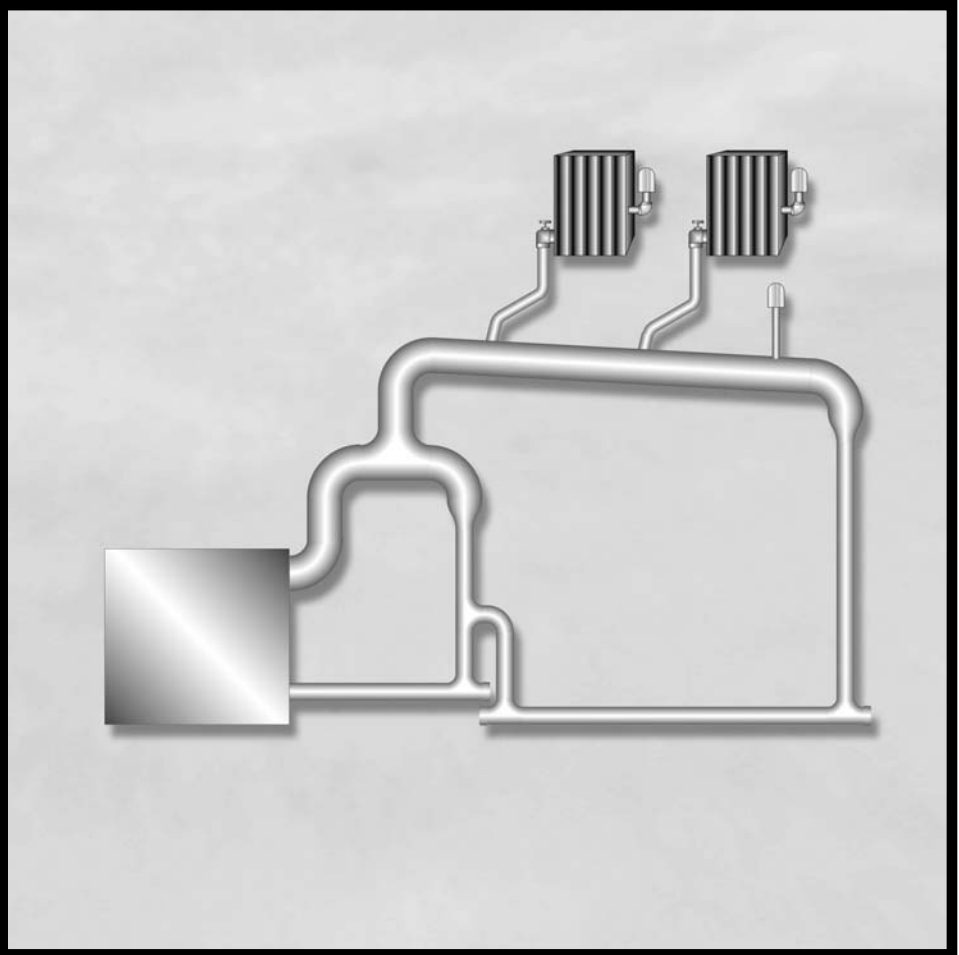


Steam Survey

Hydronic Systems



Pre-Installation Survey and Checklist for Steam Systems



PeerlessBoilers.com

INSTALLATION SURVEY – STEAM

A. Introduction

1. Use this survey to review the **system** for operating behavior and history. The survey should give you some tips on making the installation successful. It might also give you some recommendations to pass on to the owner for corrections needed in the system to avoid problems later.

2. DEFINITIONS AND RATINGS:

EDR	=	Equivalent Direct Radiation 240 Btuh per ft ² Steam <i>Note: Boiler ratings in EDR include an allowance for piping and pickup losses</i>
PPH Condensate	=	Pounds per Hour of Condensate $\text{EDR} \div 4$
GPM Condensate	=	Gallons per Minute ½ gpm per 1000 ft ² EDR 2 gpm per 1000 PPH Steam 2 gpm per Million Btuh
PPH Steam	=	Given from & at 212° F 970 Btu per Pound Steam $\text{IBR Gross Output} \div 970$

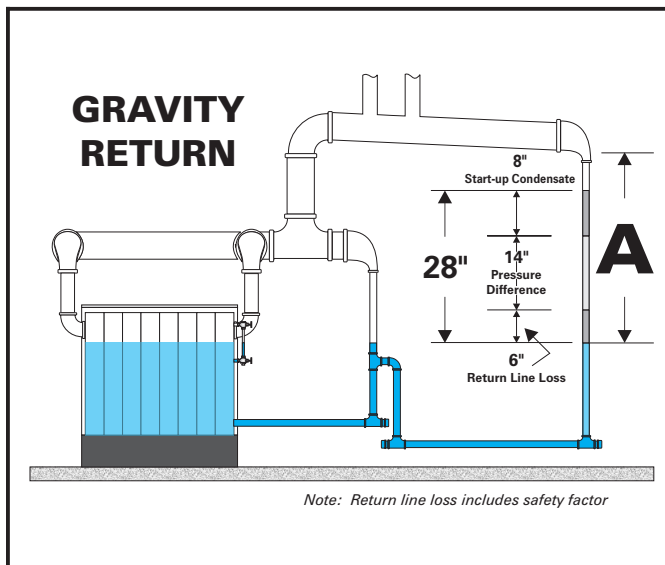


Figure 1: Gravity Return – Dimension A

The steam pressure at the end of the steam main is lower than at the boiler by about ½ psig (14 inches) on most systems. So the condensate must be **14** inches higher than the boiler water level to equalize this difference.

