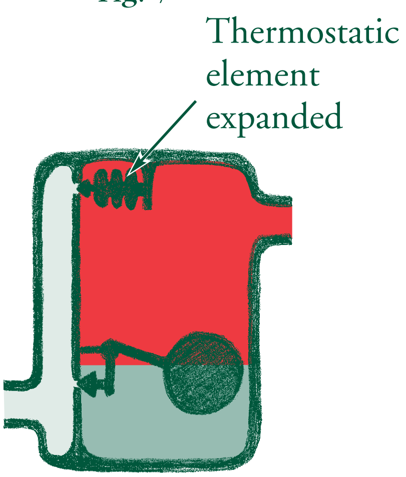
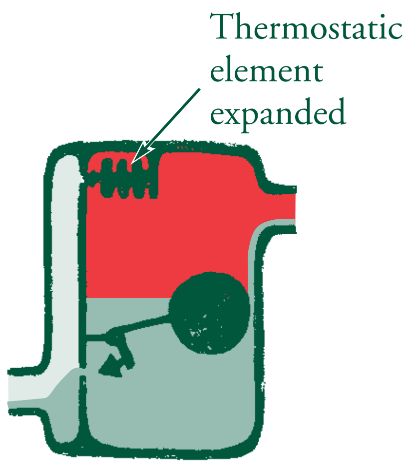


Fig. 8



AIR WATER STEAM

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

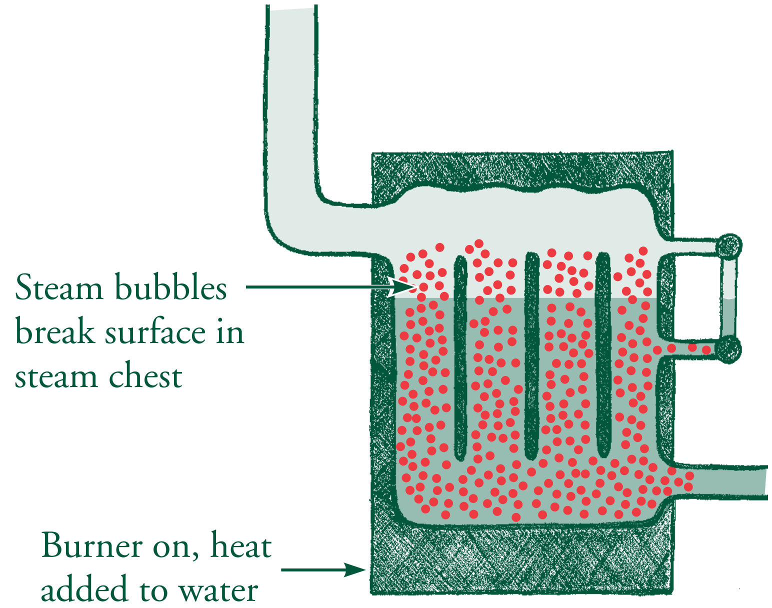
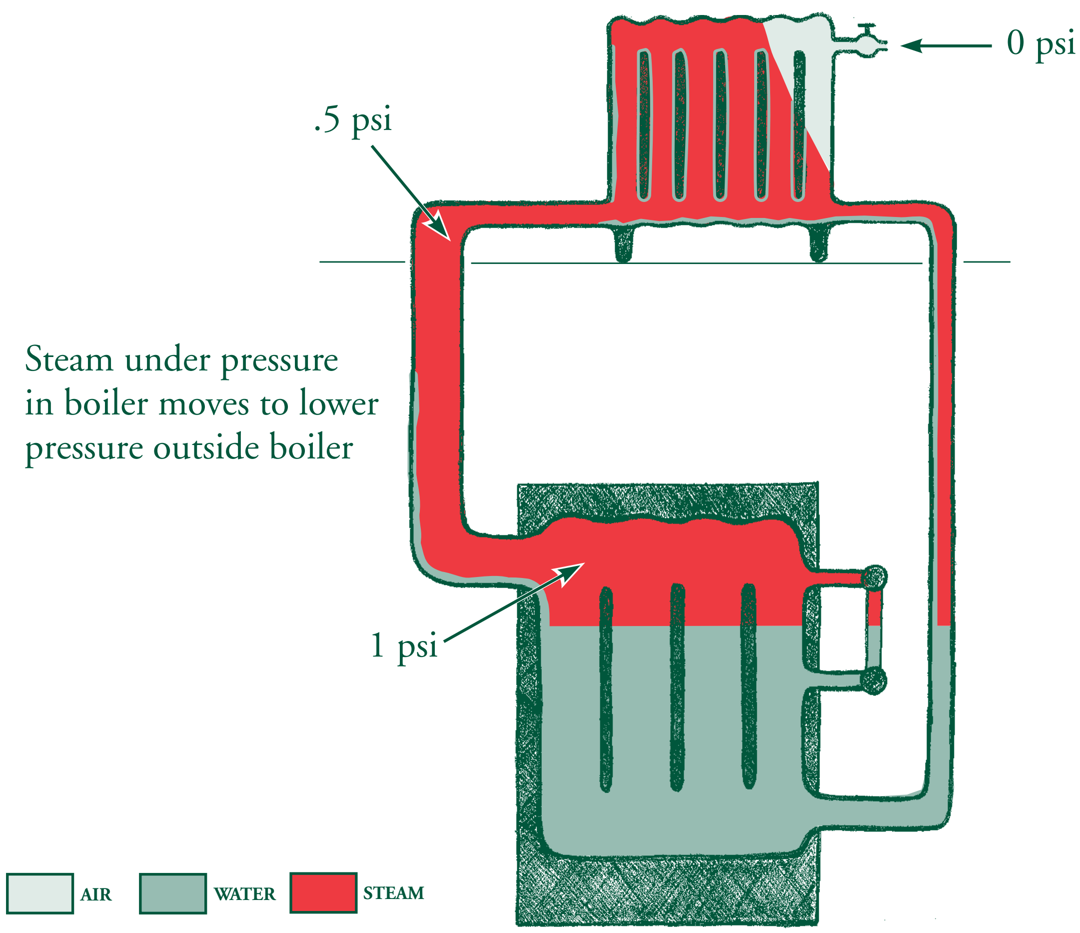

Steam bubbles break surface in steam chest
Burner on, heat added to water

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

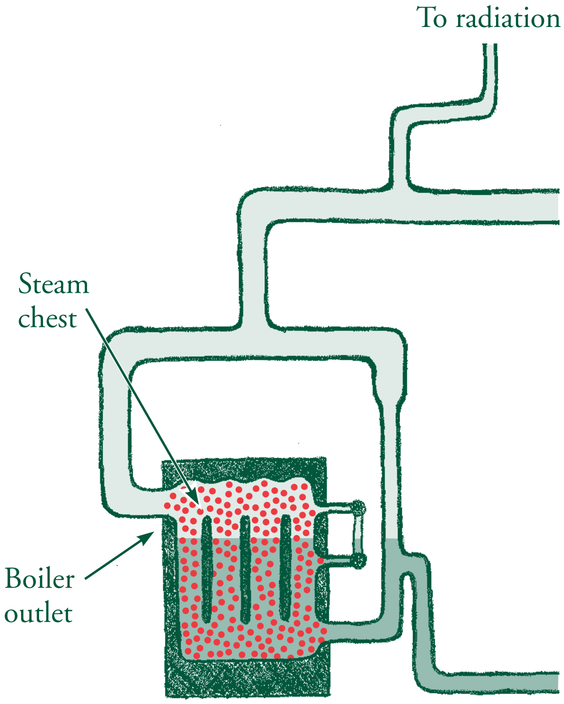


Fig. 2

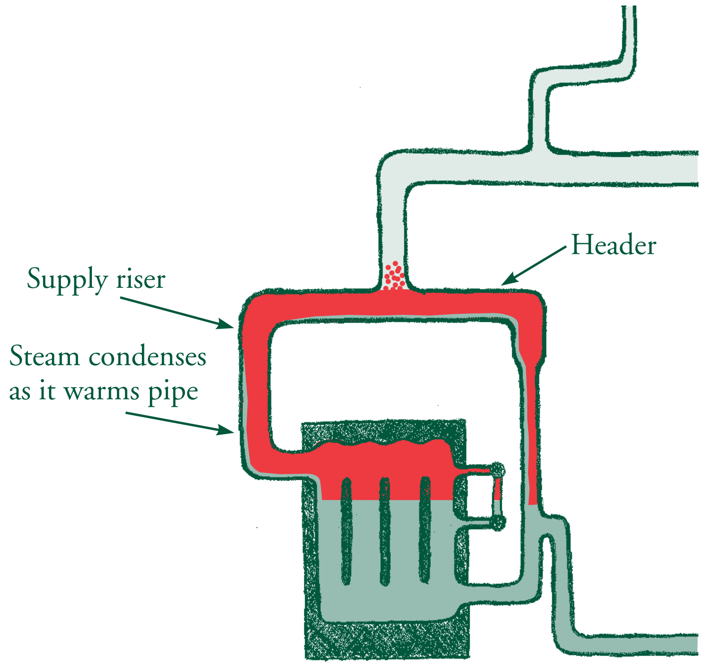


Fig. 3

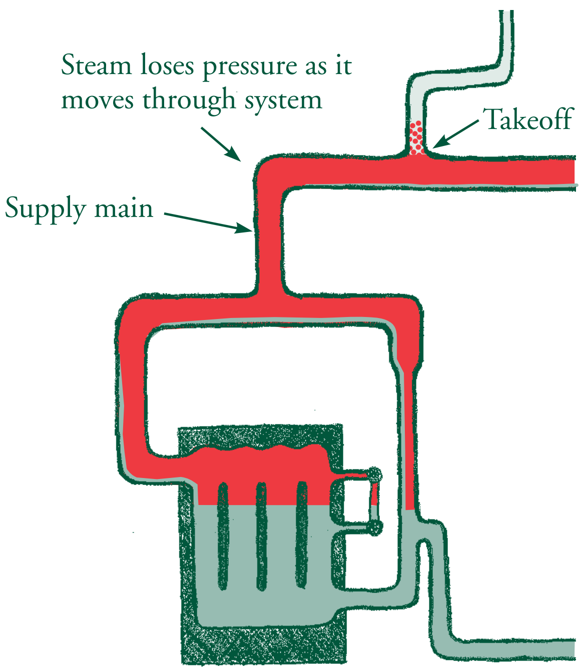
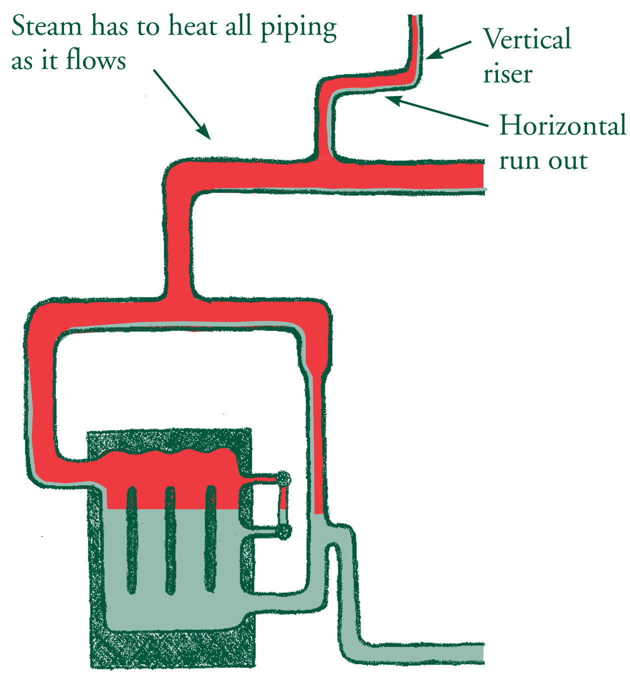


Fig. 4



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

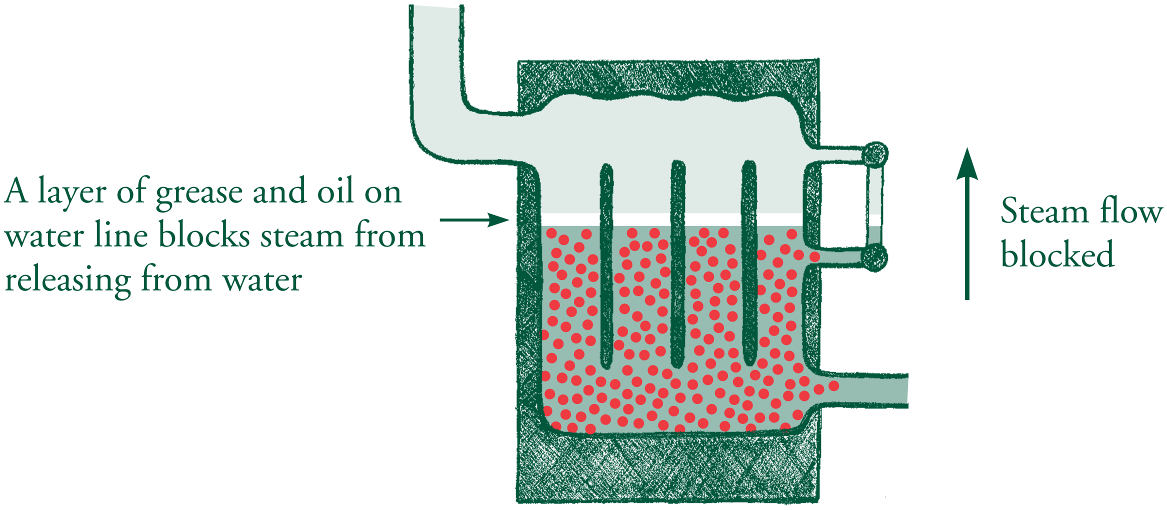


Fig. 2

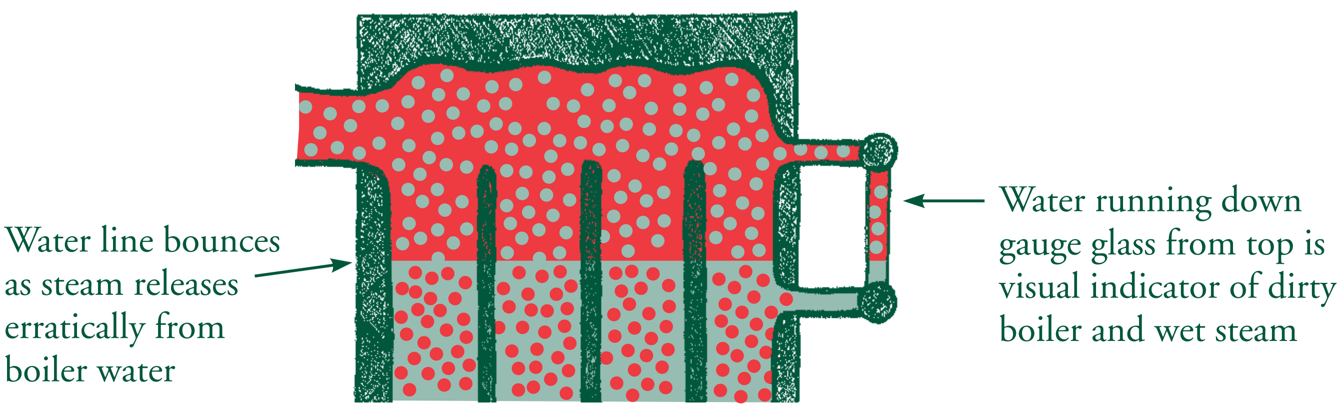
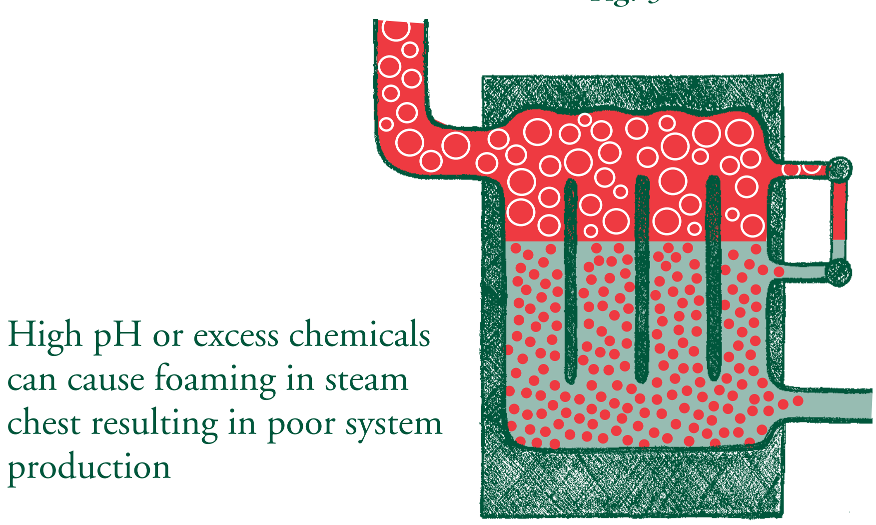


Fig. 3



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.

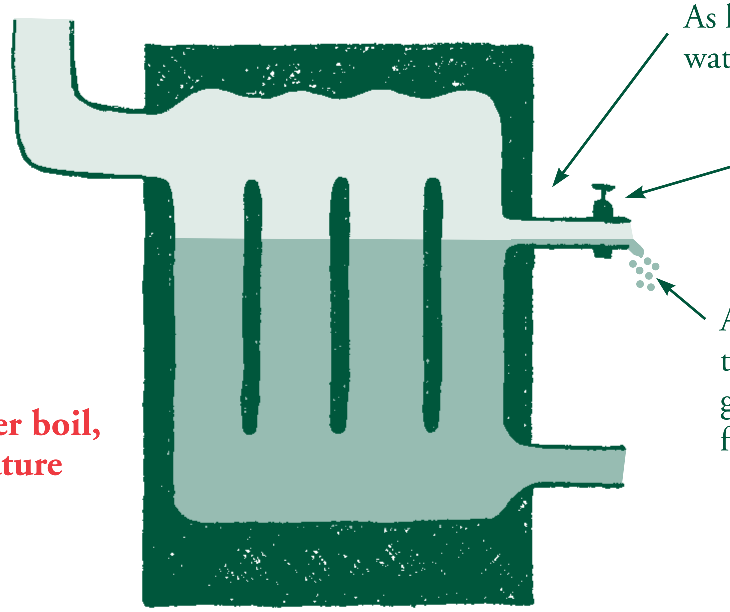
Chemical cleaning agents should be available at your local supply house.

- 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.

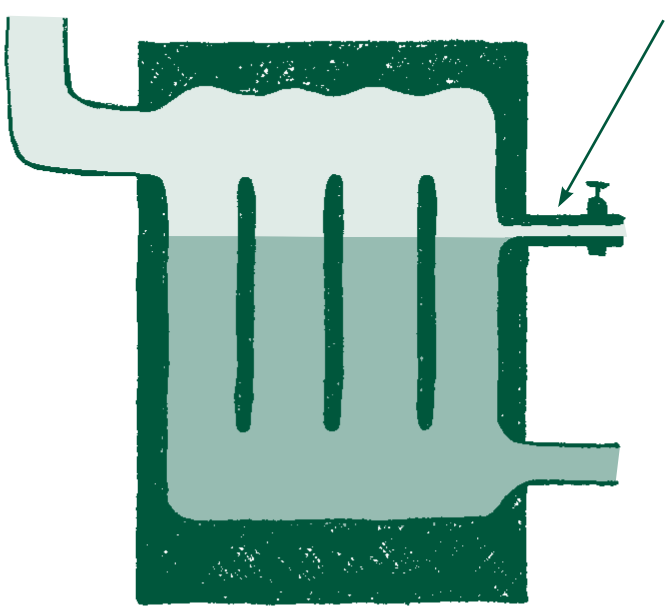
- Systems with return pumps (vacuum, condensate transfer, or boiler feed) should be checked for poor return water conditions.
- The wet return on gravity return systems should be checked for poor return water condition.

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.

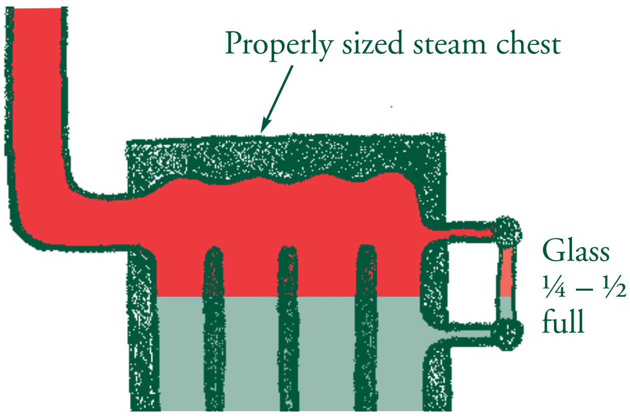
Fig. 3 A flooded boiler has a full gauge glass and little or no steam chest.
- The flooded boiler results in the highest fuel bills.
- The higher water level decreases the outlet area of the supply riser increasing steam velocity and causing wet steam.

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

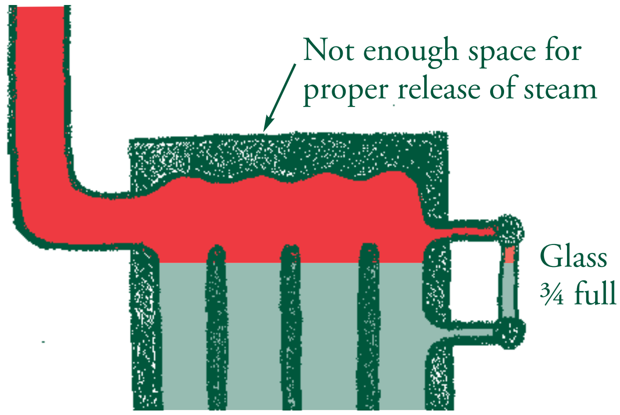
Fig. 1



NORMAL WATER LINES

NORMAL FUEL BILLS

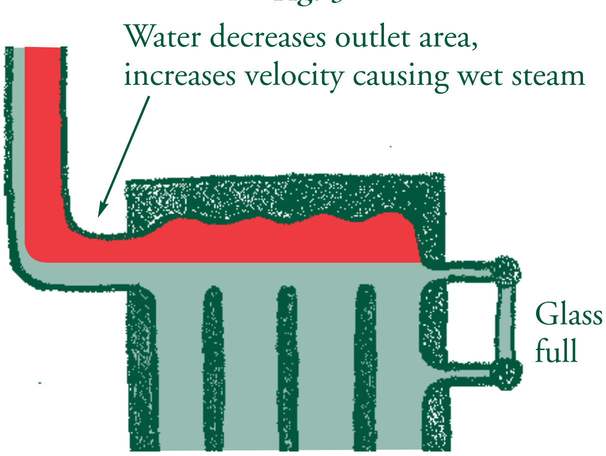
Fig. 2



WATER LINE TOO HIGH

HIGH FUEL BILLS

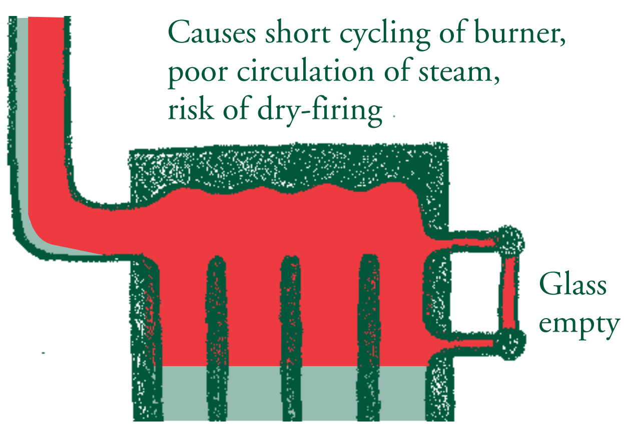
Fig. 3



FLOODED BOILER

VERY HIGH FUEL BILLS

Fig. 4



WATER LINE TOO LOW

HIGH FUEL BILLS

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.

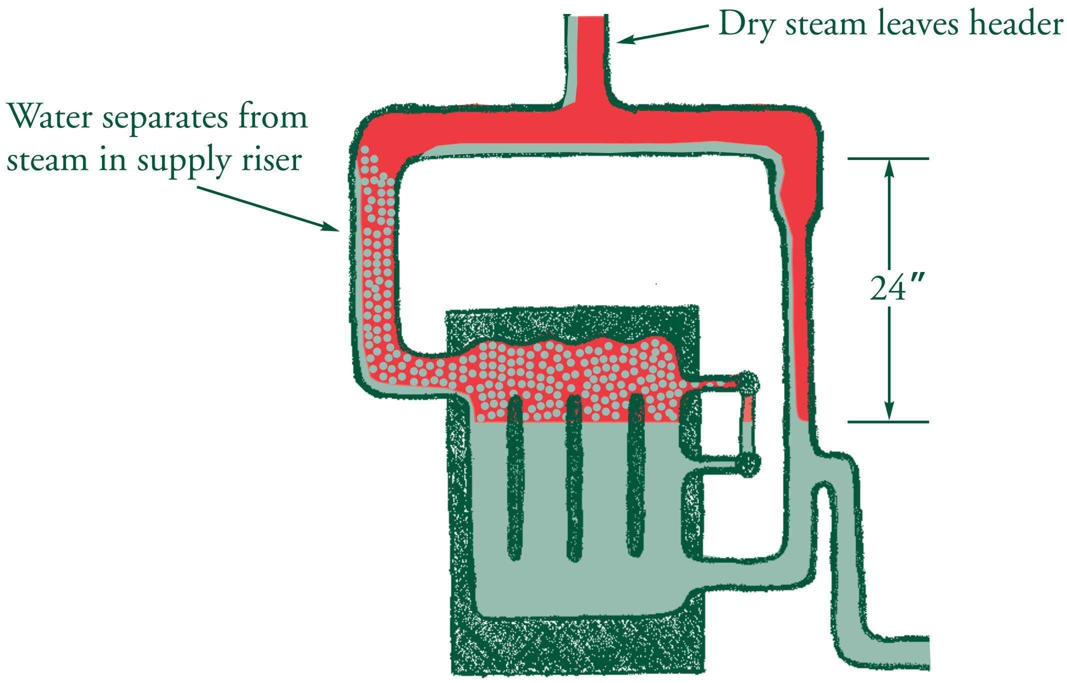
The purpose of the large steam chest and large outlet tappings was to keep the velocity of the steam flow out of the boiler to a minimum, sometimes allowing less than 10 feet per second (FPS).

- 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.

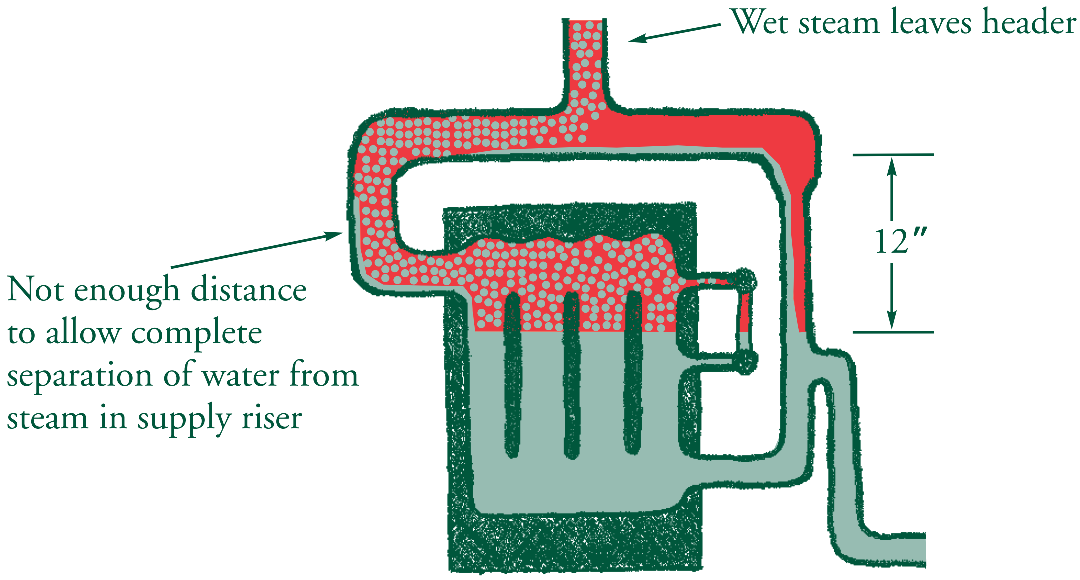
- Today's designers use the near boiler piping to produce dry steam.
- **Fig. 1** Modern boilers require a distance of at least 24 inches from the boiler water line to the steam header.
- Water will separate from the steam in this 24 inch vertical supply riser like it used to in the large steam chest.
- 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

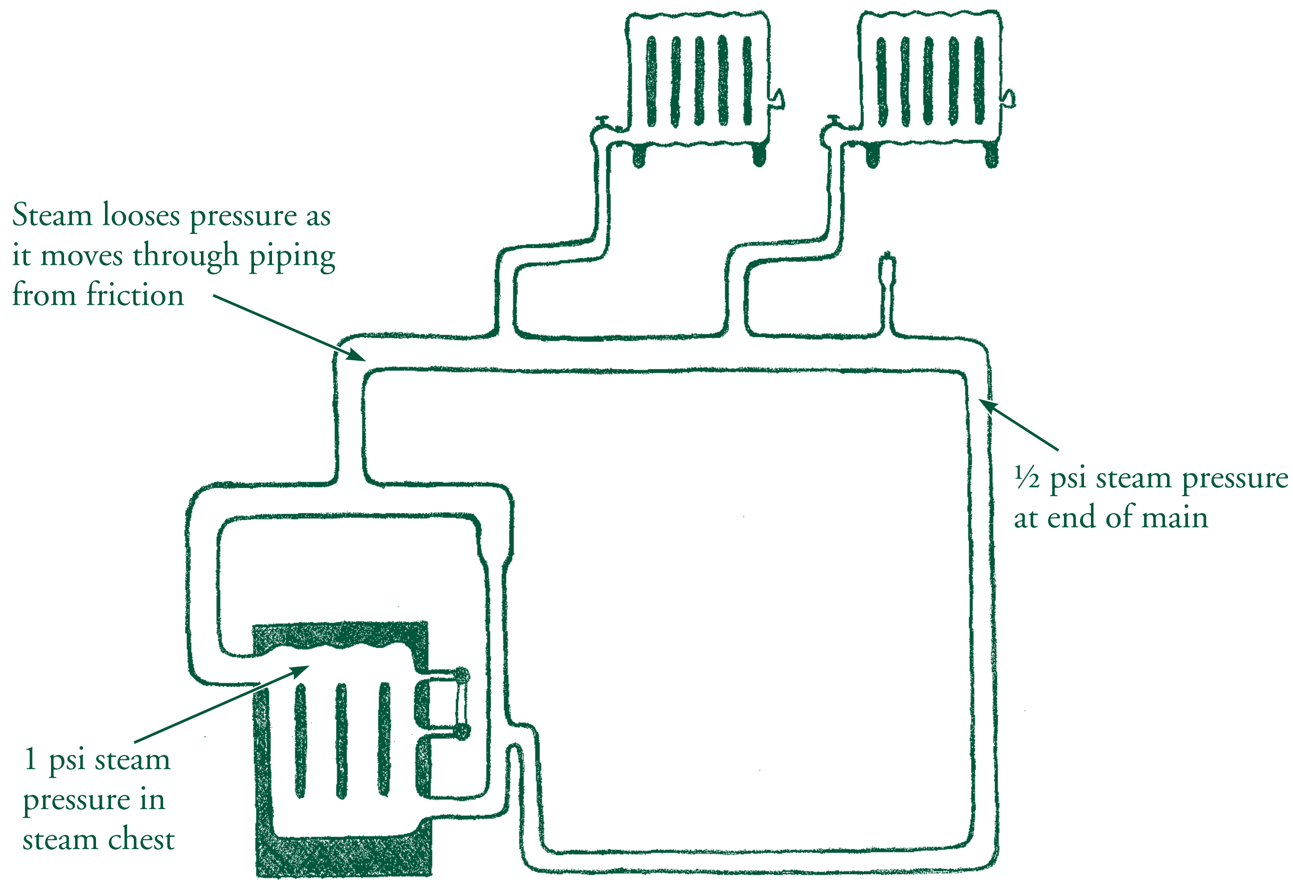
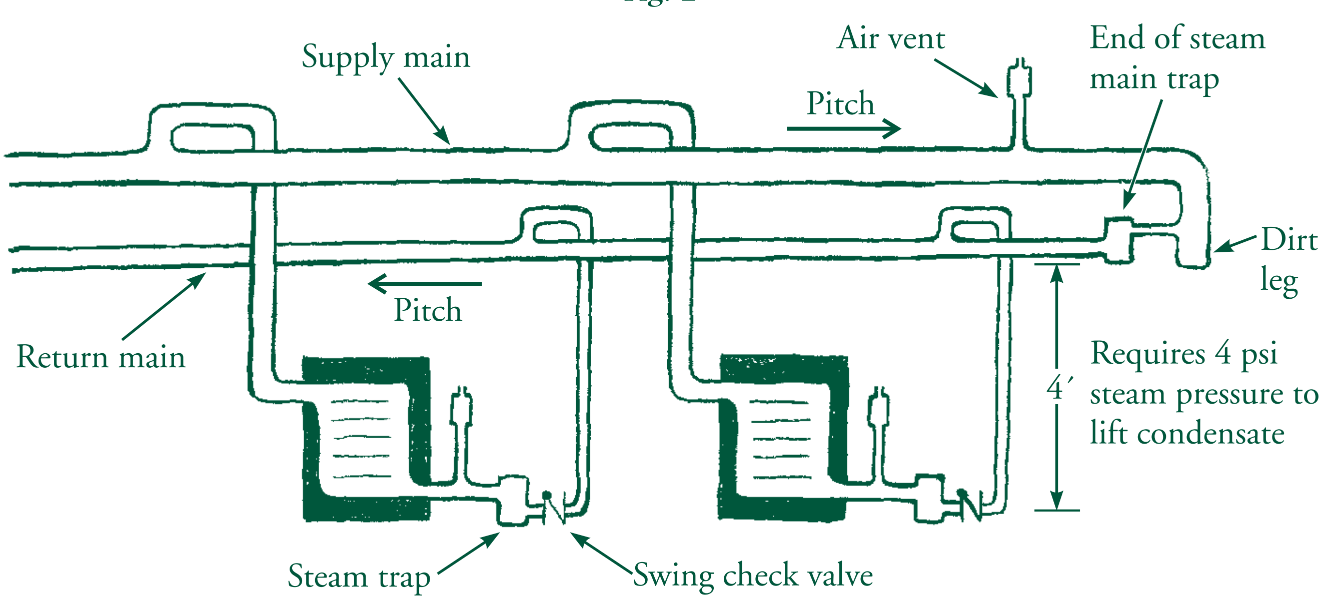

Steam looses pressure as it moves through piping from friction
½ psi steam pressure at end of main
1 psi steam pressure in steam chest

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?

Types of Steam Distribution Systems

Fig. 1

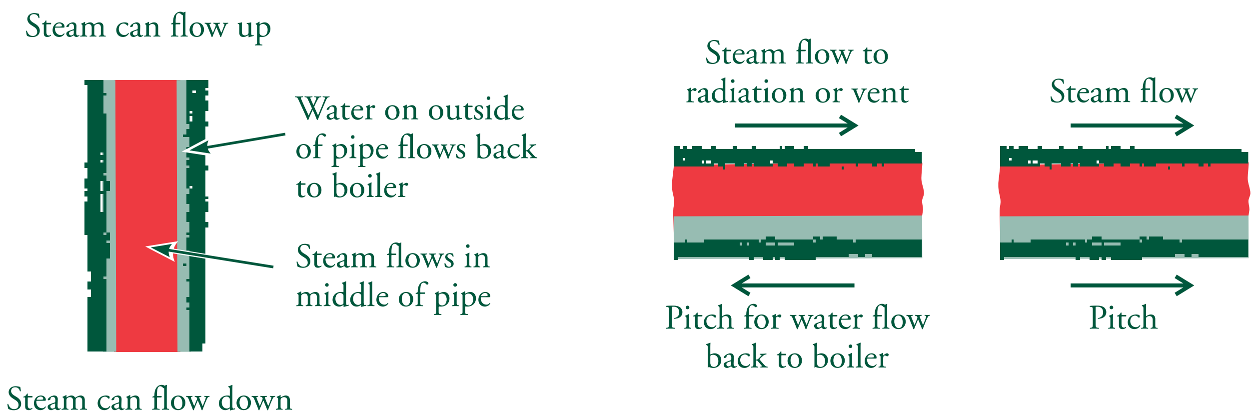


Fig. 2

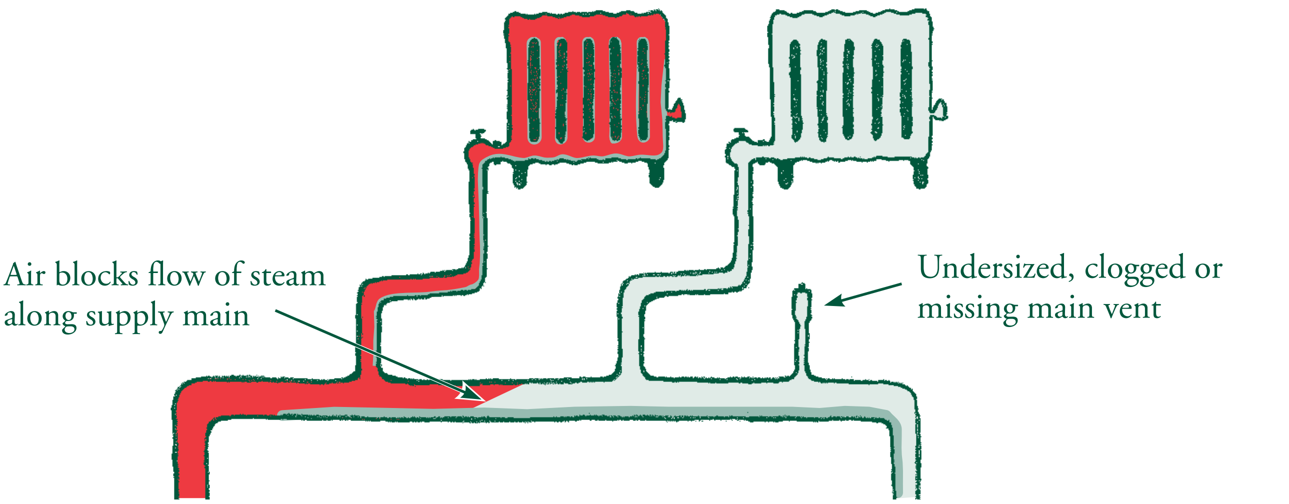
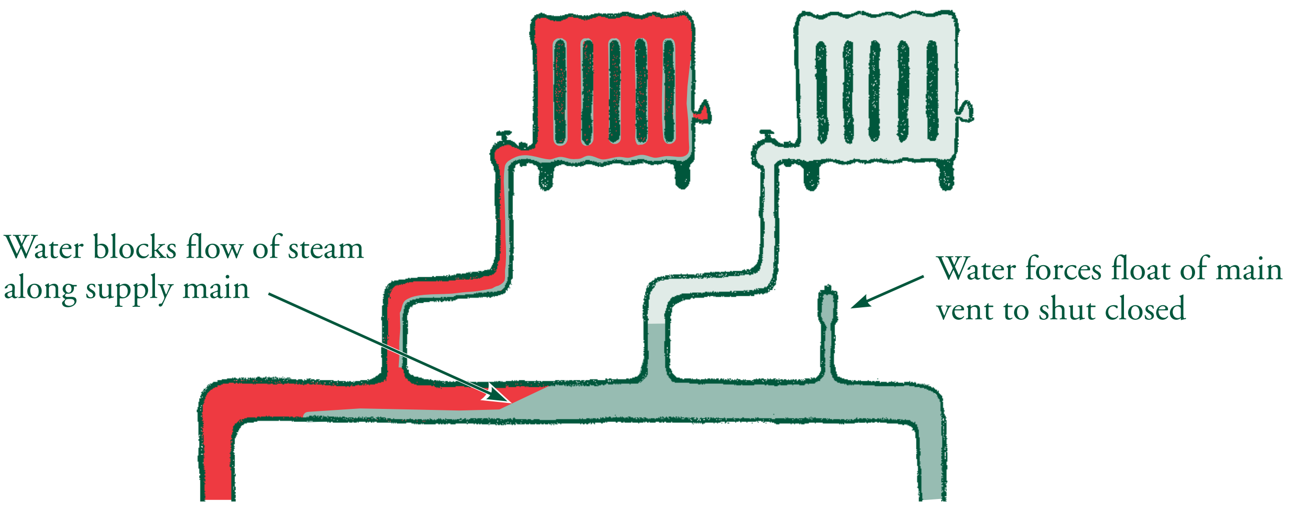


