INTRODUCTION

This book has two primary goals:

- To provide you with a sound introduction to the components, materials and mechanics of steam, electric, and space heating that you will encounter and evaluate as a home inspector;
- To provide you with a solid understanding of inspection processes, strategies and standards of practice that will help define the scope of your inspections. Specifically, the ASHI® (American Society of Home Inspectors) Standards of Practice are represented throughout.

The ASHI Standards are not the only standards for home inspectors, but they are widely used. Several states and other organizations have their own standards. The point is that standards help define a consistent scope of professional practice for home inspectors to use in their day-to-day work.

SCOPE

In its discussion of electric, steam and wall/floor heating methods, this book assumes that you already are familiar with more conventional systems, such as gas and oil furnaces and hot water boilers, and with background concepts of heat transfer. Where components of systems in this book are similar to more conventional systems, we will merely list the problems that can occur, rather than discuss them in detail. If you feel you need a better background in these topics, we recommend that you read the *Gas and Oil Furnaces* and/or *Hot Water Boilers* volumes of this series first.

Some of the heating systems discussed in this book are rare in various parts of North America. If they are common in your area, you may need to go beyond this material to get further expertise. If steam boilers are rare in your area, you probably won't retain this introductory information, and may wish to use a specialist for steam inspections. The depth of this book is sufficient to allow the general practitioner home inspector to perform a standard inspection of steam, electric, and space heating. There is always more material that can be studied and other courses that you can take.

FEATURES OF THIS BOOK

This book is structured to help you learn and retain the key concepts of home inspection. It also will help you form a set of best practices for conducting inspections. Learning features include:

- Learning objectives: At the beginning of each chapter you will find a list of concepts you should master by the end of the chapter.

- Chapter Review Questions: Each chapter ends with a set of review questions to help you test your understanding. Answers can be found at the end of the book so you can check your results.
- Key terms: Important terms appear in boldface within the text discussions so you can begin to understand them in context. A summary list of key terms appears at the end of each chapter.
- Inspection checklists: These tools summarize the important components you will be inspecting and their typical problems.
- Inspection procedures: This material helps you develop a systematic approach and best practices for your inspections.
- Standards of practice: ASHI has established a set of Standards that are widely used to define the scope of inspection that practitioners should achieve.
- Inspection tools: This summary list will help you build your toolkit of "must have" and optional tools for the job.

CHAPTER 1

PRINCIPLES OF STEAM HEATING

LEARNING OBJECTIVES

At the end of this chapter you should be able to:

- describe two common materials used for steam boilers
- describe two common materials used for steam pipes
- name the most common material used for steam radiators
- list ten differences between hot water and steam boilers that you should be able to identify on an inspection
- explain the latent heat of vaporization as it applies to steam heating systems
- explain in five sentences how steam heat gets from the boiler to the living spaces
- describe the function of **Hartford Loops** and **equalizers**
- describe in two sentences each, **one pipe counterflow systems, one pipe parallel flow systems** and **two pipe steam systems**
- describe in two sentences the differences between condensate pumps and boiler feed pumps
- describe in one sentence the function of a low water cutout
- describe in one sentence the function of a pressure relief valve
- describe in one sentence the function of a pressure limit switch

1.1 OVERVIEW

Steam heating is similar to hot water heating in many ways. We use a boiler, pipes and radiators to distribute the heat. The heat can be generated by gas, oil or electricity, for example. Steam systems are also referred to as **hydronic.**

Extra Heat Transfer Medium

While steam heating is simple in some ways, it is more complex than hot water boilers, in other ways. We are dealing with three heat transfer media (air, water, and steam) rather than a single medium. We go through a change of state twice in a steam system—water-to-steam and steam-to-water.

Many Variations on a Theme

Steam heating systems are very diverse. Identifying what type of steam system you are looking at can be a challenge in itself.

Not Used in New Construction

Steam heating is very rare in new homes. However, you may find it in older homes, depending on the area that you work in. You will probably find old and new boilers on old systems, but no new systems.

Converted to Hot Water

It is also not unusual to find two pipe steam systems that have been converted to hot water. Unless you look closely, you may not notice that the hot water system you're looking at was originally a steam system. This is largely a matter of curiosity, in any case.

You may also see systems that were converted to water, but still have a sight glass and pig tail connections in place. It will still look like a steam system at first glance. Be careful.

Some Are Both!

To make matters worse some steam heating systems have some hot water heating sections. One boiler can supply steam and hot water radiators at the same time! We don't cover these hybrid systems but if they are in your area, you'll need some local knowledge.

1.2 FUNCTION

The function of a steam boiler is the same as any other central heating system. The goal is to heat the house, making it comfortable in a safe and economical fashion.

Advantages of Steam Heat

Steam heating has some advantages. The principle is simple and there are few moving parts. There is no fan or pump associated with moving the heat through the distribution system. (There are exceptions, but for most small residential systems, this is true.)

Disadvantages

Steam heat has some disadvantages. The working environment of a steam boiler is harsh because of the high temperatures and the changes of state that take place. The interior components are variously exposed to air, water and steam.

Few Steam Specialists Left

Because steam heating systems are not being used in new construction, many service people are not well qualified to work on steam systems. There are very few people left at the residential service level who have designed steam heating systems from the ground up. Modern commercial steam systems are very different from older residential steam systems. This poses another challenge to service people who may not be used to working on house steam systems.

Parts Hard To Find

Because steam heating systems are not manufactured in large quantity anymore, parts can be difficult to obtain.

So Many Systems

Steam heating systems can be difficult to inspect and evaluate because there are so many different systems. There are several unique proprietary systems, each with their own characteristics. Many of these will no longer be in their original state or original arrangement. This creates a challenge to the home inspector who is a generalist, especially for an inspector who doesn't see a lot of steam.

Systems Modified

The problem is compounded because most older systems have been modified to some extent. Vents and traps may have been added, abandoned or removed. Gravity return systems may have been converted to pumped return systems. Dry returns may have become wet returns, by design or by accident. You get the idea.

Steam Slow

Steam heating is slower to respond than forced air and hot water heating systems.

High Temperature Radiators

The radiators on steam heating can be very hot. We're dealing with steam on one side of a cast iron radiator that is usually slightly above 212°F. The surface temperature of the cast iron radiator can be hot enough to burn skin. In this respect, steam heating is a little dangerous, especially for children.

Noisy

Although well-designed and maintained steam heating systems should be as quiet as hot water systems, the reality is that many are not in good working order and these systems can be noisy. The noise can be **very** disturbing if **water hammer** is a feature of the system. We'll look at water hammer shortly.

Steam Explosions

Because we are dealing with a change of state and higher temperatures than with hot water boilers, steam boilers can be more dangerous. However, both steam boilers and hot water boilers are safe as long as the proper safety controls are in place and in good operating order.

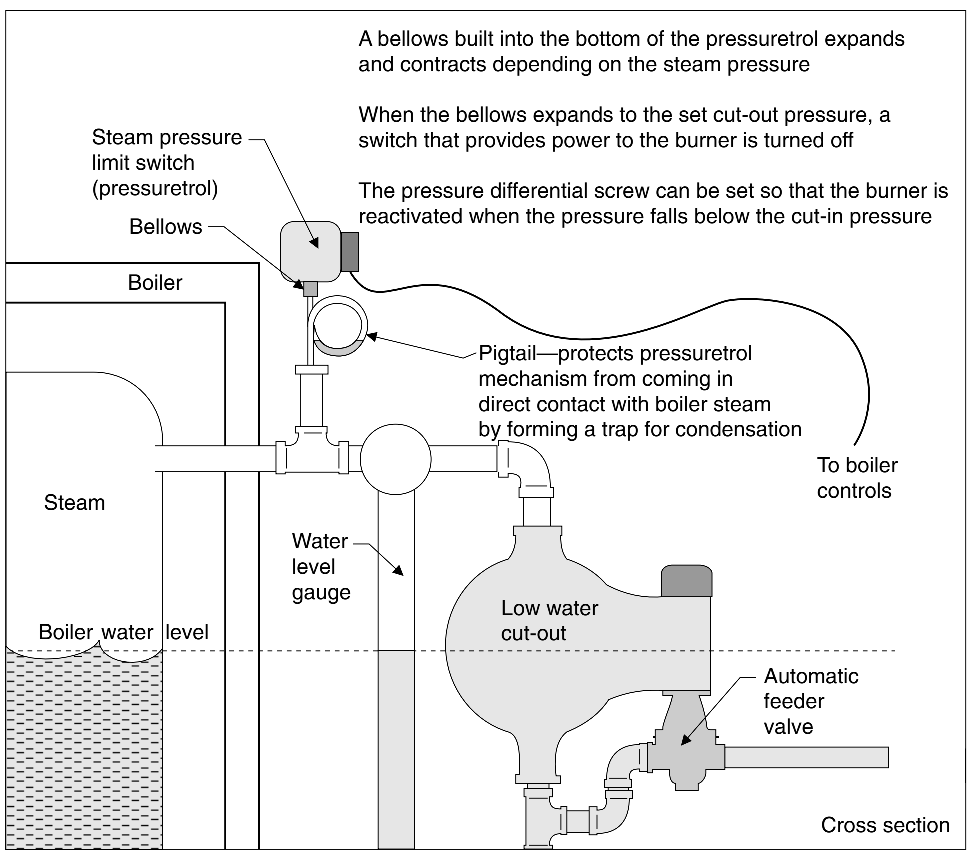
Pigtails

Connections for gauges and pressuretrols have pigtails that hold water to shield the device from direct contact with the steam (Figure 1.1). This is one way to identify steam boilers.

Many Types of Steam Systems

We have already suggested that there are lots of different kinds of steam heating systems. We will mention a few of the common categories just to give you an idea of what we are dealing with:

FIGURE 1.1 Pressuretrol



- There are **high** and **low pressure** systems. Low pressure systems operate at 15 psi or less. Most residential systems will be low pressure.
- There can be **one** and **two pipe** systems. The one pipe systems are older and the two pipe systems are modern. You will see both in houses.
- one pipe systems can be **parallel flow** or **counter flow.** In a parallel flow system, the condensate runs in the same direction as the steam. In a counter flow or **reverse flow** system, as they are sometimes called, the condensate runs in the opposite direction to the steam.
- Steam systems can be **upfeed** or **downfeed** systems. Most homes have an upfeed system.
- Steam heating systems can be classified as **gravity return** or **pumped return.** The pumped return systems have a **condensate pump** or **boiler feed pump.** Gravity return systems rely on gravity to return the condensate to the boiler.
- There are **vapor systems,** which are very low pressure (only a few ounces of steam).
- There are **vacuum systems,** which operate below atmospheric pressure.
- There are **vapor/vacuum systems** which are a hybrid.

Our Strategy

When we come across steam systems, which are rare in our working area, we call for help from a specialist. Because we don't see these systems regularly, it is difficult for our people to have a good working knowledge of them. Also, because there are so many different types, it can even be difficult for us to know which type we are looking at, especially since many of the older systems have been modified and are no longer pure systems.

May Misbehave Later

We are particularly cautious because steam heating systems may appear to be working fine during the middle of the day. However, at night or during a start up phase, there can be considerable water hammer, noise and even leaks that will not be apparent at other times.

Expensive To Repair

Steam heating systems can be expensive to work on because there are so few qualified people available.

Call For Help

In our area, we are content to identify steam heating, describe it as an unusual system (you'll need to determine whether or not this is true in your area), and recommend further evaluation by a specialist.

1.3 MATERIALS AND COMPONENTS

Boilers

Steam boilers are similar to hot water boilers. They are typically made out of cast iron or steel. Many manufacturers of hot water boilers also make steam boilers.

