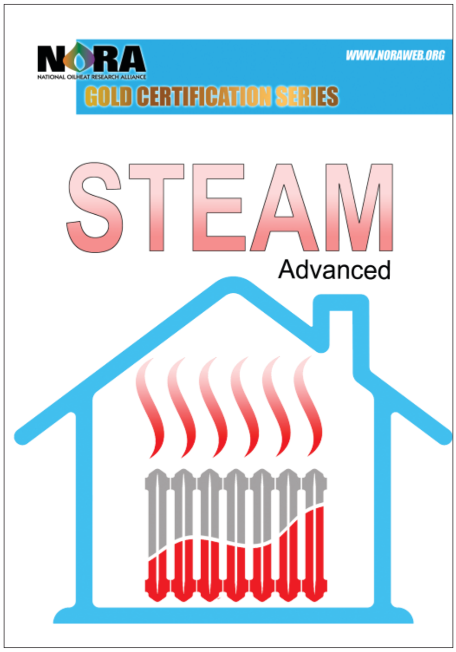
NATIONAL OILHEAT RESEARCH ALLIANCE

WWW.NORAWEB.ORG

GOLD CERTIFICATION SERIES

STEAM

Advanced



This publication is designed to serve as a training guide and to be used in conjunction with a course taught by a qualified instructor.

The reader should use local codes and equipment manufacturer's specifications and instructions in setting up and maintaining equipment.

The editors have attempted to present accurate information, however, NORA does not make any representations or guarantees and does not assume or accept any responsibility or liability with respect thereto.

By:
By Rich Michael, PB Heat Peerless Boilers

Layout:
Sue Carver

Published by:
National Oilheat Research Alliance
600 Cameron St, Alexandria, VA 22314
NORAweb.org

10.18

Introduction

Take a moment to think about the flowing three statements:

• The components of warm air systems control the flow of air.

• The components of hot water systems control the flow of water.

• The components of steam systems control the flow of steam.

They each make sense, right? The sound like “no brainers,” don’t they?

But are they accurate?

In the case of steam heat the statement is, at best, incomplete. For a steam system to operate properly, the components must control the flow of steam, water and air.

Of course, the components control the flow of steam to the heat emitters, but as that steam moves through the piping two things need to happen:

1.Air must be pushed out of the way and eliminated from the system.

2. As the steam condenses and becomes water it has to be captured and returned to the boiler.

Then, after the unit shuts off, air must be pulled back in to the system.

If the movement of the steam, water or air is interrupted the system will not operate properly.

In this publication you’ll learn about the various types of steam heating systems; the components of steam heating systems and how each affects system performance; the proper piping of steam systems; troubleshooting tips and other information that will help you to understand and service your customer’s steam heating systems.

The following publications are recommended for those who wish to learn more about steam heating systems:

• *Residential Hydronic Heating Installation & Design (I=B=R) Guide RHH*, available from the Air Conditioning and Refrigeration Institute, **www.acca.org/store**

• Any (or all) of Dan Holohan’s books on steam, especially the “*Lost Art*’ series, available at **www.heatinghelp.com/store/**

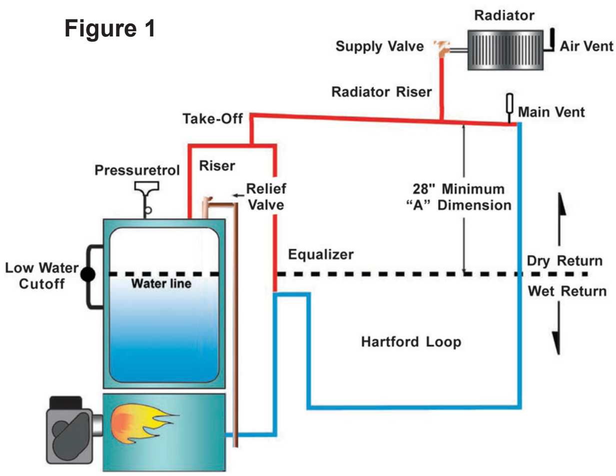
Chapter 1

Steam System Components

A steam heating system is made up of components that work together to provide and maintain comfortable temperature in a structure.

A typical one pipe steam heating system is shown in **Figure 1**.

Figure 1



Boiler – the boiler/burner combination is used to heat water that is converted to steam and distributed through piping connected to a variety of heat emitters.

Boiler nameplates contain a significant amount of information, a typical steam boiler nameplate is shown in **Figure 2**.

Input – this tells us the burner capacity, or firing rate. In this case the boiler is rated for 7.5 gallons per hour. It's important to note that this is NOT the nozzle size. To determine nozzle size fuel unit pressure must be considered.

For example, if the pressure is 100 psi, then a 7.50 gph nozzle is correct, however if the pressure is 145 psi, a 6.25 gph nozzle is correct.

Gross Output (also referred to as "DOE Capacity"). This shows that this unit is rated by the US Department of Energy at 868,000 BTU's per hour when fired at the specified burner capacity.

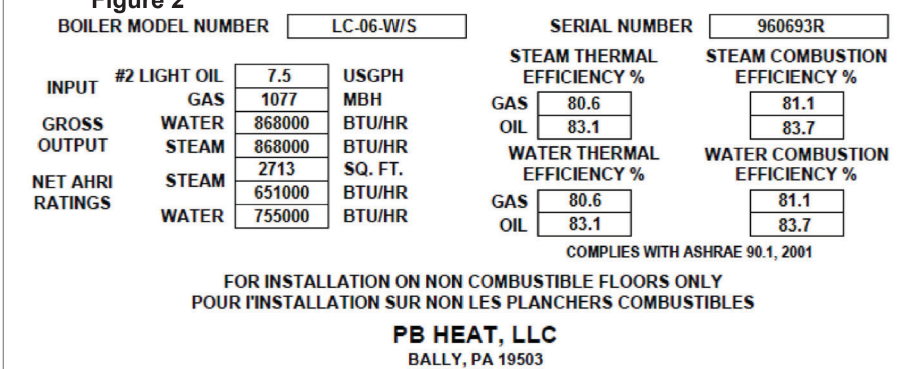
Net AHRI Rating (formerly I=B=R). This is the rating that is used to select a properly sized boiler based on the heat load calculation that is performed prior to installation. This boiler is rated for 651,000 BTUH or 2,713 SQ. FT. STEAM.

Pressure Relief Valve - the pressure relief valve protects the system from over pressurization. If the pressure rises to the systems maximum operating pressure, the relief valve is designed to open and release steam/water from the system.

Most residential steam systems are equipped with relief valves that open at 15 PSI, but may actually release and weep around 13 psi.

The relief valve MUST be properly sized, the rating MUST meet or exceed the boiler's DOE heating capacity rating. **Figure 3**.

Figure 2



Relief valve rating

Figure 3

in.	*mm*	ASME STEAM Discharge Capacity lbs./hr. @ *15psi*
¾ x ¾	20 x 20	450
1 x 1	25 x 25	643
1¼ x 1½	32 x 40	1230
1½ x 2	40 x 50	1860

This is somewhat complicated because steam boilers are rated in B.T.U./HR and relief valves are typically rated in LBS/HR. The conversion factor is 970 BTU/HR = 1 LB/HR.

A boiler rated at 868,000 BTU/HR will need a relief valve rated at 895LBS/HR

868,000÷970 = 895 LBS/HR

Low water cut-off (LWCO) - LWCO's protect boilers against damage, are required on all steam boilers and are installed at, or above, the boilers minimum safe water level.

There are two common types of steam LWCO's, float type and electronic probe type.

The float type has a device inside, similar to a toilet tank float, that moves up and down as the boiler's water level changes. If the water level gets too low, the LWCO activates a switch that cuts power to the burner.

The electronic probe type utilizes an electronic probe. When water is in contact with the probe, it completes a circuit between the probe tip and the boiler surface. If the water level drops below the probe, the circuit opens and shuts off power to the burner.

Electric water feeder - a LWCO can be connected to an optional electric water feeder. When the water level drops to an unsafe level, the LWCO sends a feed signal to the water feeder. The feeder then waits for a period of time to allow condensate to return to boiler. If make-up water is required after the delay period, the feeder opens and allows water to enter the system.

Boiler feed valve – This is typically a hand valve that is opened manually to add water to the system. Once the system is filled the valve is turned off. When an electric water feeder is piped in to the system, the manual feed valve is piped in as a bypass.

Backflow preventer - These devices are installed on boiler feed lines to prevent contaminants in the heating system from flowing back into the potable water supply.

Pressuretrol – A line voltage limit control that controls steam pressure in the boiler by starting and stopping the burner based on the pressure in the boiler. Pressuretrols must be installed above the boiler's water level and a pigtail (siphon) must be installed between the boiler and the control.

There are two common types of pressuretrols in the field, additive and subtractive:

An **additive pressuretrol** (AKA "Cut-in) has 2 adjustments, "cut-in" and "differential." The cut-in setting is the pressure at which the control's contacts will close, sending power to the burner.

The differential setting is adjusted to the amount of pressure OVER the cut-in at which power to the burner will be cut.

For example, if the cut in pressure is set at ½ psi and the differential is set to 1 psi, the pressuretrol will send power to the burner when the pressure is ½ psi and cut power to the burner at 1.5 psi.

Typically, gravity return systems should cut-in at about ½ psi and pumped return systems should cut in at about 1 psi.

A **subtractive pressuretrol** (AKA "Cut-out") also has 2 adjustments, "cut-out" and "differential." The cut-out setting is the pressure at which the control's contacts will open, removing power to the burner.

The differential setting is adjusted to the amount of pressure UNDER the cut-out at which power will be sent to the burner.

For example, if the cut out pressure is set at 1.5 psi and the differential is set to 1 psi, the pressuretrol will send power to the burner when the pressure is ½ psi and cut power to the burner at 1.5 psi.

Typically, gravity return systems should cut-out at about 1 psi and pumped return systems should cut out at about 2 psi.

> In most situations, it's best to operate residential steam systems at the lowest possible pressure, 2 psi or less.

Steam Pressure Gauge - A steam pressure gauge is used to display the amount of steam pressure in the boiler or system.

Supply Riser - Vertical piping that carries steam under pressure from the boiler up to the supply header.

Supply Header – the distribution piping from the boiler to the supply main(s)

Boiler-Header Drip Connection (Equalizer) - Piping from the supply header to the return that equalizes pressure between the two.

Supply Main - Piping that carries steam from the supply header to heat emitters and, in a one-pipe system, condensate from heat emitters to the return main. For this type of system the supply main piping is pitched away from the boiler at a minimum of ¼" per foot.

Riser – piping that carries steam up from supply main to heat emitters.

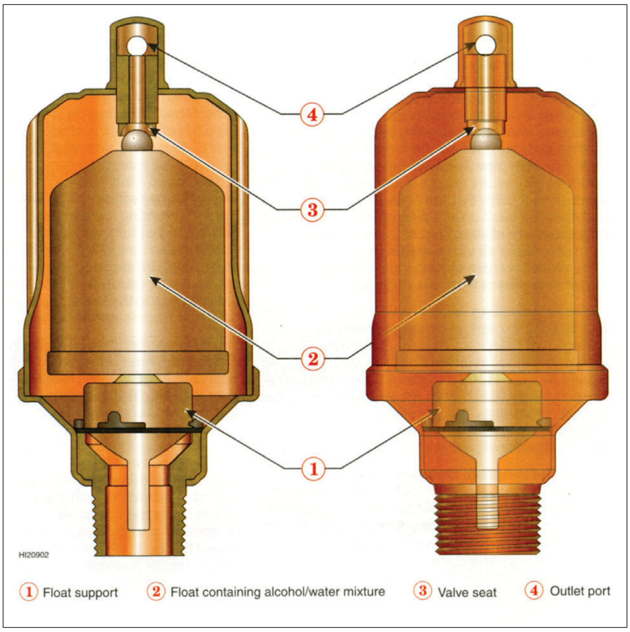
Main Steam Vents (AKA "Quick Vents") – Allow air to quickly escape from one pipe systems piping during the heating cycle, and enter back into the system after the call for heat ends. **Figure 4**.

To operate properly the vent should be installed as shown in figure on opposite page, **Figure 5**.

Main vents are rated by system size – small, medium and large. Small vents are designed for systems under 70,000 Btus.

However, in general it's best to install the largest main vent available because the quicker the air is vented from the main the better the system will perform.

Figure 4



Types of Heat Emitters (aka terminal units)

Typical stream heating systems deliver heat by convection. They circulate steam through heat emitters, warming the air around them. As the air is heated, it expands, becomes less dense and rises. As the warm air rises, the colder air it displaces falls, creating heat convection currents. These convective currents don't require a mechanical means to move the air.

Heat Emitters/Terminal Units – Steam systems can have many types of radiation to provide heat throughout a structure, including baseboard, convectors, radiators….

Heat emitters receive heat from the steam circulating through the piping and deliver it to the areas where they are installed.

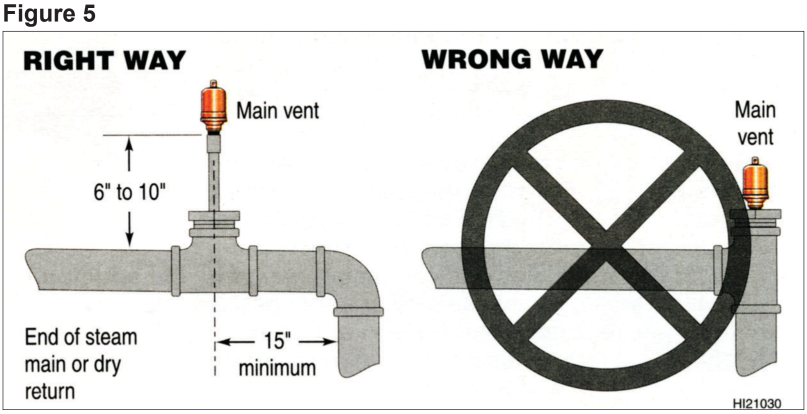
It is always good practice to check the manufacturers rating chart for the square foot of steam that is required for each heat emitter.

Baseboard Heating

Finned-tube baseboard and cast-iron baseboards use convection to circulate heat. Cooler air at the floor level enters the bottom of the baseboard and because of the heated material in the baseboards, heat is transferred to the air which then moves up the wall.

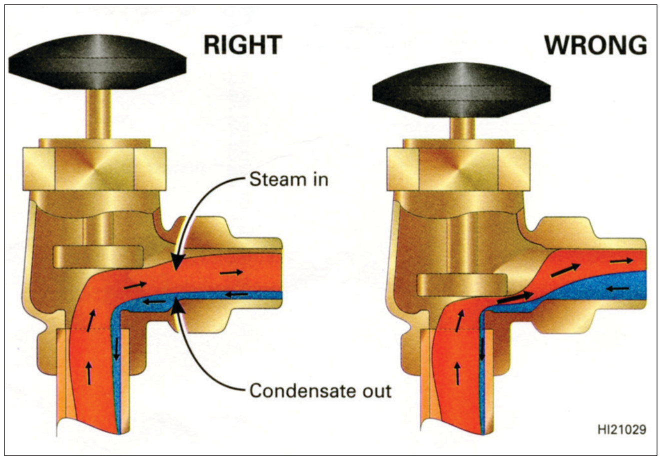
Baseboard location is usually along outside walls to help these convective currents and to remove the feeling of a cold wall or window. Steam finned- tube baseboard features steel tubing with fins attached. Manufacturers have different types, sizes and numbers of fins per inch.

Figure 5



Finned-tube baseboard heats up rapidly and dissipates its heat quickly. Surface temperatures of the units are not an issue as they are protected with covers. This system works well when there is enough clearance to create convective currents. Cool air enters the bottom and

Figure 6



the heated air comes out the top front grates. Furniture placement in front and proper space under the cabinet are critical for the finned-tube baseboard to work properly.

Cast iron baseboard heats up slowly and cools off slowly. Surface temperatures are high and there are no protective enclosures. Cast iron baseboard also provides radiant heating because the large mass of iron stays hot even after the burner shuts off, and slowly releases energy into the space.

Radiators
Cast iron radiators deliver heat in a way that is similar to cast iron baseboard; they heat up slowly and cool off slowly, but surface temperatures are high and there are no protective enclosures.

Flat Panel Radiators
Flat panel radiators are a cross between finned-tube baseboard and radiators. There is not as much mass as a radiator and also fewer fins on the back side. These are typically steel and manufactured to a variety of lengths and heights. The steel mass adds to the radiant energy into the room and the fins help create convective currents.

Fan Coils
Fan coils are small convectors with fins installed in ductwork. The steam enters the fan coils and air is circulated in the home by the unit's own fan blowing across the fins.

Steam Radiator Valves (Supply valves)

With a one-pipe steam system, supply valves are located at the heat emitter's bottom connection. They control the admission of steam, and out-flow of condensate.

In a one-pipe system, the supply valve should always be fully open or tightly closed, since a partially open valve obstructs the free flow of steam in and condensate out. **Figure 6**.

With a two pipe system, supply valves are located at the heat emitter's top connection. These valves can be throttled to regulate the heating rate.

Steam Radiator Vents - The radiator air vent or air valve (AKA steam vent or steam valve) is found on the opposite side of the heat emitter from the supply valve. The vent allows air to pass out as steam enters the emitter, closes against the passage of steam and opens at the end of the heating cycle to allow air back in.

Radiator vents are available in fixed and adjustable types. A fixed vent releases air at a fixed rate and a variable vent can be adjusted to release air at different rates.

In general, small heat emitters use smaller (slower) vents and large heat emitters use larger (faster) vents.

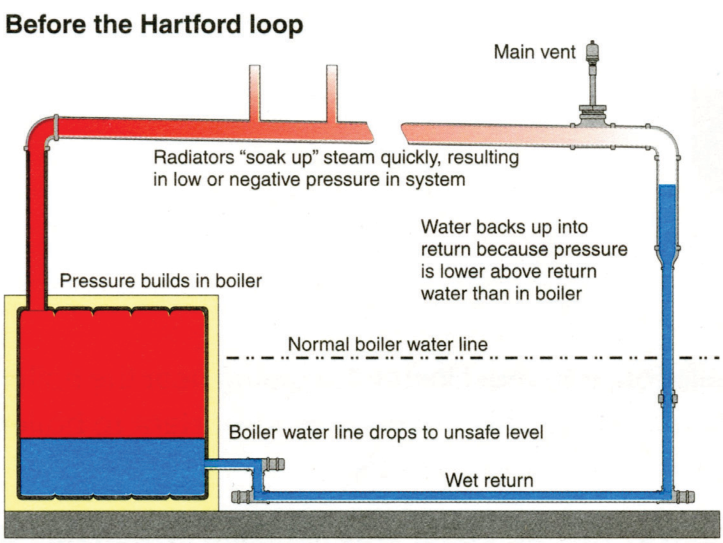
Thermostatic radiator valves (TRV) are available that, in conjunction with a standard vent, enable each heat emitter to be individually controlled. TRVs control the flow of steam into the heat emitter by sensing the temperature of room and opening or closing as required.

Wet return - The portion of the return piping that is filled with water.

Dry return - The portion of the return piping that is not filled with water.

"A" dimension – To allow condensate to return to the boiler, the lowest steam carrying pipe MUST be at least 28" above the boiler's normal water line for most systems. Counter-flow systems and boilers with a false water line piping arrangement installed do not require a 28" A dimension.

Hartford Loop – The Hartford loop prevents physical damage and personal injury by preventing water from being pushed out of the boiler and up the return piping. It also prevents a low water condition if the return piping develops a leak. **Figure 7**.



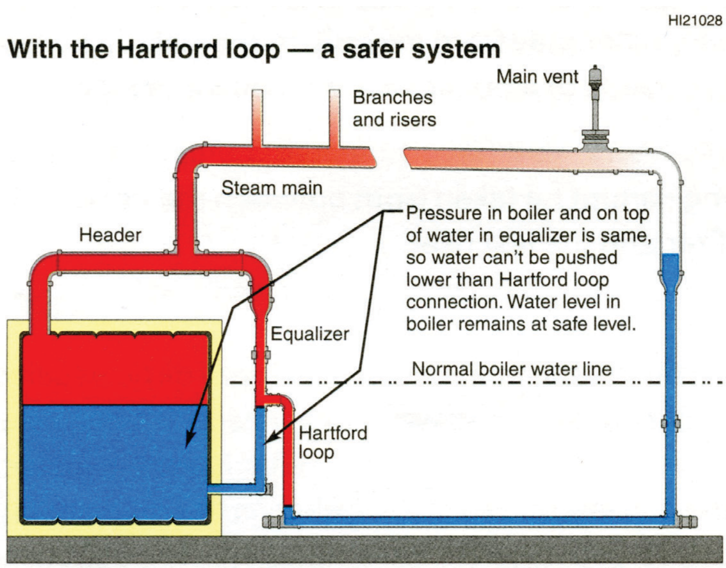


Figure 7

Chapter 2

Gravity Return Systems

There are several types of gravity return systems in the field, it is imperative that all piping and valves be sized and installed per manufacturer's instructions.

