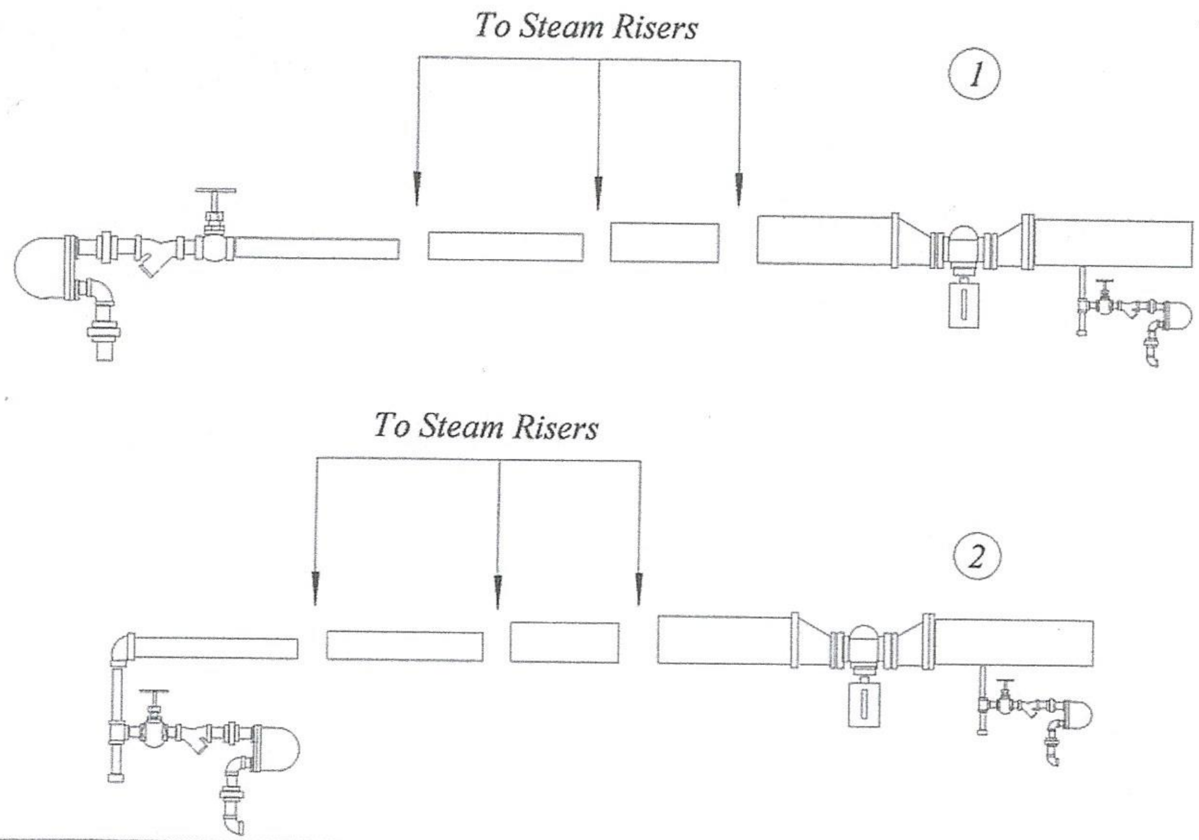
Zone Valve Installations



Drawing # 34

Look at zone valve one. The steam trap is installed in the same plane as the steam main. Four pipe reductions occurred on the steam main. This piping design requires a long run of pipe from the third riser take-off. The length of run of pipe is determined by the pitch of the pipe. Inlets of steam traps should be at least 1 inch below the bottom of the steam main. If we use a pitch set at 1 inch in every 10 lineal feet of pipe, we would need about 30 feet of pipe after the last take-off on the steam main; 30 feet of pipe will assure that the top inlet of the steam trap is 1 inch below the bottom of the steam entry point of the steam main.

Some manufacturers' catalogs or manuals call the long run of pipe a cooling leg. In actuality, this run of pipe assures that all the condensate water is removed from the steam main. Often, this piping pattern is used where the height in a basement or crawl space does not permit the use of a drop leg (collecting leg), as shown in zone valve two.