Pipes

The piping systems are typically cast iron or black steel. Copper is not as common.

Radiators

The radiators, convectors and baseboards are also similar to hot water systems. Cast iron is a common material for these.

Hostile Environment

We have touched on the fact that hot water heating systems always have their distribution pipes and radiators filled with water that fluctuates between room temperature and just under 200°F. This is a much more accommodating environment than what steam boilers and distribution systems are exposed to. These systems see everything from air at room temperature, to steam at a little over 212°F. They also see water at room temperature and water up to 212°F.

TABLE 1.1 Comparison of Hot Water and Steam Heating Systems

Component/System	Hot Water	Steam
1. Boiler	Yes	Yes
2. Burner	Yes	Yes
3. Fuel delivery system	Yes	Yes
4. Combustion air supply system	Yes	Yes
5. Products of combustion exhaust system	Yes	Yes
6. Thermostat	Yes	Yes
7. Distribution piping	Yes	Yes
8. Radiators, convectors and/or baseboards	Yes	Yes
9. High temperature limit switch	Yes	No
10. Water temperature and pressure gauge	Yes	No
11. Steam pressure gauge with pigtail	No	Yes
12. Water level gauge (sight glass)	No	Yes
13. Circulator pump and expansion tank	Yes	No
14. Bleed valves on radiators	Yes	No
15. Air vents on radiators and pipes	No	Yes
16. Pressure relief valve	Yes (30 psi)	Yes (15 psi)
17. Automatic water make-up systems	Usually	Usually
18. Low water cutout	Maybe	Yes
19. Pressuretrol (steam pressure controller)	No	Yes
20. Hartford Loop	No	Yes
21. Equalizer pipe	No	Yes
22. Steam traps	No	Yes
23. Condensate pump	No	Maybe
24. Boiler feed pump	No	Maybe
25. Backflow preventer	Maybe	Maybe
26. Zone control	Maybe	Maybe

Corrosion

Corrosion is more likely on the inside of steam systems than hot water systems because of the oxygen provided by the air, in combination with the water and the steam. Carbon dioxide in the air also mixes with the condensate to form **carbonic acid** which is corrosive.

The components of boiler systems are listed in Table 1.1 so that we can compare hot water and steam systems.

1.4 HOW STEAM SYSTEMS WORK

The Process in a Nutshell

Steam boilers use heat from the burner to convert water in the boiler to steam. The steam moves from the top of the boiler through the distribution pipes to the radiators. The steam condenses at the radiators, releasing its heat. The condensate returns to the boiler as water (Figure 1.2).

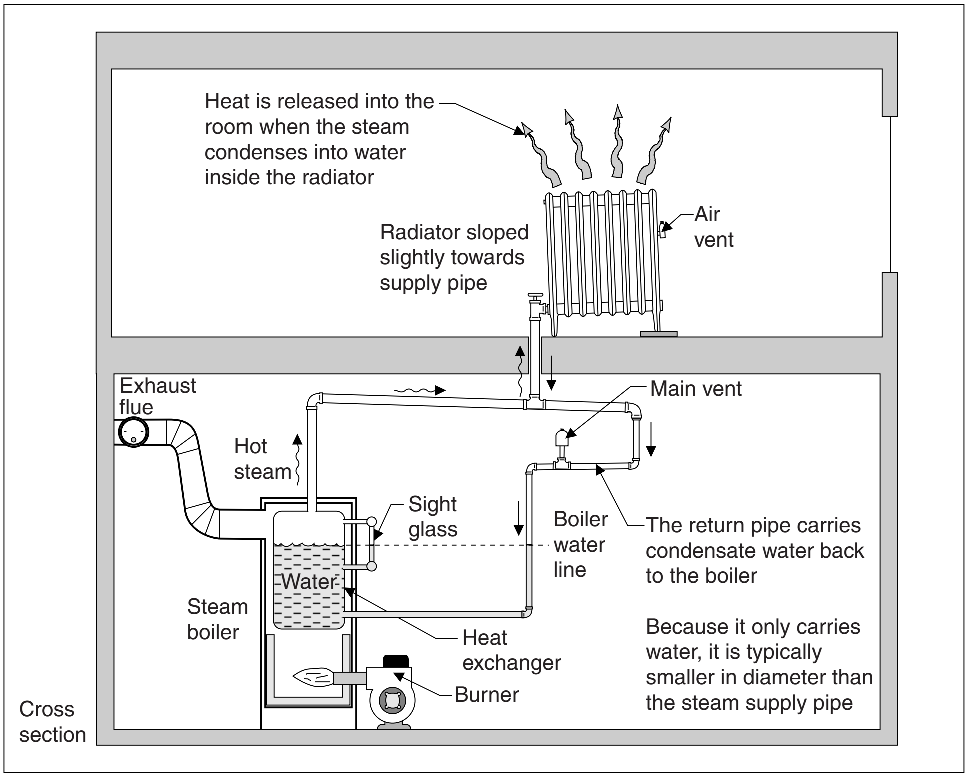
Air Is Expelled and Then Reintroduced

Before the system starts, the top of the boiler, the distribution pipes and the radiators are filled with air. As the steam moves through the system, it pushes the air out of the system. When the system shuts down, and the steam all condenses back to liquid, air is let back into the pipes and radiators, and into the top of the boiler.

Latent Heat of Vaporization

Steam heating uses the tremendous heat storage capacity of the latent heat of vaporization of water. To raise one pound of water from room temperature to 212°F takes about 140 BTUs. To convert that one pound of water at 212°F to steam at 212°F takes an additional **970 BTUs.** That large amount of heat (almost 1000 BTUs per pound) is released in the distribution system when the steam condenses back into water. In this respect, steam is a very efficient heat transfer system.

FIGURE 1.2 How Steam Systems Work



Steam Pressures and Speed

In single family systems, the steam pressure is typically less than 5 psi and can be as low as $^1/_2$ psi or even slightly less. Low pressure steam such as this moves through pipes at about 25 miles per hour.

Steam 1600 Times As Big As Water

One pint of water (which is about one pound) expands to fill about 27 cubic feet when it is converted into steam at atmospheric pressure. This is an increase of about 1600 times its original volume.

Compressible

Steam is quite compressible. We can increase the pressure on that 27 cubic feet of steam and reduce its volume. Squeezing gas into a smaller space increases its pressure and its temperature. The same bundle of steam at 5 psi pressure will occupy about 20 cubic feet. This slightly smaller package at a slightly higher pressure contains the same number of BTUs.

As you can see, it doesn't really matter whether we move steam at atmospheric pressure or 5 psi. We can deliver roughly the same amount of heat. Interestingly enough, when we increase the pressure on the steam, it actually moves more **slowly** through the pipes because of the increased friction on the pipe walls caused by the higher pressure.

High Pressure Steam May Overheat Rooms

Old steam systems had radiators designed to provide adequate heat to the room. These were designed based on steam inside the radiator at about 215°F or at about 1 psi. Moving higher pressure steam through the system may overheat rooms.

Don't Evaluate Design

We are starting to wander into the world of design and we should probably leave it right there.

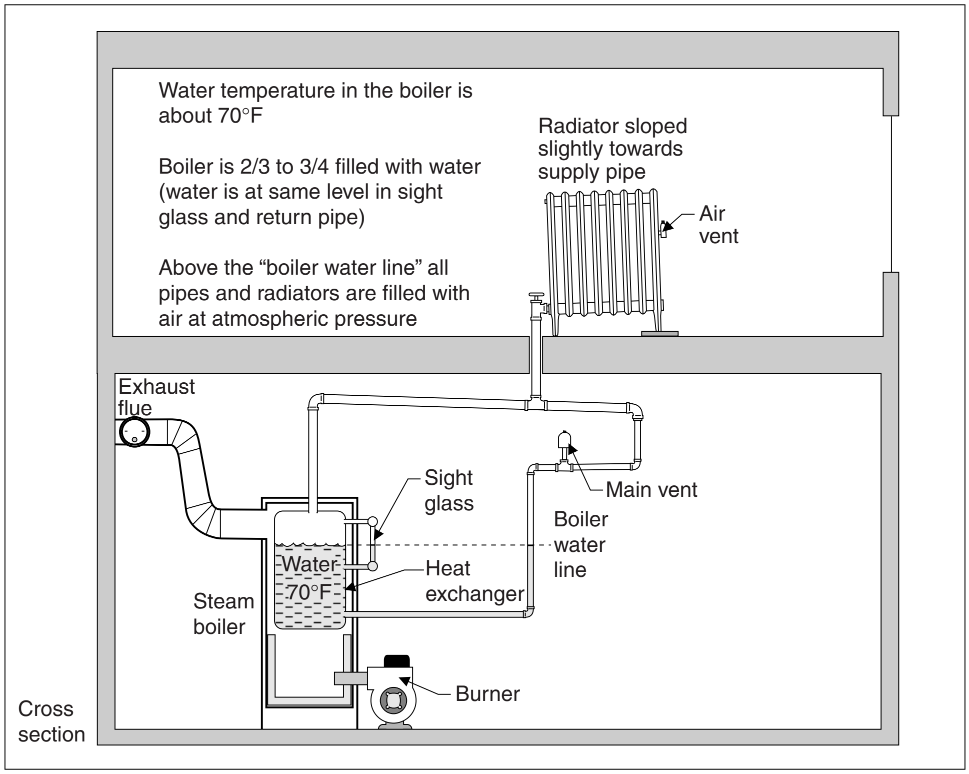
A Simple Steam System

Let's look at a simple steam boiler as it cycles through.

Cold Start

Let's look at the system at rest. The water in the boiler is at about 70°F. The boiler is about $^2/_3$ to $^3/_4$ filled with water. A sight glass mounted on the side of the boiler allows us to see the water level (Figure 1.3).

FIGURE 1.3 Steam System Operation: At Rest



Water and Air

The water in the boiler fills the return piping to the same height because the return piping connects to the boiler below the water level. The water level in the return piping is the same as the water level in the boiler. The top of the boiler, the supply piping, the radiators and the return piping above the water line are all filled with air. Everything is at atmospheric pressure (the same pressure as the house).

Call For Heat

When the thermostat calls for heat, the burner turns on. The water in the boiler heats up and boils. Steam comes off the top of the water in the boiler, just as it does in a kettle or a pot on the stove (Figure 1.4).

Thermostat and Pressuretrol

The burner is controlled by the **thermostat** and by the **pressuretrol.** The two devices are in series. The thermostat shuts off the burner when the house gets warm enough. The pressuretrol controls the steam pressure. A typical system might operate between 1/2 psi and 1 1/2 psi steam pressure. When the steam pressure in the top of the boiler reaches 1 1/2 psi, the burner will shut down even though the thermostat is still calling for heat. When the steam pressure drops to 1/2 psi, the burner will come back on if the thermostat is still calling for heat.

Moving the Air

As steam starts to form above the water in the boiler, it pushes up on the air above the water and pushes down on the water itself. Let's assume that we have one psi of steam pressure. If we want to move the steam through the system, we have to get the air out of the way.

Air Vents

Air vents in the system are open to the atmosphere. These allow the air to be pushed out of the piping and out of the radiators (depending on the type of system) to allow the steam to move into the piping and radiators (Figure 1.5). These vents remain open to the atmosphere until the steam hits them. The hot steam typically expands a bellows which pushes a valve closed. The air vents allow air to escape but don't let the steam to get out. The steam moves through the system, pushing the air out of the piping and the radiators. The steam condenses as it hits the cold pipes and radiators, releasing its heat into the radiator.