One-Pipe Parallel System with Wet Return

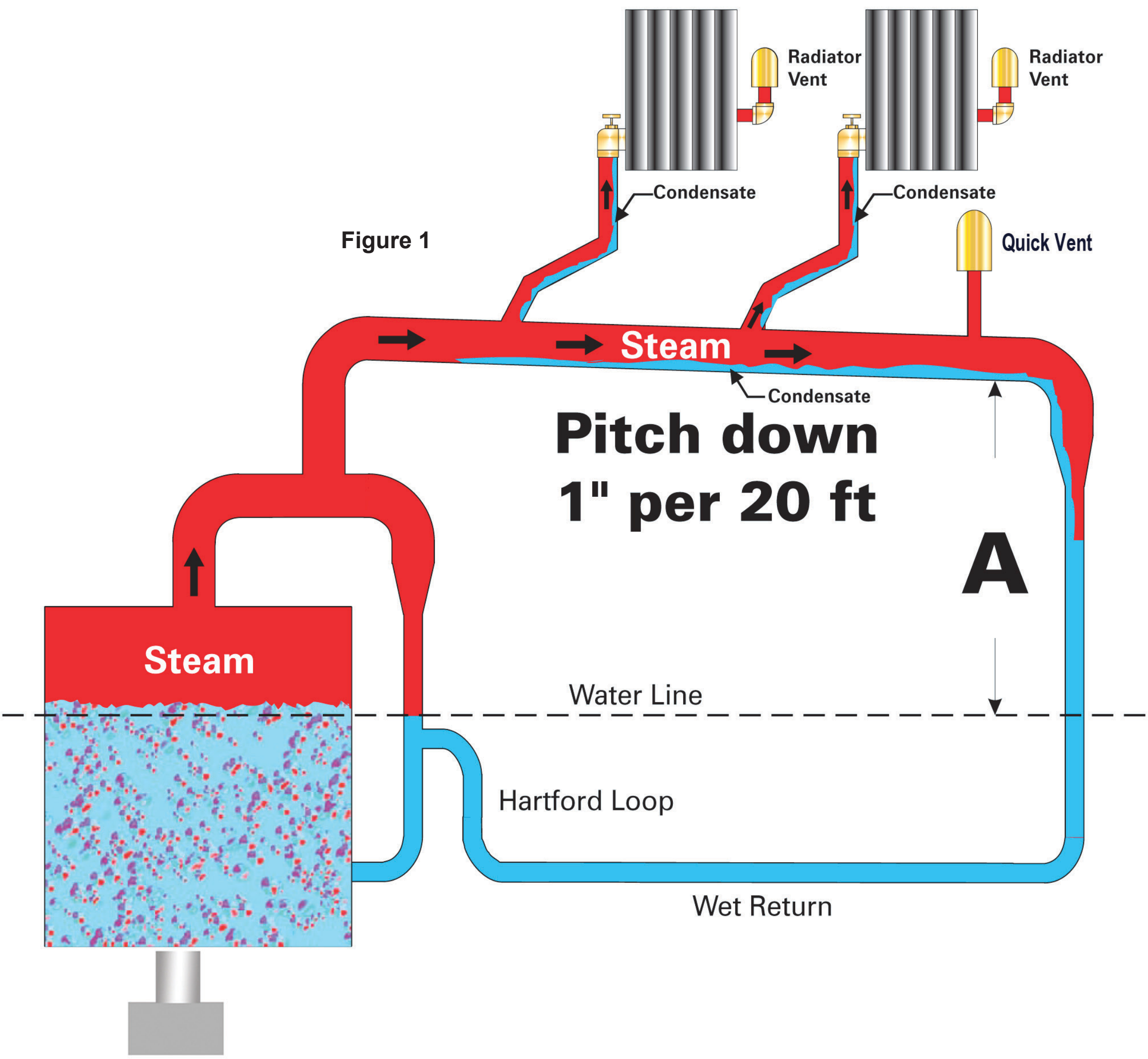


Figure 1

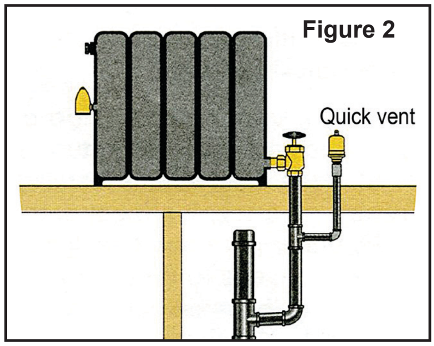
One Pipe Systems

In a one pipe gravity system both steam and condensate travel in the supply main. **Figure 1**

1. One Pipe Parallel upfeed gravity return system with wet return.

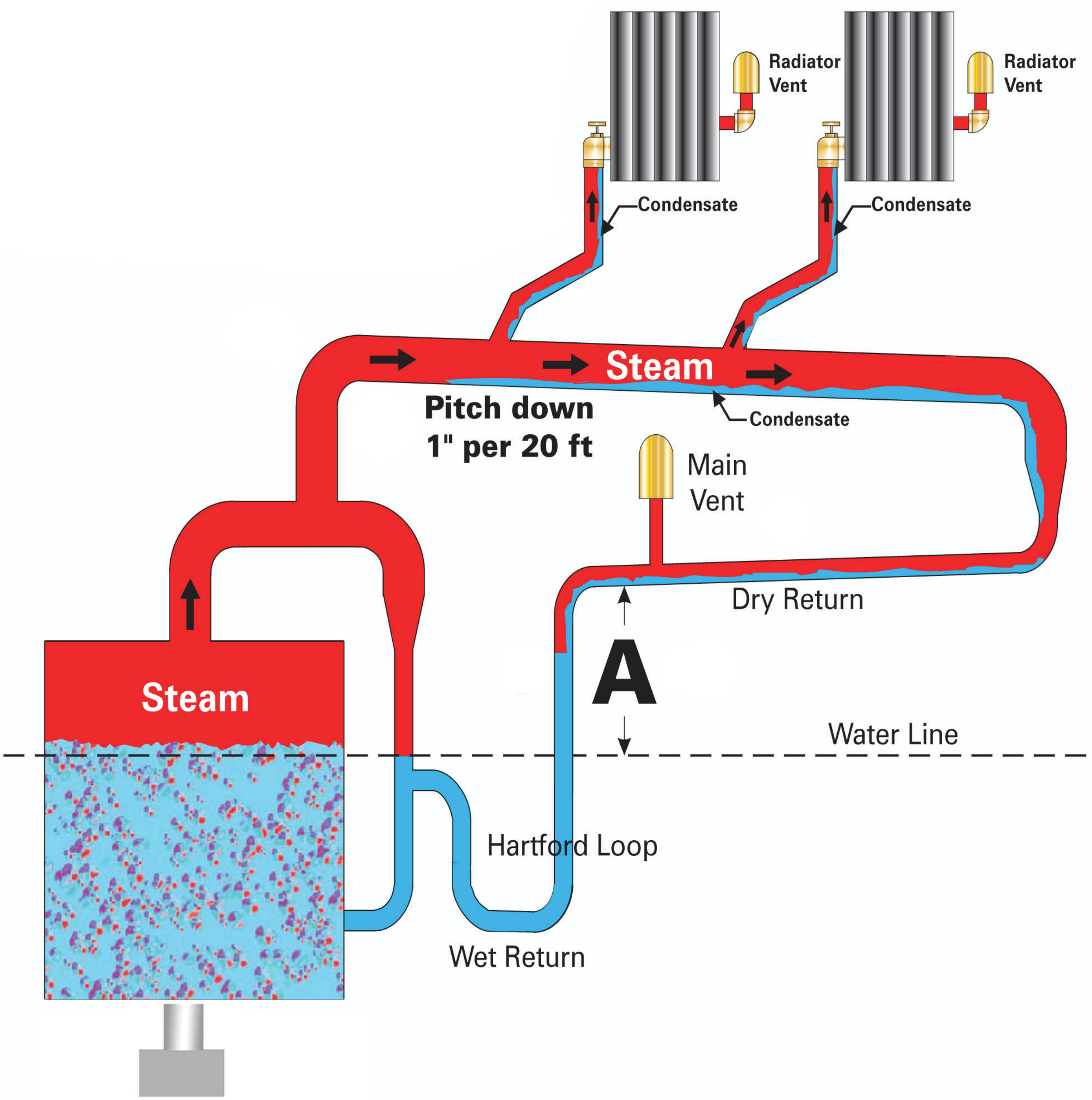
- The supply main on these systems must maintain a *minimum* of 1" per 20' pitch downwards towards the return. The *preferred* pitch is 1/4" per ft. Sags in the main will cause water hammer.

- With a multi-floor system, in addition to the quick vent on the supply main, additional quick vents should be installed at the top of every upfeed riser. Without these additional vents, the higher floor heat emitters can receive steam later than those on lower floors. **Figure 2.**



STEAM SUPPLY SIZING - ONE PIPE PARALLEL FLOW MAIN PITCHED MINIMUM 1/2 INCH PER 10 FEET			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
2"	386	92,640	97
2 1/2"	635	152,400	159
3"	1,163	279,120	291
4"	2,457	589,680	614
5"	4,546	1,091,040	1,137
6"	7,642	1,834,080	1,911
RADIATOR RUNOUT SIZING FOR RUNOUTS UNDER 8 FEET (ADD ONE PIPE SIZE FOR LONGER RUNOUTS)			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1"	28	6,720	7
1 1/4"	64	15,360	16
1 1/2"	64	15,360	16
2"	92	22,080	23
2 1/2"	168	40,320	42
3"	260	62,400	65
RADIATOR SUPPLY VALVES AND VERTICAL CONNECTORS			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1"	28	6,720	7
1 1/4"	64	15,360	16
1 1/2"	92	22,080	23
2"	168	40,320	42
WET RETURN SIZING			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1"	700	168,000	175
1 1/4"	1,200	288,000	300
1 1/2"	1,900	456,000	475
2"	4,000	960,000	1,000
BOILER EQUALIZER CONNECTION			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1 1/2"	900	216,000	225
2 1/2"	6,400	1,536,000	1,600

One-Pipe Parallel Upfeed Gravity Return System with Dry Return



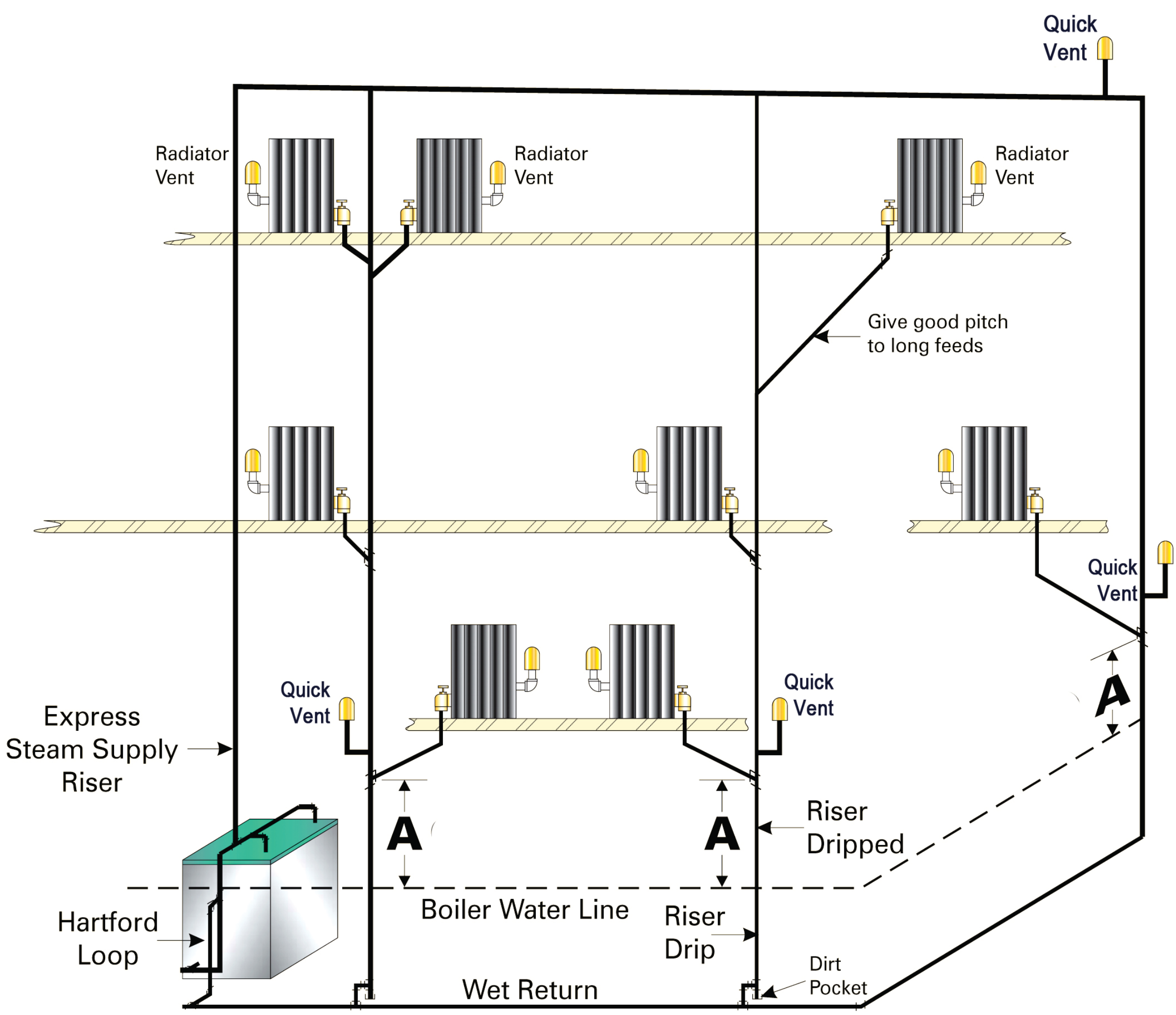
2. One Pipe Parallel upfeed gravity return system with dry return

- These systems are similar to the One Pipe system described on the previous page. The difference is that the return piping is mostly above the boiler's water line.

- The quick vent should be located near the end of the dry return.

STEAM SUPPLY SIZING - ONE PIPE PARALLEL FLOW MAIN PITCHED MINIMUM 1/2 INCH PER 10 FEET			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
2"	386	92,640	97
2 1/2"	635	152,400	159
3"	1,163	279,120	291
4"	2,457	589,680	614
5"	4,546	1,091,040	1,137
6"	7,642	1,834,080	1,911
RADIATOR RUNOUT SIZING FOR RUNOUTS UNDER 8 FEET (ADD ONE PIPE SIZE FOR LONGER RUNOUTS)			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1"	28	6,720	7
1 1/4"	64	15,360	16
1 1/2"	64	15,360	16
2"	92	22,080	23
2 1/2"	168	40,320	42
3"	260	62,400	65
RADIATOR SUPPLY VALVES AND VERTICAL CONNECTORS			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1"	28	6,720	7
1 1/4"	64	15,360	16
1 1/2"	92	22,080	23
2"	168	40,320	42
DRY RETURN SIZING			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1"	320	76,800	80
1 1/4"	672	161,280	168
1 1/2"	1,060	254,400	265
2"	2,300	552,000	575
WET RETURN SIZING			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1"	700	168,000	175
1 1/4"	1,200	288,000	300
1 1/2"	1,900	456,000	475
2"	4,000	960,000	1,000
BOILER EQUALIZER CONNECTION			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1 1/2"	900	216,000	225
2 1/2"	6,400	1,536,000	1,600

One-Pipe Parallel Downfeed Gravity Return System



3. One Pipe parallel downfeed gravity return system

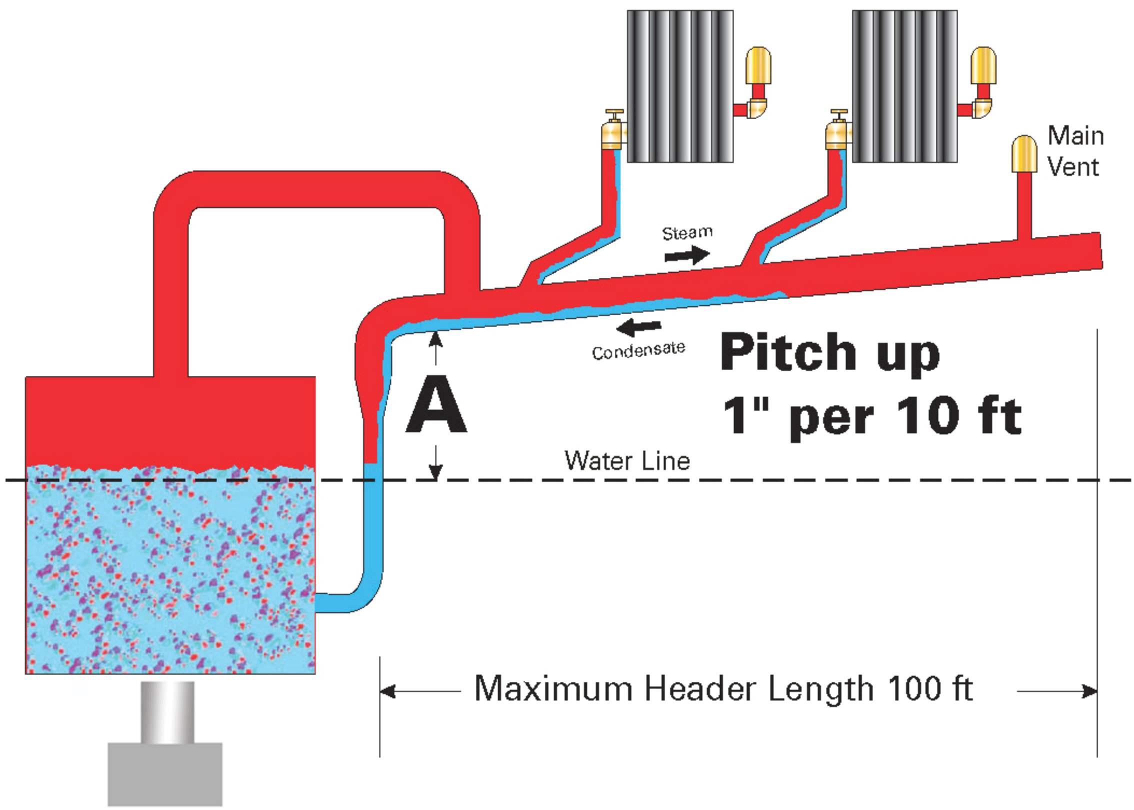
- A downfeed system features an "express riser" that brings steam to a supply main at the top of the building.

- Both steam and condensate flow downhill in the main and in the risers.

- Quick vents should be installed near the end of the supply main and near the end of each down feed riser.

STEAM SUPPLY SIZING - ONE PIPE PARALLEL FLOW MAIN PITCHED MINIMUM 1/2 INCH PER 10 FEET			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
2"	386	92,640	97
2 1/2"	635	152,400	159
3"	1,163	279,120	291
4"	2,457	589,680	614
5"	4,546	1,091,040	1,137
6"	7,642	1,834,080	1,911
EXPRESS RISER SIZING - PARALLEL DOWN FEED SYSTEM			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
2 1/2"	636	152,640	159
3"	1,128	270,720	282
3 1/2"	1,548	371,520	387
4"	2,044	490,560	511
5"	4,200	1,008,000	1,050
6"	7,200	1,728,000	1,800
8"	15,000	3,600,000	3,750
DOWN-FEED RISERS & BRANCHES TO DOWN FEED RISERS			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1"	68	16,320	17
1 1/4"	144	34,560	36
1 1/2"	224	53,760	56
2"	432	103,680	108
2 1/2"	696	167,040	174
3"	1,272	305,280	318
3 1/2"	1,848	443,520	462
4"	2,560	614,400	640
RADIATOR RUNOUT SIZING FOR RUNOUTS UNDER 8 FEET (ADD ONE PIPE SIZE FOR LONGER RUNOUTS)			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1"	28	6,720	7
1 1/4"	64	15,360	16
1 1/2"	64	15,360	16
2"	92	22,080	23
2 1/2"	168	40,320	42
3"	260	62,400	65
WET RETURN SIZING			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1"	700	168,000	175
1 1/4"	1,200	288,000	300
1 1/2"	1,900	456,000	475
2"	4,000	960,000	1,000
RADIATOR SUPPLY VALVES AND VERTICAL CONNECTORS			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1"	28	6,720	7
1 1/4"	64	15,360	16
1 1/2"	92	22,080	23
2"	168	40,320	42
BOILER EQUALIZER CONNECTION			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1 1/2"	900	216,000	225
2 1/2"	6,400	1,536,000	1,600

Counterflow System



4. Counterflow system

- With this system steam and condensate flow “counter to” (against) each other in the steam main.
- Steam MUST enter the top of the steam main to keep condensate from flowing back into the top of the boiler.
- The supply main must maintain a *minimum* of 1" per 10' pitch *upwards* towards the return to prevent condensate from causing water hammer. The *preferred* pitch is 1/4" per ft.
- A Hartford loop is NOT required because the return is above the boiler water line.
- No return riser is needed because the condensate flows back to the to the equalizer piping.
- Dimension “A” must only be 14" because there is no wet return and very little pressure drop from the boiler to the point of condensate return.