The better of the two installations is shown at zone valve two. Drop legs for steam traps should be about 12 inches below the bottom of the steam main. Whenever height permits, use longer drop legs; long drop legs create a greater static head at the inlet of the steam trap. Drop legs are also called priming legs for steam traps. A steam trap's capacity to remove water is based on the steam or water pressure at the inlet side of the steam trap. Many steam traps may not begin to drain water until a ¼-

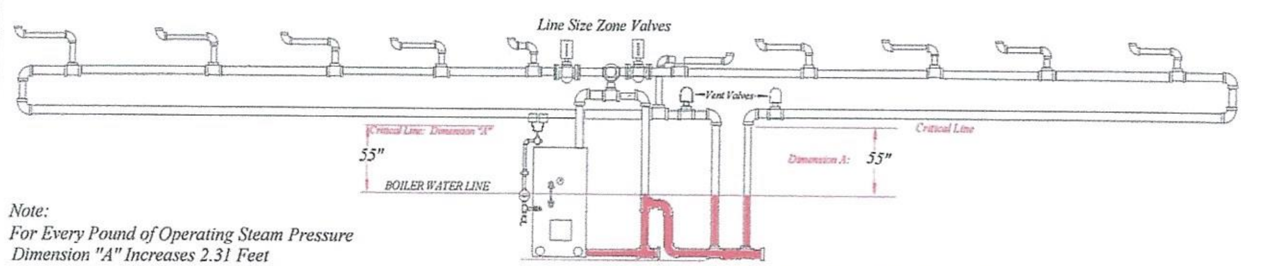
pound pressure is reached at the inlet of the steam trap. A drop leg will assure that a ¼-pound or more pressure is present at the inlet of the steam trap. Additionally, the drop leg is a condensate water-collecting area below the steam main, and that helps keep the steam main free of water.

Look at zone valve one. Because the steam trap is placed in the same plane as the steam main, condensate water can collect in the steam main until the steam pressure reaches ¼ of a pound. When a steam main fills with condensate water, steam pressure may force water to flow into the steam risers. Excess condensate water entering the base of any steam riser prevents the full measure of steam from flowing up the steam riser. Additionally, the trapped water can cause banging.

When steam enters a steam main, steam begins to condensate immediately. Steam pressure may not be established for several minutes, but condensate flow is established immediately. Under certain conditions, the steam main can become waterlogged. Steam flow may become impeded and banging in the steam main could occur.

Shown below and on the following pages are several drawings of different steam heating systems with zone valves. Each steam system has its own anomalies. Installing zone valves in a one-pipe steam system without steam traps can be problematic. Each zone must have a separate condensate return and sufficient height above the boiler waterline to the bottom of the steam main to prevent boiler water from being pushed up and into the zone that is off-line. The steam system below was designed to operate at a maximum steam pressure of 2 psig.

Zone Valve Installation for One Pipe Steam Steam Systems Without Condensate Pumps



Drawing # 35

Zone valves supply steam to different parts of the building. Each zone valve is controlled by a separate temperature control. Both zones are supplied steam at different times and in different quantities. Steam supply is based on heat loss caused by the outside temperature, wind, sun, and rain. All buildings have exposed and sheltered sides.

When both zone valves are closed and the boiler is off-line, the entire system is at atmospheric pressure and in equilibrium. When the boiler begins to produce steam pressure and both zone valves are closed, the steam pressure in the boiler is greater than the atmospheric pressure in the steam main. The greater steam pressure in the boiler causes water to flow out of the boiler through the bottom connection of the boiler and into the condensate return piping.

All one-pipe and two-pipe steam vapor vent systems have vent valves (air release points). The air vents release air and the steam piping system will stay near atmospheric pressure until the vent valves close. Vent valves will not close until the heat of the steam or the steam pressure reaches the floats or thermostatic elements in the vent valves. "The steam piping system will become pressurized when the vent valves begin to close."

Open vent valves keep the steam piping system at or near atmospheric pressure. A greater pressure in the boiler forces the boiler water into the return piping toward the zone of lower pressure. In the zone with the closed zone valve, the steam and return piping has the zone of lowest pressure. Higher pressure in the boiler pushes the boiler water out the bottom tap of the boiler into the return piping. As the pressure increases in the boiler, boiler water is forced toward the steam main and both zone valves. If air is released from the piping system, boiler water will flow out of the boiler into the zone of lowest pressure.