Fig. 3



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

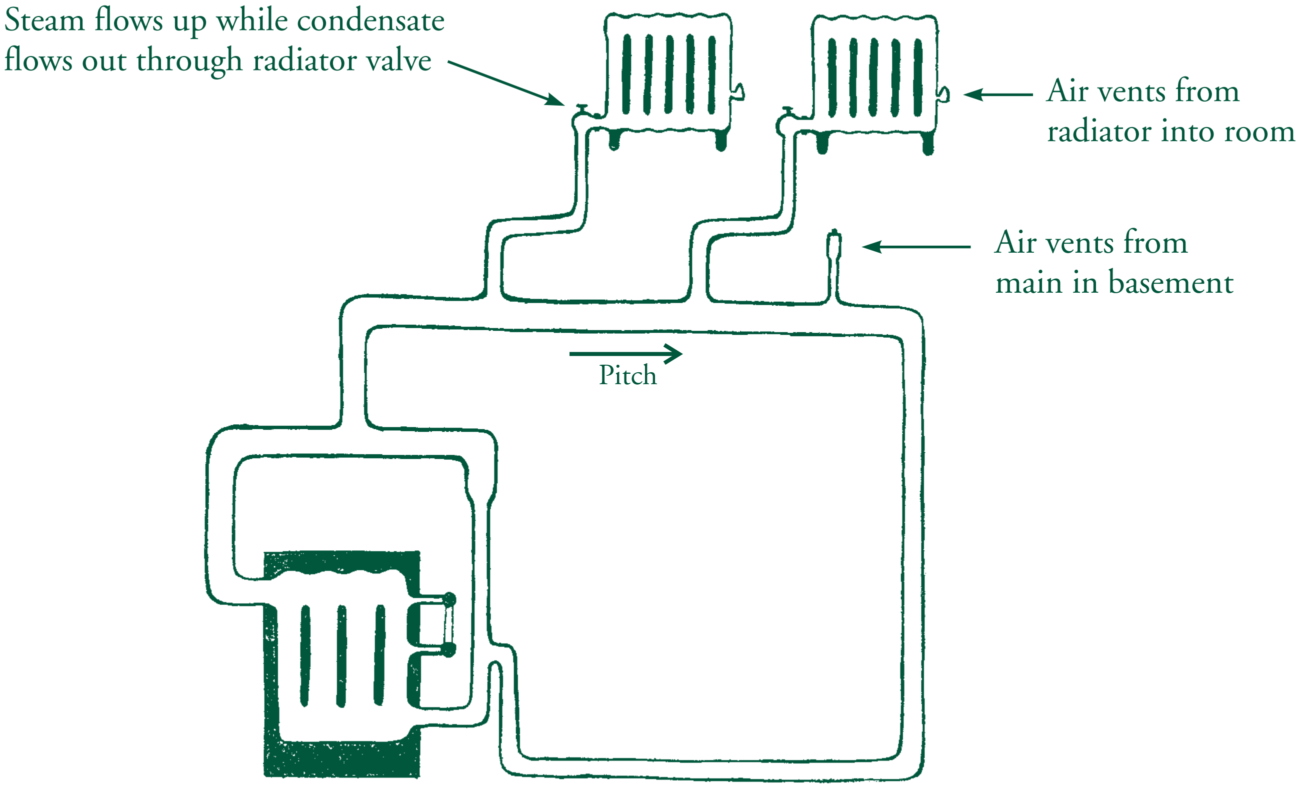
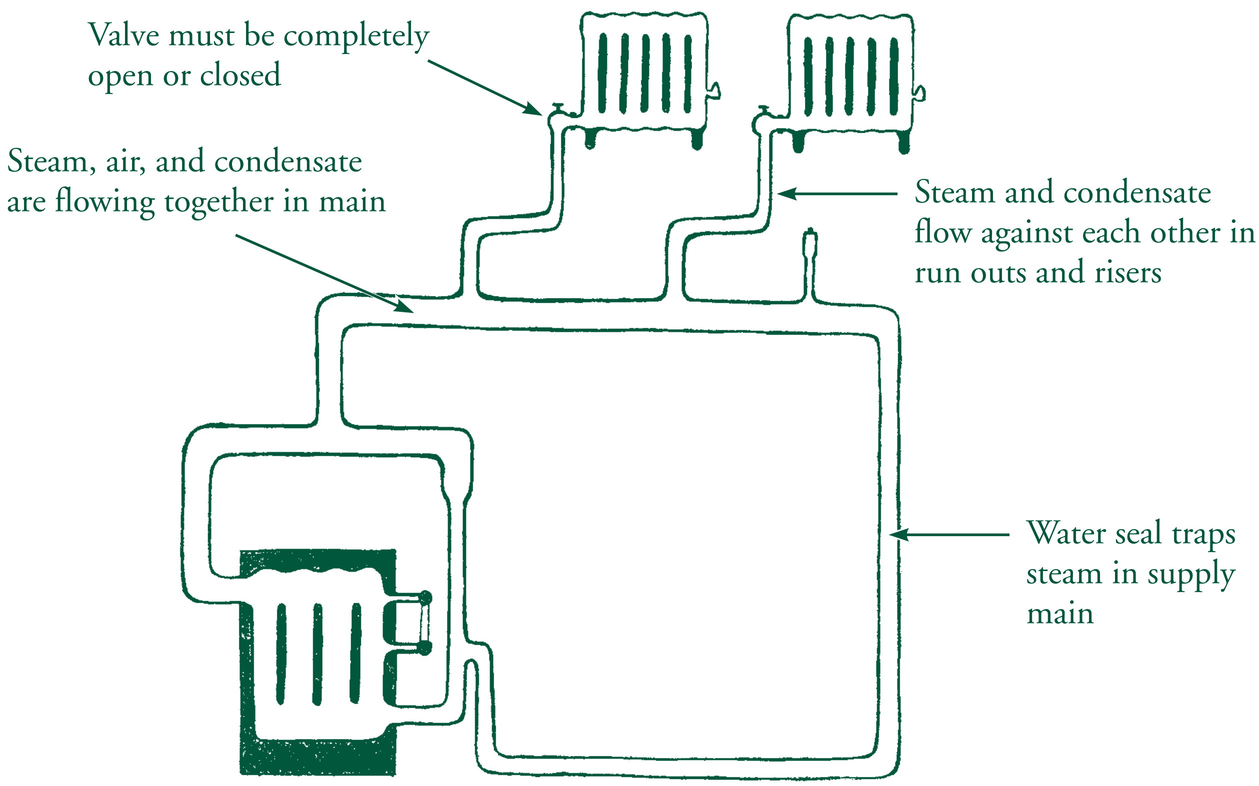

Steam flows up while condensate flows out through radiator valve
Air vents from radiator into room
Air vents from main in basement
Pitch

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

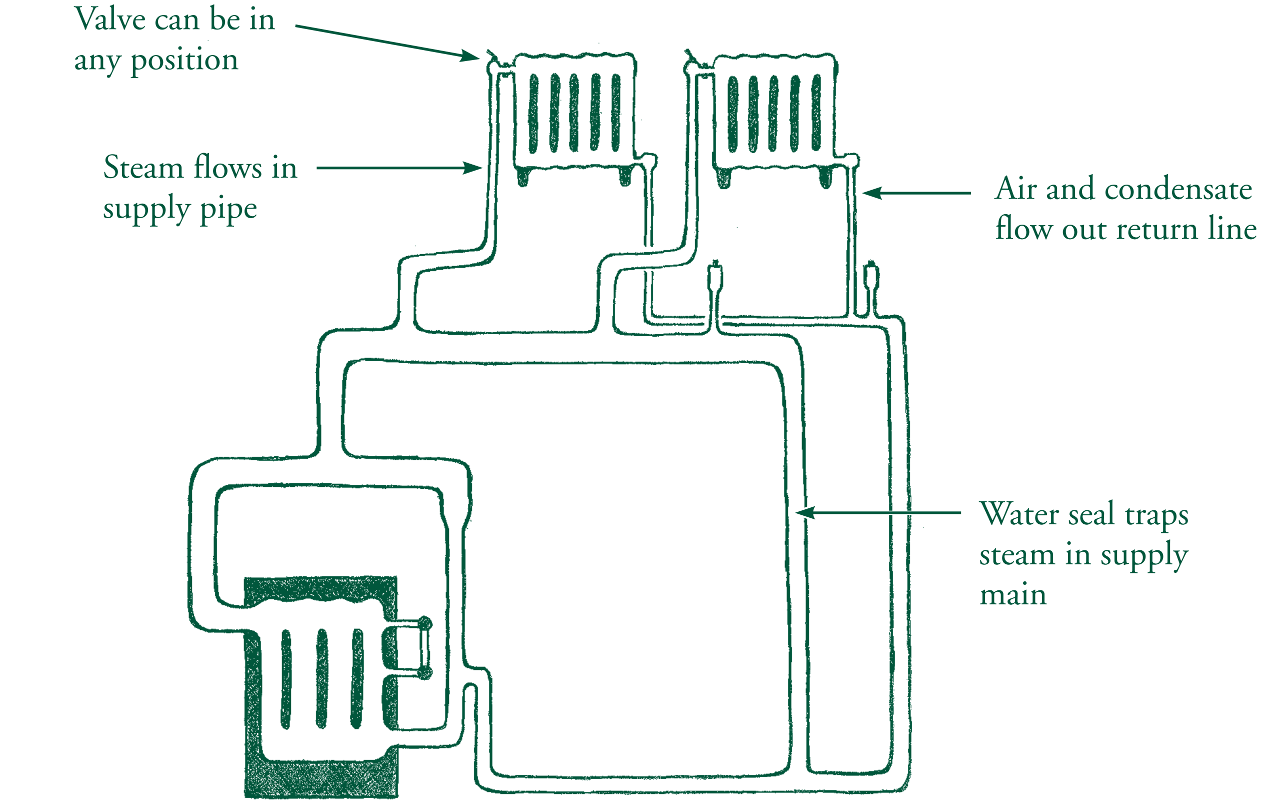
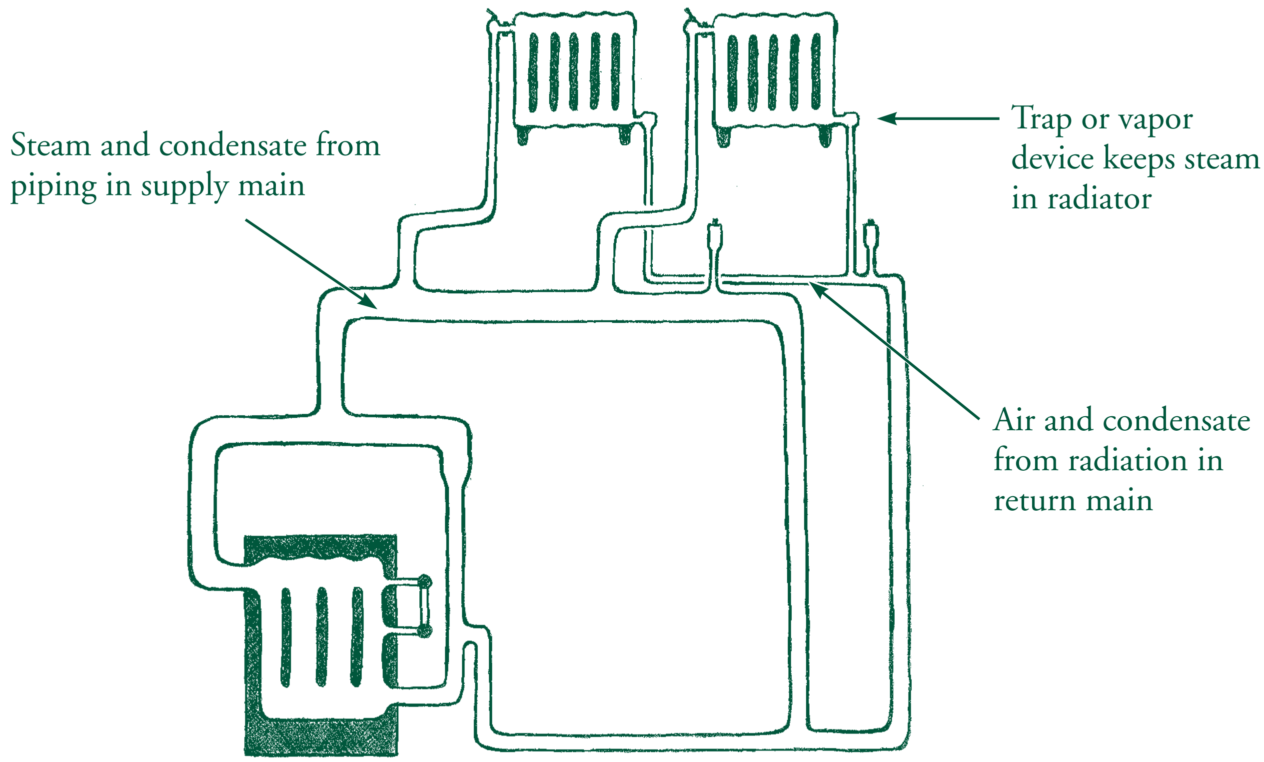

Valve can be in any position
Steam flows in supply pipe
Air and condensate flow out return line
Water seal traps steam in supply main

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.

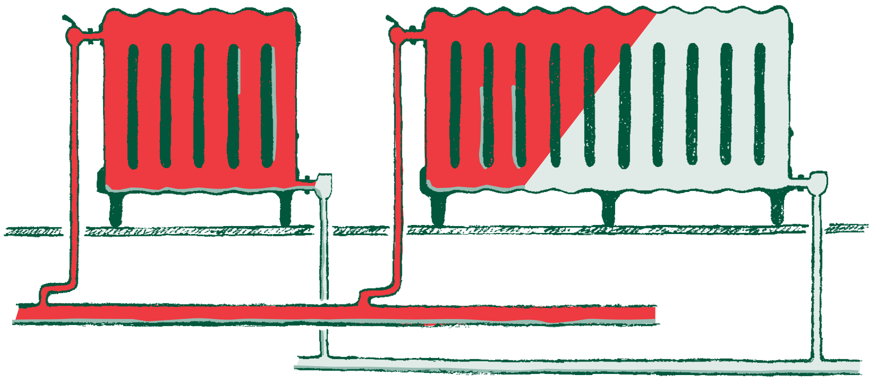
- Fig. 3 Removal of orifices or valves can allow steam to enter return lines, where it's not supposed to be, which causes uneven heating and water hammer.

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

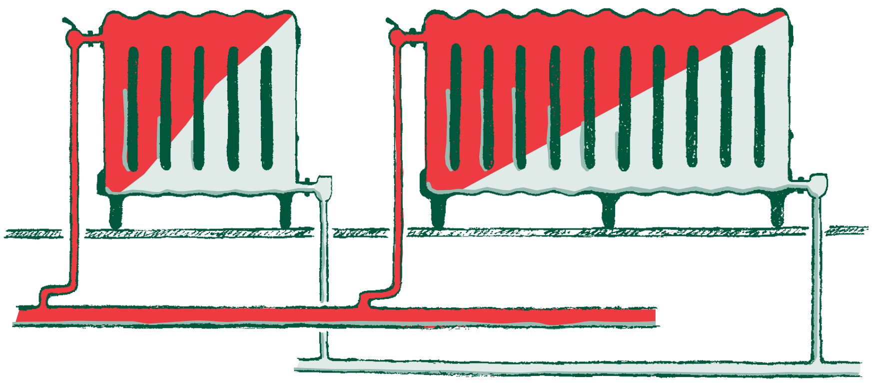
Radiator full of steam — Radiator half full of steam



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

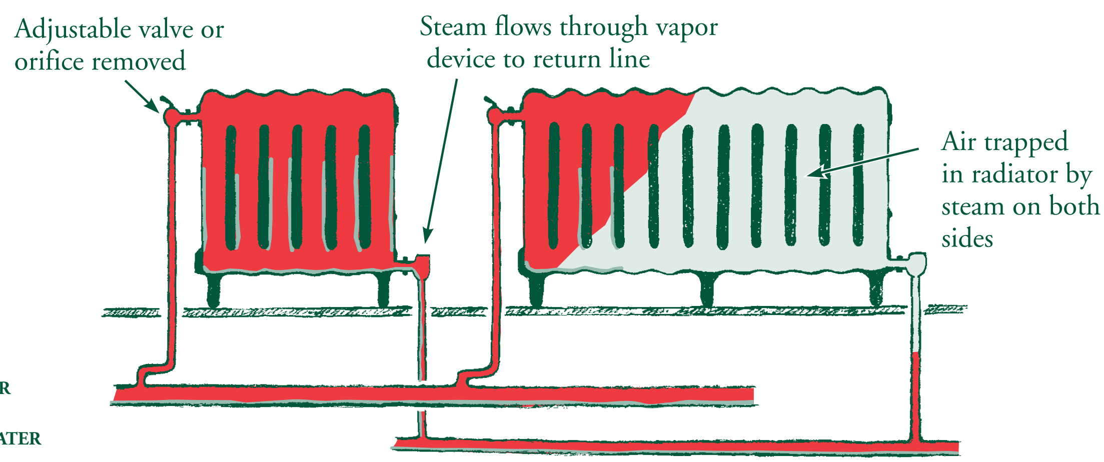
Fig. 2

Both radiators half full



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

Fig. 3



AIR
WATER
STEAM

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.

Parallel/Counter Flow and Up Flow/Down Flow

Fig. 1

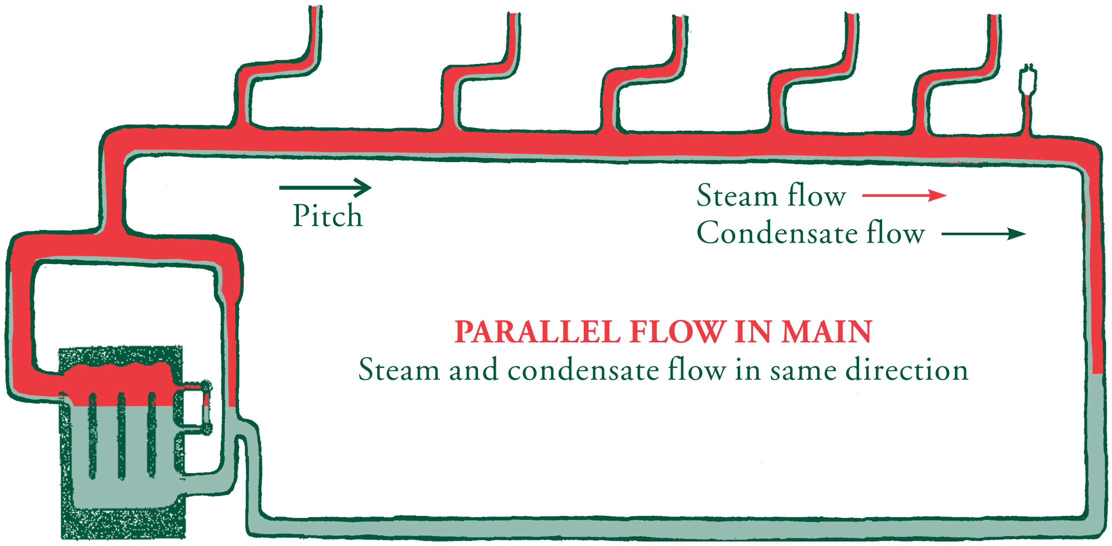


Fig. 2

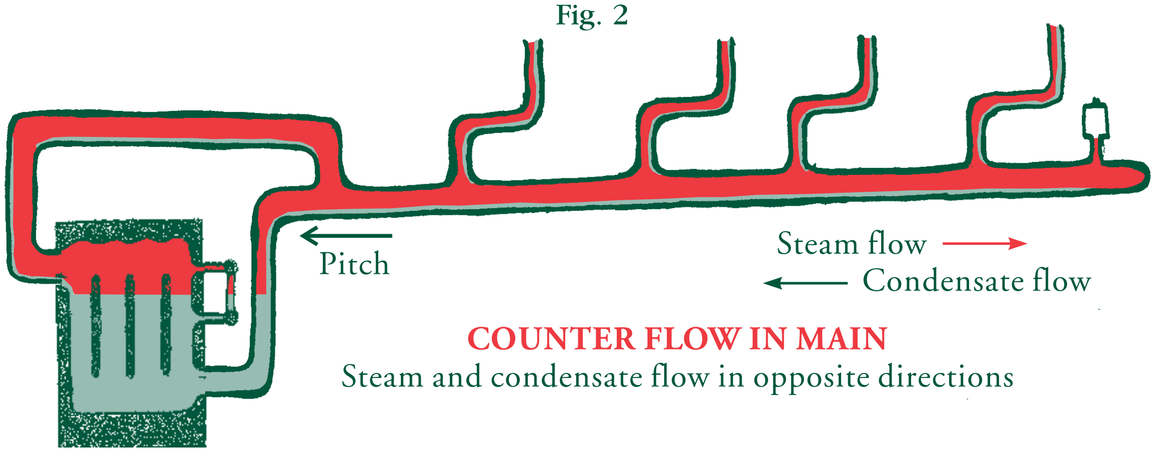


Fig. 3

DOWN FLOW

Supply main in attic

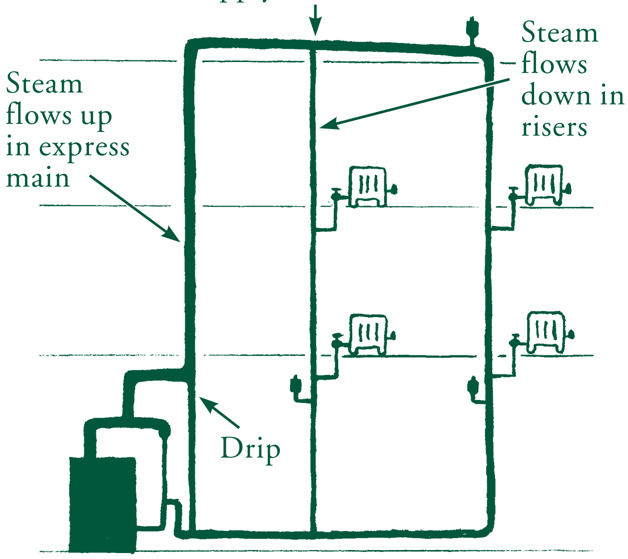
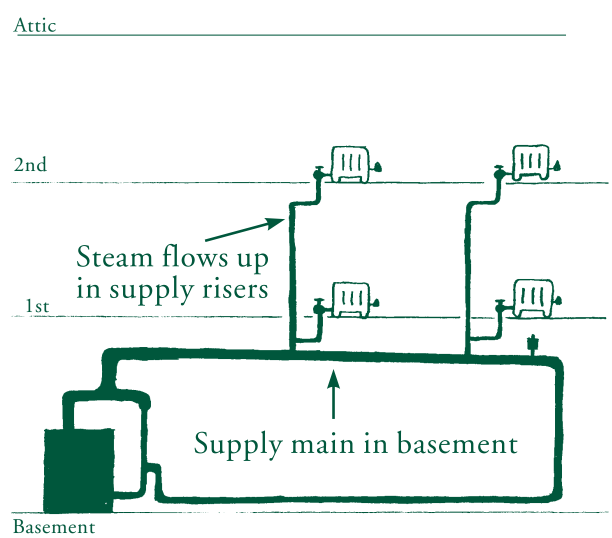


Fig. 4

UP FLOW



AIR WATER STEAM

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

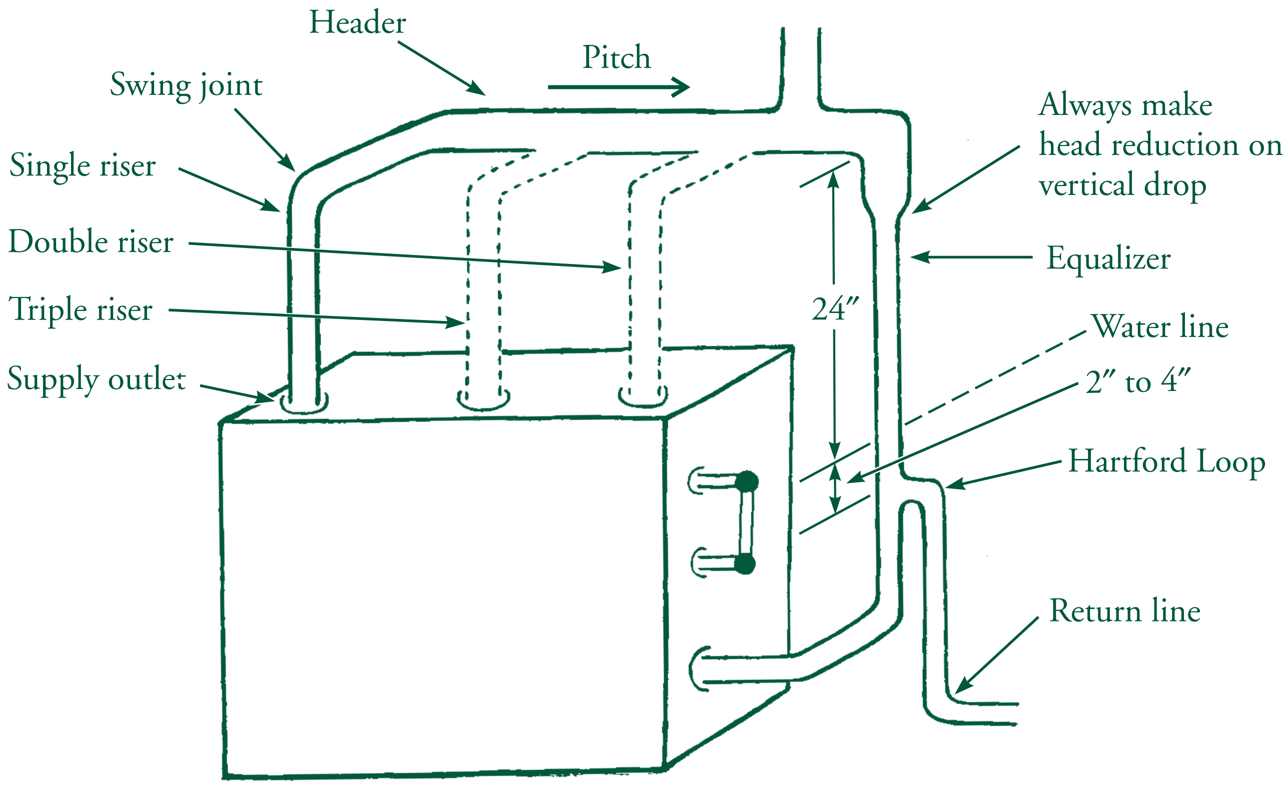


Fig. 2

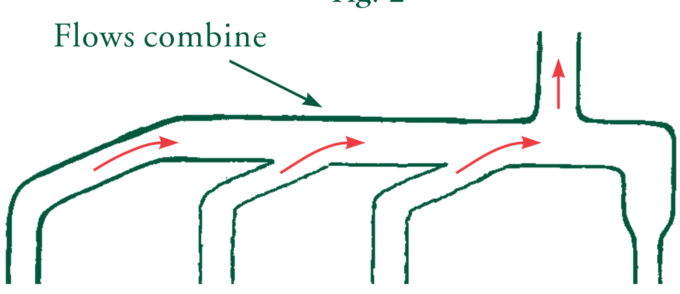


Fig. 3

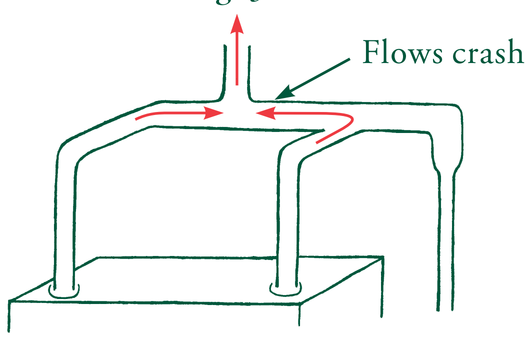
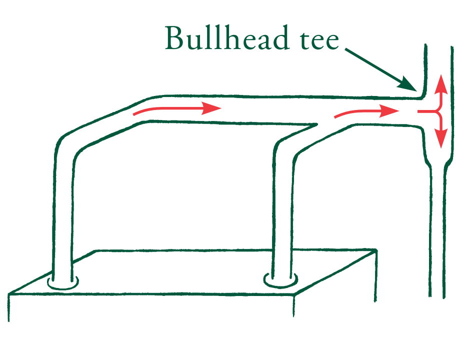


Fig. 4



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.

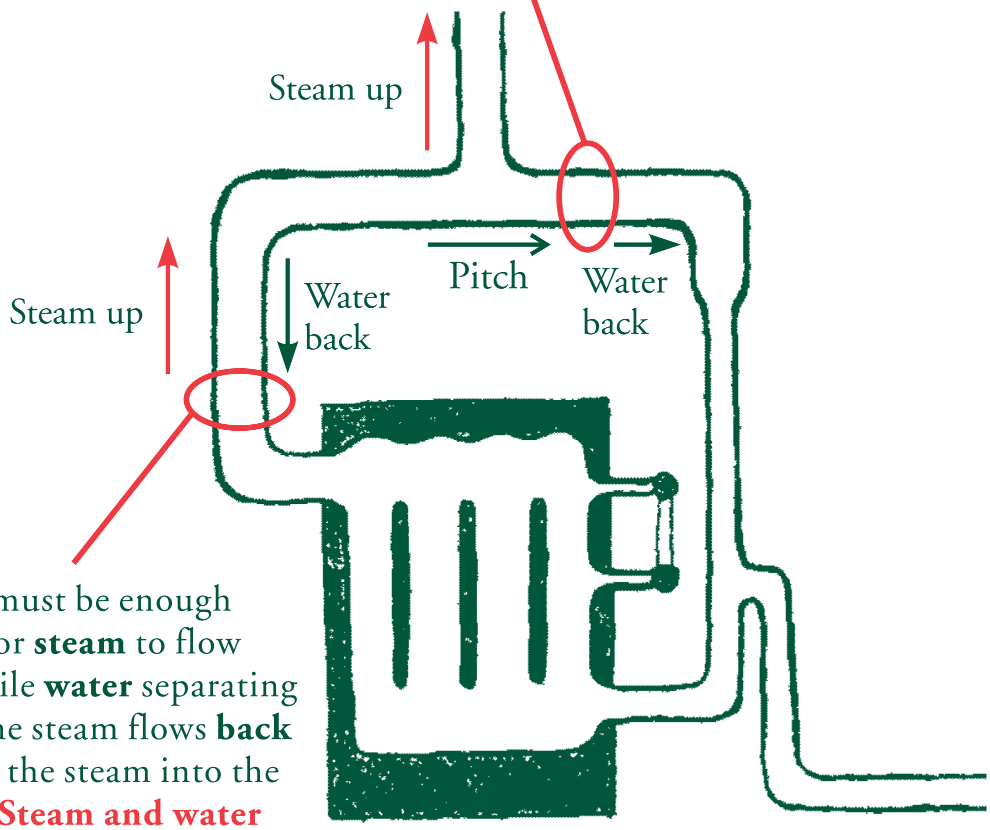
The velocity of steam flow out of the boiler is critical.

- 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.

Calculating Velocity at Boiler

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.

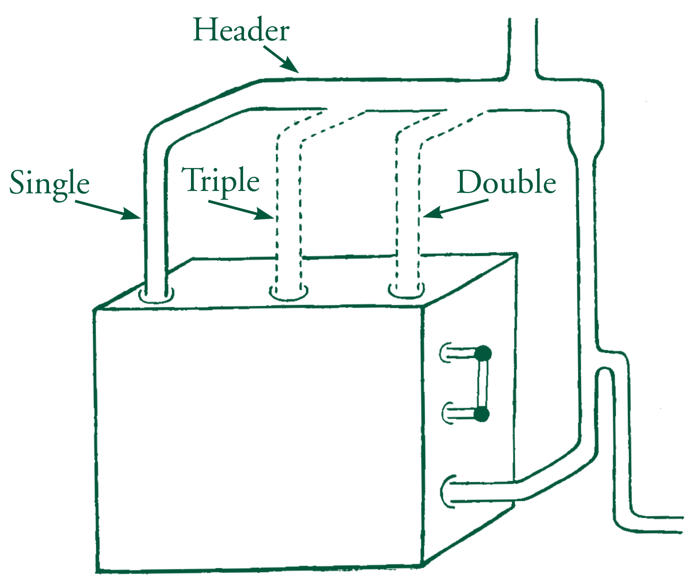
- Make sure the boiler water is clean and the water line is not set too high.

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		Double Risers		Triple Risers		Header	
			25 FPS	50 FPS	25 FPS	50 FPS	25 FPS	50 FPS	25 FPS	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

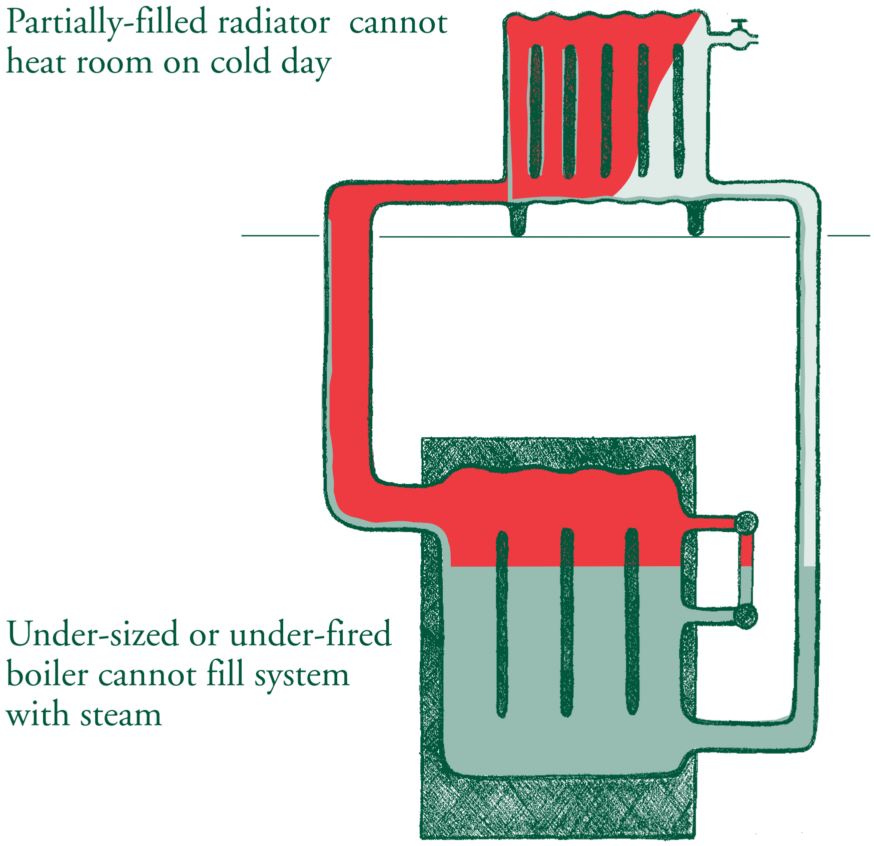
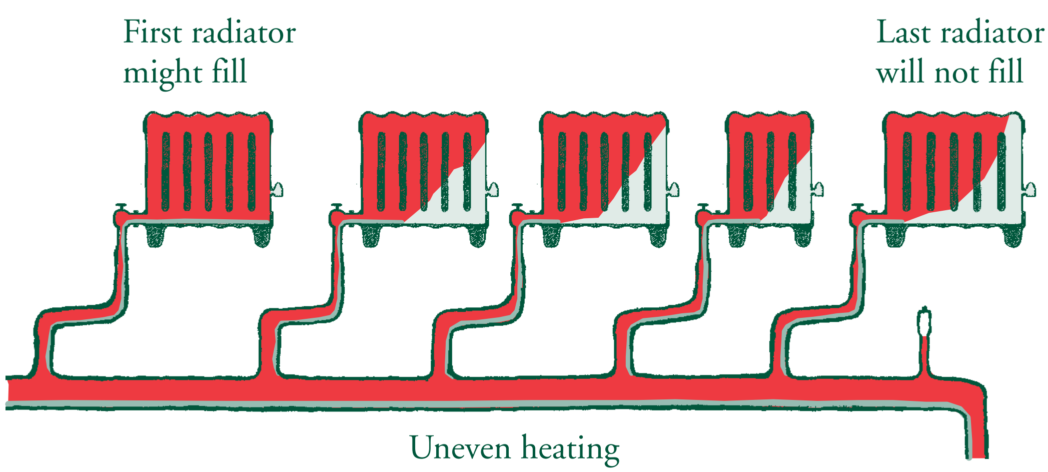

Partially-filled radiator cannot heat room on cold day
Under-sized or under-fired boiler cannot fill system with steam

Fig. 2


First radiator might fill
Last radiator will not fill
Uneven heating


AIR
WATER
STEAM

CHAPTER FOUR

Air Out

Why Venting All the Air from the Piping and Radiation Is Important

Steam and air cannot occupy the same space, therefore air must be vented from the radiation and the piping before steam can enter.

- Steam pressure could compress the air, but only with pressures not used in normal heating work.
- Air bound systems waste money trying to heat.
- The rate at which the air is removed is the rate at which the steam enters the radiation.

Fig. 1 Venting should be done at a rate that does not create any back pressure at the boiler, this is especially important with vapor systems.

- Back pressure at the boiler can cause the burner to shut off on the pressure control setting during a run cycle.
- This short cycling of the burner causes uneven heating and high fuels bills.

Fig. 2 Venting needs to be done at both the radiation and the ends of the mains. For one pipe work vent the supply main, while for two pipe work, vent both the supply and the return mains.

- In theory, the main vent on the supply main causes steam to first flow to the end of the main, then into the takeoff to feed the radiation at a uniform rate.
- Once steam is established the length of the main, the farthest radiators will receive steam as quickly as those close to the boiler.

Fig. 3 The ideal air vent, if on the radiator or the piping, will eliminate air from the system at a rate consistent with best results (too fast causes spitting, too slow causes uneven heating) and to close the vent port when steam or water is present.

- Most vents are designed for closure to both steam and water.
- Some "Quick Vents" are designed to close only to steam, not to water. These should be used only at high points of systems where water will not be present.

The ideal burner run cycle during a "call for heat" is one that is not interrupted by the high pressure limit.

- By not removing the air from the system at a fast enough rate, pressure will build up in the system and open the contacts on the high limit to shut off the burner.
- This type of short cycling wastes fuel and causes uneven heating.
- Refer to page 84 for sizing the vent to prevent short cycling.

Why Venting All the Air from the Piping and Radiation Is Important

Fig. 1

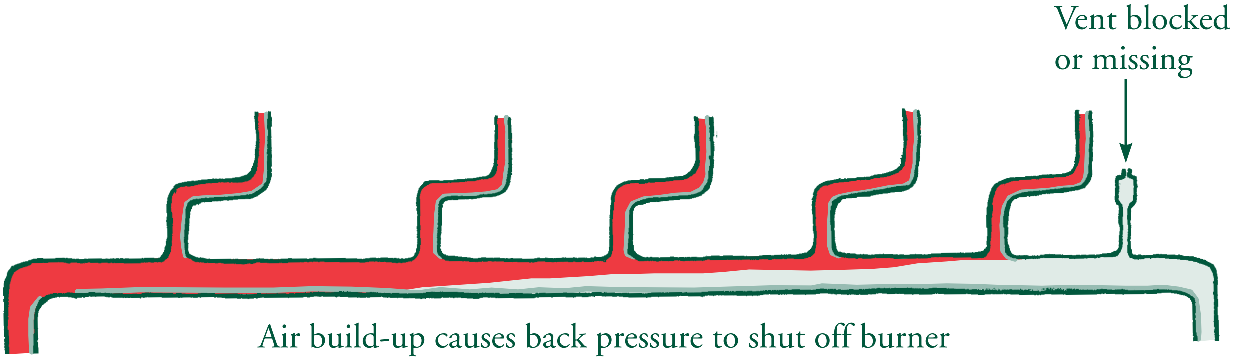


Fig. 2

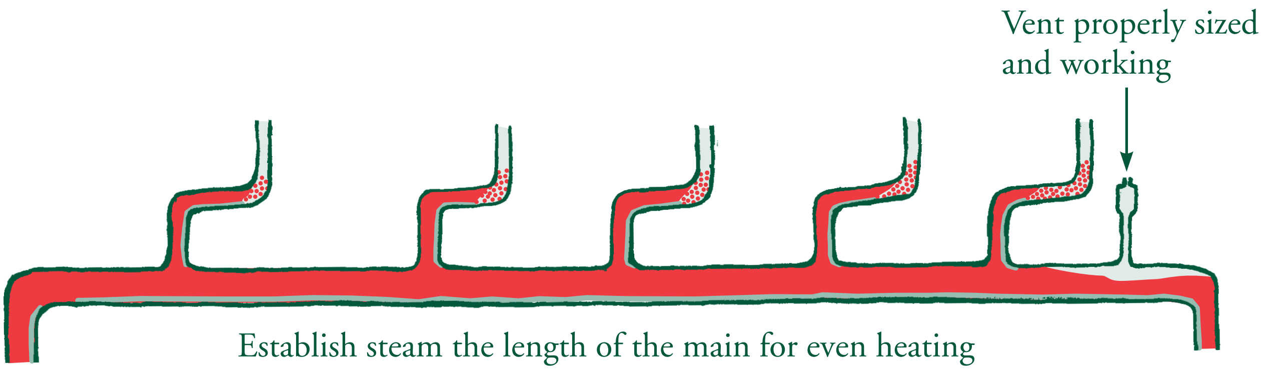
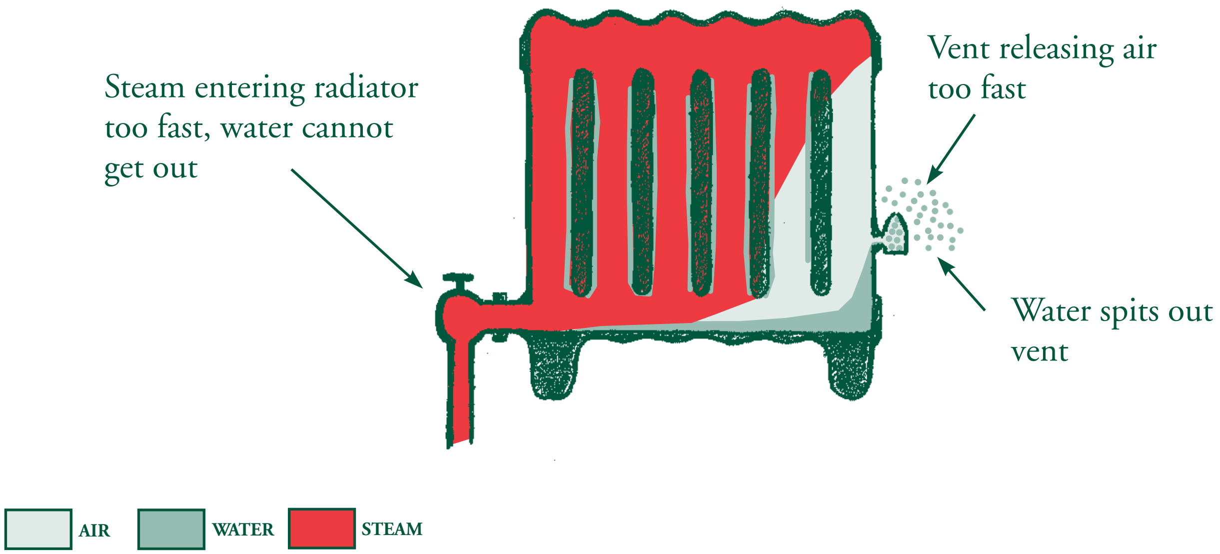


Fig. 3



Follow the Path of Air Out of the System

Air fills the radiation and piping at start-up.