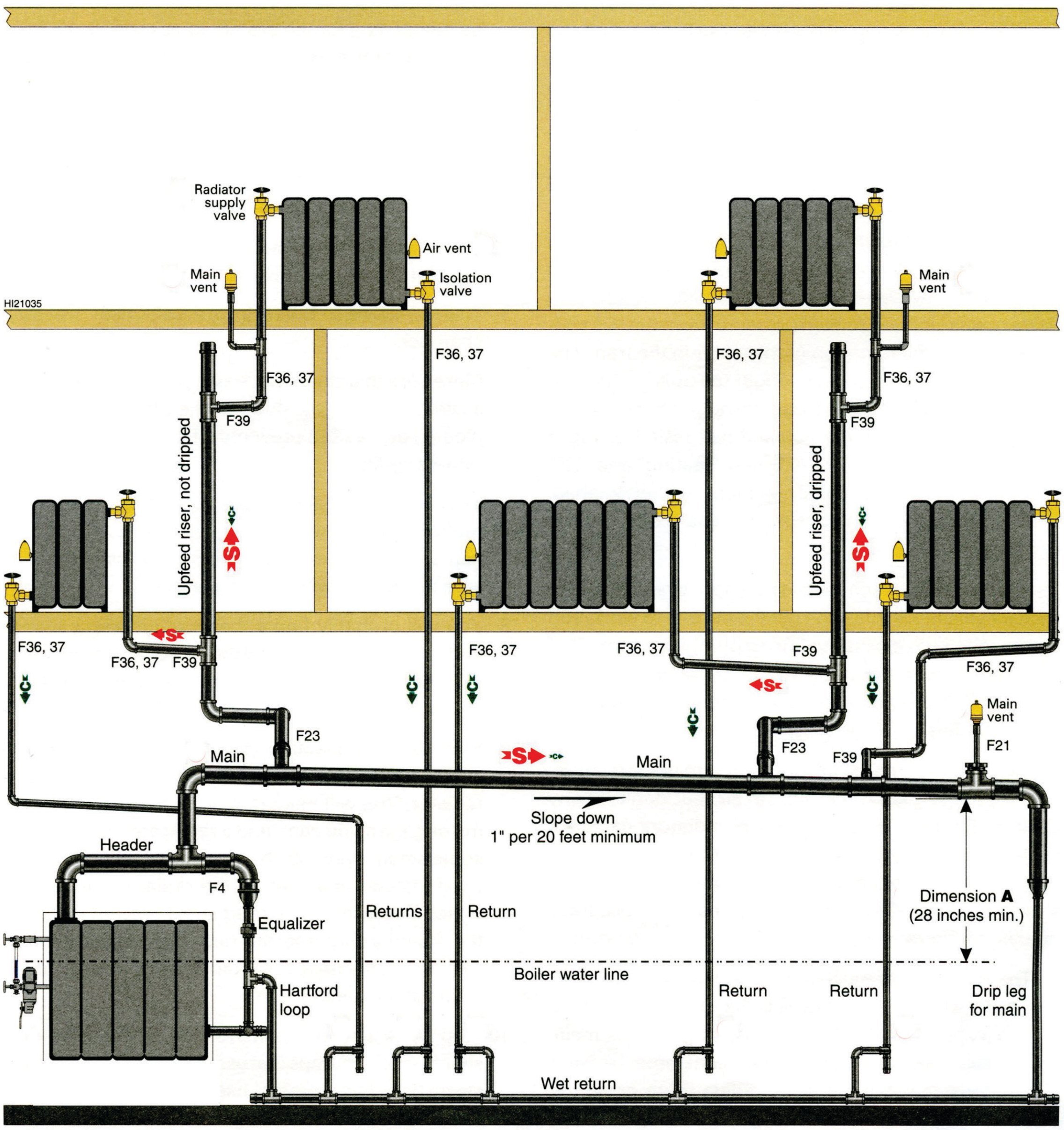
STEAM SUPPLY SIZING - ONE PIPE COUNTERFLOW MAIN PITCHED MINIMUM 1 INCH PER 10 FEET			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
2 1/2"	386	92,640	97
3"	635	152,400	159
4"	1,163	279,120	291
5"	2,457	589,680	614
6"	4,546	1,091,040	1,137
Note: Pipe capacities based on recommended increase one pipe size for counterflow one-pipe mains			

RUNOUT SIZING FOR RUNOUTS UNDER 8 FEET (ADD ONE PIPE SIZE FOR LONGER RUNOUTS)			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1"	28	6,720	7
1 1/4"	64	15,360	16
1 1/2"	64	15,360	16
2"	92	22,080	23
2 1/2"	168	40,320	42
3"	260	62,400	65

RADIATOR SUPPLY VALVES AND VERTICAL CONNECTORS			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1"	28	6,720	7
1 1/4"	64	15,360	16
1 1/2"	92	22,080	23
2"	168	40,320	42

BOILER EQUALIZER CONNECTION			
Pipe Size	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1 1/2"	900	216,000	225
2 1/2"	6,400	1,536,000	1,600

Two-Pipe Upfeed Gravity Return System



Pipe size (inches)	Steam main/Downfeed riser/Dripped horizontal runout		
	Square Ft EDR	Btu/Hr Net	Pounds/Hr
¾	36	8,640	9
1	68	16,320	17
1¼	144	34,560	36
1½	224	53,760	56
2	432	103,680	108
2½	696	167,040	174
3	1,272	305,280	318
4	2,560	614,400	640
5	4,800	1,152,000	1,200

	Upfeed or express riser		
¾	32	7,680	8
1	56	13,440	14
1¼	124	29,760	31
1½	192	46,080	48
2	388	93,120	97
2½	636	152,640	159
3	1,128	270,720	282
4	2,044	490,560	511
5	4,200	1,008,000	1,050

	Horizontal riser runout, not dripped		
¾	28	6,720	7
1	56	13,440	14
1¼	108	25,920	27
1½	168	40,320	42
2	362	86,880	91
2½	528	126,720	132
3	800	192,000	200
4	1,700	408,000	425
5	3,152	756,480	788

Pipe size (inches)	Dry return		
	Square Ft EDR	Btu/Hr Net	Pounds/Hr
1	320	76,800	80
1¼	672	161,280	168
1½	1,060	254,400	265
2	2,300	552,000	575
2½	3,800	912,000	950

	Wet return (gravity system)		
1	700	168,000	175
1¼	1,200	288,000	300
1½	1,900	456,000	475
2	4,000	960,000	1,000

	Radiator vertical piping/Radiator supply valve		
½	25	6,000	6
¾	75	18,000	19
1	150	36,000	38
1¼	200	48,000	50
1½	400	96,000	100

	Radiator vertical return piping/Radiator trap size		
½	200	48,000	50
¾	400	96,000	100
1	700	168,000	175

	Radiator horizontal return piping		
¾	400	96,000	100
1	700	168,000	175

Two Pipe Gravity Return Systems

In a two pipe gravity system steam and condensate travel in separate piping.

1. Two pipe upfeed gravity return system

- The supply main must maintain a *minimum* of 1" per 20' pitch *downwards* towards the return. Sags in the main will cause water hammer. The *preferred* pitch is 1/4" per ft.

- With a multi-floor system, in addition to the quick vent on the supply main, addtional quick vents should be installed at the top of every upfeed riser. Without these additional vents, the higher floor hear emitters can receive steam later than those on lower floors.

- Each heat emitter condensate return must terminate in the wet return, below the boiler's water line.

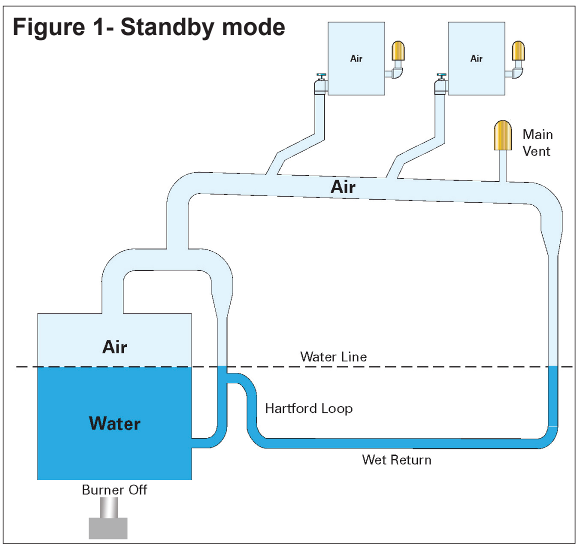
Chapter 3

How Typical One Pipe Gravity Return Steam Systems Work

Standby mode

When the system is in a standby mode the water level in the boiler is the same as in the return. The piping and heat emitters are full of air. **Figure 1**.

Figure 1- Standby mode



When the thermostat calls for heat:
Figure 2:

• the burner fires and the water in the boiler boils, creating steam.

• the boiler water level rises slightly as the steam bubbles displace water.

• the steam pressure builds as steam pushes against the air in the distribution system.

• the pressure pushes air out through the vents.

• water begins to rise in the return riser be cause flow causes a pressure drop in the pip-ing. (Pressure is lower than it is at the boiler.)

The main vent (Figure 3) quickly exhausts air from the piping and closes when steam reaches it, then:

• all branches receive steam at about the same time.

Figure 2-Thermostat calls for heat

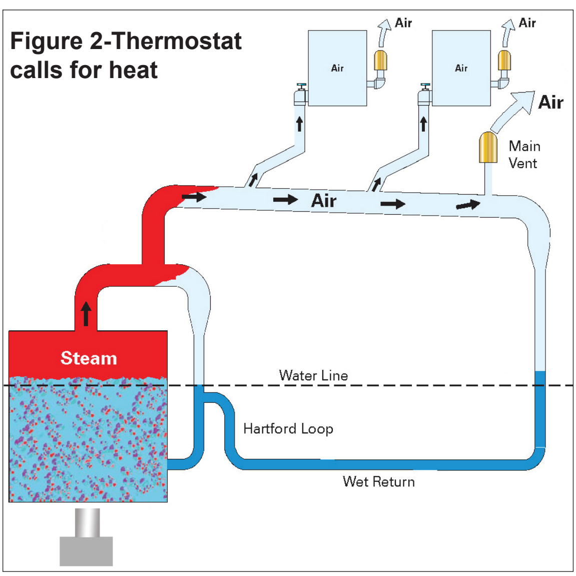
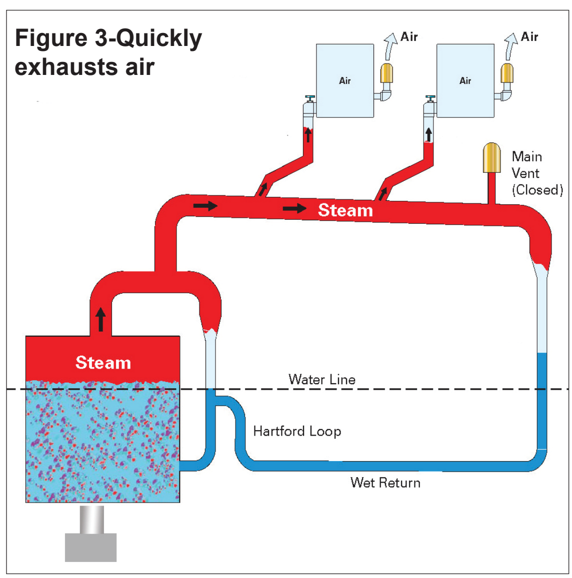


Figure 3-Quickly exhausts air



• Air is slowly exhausted through the individual heat emitter's vents.

• water rises higher in the return as the pressure drop increases.

• condensate begins to form.

Steam pushes into the heat emitters
Figure 4

• the emitters heat up and cool the steam.

• the steam begins to condense.

• condensate starts to flow back into the piping through the supply valves.

• condensate runs down the branch piping, against the flow of steam.

• the condensate load increases the pressure difference in the piping, raising the water level in the return to its highest point during the cycle.

• The water level in the boiler drops slightly because water has been "steamed off" and the condensate has not yet returned.

Steady state heating
Figure 5

• steam fills the heat emitters until it reaches the vents

• vents close when exposed to steam temperature.

• the boiler continues to fire until the thermostat is satisfied or the limit control setting is reached.

• the water level in the return drops as the start-up condensate load flows back to the boiler.

• boiler water level drops because of the condensate out in the system.

Note: the water level may drop out of the gauge glass when the boiler shuts down because the steam bubbles collapse and the condensate has not yet returned.

Figure 4-Steam pushes into heat emitters

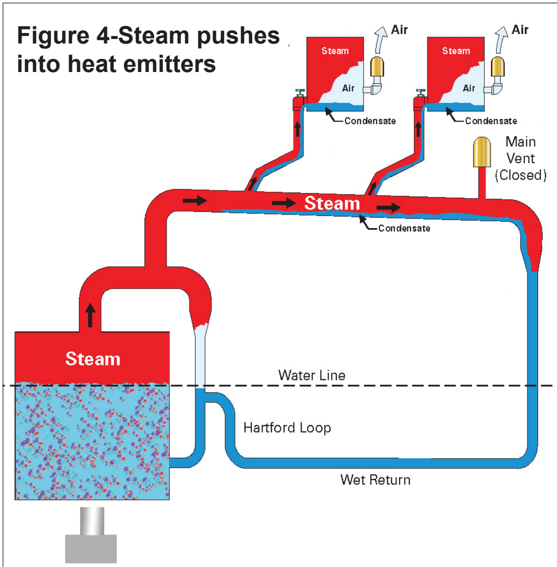
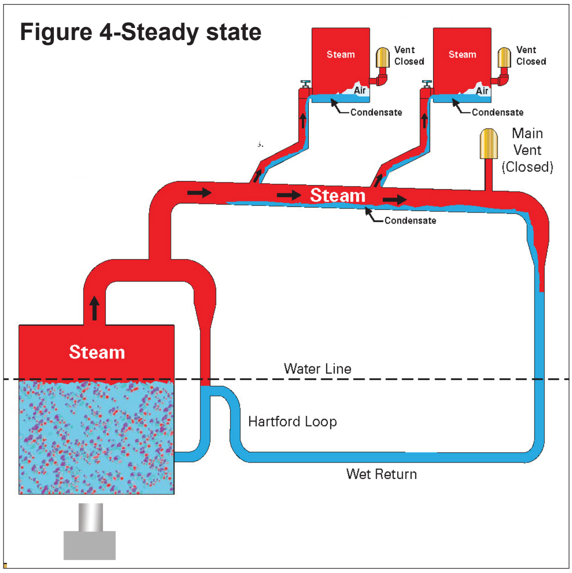


Figure 4-Steady state



Off cycle
Figure 6

- at the end of the cycle the burner shuts off.
- with no steam being supplied, the steam in the system condenses and creates a vacuum.
- the vents let air back into the system.
- the water level in the return is the same as in the boiler because there is no pressure difference in the piping.

Figure 6-Off cycle

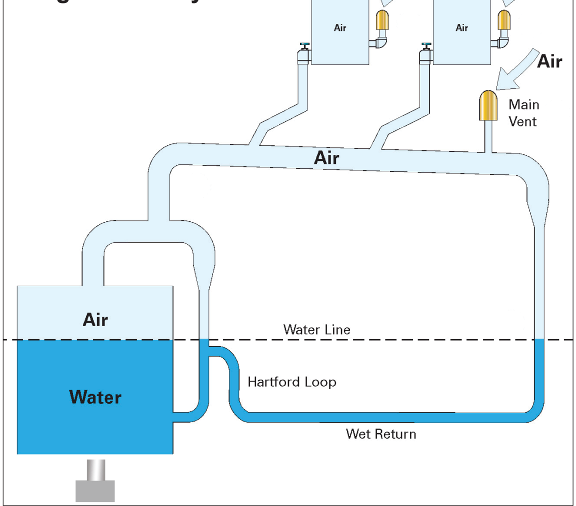


Figure 7

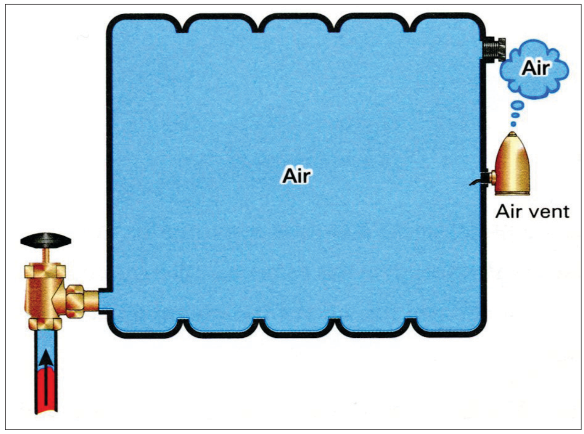
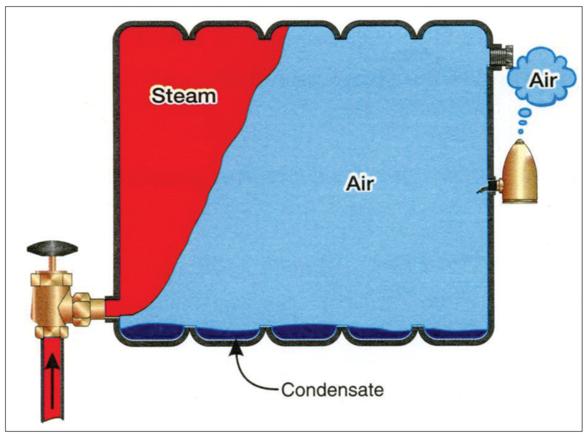


Figure 8



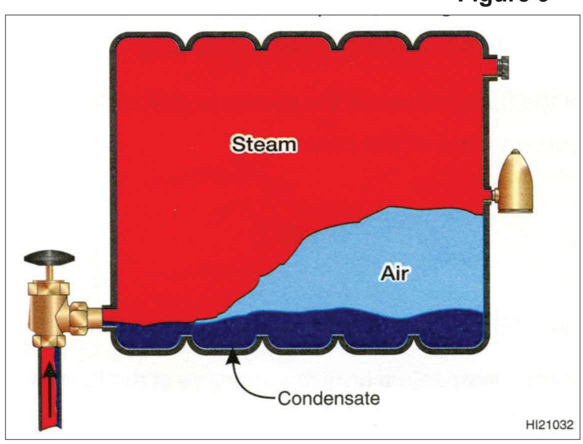
Heat Emitter operation with a typical one pipe system

Startup - Steam approaches the heat emitter and pushes air out through the vent. **Figure 7**.

Steam reaches heat emitter - Steam pushes into the heat emitter and rises to the top, air continues to be pushed out through the vent. Heat emitter starts to warm up as condensate forms and flows back through supply valve. **Figure 8**.

Steady state - Vent closes when steam reaches it, heat emitter releases heat to room and condensate flow increases. **Figure 9**.

Figure 9



Chapter 4

Pumped Return Systems

There are circumstances where a gravity return system isn't practical.

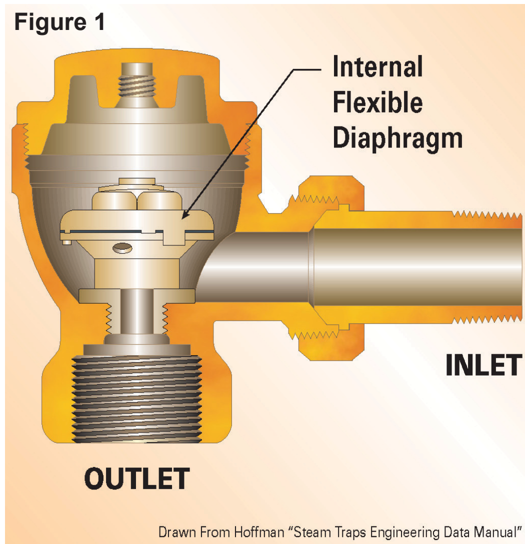
These include:

- When gravity isn't able to return the condensate due to long return pipe runs.
- When the "A" dimension is inadequate.
- When zone valves are used - when zone valves close, the boiler pressure pushes water approximately 30" up the return for every psi in the boiler. In a typical system operating at 2 PSI the return water would rise to 5' above the boiler's water level.
- When there is a long condensate return time lag.
- When a replacement boiler has a higher water level than the boiler being replaced.