FIGURE 1.4 Steam System Operation: Call for Heat

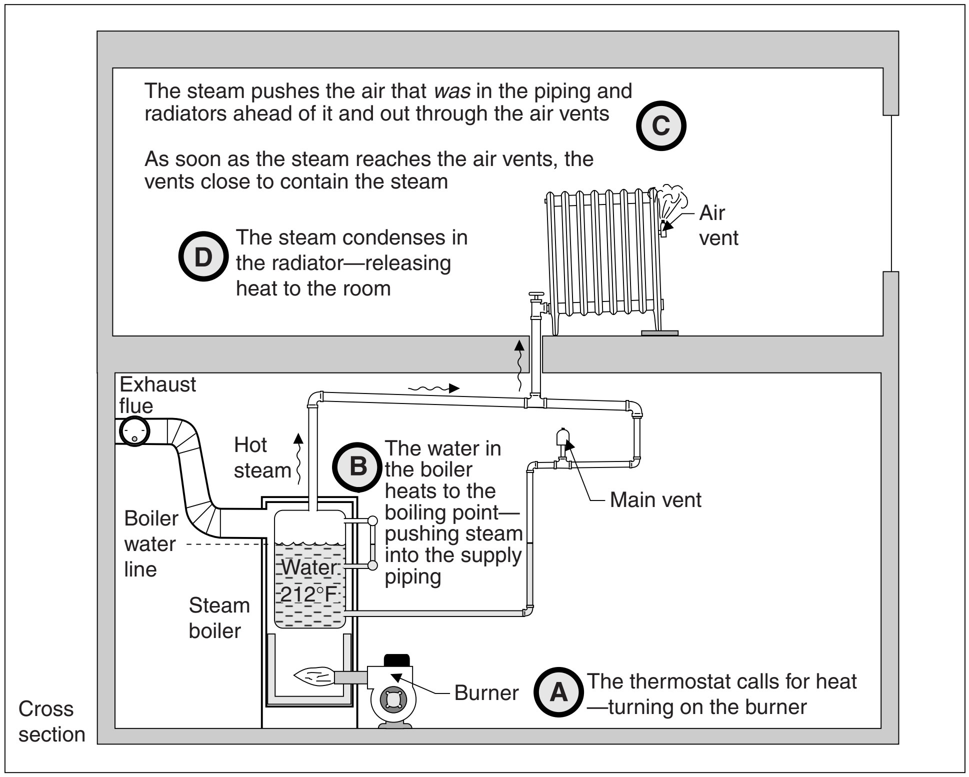
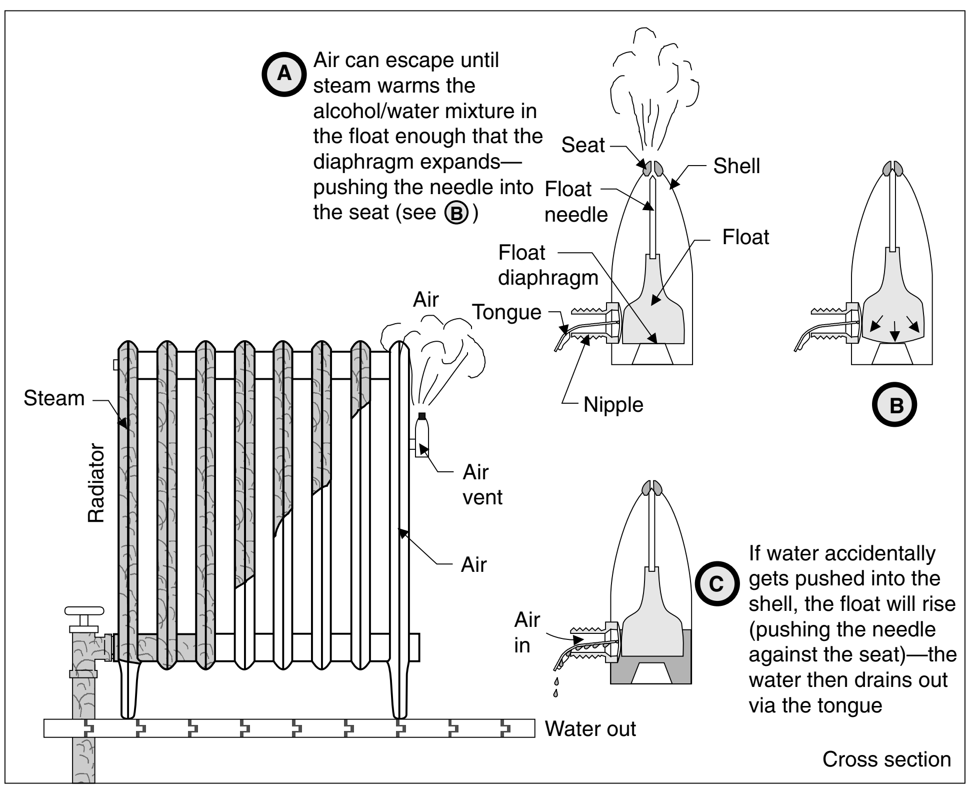


FIGURE 1.5 Air Vents



Even Heating

The goal is to have the steam hit all of the radiators at about the same time. This allows us to heat the building evenly. Some air vents on radiators are adjustable. This means that they close at rates that can be adjusted by the homeowner or service technician so that all of the radiators fill with steam at about the same time.

For a steam heating system to work, the air vents must allow the air to escape, but must trap the steam.

Balancing Water Levels

Let's look at the effect of that one psi steam pressure on the top of the boiler in a one pipe system. When the boiler was at rest, the water in the boiler and the water in the return piping were at the same height. When the boiler starts to generate steam, there is one psi of steam pressure on top of the boiler that is not on the return piping.

Steam Pressure Pushes Water up in Return Line

The pressure of the steam will push down on the boiler water causing the water level in the return pipe to rise. One psi pressure will cause that water column to rise by 28 inches. Because we have atmospheric pressure on both sides (the boiler and the return pipe) **plus one extra psi on the boiler side,** the water level in the return line can rise 28 inches. (In reality, it is a little less, but that doesn't matter to us.)

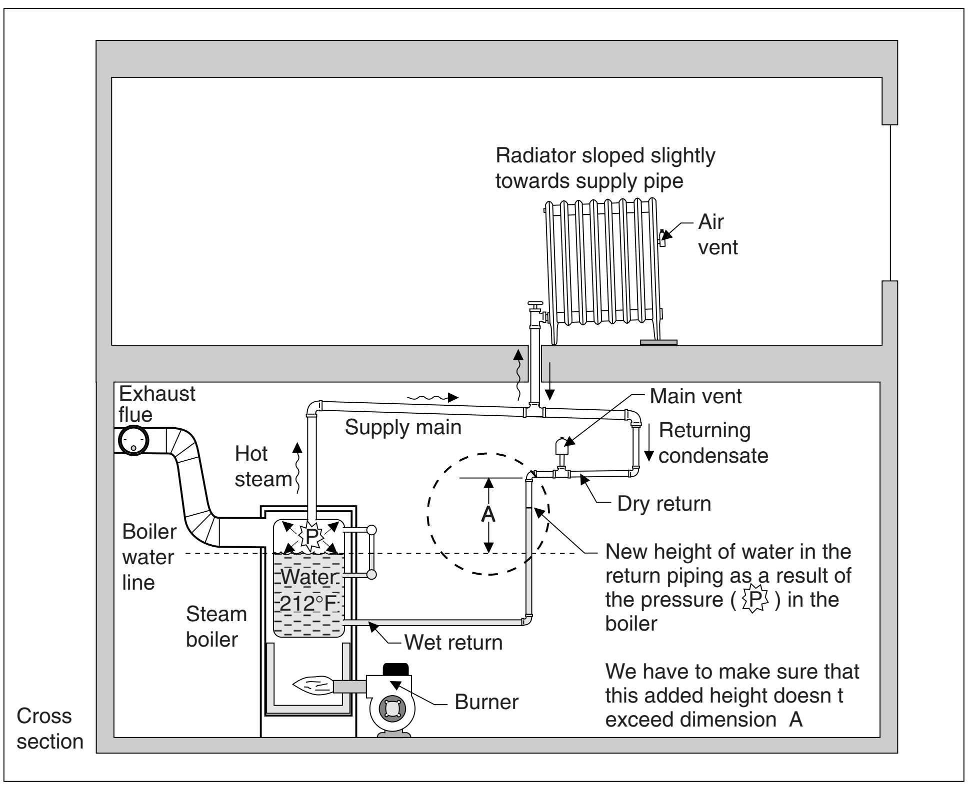
Back-up Is Bad

This can be a problem with steam boilers. We want to monitor how far that water rises in the return pipe. If the water gets pushed back into pipes that should contain steam, it will cause chaos. The steam won't be able to move and we might have heating problems. The steam slamming into the water can cause **water hammer.** Boiler water levels may also drop to a point where the boiler shuts off on low water. Generally, this is not a great arrangement.

Dimension "A"

Depending on the operating pressure of the boiler, we want to allow that return pipe to have lots of height above its "at rest" water line to allow the water to rise up as a result of the steam pressure pushing down on the boiler water. This is the critical **Dimension "A"** that shows up in the next illustration (Figure 1.6). As condensate

FIGURE 1.6 Dimension "A"



accumulates in the vertical return pipe, it will build up enough pressure to push water into the boiler, overcoming the pressure of the steam pushing down on the boiler water. Dimension "A" has to be tall enough to allow this water to accumulate, without backing up into the mains.

Equalizer Pipe

The **equalizer pipe,** which we'll talk about later, is used to create equal pressure on the boiler water and the water in the return pipe, so we don't have this problem. This is a good thing because it gets worse. We said one psi of steam pressure raises water 28 inches. Think what two, three or even five psi would do to that water in the return piping!

Steam Condenses to Water

As the steam moves through the system, it displaces all the air. Air is pushed out through the vents. The steam condenses back to water as it releases its heat. The water drains back down through the return lines into the boiler.

Water Levels

On start-up, the water level in the boiler will drop slightly as the boiler is firing up. Once the system reaches steady state, the water level in the boiler will stabilize as the condensate is returned, replacing the steam that is boiled off.