- **Air** must be pushed or pulled **out** of the system so that **steam** can fill it **up**.

Air in the near boiler piping and supply mains is forced to the end of the steam supply main by the flow of the steam.

- **Fig. 1** Air typically leaves the supply main through the main air vent.
- **Fig. 2** Air can also pass to the dry return on two pipe systems by a radiator trap installed above the main.
- **Fig. 3** End of supply main F+T traps can be used to pass air to a vented condensate, boiler feed, or vacuum unit.

Air in the run outs and upfeed risers is forced into the radiation.

- **Fig. 4** In a one pipe radiator the air is forced through an air vent to atmosphere or through an air valve to a vacuum pump or central venting point.
- **Fig. 5** In a two pipe radiator the air is forced through the trap to the dry return, where it is vented to atmosphere through a main vent or to a vacuum pump.

In systems with a vacuum pump, the air is drawn to the vacuum unit and vented to the atmosphere.

- Vacuum units do a great job of air removal, therefore creating better steam distribution.
- Vacuum units pull the air quickly through the mains and radiation to allow the steam to flow quickly and evenly.

Follow the Path of Air Out of the System

Fig. 1

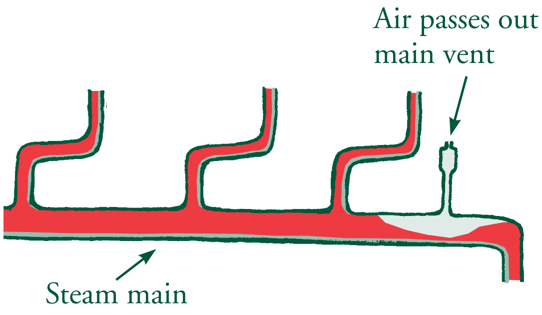


Fig. 2

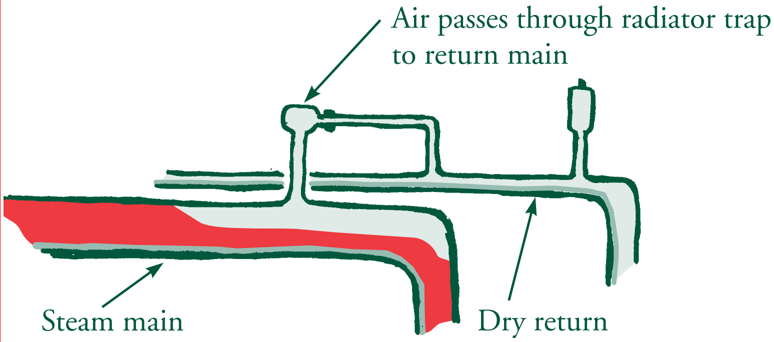


Fig. 3

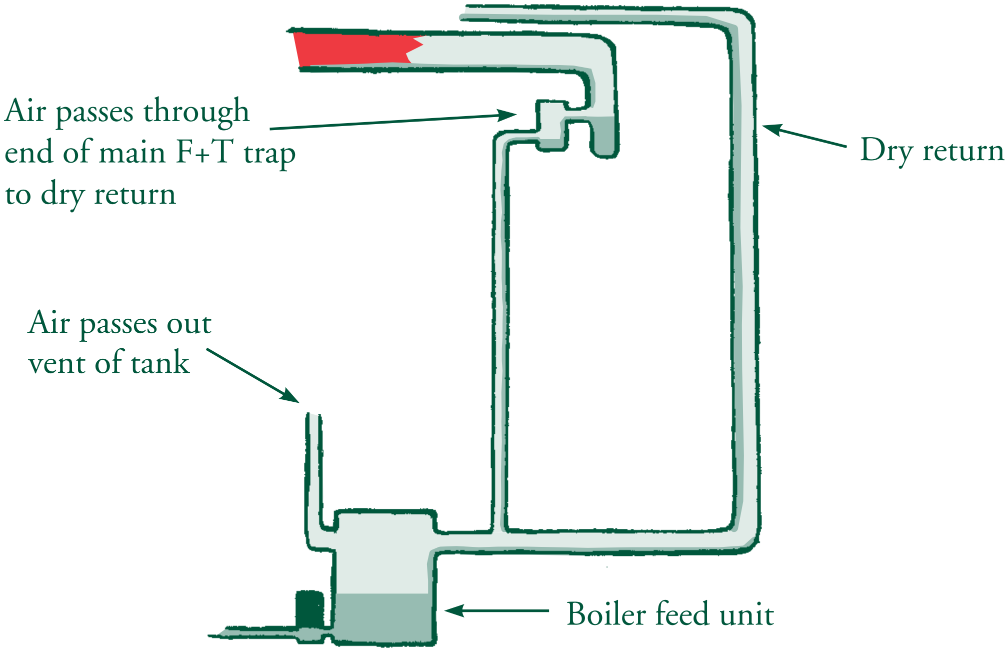


Fig. 4

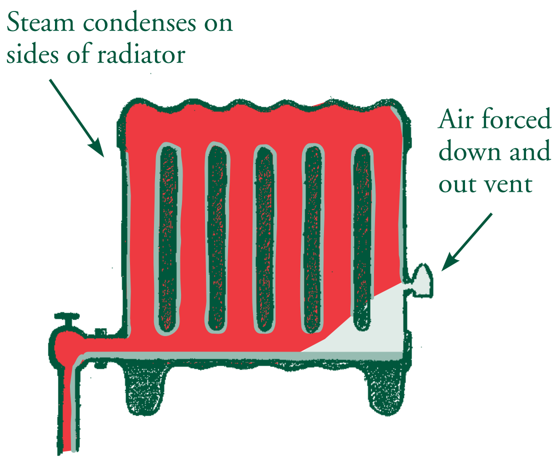
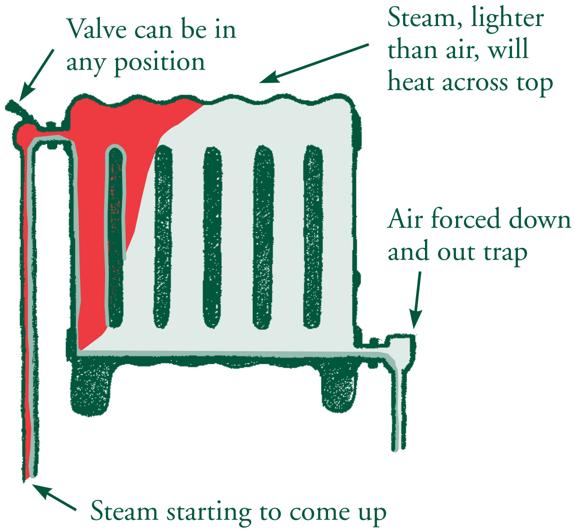


Fig. 5



Venting One Pipe Steam

Fig. 1 One pipe steam systems need vents at both the radiators and the ends of the steam main to allow even heating.

- Using vents on the radiator alone can cause radiators closest to boiler to heat faster than those radiators farthest from the boiler.
- If the thermostat is located near the boiler, the far ends will be cold.
- If the thermostat is located away from the boiler, the area closer to the boiler will be too hot.
- If the main vent is not large enough, uneven heating will result. Refer to page 84 for main vent sizing,

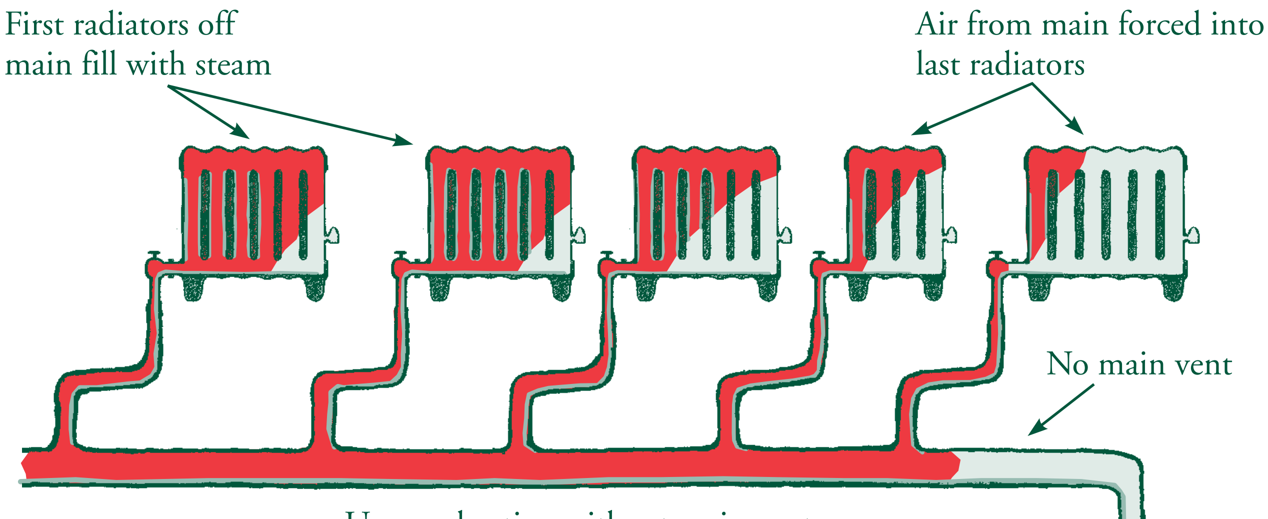
The ideal automatic air vent for a radiator on a one pipe steam system will eliminate air, close instantly for steam, and not allow water to leak or spit.

- The vent should be open to allow air to pass freely from the radiator.
- At the presence of steam, the vent should instantly close the vent port, containing the steam in the radiator.
- As this steam condenses in both the body of the vent and the radiator, the vent should not allow this water to escape through the vent port.
- The tongue of the vent allows the water to flow out of the vent.

Fig. 2 Too fast a venting rate of the radiator vent can force water to the vent end of the radiator, because the velocity of the steam is entering the radiator too fast.

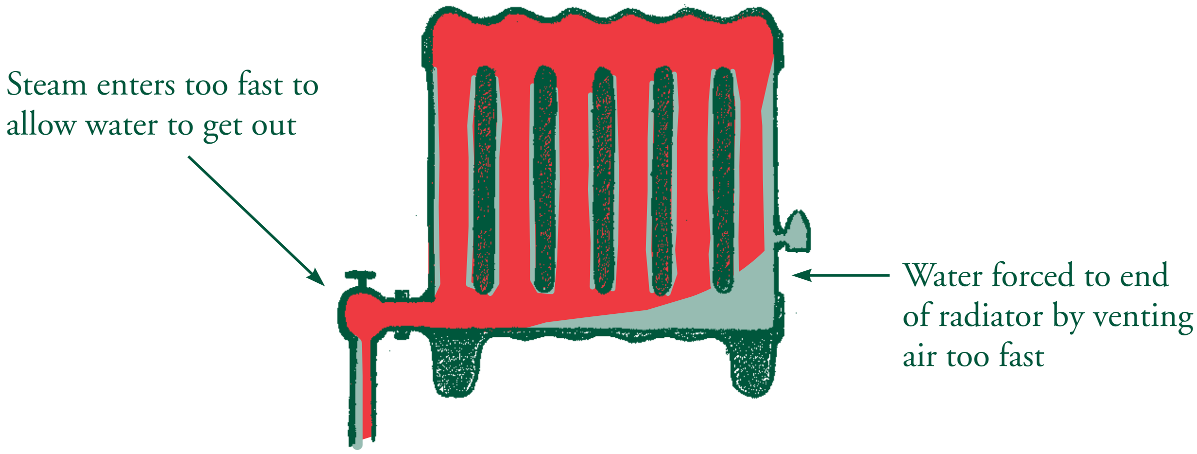
- Forcing water to the wrong end of the radiator keeps it from flowing out of the radiator.
- Too much water can close the vent with its float action, preventing any more air to leave or steam to enter.
- The high velocity of too fast a venting rate can cause any water present to be picked up and vented out with the air instead of flowing out of the radiator valve.

Fig. 1



Uneven heating without main vent

Fig. 2



AIR WATER STEAM

Venting One Pipe Steam, continued

Some vents are available with an adjustable vent rate feature.

- The vent port size can be made smaller to slow the venting rate, or made larger to speed up the venting rate.
- Adjustment can be made to compensate for location or size of the radiator.
- A large radiator may need a faster venting rate than a smaller radiator.
- A radiator at the end of the main may need a faster venting rate than a radiator at the start of the main.

Fig. 1 Radiator vents have a rating called drop-away pressure.

- The drop away pressure is the steam operating pressure that the vent can open against.
- If the steam pressure in the system is greater than the drop away rating, the vent will remain closed and no more steam will enter.
- Adjustable or quick vents can have a low drop-away pressure. Be careful with their application.

Fig. 2 One pipe steam systems with cast iron radiators work best if all the radiator vents are the same model from the same manufacturer venting at the same rate.

- A consistent venting rate proportions the steam flow throughout the supply piping
- Large radiators can be drilled and tapped to have two vents.
- With two vents, twice the volume of air is removed, but at the same rate as the rest of the system.
- Two vents can prevent water from spitting, while filling the radiator with steam.

Fig. 3 The venting rate can be controlled by a thermostatically controlled air vent.

- The actuator reacts to the temperature of the room.
- It will keep the vent open, allowing steam flow into the radiator, when the room cools down.
- It will shut off the vent, stopping the flow of steam into the radiator, when the thermostat is satisfied.

Fig. 1

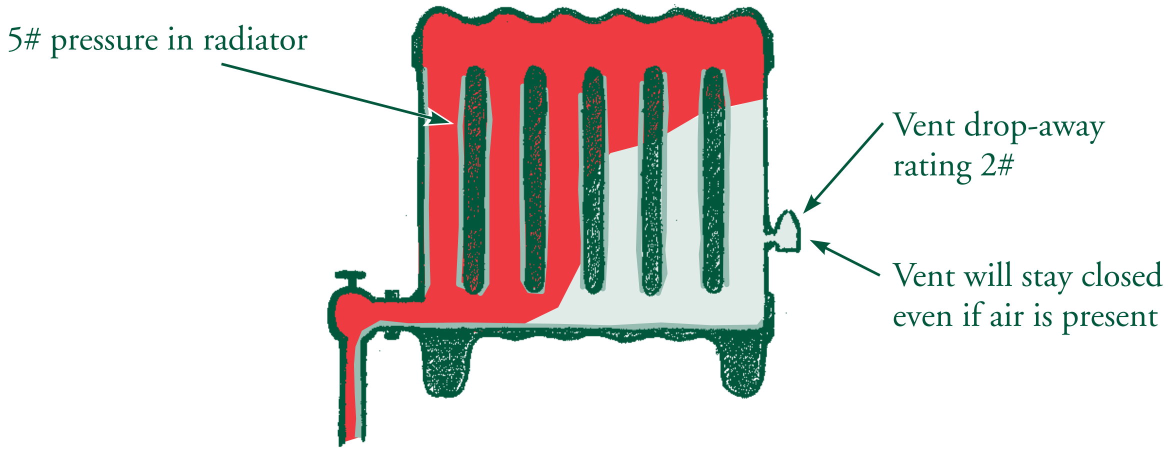


Fig. 2

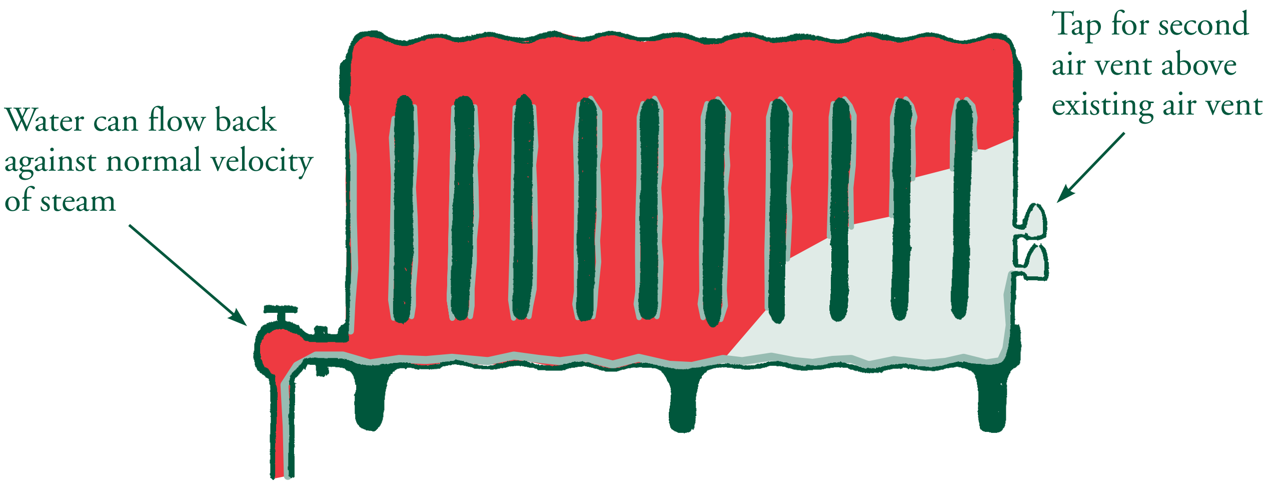
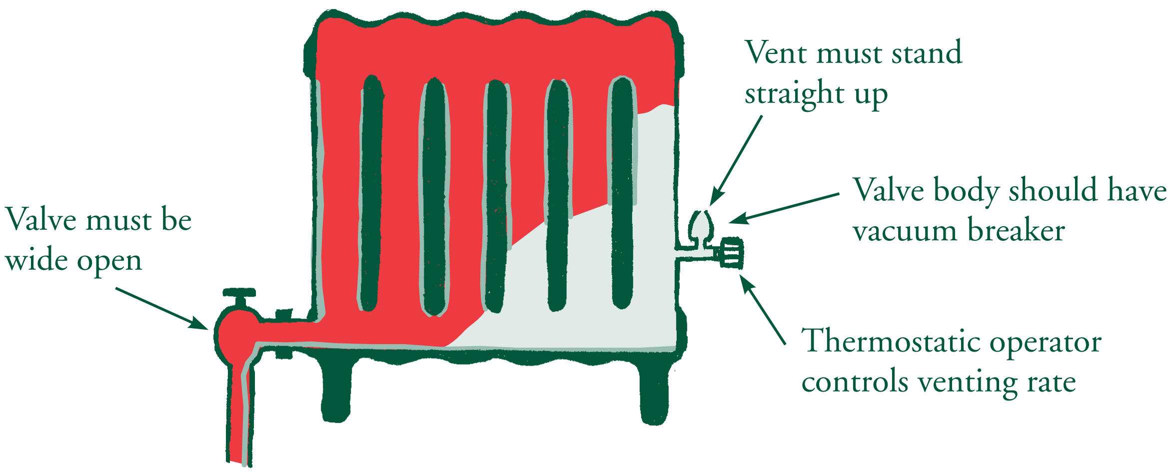


Fig. 3



AIR WATER STEAM

Venting One Pipe Steam, continued

Fig. 1 Vents used on coal-fired systems had a built-in check valve to prevent air from re-entering the system.

- The system would go into a vacuum as the steam condensed and closed the check valves.
- The vacuum would allow the boiler to continue making steam as the coal fire died down during the night. See page 169 for vacuum /temperature relationships.
- Today's systems don't use the vacuum vents because they operate with burners that are on-off, which prevent the formation of a vacuum at burner shut-off.

Fig. 2 The old coal-fired systems were slow to make steam.

- The air had more time to leave the system since the steam came up slowly.
- Modern boilers produce steam more quickly, so in order to heat evenly, more main vents may need to be added to the system.
- See page 84 for vent sizing guidelines.

Fig. 3 One pipe steam up flow systems in tall buildings will have vertical risers that feed many radiators, often several per floor.

- This vertical riser is similar to the horizontal mains in the basement in that it needs a main air vent.
- The top of the riser air vent will allow steam to flow up the length of the riser to fill it.
- Steam will then be available both at the top and bottom of the building at about the same time, giving more even heating.

Fig. 1

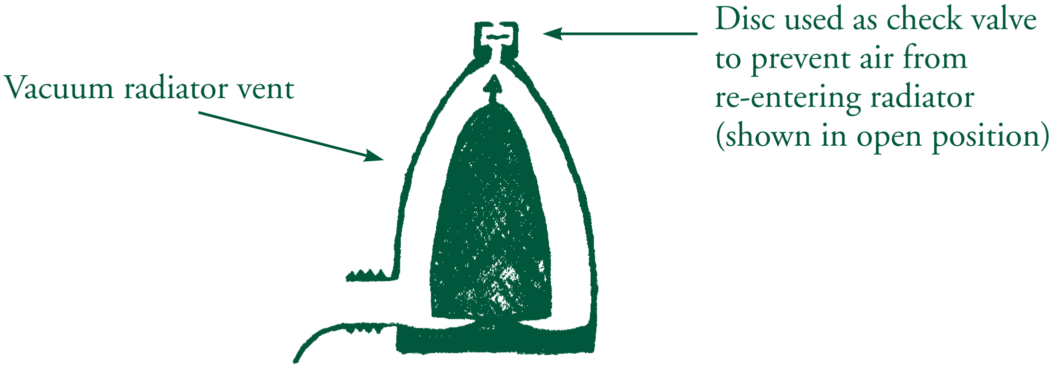


Fig. 2

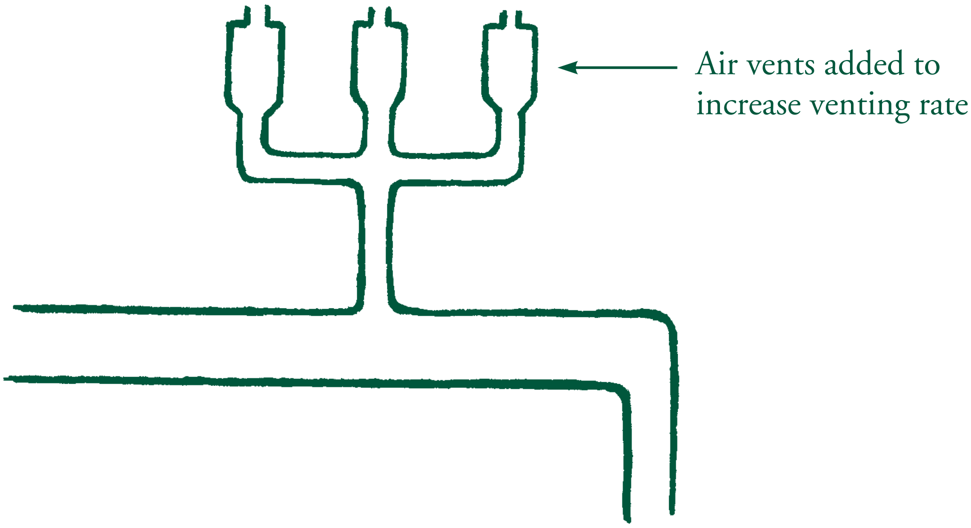
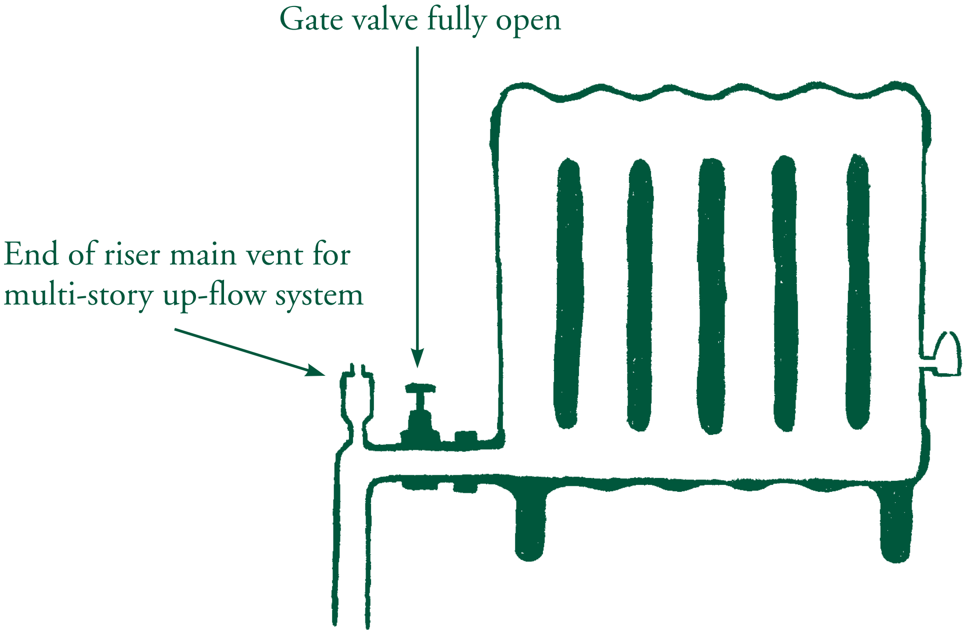


Fig. 3



Venting Two Pipe Steam

Fig. 1 The end of steam main air vent in two pipe systems are just as important as in one pipe systems.

- The end of the main vent gets steam to the radiation takeoff farthest from the boiler at about the same time as the radiation takeoff closest to the boiler.
- Without an end of main vent, pressure can build up in the boiler since the steam has less space to occupy because the air is blocking steam flow in the piping.
- Short cycling, uneven heating, and high fuel bills will be caused by removal, blockage or under sizing of the main vent.
- Refer to page 84 for main vent sizing.
- Air vents are sometimes removed because they're leaking and replaced with a pipe plug. Look at the end of all mains to follow the path of the air. If you find a roadblock like a pipe plug, remove and replace with the proper size air vent.

Fig. 2 Some two pipe steam mains use radiator style traps at the end of the supply main to vent the air over to the return main.

- These traps will be located above the mains, connecting the supply and the return mains.
- Air and steam, not water, travel from the end of the supply main to the trap.
- The trap passes the air and closes at the pressure of steam to prevent steam from entering the return line.
- On these types of systems, air passed to the return main flows all the way back through the dry return to be eliminated from the system at the main vent located in the boiler room.

Fig. 3 Air in the radiator of the two pipe system passes through the radiator trap or vapor device to the return line.

- Air will be vented from the system at the end of the return main with a main vent where the dry return ends at its connection to the wet return.

VENTING TWO PIPE STEAM

Fig. 1

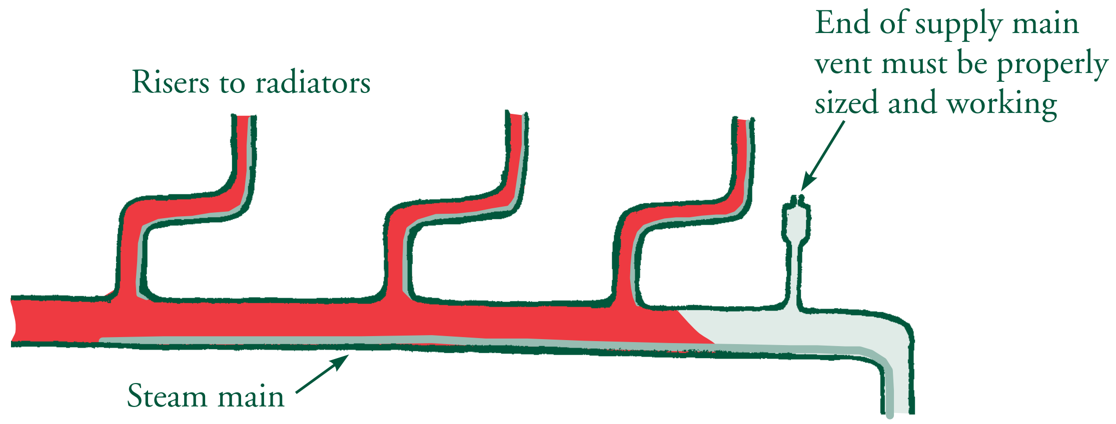


Fig. 2

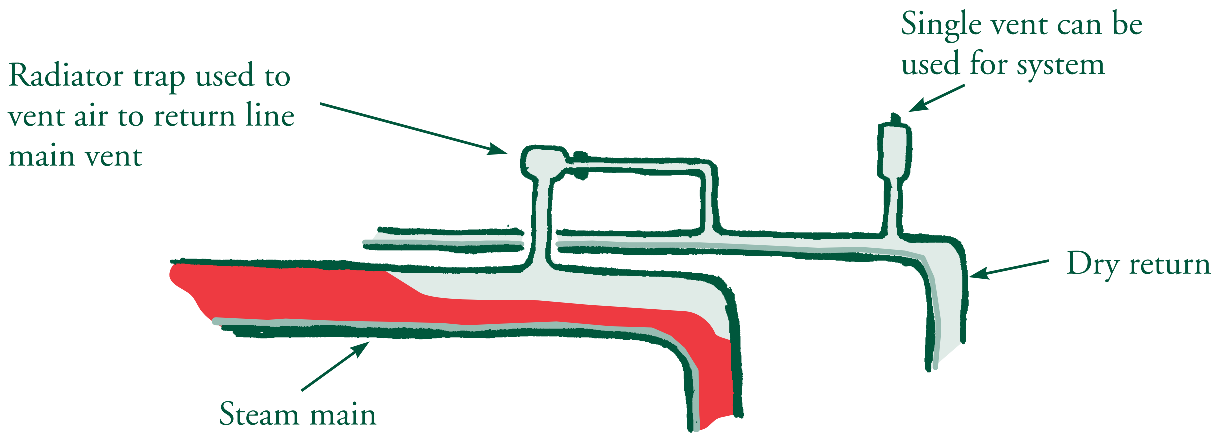
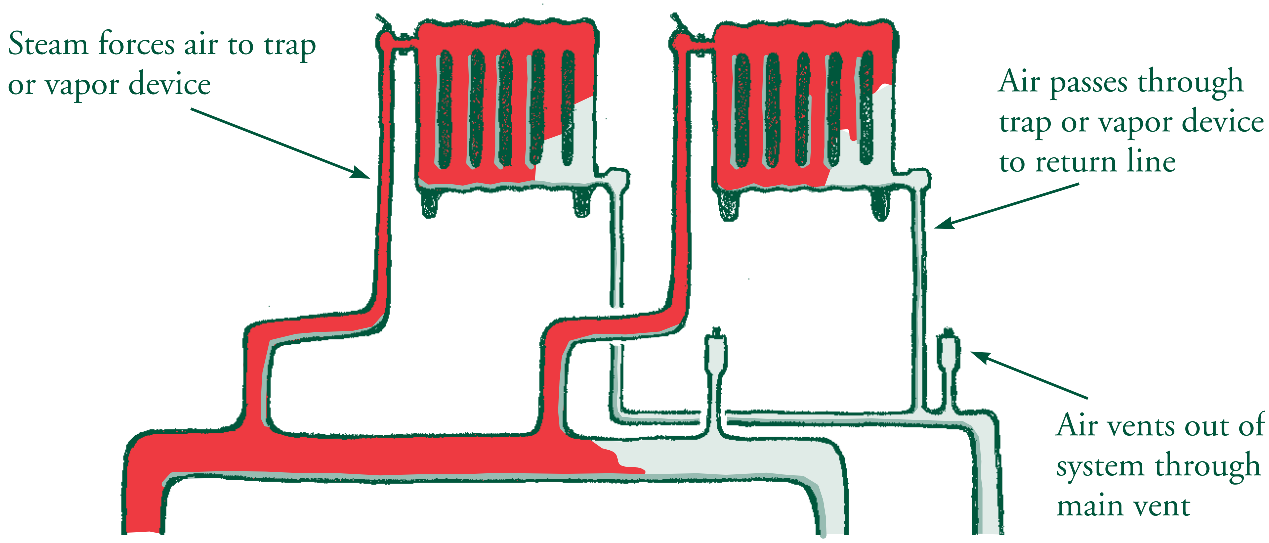


Fig. 3



Venting Vapor Systems

Vapor systems, operating on ounces of pressure instead of pounds of pressure, require a large main venting capacity.

- If any back pressure from slow removal of air from system occurs, the pressure in the boiler will quickly rise above the pressure control high pressure setting.
- This nuisance shut off will result in poor steam generation, uneven steam distribution, and high fuel bills.
- Modern steam vents do not have the same venting capacity as vents made specifically for vapor systems.
- Fig. 1 Adding a second or third main vent at the same location will increase the venting rate, keeping pressure from building up in the system.
- See page 84 for vent sizing guidelines.

Fig. 2 Vapor systems were typically two pipe systems with vapor devices instead of traps.

- Air passes out of radiator through the vapor device to be vented from the system at a main vent.
- The radiator inlet valve only allows as much steam in the radiator as it can condense. No steam should pass through the vapor device.

Some old vapor systems had dry returns connected to the chimney, without using any main vent.

- The end of the return main would be piped through a radiator in the ceiling of the boiler room.
- The purpose of the radiator was to condense any moisture or vapor left in the air.
- The pipe would then be carried into the chimney to induce a slight vacuum on the return from the draft of the chimney.
- The vacuum would pull the air out of the system to speed up the flow of steam, resulting in better economy and more even steam distribution.

Fig. 1

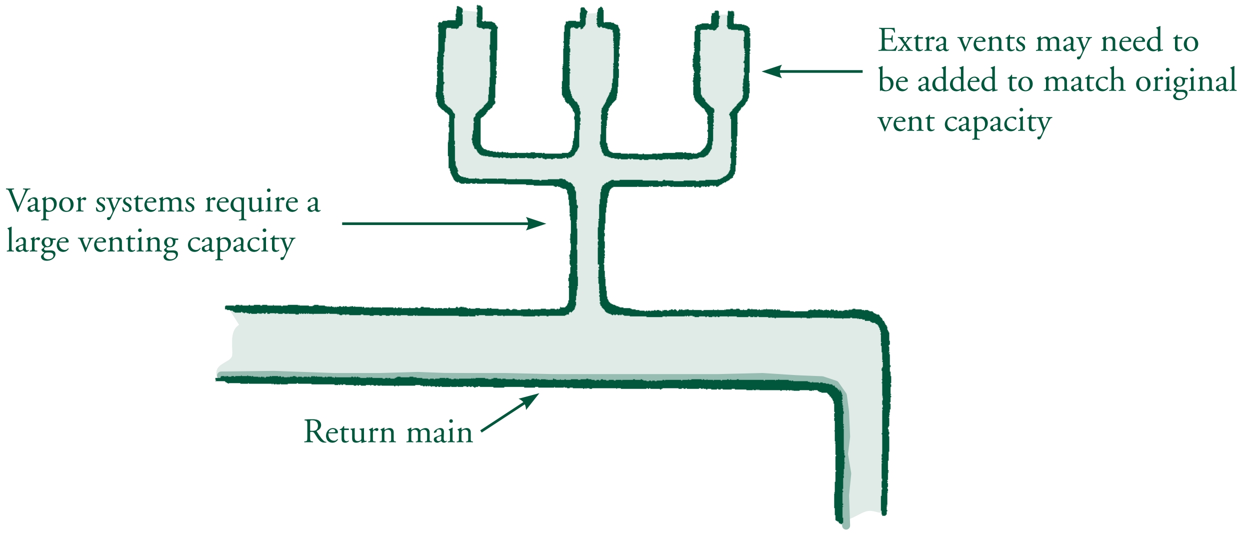
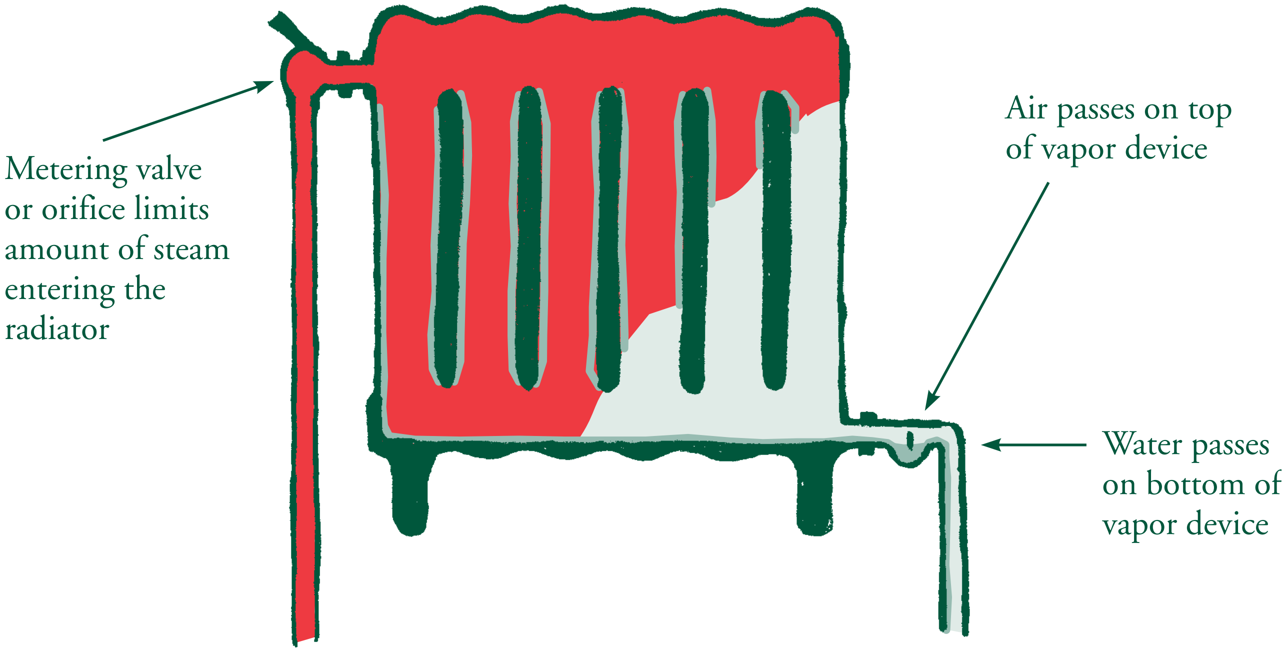

Extra vents may need to be added to match original vent capacity
Vapor systems require a large venting capacity
Return main

Fig. 2


Metering valve or orifice limits amount of steam entering the radiator
Air passes on top of vapor device
Water passes on bottom of vapor device
AIR
WATER
STEAM

Traps as Air Vents

Fig. 1 Thermostatic (radiator) traps are used as the supply main vent in some two pipe systems.

- The trap is piped between the supply main and dry return.
- Usually it's right up against the ceiling and hasn't been serviced for years.
- If it's stuck closed, the radiation off that main will not heat properly.
- If it's stuck open, steam gets into the return side and causes water hammer and uneven heating.

Fig. 2 F+T traps are used as the supply main vent when using vented (open) receiver tanks on condensate pumps and boiler feed pumps.

- The thermostatic element in the F+T trap passes air through to the vented tank.
- The piping from the discharge side of the F+T trap to the inlet of the receiver tank must pitch downhill.
- Watch out for water traps between the F+T trap and the inlet to tank, air cannot pass through the water.
- Install air vent on discharge side on F+T if water flows into receiver tank through a water trap. See page 163, Figure 2.

Don't trap multiple end of supply mains with one trap.

- Always use a separate trap for each main.
- Unequal steam pressures where multiple mains combine will create uneven circulation and heating.

Bucket traps make poor air vents.

- Bucket traps are designed for process work and do a poor job of venting air at start up.

Fig. 3 Radiation needs to be trapped individually.

- Air passes through radiation and then through trap.
- Use air vent on discharge side of radiation but before trap and check valve when lifting condensate.