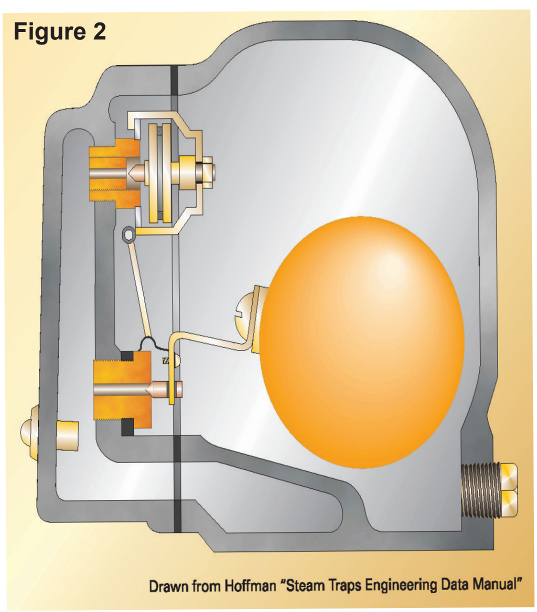
Pumped return systems have additional components not found in gravity return systems, including:

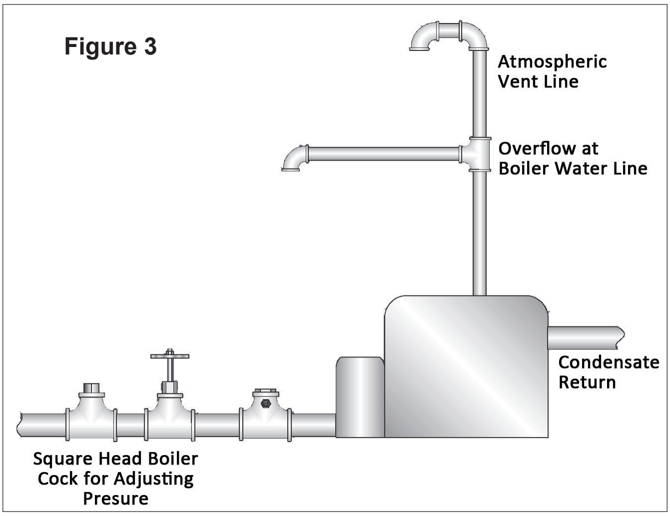
- Thermostatic traps (2 pipe systems only)
- Float & thermostatic (F&T) trap(s)
- A condensate receiver & boiler feed pump

Thermostatic traps – are typically installed on heat emitters in 2 pipe systems that don't utilize air vents. They allow air and condensate to pass, but prevent steam from passing into the return. In addition, to prevent condensate from flashing into steam in the dry return, they only allow condensate to pass through when it is at least 10°F cooler than the steam temperature. **Figure 1**.



Float & thermostatic (F & T) traps - F&T traps prevent steam from passing through, control condensate flow to a receiver and allow air to pass through to a vent in the condensate





tank. They are typically installed on riser drips, between the end of the main and the beginning of the dry return, and contain two components. **Figure 2**.

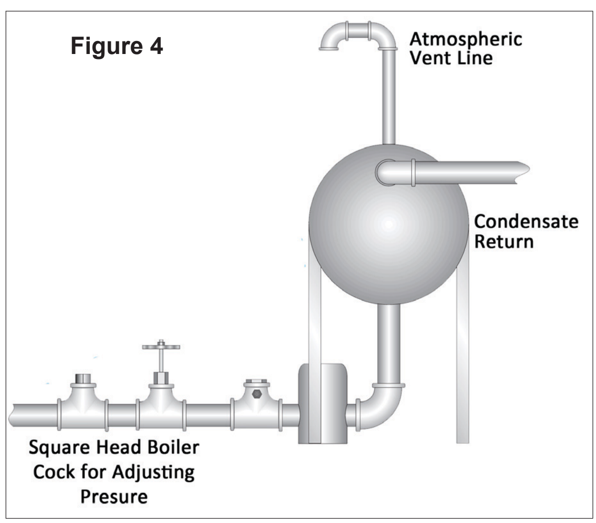
- A normally open thermostat that allows air to pass through to the condensate tank.

- A normally closed ballcock that floats when the condensate level rises, allowing condensate to pass through to the condensate tank.

Condensate receivers & boiler feed pumps– these components work together to collect condensate and pump it back into to the boiler. There are two types of pumped return units:

1) Condensate return units – these pump the condensate back to the boiler when the receiver fills with water. They must be properly sized because too large a unit will cause flooding of the boiler. They do NOT respond to the boiler's water level controller and are not effective on systems with long condensate return times. **Figure 3**.

2) Boiler feed systems – these feed water to the boiler based on a call from the boiler water level controller. They are effective on systems with long condensate return times. **Figure 4**.



One Pipe Pumped Return Systems

One pipe parallel upfeed pumped return system (Figure 5)

To convert from a one pipe gravity system to a pumped return this system had the heat emitter air vents removed, and an F&T trap, strainer, condensate receiver and pump installed.

• The F&T trap must be installed at the end of the main.

• The condensate tank/pump must be properly sized. (See Chapter 7—Sizing a Condensate Return Unit)

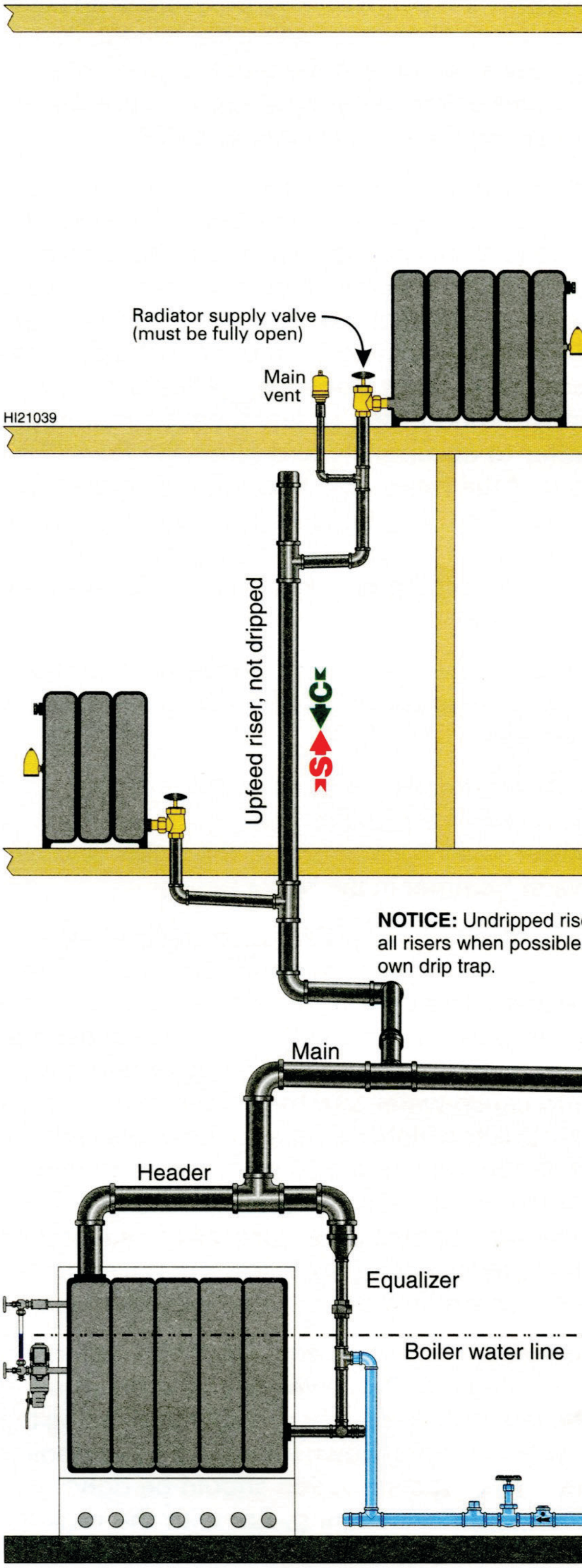
• The return piping from the trap must slope downhill to the condensate tank.

• A check valve must be installed as shown to prevent water from being pushed back to the tank.

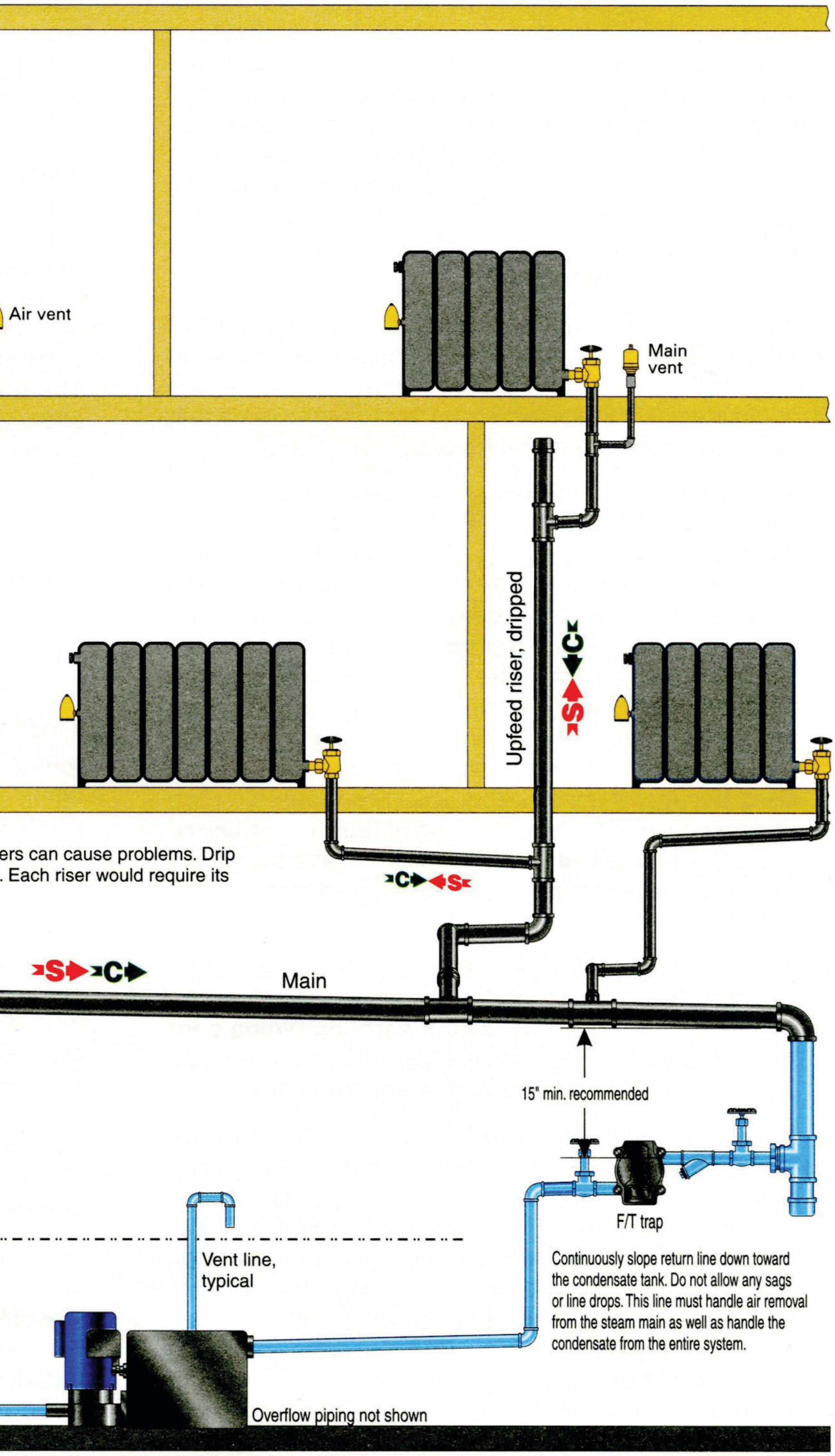
• A square head cock or a balancing valve must be installed to throttle the feed pump's flow rate to the boiler. An improper flow rate can cause water hammer and

water level fluctuations in the boiler.

• The main vent is optional (but recommended) on these systems because F&T traps allow air to escape.

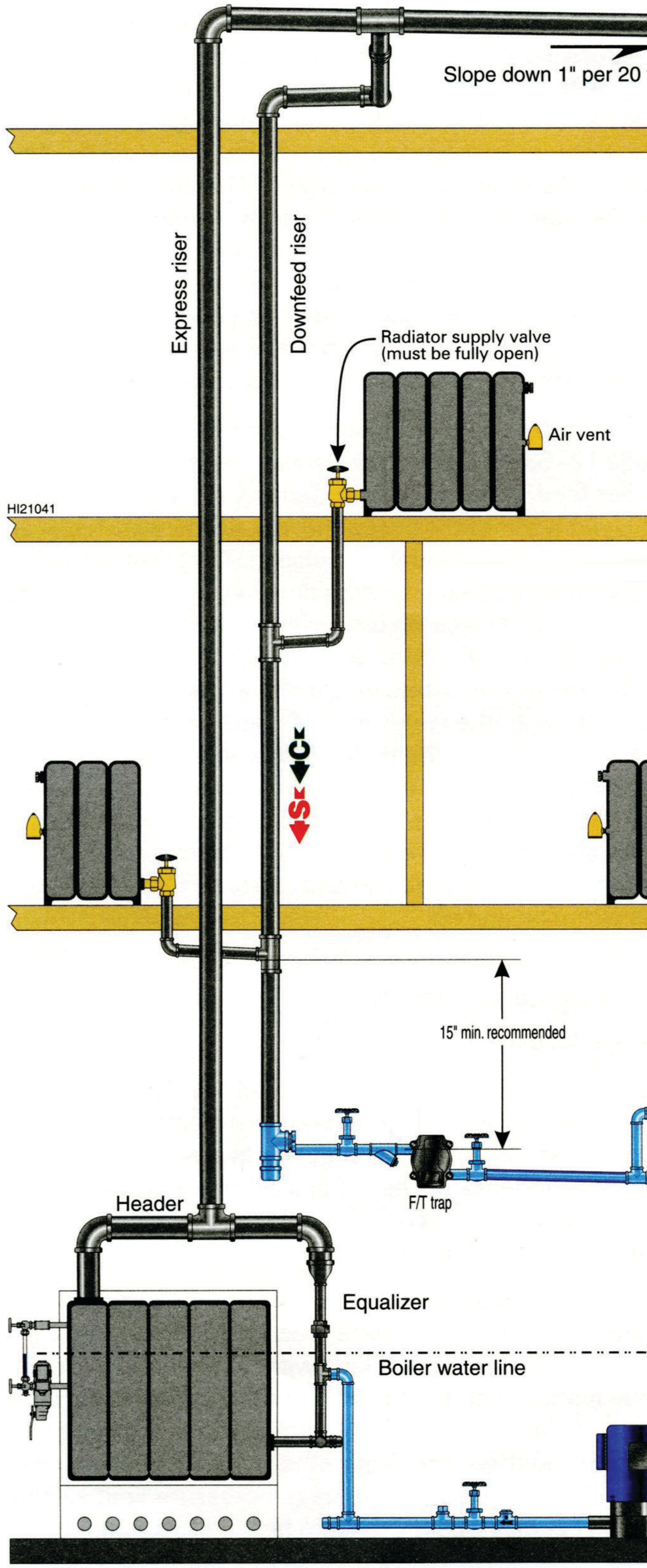


One Pipe Parallel Upfeed Pumped Return System

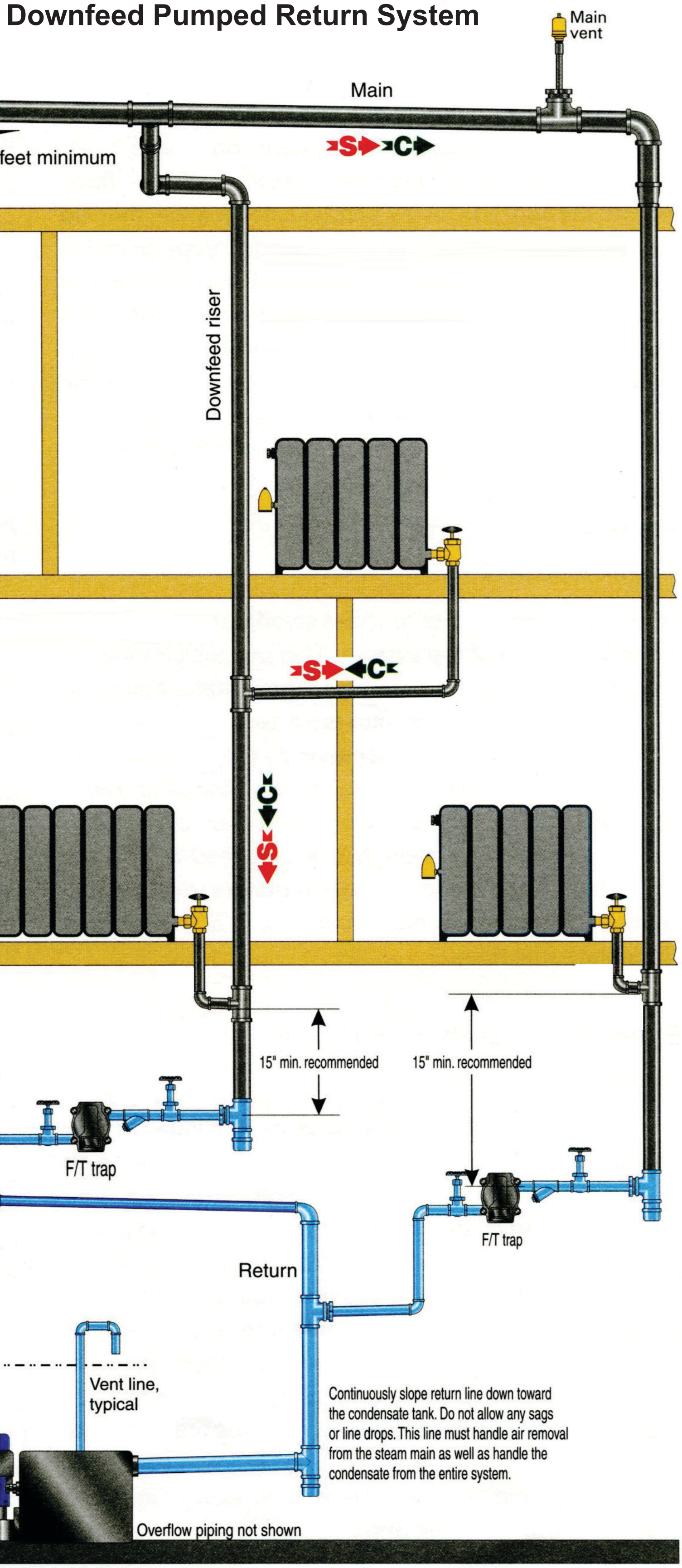


One pipe parallel downfeed pumped return system (Figure 6)

- In addition to the components added to convert an upfeed gravity return system to a pumped return, downfeed systems require additional F&T traps at the end of each riser.
- Without these additional traps, there is a risk of water hammer and reverse steam flow due to the downfeed risers being connected together above the boiler's water line.
- These traps must be located at least 15" below the lowest steam carrying pipe connected to them to allow room for the condensate to build up enough to push through the trap on start up.
- The main vent is optional (but recommended) on these systems because F&T traps allow air to escape.



Downfeed Pumped Return System



Two Pipe Pumped Return Systems

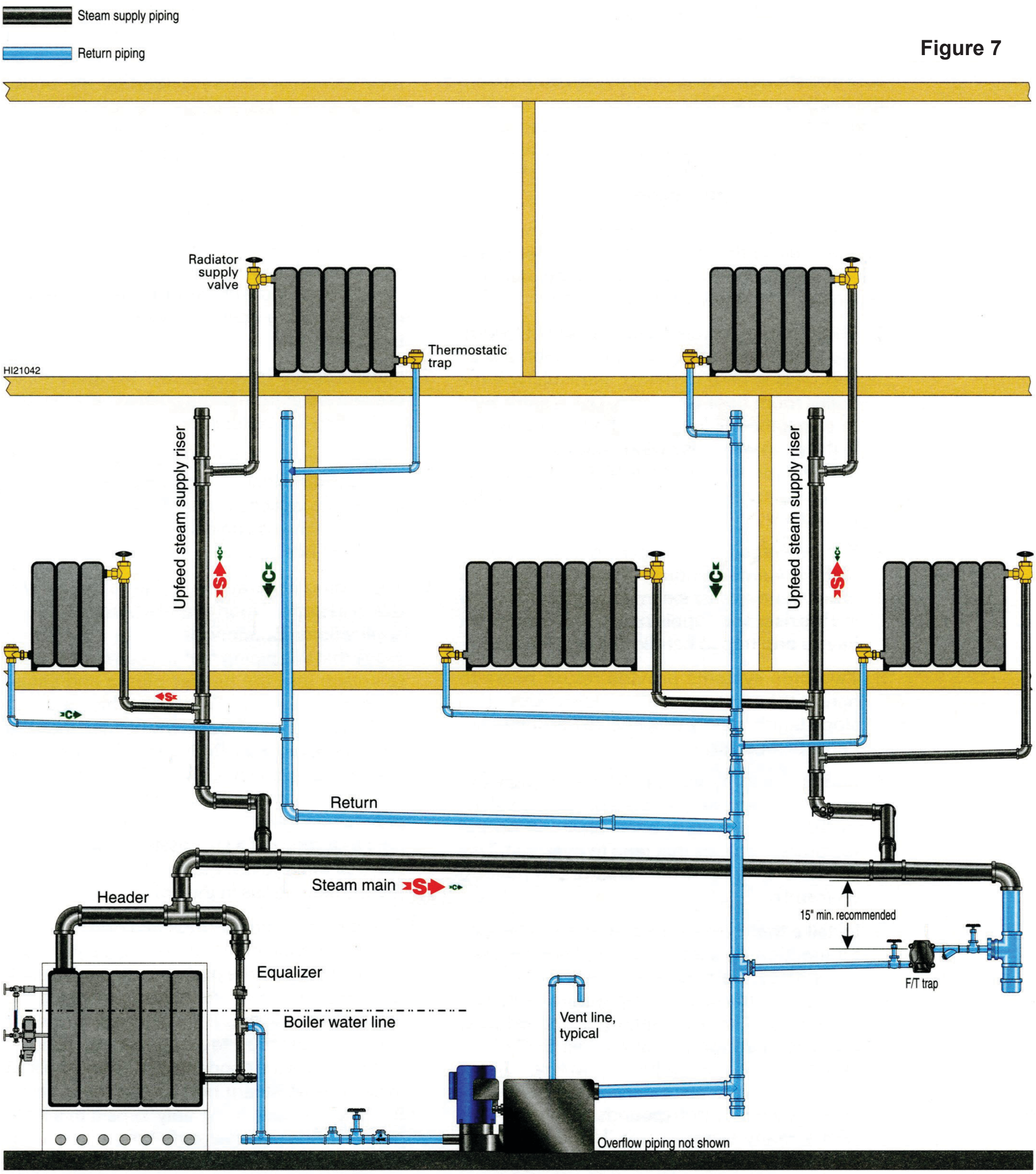
See following pages, **Figures 7 & 8**

- In a two pipe pumped return system there are no main vents or heat emitter air vents.
- The steam main must slope downhill toward the F&T trap at least 1" per 20'
- Radiator valves can be throttled to regulate the heating rate.
- Steam enters the top of a heat emitter and both condensate and air leave the heat emitter through a thermostatic trap located at the bottom of the opposite end of the emitter.
- A typical 2 pipe pumped return system should have the pressuretrol set to cut in a ½ psi and cut out at 2 psi. Higher pressures are not required unless the system includes heat exchangers or unit heaters.