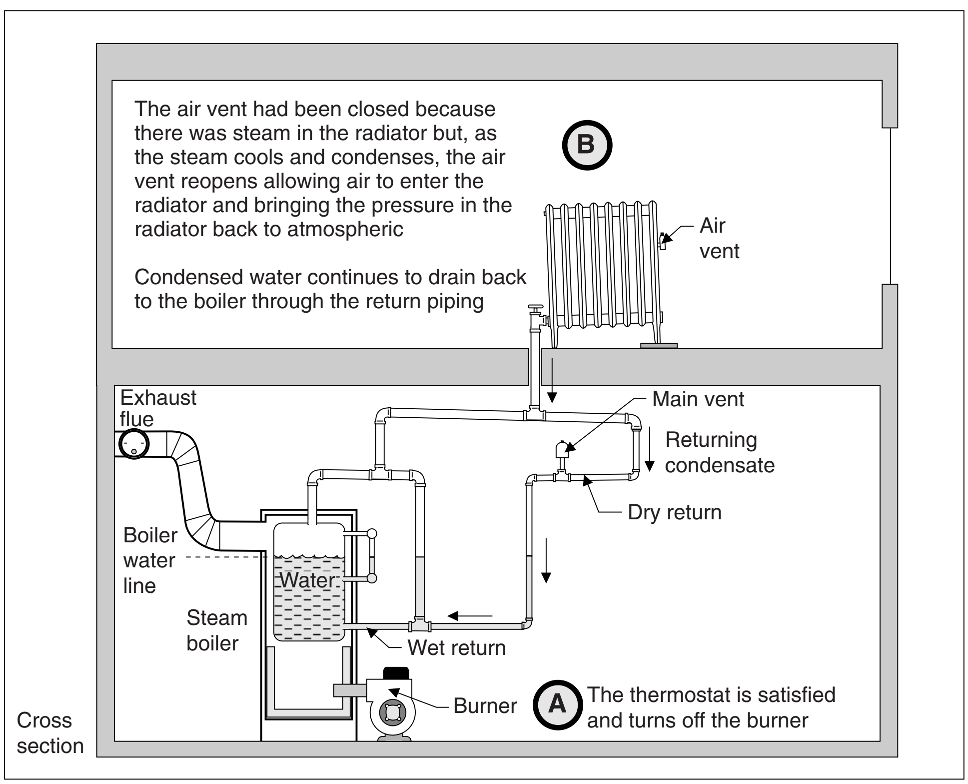
Water Must Get Back to the Boiler

The water may not return to the boiler because of a leak, an obstruction or a slope problem in the return lines, for example. The water will also accumulate in the return pipe, partially filling up the Dimension "A," if there is a pressure difference between the boiler water and return water. If the water doesn't get back to the boiler, the water level in the boiler will drop as more and more steam is generated. This will start to run the boiler dry, resulting in overheating which may crack the boiler. A low water cutout on the side of the boiler (either externally or internally) shuts off the boiler if the water level drops too far.

Thermostat Is Satisfied

When enough heat has been added to the house, the thermostat is satisfied. This causes the burner to shut off (Figure 1.7). No more steam is produced. The steam in the system condenses into water which runs back into the boiler. As the system

FIGURE 1.7 Steam System Operation: Thermostat Is Satisfied



cools, the air vents which had been driven closed by the high temperature steam are cooled and the vents reopen. Air from the house comes back in through the vents to fill the pipes and radiators. The system is restored to atmospheric pressure with water in the boiler and air in the rest of the system. The water level returns to its original level.

Summary

To summarize, we start with water and air in the system. As steam is generated, we have mostly water and steam in the system. When the system cools, we again have water and air in the system.

1.5 HARTFORD LOOPS AND EQUALIZERS

Steam Explosions

In the late 1800's and early 1900's, steam boilers were common. Unfortunately, steam boiler explosions and breakdowns were also common. Low water cutouts had not yet been invented and boilers frequently ran dry. In some cases, this caused cracking of the boiler. In other cases, water feeds would introduce cold water to very hot metal surfaces resulting in steam explosions.

Equalizer Pipe

The **equalizer pipe** (normally a 2 inch diameter pipe joining the steam header to the return line near the boiler) helped prevent water from backing out of the boiler by ensuring that the steam put equal pressure on the supply and return side of the boiler (Figure 1.8). The equalizer pipe looks like a short circuit between the supply header and return pipe.

Even with an equalizer, if a leak developed in the return piping below the water line, the boiler would run dry anyway. The **Hartford Loop** is simply an upside-down "U" added to the boiler return that prevents the water from running out of the boiler even if there is a leak in the wet return lines (Figure 1.9). As you can see in the illustration,

FIGURE 1.8 Equalizer Pipe

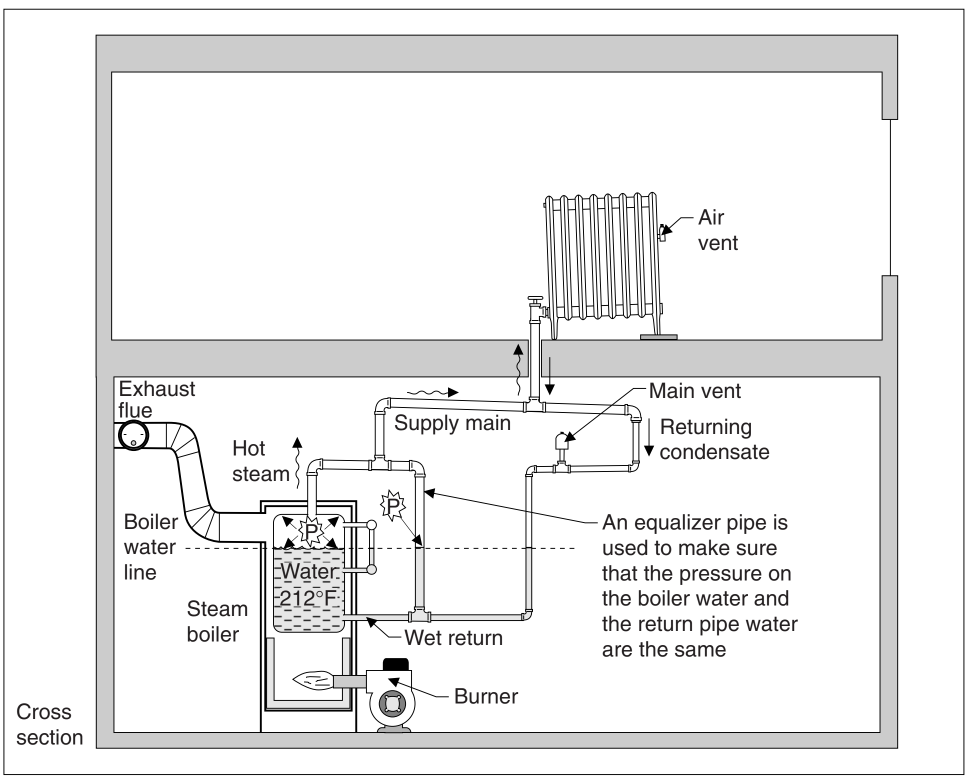
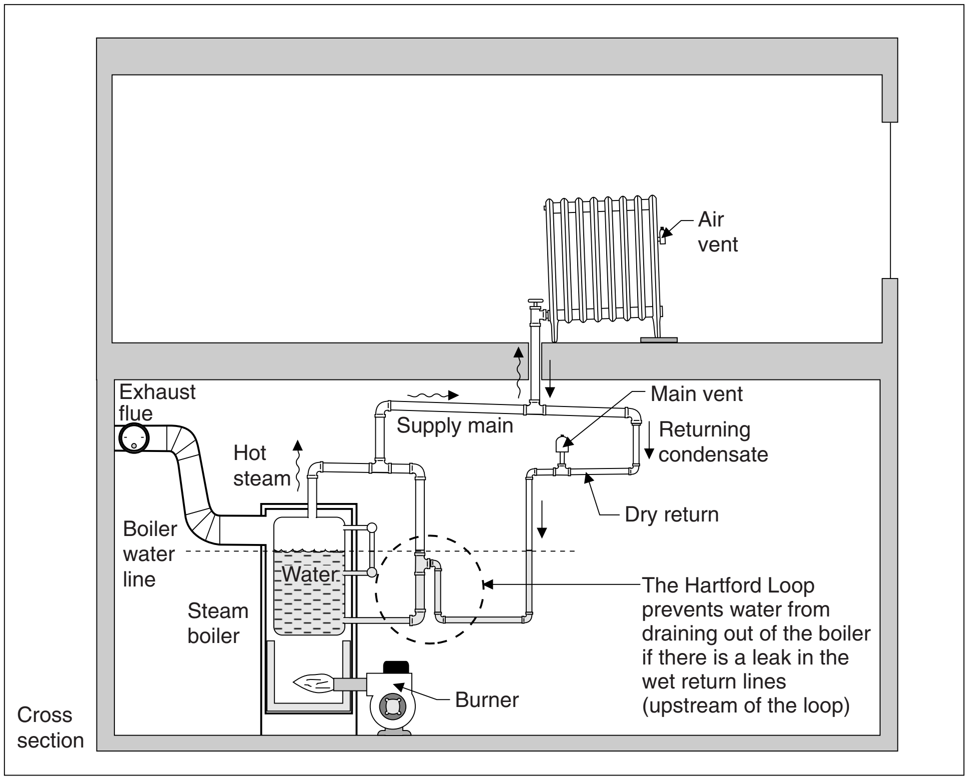


FIGURE 1.9 Hartford Loop



the Hartford Loop joins the **equalizer** making a very simple piping system that dramatically reduces the dangers associated with steam boilers.

A Back Up to a Low Water Cutout

Low water cutouts help further by shutting down the burner if the water level drops in the boiler. Some would argue that since we now have low water cutouts, Hartford Loops are no longer necessary. Since low water cutouts are mechanical devices and susceptible to failure, Hartford Loops are still recommended wherever the return lines come back to the boiler below the water line. This, incidentally, is referred to as a **wet return.** A return line that comes back above the water line of the boiler is called, strangely enough, a **dry return.**

1.6 COMMON STEAM SYSTEMS

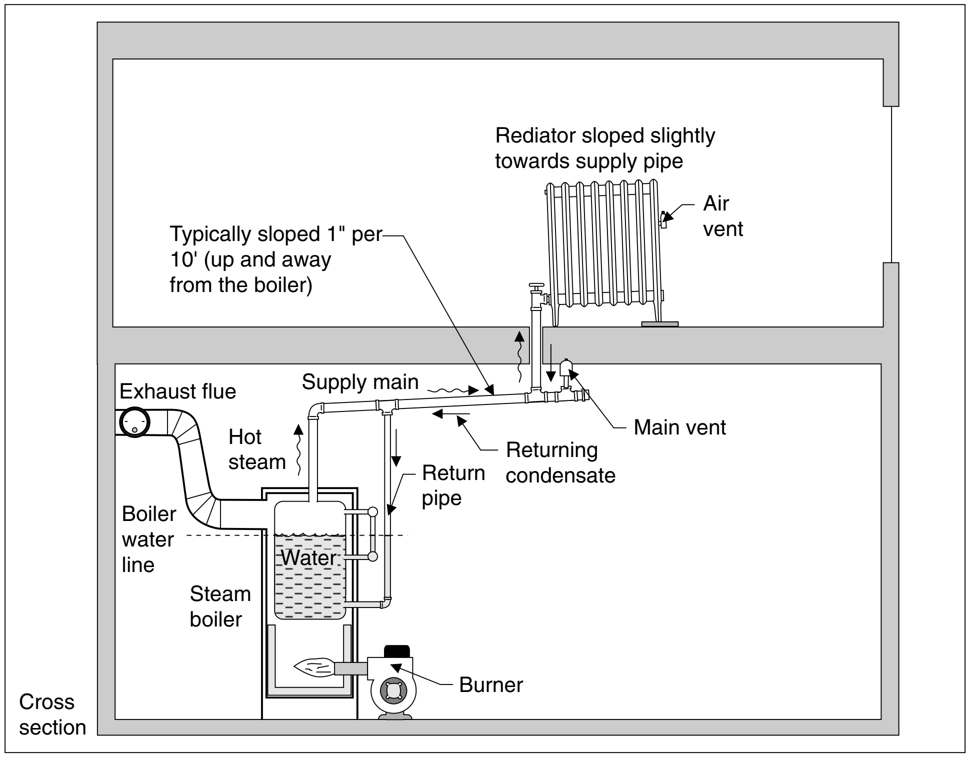
Let's apply the general principles that we have been talking about to three very simple residential steam systems. These are some of the most common systems that you will find in single family homes. We'll move from oldest to newest, and from the simplest to the most complex.