Fig. 1

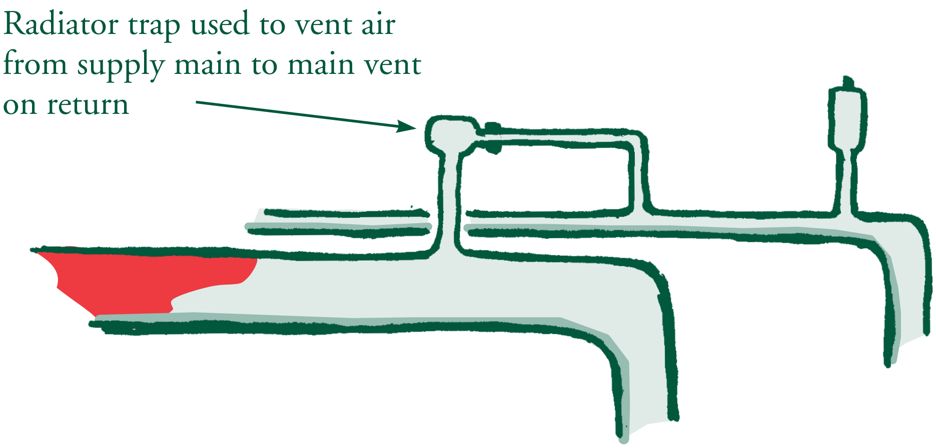


Fig. 2

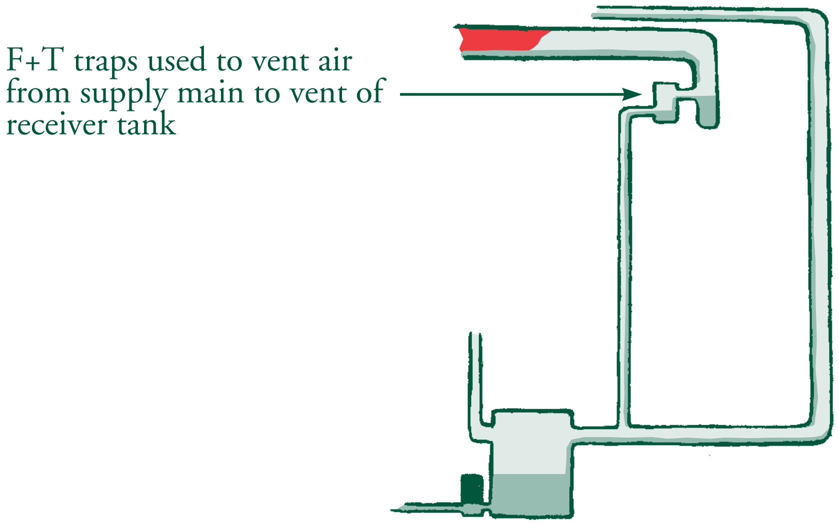
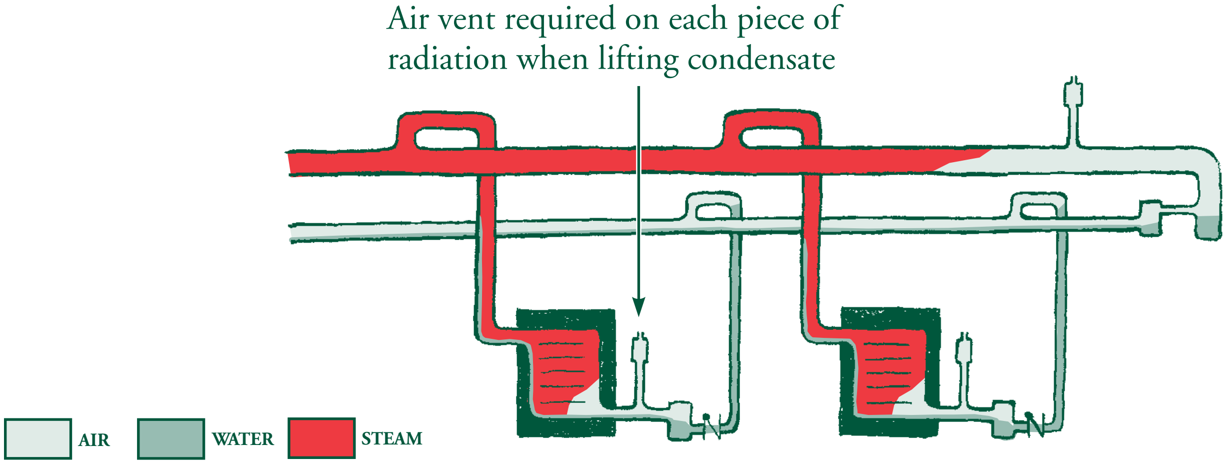


Fig. 3



Using Vacuum for Air Removal

Negative pressure in a steam system, a vacuum, can be highly effective for air removal.

- The negative pressure draws the air from the system ahead of the steam.
- The negative pressure is applied to the return side after the traps or air valves.

Vacuum can be applied to either a one pipe or two pipe system.

- **Fig. 1** The vacuum on a one pipe system is applied to the discharge side of a special air vent called an air valve.
- A 1/4´´ or 3/8´´ line extends from the air valve through the building to a central vacuum unit in basement.
- **Fig. 2** The vacuum on a two pipe system is applied to the discharge side of the traps.
- The return pipes can be sized smaller than with a gravity return system because the negative pressure helps overcome the pressure drop in the return line.

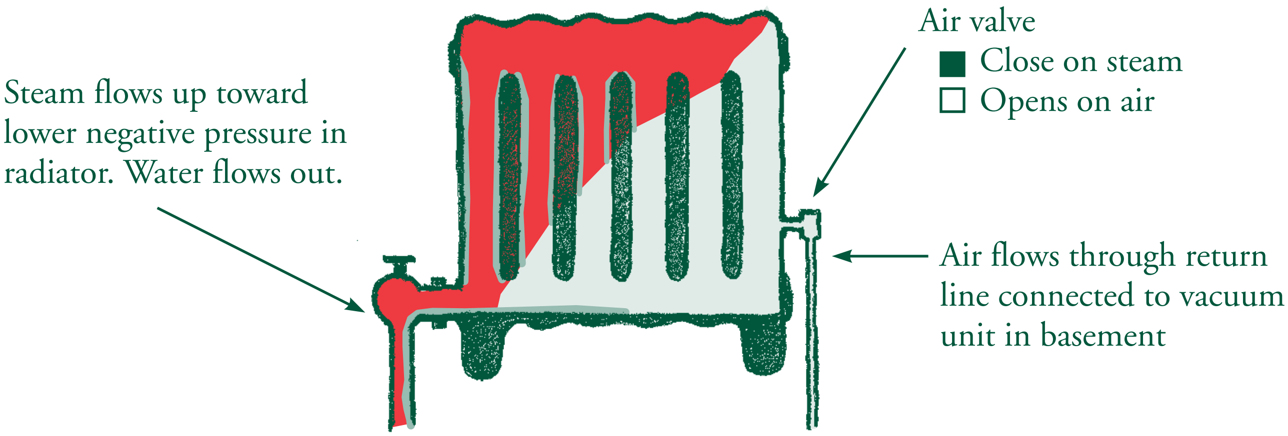
Vacuum can be naturally induced.

- The condensing action of the steam inside the radiation creates a natural vacuum that draws in more steam.
- The draft of the chimney was used for a naturally induced vacuum in some systems.

Electrically driven pumps have been designed to mechanically induce a vacuum.

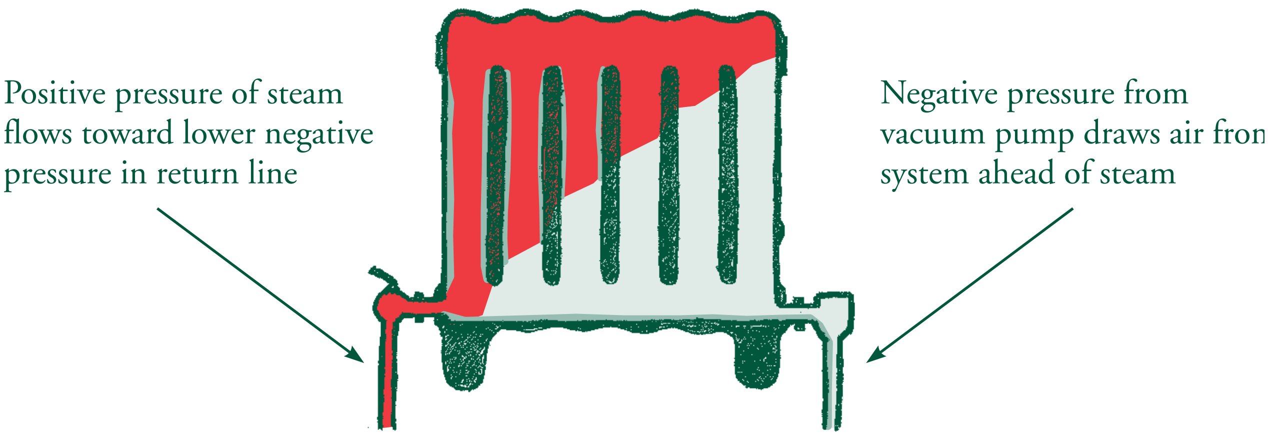
- The amount of vacuum can be adjusted and is controlled by a vacuum switch on the pump unit.
- Air is vented out of the unit to atmosphere through an open pipe.

Fig. 1



One pipe radiator at start of steam cycle

Fig. 2



Two pipe radiator at start of steam cycle

Sizing and Piping Main Air Vents

Main air vents have rated capacities that need to be matched to system size to be able to vent all the air from the main.

- Check with manufacturers specs for air removal ratings in Cubic Feet per Minute (CFM).
- Venting rates of main air vents have changed through the years.
- If using a single vent on a one pipe system, it must be able to relieve the air capacity of the whole supply piping system.
- If using a single vent on a two pipe system, it must be able to relieve the air capacity of the supply piping system and the radiation.
- If multiple vents are used on multiple steam mains, each must be able to relieve the capacity of that main.
- Using more than one vent at one location may be required to provide even heat.

Refer to Fig. 1 for help determining the air capacity of the mains.

- Measure the pipe size and length of the main.
- Find the capacity at the intersection of the pipe size and length.
- Divide the approximate capacity by the venting rate of the vent being used to estimate how long it will take to clear the main.
- Refer to the example on the opposite page to see the effect the number of vents makes.

Fig. 2 All supply main air vents should be piped to protect them from water hammer damage.

- Vents should be located after the last takeoff but at least 15″ before the end of the main.
- Vent should be at least 6″ above the main.
- If the only tapping available is at the end of the main, protect the vent from water hammer by installing elbows between main and vent.

How to Size Main Vent

Fig. 1

Air Capacity of Black Pipe (in cubic feet)

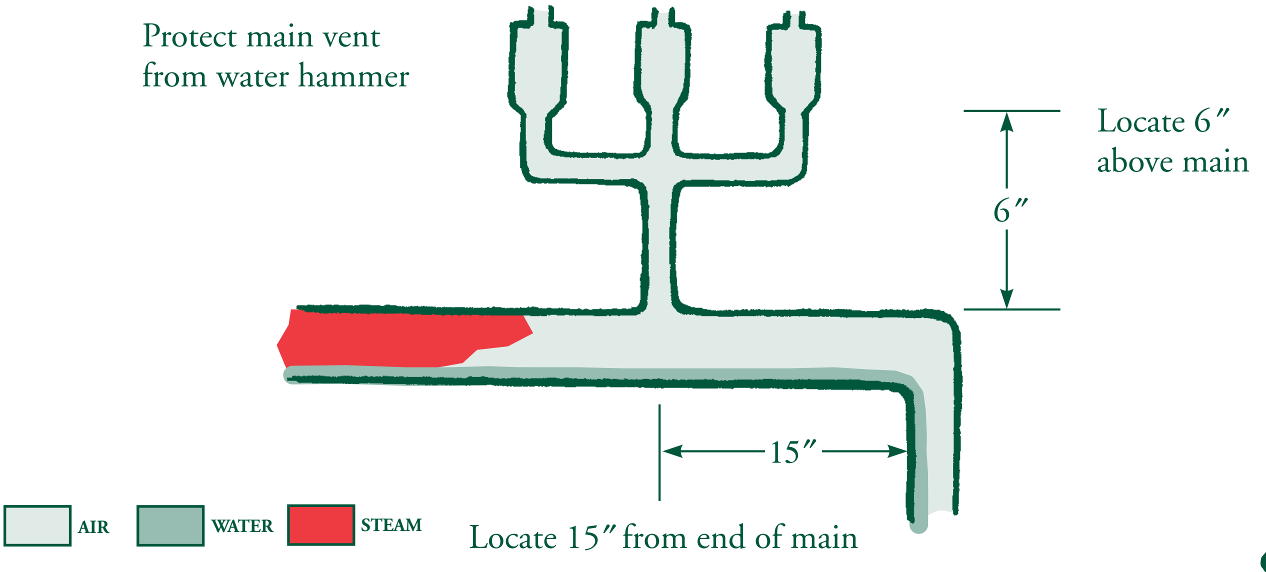
Pipe Size	Length							
	25	50	75	100	150	200	250	300
1½	0.36	0.71	1.07	1.42	2.13	2.84	3.55	4.26
2	0.58	1.17	1.75	2.33	3.50	4.66	5.83	6.99
2½	0.83	1.66	2.49	3.32	4.98	6.64	8.30	9.96
3	1.28	2.57	3.85	5.13	7.70	10.26	12.83	15.39
4	2.21	4.42	6.63	8.84	13.26	17.68	22.10	26.52
5	3.47	6.95	10.42	13.89	20.84	27.78	34.73	41.67
6	5.02	10.04	15.06	20.08	30.12	40.16	50.20	60.24
8	8.87	17.73	26.60	35.46	53.19	70.92	88.65	106.38

Shaded areas require more than 4 minutes to vent all air with typical main vent at rate of 1.4 cubic feet per minute.

Example of Vent Sizing

- A 4˝ main 200 feet long contains 17.68 cubic feet of air.
- One common main air vent passes 1.4 cubic feet of air per minute.
- 17.68 cubic feet divided by 1.4 cubic feet per minute equals about 13 minutes.
- Three vents at 1.4 cubic feet per minute equals 4.2 cubic feet of air per minute.
- 17.68 cubic feet divided by 4.2 cubic feet per minute equals about 4 minutes.

Fig. 2



CHAPTER FIVE

Water Back

Why Returning Water to Maintain the Boiler Water Line Is Important

Steam boilers cannot produce steam to heat the building without water.

- Water should be free of grease and oil as explained on page 34.

Water must be returned from the system to the boiler before the burner shuts off because of a low water condition.

- Short cycles of the burner that waste fuel and cause uneven heating are created by slow condensate return.
- Boiler flooding problems that waste fuel and water are created by slow condensate return.

The less make-up water used, the better it is for the boiler.

- Fresh water contains minerals and oxygen that are released by the temperatures required to make steam.
- Minerals, such as lime, can build up in the boiler.
- Any build up can act as an insulation, affecting the transfer of heat from the burner to the water.
- Enough build up can cause boiler failure.

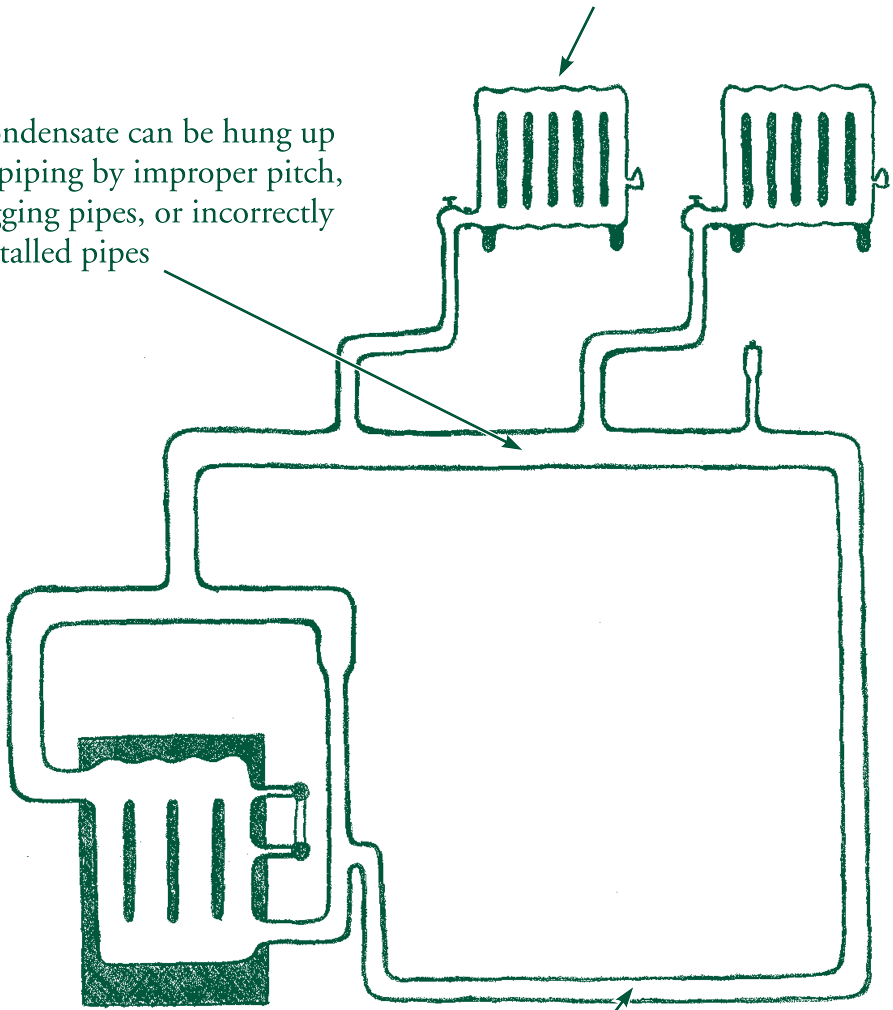
Water that remains in the radiation or piping above the water line after the system cools down can cause water hammer on the next "call for heat."

- Piping and radiation should be pitched so that all the condensate flows back to the boiler or pump units by gravity.
- Eccentric fittings need to be used in the horizontal piping whenever condensate will be present.
- Concentric fitting should be used in vertical piping.

Fig. 1 The ideal burner run cycle during a "call for heat" is one that is not interrupted by the low water cut off.

- Condensate can be slowed from returning because of a clogged wet return pipe.
- Condensate can be hung up in the system by improperly pitched, incorrectly installed, or sagging pipes.
- Condensate can be hung up in the system by unwanted vacuum in the radiation or piping caused by the closure of automatic valves.

Fig. 1


Condensate can be hung up in radiation by improper pitch, radiator valves half open, or unwanted vacuum
Condensate can be hung up in piping by improper pitch, sagging pipes, or incorrectly installed pipes
Clogged wet return can slow condensate return and cause burner short cycling and boiler flooding

Follow the Path of Water Back to the Boiler

Fig. 1 Water that condenses on the cold pipe at start-up flows back into the boiler against the flow of steam in the supply riser.

- Pipe size affects steam velocity which affects how "wet" or "dry" the steam is. See page 58 through 62.

Fig. 2 Water that separates from the steam in the header flows back to the boiler through the equalizer and return pipe.

- Header should be pitched and piped to allow all water to flow back. See page 56 for near boiler piping.

Water in the supply main flows to the end of the main in a parallel-flow system. The most common type installed. **See page 52, Fig. 1.**

- Supply main pipe is pitched to direct water away from boiler header to the end of the main.

Water in the supply main flows back to the boiler in a counter-flow system. This type is not commonly installed. **See page 52, Fig. 2.**

- Supply main pipe is pitched to direct water back toward the boiler.

Fig. 1 Water in a two pipe radiator flows back out to the dry or wet return through the trap or vapor device.

- Water in the dry return flows back to the boiler through a wet return.
- Dry return connections must be connected to the boiler below the water line.

Fig. 2 Depending on the pitch and the presence of drips or not, in a one pipe system, water in the run outs will flow back to the supply main or flow out to the riser and the drip.

- Water in the vertical risers will flow back to the run out.
- Water in a one pipe radiator flows back out to the supply riser through the radiator valve.

Wet returns collect all the condensate to return directly to the boiler or indirectly through condensate, boiler feed, or vacuum pumps.

- Wet return must be clear of sediment build up to return condensate before automatic feeder adds water to the system, causing boiler flooding.

Follow the Path of Water Back to the Boiler

Fig. 1 Two Pipe Steam

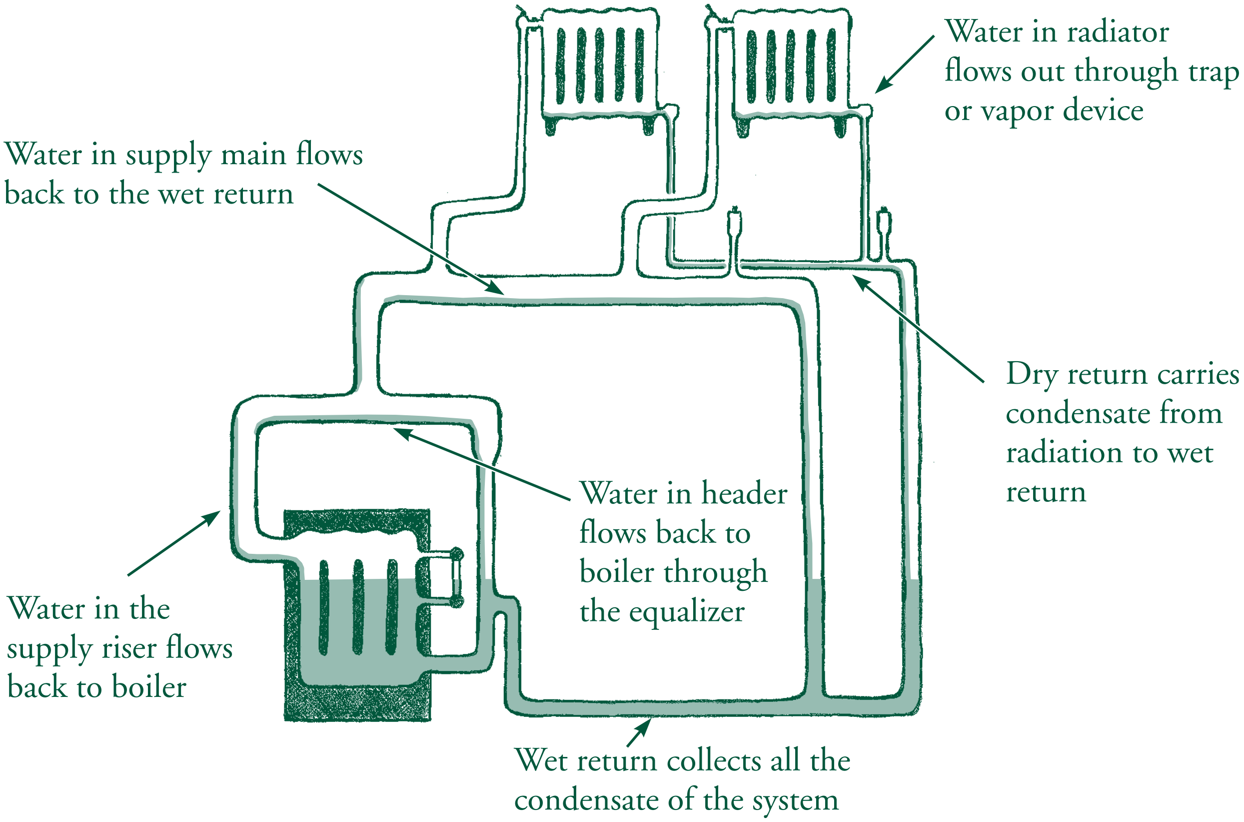
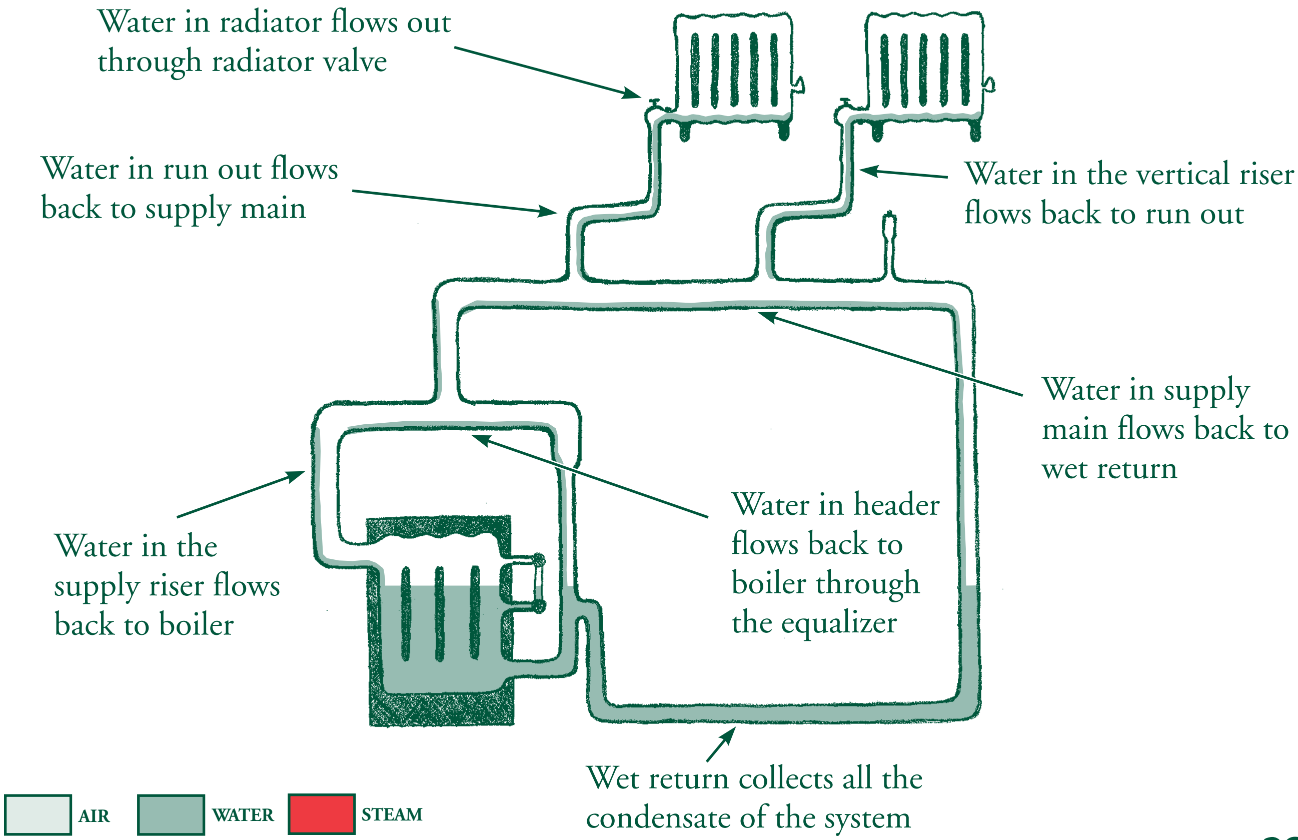


Fig. 2 One Pipe Steam



Gravity Return Systems, One Pipe Steam

Static pressure of water in vertical portion of the return makes the condensate flow back into the boiler.

- The stacking effect of water in the return plus the left over steam pressure at the end of the main combine to force the water back into boiler.
- 28″ of water stacked above the waterline equals 1 pound of pressure.

"A" Dimension: What is it?

- The estimated height that water rises above the water line in the vertical portion of the return that will cause water to return to the boiler.
- The end of steam main must be higher than "A" dimension or water will flood supply main causing water hammer and uneven heat caused by blocked runouts.

Steam loses pressure as it moves through the supply main.

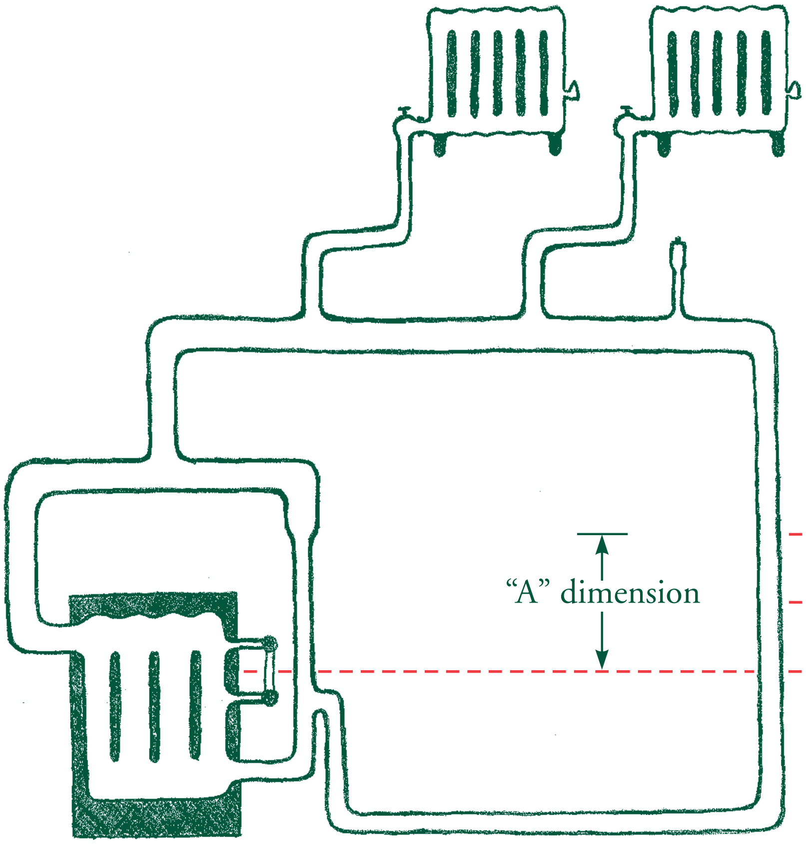
- Typical steam pressure loss from boiler to end of main is ½ pound.
- Static pressure 1 is the pressure required to make up for the system steam pressure loss.
- 14″ of water stacked above the water line creates ½ pound of pressure.

Water flow through wet return creates pressure drop.

- Typical water pressure drop through the wet return is ½ pound.
- Static pressure 2 is the pressure required to overcome the water pressure drop.
- 14″ of water stacked above static pressure 1 creates another ½ pound of pressure.
- Pitch wet return 1″ per 40′.

"A" Dimension: What can go wrong.

- New boiler may have a higher water line than old boiler.
- New boiler may have been raised out of pit to shorten existing "A" dimension.
- Pressure could be set too high for existing "A" dimension.
- Check valve in return adding friction to water flow in wet return.
- Clogged or restricted wet return adds water pressure drop to flow of condensate, making required "A" dimension higher.



Static pressure 1 — Pressure required to make up for system steam pressure loss, usually 1/2 pound pressure.

Static pressure 2 — Pressure required to overcome water pressure drop through wet return, usually 1/2 pound pressure.

Static pressure 1 + Static pressure 2 = "A" dimension

One pound of pressure = 28″ of vertical height.

If static pressure 1 equals 14″

and

If static pressure 2 equals 14″

then

"A" dimension equals 28″

Gravity Return Systems, One Pipe Steam, continued

Fig. 1 Water flow through wet return causes water pressure drop.

- Pressure drop is determined by the amount of flow and the pipe size.
- Wet return is the lowest point of system.
- The pipe in the wet return gets smaller through time by a build up of sediment, increasing pressure drop and "A" dimension.

Get rid of check valves in the wet return

- Check valves are not necessary if an equalizer is installed (see page 102).
- Check valves are the most likely place for dirt to build up in the wet return to restrict flow and cause more water pressure drop.

The pitch of the steam mains also determines how well water flows back to the wet return.

- Fig. 2 Parallel flow systems have supply mains that pitch from the boiler to the end of the supply main.
- The pitch for a parallel-flow system should be 1 inch per 20 feet of supply main.
- Fig. 3 Counter-flow systems have supply mains that pitch from the end of the supply main back to the boiler.
- The pitch for a counter-flow system should be 1 inch per 10 feet of supply main.

The size of the steam mains also determines how well water flows back to the wet return.

- The steam main needs to carry both the volume of steam to heat the connected load and the condensate flow from the connected load.
- Pipe size for counter-flow mains is always larger than for parallel-flow.

Fig. 1

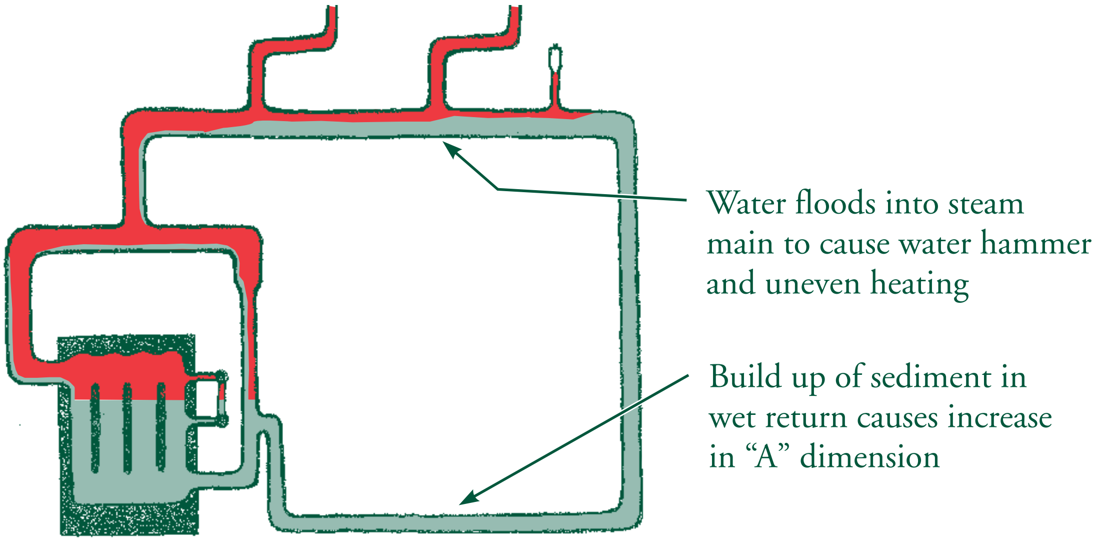


Fig. 2

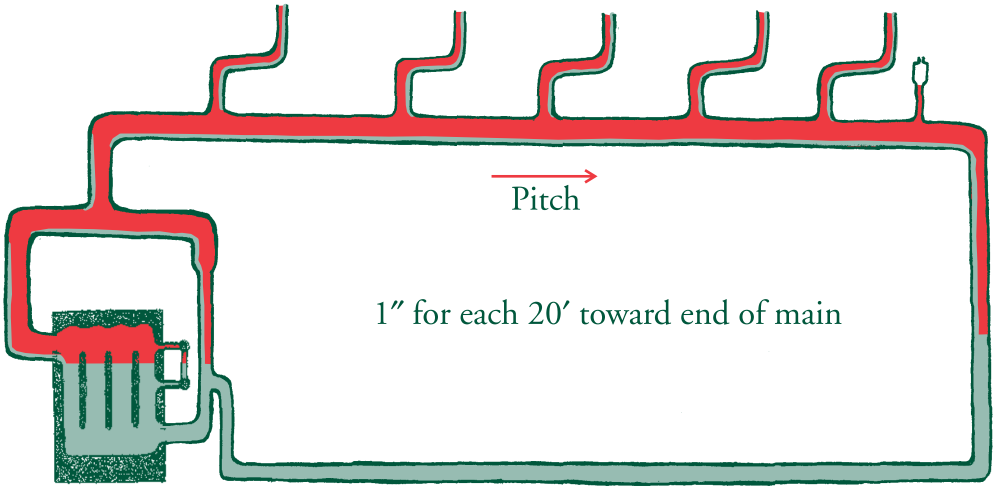
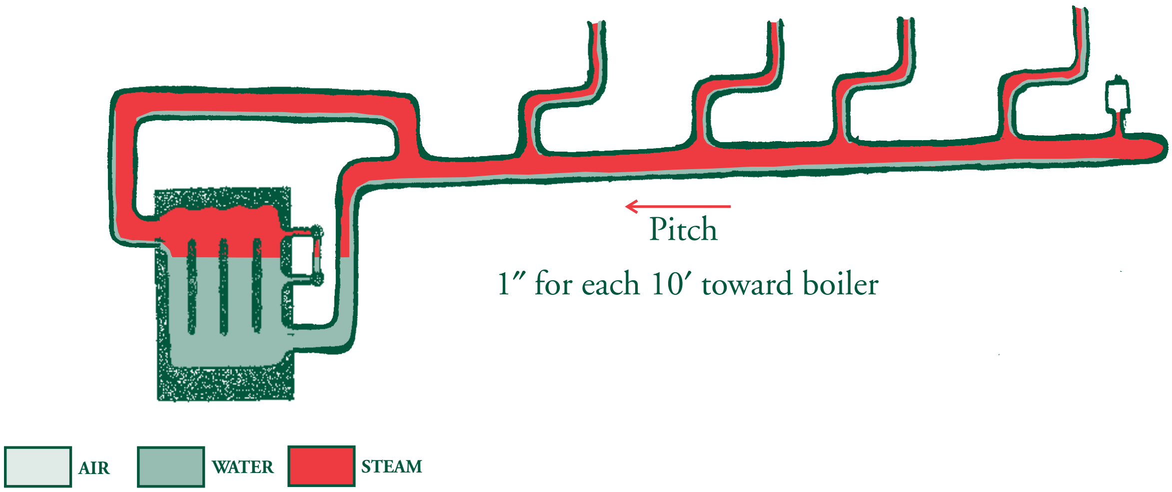


Fig. 3



Gravity Return Systems, One Pipe Steam, continued

Fig. 1 The radiator valve must always be completely open to allow the water to flow back against the flow of steam into the radiator.

- Partially closing the valve traps water in radiator.
- Never use less than 1˝. Valve must be sized properly. See chart page 55.
- Partially closed or undersized valves create more pressure drop (restriction) to the flow of water out of the radiator and increase the velocity of the steam entering the radiator.

Fig. 2 The pitch of radiation must be back towards the radiator valve.

- The building can settle or radiators can wear the floor enough to change the pitch of the radiator.
- Radiators pitched in the wrong direction will pool water at the vent end, causing water hammer in radiator and spitting air vents.

Fig. 3 The pitch of run outs must be back towards the main.

- Pitch 1 inch per 4 feet for horizontal portion of the run outs.
- Taking runout at 45° angle allows condensate to slide into bottom of main without interfering with the with the steam flowing at top of supply main.
- Taking run out at top of main causes condensate to flow into steam traveling along top of supply main.

Fig. 4 The size of run outs is determined by the amount of radiator connected.

- Use charts on pages 163, 164, and 165 to calculate load.
- Use the chart on page 161 to calculate pipe size of horizontal run outs.
- Use next size up for horizontal run outs over 5 feet long.
- If the riser is dripped, use chart on page 55.
- The horizontal run out will usually be larger than the size of the vertical riser.

Fig. 1

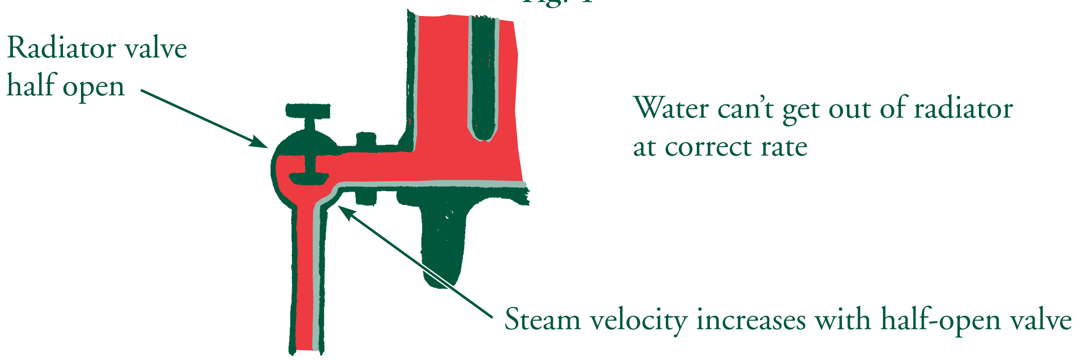


Fig. 2

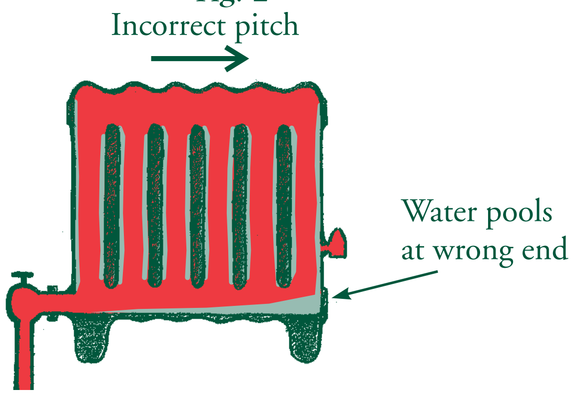


Fig. 3

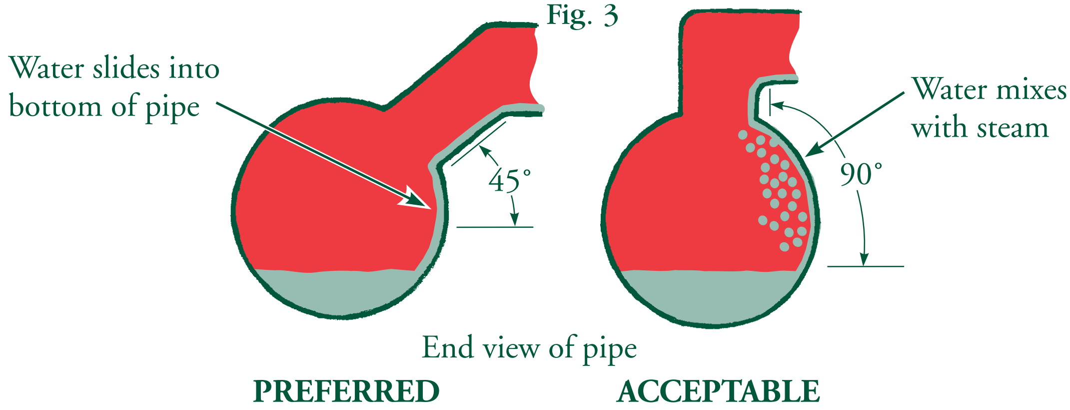
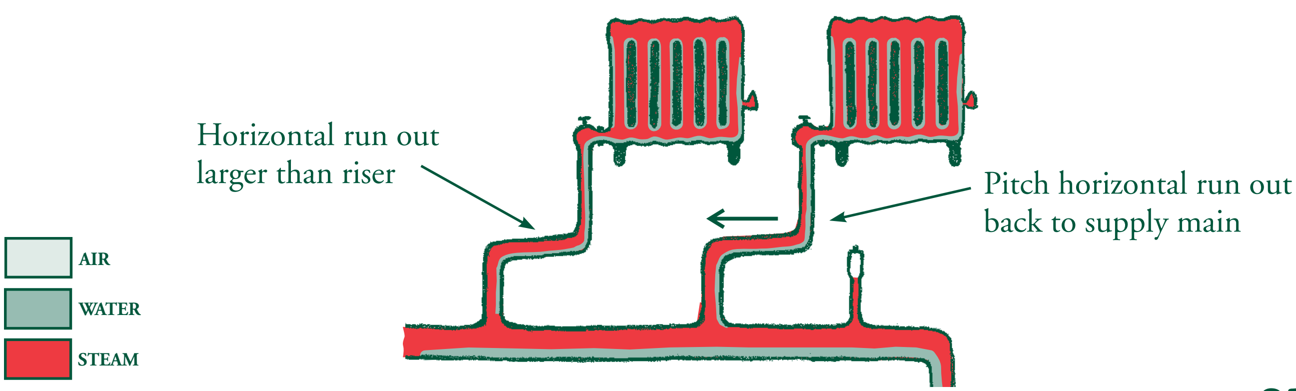


Fig. 4



Gravity Return, Two Pipe

Static pressure of water stacking up above the water line creates the pressure required to make the condensate flow back into the boiler.