• The F&T trap must be at least 15" below the steam main to provide enough static head to push condensate through the trap with no steam pressure on the system.

• The two main types of two pipe pumped return systems are the two pipe up-feed and the two pipe down-feed systems.

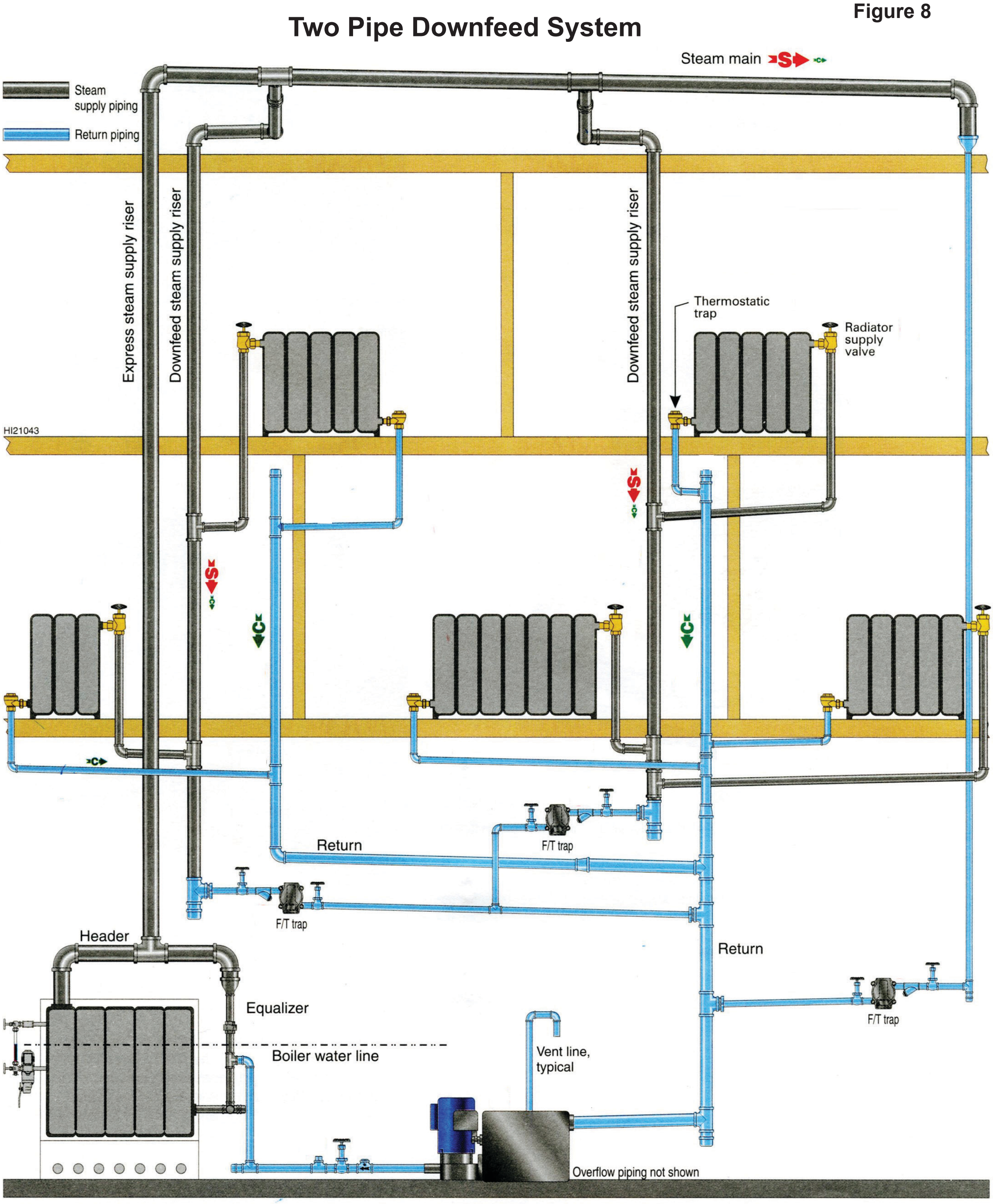
Two Pipe Upfeed System



Two Pipe Downfeed Systems

Additional F&T traps must be installed at the end of each downfeed riser.

Figure 8



Chapter 5

How Two Pipe Pumped Return Steam Systems Work

Standby mode

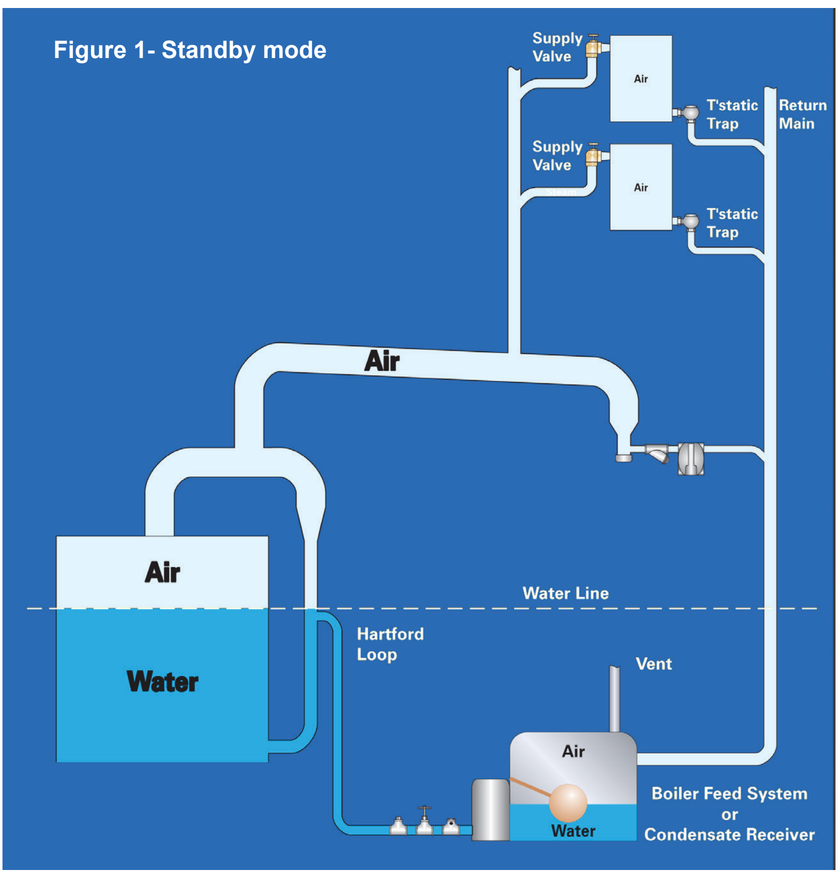
When the system has cooled and is in a standby mode, the water level in the boiler is at its normal fill line. The supply piping, heat emitters and return risers are full of air. Thermostatic traps are open, the F/T trap thermostatic valve is open and the float valve is closed. **Figure 1**.

When the thermostat calls for heat:

• the burner fires and the water in the boiler boils, creating steam.

• the boiler water level rises slightly as the steam bubbles displace water.

• the steam pressure builds as steam pushes against the air in the distribution system..



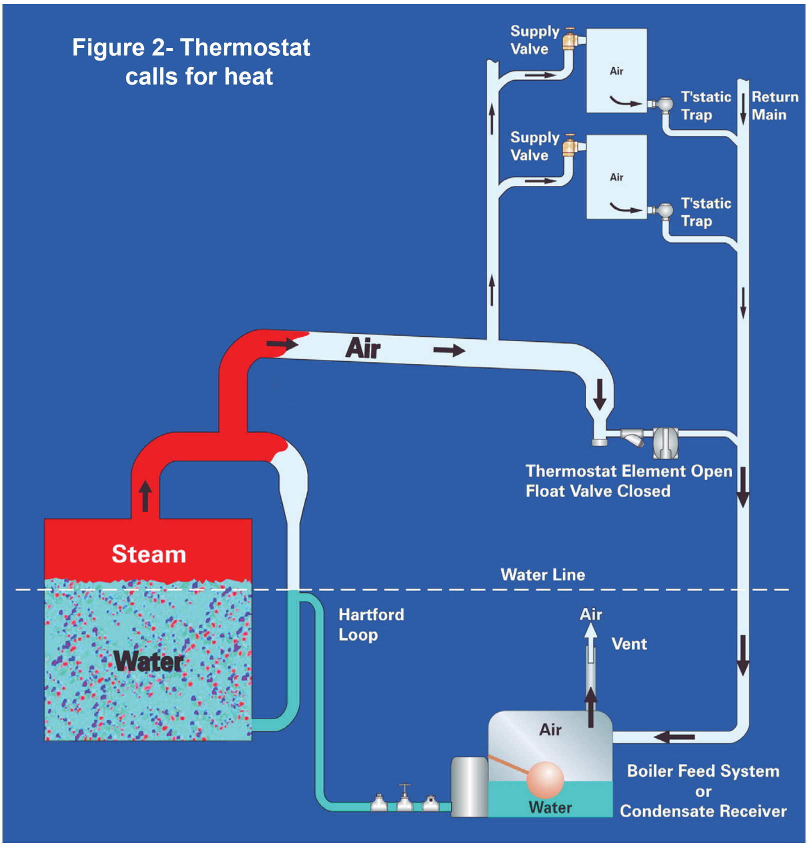
• the pressure pushes air through the piping and heat emitters.

• since the thermo static heat emitter traps and thermostatic ele- ment of the F&T trap are open, air flows through the heat emitter traps into the return piping and out through the condensate tank vent piping.

• the thermostatic traps stay open until they are exposed to steam tem perature. **Figure 2**.

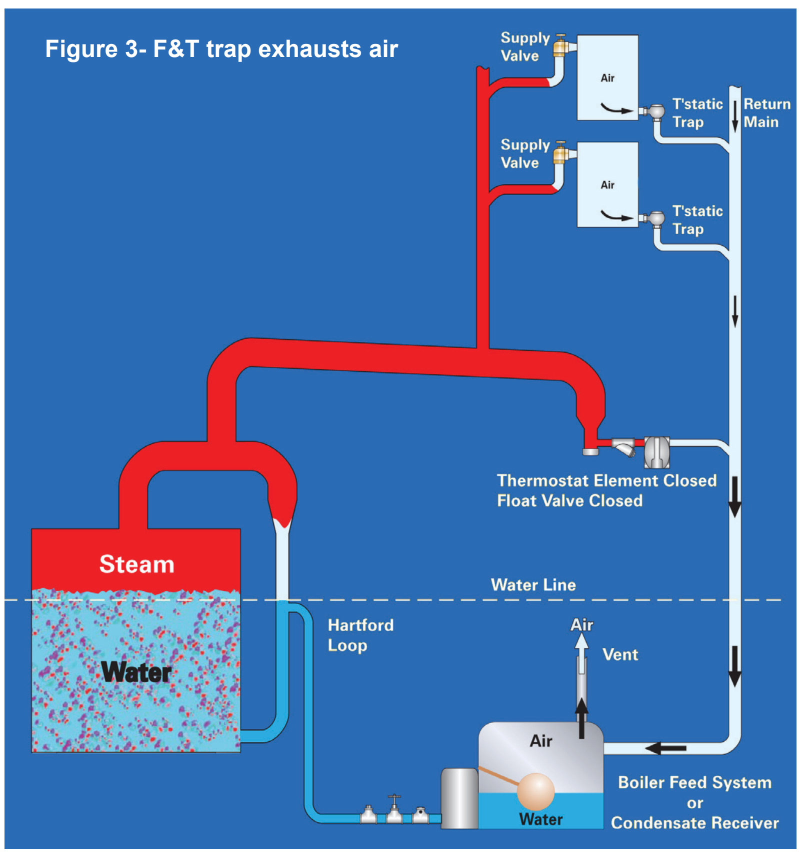
The F&T trap thermostat element quickly exhausts air from the main

• The boiler water level drops slightly because



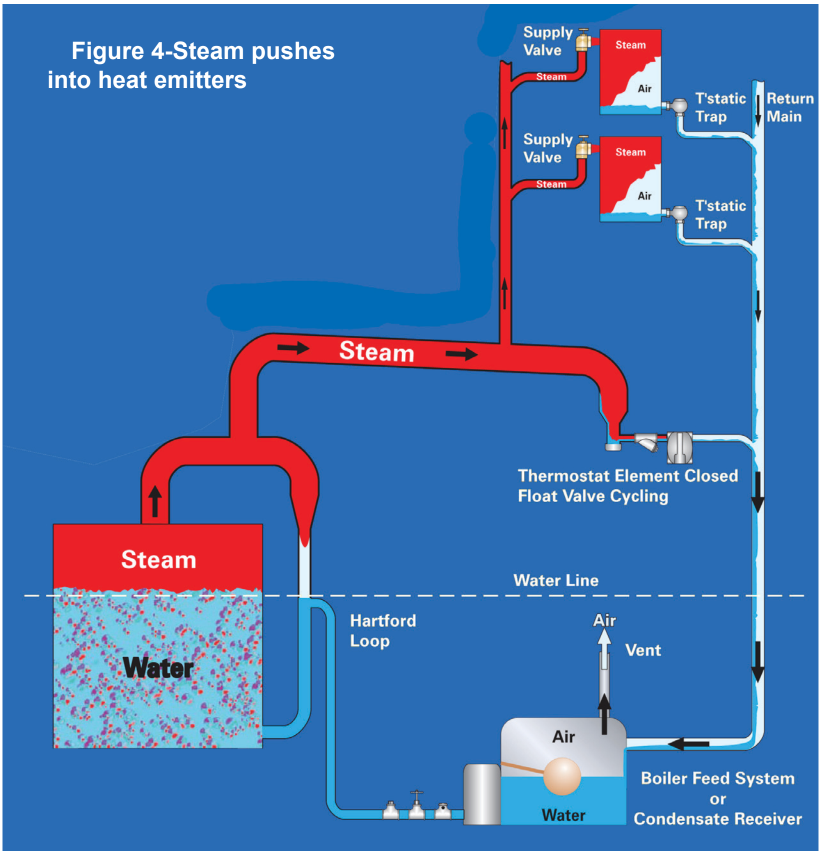
Steam pushes into the heat emitters, Figure 4, following page.

- the water level in the boiler continues to drop slightly
- heat emitters begin to heat up and cool the steam.
- condensate in the steam main drip leg builds up
- air keeps moving from the heat emitters, through the traps, to the return.



water has been "steamed off" and the condensate has not yet returned.

- all branches receive steam at about the same time.
- condensate begins to form and accumulates in the steam main drip leg.
- the thermostatic element of the F&T trap closes when heated by steam.
- air is slowly exhausted through the individual heat emitter's thermostatic traps. **Figure 3**.



temperature and cycle on and off throughout the heating cycle.

- the condensate return system cycles based on water level in the tank.
- the boiler continues to fire until the thermostat is satisfied or the limit control setting is reached. **Figure 5**

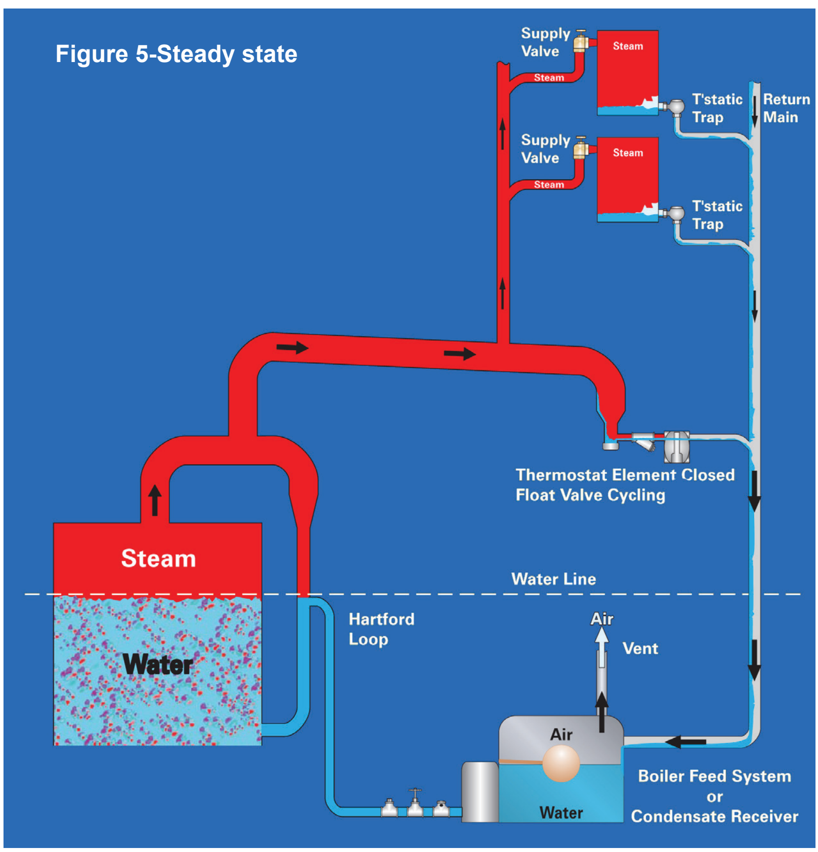
Off cycle

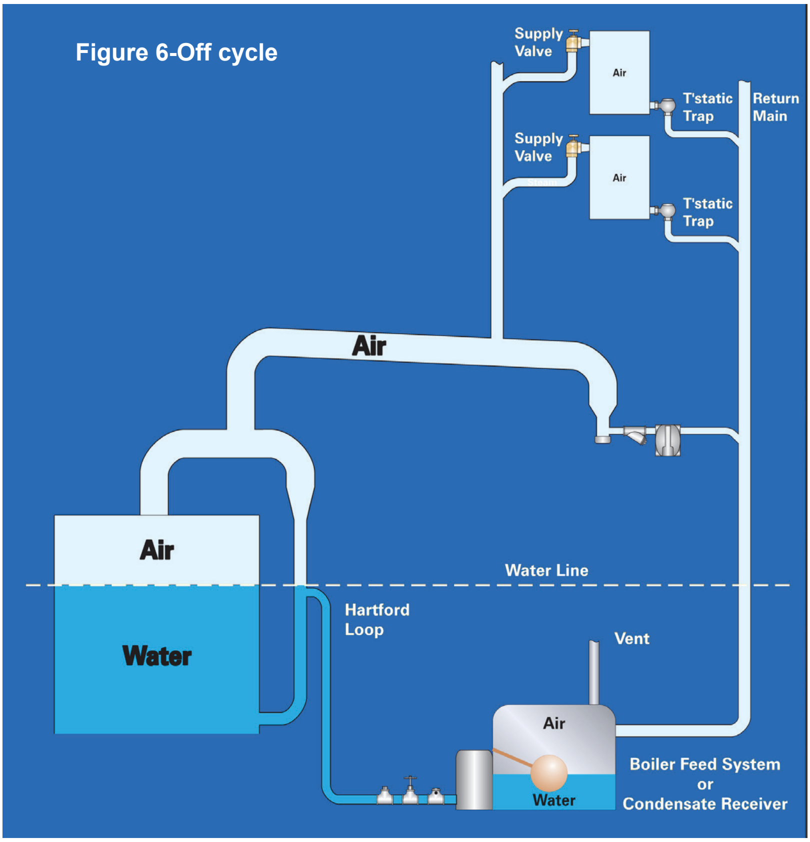
- at the end of the cycle the thermostat shuts the burner off.
- the steam in the system condenses and creates a vacuum.
- the condensate tank vent lets air back into the system and breaks the vacuum.

- condensate begins to form in the heat emitters and flows through the thermostatic traps to the return
- the water level in the condensate tank begins to rise.
- the float valve of the F&T trap cycles as condensate raises the float.