1.6.1 One Pipe Counterflow System

Simple

This is also known as a **one pipe reverse flow system.** These systems were simple, cheap and among the older steam systems. One large pipe was used to carry the steam out from the boiler. The same pipe allowed the condensate to return. The pipe was **sloped up away from the boiler** at a pitch of at least one inch for every 10 feet (Figure 1.10). This allowed condensate to run back down to the boiler. In theory,

FIGURE 1.10 One Pipe Counterflow System



the water could run back down through the header into the top of the boiler. In practice, most of these systems had a return that dropped down beside the boiler to allow condensate to flow into the bottom of the boiler. As you can see from the illustration, this pipe would have water in it to the same level that the boiler had water in it.

One Pipe to Each Radiator

The one pipe system is easy to identify because each radiator has one pipe. The radiators are pitched so that condensate flows back down into the pipe. In one pipe systems generally have an air vent on the opposite end of the radiator from the supply pipe. These vents are typically mounted about half way up and allow the steam to push air out of the radiator. The vent closes as the steam fills the radiator.

Main Vent

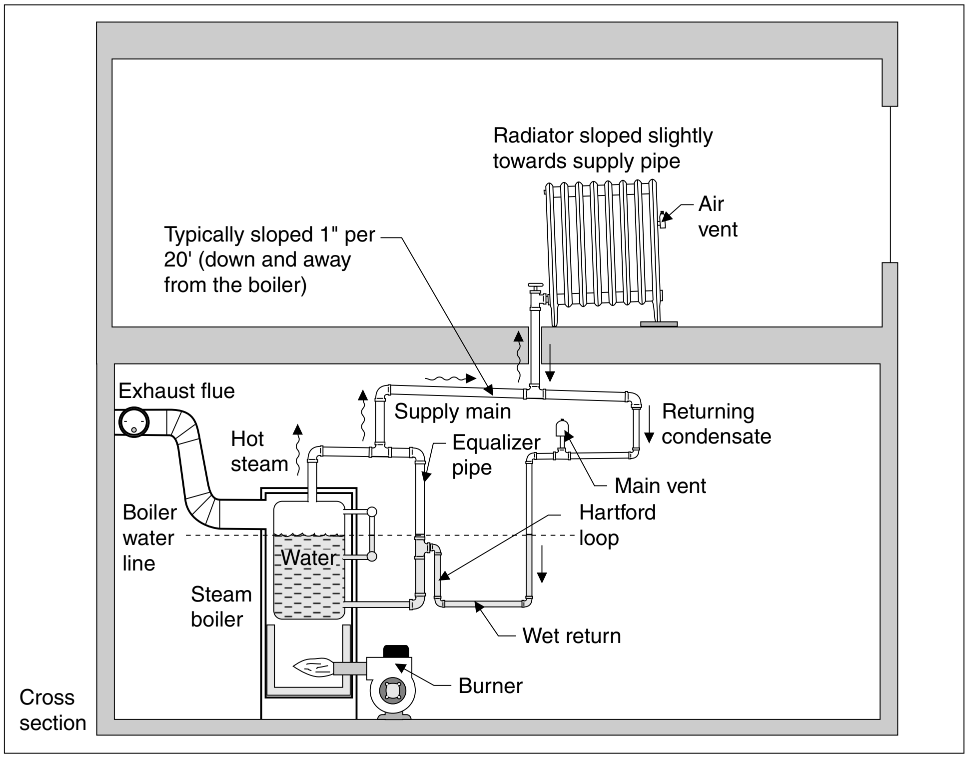
These systems also typically have a **main vent** at the end of each main. This vent allows the air to be pushed out of the mains as well as out of the individual radiators. In the system in the **One pipe counterflow system** illustration, there is no Hartford Loop needed because there is no wet return. We only have the single line coming down right beside the boiler.

1.6.2 One Pipe Parallel Flow

Simple

These systems are also simple and relatively inexpensive to install. Although they are the next generation after the counterflow system, they are old. Again, one pipe is used to carry both the steam and the condensate. However, the pipe from the header above the boiler **slopes down away** from the boiler. A return pipe slopes down toward the boiler to carry condensate back (Figure 1.11). In this system, the condensate flows in the same direction the steam is moving. This is slightly more efficient. The supply pipes are typically smaller as a result. More piping is necessary as you can see from the illustration.

FIGURE 1.11 One Pipe Parallel Flow System



Lower Pitch

Because the steam and water are not fighting each other, a pitch of 1 inch per 20 feet is sufficient. The return line can be a dry return coming back to the boiler above the water line. It could also be a wet return. A dry return line might contain steam or air. A wet return line would typically contain only water.

Location of Main Vent

The **main vent** is typically located near the end of each pipe that carries steam. Because of the possibility of water hammer, the main vent is ideally about 15 inches from the end of the pipe and 6 to 10 inches above the pipe. This wasn't always practical.

Hartford Loops and Dry Returns

One pipe parallel flow systems should have a Hartford Loop wherever there is a wet return. We suggested a minute ago that you didn't need a Hartford Loop if you only had a dry return. However, you do still want a Hartford Loop, but not for the same reason.

Steam Gets into Return Line, Stopping Flow

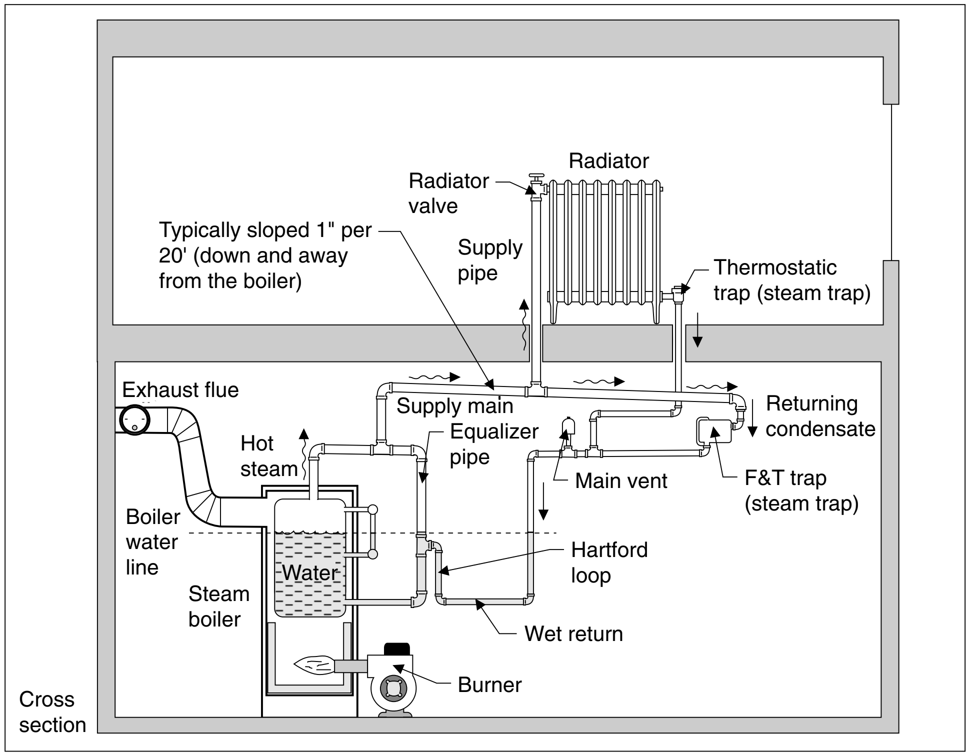
Without a Hartford Loop, the water in the return line beside the boiler would be at the same height as the boiler water. Assuming that we have an equalizer, there is steam pushing on the top of that water line. If the water level in the boiler surges slightly, the water level in the return line can drop slightly. This may allow the steam from the equalizer to get into the return line. Putting steam in the return line stops the flow through the system and can result in a no heat condition. We can also get quite a bit of noise and water hammer from the steam passing in an opposite direction to the condensate. So, it is good practice to always have a Hartford Loop, even with a dry return.

1.6.3 Two Pipe System

Not So Simple

The two pipe system is a somewhat more modern, more expensive and improved system. It still has a gravity return (Figure 1.12).

FIGURE 1.12 Two Pipe System



Big Advantage

The big advantage of a two pipe system is that we can adjust the heat at each radiator independently. We couldn't do it with one pipe systems because the condensate flowed out of each radiator into the same pipe that brought the steam in.

Adjust Radiators

Although there are isolating valves at each radiator in a one pipe system, they should be fully on or fully off. A partially closed valve will trap condensate and create water hammer problems.

Separate Pipes for Steam and Water

The two pipe system has one pipe to carry steam. It is a smaller pipe than on the one pipe system because it only has one job. A second pipe carries the condensate back to the boiler. The condensate pipe is smaller than the steam pipe because it carries a liquid. In a two pipe system, the steam is kept separate from the condensate. In a one pipe system, the steam and condensate shared the same pipe.

Conversion to Hot Water

The two pipe system can be converted to a hot water system. The one pipe system cannot, without expensive re-piping.

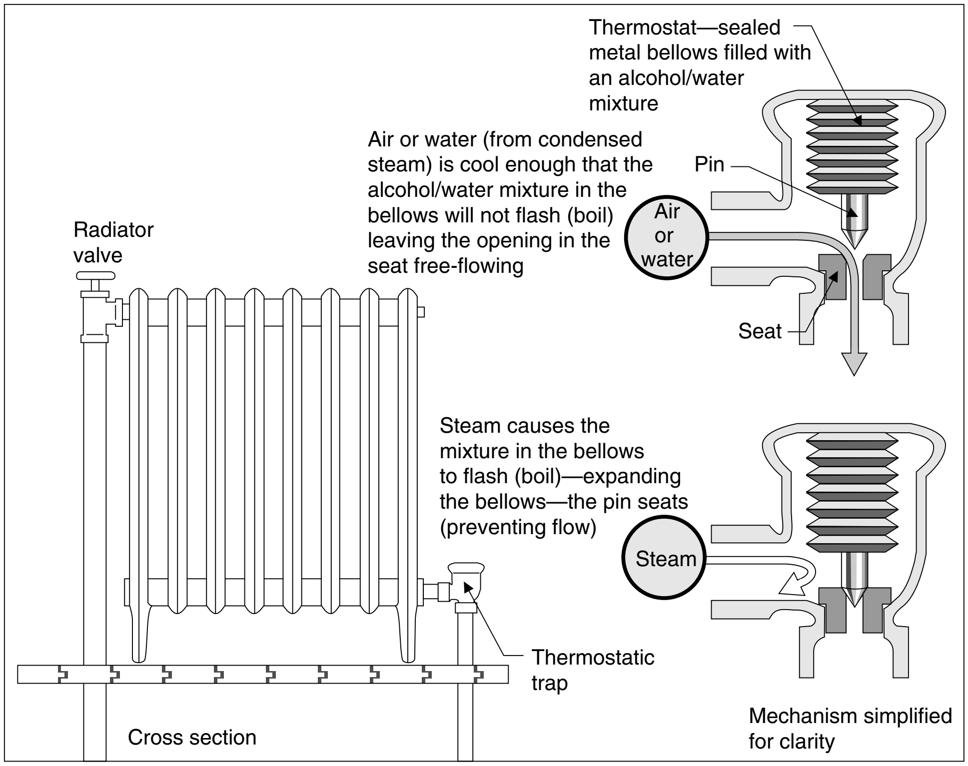
In a two pipe system, each radiator is connected to two pipes. The supply pipe typically (but not always) comes in at the top of the radiator at one end. This is where the radiator valve is. The return pipe or condensate pipe comes off the bottom of the other end of the radiator. It is common to find a **steam trap** on the condensate pipe for each radiator.

Steam Trap

The job of the **steam trap** is **similar** to the **air vent** on a one pipe system. The steam pushes the air through the supply pipe and through the radiator as it moves into the system. Air flows readily through the steam trap but when steam hits the trap, it closes.