Another **6** inches is needed for the friction loss through the return line. And **8** inches must be allowed for the cold start-up condensate load.

So the lowest steam carrying pipe in the system must be at least **28** inches above the boiler water line. This dimension is called **Dimension A**.

B. System Types

1. **One-Pipe System** – one pipe feeds each radiator, handling both the steam supply and the condensate return. This pipe is near the bottom of the radiator.
 - One-pipe *gravity return* systems need an **air vent** near the middle of each radiator and a **main vent** near the end of the steam main and each riser.
 - One-pipe *pumped return* systems have air vents on the radiators like gravity return systems. But the ends of the steam main and risers need traps instead of vents. You'll usually find they have been fitted with float and thermostatic traps or thermostatic traps with cooling legs.
 - One-pipe *Paul* systems have a special Paul air vent and an air vacuum pump to quickly remove the air.
2. **Two-Pipe System** – two pipes serve each radiator—*steam supply and condensate return*. The steam supply pipe is near the top. The condensate return pipe is near the bottom.
 - Two-pipe *pumped return* and *vapor* systems use a **trap** on each radiator condensate line to prevent steam from passing through.
 - Two-pipe *gravity* systems have individual pipes from the radiator condensate lines to the system wet return.

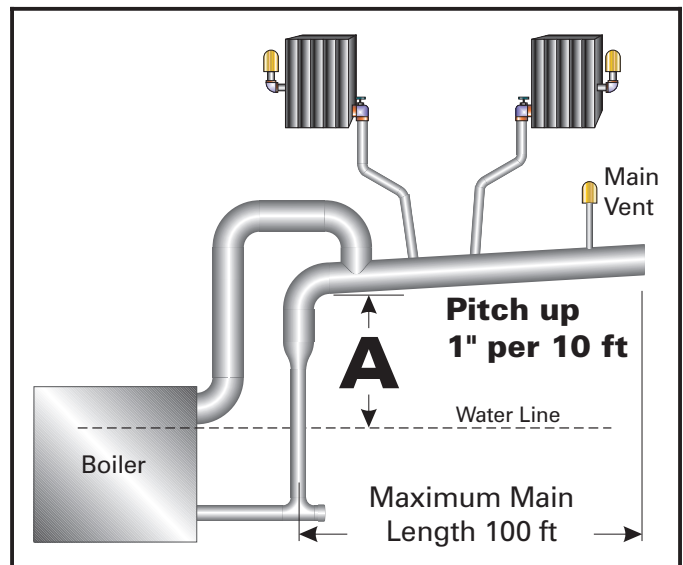


Figure 2: Counterflow System, Typical

Characteristic of a Counterflow Gravity Return System:

- Steam main pitched *upward*, away from boiler (minimum of one inch per 10 feet)
- Steam main *one size larger* than parallel flow header for same heating load
- No dry or wet return
- Condensate flows *against* steam flow
- Boiler steam line enters *top* of steam main

3. **Gravity Return System** – condensate returns to the boiler only due to gravity flow. A gravity return system works like a U-tube manometer. The pressure at the boiler is higher than at the end of the steam main. And the condensate loses pressure to friction as it flows through the returns. So condensate backs up into the return riser(s) until the weight of the water column is enough to balance the pressure difference and push the condensate into the boiler. See Figure 1.

Examples of One-Pipe Gravity Return Systems:

- Counterflow (Figure 2)
- Parallel Flow (Figures 3 and 4)
- Parallel Flow Upfeed (Figure 5)
- Parallel Flow Downfeed (Figure 6)

- a) Counterflow, Parallel Flow and Parallel Flow Upfeed systems all have a *steam main near the bottom of the system*.

- b) Parallel Flow Downfeed systems have a *steam main at the top of the system*. Steam is delivered to the branches through downfeed risers.

4. **Pumped Return System** – condensate is returned to the boiler with a *condensate unit, boiler feed unit or vacuum unit*. Pumped return is used on one-pipe and two-pipe systems.

5. **Vacuum System** – a vacuum pump pulls a suction on the condensate return lines, pulling air and condensate through and pulling a vacuum on the system. Vacuum systems are always two-pipe.

6. **Vapor System** – a two-pipe gravity return system which pushes air out and doesn't let it back in. This causes the system to drop to a very low pressure (from 0 to ½ psig usually) as the steam condenses in the radiation.