Steady state heating

- the boiler water level continues to drop because of the conden sate out in the system.
- steam fills the heat emitters
- the heat emitter's thermostatic traps close when exposed to steam





Steam reaches heat emitter - Steam pushes into the heat emitter and rises to the top, thermostatic trap allows air to pass into return. Heat emitter starts to warm up and condensate begins to form. **Figure 8, below**.

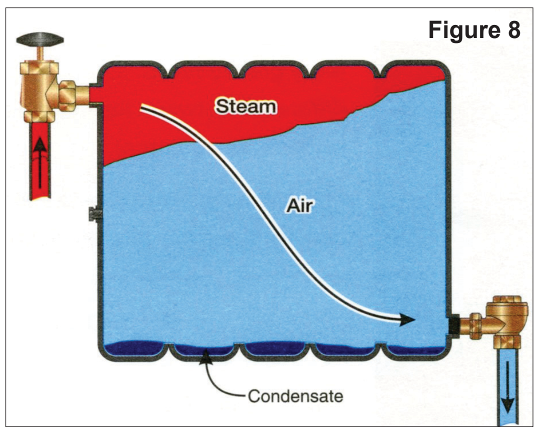
Steady state - Trap closes when steam reaches it, heat emitter releases heat to room. Condensate builds up in the heat emitter until it is at least 10° lower than the steam temperature at which time the trap opens and allows condensate to flow into the return until the thermostatic element senses steam temperature again. **Figure 9, below**.

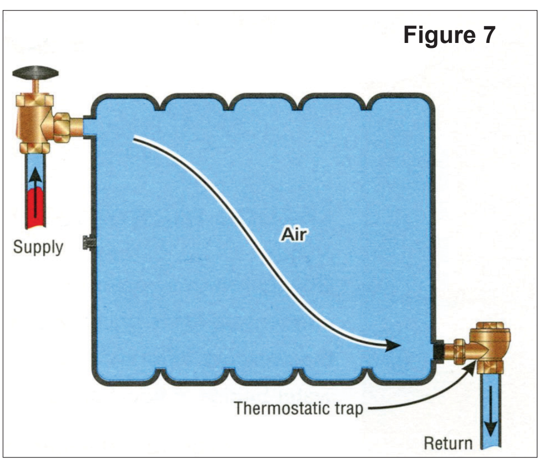
- the thermostatic trap elements cool and open.

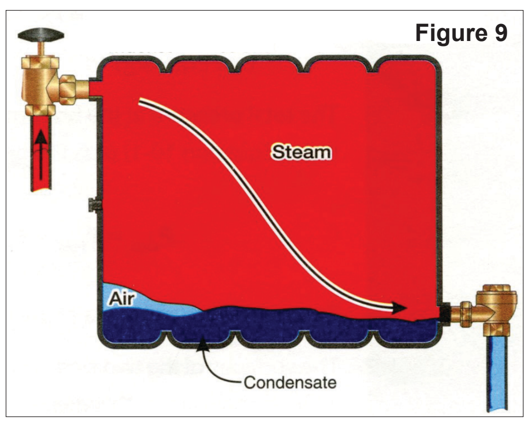
- the F&T trap float valve closes. **Figure 6**.

Heat Emitter operation with a typical two pipe system

Startup - steam approaches the heat emitter and pushes air out, through a thermostatic trap, into the return. **Figure 7, below**.







Chapter 6

Steam Traps—How They Work

Float and thermostatic Traps

Float and thermostatic traps are mechanical units that operate on both density and temperature principles.

The float valve operates on the density principle. A lever connects a ball float to a valve and seat. Condensate enters through the inlet near the top of the trap, once it reaches a certain level the float rises, opening the valve and draining condensate. Condensate drains from the port near the bottom of the trap, leaving a water seal (formed by the condensate) to prevent live steam loss.

Since the discharge valve is under water, it is not capable of venting air and non-condensable gasses.

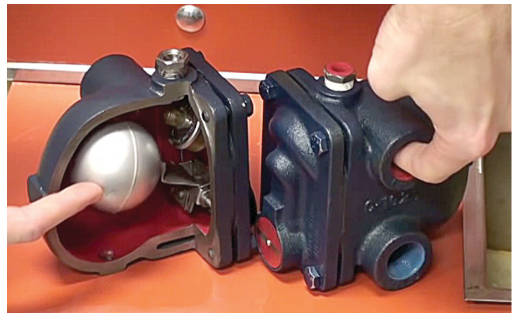
The thermostatic element operates based on temperature. When the trap is filled with steam the thermostatic valve is closed. When the accumulation of air and non-condensable gases causes a significant temperature drop, a thermostatic air vent in the top of the trap opens and discharges them.

A typical operating sequence is as follows:
1. The thermostatic air vent is open at start-up to discharge large volumes of air to the condensate Return. As steam enters the trap body the air vent closes.

2. The float is closed at start-up and stays in the closed position while steam is in the trap body.

3. When the steam condenses, the hot condensate lifts the float, moving the valve head off the seat and opening the trap to discharge condensate.

4. As condensate discharges, steam enters the trap body, the float falls and drives the valve head into the valve seat closing the trap.



For detailed info see: https://www.youtube.com/watch?v=fbJbg2kKx4Q

Heat Emitter (Radiator) Traps

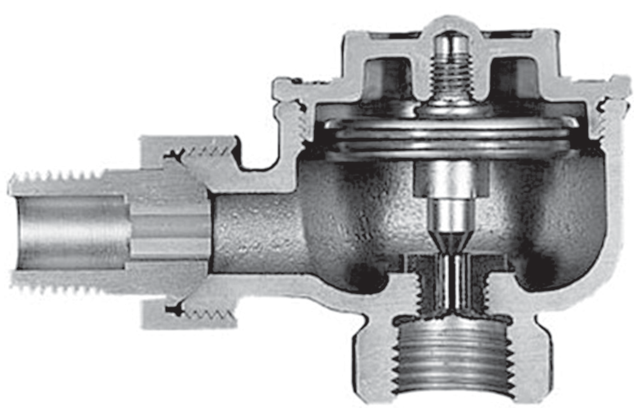
Individual radiator traps operate on temperature only.

1. At start up when air and condensate are cooler, the thermostatic element (diaphragm) contracts, pulling the valve head off the valve seat.

2. The trap then opens and discharges air and cool condensate.

3. As steam enters the heat emitter the condensate gets hotter, the element expands and drives the valve head into the valve seat, closing the trap.

4. The trap then stays closed until the condensate cools enough to contract the element and open the trap.



Chapter 7

Sizing a Condensate Return Unit

Understand the cycle

When dealing with pumped return systems it is imperative that the condensate return unit must be properly sized.

Before attempting to size a condensate return unit, it is necessary to understand how a steam heating system cycles:

- When the burner fires the boiler water temperature rises to 212°F.

- Steam starts being generated and the boiler water begins to expand, increasing the volume in the boiler.

- The water volume expands rapidly as the steam moves from the boiler into the header and system piping.

- The water level in the boiler drops as water becomes steam.

- If the system was equipped with a condensate return unit that had not collected sufficient condensate from the system, it could not pump condensate back to the boiler.

- If the water level drops to an unsafe level and the condensate does not return to the boiler, the low water cutoff will shut off power to the burner.

- The options at this point are to wait for the condensate to come back to the boiler (while generating no heat), or to add water directly to the boiler after it cools down enough so that water can be added safely without causing damage to the heating system, home or people.

Start with the load

A properly sized condensate return system can help to avoid having to utilize either of these options by pumping water from the condensate tank into the boiler before the water drops to an unsafe level.

To properly size a condensate return system one must start with the load.

Steam boiler ratings show how much steam they can produce in terms of pounds per hour (PPH), horsepower (BHP) and BTUH (British Thermal Units.)

A steam boiler puts ½ gallon of water per minute (in the form of steam) into the system, per 1,000 square foot of EDR (Equivalent direct radiation.) When the steam cools it turns back into water (condensate) at a rate of 0.000496 gpm per square feet of EDR.

The easiest way to calculate EDR is to divide the net BTUH of the boiler by 240.

The boiler label shown in Section 1 was rated for 651,000 BTUH, the calculation for EDR is:

EDR = BTUH/240

EDR = 651,000 BTUH / 240 = 2,712.5

Since condensate is typically generated at a rate of 0.000496 gpm per SQ FT EDR, this system generates condensate at a rate of:

0.000496 X 2,712.5 = 1.35 gpm

With a system condensate return time of ten minutes, this system would call for a 13.5 gallon tank.

For more information see: http://united-states.xylemappliedwater.com/2015/05/20/how-to-size-a-condensate-return-unit/

Note: If there is any likelihood that the make-up water supply to the feeder may be accidentally shut off for any reason, it is desirable to mount a float operated low water cut-off switch in the lower level of the tank.

The low water cut-off, connected to the motor starter of the boiler feed pump, would stop the pump should a low water condition occur, thus preventing running a dry pump.

Chapter 8
Sizing

To enable a heating system to operate at maximum efficiency it is imperative to properly size the boiler or furnace.

For hot water and warm air systems this requires that a "heat loss" calculation be performed on the building, but a steam boiler should NOT be sized based on the heat loss of the building.

Steam boilers must be sized based on the amount of steam required to fill all of the connected radiation and piping with steam. Properly sizing a steam boiler requires that every heat emitting device be measured to determine its BTU capacity in Square Feet (Sq. Ft.) of Equivalent Direct Radiation (EDR).

Once the total required Sq. Ft. of steam is determined, size the replacement boiler by selecting a unit with a Net I-B-R steam rating equal to or greater than the BTH/hr. capacity of the connected radiation.

If the boiler is undersized, the radiators furthest away will not heat properly. If the boiler is oversized it will short cycle, the steam flow in the main piping will cause too much pressure drop, the water in the returns will rise and water hammer can occur. In either case, undersized or oversized, overall system efficiency is compromised and fuel is wasted.

To properly size a replacement steam boiler perform the following for each heat emitter:

1. Identify the style of the heat emitter.
2. Measure the height and width of the heat emitter.
3. Count the number of tubes in each section if applicable.
4. Count the number of sections if applicable.
5. Determine the square feet of radiation in each section.
6. Multiply the square feet of radiation in each section by the number of sections.
7. Total the square feet of radiation for all the radiators in the building.
8. Convert the total square feet of radiation to BTU/Hr. Each square foot of steam radiation is based on a heat emission of 240 BTU/Hr. with standard 70°F air temperature and 215°F steam temperature in the radiator.
9. Size the replacement steam boiler by selecting a unit with a AHRI NET Steam rating equal to or greater than the BTU/Hr. capacity of the radiation.

For example:

Step 1. Identify the radiation - Go from room to room and identify the type of each heat emitting device. There are several types of heat emitters commonly found in the field:

Column radiators, tubular radiators, radiant convectors, cast iron baseboard, thin tube radiators and wall radiators.

Step 2 to step 6. Determine the Sq. Ft. of radiation of each heat emitter.

Use the manufacturer's information if it is available, if not, follow these procedures.

Measure the height and

Figure 1

Height (inches)	1 Column	2 Column	3 Column	4 Column	5 Column
14	-	-	-	-	4.00
17	-	-	-	-	4.00
18	-	-	2.25	3.00	5.00
20	1.5	2.00	-	-	5.00
22	-	-	3.00	4.00	6.00
23	1.67	2.33	-	-	5.50
26	2.00	2.67	3.75	5.00	6.75
32	2.50	3.33	4.50	6.50	-
38	3.00	4.00	5.00	8.00	-
44	-	-	-	-	-
45	-	5.00	6.00	5.00	-

width of each heat emitter, count the number of tubes or columns and count the number of sections. Then use the appropriate charts to determine the sq. ft. of radiation in each section. For example:

Column radiators. This column radiator has 3 columns and is 32" high.

- The chart shows 4.5 sq. ft. of radiation per section (**Figure 1, previous page**)
- There are 8 sections.
- 4.5 X 8 = 36 Sq. Ft. of radiation for this radiator

Tubular radiators. The sections of standard tubular radiators are generally 2.5" wide. This tubular radiator has 4 tubes and is 38" high.

- The chart shows 4.25 Sq. Ft. of radiation per section (**Figure 2, below**)
- There are 10 sections
- 4.25 X 10 = 42.5 Sq. Ft. Of radiation for this radiator

Radiant convectors. This radiant convector is 5" wide and 20" high.

- The chart shows that there

Figure 3

Height (inches)	Width (inches)	Sq. Ft. per Section
20	5	2.25
20	7½	3.40

are 2.25 Sq. Ft. of radiation per section (**Figure 3**)

- To determine the numberof sections, count the number of openings between the sections and add 1.
- This unit has 10 sections.
- 2.25 10 = 22.5 Sq. Ft. of radiation for this convector.

Cast iron baseboard. This cast iron baseboard is 10” high.

- The chart shows that there are 3.4 Sq. Ft. of radiation per linear foot. (**Figure 4)**
- Assume that 10 linear feet are installed.
- 3.4 X 10 = 34 Sq. Ft. of radiation for this section of baseboard.

Figure 4

Height (inches)	Sq. Ft. Radiation
7	2.40
9	3.35
10	3.40

Figure 2

Height (inches)	3 Tube	4 Tube	5 Tube	6 Tube	7 Tube
14	-	-	-	-	2.67
17	-	-	-	-	3.25
20	1.75	2.25	2.67	3.00	3.67
23	2.00	2.50	3.00	3.50	-
26	2.33	2.75	3.50	4.00	4.75
32	3.00	3.50	3.50	5.00	5.50
38	2.50	4.25	3.50	6.00	6.75

Thin tube (AKA "midget") radiators. The sections of thin tube radiators are generally 1.5 to 1.75" wide. (as opposed to standard tubular radiators @ 2.5" wide)

Assume the radiator is 32" high and has 3 tubes.

- The chart shows that there are 2.33 Sq. Ft. of radiation per section (**Figure 5**)

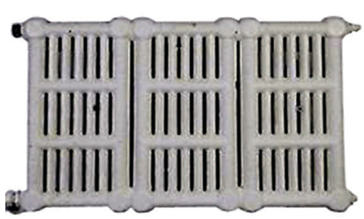
- There are 6 sections

- 2.33 X 6 = 14 Sq. Ft. of radiation for this radiator.

Figure 5

Height In.	2 tubes	3 Tubes	4 Tubes	5 Tubes	6 Tubes
38	2½	2⅔	-	-	-
32	2	2⅓	-	-	3⅔
26	-	-	2⅓	3	3
25	1½	1⅔	2	-	3
23	-	-	-	2	-
22	1⅓	1⅓	1⅘	-	-
20	-	-	1⅘	-	2⅓
19	1	1¼	1⅔	-	2⅓
17	-	-	-	2	-

Wall radiators. This picture shows 3 wall radiators manifolded together.



- Each is 13.5" X 21" X 3"

- The chart shows that there are 7 Sq. Ft. per unit. **Figure 6**

- 3 X 7 = 21 Sq. Ft. Of radiation for this radiator.

Figure 6

Height (inches)	Width (inches)	Thickness (inches)	Sq. Ft. EDR per Unit
13	15⅝	2⅞	5
13	21⅞	2⅞	7
22	13 3/16	3 1/16	7
18	29 1/16	2⅞	9
29	18 5/16	3 11/16	9

Step 7. Add up the Sq. Ft. of all the connected radiation in the building.

For example, using the Sq. Ft. of steam determined for the various types of heat emitters determined earlier, assume the building had:

Number	Type	Sq. Ft.
4	Column radiators @ 36	144
4	tubular radiators @ 42.5	170
2	radiant convectors @ 22.5	45
2	cast iron baseboard sections @ 34	68
1	thin tube radiator @ 14	14
1	wall radiator @ 21	21
	Total 462 Sq. Ft.	

8. Convert the total square feet of radiation to BTU/Hr. Each square foot of steam radiation is based on a heat emission of 240 BTU/Hr. with standard 70°F air temperature and 215°F steam temperature in the radiator.

462 X 240 = 110,880 BTU/Hr.

9. Size the replacement steam boiler by selecting a unit with a AHRI NET Steam rating equal to or greater than the BTU/Hr. capacity of the radiation.

In this case, the 4 section boiler, fired at 1.25 gph is the proper boiler for this application.

Note: Sizing calculations assume that steam main piping in unconditioned areas is insulated.

Model Number	Input		Output , MBH		Net Ratings		
	GPH	MBH	Water	Steam	Steam, sqft	Steam, MBH	Water, MBH
3-Section	0.75	105	92	91	283	68	80
3-Section	1.00	140	121	120	375	90	105
3-Section	1.20	168	144	142	446	107	125
4-Section	1.25	175	152	151	471	113	132
4-Section	1.50	210	181	180	563	135	157
4-Section	1.75	245	209	208	650	156	182
5-Section	1.75	245	214	212	663	159	186
5-Section	2.00	280	241	240	750	180	210
5-Section	2.50	350	286	286	896	215	249
6-Section	2.75	385	321	321	1004	241	279
6-Section	3.00	420	347	347	1083	261	302

Although heat loss calculations are not normally performed when replacing steam boilers there are situations in which an understanding of how to perform a heat loss is important.

For example:
A heat emitter that is necessary for the buildings comfort may have been removed.

The heat emitters may be under or over-sized.

In either of these situations a heat loss should be performed to determine if radiation needs to be added to, or removed from, certain areas. The size of the added radiation must be included when determining the size of the new boiler.

Chapter 9

Near Boiler Piping

ALL steam heating systems MUST be properly piped exactly according to manufacturer's instructions.

Excuses like:

"I've always piped them this way and never had a problem."

"That's the way the old one was piped."

"The customer just wanted a cheap price and didn't care." **...are not acceptable.**

Improperly piped steam boilers will not provide efficient, trouble-free operation. Far worse, they can be dangerous and cause severe harm to people and property.

For a steam heating system to operate properly it's imperative that both the "near boiler piping" and system piping be properly sized and connected.

Near Boiler Piping

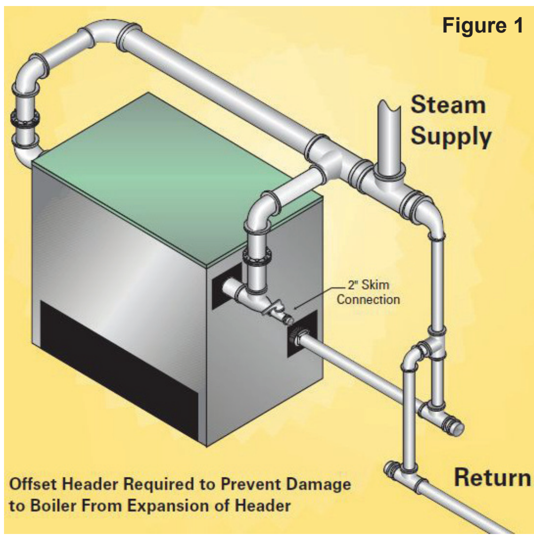
Every boiler manufacturer provides detailed installation instructions which must be followed.

Most manufacturers require that the bottom of the header on a gravity system be a minimum of 24" above the boiler's water line. The higher the header, the dryer the steam.

All manufacturers require a Hartford Loop when connected to a gravity return. The loop is normally connected between 2"– 4" below the boiler's water line. This prevents water from being pushed out of the boiler because the steam pressure pushes equally on the supply and return (through the equalizer.) The Hartford Loop also prevents a leaking wet return from draining the boiler.

The system return piping must be connected to the equalizer with a close nipple to minimize water hammer if the boiler water line drops below the top of the nipple.

Some manufacturers require an offset header to prevent damage caused by expansion. **Figure 1.**



Offset Header Required to Prevent Damage to Boiler From Expansion of Header

Smaller boilers (usually below 145,000 BTU's/Hr. and under 450 sq. ft. steam) require at least one supply riser to the header. Larger boilers generally should have two supply risers to the header.

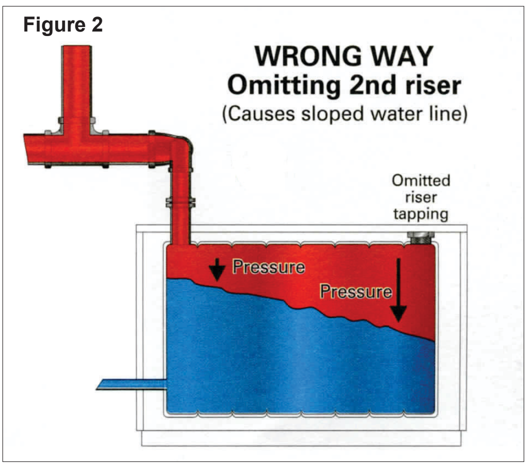
In general, two supply risers are always better because they allow the exit velocity of the steam to be cut in half and greatly reduce the chances of wet steam making its way into the supply main. The slower the steam, the better the steam.