Steam also pushes air ahead of it in the main. At the end of each main is a **steam trap** which again allows air to get past, but not the steam. We usually have steam traps at each radiator and at each main. Air vents at the end of each main allow the air to escape from the piping system.

FIGURE 1.13 Thermostatic Trap



Supply Pipe Will Have Some Condensate

Although the supply pipe is designed to carry steam, it will have some condensate in it. As a result, the steam trap at the end of the main has to allow condensate (but not steam) into the return piping system. The slope of the supply main is typically 1 inch in 20 feet, again to allow the condensate to flow back to the boiler.

Although the pipe diameters are smaller than those in a one pipe system, the two pipe system is more expensive to install because there is a double set of piping. This is comparable to a two pipe hot water system, of course.

Thermostatic Traps

The steam trap at each radiator is often different from the steam trap on the main. The steam trap at the radiator is typically a **thermostatic trap** (Figure 1.13). It operates strictly on temperature. When the trap is cold, it will allow air or water to flow out of the radiator and into the return piping system. When steam hits the trap, a bellows in the trap heats up and expands. This closes a valve so that no steam (or anything else) can enter the return pipe.

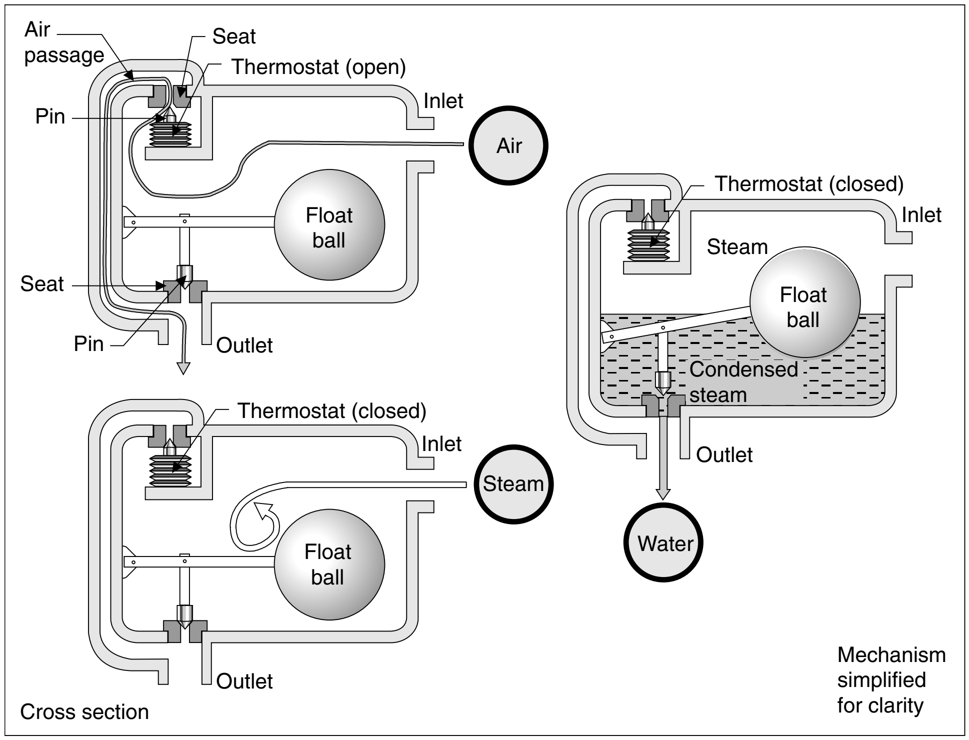
As condensate accumulates, the trap will fill with condensate. The condensate is cooler than the steam. This will cool the bellows and allow the trap to open. This allows the condensate to drain out into the return line.

When the condensate is gone, the trap will see steam and close again. To summarize, the steam trap allows air and water to get through, but stops the steam.

F & T Trap

The steam trap that is used in the mains is typically a **float and thermostatic trap** (also known as an **F & T trap**). As its name suggests, it works on a float principle as well as a thermostatic principle. There is still a bellows operated valve to control the movement of air. When the system is cool, the air valve is open and the air can move through freely. As the steam pushes the air through the trap, the air escapes into the return line and ultimately out through the main vent. When the steam

FIGURE 1.14 F & T Trap (Float and Thermostat Trap)



hits the F & T trap, it heats up the thermostatic bellows and closes the air valve. The steam can't escape through this valve into the return line (Figure 1.14).

The Float Component

The float component of the F & T trap allows condensate, but not steam, to get into the return line. This is a simple float valve (also known as a **ballcock**). As condensate accumulates in the trap, it raises the float which opens the valve. The condensate flows out of the trap. As the water level in the trap drops, the float drops and the valve closes. This prevents steam from getting into the return line.

The function of the **F & T trap** is the **same as the function** of the **thermostatic trap.** Both allow air and water to pass, but stop the steam. The F & T trap operates faster and is a better valve.

Three Year Life Expectancy

We talked about the harsh environment within a steam heating system. Steam traps have a life expectancy of three to five years.

Several Other Variations

We have talked about two types of steam traps. There are lots of others, including **bucket traps, float traps, flash traps, impulse traps, lifting traps and boiler return traps.**

Main Vents

Let's make sure we are clear on the difference between a **trap** and a **vent.** A trap allows air and water to continue **through the piping system** but stops steam. A vent allows air to escape **from the distribution system** but does not allow steam to escape. Vents also allow air back into the distribution system when the steam leaves.

Do all two pipe systems have both thermostatic traps for each radiator and F & T traps at the end of each main? No. This is considered good practice, but many systems do not have traps at all of these locations. Some do not seem to suffer as a result, others do. There are other variables, but they are beyond the scope of our program.

1.7 PUMPING THE RETURN WATER

Water Won't Flow Uphill

The systems that we have been discussing are all gravity return. Gravity return is nice because it is simple and doesn't rely on mechanical devices. Sometimes we need a mechanical device to get the water back to the boiler. That may be because we have:

- radiators that are below the boiler
- return lines that are below the boiler
- obstructions that make the pipe go up and over them before getting back to the boiler, or
- A Dimension "A" that is too short (perhaps because we replaced an old boiler with a new one that has a higher water line).

Condensate Pumps

A **condensate pump** is a fairly simple device that allows us to push the collected condensate back to the boiler (Figure 1.15). The condensate falls by gravity into a reservoir or **receiver.** A **float** controls the pump. When the water level in the receiver rises to a set point, the electric-motor-driven pump comes on. When the water level drops below a set point, the pump shuts off. A **check valve** on the discharge side of the pump prevents boiler water from flowing backwards into the return system and the receiver.

Location

The condensate pump is often located in the boiler room, close to the boiler (Figure 1.16). It may be elsewhere in the home, at the low point of the return piping.

5 psi Pressure Higher than the Steam

Condensate pumps are usually arranged so that they push water back into the boiler at five psi higher than the boiler steam pressure. If the boiler steam pressure is two psi, the condensate pump would discharge the water at seven psi, for example.

Receiver Vented to Atmosphere

The receiver for the condensate pump is typically vented to the atmosphere. This keeps the receiver and the water at atmospheric pressure. This can also act as a **main vent** to allow steam to push the air ahead of it, out of the system via the receiver vent. The vent on the receiver should never be sealed up, since the receiver may explode.

Like a Sump Pump

You can think of the condensate pump as a sump pump. When the water level rises, the pump comes on. When the water level drops, the pump shuts off.

Pump Doesn't Know the Boiler Water Level

The condensate pump is **not directly controlled by the boiler.** It pumps water back to the boiler when the receiver is full. It doesn't know whether the boiler needs the water or not. It simply assumes that the boiler needs water because it has collected the condensate.

Boiler Feed Pump

The **boiler feed pump** performs a similar function to the condensate pump. Again, it is often located in the boiler room, near the boiler (Figure 1.17). It typically has a larger receiver than a condensate pump and does not operate on a float principle (Figure 1.18). The receiver is kept partly filled with water, on standby, through an **auto water feeder** connected to the supply plumbing system.

Connected To Supply Plumbing Water

It is common to find a **pressure reducing valve (PRV)** that lowers the house supply plumbing pressure to about 12 psi before allowing it into the receiver. The receiver is kept about $^1/_4$ filled, on standby.

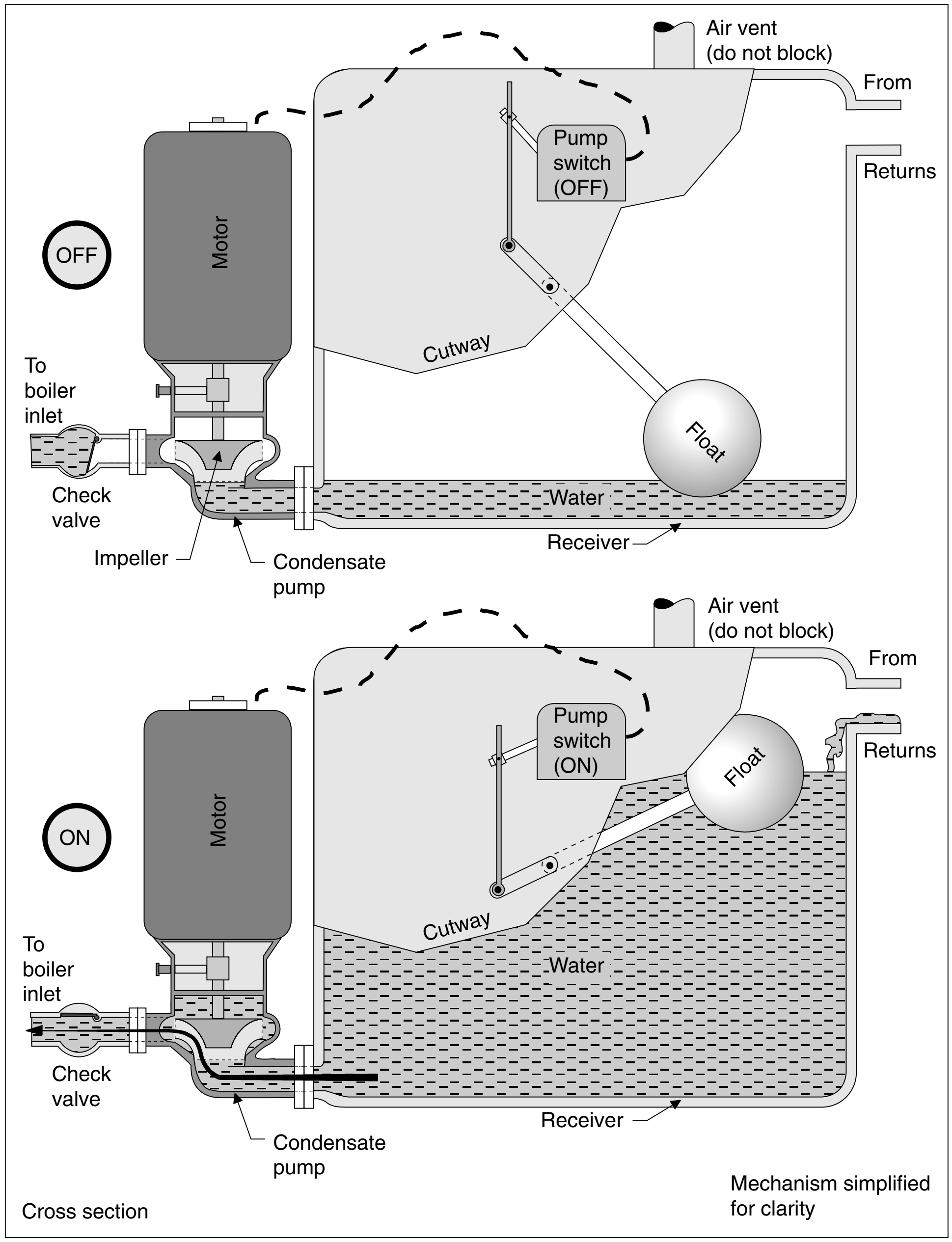
Responds to Boiler Water Level

The boiler feed pump is activated by the boiler water level. When the water level in the boiler drops below a given setting, the boiler feed pump comes on, adding water to the boiler through the return line. If the boiler water level continues to drop, the burner will shut off on a low water cutout. The boiler feed pump will continue to operate.

