Some Problems in Large Building Heating Systems

Steam Vents Out of the Condensate, Vacuum Pump Vent, or Boiler Feed Pump Receiver

See the drawing "Subatmospheric Steam Heating System with a Hot Water Generator and Storage Tank" on page 28. Each system has a separate steam supply and condensate return piping. Steam supply to both systems comes from a pressurized source, either a boiler in the building or a steam source from another location. Steam pressure is supplied at 10 pounds of pressure; 10 pounds of steam pressure is supplied to the inlets of the hot water temperature regulator and the zone valve. Both valves are sized to supply the proper EDR or pounds of steam per hour to heat the building and make hot water. Because both valves are sized properly, the valves may be smaller than the pipe that supplies them steam. Sometimes, the valves are line size, but the seat and disc of the valve will be smaller in diameter. Both the zone valve and temperature regulator restrict the steam volume, and as a result, the steam pressure after the valves can be less than 10 psig.

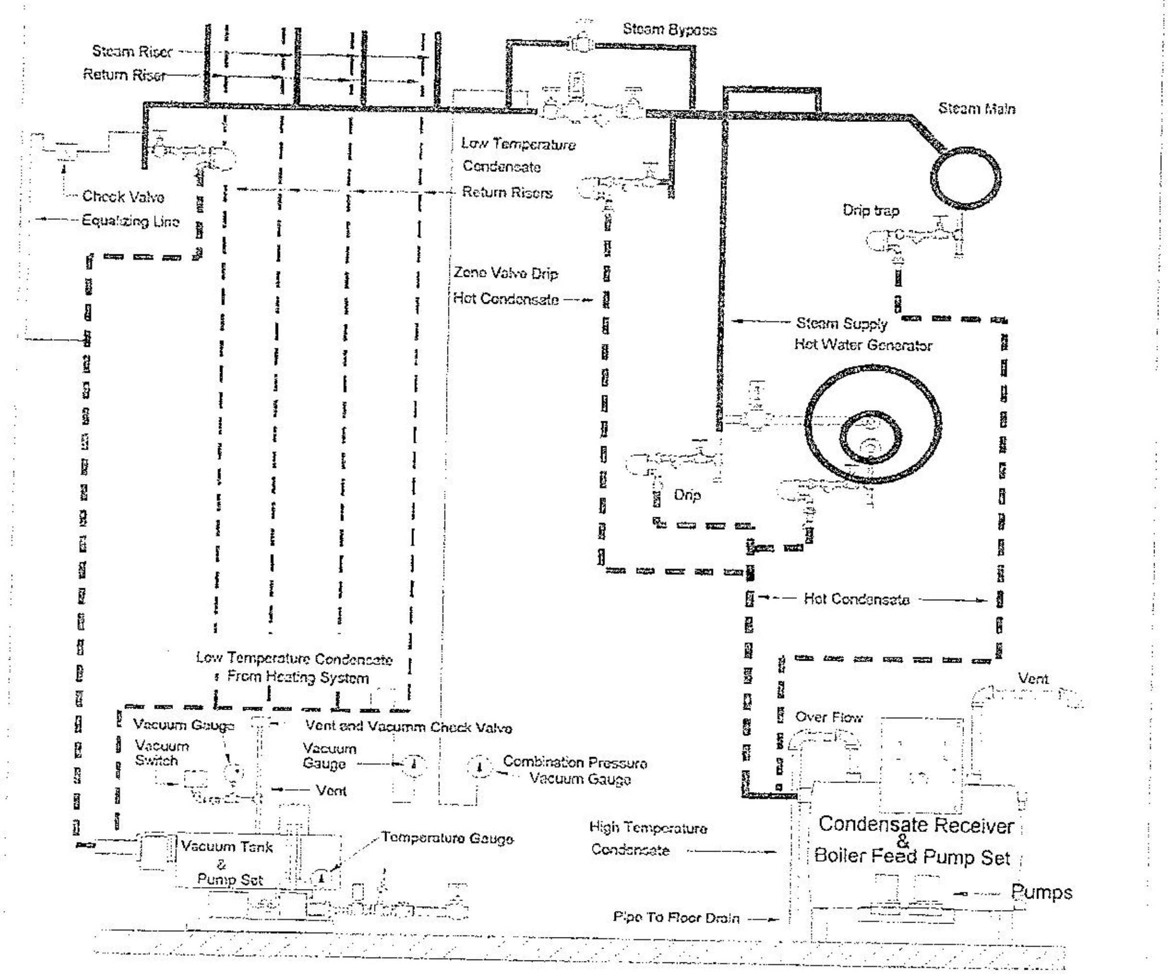
Zone valves for subatmospheric heating systems are sized to supply the EDR needed to heat the building. Heating control panels open, close, or modulate a zone valve to maintain a set temperature in the building. When all the controls work properly, the steam pressure to the heating system will not exceed 2 pounds of steam pressure. The temperature regulator supplies steam to the coils at a pressure lower than 10 psi.