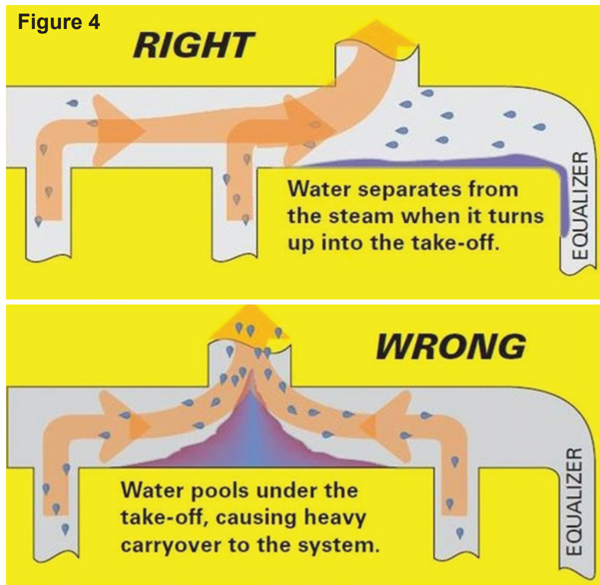
If the manufacturer's instructions call for two or more risers and the system in installed with less, the water level in the boiler will become sloped. This often causes the boiler section(s) at the opposite end from the riser to fail due to low water content. **Figure 2.**

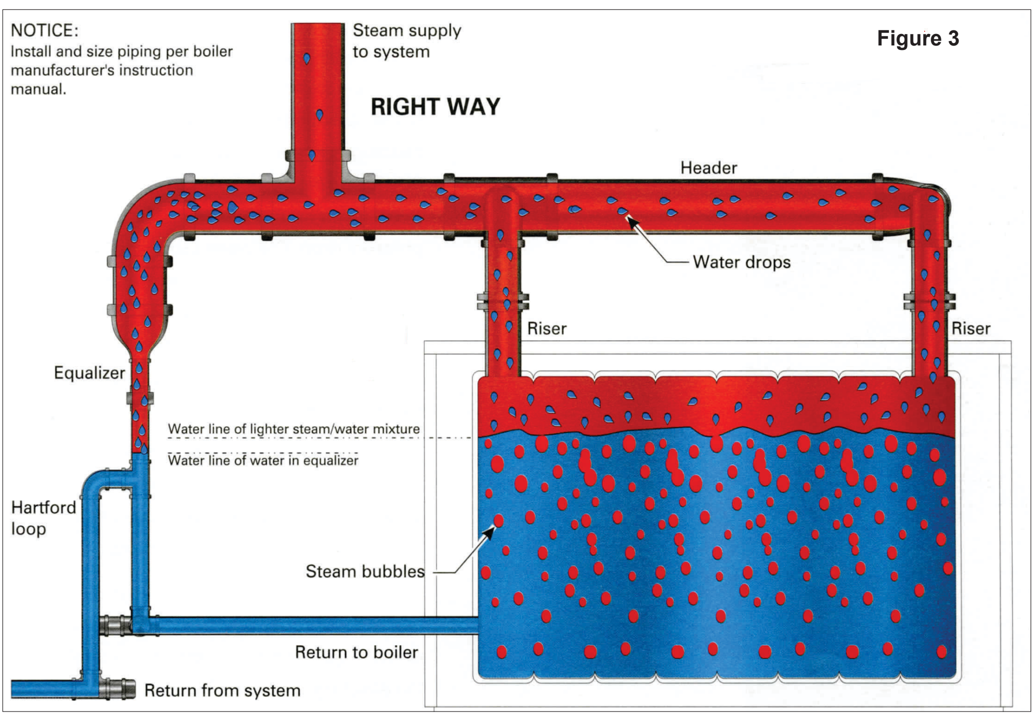
Correct near boiler piping for parallel flow systems with two supply risers is shown in **Figure 3**.

Turbulence causes water droplets to be present in the steam flow. When a boiler is piped as shown, most of the water droplets continue to the equalizer while the steam rises up to the system. The piping helps to separate the water from the steam resulting in 'dryer" steam in the distribution system.

Many older boilers were piped with the take-off located between the risers. With a new boiler, this piping arrangement causes water to pool under the take-off which leads to much wetter steam causing water to be carried into the system. This leads to water hammer, damage to system components and the frequent addition of make-up water due to low water conditions in the boiler. **Figure 4**.



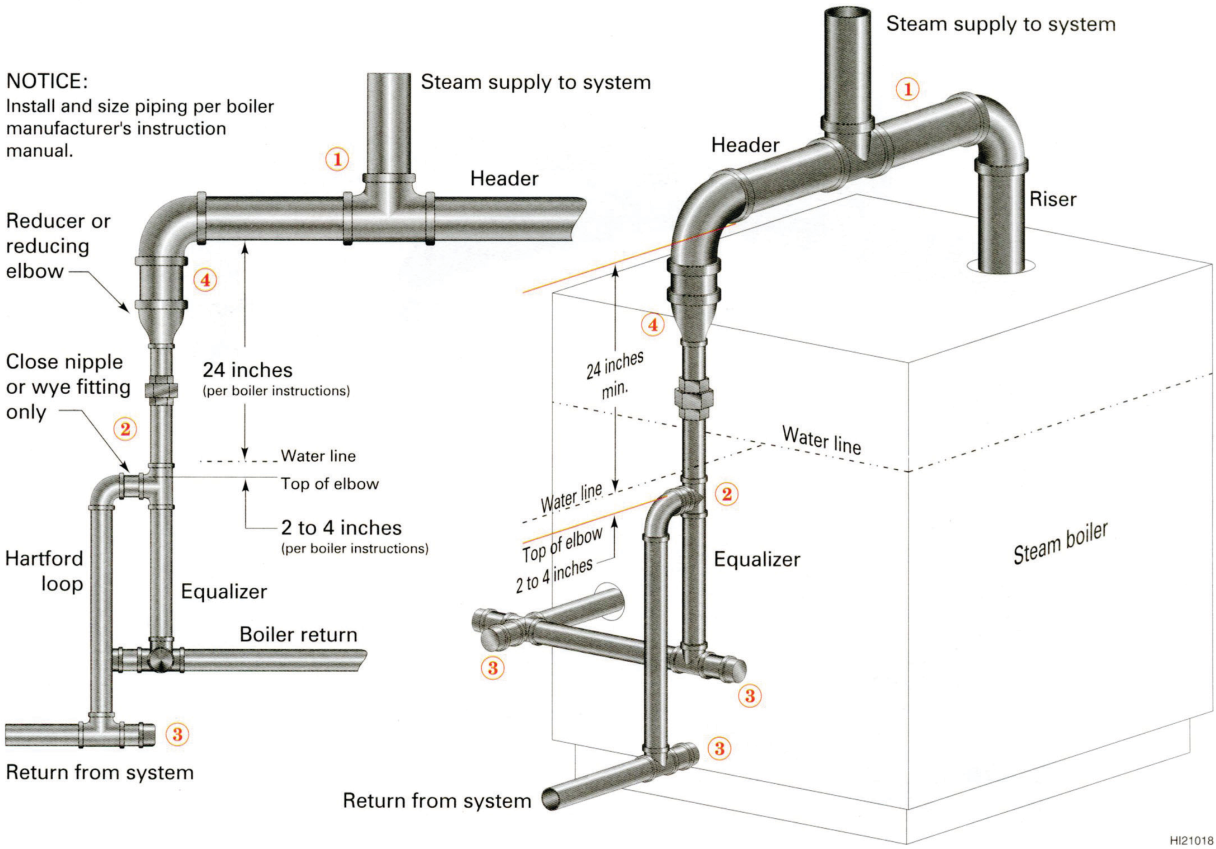




Near boiler piping for various system types

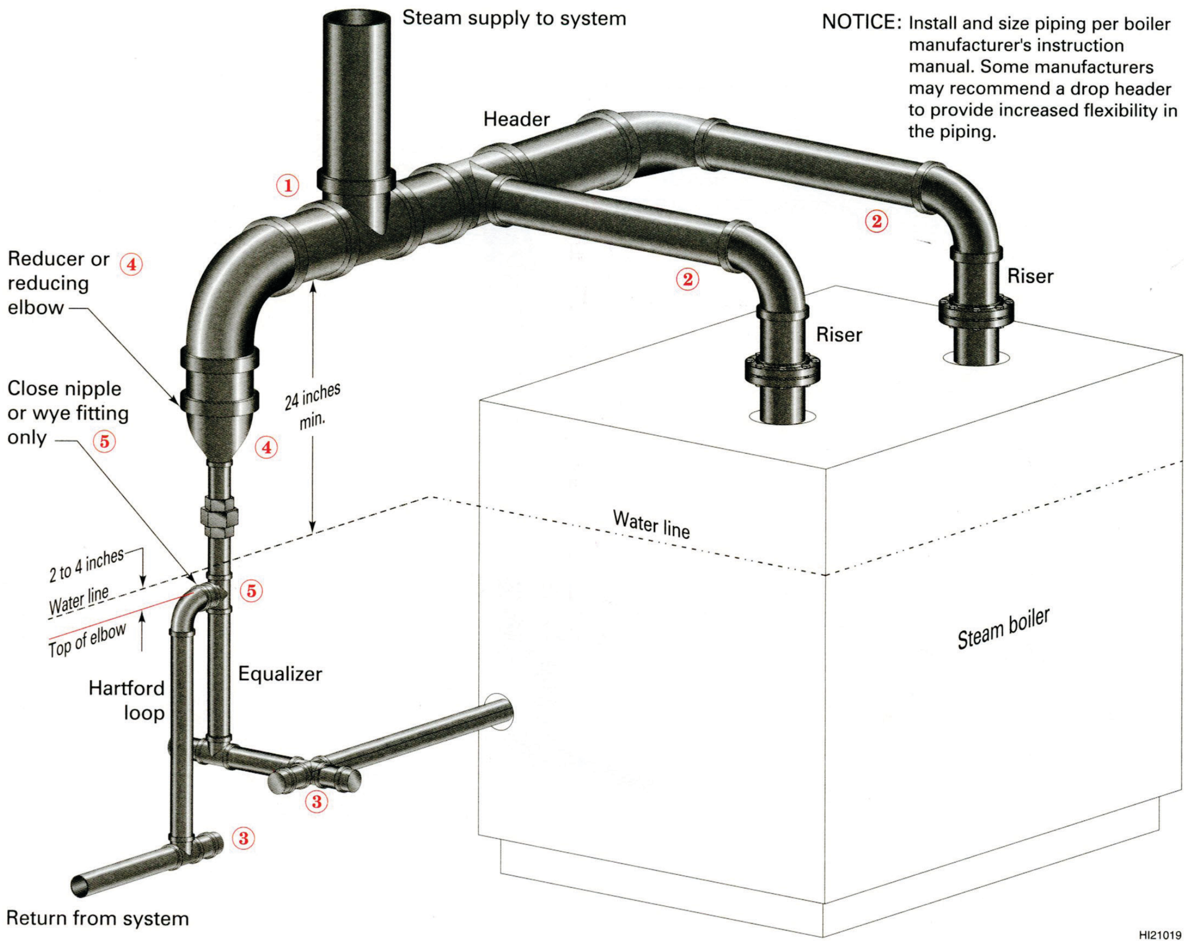
Near boiler piping recommendations vary by system type. The following pages contain general recommendations, always refer to the manufacturer's literature for specific instructions.

Typical near boiler piping for a parallel flow steam system with 1 riser.



1. Always connect steam supply between boiler riser and equalizer. This ensures the greatest possible separation of moisture from the steam. Provide at least 24 inches height between the bottom of the header and the boiler water line.
2. Connect the Hartford loop using nothing longer than a close nipple or wye fitting. Water level may often drop below top of fitting. A long horizontal connection would cause severe water hammer.
3. Install tee or cross with nipple and cap at all direction changes in return lines. Steam systems typically contain large quantities of sediment. You should periodically inspect and clean return lines to ensure reliable operation.
4. Reduce pipe size only after turning downward. Use a reducing elbow or reducing fitting in the vertical (equalizer) line.

Typical near boiler piping for a parallel flow steam system with 2 risers



(1) Always connect steam supply between last boiler riser and equalizer. This ensures the greatest possible separation of moisture from the steam. Connecting the steam supply between the boiler risers will cause water carry-over to the system. The large flow of water from the boiler will cause the system to add make-up water unnecessarily, resulting in eventual flooding. Provide at least 24 inches height between the bottom of the header and the boiler water line.

(2) You must pipe the risers into the header with offset joints as shown. The horizontal piping and elbows provide swing joints to compensate for the expansion and contraction of the header piping. If you don't pipe this way, cast iron boiler sections can crack, or steel boiler welds can fail.

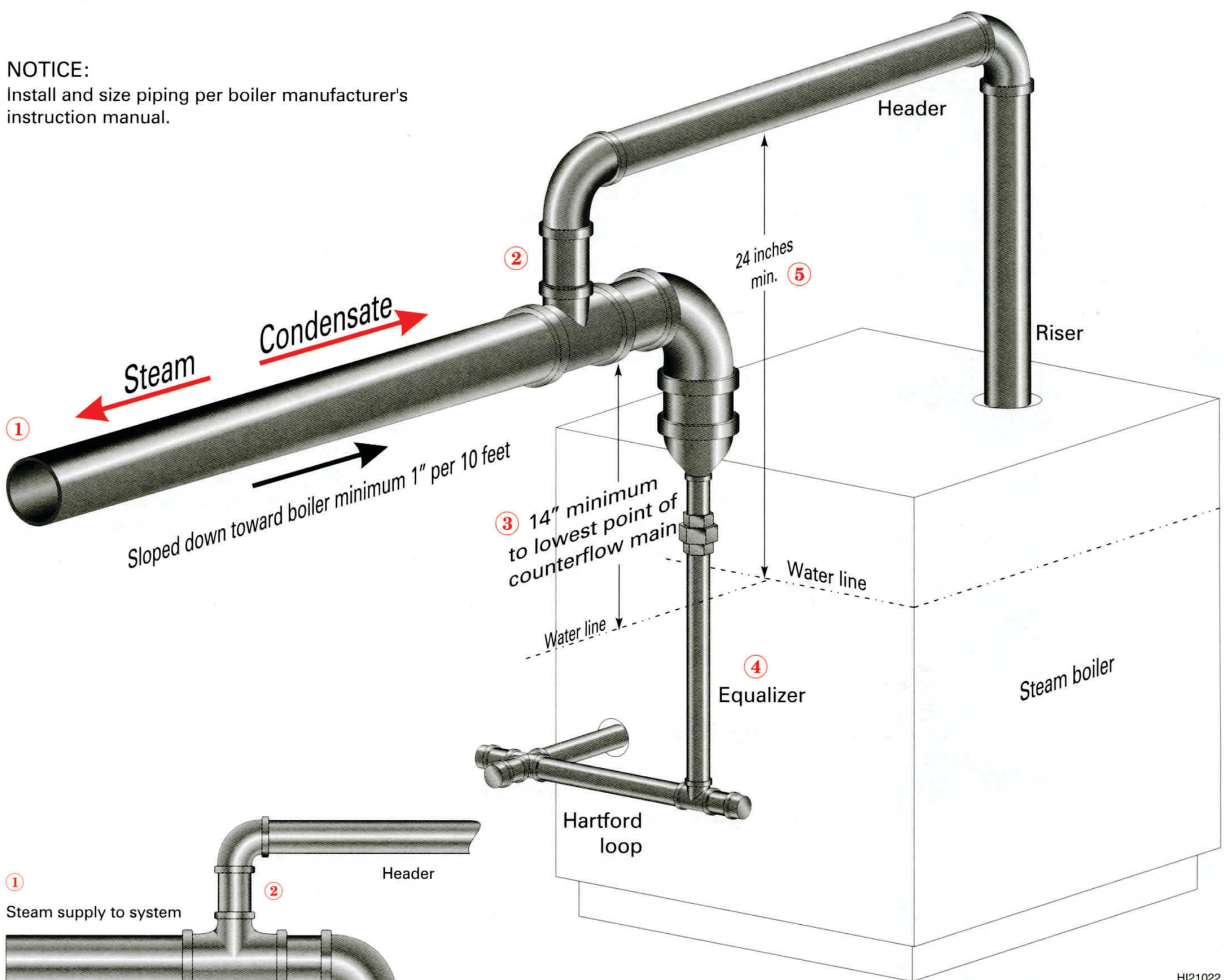
(3) Install tee or cross with nipple and cap at all direction changes in return lines. Steam systems typically contain large quantities of sediment. You should periodically inspect and clean return lines to ensure reliable operation.

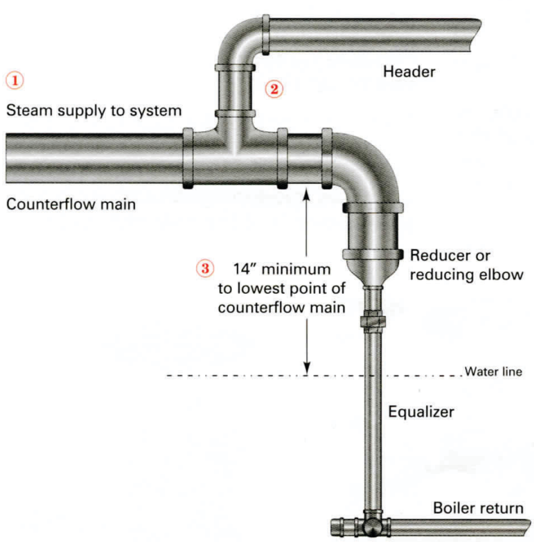
(4) Reduce pipe size only after turning downward. Use a reducing elbow or reducing fitting in the vertical (equalizer) line.

(5) Connect the Hartford loop using nothing longer than a close nipple or wye fitting. Water level may often drop below top of fitting. A long horizontal connection would cause severe water hammer.

Typical near boiler piping for a counterflow steam system with 1 riser

NOTICE:
Install and size piping per boiler manufacturer's instruction manual.



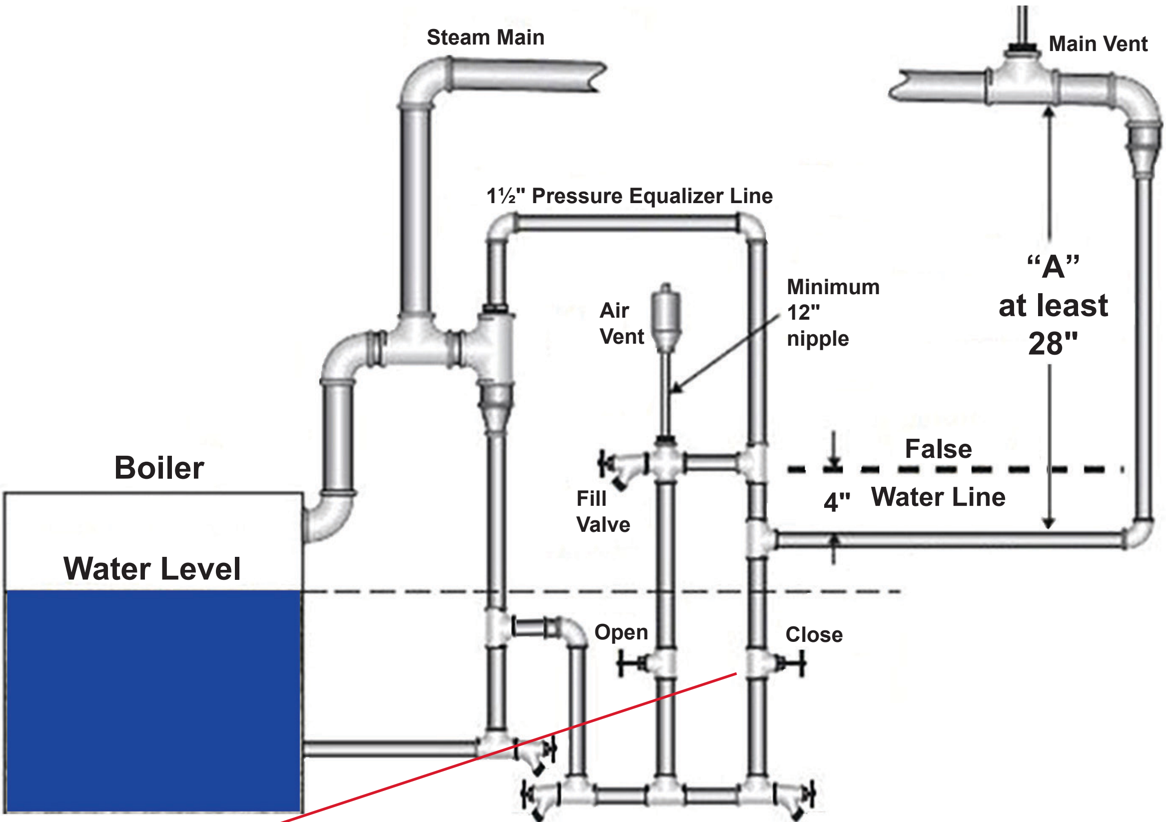


1. Counterflow mains do double duty. They supply steam to the system going out the pipe, but must also carry the condensate flowing back from the system. Counterflow systems do not have a separate return line.
2. The boiler header must connect to the top of the counterflow main. This prevents system condensate from entering the boiler header.
3. The lowest point of the counterflow main should be at least 14 inches above the boiler normal water line. This will prevent the possibility of condensate rising into the counterflow main, causing water hammer.
4. The equalizer connection is all that is required on this system. Since there is no wet return line below the boiler water line, no Hartford loop is needed.
5. Provide at least 24 inches height between the bottom of the header and the boiler water line.