More Sophisticated than the Condensate Pump

Because the boiler feed responds to the boiler water level, it is more sophisticated. You are less likely to flood a boiler with a boiler feed pump than with a condensate pump. The condensate pump operates independently of the auto water feeder. It is

FIGURE 1.15 Condensate Pump



possible that the condensate pump and the auto water feeder could both be adding water to the boiler causing it to flood. This would not happen with a boiler feed pump.

Don't Need Hartford Loop or Equalizer

When a pump is used to return the condensate to the boiler, a **Hartford Loop isn't needed.** The check valve on the pump discharge pipe prevents water backing out of the boiler. **The equalizer is no longer needed** either. You may see pumped returns with Hartford Loops and equalizers, but they aren't needed.

Again, we are in danger of going beyond our scope and it is only important that you understand that condensate can be pumped back into the boiler and that there are two different principles for doing so. We are not going to go further than that.

FIGURE 1.16 Location of Condensate Pump

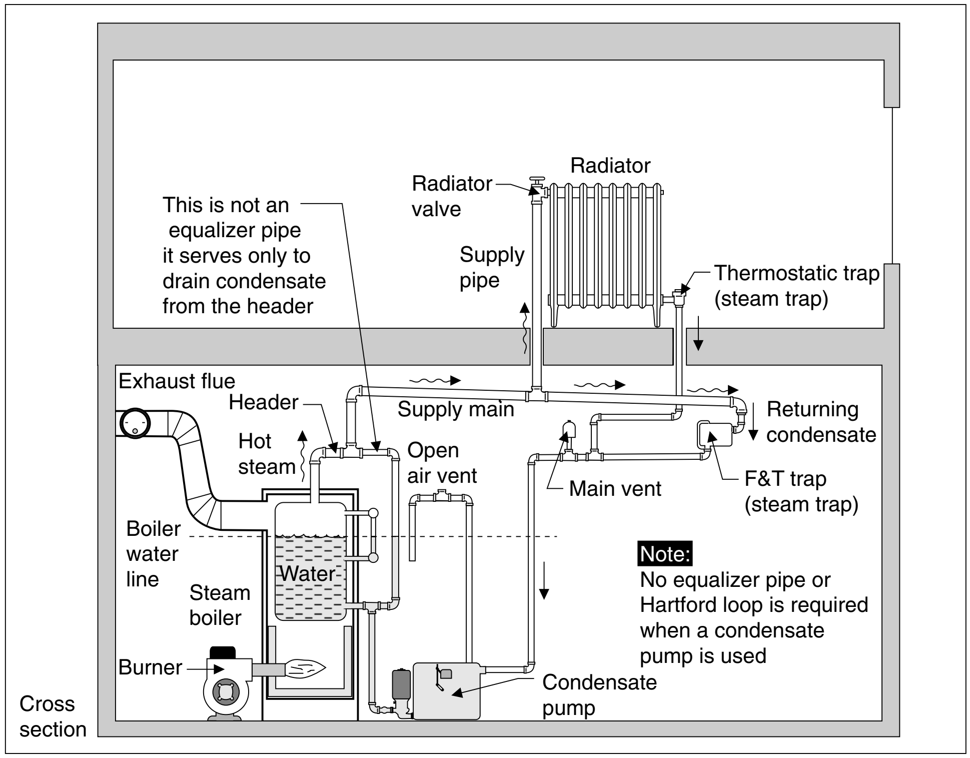


FIGURE 1.17 Location of Boiler Feed Pump

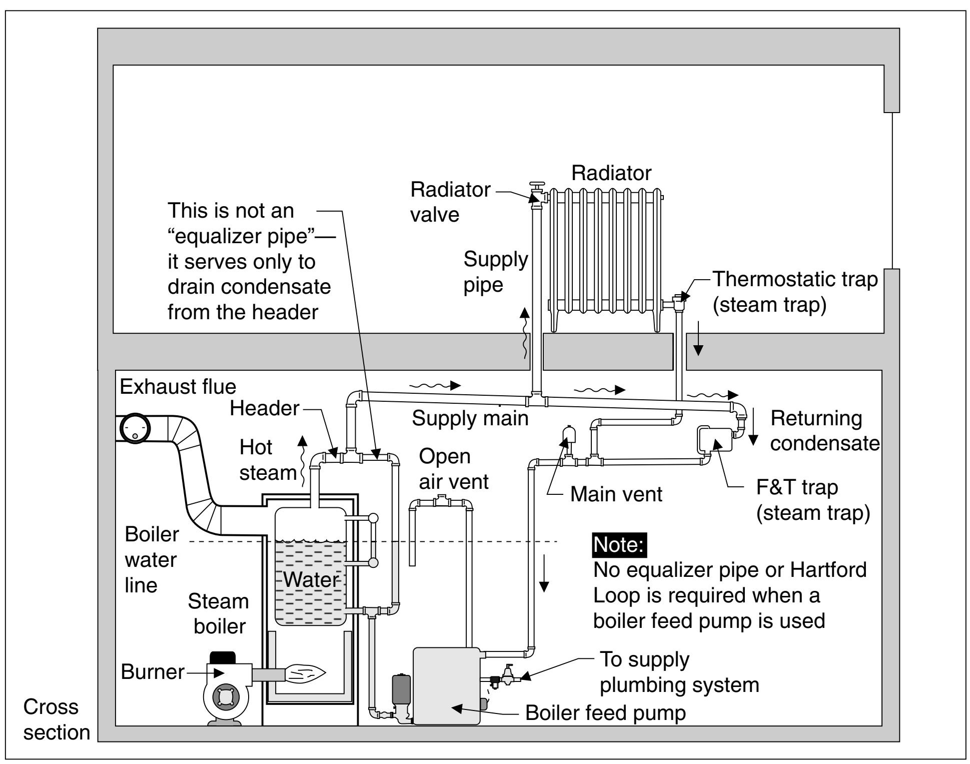
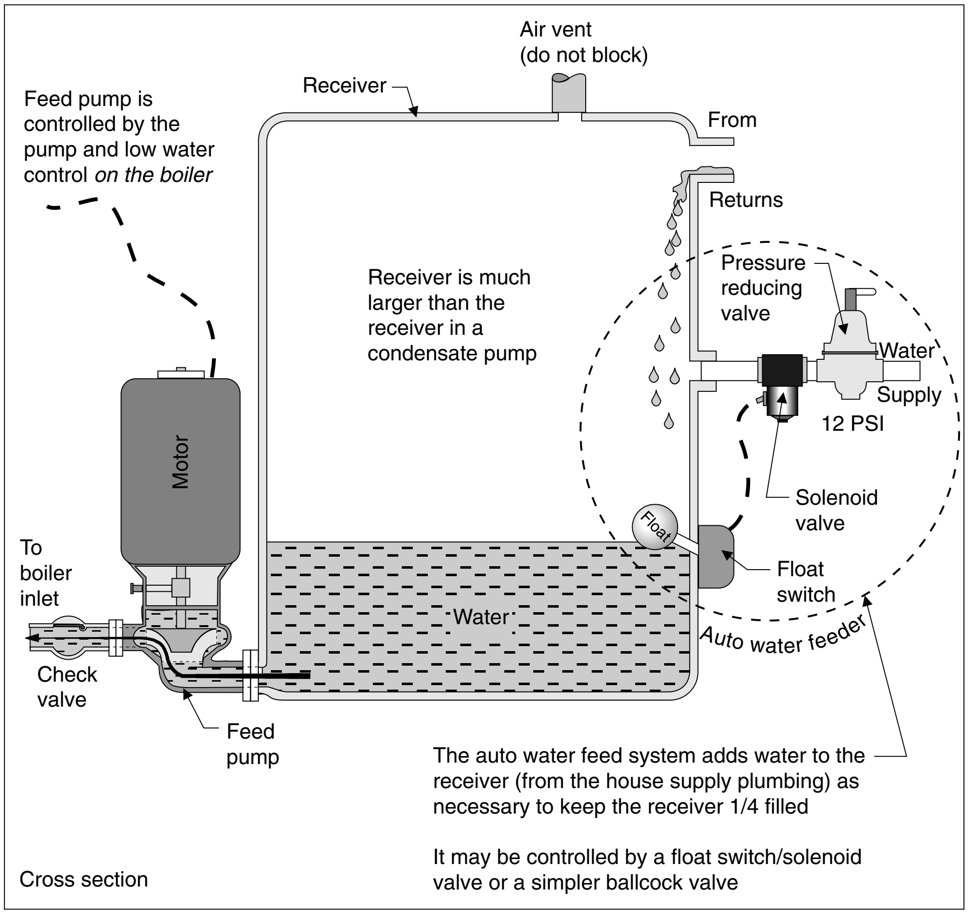


FIGURE 1.18 Boiler Feed Pump



1.8 STEAM CONTROLS: KEEPING IT SAFE

Safety Controls

We have touched on some of the safety devices for steam, but let's list them again. The things we have to keep the system safe include—

1. a low water cutout
2. a pressure relief valve
3. a steam pressure limit switch (pressuretrol)
4. a Hartford Loop and equalizer

Let's look at the role each one of these plays.

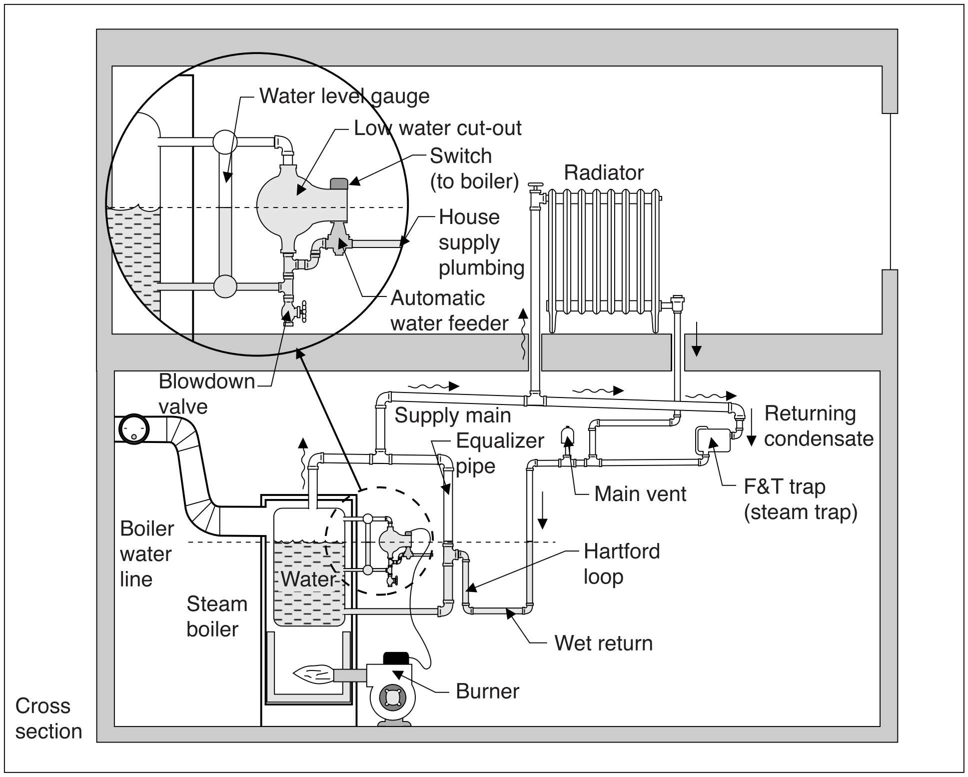
1.8.1 Low Water Cutout

Blowdown Valve

This one is fairly obvious. It shuts off the burner in the event that the water level in the boiler drops too low. It can be mounted inside or outside the boiler.