Condensate from the steam main drips lines and the hot water generator steam supply drips will be discharged close to steam temperatures. Condensate from a properly-designed and maintained subatmospheric steam system will be less than 160 degrees Fahrenheit.

The vacuum tank and pump set collects all returning condensate from the heating system and a separate condensate tank should receive the hot condensate from the 10-pound pressurized steam piping and the hot water generator.

In the drawing below, a single steam main supplies steam to two separate steam systems, a subatmospheric steam heating system and a steam-fired domestic hot water generator. Let us use this drawing as a reference and do a little troubleshooting.

Sub Atmospheric Steam Heating System & Hot Water Generator



1. Steam exits the condensate receiver:

Some steam, water vapor, or minor puffing is often visible at the vent from a condensate receiver; these wisps of steam do not suggest a problem. When copious amounts of steam exit the vent, one or more steam traps are passing steam. To correct this problem, check the four float and thermostatic steam traps at the 10 psig steam supply pipes. Additionally, check all the steam drips found at the steam mains, zone valve, steam supply to the hot water generator and inspect the check valve at the equalizing line.

2. Steam exits the atmospheric vent of the vacuum tank:

Steam exits the vacuum tank vent pipe when heat is supplied to the building. In a properly-controlled system, the vacuum pumps operate when the zone valve is open. Some steam or water vapors will always be present at the vent from the vacuum tank. This happens because the vacuum pumps remove system air continuously, and as a result, visible water vapors are expelled with the air.

Let us assume that the heating system operates at a vacuum of 15 inches Hg. At 15 inches Hg, the temperature of steam is about 179 degrees. Typically, condensate leaving a steam trap is about 169 degrees and it drains down the uninsulated return risers and return mains. The cool, uninsulated return pipes in basements or pipe chases where the ambient air temperatures could be less than 70 degrees cools the hot waters of condensation. As the cold piping heats up, it will remove much of the latent heat in the hot condensate water. The condensate can return to the vacuum tank at temperatures as low as 110 degrees F. During the pump's operation, a slight vacuum occurs at the eye of the impeller; some water is hurled out of the pump volute as a vapor and is discharged with damp system air from the vent as hot water vapor.

Do not start to look for defective steam traps until the condensate accumulator temperature gauge is read. Here is the reason: vacuum tank and pump manufacturers design and build these units at this specification. The vacuum tank and pump sets pumps and will pump _fill in before ordering a pump set__ gallons of water per minute. Can exhaust _fill in before ordering a pump set______cubic feet of air per minute and produce a vacuum of 5½ inches Hg when the temperature of the condensate water is 160 degrees Fahrenheit. Based on this specification, we know that the zone valve may be at or near fully open. When a zone valve is at a low valve opening, less steam enters the piping. System condensate is at low temperature and the vacuum in the system will be deeper. When the stored condensate in the accumulator rises above 160 degrees, some steam traps may be defective; as a result, steam will enter the return piping.

Several hundred radiator traps may be installed in a large apartment building. Checking for defective radiator traps in each apartment is time consuming and expensive. First, check for defective float and thermostatic steam traps. If none are found leaking, check for very hot radiator return risers. Hot return risers suggest that steam traps on some radiators are leaking steam into that riser. Once a hot return riser is found, check for leaking traps in each apartment. All defective radiator traps must be repaired or replaced. Leaking steam traps can cause high condensate water temperatures. High return water temperatures lower a vacuum pump's ability to produce a vacuum in the system. The combination of defective traps and poor vacuum lowers system efficiency and will cause an increase in fuel consumption.

Troubleshooting a Subatmospheric Steam System

Subatmospheric steam heating systems have the same problems as one- or two-pipe steam systems. The following problems occur in vacuum systems:

1. Banging in radiators:
   Banging in radiators is caused by a radiator being improperly pitched or back pitched, a defective steam trap, scale blocking the outlet of the radiator, or retained condensate flashing into steam.
2. Banging in return lines:
   Banging in the return line is caused by a defective steam trap, allowing steam to enter a back pitch or waterlog the return.
3. Banging at the start of a heating cycle:
   Banging occurs at the start of a steam cycle when condensate water is retained in the steam main and the steam main is in a higher vacuum than the return piping, or the steam piping is not properly pitched or sagged.