- **Fig. 1** When the end of the supply main ends with a water trap, the "A" dimension applies because there is leftover steam pressure.
- **Fig. 2** When the end of the supply main ends with an F+T trap, the "B" dimension applies because there is no steam pressure on the discharger side of the F+T trap.
- The "B" dimension always applies on the return main since there is no leftover pressure. There is no steam pressure on the discharge side of the radiator traps.

The "B" dimension is the estimated height of water stacked in the vertical portion of the return above the water line that is required to return condensate by gravity.

- Water height creates the pressure necessary to overcome the pressure in the boiler and the pressure drop in the wet return.
- 1 pound of pressure is created for every 28″ of water above the water line.
- Steam and return mains can flood if enough "B" dimension is not available.

The returning water pressure has to exceed the operating pressure of the boiler.

- Typical operating pressure of the boiler is 2 pounds.
- Static pressure 3 is the pressure required to overcome the operating pressure of the boiler.
- At 2 pounds pressure, 56″ would be required.

Water flow through the wet return creates pressure drop.

- Typical water pressure drop through the wet return is 1/2 pound.
- Static pressure 2 is the pressure required to overcome the water pressure drop.
- 14″ of water stacked above static pressure 3 creates another 1/2 pound of pressure.
- Pitch wet return 1″ per 40′.

"B" dimension—what can go wrong.

- Basement ceiling can be too low.
- Wet return can get clogged.
- Pressure setting can be too high.
- New boiler's water line can be lower than an existing mid-level wet return, creating water hammer.

Fig. 1 Water Seal on Supply Main

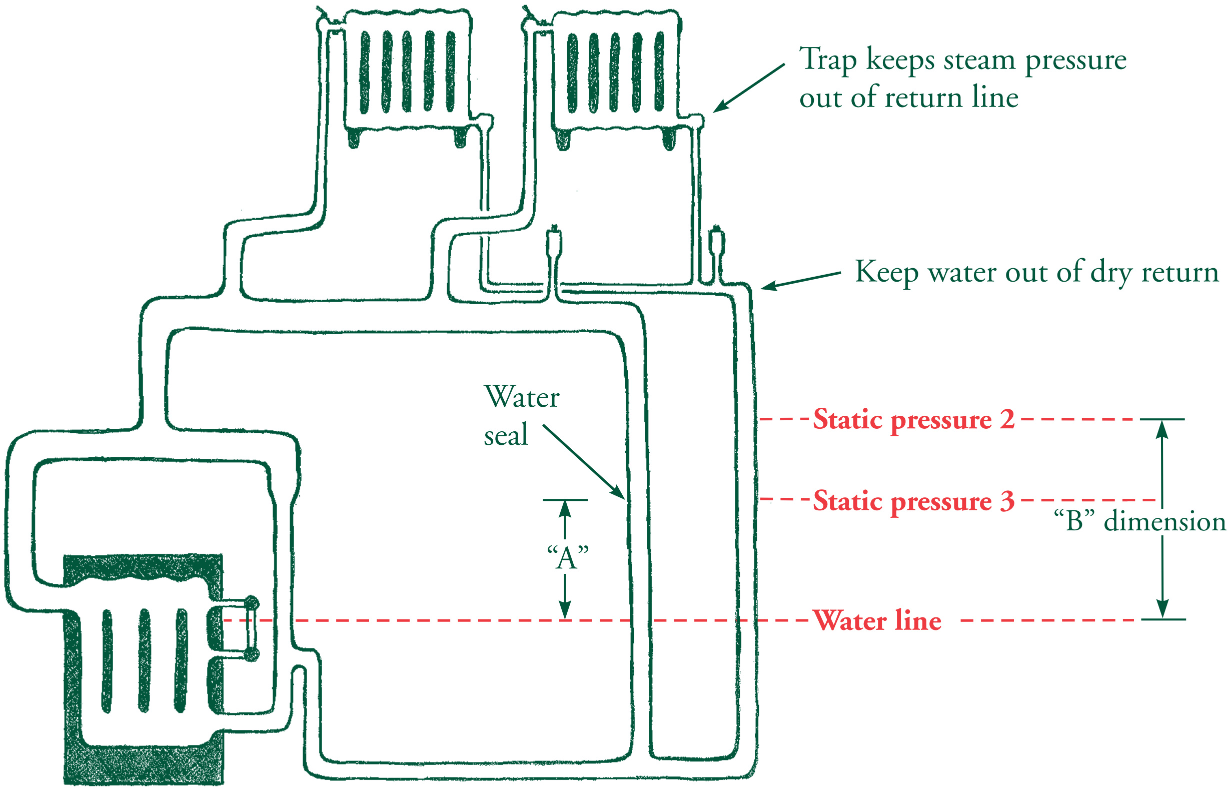
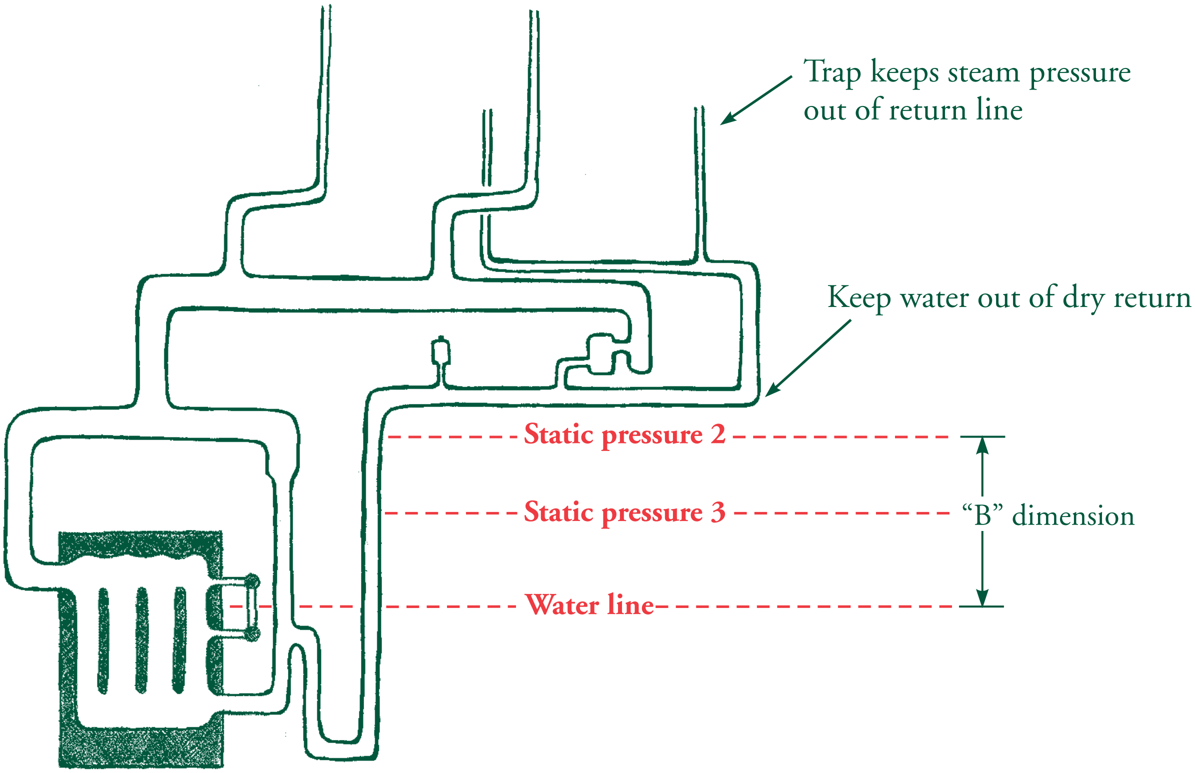


Fig. 2 F+T Trap on Supply Main



Static pressure 2 + Static pressure 3 = "B" dimension

Gravity Return, Two Pipe, continued

Fig. 1 The radiator trap or vapor device passes the water formed by the condensing steam out of the radiator.

- Size radiator traps per trap manufacturer's capacity chart, usually ½˝.
- Dirt or scale can form on seat blocking the flow of water out of radiator.
- Pitch of radiator must be toward trap or vapor device to drain condensate.

Fig. 2 End of main water traps pass the water from the main back to the boiler.

- Operating pressure of boiler determines how high water will stack.
- End of one pipe mains carry condensate from radiation and main.
- End of two pipe mains carry condensate from main only.

Fig. 3 End of main F+Ts trap pass the water at a fairly constant rate.

- Water is discharged at the temperature of steam. Provide at least 12´ of pipe to act as cooling leg before connecting to open receiver tank on boiler feed or condensate unit.

Fig. 4 Unit heaters in factories or warehouses commonly have return lines above the discharge of the trap.

- Condensate can be lifted to overhead return lines by the steam pressure.
- A rule of thumb is 1 pound of steam can raise condensate 1´.
- Use a swing check valve on the discharge side of the trap to keep water from flowing back into the unit heater.

Pitch dry return 1˝ in 100´.

Fig. 1

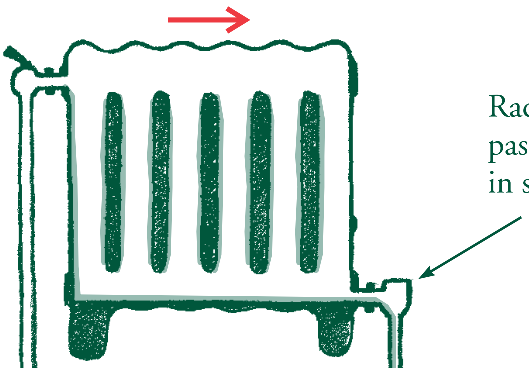


Fig. 2

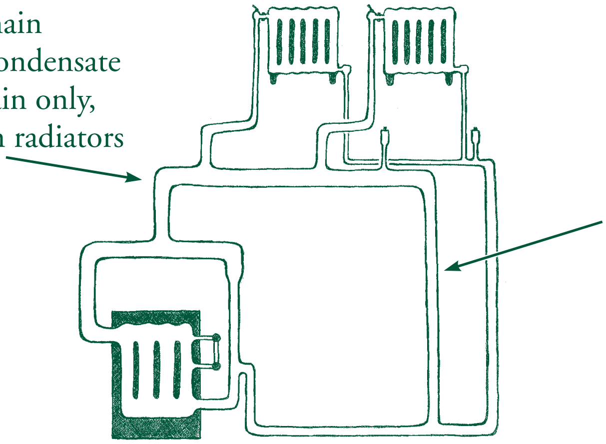


Fig. 3

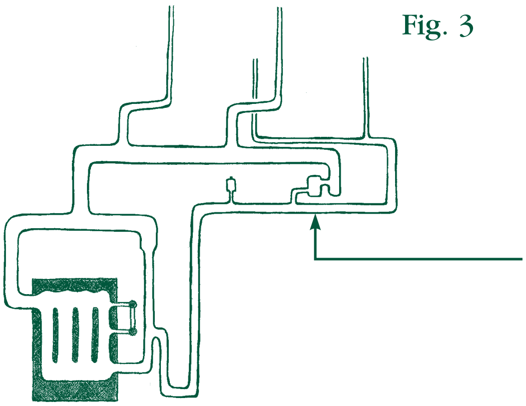
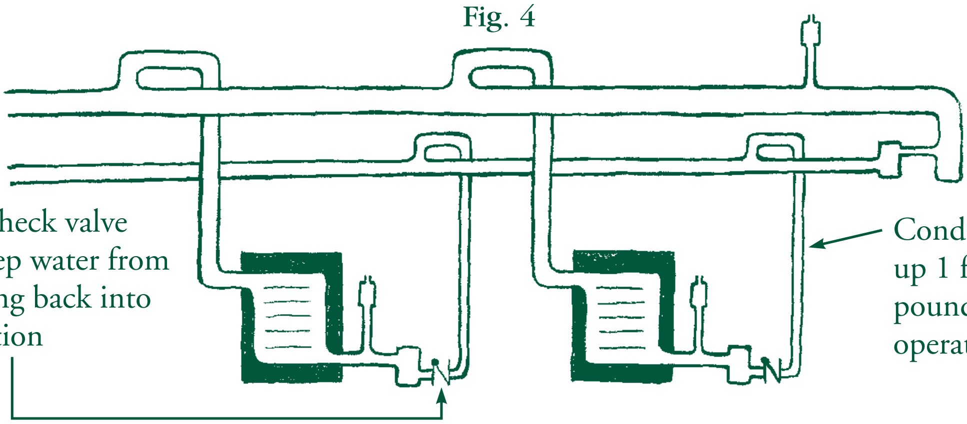


Fig. 4



Two Pipe Gravity Return, Boiler Return Traps

Boiler return traps, also called alternating receivers, were designed to return condensate to a coal-fired boiler if the steam pressure got too high.

- Steam pressure was hard to control in a coal-fired boiler.
- They would act as a steam pressure high limit to prevent water from flooding the mains.

Differential loops are similar in function to boiler return traps, but have no moving parts.

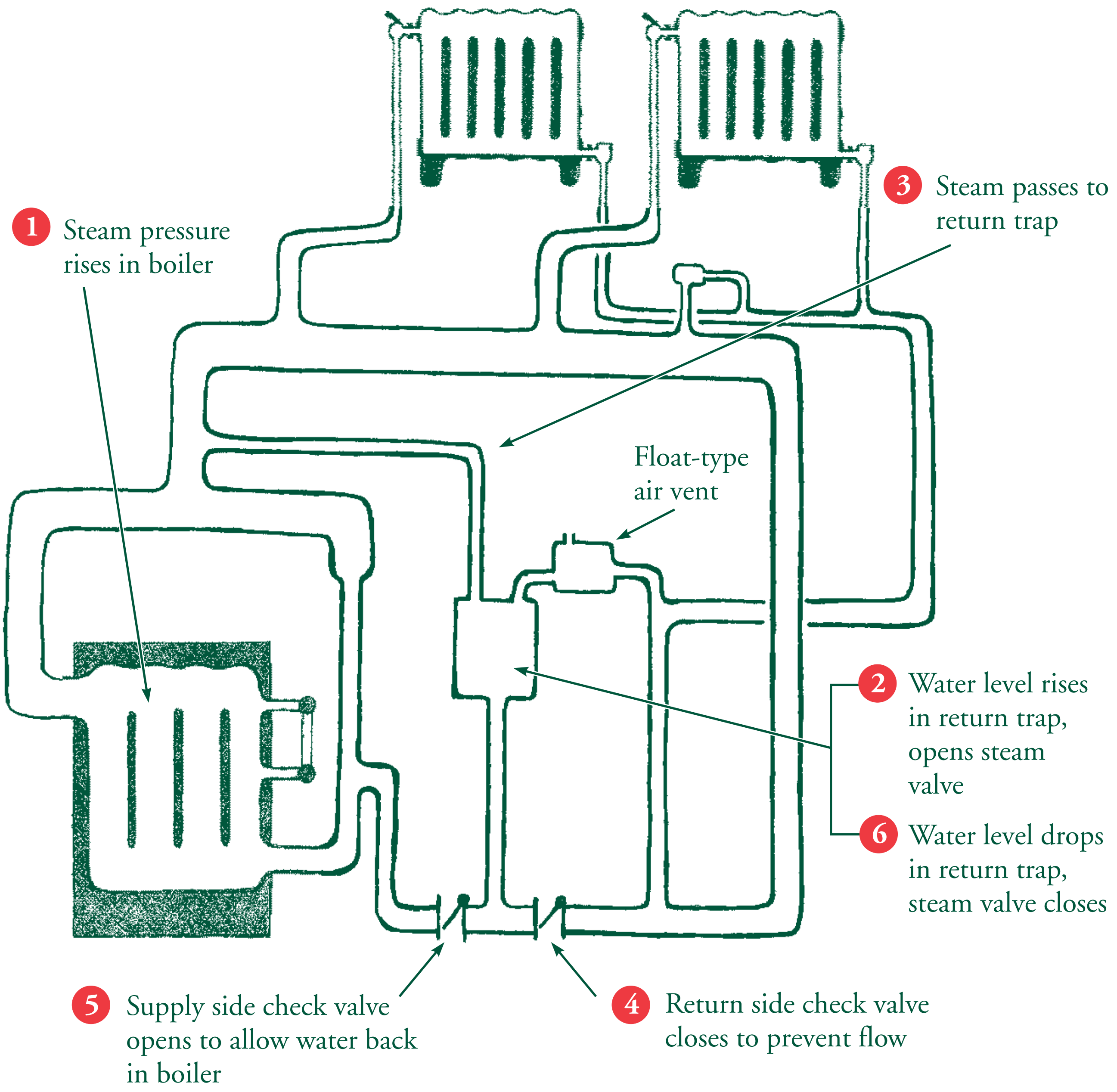
- Float chambers and dip tubes accomplish what floats, weights, and valves do in the return traps.

On boiler replacements, these devices can be left alone.

- If "B" dimension of installation is enough for operating pressure, device can be eliminated.
- Adjust pressure high limit to lowest setting possible or operate with vaporstat.
- If boiler feed unit is being installed, device can be eliminated.

Fig. 1 Boiler Return Trap Sequence of Operation:

1. Steam pressure rises in boiler.
2. Water level rises in float chamber of boiler return trap to open steam inlet valve.
3. Steam passes from steam main to boiler return trap.
4. Steam pressure forces water down and out of boiler return trap, closing check valve on return side.
5. Supply side check valve opens to allow water from boiler return trap to enter boiler.
6. When water level drops in float chamber of boiler return trap, steam inlet valve closes.



1 Steam pressure rises in boiler
3 Steam passes to return trap
Float-type air vent
2 Water level rises in return trap, opens steam valve
6 Water level drops in return trap, steam valve closes
5 Supply side check valve opens to allow water back in boiler
4 Return side check valve closes to prevent flow

Hartford Loop and Equalizer

Fig. 1 The Hartford Loop was developed by the Hartford Insurance Company to prevent boiler explosions.

- Water leaks in the return line would drain the water out of the hot boiler. Cold water would be released into the boiler by an unreliable water level control or inattentive operator. The sudden temperature change would send the boiler through the roof.
- The new piping arrangement kept water in the boiler in the event of a leak in a return line.
- It greatly reduced the number of boiler accidents and insurance claims.
- Today, it's a non-mechanical backup for the LWCO.

The height of the loop should be piped 2″ to 4″ below the water line to keep the horizontal portion underwater to prevent water hammer.

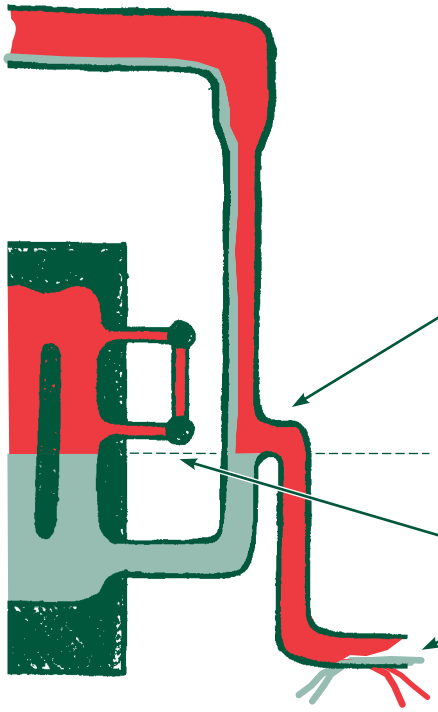
- Keep the horizontal pipe as short as possible by using a close nipple, street 90, or Y-tee pointed down.
- If steam would get into the horizontal pipe, the close nipple will prevent water hammer.

Fig. 2 The equalizer has two functions, to apply steam supply pressure to the return side to keep water in boiler and to drain the water from the header to assure dry steam.

- See chart on page 160 to size equalizer. It has to be large enough to handle the volume of water from the header and not cause steam pressure drop.
- The equalizer pipe is always sized smaller than the header.
- The best place to make the reduction is just below the elbow. A concentric reducer can be used on the vertical drop.
- Too much of a pipe size reduction or too long a pipe will result in steam pressure reduction in the equalizer.

Hartford Loop and Equalizer

Fig. 1 Hartford Loop

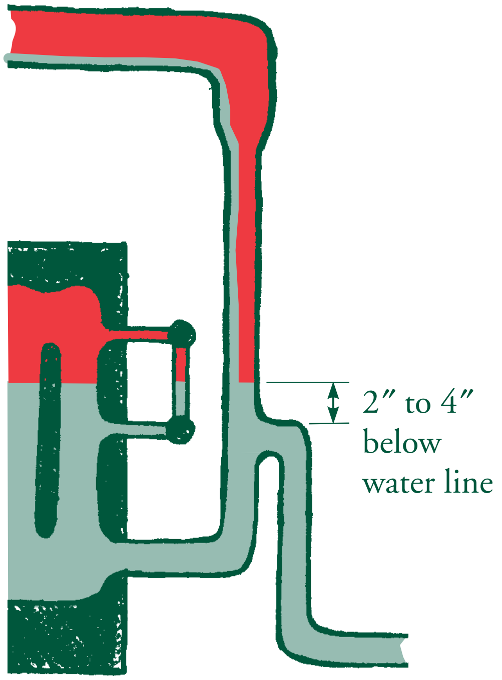


As short as possible to prevent water hammer
Can use:

1. Close nipple
2. Street elbow
3. Y-tee pointing down

Lowest level of boiler water line if return line starts leaking

Fig. 2 Equalizer



Equalizer:

1. Drains header to assure dry steam in system
2. Equalizes pressure to return, keeping water in boiler
3. Replaces check valve in return line
   - **a.** Would stick open to allow water to back out of boiler
   - **b.** Would clog up to slow water returning to boiler
   - **c.** Both could cause water hammer at end of mains, spitting air vents, and/or flooded take offs

AIR WATER STEAM

Maintaining the Boiler Water Line

Proper steam generation is affected by the location and maintenance of the boiler water line.

- If the water line is set too high or too low, the boiler will experience problems described on page 38.
- Returning the water to restore the water line is one of the most important components of "Water Back."

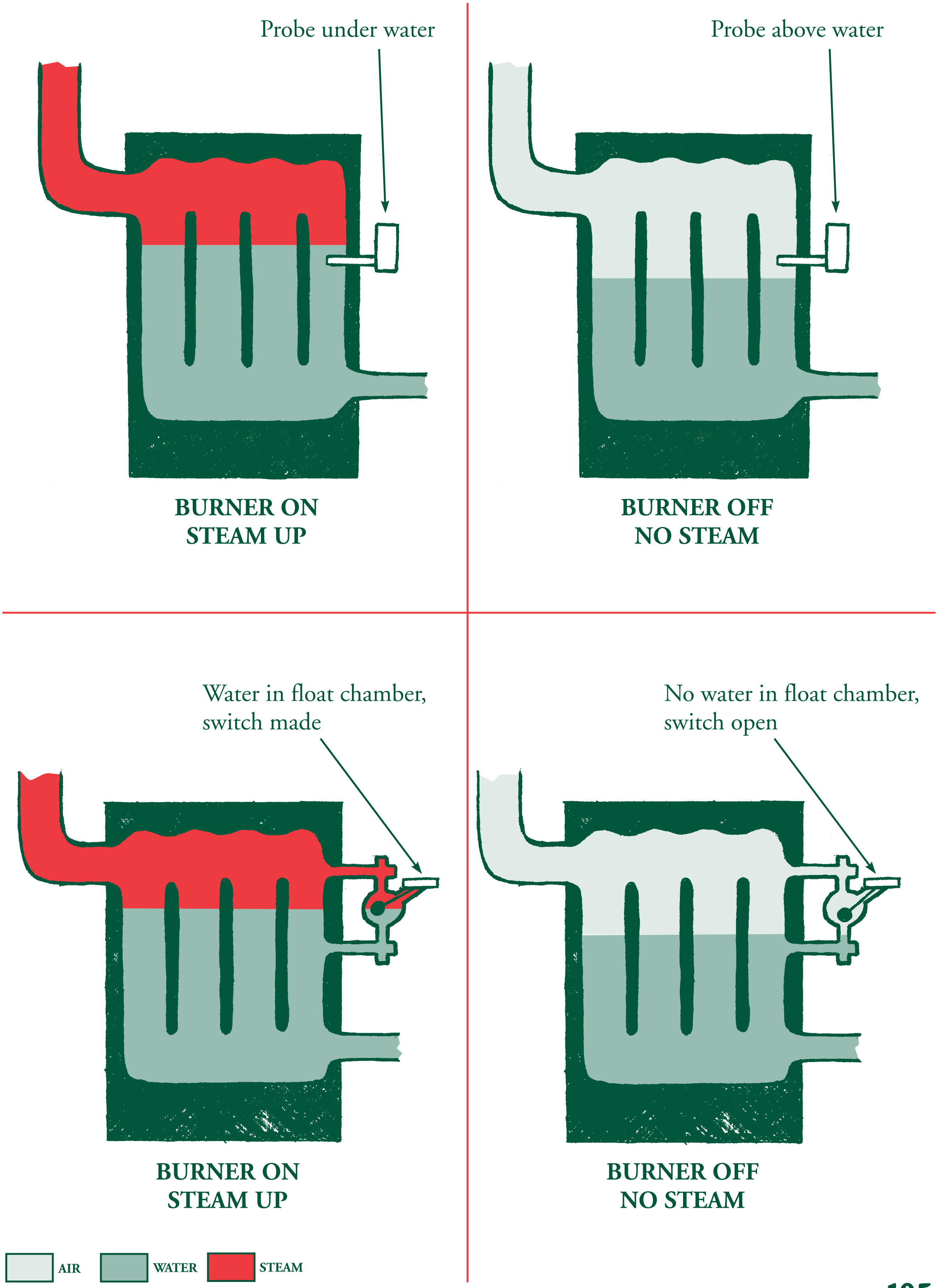
If the water line gets too low during a run cycle, the low water cut off will shut off the burner.

- When the burner is shut off during a "call for heat," the production of steam is interrupted.
- Poor steam distribution is the result.
- Higher fuel bills are caused by the short cycling of the burner. The similarity is to the gas mileage of a vehicle–highway mileage with a steady steam cycle; city mileage with a short cycling burner.
- Burner should not be interrupted by low water during "call for heat" burner.

Some boilers still maintain the water line with a manual (hand) feed.

- This requires someone (homeowner, maintenance person, or building super) to check boiler on a regular basis and adjust the water line.
- This is a good method of controlling the water line if done properly.

Maintaining the Boiler Water Line



Automatic Feeders

Most boilers are now equipped with some method of automatic feed to refill the boiler.

- As the water is lost through evaporation from the venting process, the automatic feeder senses the drop in water line and opens a valve to put water back into the boiler.

One type of automatic feed is a direct feeder.

- The direct feeder has a float chamber connected to the boiler with equalizing lines.
- **Fig. 1** The float is connected to a valve that opens as the float sinks.
- **Fig. 2** When enough water enters the boiler and the float rises, the valve shuts off.
- See page 132 for flooding problems, page 156 for servicing feeders.

A second type of direct automatic feed uses a low water cut off and water solenoid valve in combination.

- The low water cut off (LWCO) has a two position switch, or the boiler is using two separate LWCO's.
- The first switch on the LWCO that will make on the fall of the boiler water line, or the LWCO positioned higher, will activate the solenoid valve to open and feed water into the boiler.
- As the water level returns to its normal position, the switch opens to close the solenoid valve and stop feeding water into the boiler.

A newer method of automatic boiler feed uses a time delay on the feed valve.

- The purpose of the time delay is to allow returning condensate to reestablish the water line before activating the feed valve, to prevent flooding.
- Besides the time delay, some feeders will only feed a certain amount of water, about ½ gallon, then wait another amount of time before feeding again, also to prevent flooding.

Boiler feed pumps are controlled by a float type control at the boiler water line.

- As soon as the water level drops, the feed pump is energized. See page 108 for operation.

Multiple steam boilers piped to a common supply header can be fed individually if they don't share a common return header.

- Feed methods for each boiler could be any of the above methods.
- An F+T trap at the boiler water line can keep the standby boiler(s) from flooding.

Fig. 1 Direct Feeder

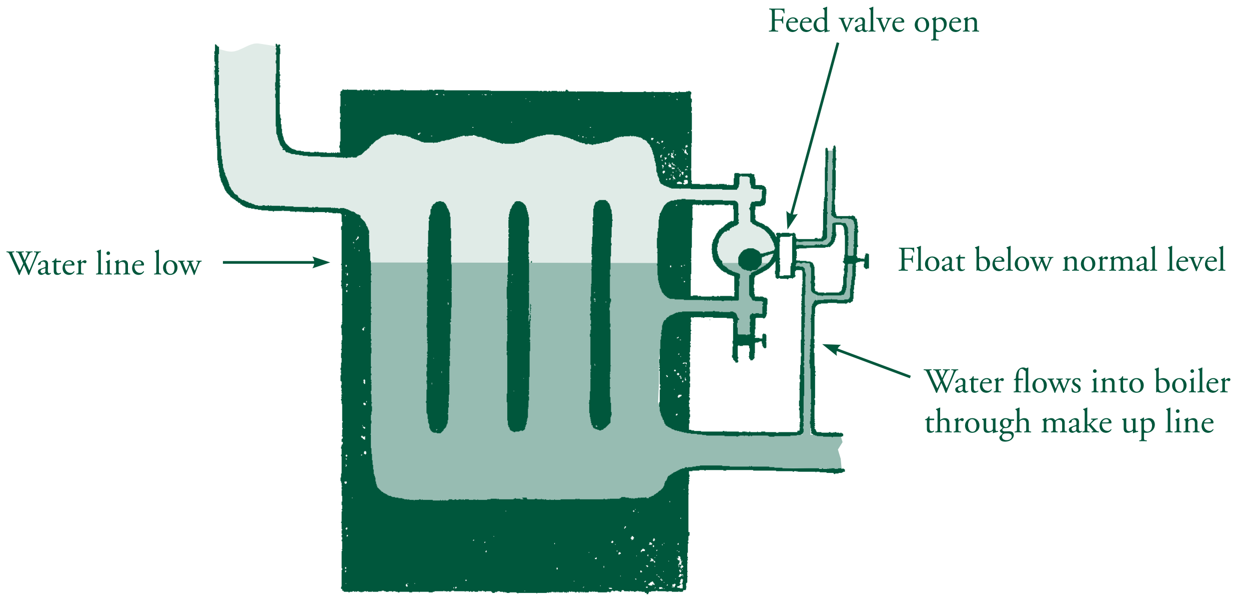
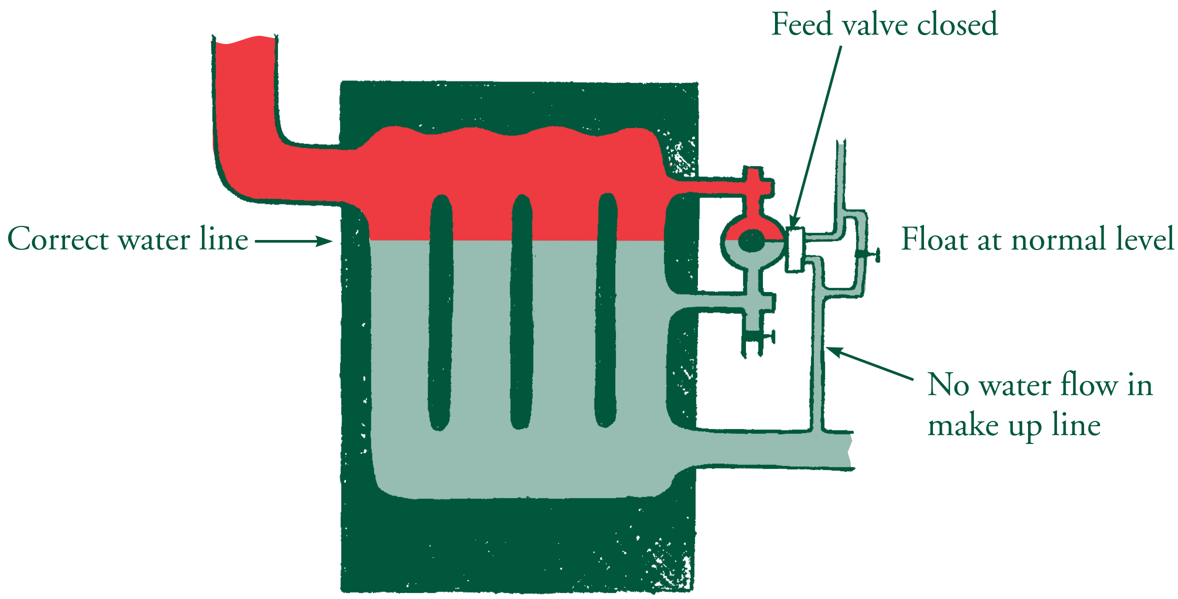


Fig. 2 Direct Feeder



AIR WATER STEAM

Boiler Feed Units

The purpose of a boiler feed unit is to provide a reservoir of water to be used to refill the boiler.

- Modern boilers have much less water capacity than older boilers.
- As modern boilers produce steam, the water level drops faster than with an older boiler.

Boiler feed units are designed to prevent both the short cycling and the flooding.

- The water level may drop to shut off the burner in the middle of a "call for heat" before the condensate has a chance to make it back.
- This kind of short cycling causes high fuel bills and uneven heating.
- The water level may drop and cause a feeder to put more water into the system before the condensate has a chance to make it back.
- This kind of extra water feeding causes flooding problems.

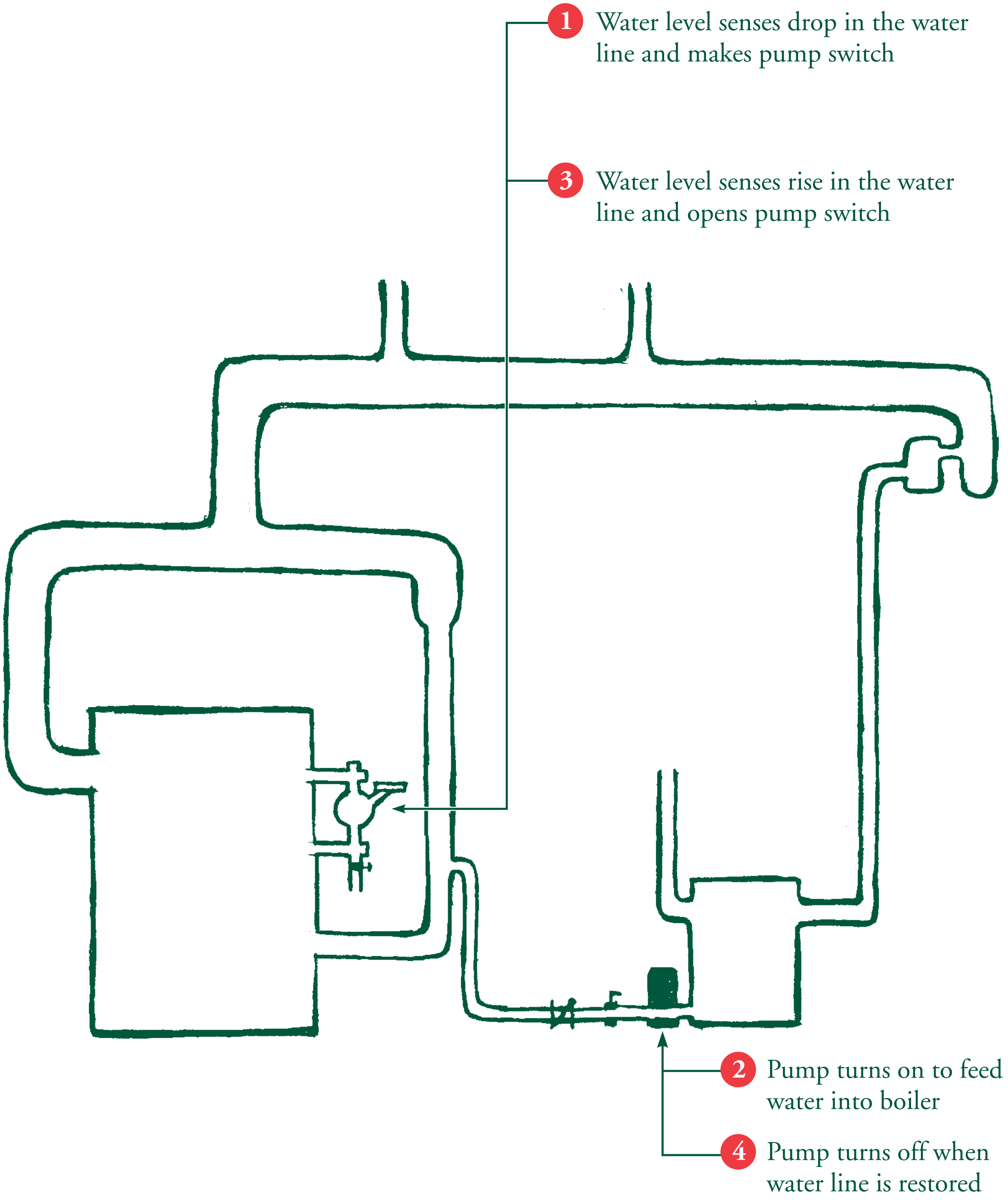
Fig. 1 The boiler feed unit sequence of operation.

1. A water level control on the boiler senses the drop in the water line and makes pump switch.
2. The level control then turns on the pump to feed water from the reservoir tank into the boiler.
3. The level control then senses the water level rising.
4. When the boiler water line is restored to the correct level, the water level control turns off the pump.

A boiler feed system consists of a reservoir tank, a pump, a water level control on the boiler, and a water make-up valve on the tank.

- The reservoir tank adds the water volume lost as boilers got smaller and more efficient.
- The pump provides the pressure to get the water back into the boiler. Now you don't have to worry about "A" or "B" dimensions.
- The water level control cycles the pump on and off to maintain an almost constant water line.
- The make-up valve on the tank feeds water back into the tank, not into the boiler.

Fig. 1


1 Water level senses drop in the water line and makes pump switch
3 Water level senses rise in the water line and opens pump switch
2 Pump turns on to feed water into boiler
4 Pump turns off when water line is restored

Sizing and Piping Boiler Feed Units

The reservoir tank should store at least 1 gallon of water for each boiler horsepower.

- Multiply boiler input in BTUs by 0.00003 for number of gallons needed in tank. See page 160 for common boiler sizes.

The pump has to have enough discharge pressure to overcome the operating pressure of the boiler and the friction loss of the piping.

- Most stock units have at least 20 pounds of discharge pressure.

The pump has to be able to move enough gallons of water per minute to keep up with the boiler's condensing rate.

- Multiply boiler input in BTUs by 0.000006 for number of gallons per minute pump needs to move.

When adding a boiler feed unit to an existing system, traps may have to be added to the system.