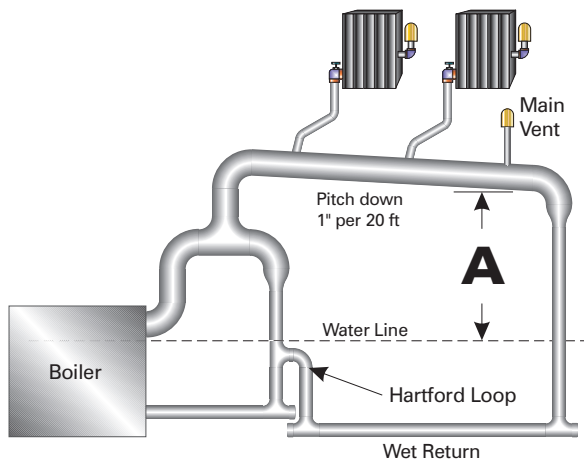


Figure 3: Parallel Flow Gravity, Wet Return

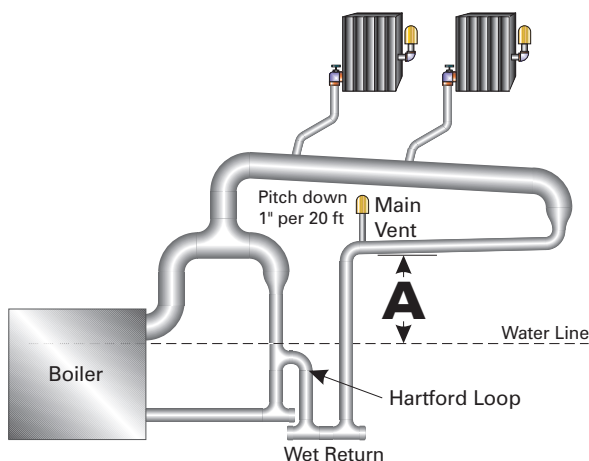


Figure 4: Parallel Flow Gravity, Dry Return

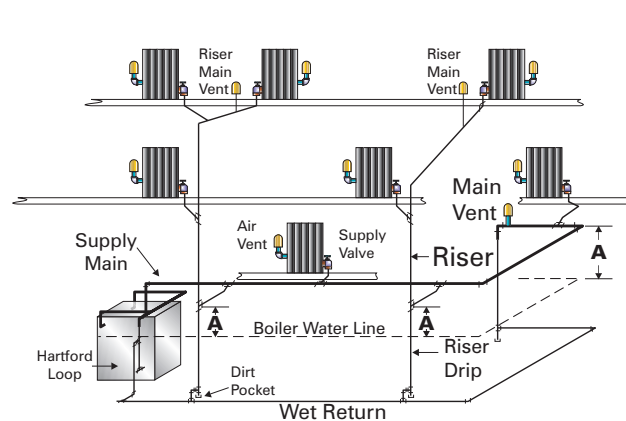


Figure 5: Parallel Flow Upfeed Gravity

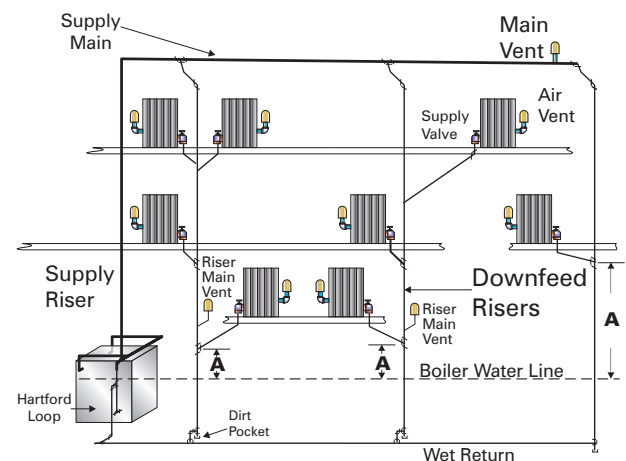


Figure 6: Parallel Flow Downfeed Gravity

Characteristics of Parallel Flow Systems:

- Steam main pitched downward away from boiler (minimum 1 inch per 20 feet)
- Condensate flows with steam, returning through risers to dry or wet return
- Steam main taken off top of boiler header between equalizer and last boiler riser

C. Gravity Return Systems

- Figure 1 shows how a gravity system works. The 28 inch dimension for the back-up of water in the returns allows for a system steam pressure loss of $\frac{1}{2}$ psig. Make sure to add additional height allowance if the system pressure drop is more than $\frac{1}{2}$ psig.
- The height of the lowest steam carrying pipe (main or branch) above the boiler water line is called **Dimension A**. Make sure that Dimension A is always at least 28 inches on a gravity return system. If it is less, condensate may back into the steam main or branches, causing water hammer, no-heat problems and boiler water level problems. Make sure you pipe the new boiler so this dimension is maintained.
- When a **zone valve** or **trap** is installed between the steam supply and the condensate return lines, there is no steam pressure downstream of the valve or trap when it is closed.
 - So **all** of the boiler pressure pushes backward on the return lines. This raises the condensate level about 30 inches for every psig pressure at the boiler. That would be 5 feet (60 inches) for only 2 psig at the boiler. Think what would happen if someone cranked up the steam pressure to 5 psig or more.
 - In such cases, the height of the lowest steam carrying pipe (main or branch) above the boiler water line is called **Dimension B**. Make sure Dimension B is at least **30 inches for every psi at the boiler**.
 - Figure 7 shows Dimension B for a One-Pipe Gravity System. Figure 10 shows Dimension B for a typical vapor system.

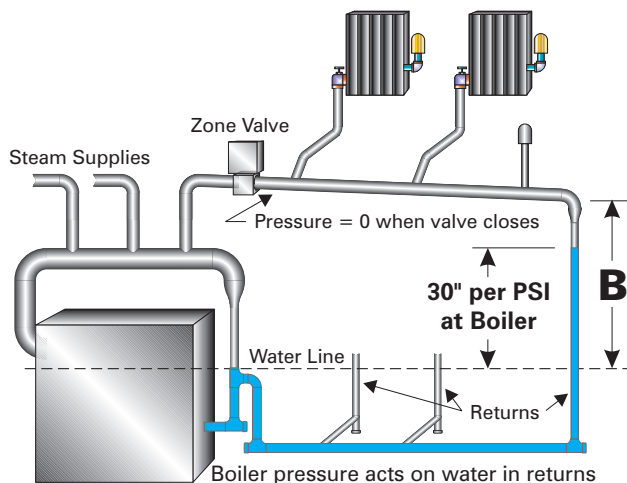


Figure 7: Dimension B – Result of Zoning or Using Traps on Gravity Systems

- One-pipe systems** and **two-pipe gravity systems** provide heat by pushing air out the radiators and steam lines through **air vents**. The air is pushed out during the heating cycle. After the boiler shuts down, the vents prevent a vacuum by allowing air to return.