How does the vacuum in the steam side of the system become greater than the vacuum in the return side of the system? When a zone valve closes, steam in the steam piping condenses. Steam occupies 1,700 times the space of water. As the steam condenses, a vacuum is formed. That vacuum can become greater than the vacuum in the return line. If a subatmospheric system does not have an equalizer between the steam and return piping, the steam main can develop a higher vacuum than the return side of the system.

In the drawing on page 210, find the equalizer piping. Look at the check valve. This check valve may be locked or broken. The function of the check valve is to prevent steam from entering the return and allow the steam and return sides to equalize. In nature, everything tries to be in balance. When an equalizer is installed in the system, the greater vacuum in the steam side of heating system will cause the return piping to go into a deeper vacuum. The vacuum will increase in the return until both the steam and return sides of the heating system are in balance. Once they reach equilibrium, a no-flow condition (no differential exists) will occur. Equalization of both sides of the system permits all condensate in the steam piping to drain by gravity. When all the condensate drains out of the steam piping, banging will not occur at the next heating cycle.

1. Banging during a heating cycle:
   Banging during a heating cycle happens when some steam traps are defective and steam enters the return piping, or the vacuum in the steam piping is greater than the vacuum in the return.
2. Building does not heat:
   1. The heating control panel is not set properly or is defective.
   2. The zone valve linkage is not adjusted properly.
   3. A zone valve does not open.
   4. The boiler or source that supplies steam is off-line.
   5. A steam shut-off valve is not fully open or is closed.
   6. A main return valve before the vacuum pump is closed; the inlet strainer to the vacuum pump is clogged or the pumps are off-line.
3. Building overheats:
   1. A temperature control panel is set too high or is set to keep the zone valve in a fixed open position.
   2. A zone valve is hung open or passes steam due to a defective seat or valve plug.
   3. The seat and disc in the zone valve leaks profusely.
   4. A bypass valve is open.
   5. Many radiator steam traps failed in the open position.
4. Heating is uneven:
   1. Some radiator steam traps failed in the open position.
   2. Zone valves operate erratically.
   3. The differential pressure between the steam side of the system and the return side of the system is erratic due to defective steam main steam traps or the vacuum pumps are not operating properly.
5. A vacuum tank has a hole in it, gaskets on the vacuum tank leak, or the vacuum high or low switch is defective or set wrong.
6. The return piping has many leaks, causing a low differential in pressure or no differential is present between both sides of the system. Remember, the differential pressure between the return and steam side of the system should be 2 to 4 inches of mercury. A deeper vacuum must be present at the return side of the system when the heating system is operating in a vacuum.
7. Fuel bills are high:
   1. The temperature controller is set too high.
   2. Many steam traps are leaking.
   3. Insufficient or no vacuum is present, or the steam system is always pressurized.
   4. A bypass valve is open.
   5. A zone valve leaks when it is closed.
   6. The vacuum pumps operate erratically.

8. System takes a long time to heat:
   1. There is insufficient steam pressure at the inlet of the zone valve.

   Zone valves are sized by the steam inlet pressure. Most zone valves need 5 or 10 pounds of steam pressure at the inlet to supply the needed pounds of steam per hour to heat the building properly. Sometimes, the steam pressure to the building is a bit low. When the hot water generator draws steam to heat large amounts of water, the steam pressure to the zone valve may drop below the steam pressure needed at the zone valve.
   2. The basement is very cold because of broken windows or open exterior doors.
   3. The steam piping is not insulated.
   4. Water is retained in the steam main and the steam traps cannot discharge the water fast enough.
9. Parts of the building do not heat:

   Usually, this happens because of problems at the steam or return risers.
   - A. Water collects at the base of a steam riser.
   - B. The base of a return riser is blocked by rust or scale, where the removal of air and condensate water becomes retarded or is nonexistent.
   - C. A return riser has a bad leak. A bad leak on a return riser allows air to enter the piping. When air enters a return riser, it will lower or eliminate the differential between the steam and return risers. When the pressure differential between the steam and the return risers equalize, steam will not flow. Steam will flow only when the zone valve opens more and the steam pressure increases in the steam piping. A greater pressure in the steam piping causes a differential between the steam riser and return riser.
10. Poor circulation:
    1. There is low vacuum or low pressure differential.
    2. Water is retained in the steam piping.
    3. Many steam traps are defective on one side of a building.
11. Pressure gauges do not read pressure:
    1. The pressure gauge is broken or the pipe to the gauge is obstructed.
    2. There is no steam pressure.
12. A vacuum gauge does not read the vacuum:
    1. A gauge is broken or the piping is plugged.
    2. The vacuum pumps are off-line.
    3. A return pipe is leaking.
    4. The vacuum tank leaks and cannot hold a vacuum.
    5. An air check on the vacuum tank is defective or was removed.
    6. The vacuum pumps do not discharge the condensate and the condensate tank is flooded.
    7. An inlet valve to the vacuum tank is closed or the strainer is plugged.
13. A combination pressure vacuum gauge shows pressure:

    The zone valve is open more than 50% and the system is in pressure. This condition happens on very cold days or when the zone valve is defective or set to manual open.
14. Radiators do not heat properly:
    1. The radiators are back pitched.
    2. A steam trap is broken in the closed position.
    3. A steam supply valve is not full open.
    4. The steam supply valve is plugged with dirt. If this valve has an orifice, dirt can be blocking the orifice and restricting the steam to the radiator.
    5. A leak occurred in the radiator and air enters the radiator when the system operates in a vacuum.
    6. The radiator is too hot. This is caused by a broken steam trap held in the open position or too much steam is being supplied to the heating system.

15. Radiators gurgle:
    The radiator does not have enough pitch or is back pitched, causing water to be retained in the radiator.
16. Steam riser is slow to heat:
    1. The return line has a leak in it.
    2. A riser valve may be partially open or closed.
17. Water is sucked out of the vacuum pump accumulator into the return piping or water is retained in the steam main. This condition happens when the vacuum at the steam side of the system is greater than the vacuum in the return side of the system.
    1. The check valve on the equalizer is broken in the closed position.
    2. An equalizer line was not installed.

Low Pressure Steam Systems Supplied by High Pressure Steam

Contents: Drawing of reducing stations

Flash tanks

Flash steam

Float and thermostatic steam traps

Pressure-reducing valve problems

Thermodynamic steam traps

Types of pressure-reducing valves

Problems That Occur in Low Pressure Steam Systems Supplied with High Pressure Steam

High pressure steam is used in factories, process plants, office buildings, and very long buildings where the cost of installing low pressure steam piping is too expensive. Additionally, some large buildings or multiple dwellings were built without boiler plants and steam is purchases from a utility or private company. Often, steam supply from the remote boiler plants is produced at high pressure and transmitted via underground piping to pressure-reducing stations in the building.

These buildings have one thing in common: the steam pressure to the heating system has to be lowered to 10 pounds pressure or less. To do this, steam regulators and pressure-reducing valves are used.

Depending on the type of system and steam supplied equipment, one- or two-step steam pressure-reducing stations are needed. The area where the reducing valves are installed is called a steam pressure-reducing station. Steam pressure-reducing stations or steam pressure-reducing systems comprise of these parts: steam supply shut-off valves, strainers, possibly a steam meter, pressure-reducing valves, gauges, and condensate drip traps. Other equipment needed to handle condensate from the high pressure steam side of a system and condensate from the building are strainers, steam traps, flash tanks, high temperature condensate pumps, condensate cooling stations, economizers, and, in some buildings, a condensate transfer station or a condensate receiver and boiler water feed pumps.

The most important thing to remember is that ***the entire high pressure steam system and ancillary equipment is an engineered system.*** These systems should never be altered without a professional engineer and the approval of the local or governmental body that has the code jurisdiction.

High pressure steam valves, regulators, pressure-reducing valves, combination temperature- and pressure-reducing valves, pumps, flash tanks, steam traps, and other ancillary equipment come in many sizes, varieties, and shapes. To have a better understanding about these systems, we need to recognize what these items look like. Reproductions of some items will appear on the following pages.

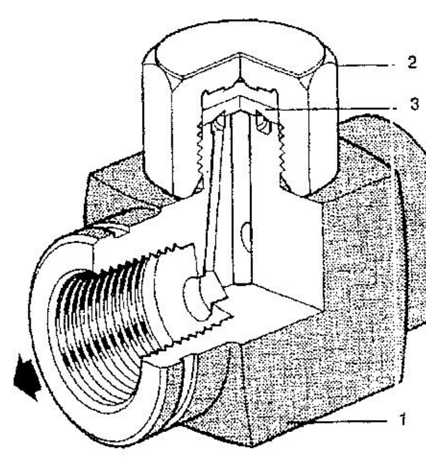
Two manufacturers of regulators, valves, pilots, and vents were selected. I chose Spirax/Sarco and Spence because I installed, serviced, and maintained the equipment they manufacture. Additionally, I attended seminars at their factories and plants.