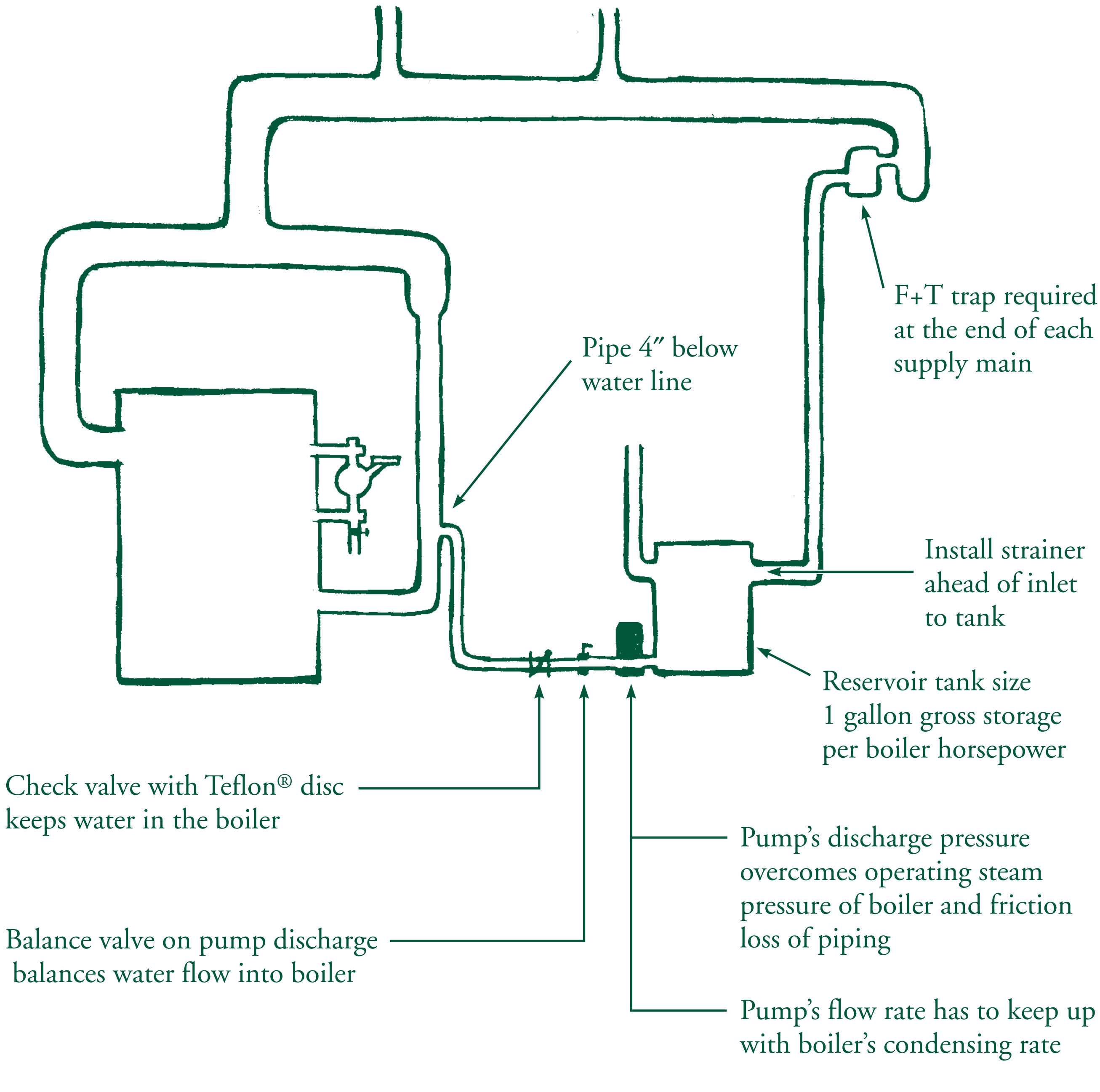
- Boiler feed tanks are open and vented to the atmosphere.
- On one and two pipe systems, the end of each steam supply main needs to be trapped individually.
- F+T traps work best because they vent air well and don't back up condensate.
- A vent may need to be added to the discharge side of the trap if the air cannot pass to the vent on the tank because of a water trap. See page 162.
- Don't forget a cooling leg after any trap located near the tank.

Don't master trap right ahead of the boiler feed unit on a two pipe system.

- The system already has traps.
- If steam is getting to the tank, fix the existing traps.
- Adding a second trap takes away the pressure differential that makes the existing trap work.
- Condensate won't return properly from the system.

Pipe the discharge of the pump to the boiler 4″ below the water line.

- Include a strainer between reservoir tank and pump inlet if possible. Install strainer ahead of reservoir tank if not.
- Include a check valve with Teflon® disc and a balance valve between the pump and the boiler.
- Use an amp meter to check the motor current draw while setting the balance valve.
- Don't operate motor of pump above its rated amperage.


F+T trap required at the end of each supply main
Pipe 4″ below water line
Install strainer ahead of inlet to tank
Reservoir tank size 1 gallon gross storage per boiler horsepower
Check valve with Teflon® disc keeps water in the boiler
Pump's discharge pressure overcomes operating steam pressure of boiler and friction loss of piping
Balance valve on pump discharge balances water flow into boiler
Pump's flow rate has to keep up with boiler's condensing rate

Condensate Pump Units

The purpose of a condensate pump unit is to move condensate.

- Condensate can be moved from a low point in the system.
- Condensate can be moved back into the boiler.

The condensate pump unit consists of a storage tank, a float switch, and a pump(s).

- The storage tank collects the condensate from the return lines.
- The float switch activates the pump when enough water collects in the tank.
- The pump moves the water out of the tank to a boiler feed unit, overhead return, or directly to the boiler.

Modern boilers with their small water content don't operate well with a condensate unit returning the water directly to the boiler.

- Boiler flooding problems are common when condensate units are used for boiler feed, especially in mild weather.
- Condensate units pump water into the boiler if the boiler needs it or not.

Condensate units can be used when underground wet return mains are removed because of leaks or remodeling.

- End of supply main steam traps may need to be added to the system since the condensate unit will be vented to the atmosphere.
- Pipe all returns that previously connected to underground line to condensate unit now located above ground or in a pit.
- Pipe new overhead return with pitch back to boiler room.

The radiation load connected to the condensate unit determines its size.

- Check manufacturer's literature for rated capacity of unit.
- Select unit with capacity that exceeds the radiation load.
- Don't undersize, because water will be lost out of the overflow.

Fig. 1 and Fig. 2 Sequence of operation of condensate pump unit.

1. Condensate from system flows into the tank.
2. Water level in tank rises.
3. Float in tank rises to make switch for pump.
4. Pump activates to move water out of tank through discharge piping.
5. Float in tank drops to open switch for pump.
6. Pump turns off.

Fig. 1

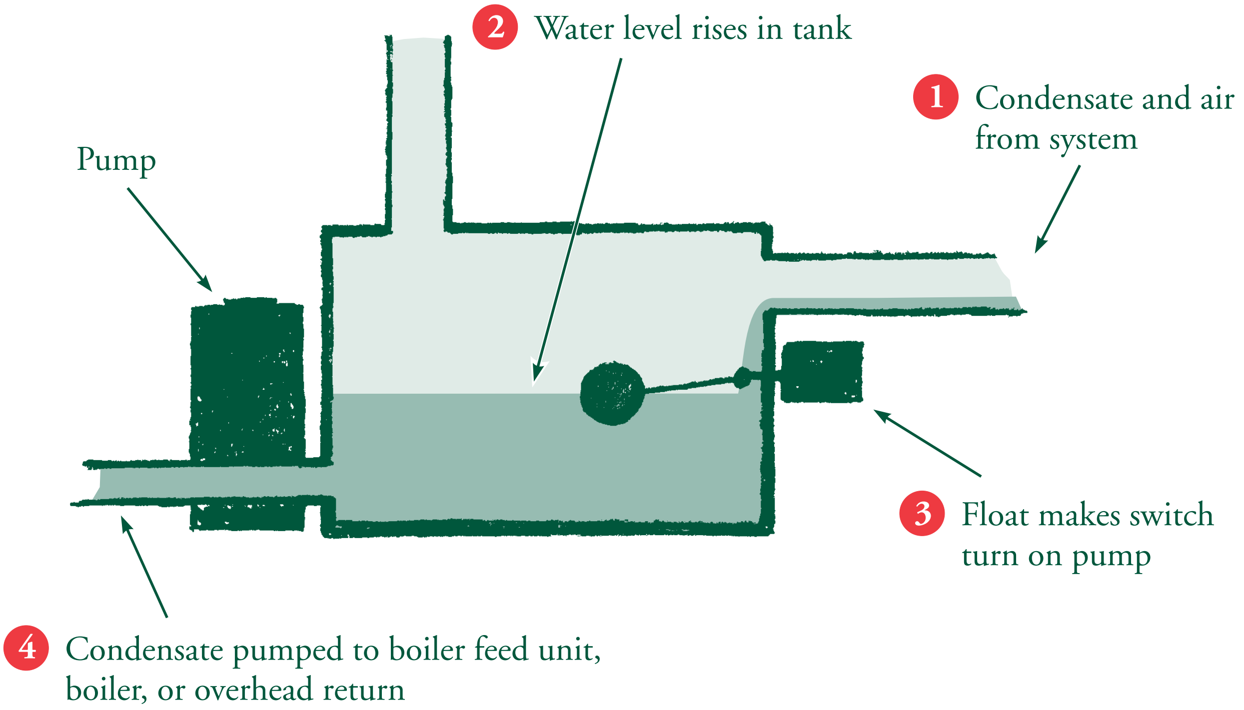
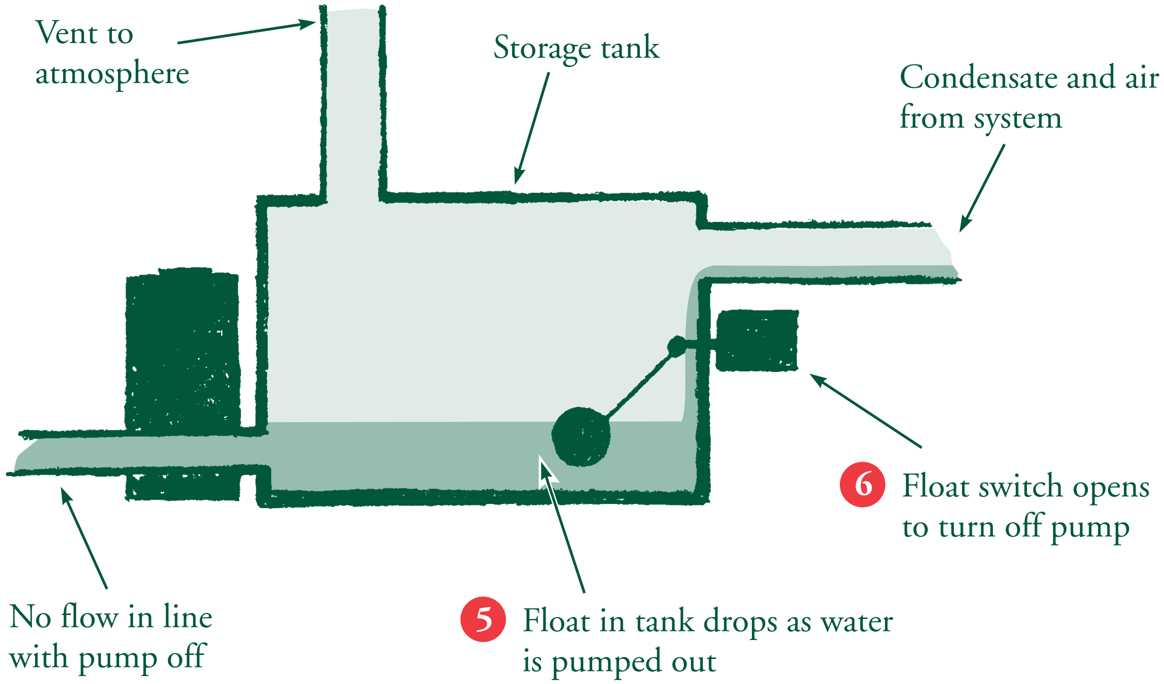

2 Water level rises in tank
1 Condensate and air from system
Pump
3 Float makes switch turn on pump
4 Condensate pumped to boiler feed unit, boiler, or overhead return

Fig. 2


Vent to atmosphere
Storage tank
Condensate and air from system
6 Float switch opens to turn off pump
No flow in line with pump off
5 Float in tank drops as water is pumped out


AIR
WATER
STEAM

Water Hammer Theory

Water hammer occurs when steam slams pockets of water around in the system.

- It is not normal for a steam system to make noise.
- Water hammer is an indication that something is wrong and should be fixed.

Most water hammer is caused by condensate return problems.

- Condensate has to return to the boiler at the end of a steam cycle.
- Water left in the return or supply piping systems during the off cycle can be the cause of water hammer.

There are many different problems that can cause water hammer.

- Knowing at what point in the steam cycle the hammering occurs can help you find the problem.
- The next three sections explain the causes of water hammer at the beginning, middle, and end of the steam cycle.

The most common cause of water hammer is the pitch of the pipe.

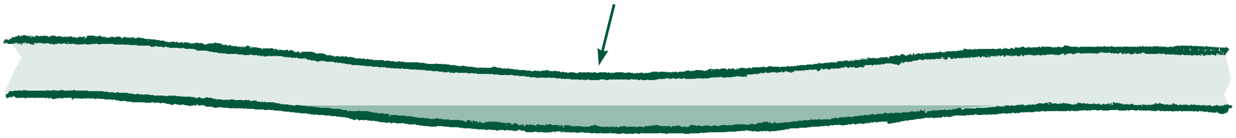
- Sags in the pipe due to the building settling or a hanger coming loose change the pitch of the pipe.
- **Fig. 1** Puddles of water stay in the piping during the off cycle instead of draining back to the boiler.
- **Fig. 2** The water is then whipped up by the velocity of the steam as it flows through the pipe during the on cycle.
- **Fig. 3** Slugs of water fill the pipe until the steam pressure blasts the slug down the main into the first bend, with a resulting bang.

Using concentric fittings or pipe that has not been properly reamed are other common causes of water hammer.

- They can both form puddles of water in the horizontal piping. See pages 116 and 117.

Fig. 1

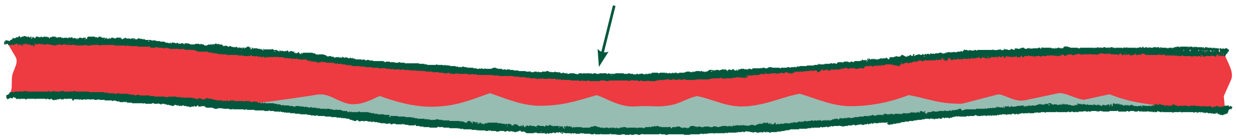
Pipe size is reduced by water which increases steam velocity



Puddle of water forms in sag of pipe

Fig. 2

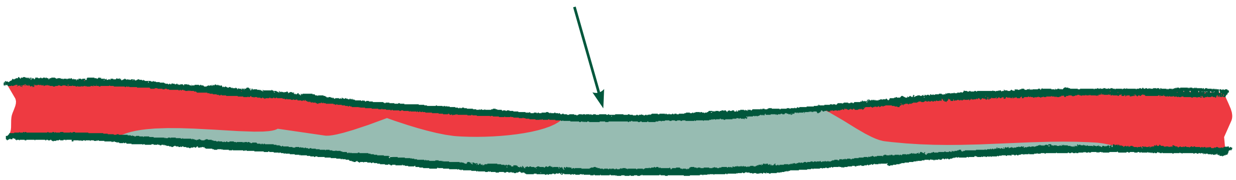
Waves decrease pipe size more, which increases steam velocity more



Steam velocity whips up puddle of water into waves

Fig. 3

Slug blocks steam flow



Slug of water is created and then blasted down pipe to bang or hammer at first bend

Causes of Water Hammer at the Beginning of the Steam Cycle

When the water hammer occurs at the beginning of the system cycle, look for places that the water can lay in the steam horizontal mains and run outs during the off cycle.

- The supply mains and run outs should be free of any puddles of water at start-up.
- All the condensate from the previous run cycle should be able to drain back to the wet return, condensate unit, or boiler feed unit.

The most common place for water to form puddles is in sagging pipe.

- As buildings settle, the pitch of the pipe can change.
- Fig. 1 Pipe hangers that have come loose or been removed can cause dips and sags.
- Run outs that have been used for hanging items or used by teenage boys for chin-ups can have changes in the pitch of the pipe.

The bottom of the horizontal supply piping must not go uphill.

- Fig. 2 A regular bell reducer (concentric) when used in a horizontal line creates a puddle of water.
- Fig. 3 A tee that makes a pipe reduction on both the branch and the run creates a puddle of water.
- Fig. 4 Pipe that is not reamed can create a puddle of water.

Steam mains that change elevation by rising up need to have a working drip.

- The drip can be with a water trap to a wet return or with a steam trap connected to a dry return, wet return, or condensate unit.
- The drip trap can become clogged or plugged with sediment.

Zone valves must be piped with a drip to return condensate when they are closed.

- If condensate can collect on outlet side, use drip and vacuum breaker on outlet of zone valve.
- If condensate can collect on inlet side, use drip on inlet of zone valve.

Fig. 1

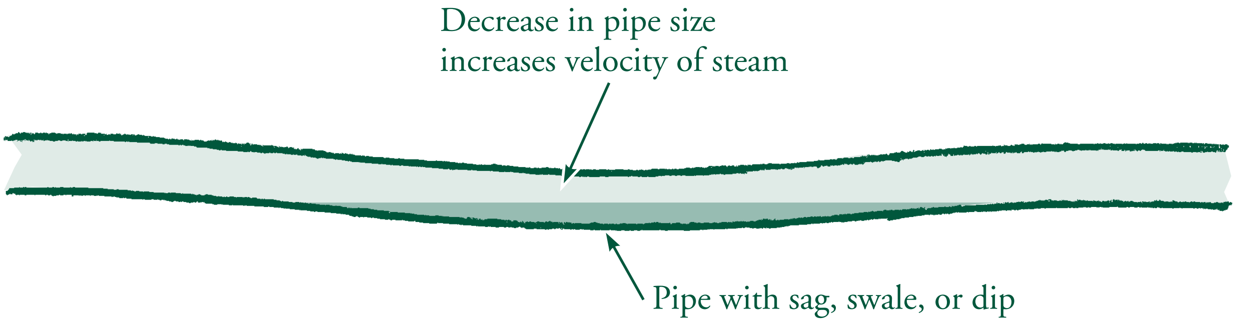


Fig. 2

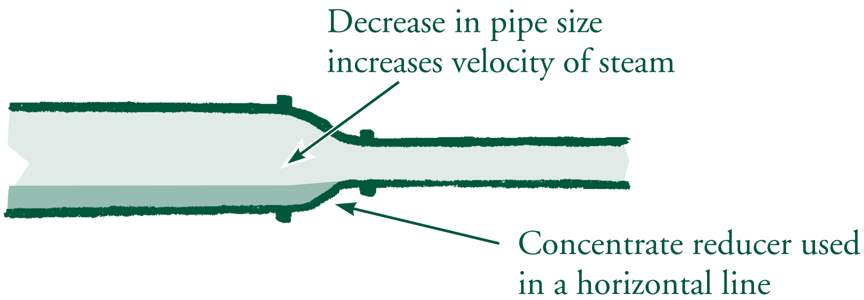


Fig. 3

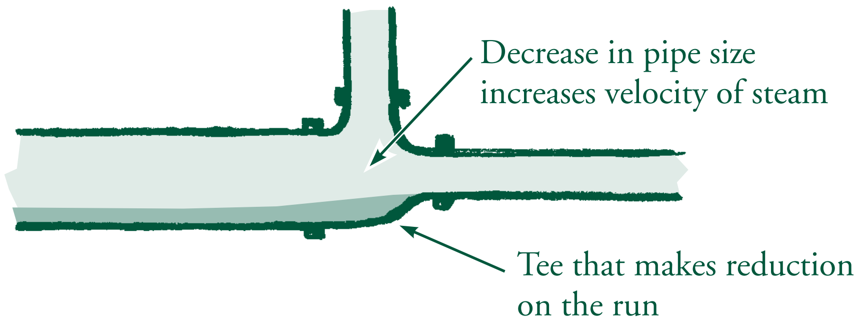
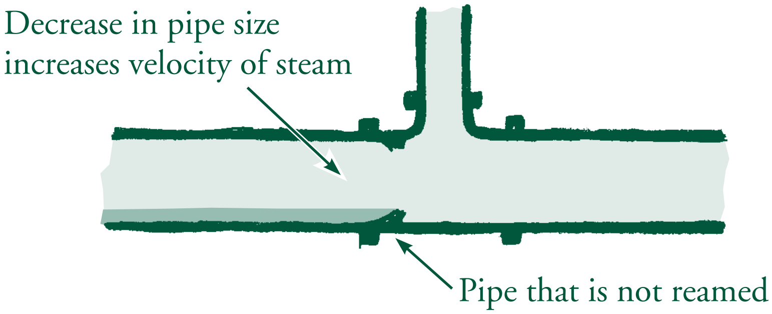


Fig. 4



Causes of Water Hammer at the Middle of the Steam Cycle

When the water hammer occurs at the middle of the steam cycle, look for places that will slow or block condensate during the steam cycle.

- During the steam cycle, condensate is constantly being produced.
- Condensate has to have a properly sized and pitched pipe to handle the volume of condensate produced.

Fig. 1 The most common place for condensate to be slowed or blocked is in the wet return.

- It is the lowest spot in the piping and will accumulate the most sediment.
- Sediment build up in the wet return can turn a 2″ pipe into a ¾″ pipe on the inside.
- The reduction in pipe size slows the flow of condensate, backing it up into the supply main where it will hammer.

A boiler making wet steam puts more condensate in the piping than it was designed for.

- Depending on how bad the problem is, the existing pipes cannot handle the extra load.
- The condensate then backs up in the system and starts to hammer.
- Overfiring or oversizing the boiler can cause wet steam or excess condensate loads for existing piping.

Fig. 2 Steam traps that are undersized or clogged with dirt or sediment can slow or block condensate.

- The condensate then backs up into the steam main during the steam cycle until it starts hammering.
- Sometimes the bellows assembly will break off and lodge in the seat to also slow or block condensate.

Uninsulated supply pipes produce more condensate than insulated pipes.

- Depending on how much pipe or how cold an area it runs through, the existing pipes cannot handle the extra load.
- The condensate then backs up in the system to start the hammering.

On one pipe radiators, if the venting rate is too fast, water hammer in the radiation can occur.

- The velocity of the steam increases to the point that the water cannot get back out of the radiator. See page 70 and 71.
- It's similar to not having the valve fully open.

Causes of Water Hammer at the Middle of the Steam Cycle

Fig. 1

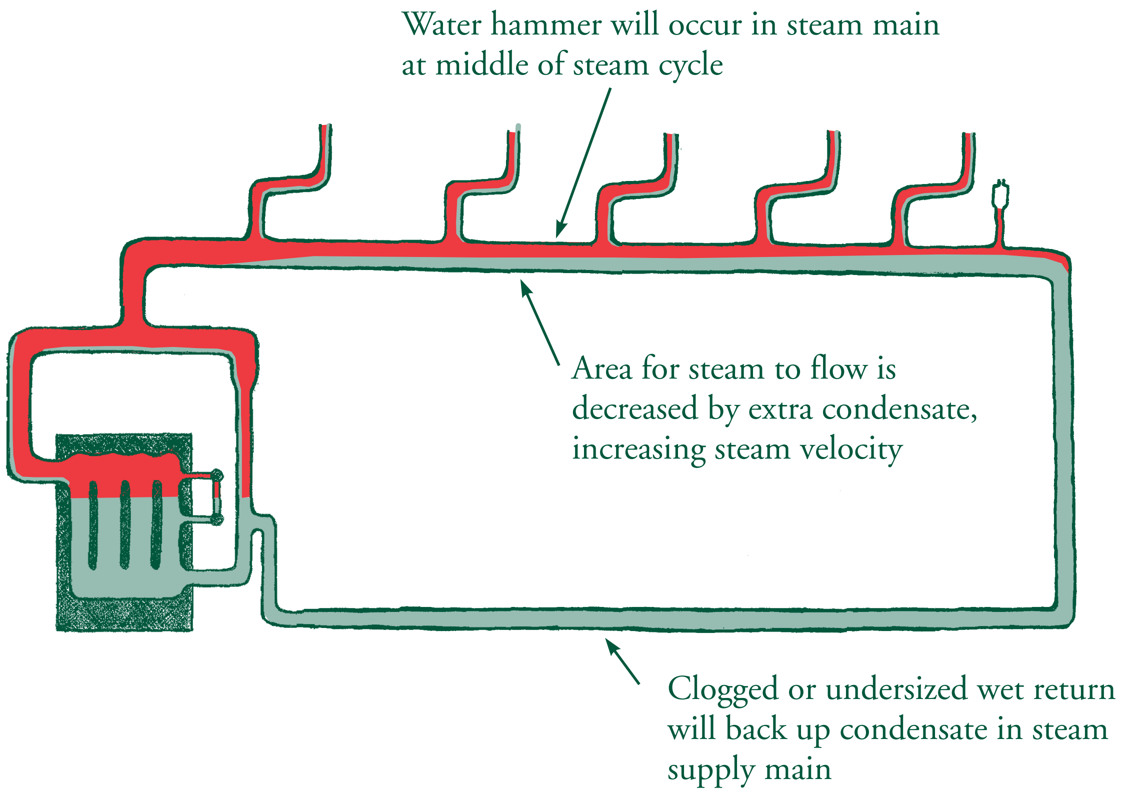
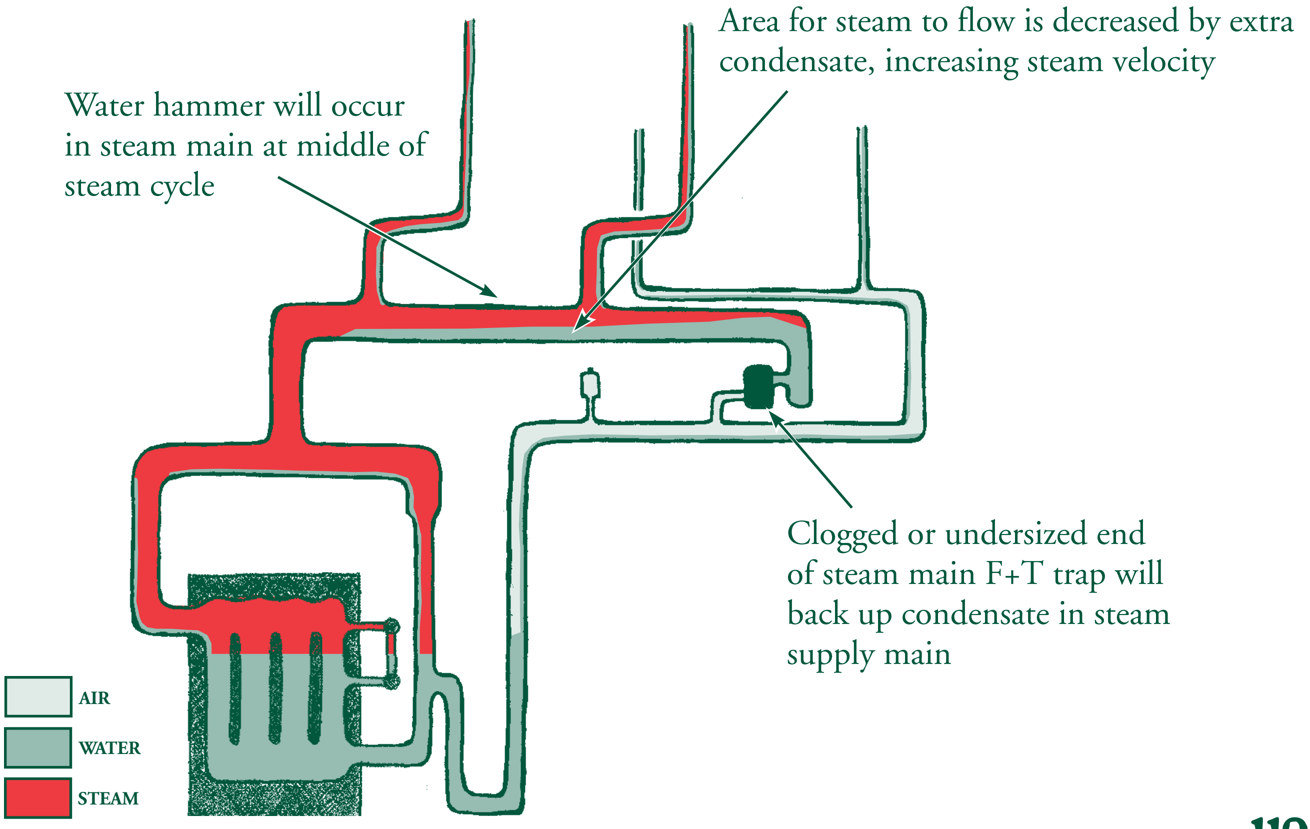


Fig. 2



Middle Cycle Hammering, continued

Incorrect piping around the Hartford Loop or boiler feed unit can cause water hammer at the middle of the steam cycle.

- The details of near boiler piping need to be followed, refer to pages 56 and 57.
- The details of piping boiler feed units need to be followed. Refer to pages 110 through 111.

Avoid water traps before the inlet to a boiler feed unit.

- If the water trap cannot be avoided, like going under doorways, make sure to use an air vent after the trap. See page 162.

Don't master trap right ahead of the boiler feed unit on a one pipe system.

- Steam vapor will come out the reservoir tank vent because the trap does not have a cooling leg.
- The system will water hammer because steam is getting into the horizontal piping before the trap that has water in it.
- The steam wants to go to the trap and its lower pressure, so it hammers through the condensate laying in the horizontal piping.

Always use the close nipple in the horizontal portion of the Hartford Loop.

- If the water line drops low enough, steam can bounce around in the horizontal pipe.
- If the pipe is long enough, water hammer will occur.

Fig. 1 Pumped condensate from the boiler feed pump can be forced up into the steam portion of the equalizer where it will hammer.

- When piping from a boiler feed pump into the Hartford Loop, make certain the horizontal connection is 4″ below the water line.
- The returning pumped condensate will be less likely to be forced up into the equalizer.

Fig. 2 On two pipe systems, steam traps that have failed in the open position can cause water hammer at mid-cycle.

- At the beginning of the cycle, steam is condensing on the cold surfaces of the radiator and does not pass through the open trap.
- At mid-cycle when the radiator surfaces are warm, steam passes through the open trap.
- Steam then reaches the dry return, where it will cause water hammer, as well as uneven heating and high fuel bills.
- Don't neglect trap maintenance.

Fig. 1

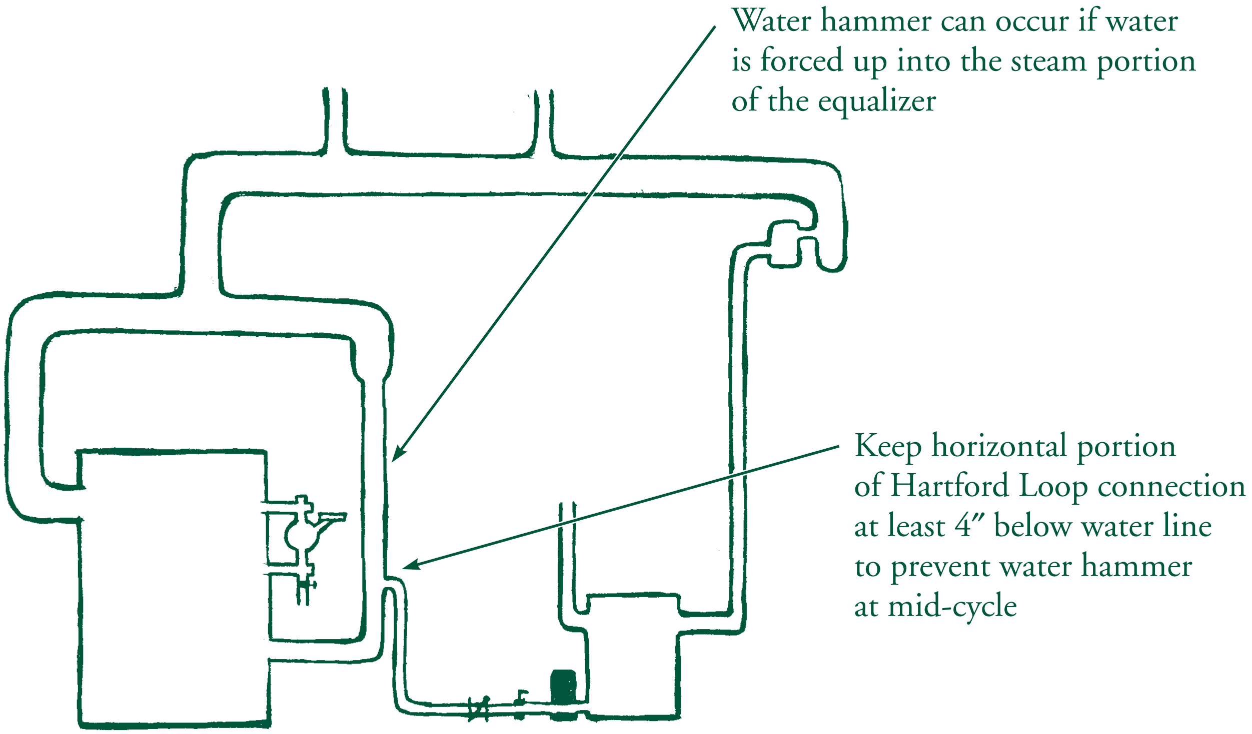
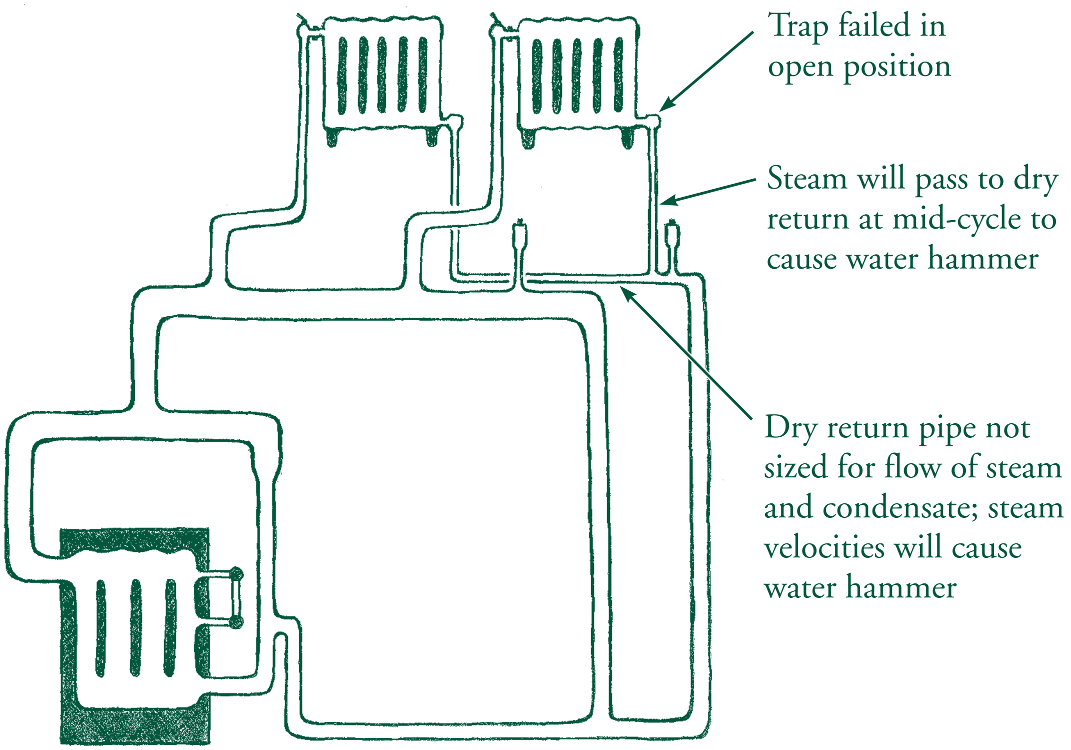

Water hammer can occur if water is forced up into the steam portion of the equalizer
Keep horizontal portion of Hartford Loop connection at least 4″ below water line to prevent water hammer at mid-cycle

Fig. 2


Trap failed in open position
Steam will pass to dry return at mid-cycle to cause water hammer
Dry return pipe not sized for flow of steam and condensate; steam velocities will cause water hammer

Causes of Water Hammer at the End of the Cycle and in the Boiler

Fig. 1 When the water hammer occurs at the end of the boiler cycle, look at the near boiler piping.

- On gravity return systems, the Hartford Loop connection must be at least 2˝ below the water line.
- At the end of the boiler cycle, the steam pressure is generally at its highest while the water level is at its lowest.
- The steam pressure pushes the water down in the equalizer to expose the horizontal portion of the Hartford Loop to steam.
- Steam then mixes with the returning condensate to create hammering.

Check for insulation on the near boiler piping of gravity return systems.

- Without insulation on the boiler piping, when the boiler shuts down it can create a vacuum.
- This vacuum can cause the water level in the boiler to surge, allowing steam into the return lines where it will momentarily hammer.
- Insulate all steam piping, even around the boiler.
- To correct, install a vacuum breaker above the water line of the boiler or on supply piping.

Fig. 2 When the water hammer occurs in the boiler, look for causes of uneven temperatures in the boiler.

- Sediment build up, mineral deposits from excessive fresh water make up and core sand from manufacturing can all cause uneven temperatures of the boiler water.
- Steam systems rust from the inside.
- The returning condensate can carry that rust or sediment back to the bottom of the boiler.
- Heat from the burner can dislodge this sediment causing hammering in the boiler.

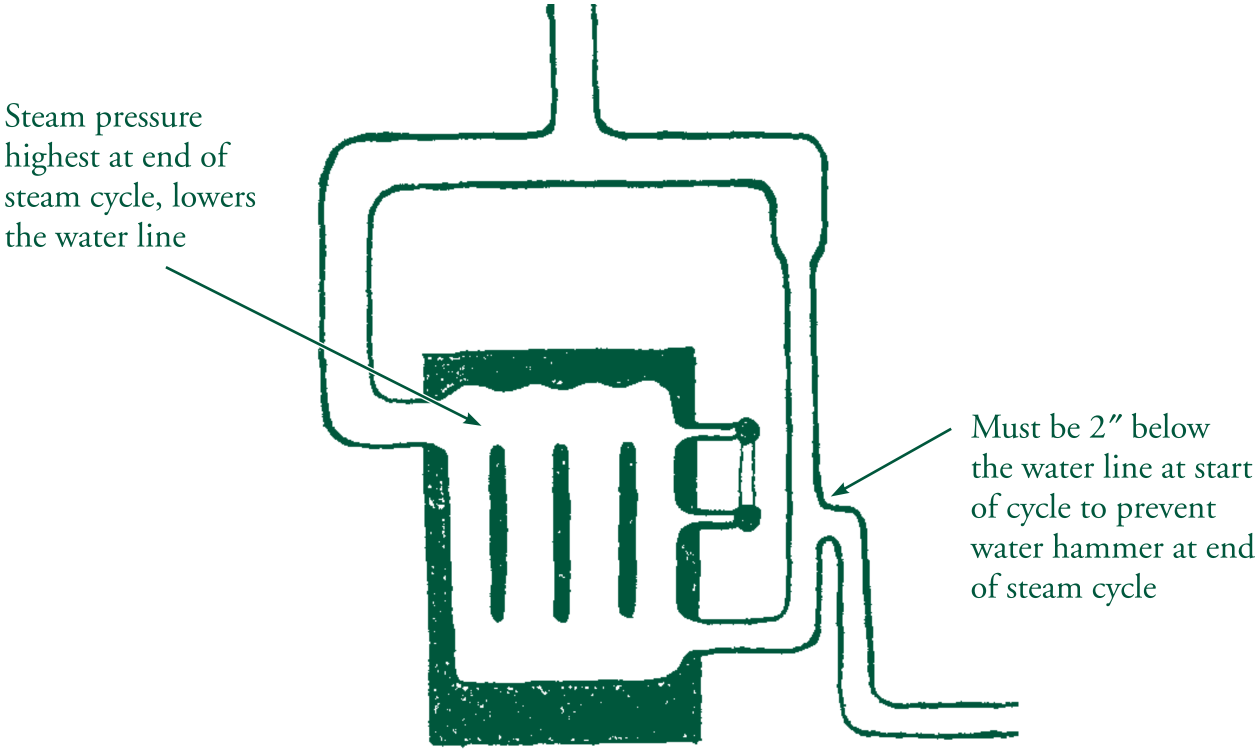
Poor circulation can cause areas of the boiler water to have different temperatures.

- When very hot water in the boiler suddenly moves to areas of cooler water, hammering can occur.
- To correct, flush bottom of boiler of any build up to improve circulation. See page 155.

Another cause of uneven temperature of the boiler water is the flame pattern of gas or oil power burners.

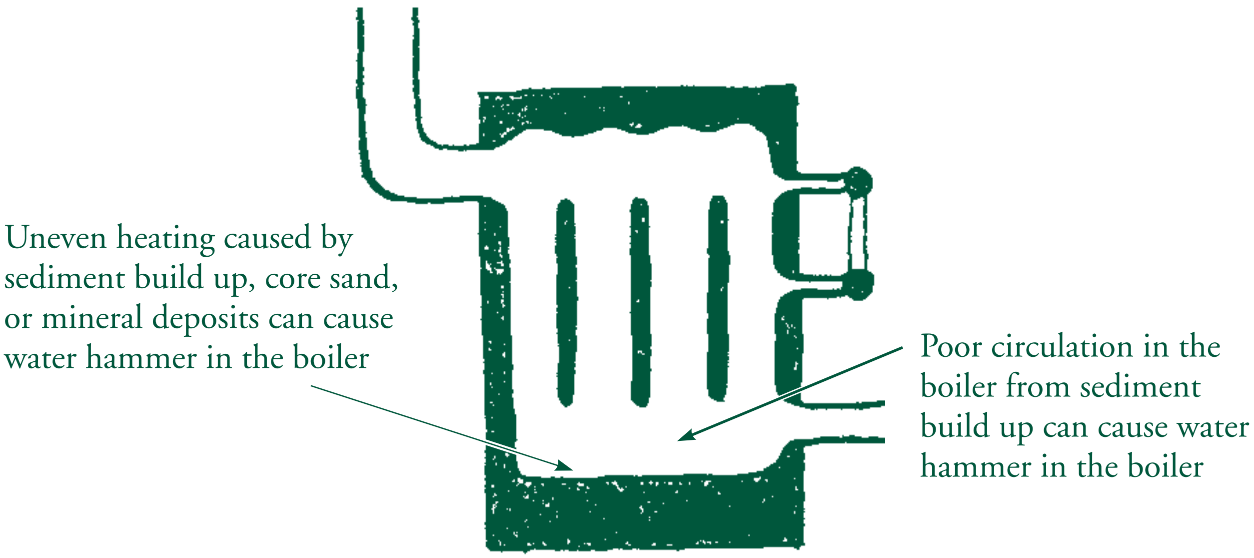
- If the heat from the burner is concentrated into one area of the combustion chamber, it causes uneven temperature of the boiler water.
- The surging of the hotter water to cooler areas of the boiler can cause the boiler itself to hammer.
- Make sure that all insulation blankets and wet packs are properly installed in an oil fired boiler's combustion chamber to avoid temperature imbalance.