Externally mounted low water cutouts typically have a **blowdown (blowoff) valve** that allows them to be tested. Some manufacturers recommend monthly testing. In practice, they are rarely tested that frequently.

FIGURE 1.19 Location of Low Water Cut-Out



Low water cutouts can be incorporated with water level gauges and automatic water feeders. They are typically mounted on the side of the boiler, near the top (Figure 1.19).

1.8.2 Pressure Relief Valve

The pressure relief valve is typically set at 15 psi. It senses the steam pressure at the top of the boiler and discharges steam to relieve pressure if it exceeds this setting (Figure 1.20).

1.8.3 Steam Pressure Limit Switch (Pressuretrol)

Pressuretrol

This is both an operating device and a safety device in the sense that it triggers the burner when the thermostat is calling for heat and when the steam pressure is low, and cuts the burner out when the pressure is high (Figure 1.21). The pressuretrol might be set for a cut-in of $^1/_2$ psi and cutout of two psi. It is the first device which should shut off the burner with rising steam pressure. The pressure relief valve, set at 15 psi, is the second level safety device.

1.8.4 The Hartford Loop and Equalizer

The Hartford Loop and equalizer prevent water level in the boiler from dropping as a result of a leak in a wet return or a pressure imbalance between the supply and

FIGURE 1.20 Pressure Relief Valve

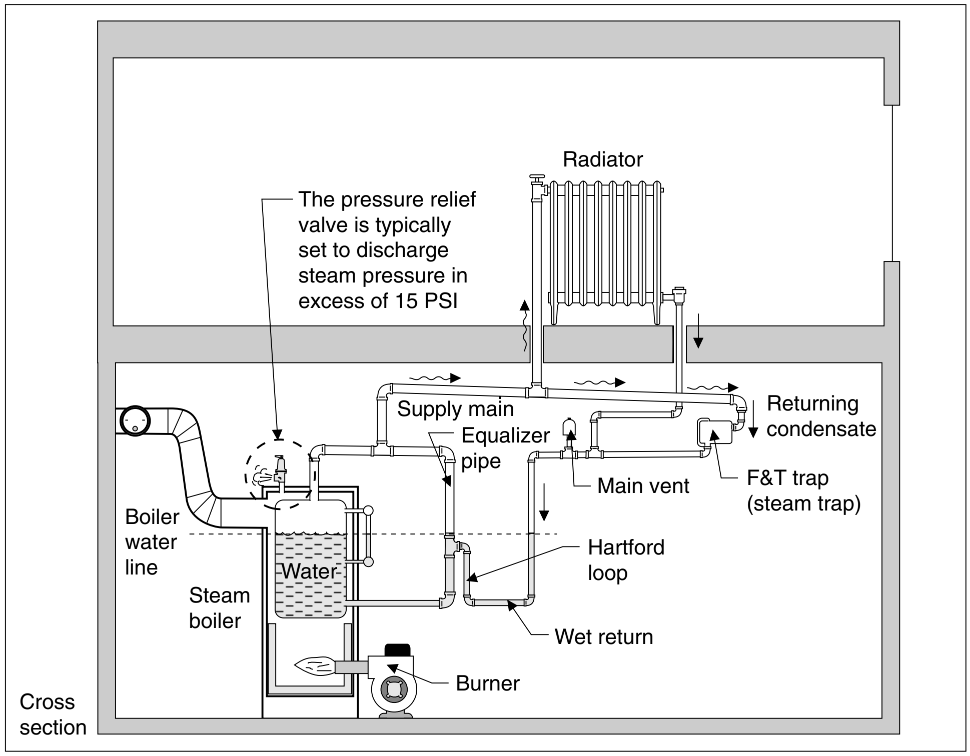


FIGURE 1.21 Location of Pressuretrol

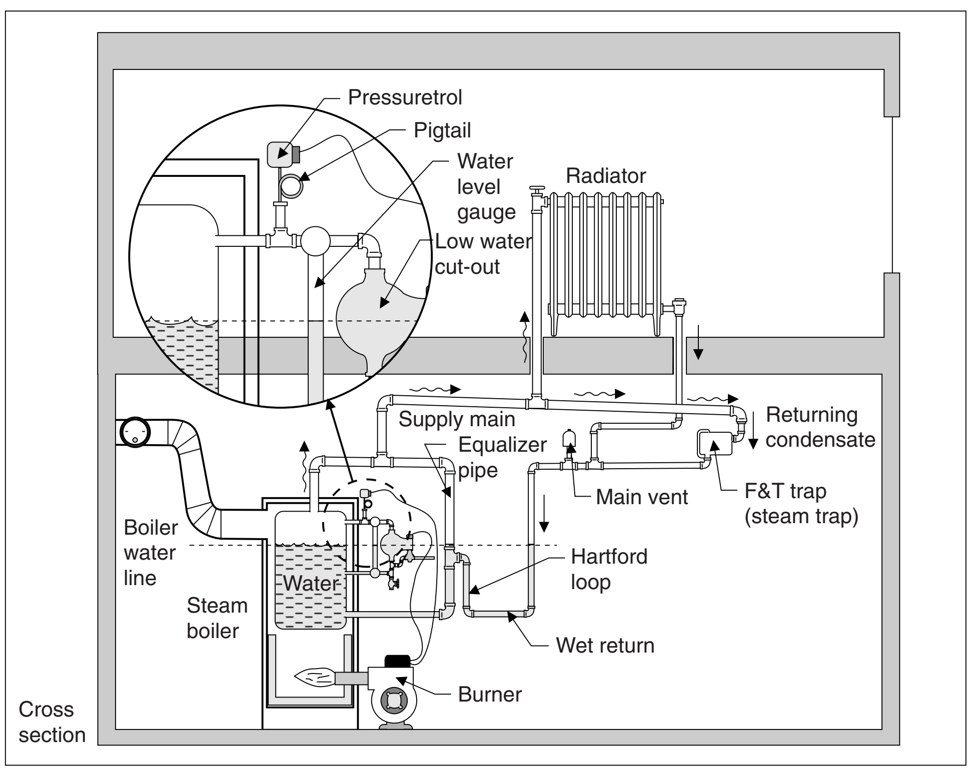
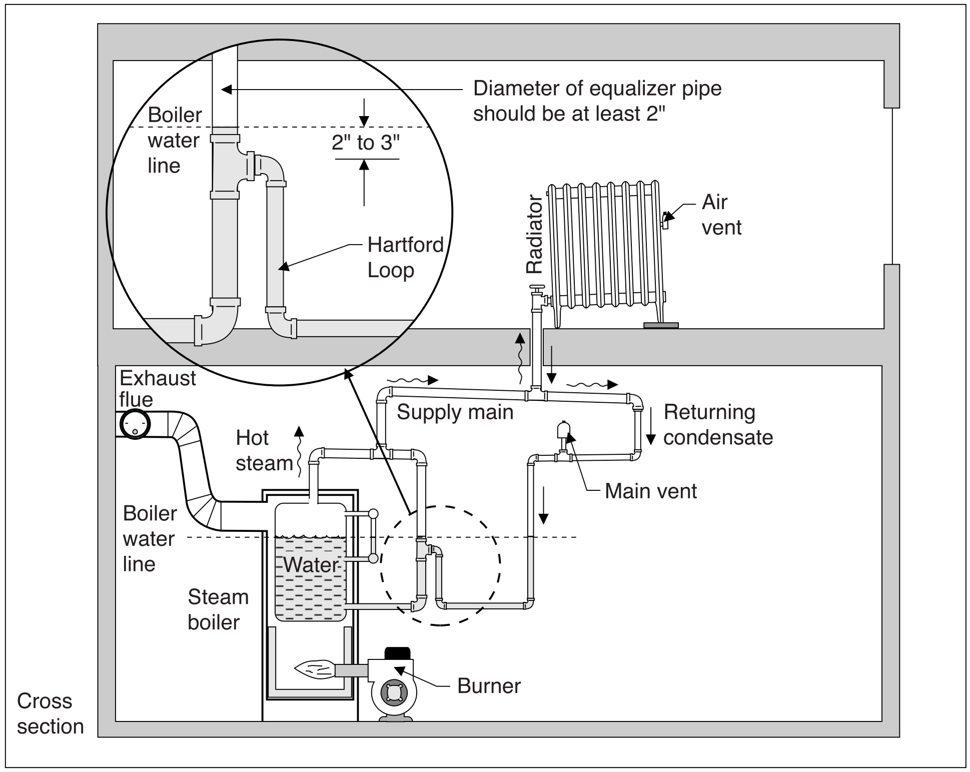


FIGURE 1.22 Hartford Loop and Equalizer—Details



return piping side of the boiler. The Hartford Loop is somewhat redundant to the low water cutout, but is still recommended and required in many jurisdictions (Figure 1.22).

CHAPTER REVIEW QUESTIONS

Answer the following questions on a separate sheet of paper, then check your results against the answers provided in Appendix E. If you have trouble with a question, refer back to the chapter to review the relevant material.

1. What is one way that steam is simpler than hot water?

2. What is one way that steam is more complex than hot water?

3. One pipe steam systems can easily be converted to hot water systems.

True False

4. Operating temperatures in a steam boiler are higher than in a hot water heater.

True False

5. Water hammer is more likely to occur in a hot water heating system than a steam heating system.

True False

6. What is the purpose of pigtails on connections to steam pressure gauges and pressuretrols?

7. What are the typical steam pressures in a residential steam system?

8. How fast does the steam move through the pipes?
9. When a steam boiler is cold it should be completely filled with water.

   True False
10. As steam develops in a boiler, the water level in the ______ tends to rise.
11. In many steam heating systems, the water level gets back to the boiler via gravity.

    True False
12. What is the function of an equalizer pipe?
13. What is the function of a Hartford Loop?
14. Briefly describe the difference between a one pipe counter flow system and a parallel flow system.
15. Are steam traps used on a one pipe system?

    Yes No
16. Are air vents found on the radiators in a two pipe system?

    Yes No
17. Are air vents found on the piping systems in both one and two pipe systems?

    Yes No
18. What makes a condensate pump start?
19. What makes a boiler feed pump start?
20. Why is there a check valve on the discharge side of a pump?
21. What is the function of a low water cutout?
22. What is a blowdown valve?
23. What is a pressure relief valve?
24. Describe the cut-in and cutout on a pressure limit switch or pressuretrol.
25. The Hartford Loop is arguably redundant to the:
26. Do all steam boilers have condensate pumps or boiler feed pumps?

    Yes No

KEY TERMS

boiler
steam
latent heat of vaporization
water hammer
condensate
low water cutout
air vent
steam traps
thermostatic traps
float and thermostatic traps
Hartford loops
equalizers
wet return
dry return
one pipe counter flow system
one pipe parallel flow system
condensate pump
boiler feed pump
low water cutout
pressure relief valve
pressure limit switch
Equalizer