- The steam main (and each riser) needs a **Main Vent** installed near the end. (*Never install the Main Vent on a tee at the end of the steam main. It will be quickly destroyed by water hammer. See Figure 12.*) Use smaller capacity vents on the radiators. Venting the radiators too fast will cause water hammer in the radiators because the condensate can't get out past the rushing steam.
- The air vents must be working for the building to heat properly. *The Main Vents on the steam main and risers are important for uniform heat in the building.* If they don't work, the radiator vents have to try to remove the air from the steam lines. This will cause the radiators near the boiler to heat much sooner than those further away. So some areas will be hotter than others. See Figure 12 for the correct location of the Main Vents.
- Set the **operating pressure** for a gravity return system as low as possible, usually around 2 psig or less at the boiler. The older steam systems were generally designed for this. And many air vents won't work correctly at pressures over 2 psig.

D. Pumped Return Systems

- Always install a **boiler cock** after the pump to allow reducing the discharge pressure to the boiler. Pumping at too fast a rate will cause spraying in a Hartford loop and can cause collapse of the boiler water level. The discharge pressure after the valve should be around 5 psig higher than the boiler operating pressure. Figure 8 shows a detail of the pump discharge piping.
- When pumping to **multiple boilers**, always provide a *separate feed for each boiler*. Otherwise, water levels won't be maintained correctly. Either use separate pumps or provide motorized or solenoid valves on the feed lines. When using valves, wire the valve to open when the boiler calls for water. Wire the valve end switch or a relay to operate the pump when the valve opens.

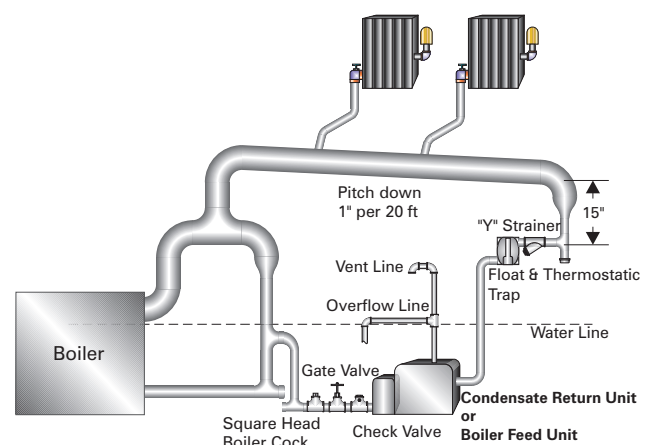


Figure 8: One-Pipe Pumped Return System

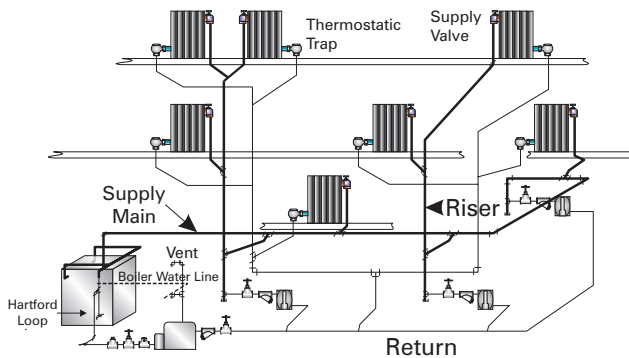


Figure 9: Two-Pipe Parallel Upfeed System, Pumped Return

3. Condensate Units

- Small receiver tank (usually one minute boiler steaming time) with one or more boiler feed pumps attached. The standard pump outlet pressure is 20 psig.
- Condensate unit pumps start when the level in the receiver tank rises. The pump is not operated by the boiler water level controls. *This is why you're always better off installing a boiler feed system instead if possible.*
- Make-up water is usually added at the boiler with a float-operated feeder control.
- Condensate units are not effective when pumping to multiple boilers. There is no way of setting which boiler will receive the water since the condensate unit only pumps based on the water level in its receiver.

4. Boiler Feed Units

- Larger receiver tank, usually sized for at least 15 minutes boiler steaming time (more if condensate return time is longer), with one or more pumps attached.
- Boiler feed unit pumps start on a call from the boiler water level controller.
- Make-up water is added at the feed unit receiver.

5. Vacuum Units

- A vacuum pump pulls a vacuum on the system through the condensate, supply and return lines, pulling both air and condensate.
- Air is eliminated through the receiver tank vent.
- Vacuum units can be either condensate unit type (operated by a float in the tank) or boiler feed type (pumping to the boiler on a call from the boiler level control.)

6. **Two-Pipe Pumped Return Systems** provide heat by pushing air through the *radiator, main and riser traps*, allowing steam to enter the radiators. The traps must be working for the air to be moved out through the condensate lines to the vent on the condensate or boiler feed unit. As steam condenses in the radiators, the condensate drains through the traps. When the condensate has drained and steam reaches the thermostatic element in the trap, the element expands. This closes the trap seat, preventing steam from entering the condensate lines.