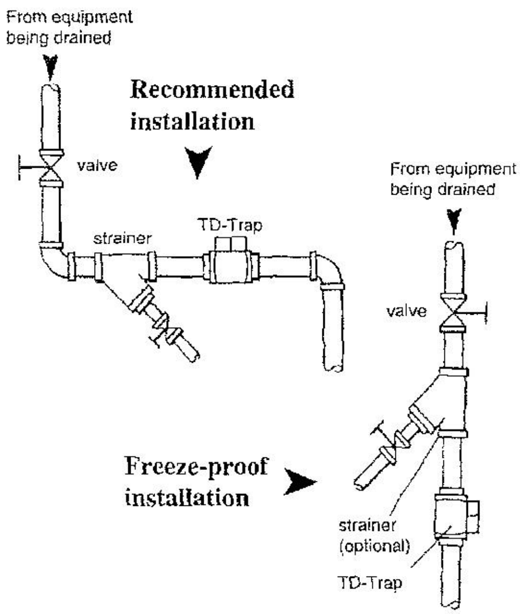
TDLC thermodynamic steam trap is manufactured by the Spirax/Sarco Company.

For educational purposes only, one-style trap is shown. The sketch lists the materials and the parts of the steam trap. Thermodynamic steam traps come in many different shapes and are used as condensate drip traps at reducing valve stations and building entry points or low points on high pressure steam piping. These traps operate from 3.5 to 600 psig. Before selecting any steam trap for an application, always check the trap's maximum operating pressure, temperature, and its capacity to drain condensate.

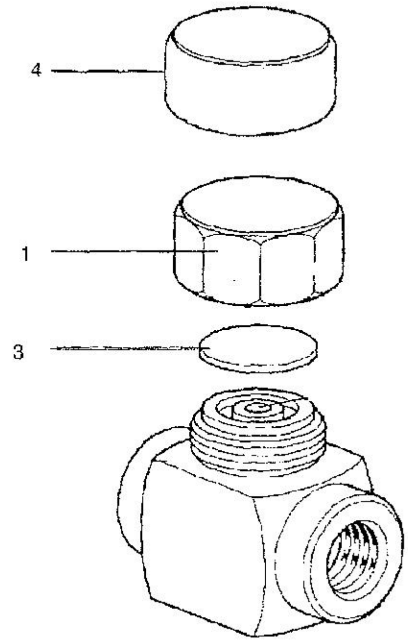
The **thermodynamic steam trap** cycles periodically to discharge condensate very near to steam temperature. It is unaffected by waterhammer or superheat.

Model ⇨	TDLC
PMO	300 psig
Sizes	1/2"
Connections	NPT
Construction	Stainless Steel
Options	BSP connections Insulcap