False Water Lines

When a steam boiler can't be installed above the systems return lines, the use of a false water line will allow the boiler to operate at its normal water level.

The key to piping the loop is to ensure that there is a minimum of 28 inches of pipe ("A" dimension) before tying into the wet return. (The longer the better because the loop is now the system equalizer)



NOTE:
The closed valve on the right side of the false water line loop is to increase the systems "A" dimension and to prevent steam from pushing up the return line, causing bouncing water in the boiler. The closed valve allows water to rise in the second equalizer creating the false water line.

To establish a false water line, a tee is installed at the end of the header, after the supply to the system, with the "run" of the tee in the vertical position.

The "bull" of the tee is installed to the header.

The top of the tee is piped in a1 ½" equalizer loop to the boilers wet return.

The bottom of the tee connects into the Hartford Loop piping.

A quick vent must be installed a minimum of 4" above the system water line where it ties into the false water line loop. Also, the vent will need to be 8" or higher than the return water line coming into the loop.

The vent and a boiler drain valve should be installed into a cross tee. The cross tee will tie into both the loop and the wet return for the boiler.

To minimize water hammer, the loop should be filled with water before the boiler is first fired.

Chapter 10

Tankless Coil Piping

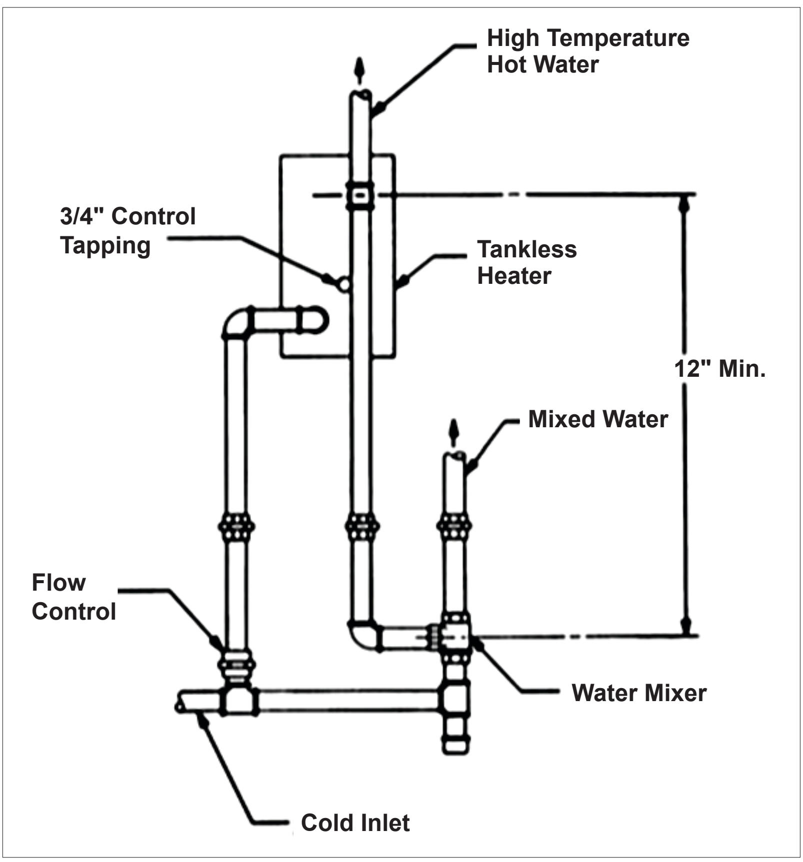
Tankless coils are typically installed as shown below. However, the specific boiler manufacturer's instructions must always be followed.

Anti-scald devices are required to prevent high temperature water from causing severe burns. Water temperatures above 120°F can cause serious injury. To ensure correct temperature control use a thermometer at a faucet outlet.

The "high temperature hot water" piping shown is attached to appliances that require hotter water than is provided through a mixing valve. (commercial dish washers, etc.) All other hot water connections should be piped to the "mixed water" piping.

Anti-scald Valve

It is a good practice to install the anti-scald mixing valve 6 -10 inches below the tankless coil to prevent the valve from being exposed to high water temperatures that can stack at the top of the coil.



Chapter 11

Troubleshooting

In this section, common challenges encountered by service technicians working on steam heating systems will be explained.

Water Hammer

There are a number of reasons why water hammer occurs in a steam system, including:

• When steam encounters condensate that is too deep in the horizontal piping.

• When hot condensate flashes into steam in return piping.

• When the boiler is oversized for the connected radiation, causing water to be carried over into the system piping.

• When an over-sized tankless coil is installed in the boiler. When cold water flows through the coil it can cause the water level to collapse quickly, pulling down the water level in the area surrounding the coil. The water from the rest of the boiler causes hammer as it flows into the void.

Water hammer can occur on start-up, during a heating cycle or on shut down.

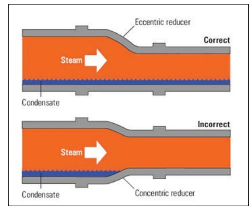
Start-up water hammer – when water hammer is present when the unit fires, check for:

• Improper near-boiler piping.

• Sagging or insufficiently pitched steam mains and returns.

• Improperly installed concentric reducers in steam carrying pipes and returns (they should always be flat at the bottom)

Reducers



• Drip traps that are not removing condensate or that don't have enough static head on the inlet to drain condensate without pressure upstream

> If start-up water hammer is present after a new boiler installation, the water level on the new boiler may be higher than on the old boiler and "dry" returns may now be partially wetted.

Mid-cycle water hammer – if water hammer occurs mid-cycle, after the system starts to make condensate, check for:

• Clogged returns on gravity systems, which cause water to back up the return riser into steam pipes or dry returns.

• An oversized boiler which will cause too high a flow in the steam lines and too much pressure drop, forcing water to back up the riser into the main or dry returns.

• Improper near boiler piping which can cause wet steam to be carried into the system.

• Defective steam traps, failed open, allowing steam to pass into the returns.

• Large one-pipe heat emitters that are venting too quickly – use a smaller vent or two smaller vents, one mounted above the other.

• Too long a nipple (anything longer than a "close" nipple) at the Hartford Loop, causing water hammer as the boiler water moves up and down.

• Improperly pitched return line to the boiler feed system or receiver. A water leg here will cause hammer and prevent proper venting of air.

• An added "master" trap at the receiver of feed system. Double trapping will cause hammer in the piping between the steam main drip trap and the trap at the tank.

• Problems with the pumped return piping. When pumping into a Hartford loop connection hammer will occur if the feed rate is too high and the equalizer isn't large enough

If water hammer occurs mid-cycle, check the return piping and the boiler feed piping. Use a level to make sure that the piping is pitched properly.

Shut-down water hammer – if water hammer occurs on shut-down, check for:

• Improperly Hartford Loop horizontal connection.. The top of the close nipple should be 2" below the water line, if it is too close to the water line, steam can enter the horizontal line as the boiler shuts down and the water level drops.

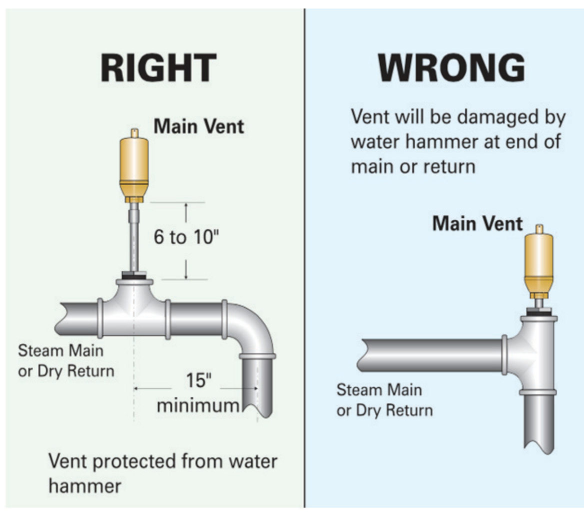
The boiler level drops on shut-down. This causes a bouncing water level in the equalizer line. If the Hartford Loop connection is too close to the water line the horizontal connection can be exposed to steam, causing hammering.

• Uninsulated piping in the boiler area. If the piping in the building is insulated but the piping in the boiler room is not, the system piping will be kept warm by the insulation and cool more slowly. The cooler boiler room piping will cause a quick vacuum on shutdown as the steam condenses. The rapid vacuum will cause lifting of the boiler water into the header, bouncing of the water level and water hammer.

Main Vent Problems

The Main Vent, and Riser Vents, are the heart of a one-pipe system. They must work to provide uniform heat in the building by removing air from the steam distribution piping. When they work properly, all the radiators receive steam at the same time.

Main steam vents are often piped as shown on the right. This allows water hammer at the end of the main to slam into the vent, causing the float to quickly collapse, causing the vent to fail in the closed position.



The main vent should be piped as shown on the left. This piping method protects the vent from water hammer at the end of the main and provides an air cushion against shock.

If the main vent doesn't work, the heat emitter vents must remove the air from the system piping. This will cause the heat emitters closest to the main to heat first and the furthest heat emitters will either under-heat or may not heat at all.

System/Boiler Overfilling or Flooding

Overfilling can be caused by:

• A replacement boiler that is significantly smaller than the one it replaced. If the boiler doesn't have enough storage water volume it can lead to unnecessary feeder operation. A boiler feed system may be necessary.

• The boiler feed rate may be too fast, causing the boiler water level to collapse when feeding. Check to be sure that the pump discharge pressure or feeder make up rate is no higher than necessary. In some cases an electronic water feeder may be needed to control the feed rate.

• The boiler may be "foaming" due to poor water quality or incorrect near boiler piping. Either of these conditions can cause water carryover to the system and premature low water conditions.

> "System flooding often occurs because the boiler steaming time is shorter than the time it takes for condensate from the system to return to the boiler. As the boiler water level drops, the feeder adds water to keep the boiler running and when the condensate returns the boiler floods."

Excessive boiler water level bounce

Water level movement is normal in all steam systems. When the water level bounces excessively (from top to bottom of gauge glass) check for:

- Incorrect near boiler piping.
- Dirty boiler water. If the water is dirty clean and skim it according to the manufacturer's instructions.
- High pH.
- Excessive feed rates from the pump or feeder.

> Most systems will foam excessively when the pH is higher than 9.5

Rapid cycling

If the burner is cycling rapidly, check for:

- Improper near boiler piping.
- Low water cutoff cycling due to water level bounce.
- Proper operation of air vents or traps.
- Improperly adjusted differential in the pressure control.
- Improperly adjusted thermostat heat anticipator.

> If the system is operating at 2 psig or less, the pressure control differential should be set to a minimum of 1 to 1.5 difference between cut-out and cut-in.

Definitions of Steam Heating Terms

Absolute Pressure - the atmospheric pressure added to the gauge pressure and is typically expressed as a unit of as pounds per square inch absolute.

Accumulator Tank – a tank installed when the returns in a vacuum pump heating system are below the inlet connection of a vacuum pump receiver. Its location should be such that condensate flows by gravity to the accumulator, and is lifted to the vacuum pump receiver.

Atmospheric Pressure - the weight of a column of air, one square inch in cross section and extends from the earth to the upper level of the blanket of air surrounding the earth. This air is a pressure of 14.7 pounds per square inch at sea level, where water can be boiled at 212°F.

Blow Down Valve (aka blowoff valve) - A valve that permits a boiler control to be flushed out and the proper operation of the control to be checked.

Boiler - A closed vessel in which steam is generated by heating water with a fuel.

Boiler Crown - the part of the boiler that is at the top of the fire chamber.

Boiler Feed Pump - a pump that is operated by a control that monitors the actual water level in a boiler.

Boiler-Header Drip Connection – a piping arrangement that drips a steam header to a return header and equalizes pressure between the two.

Boiler Heating Surface - the area of the boiler's heat transmitting surface that is in contact with water or steam in the boiler.

Boiler Horse Power - the equivalent evaporation of 34.5 lbs of water per hour at 212°F to steam at 212°F. This is the equal to a heat output of 33,475 BTU per hour, which is equal to approximately 140 sq. ft. of steam radiation (EDR).

British Thermal Unit - The quantity of heat required to raise the temperature of 1 lb. of water 1°F.

Check Valve – a valve that allows water to flow in one direction only. In a steam system it controls water flow between a pump and the boiler inlet, so that water cannot flow back from the boiler to pump.

Condensate - the water formed when steam cools in a heat emitter or piping. The capacity of traps, pumps, etc., is sometime expressed in lbs. of condensate they will handle per hour. One pound of condensate is equal to approximately 4 sq. ft. of steam heating surface (240 BTU per hour per sq. ft.)

Condensate Pump - a pump used to return condensate to the boiler where it cannot be done by gravity.

Cooling Leg - a length of uninsulated pipe with sufficient cooling surface to dissipate enough heat so that steam condenses so a trap can open to discharge condensate from a heat emitter.

Counter-Flow System - a heating system in which steam and condensate flow in opposite directions within the same piping. Piping should be one size larger than in a parallel-flow system to allow sufficient space for free flow of both steam and condensate.

Differential Pressure - is the difference in pressure measured between inlet and outlet of trap or similar equipment.

Down Feed Riser - Piping that carries steam from supply main above to heat emitters below. This piping also carries condensate from heat emitters to the return.

Down-Feed System – a heating system serving a multi-floor building in which steam supply main is near the top of structure and down-feed risers carry steam to heating units, as well as condensate to wet return. The condensate then flows to the boiler via the Hartford Loop.

Drip Connection - This section of piping, at least 18" long, is the minimum distance the end of the supply main must be above boiler water line for gravity flow of condensate back to the boiler.

Where piping carries both stream and condensate, it is often desirable to drain off condensate at various points to expedite steam flow. This condensate is drained off to a return line by a connection called a “drip.”

Dry Return - the portion of the return piping located above the boiler water line.

Dry Saturated Steam - steam containing no water in suspension.

Equalizer - Piping from the end of the supply header that connects to the Hartford Loop and then the bottom of the boiler to maintain pressure balance between the boiler’s steam outlet and the condensate return inlet.

Flash Steam - the re-evaporation of condensate back to steam. It occurs when condensate flows into a reduced pressure area where the condensate's temperature is above boiling point for that reduced pressure. For example: if hot condensate is discharged by a trap into a low pressure return, a certain percentage of that condensate will be immediately transformed into steam.

Foaming - a condition that occurs when oil, organic materials and other substances contaminate the boiler water causing froth to build up on the surface water in a boiler. This leads to wetter steam, lower efficiency and the water level bouncing in the gauge glass.

Float and Thermostatic Traps - Stop steam flow and discharge condensate and air accumulations into returns. These traps should be located far enough away from condensate pump receivers so flash steam does not affect the pump's operation.

Gate Valves - close off the flow of water from a condensate pump. In a steam system they are normally open and are closed to isolate pumps for repair.

Gauge Glass - (aka water glass or sight glass) – a device that gives a visual indication of the water level in a boiler. .

Gauge Pressure - is the pressure, measured in pounds per square inch gauge (PSIG), inside the boiler as shown on a properly operating pressure gauge.

Hartford Loop - a system of piping that prevents the water from draining out of a boiler if a leak develops in the return piping.

Heat Emitters (aka Heating Units) - convectors, cast iron radiators, wall-fin radiation units, and similar heating devices.

Latent Heat - heat that is absorbed by the body or a thermodynamic system, during a constant process.

Loop Riser – the vertical portion of the wet return that brings water into the equalizer, 2" below the water line.

Low Pressure Steam - 15 PSIG or less.

Main Vent Valve (AKA Quick Vent) - a device that lets air escape quickly from the supply main so steam can circulate and reach heating units for fast warmup. It should be located at least 15" closer to the boiler than the last fitting of the supply main.

Make-Up-Water - fresh water added to a system to compensate for water lost through evaporation and leakage.

Mechanical Return - a method of returning condensate to a boiler when the height between the end of the main and the boiler water line (drip connection) is insufficient. A mechanical return system is typically comprised of a condensate receiver and a condensate pump.

Minimum Water Level - is the lowest boiler water level where the burner can be safely operated.

No Pressure Return - a dry return below the boiler water line. Condensate flows by gravity through this return and enters the condensate pump above the high water line of the pump's receiver. Air in this return is at atmospheric pressure because the receiver has an open air vent that extends above the boiler water line.

Open Air Vent - an open length of piping extending up from a condensate pump receiver to above the boiler water line. The vent keeps air pressure in both the pump receiver tank and the no pressure return equal to atmospheric pressure outside the system.

Over-firing - a situation where the firing rate of the boiler is above the boiler's rating. This can cause short cycling, the system pressure to rise and the relief valve to open.

Parallel-Flow System - Piping arrangement in which both steam and condensate flow together in the same direction in the supply main and return.

Pitch of Mains - is the amount of slope given to a horizontal main pipe. Correct pitch for horizontal supply mains and dry returns must be 1/4" min. in 10' in the direction of steam and condensate flow.

Pressure Drop - the difference between steam pressure at top of boiler and pressure at the end of the steam supply main. It is caused from friction within piping and the condensing process in mains and heating units.

Safety Factor - additional static head needed to compensate for higher pressures and greater steam consumption during warm-up periods.

S**ensible Heat** - is the amount of thermal energy that is required to raise an objects temperature.

Skimming - a procedure for cleaning the surface of the water in a boiler. This process should be done on ALL new boiler installations, and when foaming occurs.

Square Foot of Heating Surface AKA Equivalent Direct Radiation (EDR)
the amount of heating surface which will give off 240 Btu per hour when filled with steam at 215°F and surrounded by air at 70°F. (Equivalent square foot of heating surface may have no direct relation to the actual surface area.)

Static Head - the amount of water needed in returns to build up necessary pressure to force water back into the boiler in a gravity feed system.

Steam Boiler - a closed vessel for conversion of water into steam. It should be equipped with automatic controls to maintain water level and sufficient safety devices for proper burning of fuel.

Steam Heating System - a heating system in which the heating units give up their heat to the room by the way of a radiator, convector, steam baseboard, ect;. and the condensate returns back to the boiler.

Steam Pop Safety Valve (Relief Valve) - a device to prevent over pressurization in a boiler. The relief valve in a low pressure steam system should be set for 15 psi. High Pressure Boilers should be set to the maximum working pressure of the boiler.

Steam Trap - a device that allows the passage of condensate and air but prevents the passage of steam.

Strainer - a device used to protect valve pins, seats, and other components from dirt and foreign matter.

Supply Main - primary piping that carries steam from boiler to heating units, and, in a one-pipe system, condensate from heating units to return main.

Supply Riser - vertical piping that carries steam under pressure from the boiler up to the supply main(s). A riser then carries steam up from supply main to heating unit.

Supply Valve :
One-Pipe System - located at the bottom of heating unit's inlet connection. Supply Valves control the admission of steam and flow out of condensate. In a one-pipe system, the supply valve should be fully open or closed tightly, since a partially open valve obstructs the free flow of steam in and condensate out.

Two-Pipe System - Modulating-type supply valves admit steam to the heating unit through its top inlet connection. Selection depends upon system configuration and system pressures.

Thermostatic Steam Trap - located at the bottom outlet connection of a heat emitter, thermostatic traps open to drain condensate and air into the return but prevent flow-out of live steam into the return piping.

Two-Pipe Vacuum System - an ordinary two pipe vacuum system uses a vacuum pump to create a sub atmospheric pressure, usually 3" to 8" Hg (Mercury), in the return piping. Vacuum removes air from system piping and heat emitters to provide quick heating and efficient steam distribution. Condensate flows to the pump receiver by gravity.

Up-Feed System - Steam system for multiple floor buildings in which the steam supply main is in the basement above the boiler. Risers carry steam to the heating units. Condensate from each up-feed riser is dripped by gravity into wet return and then flows via Hartford Loop to the boiler. The supply main is kept free of condensate accumulation for free flow of steam.

Vacuum Heating System (Steam) - a one or two pipe heating system equipped with the necessary accessories to allow the pressure in the system to go below atmospheric. A closed heating system in which a partial vacuum is induced when the heating units and the main cool below the boiling point of water at atmospheric pressure. Pressures in a vacuum system range from below atmospheric pressure to a higher pre-determined pressure. Space heating is more even, and boiler water temperatures are usually lower; heating is more economical. Vacuum vent valves and vacuum main vents must be used.

Vacuum Pump Equalizer - a piping arrangement that equalizes induced vacuum between the supply header and vacuum pump receiver.

Vapor Stat - a device that provides an operating control and high limit protection for vapor heating systems with pressures up to 4 psi (8 kPa). All models have Microswitch snap switches to open or close a circuit on a pressure rise.

Vent Valve (heat emitter) - a device which opens to allow air to be pushed out of a pipe or a heat emitter but which closes against water. Installed on a tapping at the opposite end of the heat emitter from the supply valve, float and thermostatic vent valves let air escape from the heating unit under pressure, but close against the passage of steam and condensate.

Water Hammer - a wave transmitted through a pipe filled, or partially filled, with water. It may originate as waves set up by steam passing at a high velocity over condensate collected in piping. It is one of the main causes of noise in steam heating systems and is the cause of much damage to thermostats and floats in traps.

Wet Return - the part of the return main that is below the boiler water line and filled with water (does not carry air or steam).