7. The **main and riser traps** must be working for the system to heat evenly. If these traps let the air out of the steam lines quickly, all of the branch lines will receive steam at the same time. If not, the radiator traps have to do the job, causing radiators near the boiler to heat sooner than those further away. If the traps fail open, steam will pass into the receiver tank, causing high condensate temperature. This will cause cavitation in the pump impeller, damaging the pump.

8. Traps which **fail open** on two-pipe systems allow steam to pass into the condensate lines. Steam in the returns causes hammer and damage to other traps. It also pressurizes the condensate lines. This eliminates the pressure difference across other traps and prevents them from moving air and condensate out of their radiators. The radiators won't heat.

Traps which **fail closed** allow condensate to accumulate, resulting in water hammer, no-heat problems and boiler water level problems (since the condensate can't get back).

9. **Thermostatic traps** are used on radiators. They have a thermal element which expands to close the trap when exposed to steam temperature. They release condensate at 10° to 30° F below steam temperature. So thermostatic traps also work well for drip lines if piped with at least a five foot cooling leg ahead of the trap.
10. You'll find **Float and Thermostatic Traps** on most drip lines and heat exchanger drain lines. They contain a thermostatic element for rapid movement of air and a float mechanism for handling condensate. Because they are float-operated, the condensate can drain at steam temperature. Float and thermostatic traps are effective under varying or light condensate rates.
11. Water hammer will damage most *thermostatic traps* and *float and thermostatic traps*, though heavy duty hammer resistant traps are available.
12. Where water hammer is likely, **Bucket Traps** are often used. They have a more rugged construction. Bucket traps are less effective at removal of air and must be manually primed. They can also lose their prime under light loads, allowing live steam to pass through.

E. Vapor Systems

1. Characteristics of Vapor System:

- System designed to run at very low pressure or vacuum
- Usually includes a *Boiler Return Trap* (or Alternating Receiver or Differential Loop) and *Air Eliminator Trap*. See Figure 10.

2. A **Vapor System** is a special type of two-pipe steam system. The Air Eliminator Trap is designed to let the air out. The air check valve on the trap vent prevents the air from returning. As steam condenses in the radiators, a low pressure develops in the system.
3. Vapor systems need a special boiler pressure control called a Vaporstat. This control has a very low range, allowing accurate setting of the pressure and preventing setting the pressure too high for the system.
4. Operating a vapor system at too high a pressure can cause blow through on loop seals and overheating (since the radiators were sized for low temperature steam.)

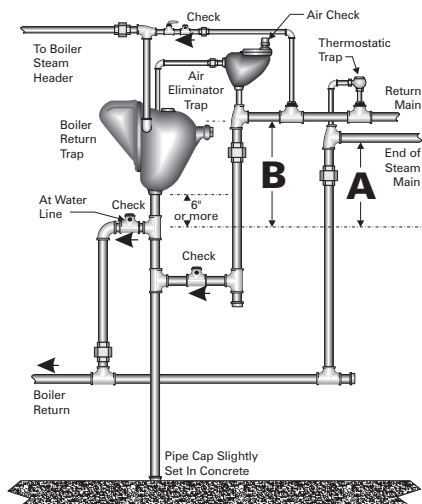


Figure 10: Typical Vapor System Boiler Return Trap and Air Eliminator Trap

5. Vapor system radiators are equipped with special traps on the condensate lines to prevent steam from passing through. Some vapor systems also use orificed radiator supply valves. The orifice is sized to allow slightly less steam through than the radiator can handle. This makes sure all the steam condenses so it can't pass through to the condensate line.
6. Because the radiators have traps on the condensate lines, the pressure difference between the condensate line and the boiler is usually too much for gravity return to overcome. The **Boiler Return Trap** compensates for this. When the condensate backs up high enough to lift the boiler return trap float, a valve opens to allow steam pressure from the boiler to balance the pressure in the trap chamber. This allows condensate to flow into the boiler by gravity. When the condensate flows out the float drops and the cycle starts again.
7. The Boiler Return Trap is essential to the operation of a vapor system. Always replace it with the same thing. The only alternative is to repipe the returns, install thermostatic traps on all the radiators, drip traps on the steam main and risers and install a condensate unit or boiler feed unit.

F. Installation Checklist

☐ Check the **System History**

- If the system has a history of **no-heat problems**, check the air vents or traps to make sure they're working. Some of them may need to be replaced. The Main and Riser vents often fail due to water hammer because of being piped too close to the ends of mains or dry returns. See Figure 12.
- If the system has a history of **water hammer**, check the pipe slopes and check for sags in the steam piping or concentric reducers. Also make sure drip traps are working. Also check to see if insulation has been removed from steam piping and not replaced.

- Find out whether there has been a history of **leaks in the system**, particularly in the condensate lines. If the old boiler failed due to oxygen corrosion there is a good chance the system was leaking.
- Use the **troubleshooting guide** in the complete installation manual as an aid to locating problems. This is a chance to let the owner know that just changing the boiler won't fix the whole system.

☐ Check the height of the new **Boiler Water Level** compared to the old boiler.