Fig. 1



WATER HAMMER AT END OF STEAM CYCLE

Fig. 2



WATER HAMMER IN THE BOILER

CHAPTER SIX

Troubleshooting Flow Charts

How to use.

- Troubleshooting charts are divided into the common problems for the different areas of the system.
- Find the problem that is most closely related to the symptoms of the system you are working on.
- Work your way down the flow chart.
- Refer back to the pages listed in the flow charts for theory and diagrams relating to the problem.

What to look for.

- Observe the gauge glass. Boiler has to be clean before troubleshooting. See page 34.
- Get out of the boiler room to see the whole system.
- If steam, air, or water are in parts of the system that they are not supposed to be, that is part of your problem.
- If steam, air, or water are not where they are supposed to be, what is blocking the path is part of your problem.

What to ask.

- How long has the problem been occurring?
- Has anything in the system been changed lately?
- In what areas of the building or system is the problem occurring?
- Has the fuel usage increased?

Bonus Feature
Page 153
15 tips for top performance
and low fuel bills
for steam systems.

Index of Troubleshooting Flow Charts

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128	Pressure builds up quickly, but steam does not circulate
129	Water hammer in Hartford Loop
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131	Boiler does not build up pressure on gauge
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133	Burner shuts off on low water
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138	Steam does not reach end of main
139	Steam coming out of vent on condensate, vacuum, or boiler feed unit
140	Hissing main air vent
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150	Building is too hot
151	Building is too cold
152	High fuel bills
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Unsteady or Bouncing Water Line

Is the boiler clean? See Pages 34 & 35

- Yes → Water line is set correctly? Pages 38 & 39
- No → Clean boiler. Pages 36 & 37

Water line is set correctly? Pages 38 & 39

- Yes → Is near boiler piping correct? Pages 56 & 57, 62 & 63
- No → Set water line to correct level. Pages 38 & 39

Is near boiler piping correct? Pages 56 & 57, 62 & 63

- Yes → Is boiler sized properly? Pages 64 & 65
- No → Correct piping. Pages 56 & 57, 62 & 63

Is boiler sized properly? Pages 64 & 65

- Yes → Is boiler fired at correct rate? Pages 64 & 65
- No → Correct sizing. Pages 64 & 65

Is boiler fired at correct rate? Pages 64 & 65

- Yes → Is flame pattern correct? Pages 64 & 65
- No → Change firing rate. Pages 64 & 65

Is flame pattern correct? Pages 64 & 65

- Yes → Check for internal circulation. Pages 122 & 123
- No → Adjust flame.

Water Suddenly Leaves Gauge Glass

Is the boiler clean? **See Pages 34 & 35**

- Yes → Is water line set correctly? **Pages 38 & 39**
  - Yes → Is near boiler piping correct? **Pages 56 & 57, 62 & 63**
    - Yes → Is firing rate correct? **Pages 64 & 65**
      - Yes → Is flame pattern correct?
        - Yes → Is boiler gravity return or pumped?
          - Gravity → Check equalizer. **Pages 102 & 103**
          - Pumped → Is water backing into receiver tank through check valve? **Pages 110 & 111**
            - Yes → Replace check valve.
            - No
        - No → Correct flame pattern.
      - No → Correct firing rate. **Pages 64 & 65**
    - No → Correct piping. **Pages 56 & 57, 62 & 63**
  - No → Set water line to correct level. **Pages 38 & 39**
- No → Clean boiler. **Pages 36 & 37**

Pressure Builds Up Quickly, But Steam Does Not Circulate

Is the boiler clean? **See Pages 34 & 35**

- Yes → Is water line set correctly? **Pages 38 & 39**
- No → Clean boiler. **Pages 36 & 37**

Is water line set correctly?

- Yes → Are air vents on mains properly located and working? **Pages 84 & 85**
- No → Set water line to correct level. **Pages 38 & 39**

Are air vents on mains properly located and working?

- Yes → Are air vents properly sized? **Pages 84 & 85**
- No → Fix vents.

Are air vents properly sized?

- Yes → Are traps working?
- No → Add vents if necessary. **Pages 84 & 85**

Are traps working?

- Yes → Is pressuretrol mounted properly?
- No → Fix traps.

Is pressuretrol mounted properly?

- Yes → Is pressuretrol pigtail clear?
- No → Correct or level.

Is pressuretrol pigtail clear?

- Yes
- No → Clean or replace.

Water Hammer in Hartford Loop

Gravity or Pumped Return

- Gravity
  - Is the horizontal portion of the Hartford Loop as short as possible? **Pages 102 & 103**
    - Yes
      - Is horizontal portion at least 2" below water line. **Pages 102 & 103**
        - Yes
          - Is water line steady?
            - Yes
              - **See Pages 120 & 121**
            - No
              - Check for clean boiler. **Pages 34 & 35**
        - No
          - Adjust level.
    - No
      - Use a close nipple or Y tee. **Pages 102 & 103**
- Pumped
  - Is the horizontal portion at least 4" below the water line? **Pages 110 & 111**
    - Yes
      - Is water line steady?
        - Yes
          - **See Pages 120 & 121**
        - No
          - Check for clean boiler. **Pages 34 & 35**
    - No
      - Adjust to 4" below the water line.

Boiler Takes on a Lot of Make-up Water

Is the boiler flooding?

- **Yes** → **Page 132**
- **No** → Does system have any underground piping?
  - **Yes** → Locate leaks in piping and fix. If not practical to repair, install condensate pumps to transfer condensate. **Pages 112 & 113**
  - **No** → Are there any leaking pipes?
    - **Yes** → Fix leaks.
    - **No** → Are there any leaking vents?
      - **Yes** → Fix vents.
      - **No** → Is the boiler leaking steam above the water line? Check by manually raising water level to flood boiler.
        - **Yes** → Replace boiler or repair leak in boiler.
        - **No** → **See Page 132**

Boiler Does Not Build Up Pressure on Gauge

Does system heat well?

- Yes
  - Systems can heat at pressures so low that the gauge will not register. This is not a problem.
- No
  - Is boiler clean? **Pages 34 & 35**
    - Yes
      - Is the near boiler piping correct? **Pages 56 & 57, 62 & 63**
        - Yes
          - Is there a leak in the boiler above the water line? Check by manually raising water level to flood boiler.
            - Yes
              - Repair leak in boiler or replace boiler.
            - No
              - Is the boiler correctly sized and fired? **Pages 64 & 65**
                - Yes
                  - Are supply pipes insulated?
                    - Yes
                      - **See Pages 30 & 31**
                    - No
                      - Insulate pipes.
                - No
                  - Correct boiler size or firing rate. **Pages 64 & 65**
        - No
          - Correct piping. **Pages 56 & 57, 62 & 63**
    - No
      - Clean boiler. **Pages 36 & 37**

Boiler Is Flooding

Is boiler clean and making dry steam? **See Pages 34 & 35**

- No → Clean boiler. **Pages 36 & 37**
- Yes → Is near boiler piping correct? **Pages 56 & 57, 62 & 63**
  - No → Correct piping. **Pages 56 & 57, 62 & 63**
  - Yes → Is boiler operating pressure too high? **Pages 42 & 43**
    - Too high → Reduce pressure. **Pages 42 43**
    - Correct → Is tankless heater leaking?
      - Yes → Replace or repair.
      - No → Is manual bypass leaking?
        - Yes → Replace or repair.
        - No → Is wet return clean or clogged?
          - Clogged → Repipe or flush.
          - Clear → Is boiler sized and fired correctly? **Pages 64 & 65**
            - No → Correct sizing or firing. **Pages 64 & 65**
            - Yes → Is feeder leaking water into boiler? **Page 156 for broken union test**
              - Yes → Repair.
              - No → Are vacuum breakers installed with zone valves? **Page 116**
                - No → Install vacuum breakers. **Page 116**
                - Yes → Check for operator error.

Burner Shuts Off on Low Water

Is boiler clean? **See Pages 34 & 35**

- No → Clean boiler. **Pages 36 & 37**
- Yes → Is water line set too low? **Pages 38 & 39**
  - No → Set water line to proper level. **Pages 38 & 39**
  - Yes → Is near boiler piping causing the steam to create too much velocity? **Pages 56 & 57, 58 & 59, 60 & 61, 62 & 63**
    - Yes → Correct near boiler piping. **Pages 56 & 57, 62 & 63**
    - No → Is boiler operating pressure too high? **Pages 42 & 43**
      - Yes → Adjust steam pressure. **Pages 42 & 43**
      - No → Is wet return clear or clogged?
        - Clogged → Repair or flush.
        - Clear → Is there a leak in the boiler above or below water line?
          - Boiler leaks → Repair or replace boiler.
          - No leak in boiler → Are there leaks in the system?
            - Yes → Fix leaks.
            - No → Consider a boiler feed unit. **Pages 108 & 109**

Boiler Shuts Off on Pressure

Is boiler oversized for the amount of radiation installed? **See Pages 64 & 65**

- Yes → Reduce input to burner if possible. **Pages 64 & 65**
- No → Is burner overfiring for the amount of radiation installed? **Pages 64 & 65**
  - Yes → Adjust boiler firing rate.
  - No → Is the main air vent(s) installed and working? **Pages 66 & 67**
    - No → Install and replace main air vent(s).
    - Yes → Is the main air vent(s) properly sized? **Pages 84 & 85**
      - No → Replace with properly sized vent(s). **Pages 84 & 85**
      - Yes → Is the pigtail of the pressure control clear?
        - No → Clean or replace.
        - Yes → Is pressure control level?
          - Yes → Replace pressure control.
          - No → Level.

Spitting Main Air Vent

Is the system one pipe or two pipe?
See Pages 46 & 47, 48 & 49

- One pipe
  - Calculate "A" dimension. **Pages 90 & 91**
    - Is "A" dimension enough for operating pressure?
      - Yes
        - Is vent protected from water hammer? **Pages 84 & 85**
          - Yes
            - Is vent defective?
              - Yes
                - Replace.
              - No
                - Repair or clean.
          - No
            - Change location. **Pages 84 & 85**
      - No
        - Adjust pressure or add boiler feed.
- Two pipe
  - Calculate "B" dimension. **Pages 96 & 97**
    - Is "B" dimension enough for operating pressure?
      - Yes
        - Is vent protected from water hammer? **Pages 84 & 85**
          - Yes
            - Is vent defective?
              - Yes
                - Replace.
              - No
                - Repair or clean.
          - No
            - Change location. **Pages 84 & 85**
      - No
        - Adjust pressure or add boiler feed.

Main Air Vent Leaks Steam

Is boiler operating pressure too high? **See Pages 42 & 43**

- Yes → Adjust pressure. **One Pipe: Pages 90 & 91** **Two Pipe: Pages 96 & 97**
- No → Is air vent too small? **Pages 84 & 85**
  - Yes → Install proper size or number of vents. **Pages 84 & 85**
  - No → Is boiler oversized or overfired? **Pages 64 & 65**
    - No → Correct size or firing rate. **Pages 64 & 65**
    - Yes → Is vent protected from water hammer? **Pages 84 & 85**
      - No → Change location. **Pages 84 & 85**
      - Yes → Are zone valves being used? Is vent size for each zone rated for full boiler capacity? **Pages 84 & 85**
        - No → Install proper size or number of vents. **Pages 84 & 85**
        - Yes → Is vent defective?
          - Yes → Replace.
          - No → Repair or clean.

Water Hammer in Mains

Is boiler clean and making dry steam? See Pages 34 & 35

- Yes → Is near boiler piping correct? Pages 56 & 57, 62 & 63
  - Yes → Is boiler operating pressure too high for gravity return? Pages 70 & 71, 96 & 97
    - No → Pitch of pipe correct? Pages 114 & 115
      - Yes → Is the wet return clean or clogged?
        - Clear → Is pipe size of mains correct? Pages 54 & 55
          - Yes → On two pipe systems, are radiator traps working?
            - Yes → Has insulation been removed?
              - No → See Pages 114 & 115, 116 & 117, 118 & 119, 120 & 121
              - Yes → Replace insulation.
            - No → Repair or replace traps.
          - No → Correct piping. Pages 54 & 55
        - Clogged → Repipe or flush.
      - No → Correct pitch. Pages 114 & 115
    - Yes → Adjust pressure. One Pipe: Pages 90 & 91
Two Pipe: Pages 96 & 97
  - No → Correct piping. Pages 56 & 57, 62 & 63
- No → Clean boiler. Pages 36 & 37

Steam Does Not Reach End of Main

Is the boiler clean and making dry steam? See Pages 34 & 35

- **No** → Clean boiler. Pages 36 & 37
- **Yes** → Is near boiler piping correct? Pages 56 & 57, 62 & 63
  - **No** → Correct piping. Pages 56 & 57, 62 & 63
  - **Yes** → Is there a working main air vent(s)? Pages 66 & 67
    - **No** → Install or replace vents. Pages 66 & 67
    - **Yes** → Is vent(s) properly sized? Pages 84 & 85
      - **No** → Install correct vent(s). Pages 84 & 85
      - **Yes** → Is boiler adequately sized or fired? Pages 64 & 65
        - **No** → Correct sizing or firing rate. Pages 64 & 65
        - **Yes** → On two pipe, are traps keeping steam out of returns? Pages 48 & 49
          - **No** → Repair or replace defective traps.
          - **Yes** → Is main pitched correctly? Pages 54 & 55
            - **No** → Adjust pitch of pipes. Pages 54 & 55
            - **Yes** → Has insulation been removed from supply main?
              - **No** → See Pages 30 & 31, 32 & 33
              - **Yes** → Repair.

Steam Coming Out of Vent on Condensate, Vacuum, or Boiler Feed Units

At beginning or middle of run cycle

- **Beginning** (and **Middle → 1 PS**)
  - Check for end of supply main(s) trap(s). **Pages 110 & 111**
    - **Yes** → Check operation.
      - **Working** → Check distance from outlet of trap to receiver tank. Install cooling leg. **Page 158**
      - **Not working** → Replace.
    - **No** → Size and install trap for each supply main. **Page 158**
- **Middle**
  - **1 PS** → (see Beginning: Check for end of supply main(s) trap(s).)
  - **2 PS** → Check temperature of return main. Are radiator traps leaking steam into return line?
    - **Yes** → Locate faulty traps and repair all.
    - **No** → Check distance from outlet of steam main trap to receiver tank. Install cooling leg. **See Page 158**

Hissing Main Air Vent

One pipe

Two pipe

Does it hiss before steam is up?

Yes

Check capacity of main vent.
Add vent if required.
Pages 84 & 85

No

Is it air or steam?

Air

Check capacity.
See **Pages 84 & 85** for sizing main vent.

Add vent(s) if required.

Steam

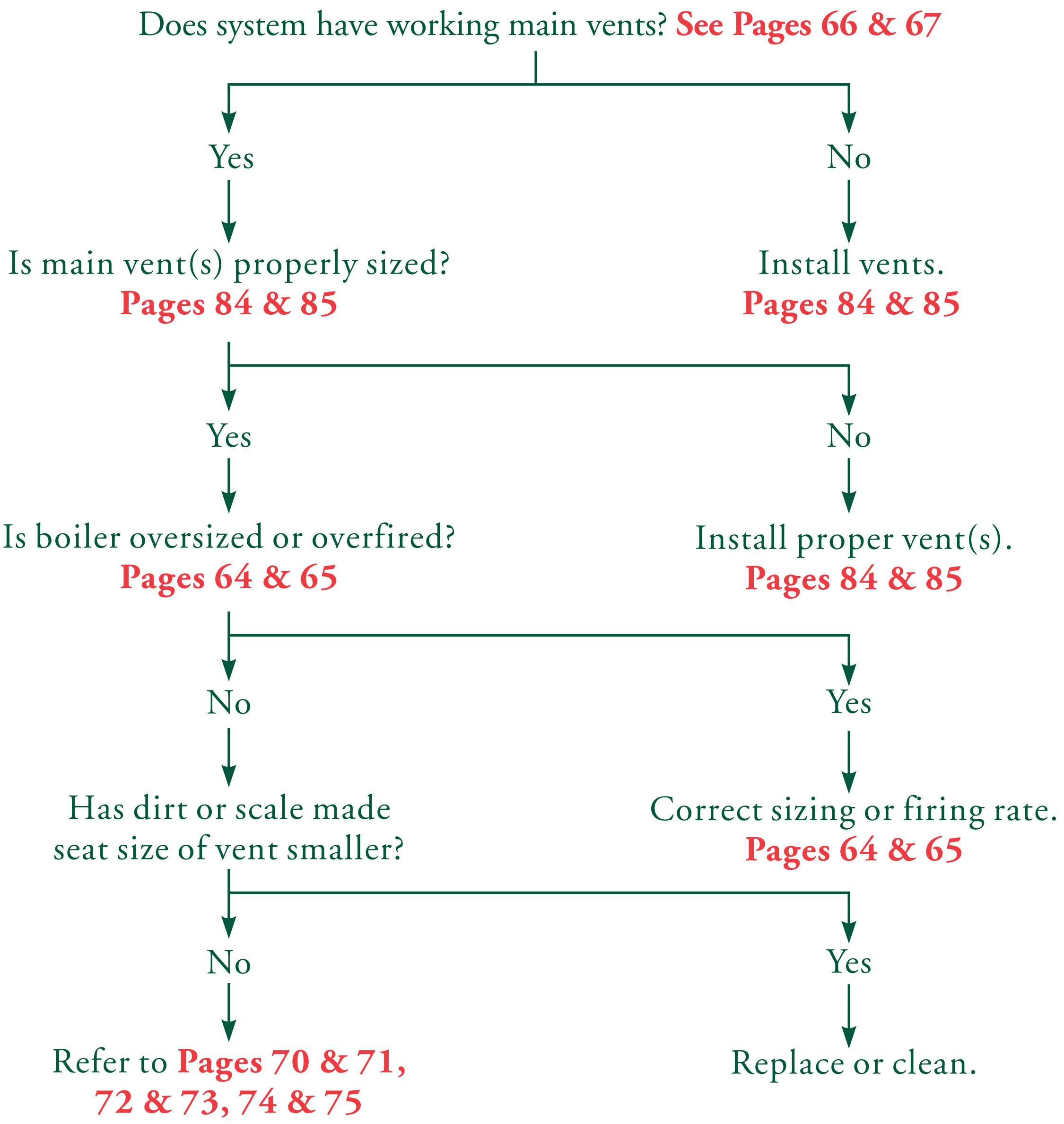
Check for dirt on seat.
If not repairable, replace vent.

Spitting Radiator Air Vent

Is radiator valve completely open? **See Pages 46 & 47**

- **Yes** → Is radiator pitched so condensate flows toward radiator valve? **Pages 46 & 47**
  - **Yes** → Is rate too fast? **Pages 70 & 71**
    - **No** → Is vent defective or have dirt on seat? Test with known good vent
      - **No** → Does system have working main vents properly sized? **Pages 84 & 85**
        - **Yes** → Refer to **Pages 70 & 71, 72 & 73, 74 & 75**
        - **No** → Replace defective main vent or re-size. **Pages 84 & 85**
      - **Yes** → Replace vent or clean.
    - **Yes** → Slow venting or add second vent to radiator. **Pages 72 & 73**
  - **No** → Re-pitch radiator.
- **No** → Open valve or replace valve if stem is broken. **Pages 46 & 47**

Hissing Radiator Vents



Radiator Vent Leaks Steam

Has dirt or scale built-up on seat of vent to prevent it from closing?

- **No** → Is operating pressure of system too high? **Pages 42 & 43**
  - **No** → Is boiler oversized or overfired? **Pages 64 & 65**
    - **No** → Refer to **Pages 70 & 71, 72 & 73, 74 & 75**
    - **Yes** → Correct sizing or firing rate. **Pages 64 & 65**
  - **Yes** → Lower pressure. **Pages 42 & 43**
- **Yes** → Replace or clean vent.

Water Hammer in Radiator

One Pipe or Two Pipe?

- **One Pipe Steam**
  - Is radiator valve completely open? **Pages 20 & 21**
    - **Yes** → Is radiator pitched so condensate flows toward radiator valve? **Pages 20 & 21**
      - **Yes** → Is vent rate too fast? **Pages 66 & 67**
        - **No** → Refer to **Pages 70 & 71, 72 & 73, 74 & 75**
        - **Yes** → Use slower vent or add second vent. **Pages 72 & 73**
      - **No** → Re-pitch radiator.
    - **No** → Open valve or replace if system is broken. **Pages 46 & 47**
- **Two Pipe Steam**
  - Check pitch, does it slope towards trap or vapor device? **Pages 24 & 25**
    - **Yes** → Break union at trap or vapor device, is water present?
      - **No** → **See Pages 96 & 97, 98 & 99**
      - **Yes** → Clear blockage or replace.
    - **No** → Re-pitch radiator.

Radiator Does Not Completely Fill with Steam

(System does not heat completely on cold day)

Is the boiler clean and making dry steam? **See Pages 34 & 35**

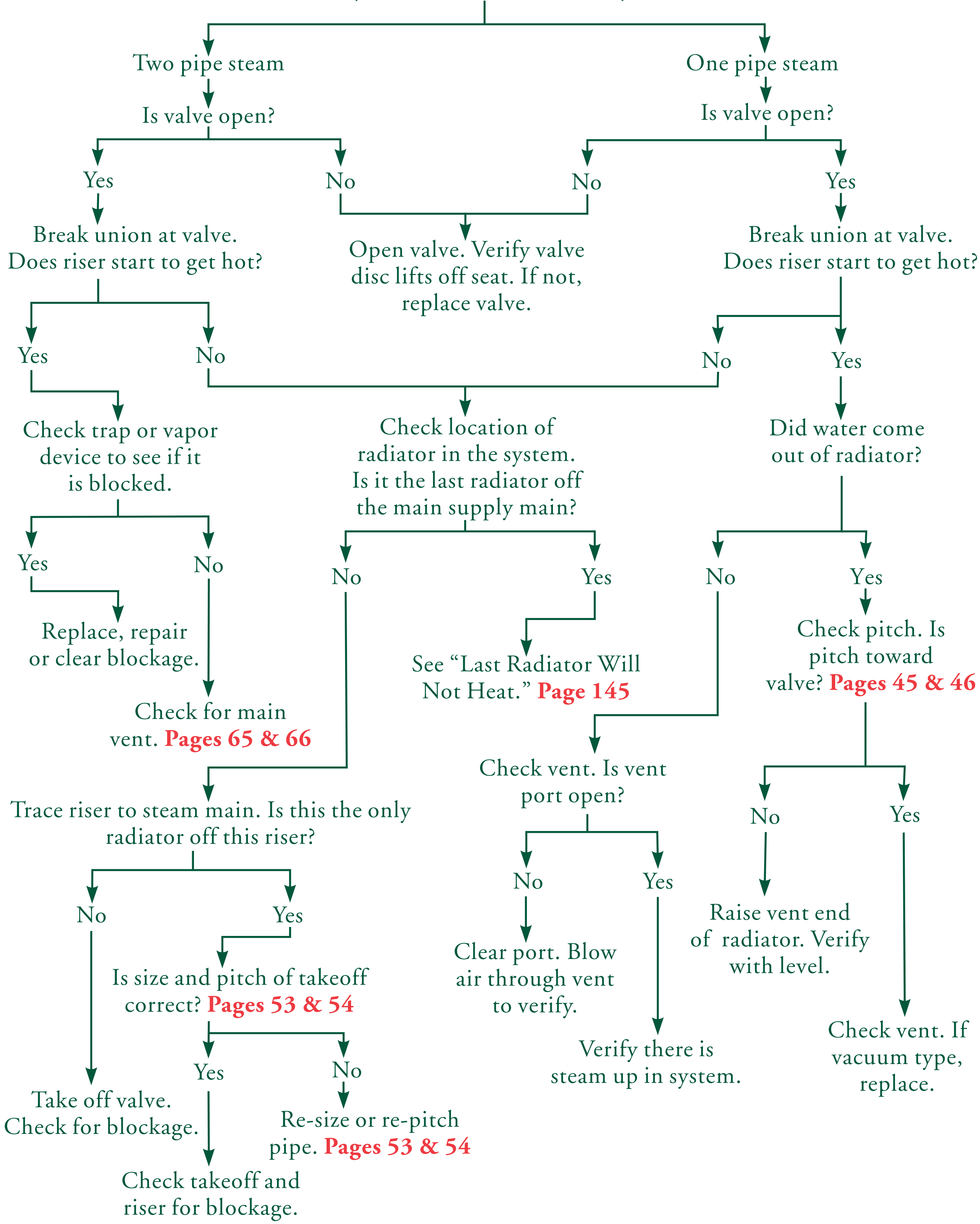
- No → Clean boiler. **Pages 36 & 37**
- Yes → Is near boiler piping correct? **Pages 56 & 57**
  - No → Correct piping. **Pages 56 & 57**
  - Yes → Is boiler water line correct? **Pages 38 & 39**
    - No → Set water line. **Pages 38 & 39**
    - Yes → Is the building control (cycle controller, t-stat) working correctly?
      - No → Adjust or fix.
      - Yes → Is boiler big enough, or under-fired? **Pages 64 & 65**
        - Too small or under-fired → Re-size or adjust firing rate.
        - Big enough → Is steam pressure correct? **Pages 42 & 43**
          - No → Adjust pressure. **Pages 42 & 43**
          - Yes → Are main vents present, working and properly sized? **Pages 66 & 67, 84 & 85**
            - No → Install, replace, or resize. **Pages 66 & 67, 84 & 85**
            - Yes → One or two pipe?
              - One pipe → Is radiator valve completely open? **Pages 46 & 47**
                - Yes → Is vent port opening restricted by sediment buildup or paint?
                  - No → **See Pages 30 & 31**
                  - Yes → Clean or replace.
                - No → Open or replace if stem is broken.
              - Two pipe → Are traps seats or vapor devices outlets restricted by sediment buildup?
                - No → Is inlet valve opening restricted?
                  - No → **See Pages 30 & 31**
                  - Yes → Clean or replace.
                - Yes → Clean or replace.

Last Radiator or Radiator Off Supply Main Will Not Heat

Is supply main hot all the way to the end?

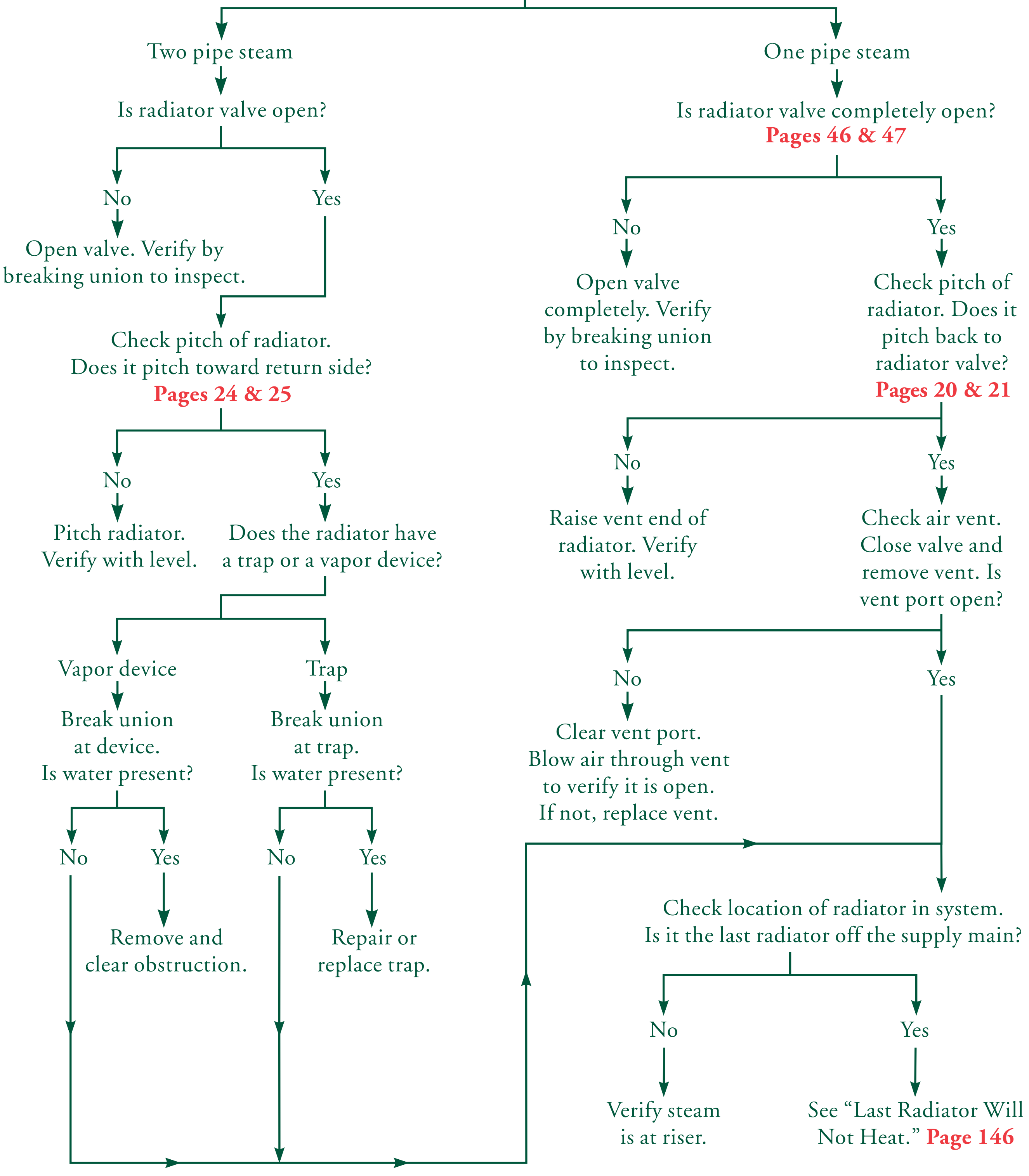
- **No** → Is an end of main vent installed? **Pages 66 & 67**
  - **No** → All steam supply mains should have a main air vent. Look for tapping that may be plugged and replace with a correctly sized vent. **Pages 84 & 85**
  - **Yes** → Does the vent work?
    - **No** → Replace vent. Check size. **Pages 84 & 85**
    - **Yes** → Is the vent the right size? **Pages 84 & 85**
      - **No** → Install correct size vent. **Pages 84 & 85**
      - **Yes** → Check "A" dimension for one pipe systems, "B" dimension for two pipe systems. Is there enough static height for the operating steam pressure? **One pipe: Pages 90 & 91, Two pipe: Pages 96 & 97**
        - **No** → Lower steam operating pressure. End of main may be flooded
        - **Yes** → Check pitch of supply piping. Is last riser takeoff in a low point or sag in the main?
          - **No** → Refer to "Why Size Matters." **Pages 64 & 65**
          - **Yes** → Re-pitch pipe.
- **Yes** → Is an end of main vent installed? **Pages 66 & 67**
  - **No** → All steam supply mains should have a main air vent. Look for tapping that may be plugged and replace with a correctly sized vent. **Pages 84 & 85**
  - **Yes** → Is the vent the right size?
    - **No** → Install correct size vent. **Pages 84 & 85**
    - **Yes** → Refer to **Page 148,** "One Radiator in System Will Not Heat, or **Pages 64 & 65,** "Why Size Matters."

One Radiator in System Will Not Heat
(No steam at riser)



One Radiator in System Will Not Heat

(Steam is at riser)



Building Heats Unevenly

Is boiler clean and making dry steam? **See Pages 34 & 35**

Yes → Is near boiler piping correct? **Pages 56 & 57, 62 & 63**

No → Clean boiler. **Pages 36 & 37**

Is near boiler piping correct?

Yes → Is water line set correctly? **Pages 38 & 39**

No → Correct piping. **Pages 56 & 57, 62 & 63**

Is water line set correctly?

Yes → Is operating pressure correct? **Pages 42 & 43**

No → Set water line. **Pages 38 & 39**

Is operating pressure correct?

Yes → Are main vents present, working and correctly sized? **Pages 66 & 67, 84 & 85**

No → Adjust pressure. **Pages 42 & 43**

Are main vents present, working and correctly sized?

Yes → Is boiler too small or undersized? **Pages 64 & 65**

No → Install, replace, or resize.

Is boiler too small or undersized?

Yes → Resize or adjust firing rate. **Pages 64 & 65**

No → Is building control operating correctly?

Is building control operating correctly?

Yes → Has insulation been removed from supply piping?

No → Adjust or replace operating control.

Has insulation been removed from supply piping?

No → If two pipe steam, are radiator traps working correctly?

Yes → Re-insulate.

If two pipe steam, are radiator traps working correctly?

Yes → If equipped with a boiler feed unit, are end of main traps restricted?

No → Replace or repair traps.

If equipped with a boiler feed unit, are end of main traps restricted?

No → If there is a water leg on return line ahead of boiler feed unit, is there an air vent on discharge side of end of main trap? **Page 162**

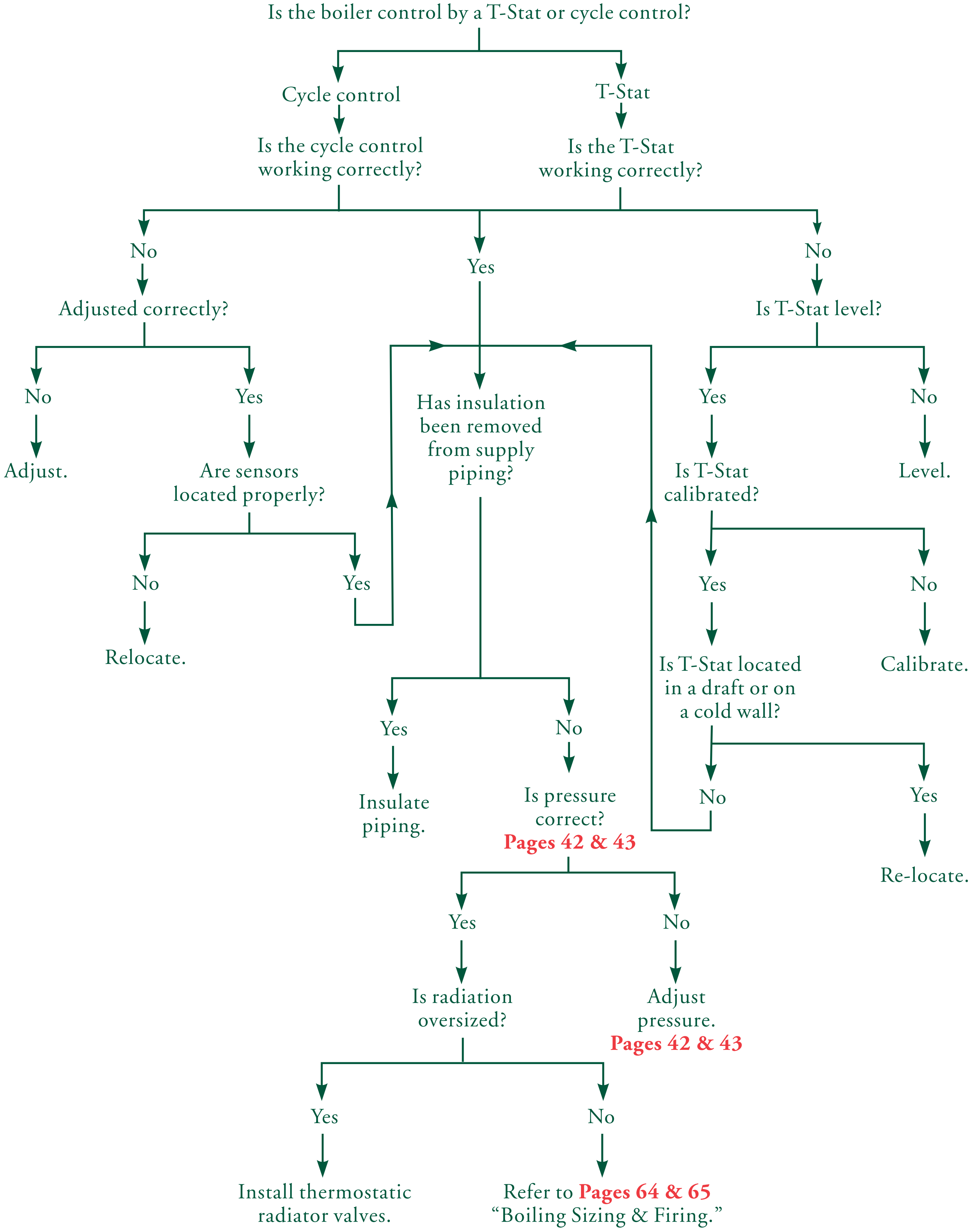
Yes → Clean or replace.

If there is a water leg on return line ahead of boiler feed unit, is there an air vent on discharge side of end of main trap?

Yes → **See Pages 66 & 67**

No → Install vent.

Building Is Too Hot



Building Is Too Cold

Is boiler clean and making dry steam? **See Pages 34 & 35**

- Yes → Is near boiler piping correct? **Pages 56 & 57, 62 & 63**
- No → Clean boiler. **Pages 36 & 37**

Is near boiler piping correct?

- Yes → Is water line set properly? **Pages 38 & 39**
- No → Correct piping. **Pages 56 & 57, 62 & 63**

Is water line set properly?

- Yes → Is boiler size and firing rate correct? **Pages 64 & 65**
- No → Adjust water line. **Pages 38 & 39**

Is boiler size and firing rate correct?

- Yes → Is steam pressure set correctly? **Pages 42 & 43**
- No → Correct sizing or adjust firing rate. **Pages 64 & 65**

Is steam pressure set correctly?

- Yes → Are vents working and sized correctly? **Pages 66 & 67, 84 & 85**
- No → Adjust pressure. **Pages 42 & 43**

Are vents working and sized correctly?

- Yes → Is insulation on all supply piping?
- No → Replace or resize. **Pages 83 & 84**

Is insulation on all supply piping?

- Yes → Is T-Stat out of calibration?
- No → Re-insulate supply piping.

Is T-Stat out of calibration?

- No → Is control device working correctly and properly adjusted?
- No → Recalibrate.

Is control device working correctly and properly adjusted?

- Yes → Are sensors located correctly?
- No → Repair, replace, or readjust.

Are sensors located correctly?

- Yes → **See Pages 30 & 31, 32 & 33**
- No → Relocate.

High Fuel Bills

Is boiler clean and making dry steam? **See Pages 34 & 35**

- No → Clean boiler. **Pages 36 & 37**
- Yes → Is near boiler piping correct? **Pages 56 & 57, 62 & 63**
  - No → Correct piping. **Pages 56 & 57, 62 & 63**
  - Yes → Is water line set correctly? **Pages 38 & 39**
    - No → Adjust water line.
    - Yes → Is boiler oversized or overfired? **Pages 64 & 65**
      - No → Correct sizing and firing rate. **Pages 64 & 65**
      - Yes → Are main vents present, working, and sized properly? **Pages 66 & 67, 84 & 85**
        - No → Replace or resize. **Pages 66 & 67, 84 & 85**
        - Yes → Is steam pressure set correctly? **Pages 42 & 43**
          - No → Adjust pressure. **Pages 42 & 43**
          - Yes → Is there a hole in the boiler above the water line?
            - Yes → Replace section or boiler.
            - No → If two pipe system, are traps working? **Pages 48 & 49**
              - No → Repair or replace.
              - Yes → Has insulation been removed from supply piping?
                - Yes → Re-insulate.
                - No → Is T-Stat in draft or on cold wall?
                  - Yes → Relocate T-Stat.
                  - No → Is building control working correctly and properly adjusted?
                    - No → Repair, replace, or re-adjust.
                    - Yes → **See Page 153**

FOR ALL SYSTEMS

1. Make sure boiler is clean, page 34 A dirty boiler is the cause of so many problems and affects the quality of steam.
2. Make sure main vents are installed and working properly, page 66. Main vents have to be there to have even distribution of the steam along the main.
3. Check steam pressure control setting, page 42. It is the simplest adjustment to make, but has a major effect on the system.
4. Check water line position, page 38. Normal water line position has a huge impact on the production of steam.
5. Check the main vent(s) size, page 84. The bigger the opening is in the main vent, the faster the system will heat.
6. Check near boiler piping for proper size and orientation, page 56. This has to be right to get dry steam.
7. Check for the amount of combustion air that is available to burner. The burner has to have enough air to fire optimally.
8. Perform a combustion analysis to fine tune the burner. Record the results so they can be compared at next check
9. Insulate or re-insulate all the supply piping, including the near boiler piping. This may be the best investment to reduce the fuel bill.

FOR SYSTEMS OVER 500,000 BTU/HR

10. Install a boiler feed unit, pages 108, 110 and 158. A steady water line equals peak performance.
11. Install a cycle rate type control that senses both outdoor temperature and return water temperature. They are not cheap, but they have a great payback.

FOR ONE PIPE SYSTEMS

12. Make sure all radiator valves are fully open or closed, page 46. Partially closed valves slow condensate return.
13. Replace all radiator vents throughout system with one common size vent, page 72. The same size port on each vent proportions the steam flow for even heating.