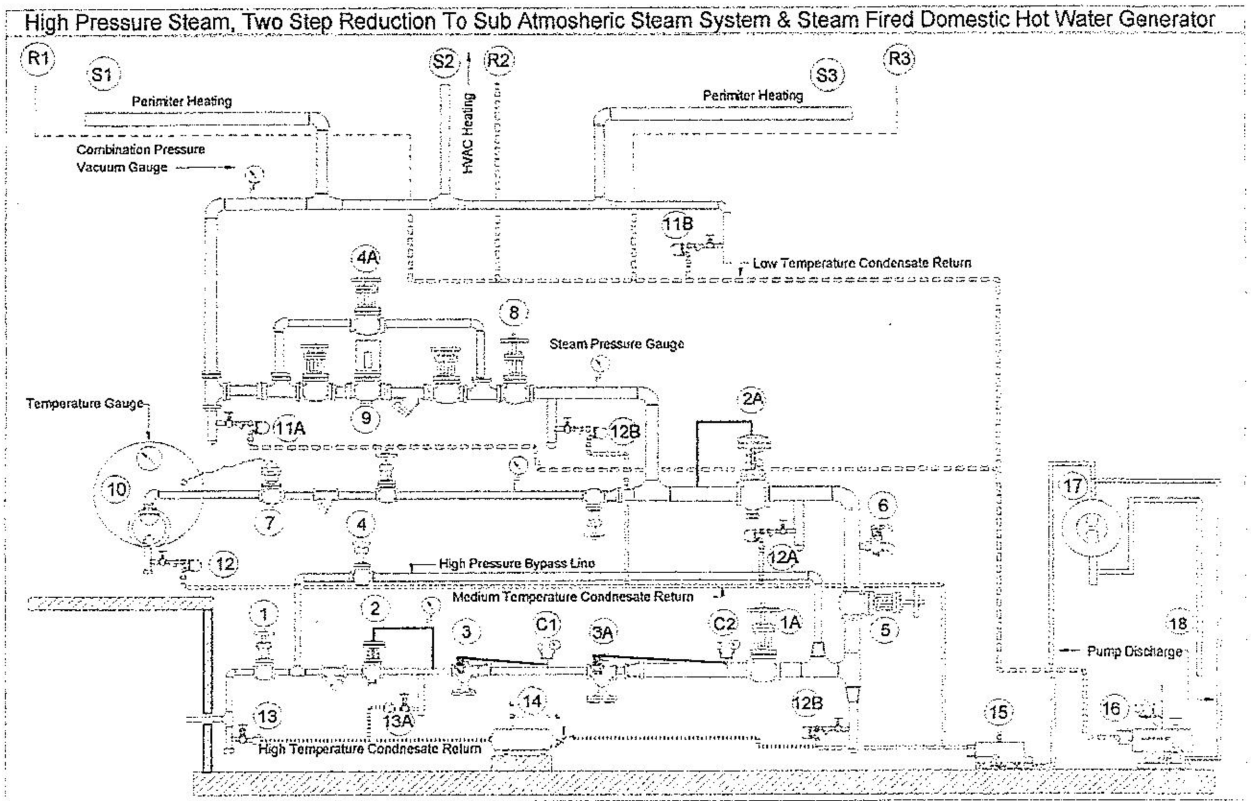


SPARE PARTS



Disc	3
Cap	1
Insulcap	4

Simplified Low Pressure Steam System Supplied by High Pressure Steam



This drawing shows a single-stage two-step reducing station and the application of pressure regulators, temperature regulators, zone valves, steam-fired hot water generators, flash tanks, heat recovery equipment, steam traps, safeties, and valves. Although the drawing appears complex, it is a basic system showing one regulating station with electric safety protection. Systems such as these must be designed by professional engineers and may need approval from local regulatory agencies.

Minimally, all high pressure steam piping greater than a 2-inch pipe should be welded. Some engineers or governmental authorities may require magna flux or X-ray testing of some or all of the welded joints. All equipment and pipe must be rated for use in high pressure steam. All pipes, equipment, welding rods, and welding procedures must conform to ASME, ANSI, and code requirements.

Numerical Guide

1. Main steam stop, 250-pound steam rated gate valve
   1A. A primary house shut-off 250-pound steam rated gate valve
2. A normal open external diaphragm spring-loaded pressure-regulating valve set to125 psig steam pressure. This regulator prevents the steam pressure from exceeding 125 psig.
   2A. A normal open exterior diaphragm spring-loaded pressure regulator, set at 10 psig, prevents steam pressure from exceeding 10 psig.
3. A normal closed pressure regulator with electric safety pilot set at 50 psig. An electric pilot safety valve causes the main valve to close when the steam pressure reaches 50 psig. This pressure regulator is set at 125/45 and lowers steam pressure to 45 psig.

3A. Normal closed pressure regulator with electric safety pilot set at 40/10, this valve lowers the steam pressure to 10 psig and the electric pilot shuts down the valve when steam pressure goes above 10 psig.

4. High pressure steam bypass valve, 250 pounds steam-rated globe valve.
   4A. Low pressure zone valve, bypass valve, 125 pounds steam rated globe valve.
5. Secondary house steam stop valve, 125-pound rated gate valve.
6. A safety valve, set at a maximum of 15 psig. Discharge pipe must be piped to a safe location.
7. Steam supplied domestic water temperature regulator. This regulator controls the domestic hot water temperature. Domestic hot water should not be set above 120 degrees Fahrenheit. Many municipalities require domestic hot water settings at 115 degrees F.
8. Primary steam stop for the zone valve, 125 pounds steam-rated gate valve.
9. Zone valve. Building temperature control occurs by master building temperature controller.
10. A steam-fired domestic hot water maker and storage tank. Depending on the building size or a specific need, the tanks can be made to store 200 to 2,500 gallons of hot water.
11. 11A and 11B, steam drip traps for the subatmospheric steam heating system.
12. 12A and 12B, steam traps for hot condensate from 10 pounds steam lines. The discharge piping is piped to a separate condensate tank.

13 and 13A are thermodynamic drip steam traps used to remove high pressure steam condensate. All the discharge pipes are discharged separately to a flash tank. Shut-off gate valves rated at 250 psi. These steam traps are rated at 600 psi. The piping and flash tanks are rated at 300 psig.

Flash tank, steam, and vapors are vented to the atmosphere, usually to the roof or other safe locations. Hot condensate water flows to a condensate receiver with pumps equipped with high temperature bearings and seals, and are pumped to the heat exchanger.