If new boiler water level is **Higher**:

- **Parallel flow gravity systems** – make sure that the distance from the new water line to the lowest steam carrying pipe (Dimension A) will be at least 28 inches. If Dimension A is less than 28 inches, you may need to install a condensate unit or boiler feed unit plus a float and thermostatic trap at the end of the main and all riser drips. See Figure 8. On some systems, less than 28 inches may work, but the risk is that condensate will back into the main or branches and cause water hammer or lack of heat.
- If a gravity system is fitted with **traps or zone valves**, the minimum height difference from the boiler water line to the lowest steam carrying pipe is 30 inches per psig at the boiler. Set the boiler operating limit only high enough for the steam to reach the last radiator.
- **Vapor systems** – make sure the distance to the Boiler Return Trap is still high enough for condensate to return by gravity. The height from the boiler water level to the bottom of the trap should be at least 6 inches.
- **Pumped return systems** – check new water line against overflow line on receiver vent piping. Some vent lines include an overflow tee at the boiler water level.

If new boiler water level is **Lower**:

- **Parallel flow gravity systems** – check the height of the lowest dry returns. If any part of a **gravity return** wet return line will be above the new boiler water line, mount the boiler on a pedestal if possible to obtain the correct height. If this can't be done, install a false water line (Figure 11) in order to completely cover the return. Otherwise, water hammer will occur in the return.
- **Vapor systems** – water level must be at least as high as the loop seal pipe at the end of the main. Elevate the boiler base if needed for this loop seal to be below the boiler water line. If the loop seal is exposed steam will pass through to the returns, causing water hammer and no-heat problems.

☐ Check the system **Condensate Return Time Lag**

- If the old boiler is still operational, time how long it takes for the condensate return line to begin warming when the boiler is started from a cold system. This is the **Condensate Return Time Lag**. If the time lag is over 15 minutes, you will probably need to install a boiler feed unit. The storage receiver on the feed unit would be sized to be at least the time lag (minutes)

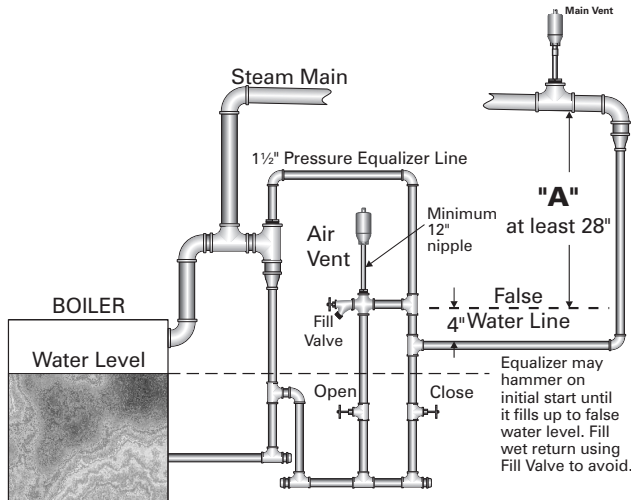


Figure 11: Installing False Water Line to Submerge Returns When New Boiler Water Level is Too Low

times the boiler steaming rate (GPM) times 1.33 (to allow for the unused storage in the receiver).

- **Always use a boiler feed unit when possible.** Boiler feed units compensate for large or slow returning systems by providing the water the boiler needs until the condensate begins to return. Condensate units and gravity return systems can't do this. If the boiler doesn't have enough water content to steam until the condensate returns, make-up water will be added. This will cause flooding and oxygen corrosion (because of the oxygen carried in by the fresh water).
- If you decide to convert a gravity system to pumped return, make sure you can place traps in all the places needed—radiator traps and drip traps on mains and risers.
- If the old boiler is not operational, make a judgment on the size of the system and how long it will take for the condensate to come back. When in doubt, recommend a boiler feed unit to the owner. A boiler feed unit is always preferred because it responds to the needs of the boiler.

Check the System Piping

- Check **steam lines, runouts and branches for right amount of pitch.** Lines need to pitch in the direction the condensate is supposed to flow. If they don't, water hammer and no-heat problems may occur. On counterflow systems, the pipes must pitch back toward the boiler. On parallel systems, the lines must pitch toward the returns.
- **Check steam lines for sags.** Sags allow water to pocket, causing water hammer when the system starts up.
- Make sure there are **no concentric reducers** in any steam lines except where the pipe size is increasing. Concentric reducers cause water pocketing and water hammer when used in the wrong places.

- The **steam lines must be insulated.** If the insulation has been removed in the past it should be replaced. Uninsulated steam lines cause heavy condensate loads due to heat loss from the piping and can cause hammer on shutdown due to momentary vacuum in the lines. The extra steam and condensate loads can also cause boiler water level problems and overfilling of the system.
- **Check wet returns for leaks.** The wet return lines are usually corroded worse than any other part of the system because acidic water constantly lays in the pipes. If the returns are leaking, recommend replacement of the piping to the owner. If the old wet returns were buried, you may need to run new dry returns. Make sure Dimension A will be at least 28 inches (to the lowest part of the dry return).
- If you leave leaks as is, make-up water will constantly be added to the system. This will risk liming and oxygen corrosion of the boiler and result in a short boiler life.

Check Air Vents and Traps

One-Pipe Systems – Check Main, Riser and Radiator Air Vents

- The steam main piping Main Vent is often piped at the very end of the main on a tee. This can lead to quick failure of the vent due to water hammer at the end of the steam main. **Figure 12 shows the correct way to install the Main Vent to be sure it will last.**
- Make sure the **riser vents** (at tops of risers on upfeed systems; on lower part of risers on downfeed systems) are working. These should be high capacity vents like the Main Vent on the steam main piping.
- Check **radiator air vents.** They must be working for the radiators to heat correctly.
- Make sure the **radiator supply valves** on one-pipe systems are fully open. One-pipe radiators cannot be regulated by closing down on the radiator supply valve because this will cause water hammer in the radiator since condensate has to flow back through the valve against the steam flow.