FOR TWO PIPE SYSTEMS

14. Make sure all the radiator traps are working correctly, page 48. If traps are failed open, steam is being wasted and system will heat unevenly.
15. Install thermostatic radiator valves on each radiator, page 50. They will balance the flow of steam similar to the metering systems.

CHAPTER SEVEN

Service Techniques

Servicing the Boiler

Suggested servicing at the beginning of season.

- Check water line setting. Pages 38 and 39.
- Check operation of LWCO. Pages 104 and 105.
- Check operation of T-Stat.
- Check setting of pressure control. Pages 42 and 43.
- Check operation of automatic feeder. Pages 106 and 107.
- Check for leaks in piping.
- Check for leaks under boiler.
- Flush boiler if required or scheduled.
- Check operation of any condensate, boiler feed, or vacuum pumps. Pages 108 and 109, 112 and 113.
- Check fireside flue passages and clean if required.
- Blow down strainers before traps.
- Check operation of main vent(s).
- Check pH level of water, should be between 7.0 to 8.5. Pages 34 and 35.

Questions to ask the home owner or building superintendent.

- Any noises, new or old?
- Any areas of home or building hot or cold?
- Has fuel usage gone up?

Periodic Maintenance

Suggested interval for blowing down any low water cutoffs.

- Blow down twice a month during the middle of heating season.
- Blow down once a month in mild weather.

Suggested technique for blowing down the boiler.

- To check operation of low water cutoff, open blow down valve while burner is firing. The burner should shut off.
- Close valve as soon as burner is shut off. Burner should re-fire when water line is restored.

Suggested interval for flushing boiler water completely.

- After first year of operation, flush completely.
- If water was dirty, flush again the next year.
- If water was clean, skip one year.
- After 5 years of operation, flush once every 5 years.

Suggested technique for flushing boiler water completely.

- Open boiler drain and any dirt legs or cleanouts.
- Take off relief valve and open skim trapping.
- Work hose nozzle or flushing pipe under full pressure through as much of the boiler as possible.

Notes on Fresh Water Make Up

Keep fresh water to a minimum.

- Fresh water has minerals such as lime that come out of solution with the high heat required to make steam.
- These minerals will build up over time on the inside of the boiler.
- This build up decreases the heat transfer causing fuel bills to go up. At worst, the build up can cause cast iron sections to crack.

Fresh water also has oxygen.

- Excessive fresh water can create holes caused by oxygen corrosion in cast iron sections or boiler tubes.

Servicing the Direct Feeder

See pages 106 and 107 for feeder operation theory and diagrams.

If boiler is over filling, break union after feeder valve.

- If water is flowing through feeder valve,
  - Manually open and close feeder valve several times to clean any obstructions.
  - Replace or repair feeder valve if any water keeps flowing.
- If water is not flowing through feeder valve,
  - Check for leaking manual bypass valve.
  - Replace manual bypass valve if leaking.
  - Check for clogged pipe in feed line, lime deposits can build up where cold make-up water enters the hot boiler piping.
  - The clogged feed pipe can cause back pressure which can hold the valve off its seat allowing too much water through.
  - Repair or replace piping.

If boiler is under filling, break union after feeder valve.

- Manually open feeder valve. It should move freely and water should flow at full stream.
  - If valve does not move freely, open float chamber to check for sediment build up that may be blocking float movement.
  - If water does not flow at full steam, check strainer ahead of valve for blockage.

Other items to check if system is experiencing feeder problems.

- Check piping connections to manufacturers instructions.
  - When feeder or pump control is installed with 1″ equalizing pipes, connecting the bottom pipe into boiler return line or the bottom of the boiler can cause flooding.
  - Check incoming water pressure. If pressure is above 100 pounds, use a pressure reducing valve.
  - Inspect piping connecting feeder to boiler for obstructions.

Detailed Cleaning Techniques

Skimming the water line.

1. Locate skim valve on the side of the boiler. If there is not a skim valve, open as large as possible a tapping on the side of the boiler near the water line. Install at least a 12″ nipple with a gate valve the full size of the tapping to use as the skim port.
2. Use the manual feed valve to slowly push water out of the skim port through the open valve.
3. Set system T-stat or cycle rate control to "call for heat."
4. Use the service switch to cycle the burner on and off to keep the water temperature below the boiling point.
5. Continue this process until water flowing out of skim valve is clear of impurities. This may take many hours.
6. Close valve and plug opening.
7. Refill boiler to proper water line.
8. Test operation for a "clean" boiler. Refer to pages 34 and 35.
9. Repeat the process until boiler is clean. This may take many times.

Chemical treatment of the boiler water (1 hour method).

1. Purchase correct amount of cleaner at local supply house. Quantity is based on boiler size.
2. Remove safety valve from boiler and carefully set aside.
3. Pour chemical product into boiler through safety valve opening.
4. Replace safety valve on boiler.
5. Set system T-stat or cycle rate control to "call for heat."
6. Fire boiler constantly for one hour, while observing.
7. Drain the boiler water. The impurities (grease, oil, pipe dope) will drain out with the boiler water.
8. Let boiler cool.
9. Flush the inside of the boiler.
10. Refill the boiler to the proper water line.
11. Test the operation for a "clean" boiler. Refer to pages 34 and 35.
12. Treat the boiler again if dirty. This may take several treatments.

Adding a Boiler Feed Unit

1. Find the end of each steam supply main.
2. Find any steam main drips to the wet return.
3. Float and thermostatic traps will need to be added at the end of each steam main and steam main drip.
4. For one pipe steam, size F+T traps for radiation load and piping load.
5. For two pipe steam, size F+T traps for piping load only.
6. Trace the return line back to the boiler room.
7. Can the condensate flow downhill from the newly installed traps to the boiler feed unit?
8. Does the wet return go under any doorways?
9. Will there be a water leg ahead of the boiler feed unit?
10. Install strainer or dirt leg ahead of trap(s) on supply main(s).
11. Install air vent on discharge side of trap if return piping passes through water leg.
12. Find the location of the new boiler feed unit.
13. Make sure that cooling legs are installed between trap and boiler feed unit. Allow at least 10´ of piping distance from trap to boiler feed unit.
14. Add pump control on boiler to activate pump.
15. Install pressure reducing valve on make-up fill line to boiler feed reservoir tank.
16. Install back flow preventor on make-up fill line per local code.
17. Install balance valve on discharge of pump to adjust flow back to boiler.
18. Install check valve with Teflon® (soft) disc on discharge side to keep water in the boiler.
19. Connect pump line to Hartford Loop at least 4˝ below water line.

Service Ideas for the Safety of Equipment, Property, and People

1. Check the operation of the low water cutoff while the boiler is operating to make sure the burner shuts off.

2. Check the capacity of the safety valve to make sure it exceeds the gross output of the boiler.

3. Replace any safety valve that does not have a piped discharge with a properly sized safety valve that does have a piped discharge.

4. Make sure the safety valve discharge piping is open and piped to within 4″ to 6″ of floor, or per local code.

5. Check operation of the steam pressure operating control and the steam pressure high limit control.

6. Inform owner to keep combustible materials at least 36″ from the boiler.

7. Check chimney and flue for any obstructions, blockages, or leaks.

8. Advise owner to install a carbon monoxide detector and a smoke detector in the boiler room.

9. Perform a carbon monoxide test while the boiler and any other appliances connected to the same chimney are operating.

10. Check to make sure that the available combustion air is adequate and cannot be reduced or closed off.

11. Install a second low water cutoff to act as a back-up to prevent boiler dry-fire.

Reference Material

Near Boiler Piping Sizing Chart

Gas Input BTUs	Oil Input GPH	Horse-power	EDR	Pipe Size Based on 50 FPS: Single Riser	Double Riser	Triple Riser	Header	Equalizer
75,000	0.5	2.0	215	1½	–	–	1½	1¼
100,000	0.7	2.5	285	1½	1¼	–	1½	1¼
125,000	0.9	3.0	355	1½	1¼	–	1½	1¼
150,000	1.1	3.6	425	2	1¼	–	2	1½
175,000	1.3	4.2	496	2	1¼	–	2	1½
200,000	1.4	4.8	567	2	1½	–	2	1½
250,000	1.8	6.1	708	2½	2	–	2½	1½
300,000	2.1	7.2	850	3	2	–	3	1½
350,000	2.5	8.5	992	3	2	–	3	2
400,000	2.9	9.7	1,133	3	2	–	3	2
450,000	3.2	10.9	1,275	3	2½	–	3	2
500,000	3.6	12.1	1,417	4	2½	–	4	2½
600,000	4.3	14.5	1,700	4	3	–	4	2½
700,000	5.0	16.9	1,983	4	3	–	4	2½
800,000	5.7	19.3	2,267	5	3	–	5	3
900,000	6.4	21.8	2,550	5	3	–	5	3
1,000,000	7.0	24.2	2,833	5	4	3	5	3
1,500,000	10.7	36.3	4,250	6	4	4	6	3
2,000,000	14.3	48.3	5,667	–	5	4	8	4
2,500,000	17.9	60.4	7,083	–	6	5	8	4
3,000,000	21.4	72.5	8,500	–	6	5	8	4

Note: Pipe sizes smaller than listed can cause high velocity. See page 58

Relationship of Pipe Size to Pressure Drop in Supply Piping

Capacities Shown in Square Feet EDR

Pipe Size in Inches	Pressure Drop in PSI per 100 Feet: 1/16 PSI	1/8 PSI	1/4 PSI	1/2 PSI	3/4 PSI	1 PSI
1	50	100	150	200	250	300
1½	200	300	500	700	850	950
2	400	650	900	1300	1600	1900
2½	650	1000	1500	2100	2700	3100
3	1250	1850	2600	3800	4700	5500
4	2500	3800	5600	7900	9800	11500
5	4800	6700	9700	14200	17500	20400
6	7600	11000	15800	22800	28800	33600
8	15600	22000	32400	45600	58000	66000

Steam and water flowing in same direction.
Can be used for pressures 1 PSI to 6 PSI.

One Pipe Steam

Pipe Size	Capacity In Square Feet Per Pipe Size					
	Up to 200´ Main	Run Out	Upfeed Riser	Radiator Valves	Dry Return	Wet Return
¾″	–	20	24	–	–	–
1″	–	25	45	25	320	700
1¼″	–	60	98	60	670	1,200
1½″	–	70	152	90	1,058	1,900
2″	260	100	288	160	2,300	4,000
2½″	425	260	464	–	3,800	6,700
3″	775	475	799	–	7,000	10,700
4″	1,640	–	–	–	–	–
5″	3,030	–	–	–	–	–
6″	4,975	–	–	–	–	–

Use one pipe size larger for: counter flow mains and horizontal run outs over 6 feet.

Two Pipe Steam

Pipe Size	Capacity in Square Feet Per Pipe Size								
	Up to 200´ Main	Supply Run Out	Supply Riser	Radiator Valve	Radiator Trap	Return Riser	Return Run Out	Dry Return	Wet Return
½″	–	–	25	25	200	200	–	–	–
¾″	80	25	75	75	400	400	400	–	–
1″	150	75	150	150	700	700	700	460	1,400
1¼″	300	150	200	200	–	1,300	1,300	960	2,400
1½″	500	200	400	400	–	2,200	2,200	1,500	3,800
2″	950	400	650	–	–	–	–	3,300	8,000
2½″	1,500	650	900	–	–	–	–	5,500	13,400
3″	2,600	900	–	–	–	–	–	10,000	21,400
4″	5,500	–	–	–	–	–	–	21,000	44,000
5″	9,700	–	–	–	–	–	–	–	–
6″	15,500	–	–	–	–	–	–	–	–

Use one pipe size larger for: counter flow mains and horizontal supply run outs over 6 feet.

Two Pipe Vacuum

Pipe Size	Capacity in Square Feet Per Pipe Size						
	Up to 200´ Main	Supply Run Out	Supply Riser	Radiator Valve	Radiator Trap	Return Riser	Return Run Out
½″	–	–	25	25	200	500	–
¾″	80	25	75	75	400	1,000	500
1″	150	75	150	150	700	2,000	1,000
1¼″	300	150	200	200	–	4,500	2,000
1½″	500	200	400	400	–	–	4,500
2″	950	400	850	–	–	–	–
2½″	1,500	650	1,500	–	–	–	–
3″	2,600	900	2,600	–	–	–	–
4″	5,500	–	–	–	–	–	–
5″	9,700	–	–	–	–	–	–
6″	15,500	–	–	–	–	–	–

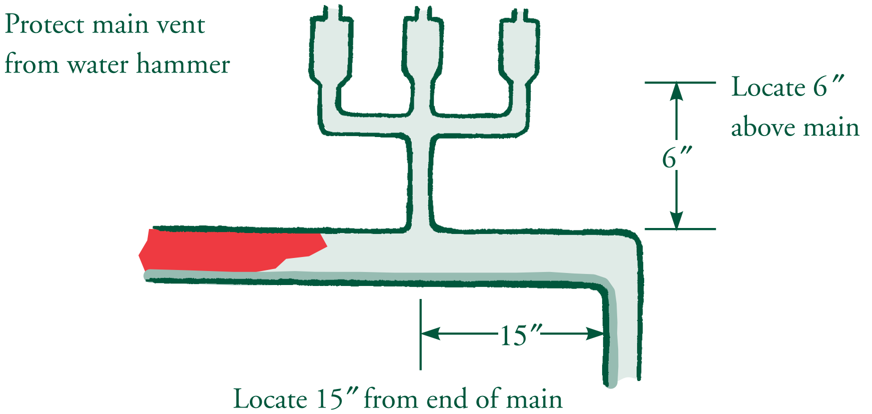
How to Size Main Vent

Air Capacity of Black Pipe (in cubic feet)

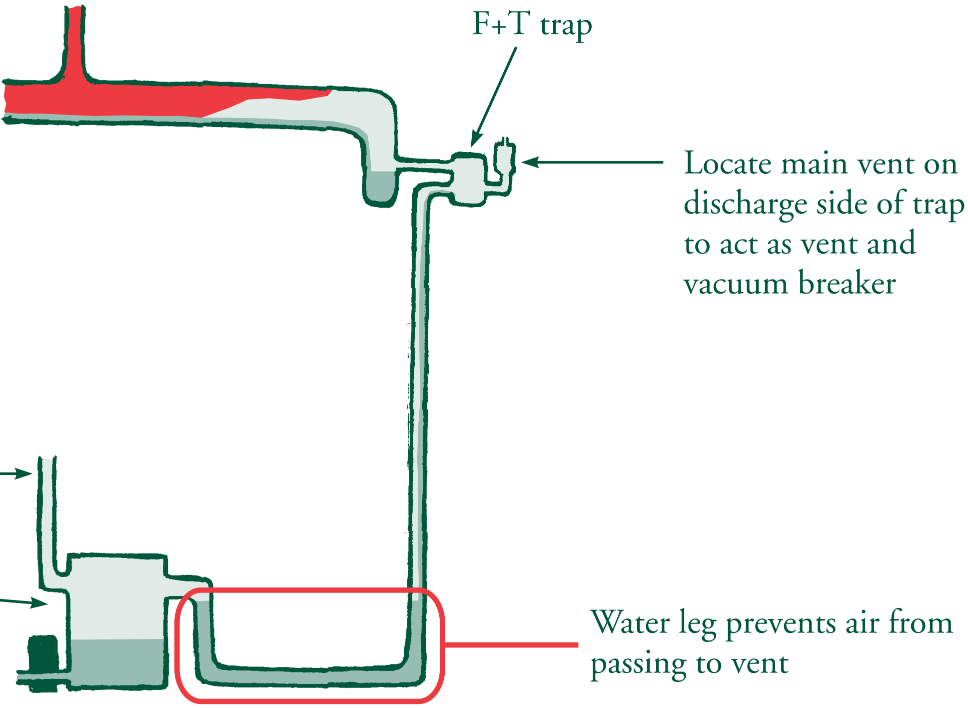
	Length							
Pipe Size	25	50	75	100	150	200	250	300
1½	0.36	0.71	1.07	1.42	2.13	2.84	3.55	4.26
2	0.58	1.17	1.75	2.33	3.50	4.66	5.83	6.99
2½	0.83	1.66	2.49	3.32	4.98	6.64	8.30	9.96
3	1.28	2.57	3.85	5.13	7.70	10.26	12.83	15.39
4	2.21	4.42	6.63	8.84	13.26	17.68	22.10	26.52
5	3.47	6.95	10.42	13.89	20.84	27.78	34.73	41.67
6	5.02	10.04	15.06	20.08	30.12	40.16	50.20	60.24
8	8.87	17.73	26.60	35.46	53.19	70.92	88.65	106.38

Shaded areas require more than 4 minutes to vent all air with typical main vent at rate of 1.4 cubic feet per minute.

How to Locate End of Main Vent



How to Vent End of Main with Water Leg Ahead of Boiler Feed or Condensate Tank



Square Feet Output per Section of Column Style Radiators

Width	4½″	7 3/8″	9″	11½″	12½″	12½″
	Number of Columns at End of Radiator					
Height	1	2	3	4	5	6
45″	3.5	5	6	10	–	–
38″	3	4	5	8	10	–
32″	2.5	3.33	4.5	6.5	8.5	–
26″	2	2.67	3.75	5	7	7
23″	1.67	2.33	3.25	4.5	–	–
22″	1.67	2.25	3	4	6	6
20″	1.5	2	2.75	3.5	5	5
18″	1.33	1.75	2.25	3	5	4.33
16″	–	–	–	–	4	3.75
13″	–	–	–	–	3	3

Square Feet Output per Section of Tube Type Radiators

Width	5″	7″	8¾″	9¾″	12½″
	Number of Tubes at End of Radiator				
Height	3	4	5	6	7
38″	3.5	4.25	5	6	–
36″	3.5	4.25	5	6	7
32″	3	3.5	4.33	5	6
26″	2.33	2.75	3.5	4	5
23″	2	2.5	3	3.5	4.5
20″	1.75	2.25	2.67	3	3.67
16″	–	–	–	–	3
14″	–	–	–	–	2.5

Square Feet Output per Section of Thin Tube Radiators

Width	3½″	4″	4¾″	6″	7 7/8″
	Number of Tubes at End of Radiator				
Height	2	3	4	5	6
38″	2.5	2.6	–	–	–
32″	2.0	2.4	–	–	3.7
26″	–	–	2.4	3.0	3.0
25″	1.6	1.6	2.0	–	3.0
23″	–	–	–	2.1	–
22″	1.3	1.4	1.8	–	–
20″	–	–	1.8	–	2.3
19″	1.1	1.2	1.6	–	2.3
17″	–	–	–	2.0	–

Convector Ratings in Square Foot Output

Depth in Inches	Length in Inches	Front Outlet Models									
		Cabinet Style					Wall Mount Style				
		Height in Inches									
		18	20	24	26	32	14	18	20	26	32
4	24	12	13	15	15	17	13	15	15	17	17
	32	16	19	21	22	23	19	21	22	23	25
	36	18	22	24	25	27	22	24	25	27	28
	40	21	24	28	28	30	24	28	28	30	32
	44	23	27	31	31	34	29	31	31	34	36
	48	25	30	34	35	37	30	34	35	37	39
	56	30	35	40	41	44	35	40	41	44	47
	64	34	41	46	47	51	41	46	47	51	54
6	24	17	19	22	23	26	19	22	23	26	27
	32	24	27	31	33	36	27	32	33	36	37
	36	27	31	36	37	41	31	36	37	41	43
	40	30	35	41	42	47	35	41	42	47	48
	44	34	39	45	47	52	39	45	47	52	54
	48	37	43	50	52	57	43	50	52	57	59
	56	44	51	59	61	67	51	59	61	67	70
	64	51	58	68	71	78	58	68	71	78	81
8	24	22	24	27	27	29	24	27	27	29	31
	32	32	34	38	39	42	34	38	39	42	44
	36	37	39	43	44	48	39	43	44	48	50
	40	41	44	49	50	54	44	49	50	54	56
	44	46	49	54	56	60	49	54	56	60	63
	48	51	54	60	61	66	54	60	61	66	69
	56	61	64	71	73	79	54	71	73	79	82
	64	70	74	82	84	91	74	82	84	91	95
10	24	23	28	30	31	35	28	30	31	35	36
	32	33	39	43	44	50	39	43	44	50	51
	36	39	45	49	50	57	45	49	50	57	59
	40	45	51	55	57	64	51	55	57	64	66
	44	51	57	62	63	71	57	62	63	71	73
	48	57	62	68	70	79	62	68	70	79	82
	56	69	74	80	82	93	74	80	82	93	96
	64	81	85	93	95	107	85	93	95	107	111

Depth in Inches	Length in Inches	Slope Top Models									
		Cabinet Style					Wall Mount Style				
		Height in Inches									
		18	20	24	26	32	14	18	20	26	32
4	24	15	16	17	17	18	16	17	17	18	18
	32	21	22	23	24	25	22	23	24	25	26
	36	24	25	27	27	29	25	27	27	29	30
	40	28	28	30	31	32	28	30	31	32	34
	44	31	32	34	35	36	32	34	35	36	38
	48	34	35	37	38	40	35	37	38	40	41
	56	40	41	44	45	47	41	44	45	47	49
	64	46	48	51	52	55	48	51	52	55	58
6	24	22	24	26	27	29	24	26	27	29	30
	32	32	34	37	38	41	35	37	38	41	42
	36	37	39	42	43	47	39	42	43	47	49
	40	41	44	48	49	53	44	48	49	53	55
	44	46	49	53	54	59	49	53	54	59	61
	48	51	54	58	60	65	54	58	60	65	67
	56	62	63	69	71	75	63	69	71	76	80
	64	70	73	80	82	88	73	80	82	88	92
8	24	30	31	32	33	36	31	32	33	36	37
	32	42	44	46	47	51	44	46	47	51	53
	36	49	50	53	54	59	50	53	54	59	61
	40	55	56	60	61	66	56	60	61	66	69
	44	61	63	67	68	74	63	67	68	75	77
	48	68	69	73	75	81	69	73	75	81	85
	56	80	82	87	89	97	82	87	89	97	101
	64	93	95	101	103	112	95	101	103	112	116
10	24	34	35	38	40	44	35	38	40	44	45
	32	47	49	54	56	61	49	54	56	61	64
	36	54	57	62	64	71	57	62	64	71	74
	40	61	64	70	72	80	64	70	72	80	83
	44	68	71	78	81	89	71	78	81	89	93
	48	75	78	86	87	98	78	86	89	98	102
	56	89	93	101	105	115	93	101	105	115	120
	64	102	107	117	121	133	107	117	121	133	138

Square Feet Output of Baseboard Radiation

Type	Height	Square Feet per Linear Foot
Cast Iron	7″	3.00
Copper/Aluminum Fin	7″	3.25
Cast Iron	9″	3.33
Copper/Aluminum Fin	9″	4.33

Square Feet Output from Direct Pipe Coils per Linear Foot

	Pipe Size		
Number of Rows	1″	1¼″	1½″
1	0.55	0.675	0.77
2	1.05	1.3	1.45
4	1.83	2.27	2.57
6	2.36	2.93	3.30
8	2.71	3.32	3.78
10	3.05	3.78	4.25
12	3.38	4.19	4.73

Square Feet Output from Un-Insulated Pipe

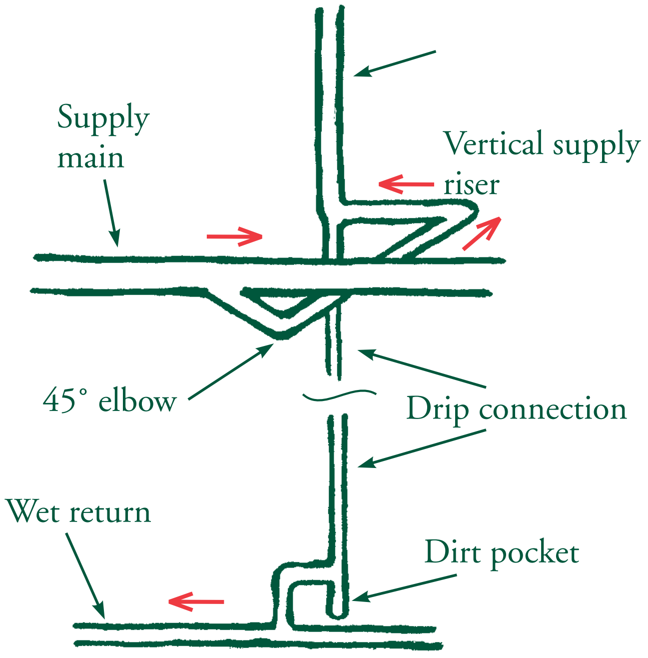
Length of Pipe (in feet)	Pipe Size								
	1″	1¼″	1½″	2″	2½″	3″	4″	5″	6″
1	0.5	0.625	0.70	0.875	1.0	1.25	1.58	1.75	2.3
10	5.0	6.250	7.00	8.75	10.0	12.5	15.8	17.5	22.0
25	12.5	15.600	17.50	21.90	25.0	31.25	39.5	43.75	57.5
50	25.0	31.250	35.00	43.75	50.0	62.50	79.0	87.50	115.0
100	50.0	62.500	70.00	87.50	100.0	125.00	158.0	175.00	230.0

Square Feet Output of Wall and Ceiling Type Radiators

Size	Square Feet per Radiator
13½ × 17 x 3	5
13½ × 21 x 3	6
13½ × 22 x 3	7
13½ × 29 x 3	9

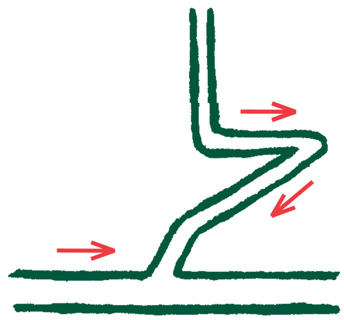
Square Feet Output of Sectional Wall Type Radiators

Height	Depth	Square Feet per Section
13⅞	2¾	¾
15	2¾	1
21½	2¾	1½
26½	2¾	1⅘
37	2¾	2½

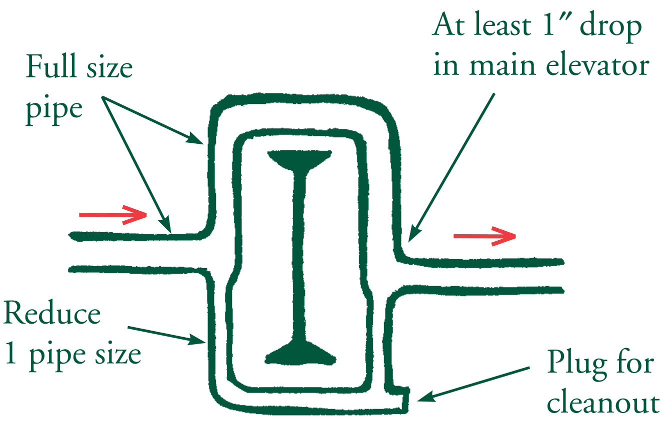


RISER MAIN WITH
DRIP CONNECTION

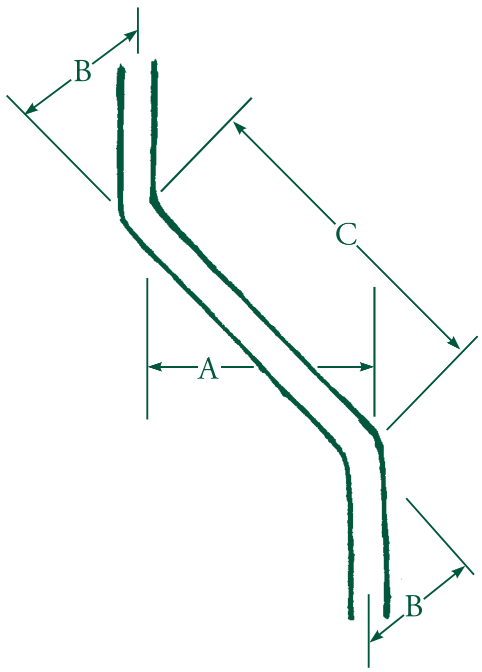
→ Direction of pitch



UPFEED RISER CONNECTION
TAKEN FROM HORIZONTAL
MAIN AT 45°



LOOPING MAIN AROUND
STEEL BEAM

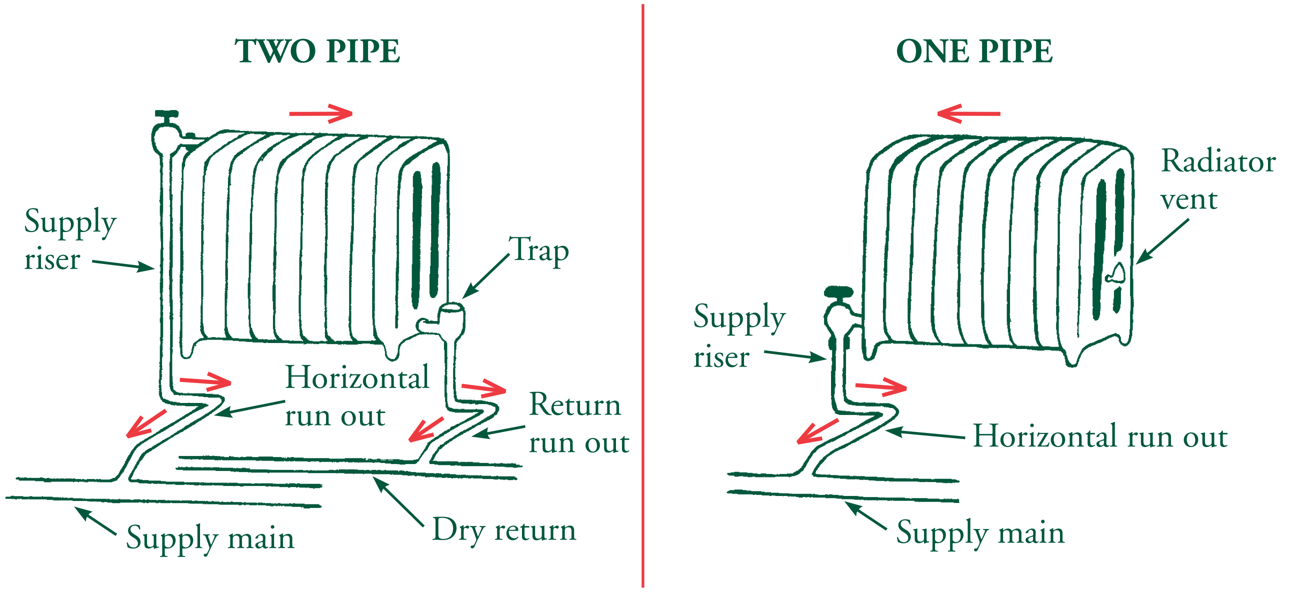


ANGLE B	CONSTANT
30°	2.000
45°	1.414
60°	1.155

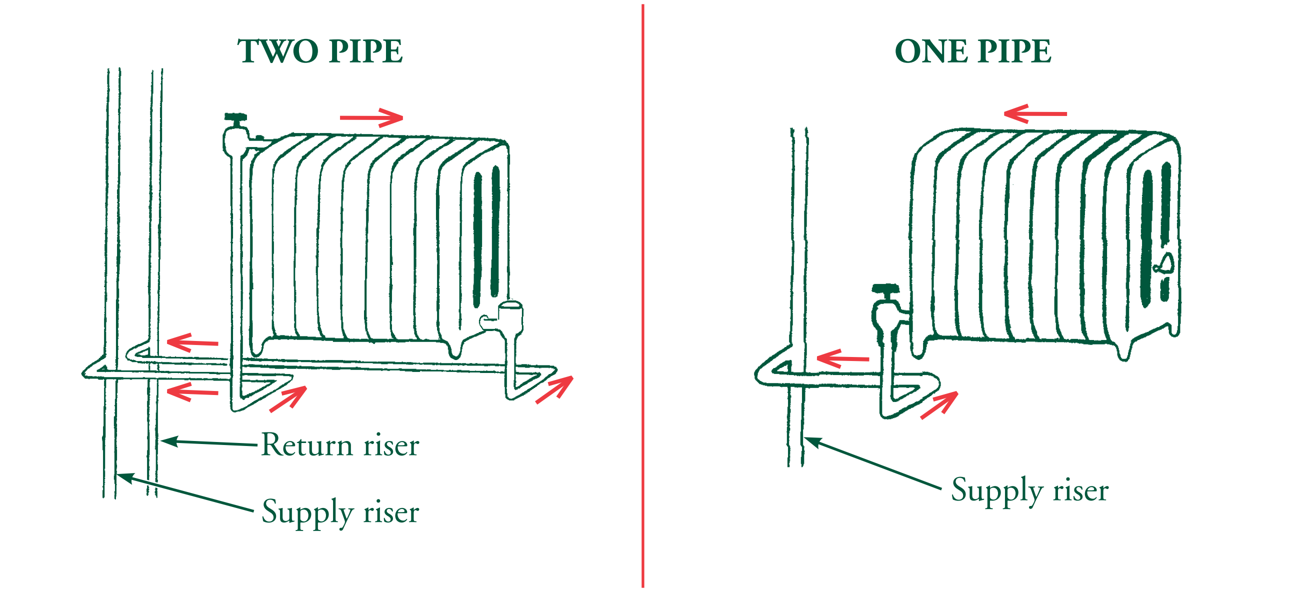
MULTIPLY A BY CONSTANT
FOR ANGLE B TO FIND C

TO CALCULATE FOR
OFFSET IN PIPE

RADIATOR CONNECTIONS



UPFEED CONNECTION
TAKEN FROM HORIZONTAL MAIN



CONNECTION TAKEN FROM
UPFEED OR DOWNFEED RISER

→ Direction of pitch

Conversions

Sq. ft. Output x 240 = BTU/HR
Sq. ft. Output x 0.000496 = Gallons of water per minute
BTU/HR / 1000 = Pounds per hour
Pounds of steam per hour x 4 = Sq. ft. Output
Pounds of steam per hour x 0.002 = Gallons of water per minute
Pounds of steam per hour x 1000 = BTU/HR
One gallon of water x 8.345 = Pounds of water
Boiler horsepower x 34.5 = Pounds per hour
Boiler horsepower x 139 = Sq. ft. Output
Boiler horsepower x 33,479 = BTU/HR

Diameter x 3.14 = Circumference
Circumference x 0.3183 = Diameter
Diameter^2 x 0.7854 = Area of a circle
Square inches x 0.00695 = Square feet
Cubic inches x 0.00058 = Cubic feet
Cubic inches x 0.004329 = U.S. gallons
Cubic feet x 7.4805 = U.S. gallons
U.S. gallons x 231.0 = Cubic inches
U.S. gallons x 0.13368 = Cubic feet

Pipe Data

Normal Size	Actual Outside Diameter	Inside Area in Square Inches	Gallons of Water per 100 Feet	Length of Pipe Containing 1 Cubic Feet	Number of Threads per Inch of Screw
1/8	0.410	0.06	0.3	2513.0	27
¼	0.540	0.10	0.5	1383.3	18
3/8	0.675	0.19	1.0	751.2	18
½	0.840	0.30	1.6	472.4	14
¾	1.050	0.53	2.7	270.0	14
1	1.315	0.86	4.5	166.9	11.5
1¼	1.660	1.50	7.7	96.3	11.5
1½	1.900	2.04	10.6	70.7	11.5
2	2.375	3.36	17.4	42.9	11.5
2½	2.875	4.78	24.8	30.1	8
3	3.500	7.39	38.4	19.5	8
4	4.500	12.73	66.1	11.3	8
5	5.563	19.99	103.8	7.2	8
6	6.625	28.89	150.0	5.0	8
8	8.625	51.15	260.0	2.8	8
10	10.750	81.55	410.0	1.8	8
12	12.750	114.80	600.0	1.3	8

Expansion of Pipes in Inches per 100 Feet

Temperature in Degrees Fahrenheit	Type of Pipe: Steel	Type of Pipe: Copper
0	0.00	0.00
50	0.38	0.57
100	0.76	1.14
125	0.92	1.40
150	1.15	1.75
175	1.34	2.04
200	1.57	2.38
225	1.78	2.70
250	1.99	3.02

About How Many Small Pipes Equal One Larger Pipe

Pipe Size	No. of small pipes equivalent to one large pipe: ½″	¾″	1″	1¼″	1½″	2″	2½″	3″	4″	5″	6″
½″	1	2	4	10	15	31	52	96	205	377	620
¾″	–	1	2	4	6	14	23	42	90	166	273
1″	–	–	1	2	3	6	11	20	44	81	133
1¼″	–	–	–	1	1.5	2	5	9	19	32	68
1½″	–	–	–	–	1	1	3	6	13	23	39
2″	–	–	–	–	–	1	1.5	3	6	11	19
2½″	–	–	–	–	–	–	1	1.5	3	7	11
3″	–	–	–	–	–	–	–	1	2	3	6
4″	–	–	–	–	–	–	–	–	1	1.5	3
5″	–	–	–	–	–	–	–	–	–	1	1.5
6″	–	–	–	–	–	–	–	–	–	–	1

If you have four 1¼" pipes to combine into one large pipe, from the left 1¼" pipe size read to the right until it exceeds four, then read up for pipe size required. Answer: 2½"

Approximate Properties of Saturated Steam

Vacuum Gauge Reading at Sea Level; Inches of Mercury	Absolute Pressure; Inches of Mercury	Temperature in Degrees Fahrenheit	Latent Heat of Evaporation in BTUs	Volume of 1 Pound of Steam in Cubic Feet
10	20	192	983	39
8	22	197	980	36
6	24	201	977	33
4	26	205	975	31
2	28	209	972	29
1	29	210	971	28
0	30	212	970	27

Pressure Gauge Reading at Sea Level; Pounds per Square Inch	Absolute Pressure; Pounds per Square Inch	Temperature in Degrees Fahrenheit	Latent Heat of Evaporation in BTUs	Volume of 1 Pound of Steam in Cubic Feet
0	14.7	212	970	27
1	15.7	216	968	25
2	16.7	219	966	24
3	17.7	222	964	22
4	18.7	225	962	21
5	19.7	227	960	20
6	20.7	230	958	19
7	21.7	232	957	19
8	22.7	235	955	18
9	23.7	237	954	17
10	25.7	240	952	16

Relation of Altitude and Pressure to the Boiling Point

Altitude in Feet	Atmospheric Pressure in PSI	Boiling Point of Water in Degrees Fahrenheit	
		At 0#	At 5#
Sea Level	14.69	212.0	227.0
500	14.42	211.0	226.3
1000	14.16	210.1	225.5
1500	13.90	209.4	225.0
2000	13.65	208.2	224.1
2500	13.40	207.3	223.4
3000	13.15	206.4	222.7
4000	12.68	204.7	221.4
5000	12.22	202.7	220.1
10,000	10.17	194.0	213.5

CHAPTER NINE

Acknowledgements

This chapter has nothing to do with steam heating, but everything to do with thanking and acknowledging all the people who helped make this field guide possible. So if you are looking for help with a steam heating problem, go back to Chapter Six. However, if you are looking for your name to be mentioned, please read on. Now I'm sure there will be someone that I will forget to mention, so I will offer my apologies to you right at the start. Sorry about that, but as I get old, it's my mind that is going first.

I would like to first thank my parents, Frank and Margaret Linhardt, for giving me the freedom to try my many different pursuits in life. They have always been there for me. In fact, the field guide is named for my father, not for me.

I couldn't have written and illustrated and rewritten and edited and redrawn this guide without my wife Jan and two sons, Kyle and Trent. Jan has sacrificed many days, nights, projects around the house, and time together to see this book to its conclusion. Thank you from the bottom of my heart. My oldest son Kyle has done a yeoman's job of data input. How he can read my handwriting is beyond me; maybe it is genetic. He has a real knack for everything computer; he set up the website too. If you bought the field guide off the web, you've got Kyle to thank because I am a computer idiot. Trent gets credit for being the shipping department.

Since it is my book and my dime, I'm going to acknowledge my five older sisters–Becky, Helen, Joan, Janet, and Kay. Together they shared and shaped my youth. While I am on family, I'd like to thank my Aunt Betty and Uncle Roger for being my favorite aunt and uncle. And I can't neglect to mention my great uncles Max and Cliff.

After my family, I have to thank another, the Arata family. The patriarch, "Silver Dollar Jimmy" Arata, founded the family business where I've worked for twenty years. A true Renaissance man, from playing the violin to bathtub gin to distributing boilers to cooking lunch for his employees, he did it his way. I have known and grown up with and gone to school with and worked with and learned from and played soccer with and been great friends with his grandson "Jimbo" since we met when we were four years old.

His father, Lou Sr., hired me out of the Air Force with no experience in hydronic heating, but somehow saw my potential. Using an applicable cliché, he has forgotten more about steam and hot water heat than I'll ever know. I have to thank Lou's sister Mary Anne for all her help in getting the grammar and spelling correct, all except this chapter. If you ever call Aramac Supply, she will be the pleasant voice at the other end of the line, give it a try sometime at 513-541-2142. Mary Anne's daughter, Gina, keeps the spirit of her grandfather alive at Aramac Supply. Occasionally we cook lunch together, argue about the food preparations, drink some wine, and then enjoy it when our workmates and guests share the company of the kitchen with us. Those sharing the kitchen, the office, the sales counter, and the workload are Emily, Lisa, Bobby Lee, Jim, Calvin, Scott, Gerry, John and Jeff. Thanks to all.

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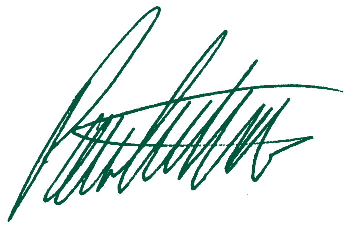

Patrick Linhardt

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