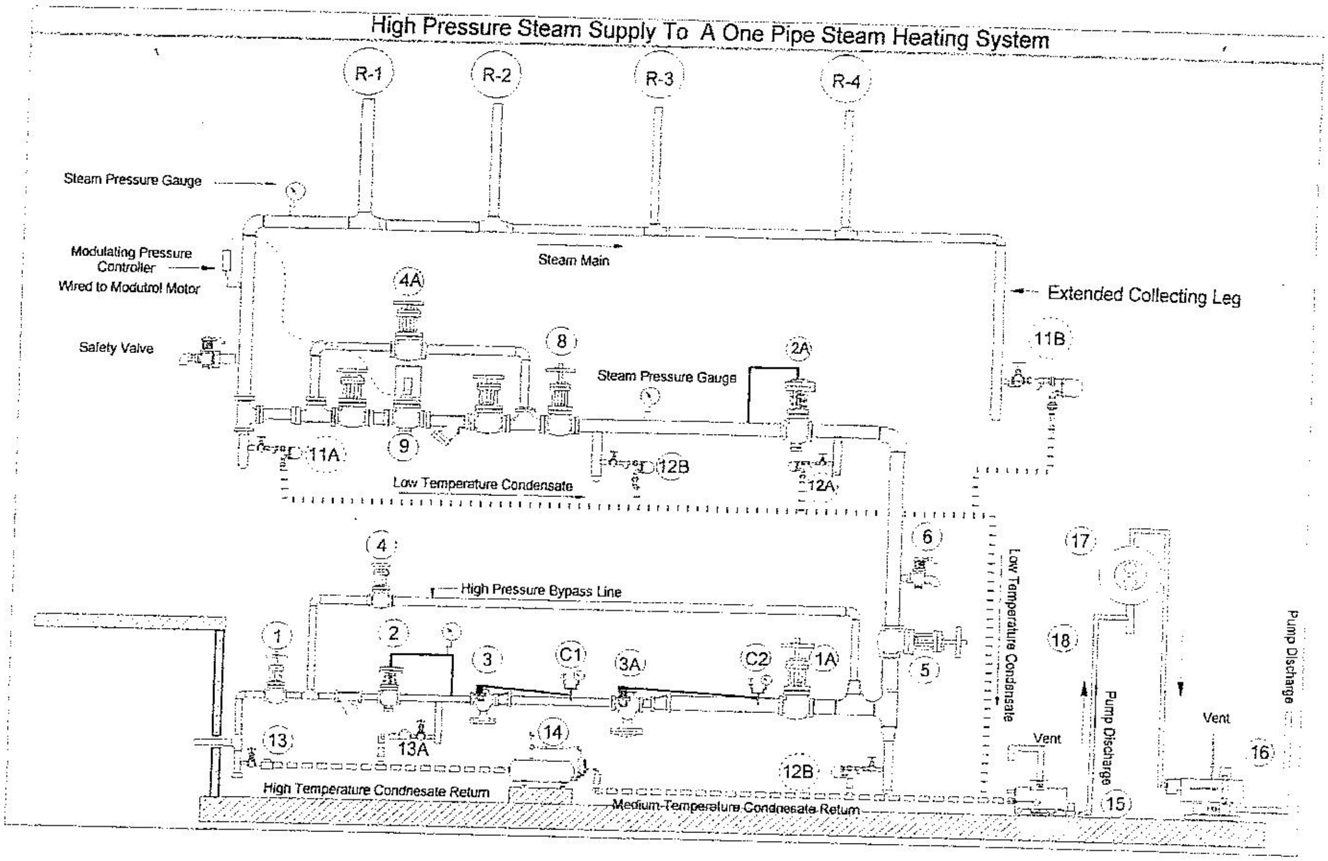
Condensate accumulator and pumps receiving hot condensate from the high pressure steam and the 10 psi steam drip stations.

A combination condensate receiver/vacuum tank with air removal pumps. The condensate vacuum tank and pump set receive all condensate from the subatmospheric steam heating system. Both the hot condensate tank and pumps and the vacuum tank pumps expel system condensate to the preheater for the domestic hot water generator. The latent heat stored in the hot condensate water is extracted by the preheater.

Hot water preheater. Economizer coils preheat the cold water before it enters the domestic hot water maker.

Outlet piping from the shell of the preheater. Note: The pipe trap keeps the heat exchanger full and the coils immersed in water. The cooling coils extract the latent heat from the high temperature water. After the water temperature drops below 150 degrees, it may be discharged to a sewer or undergo further cooling in a cooling tank. In many locations, the water temperature must be below 150 degrees Fahrenheit before it can be discharged to a sanitary or storm sewer. Additionally, if the condensate water is recovered, it can be discharged to a separate condensate tank, and pumped and returned to the originating source. C1and C2, pressure controller with a pressure gauge. The pressure controller operates the electric safety pilot on the pressure-reducing valve. The safety pilot will close or modulate the pressure-reducing valve to prevent steam pressure greater than the set points from entering the piping system.