Two-Pipe Systems – Check Main and Riser Drip Traps

- The steam main and risers are usually provided with **drip traps**, most often float and thermostatic traps. Thermostatic traps may also be used, piped with a cooling leg at least 5 feet long on the trap inlet.
- The drip traps serve to remove condensate from the main and risers and to allow air to pass on the start of the heating cycle and return at the end of the cycle.
- A **drip trap on the steam main or return main** needs to be installed as shown in Figure 13. The piping ahead of the trap provides a column of condensate high enough to be sure the trap will drain the condensate even with no pressure on the steam line. This prevents condensate from backing up in the horizontal pipe and causing water hammer.
- Riser and main drip traps are important in the quick removal of air from the steam lines. They assure that all radiator branches receive steam at the same time.

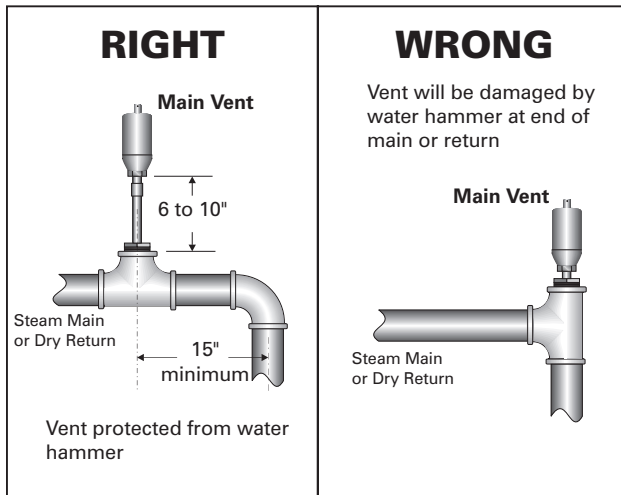


Figure 12: Correct Piping of Main Vent to Prevent Water Hammer Damage

- **Vapor systems** – check the thermostatic trap between the end of the steam main and the return main. This trap allows air to flow to the condensate return line and out the Air Eliminator trap.

Two-Pipe Systems – Check Radiator Traps

- **If any radiator traps have failed open**, steam can enter the condensate lines. This will cause a no-heat problem on radiators higher in the system because the pressure in the condensate lines prevents the other traps from passing air and condensate.
- If radiator traps need to be replaced, **all defective traps should be replaced at the same time, and with the system cold**. Otherwise, the new traps could be damaged by water hammer caused by steam passing into the returns.
- Bear in mind that the radiators that aren't heating may not have defective traps. Their traps may just be prevented from working because traps lower in the system are allowing steam to enter the condensate lines. When a trap fails open, its radiator usually heats, but other radiators above it don't.
- Thermostatic traps can be tested by checking the temperature of the condensate line after the trap. The outlet temperature of a thermostatic trap should be at least 10° F cooler than the steam. If the outlet of the trap is too hot, either the trap tested is bad or one near it is bad. This temperature method can be done with thermal markers (such as Tempilstiks). This method may work in most cases, but the best way to test the trap elements is in a separate testing station. The stations can be piped off the steam line in boiler room.

☐ Check the **Pump Unit** (Condensate, Boiler Feed or Vacuum)

- **Make sure the pump is working and that the pump seals are in good condition**. Leakage at the seals will cause make-up water to be added to the system.

- Defective traps can result in damage to any pump. Steam in the condensate lines causes high temperature condensate, which flashes in the pump impeller, causing cavitation. This will quickly erode the impeller blades and destroy the pump.
- Check the **return line** leading to the receiver. It must be sloped downward to the receiver with no sags or rises. Anything which will allow water to sit in the lines will prevent air from being pushed into the receiver and out the receiver vent line. This can also cause water hammer in the return.
- Check that the **vent line** is installed and open to the atmosphere on condensate units, boiler feed units and vacuum units. Their receivers are not designed to be pressurized.

☐ Plan the **Near-Boiler Piping** and its connection to the steam main

- The boiler steam header must be at least **24 inches** above the normal boiler water line (center of the gauge glass).
- On boilers with multiple risers, **the system steam take-off(s) should be between the last boiler riser and the equalizer line**. When the piping is installed correctly, as shown in Figure 14, water is separated from the steam as the steam turns up into the take-offs. The figure also shows how water pools under the take-off if it is between the boiler risers, causing water carryover to the system.
- Use the number of risers off the boiler in the locations shown in the manual. **Reducing the number of risers or incorrectly placing them will cause the water level to be sloped inside the boiler**. This can cause overheating of the sections and result in cracks.

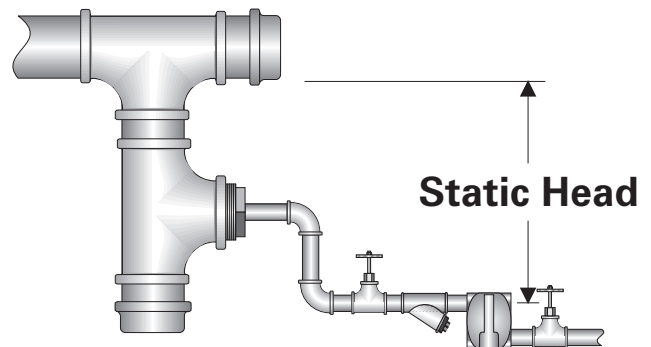
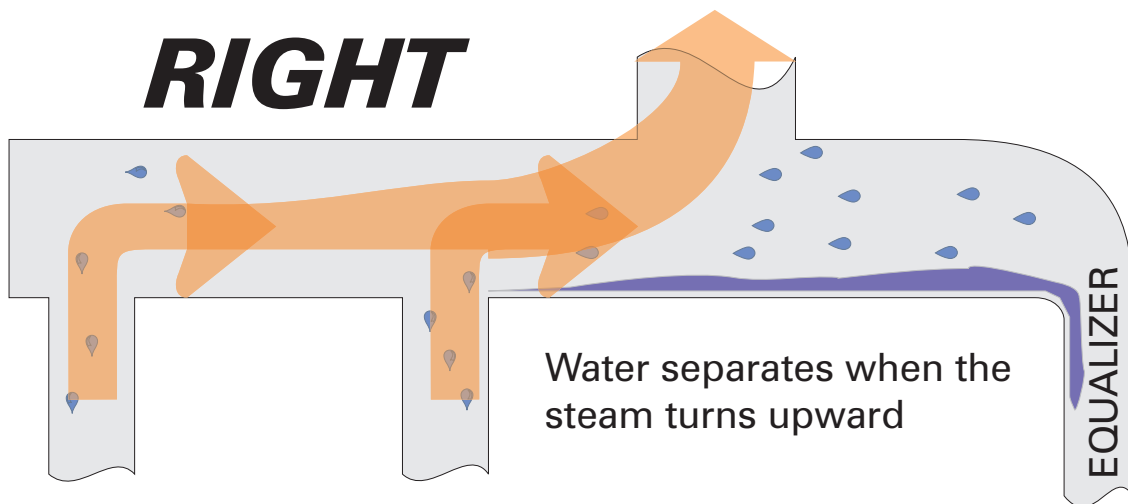


Figure 13: Piping a Drip Trap on the End of a Steam Main

- **The boiler header must be offset to provide swing joints.** The swing joints prevent the expansion and contraction of the header from damaging the boiler.
- Size the boiler equalizer line as recommended in these instructions. This assures the most stable water level possible and prevents water from spraying up into the header.
- We recommend the use of a Hartford loop even on pumped return as an added precaution against water leaking back through the check valve into the receiver tank. The equalizer sizes recommended should be adequate for pumped return, provided the pump rate is not excessive.
- **The near-boiler piping must be done as shown in these instructions.** This piping is designed to assure dry steam is provided to the system. Undersized pipes and steam take-offs in the wrong locations can cause large amounts of water to be carried into the system (Figure 14). The result would be water hammer and damage to system traps and vents. It will also cause make-up water to be added to the system due to frequent low water conditions in the boiler.
- **Vapor systems** – the **two check valves** below the Boiler Return Trap are essential to the system. They must be piped as required for the system and must be working correctly. Maintain the correct positions of the Boiler Return Trap and Air Eliminator Trap relative to the boiler water line.



HEADER CONNECTIONS FOR MULTIPLE BOILER RISERS

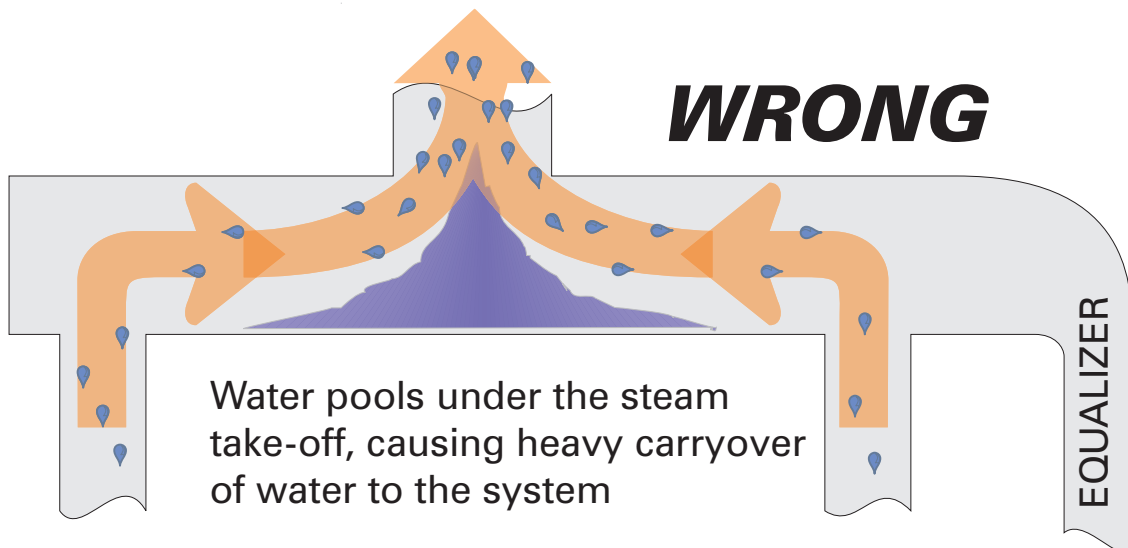


Figure 14: Location of Steam Take-Off on Multiple Riser Boiler

Steam Survey

Hydronic Systems

Pre-Installation Survey and Checklist for Steam Systems



Mixed Sources
Product group from well-managed
forests and recycled wood or fibre

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