Low Pressure One-Pipe Steam System Supplied by High Pressure Steam



Note: Numerical code explanations are found on page 232-233.

Look at both drawings closely. Each drawing represents a heating system in a large building. Both steam systems are supplied with high pressure steam and equipped with master heating panels, zone valves, steam traps, condensate tanks, flash tanks, and condensate cooling equipment. A difference between both steam systems is exhibited by the fact that a one-pipe steam system does not have condensate return piping from the radiators and each radiator is equipped with air vent valves.

Note: the one-pipe steam system shown above has a safety valve and modulating pressure control downstream from the zone valve. This modulating pressure controller is wired to the modulating zone valve. The purpose of the modulating pressure controller is to cause a fluctuation to the steam pressure in the piping system. A modulating pressure controller can be adjusted to make the zone valve mimic the operation of a steam boiler. During a heating cycle, the rise and fall of the steam pressure permits air to reenter the system via the vent valves, and this occurrence helps the condensate water to drain from the radiators and air vents. Most importantly, air can reenter the system and prevent a vacuum from forming in the radiators and the piping system.

How do we determine the operating steam pressure for the steam piping system before we set the modulating pressure controller? We learned that a minimum of 1 pound of steam must be present always in each radiator for the radiator to give off the proper amount of heat to warm up the rooms.

We also learned that piping systems have a resistance factor that causes the steam to lose energy, which results in steam pressure loss. In the steam heating system shown above, the pressure drop is 1.5 pounds. Therefore, add 1 pound of steam pressure to the 1.5 pound pressure drop. Thus, the minimum steam pressure is 2½ pounds. The maximum steam pressure should not exceed twice the pressure drop; therefore, the maximum steam pressure will be set at 3 psig. Based on this information, the pressure controller can be set with a ½ pound subtractive differential, causing the system to operate between 3 and 2½ pounds of steam pressure.Once we have established the operating steam pressures, we now can select the radiator vent valves.

Hoffman Radiator Vent Valves

Vent Valve Model No.	Type	Threaded Connection	Number of Ports	Non-Vacuum	(1)Drop-away Pressure Lbs. per sq. inch	Chief Use	Remarks
40	Angle	⅛"	1	Yes	6	Radiator	
41	Straight	⅛"	1	Yes	6	Convector	
43	Straight	¼"					
45	Straight	½"F x ¾"M					
70-A	Angle	⅛"	1	Yes	11	Radiator	Individually adjusted
71-A	Straight	⅛"	1	Yes	11	Convector	Individually adjusted
71-B		¼"					
71-C		½"F x ¾"M					
1-A	Angle	⅛"	6	Yes	1.5	Radiator proportional venting	Individually adjusted
1-B	Straight	¼"					
3	Angle	⅛" to radiator ¼" to airline				Air line or Paul Systems	Chief use for replacement
74	Straight	½"F x ¾"M	1	Yes	35	Unit Heater	High pressure mains up to 35 PSI

(1) See drop-away pressure definition on pages 2 and 3.

Remember the term "drop-away pressure." Drop-away pressure refers to the range of steam pressures in which a vent valve will operate. Most radiator vent valves are designed to operate up to 10 pounds of steam pressure. At this juncture, we need to consult the vent valve manufacturer's valve guide.

In this example, I will use the most common style of vent valve used in low pressure steam heating systems. Hoffman provides this data for two widely used vent valve models, the 40 series and the 1A series vent valves.

Hoffman stated that the 40 series vent valves will operate up to 10 pounds of pressure and has a drop-away pressure of 6 psi. That statement means the steam pressure in the system must drop below 6 psi for the vent valve to cycle. Water drains out of the vent valve and air is released each time the vent valve cycles. Because the steam system will operate far below the 10- and 6-pound restriction, the vent valves will work properly.

Additionally, Hoffman stated that the multi-ported 1A vent valve is used to help regulate the distribution of steam in the heating system. The 1A vent will operate up to 10 psi and the valve has a drop-away pressure of 1.5 psig. That shows that the 1A vent valve cannot be used in a steam system where the operating steam pressure does not drop below 1½ psi. Based on this information, the 1A vent valve cannot be used in a steam heating system unless the steam pressure modulates between the maximum set operating pressure and below 1.5 pounds per square inch operating steam pressure (drop back).