The greater pressure in the boiler (2 psi) and the lower pressure in the steam piping system (0 psi) will cause the water to flow out of the boiler. Boiler water will continue to flow out of the boiler until the piping system and the boiler reach equilibrium. Equilibrium occurs when the combined steam pressure and the static pressure of the water in the water columns at the end of the steam main can counterbalance the pressure in the boiler. In other words, the boiler water has reached the highest level in the steam main drip piping based on the static head of the water column. When the system reaches equilibrium, the higher pressure in the boiler cannot push water out of the boiler. When equilibrium occurs, a zone of lower pressure between the boiler and the system piping does not exist and boiler water can no longer flow into the return piping.

To achieve equilibrium in the system on page 94, a water column equal to the boiler pressure must be reached. The stacked water in the water column (the vertical drops at the end of the steam main) must reach a height of 55.44 inches above the boiler waterline. If the end of the steam main is lower than 55.44 inches, water will flow into the steam main. Therefore, dimensions "A" cannot be less than 55.44 inches plus 4 inches. The additional 4 inches is the height needed to force the condensate back into the boiler.

If the zone valve on the left side of the system is open and the zone valve on the right is closed, only the left side of the steam system can reach equilibrium. This zone equilibrium is reached when the water rises to about 15 inches above the boiler waterline in the vertical drop of the steam main drip. Because steam pressure cannot enter the right side of the heating system and counterbalance the boiler pressure, boiler water is forced out of the boiler into the return piping of the zone on the right side.

When a zone valve opens, steam pressure in the boiler drops off, and as steam enters a zone, the steam pressure increases. That increase in steam pressure combined with the static pressure in the water column counterbalances the higher steam pressure in the boiler. A fully-charged boiler with a steam pressure of 2 psi and a ½ psi pressure loss in the steam piping causes the steam pressure at the end of the steam main to be 1½ psi. Water in the water column will rise 14 inches above the boiler waterline. Condensate in the steam main drains to the steam main drip and the height of the water in the drip pipe increases. Once an additional 4 inches of water stacks in the vertical drop leg, the static head pressure has increased enough to overcome the boiler pressure. At that juncture, condensate water will flow into the boiler.

Zone valves cycle often during the day. In steam systems where multiple zone valves are used, a boiler often produces more steam than a zone needs. Zone valves supply steam to a zone based on a temperature need. A zone may be closed while the other calls for heat or a zone valve can be closing while the other valve is opening. The boiler responds to the operating pressure control or a microswitch on the zone valve, and as a result, the burner continues to fire and will not shut down until the set point is reached. Steam pressure in the boiler will increase to 2 psi (the set point) and the water in the boiler will be pushed into the drop legs. When a zone valve is closed, steam pressure in that zone is 0. When a zone valve is partially open, opening or closing the steam pressure in that zone is greater than 0 and less than the boiler's set points. As a result, the greater pressure in the boiler will push the boiler water into the vertical steam main drip.

Let us look at the system again. One zone valve is open and one zone valve is closed. The zone with the open zone valve is in balance. The boiler is making 2 psi steam and the water in the vertical drop of the steam main rose about 14 inches above the boiler water level. In the zone, where the zone valve is closed, water in the drop leg rose about 55 inches above the boiler water level.

When the boiler is at 2 psi, and steam pressure and both zone valves are open, the ends of both steam mains are at 1½ psi. That ½ pound difference of pressure between the boiler and the end of piping system is the pressure differential and the pressure differential is caused by the friction of the pipe and fittings. This imbalance in pressure will raise the water in the steam main drop leg for about 14 inches. When one zone valve closes, the steam pressure in that zone drops to 0 psig or atmospheric pressure; therefore, the difference between the boiler pressure and the zone is 2 psi. The difference of pressure between the boiler and the zone causes the water to rise about 55 inches in the vertical drop leg.

A zone with an open zone valve is in equilibrium with the boiler and the water in the drop leg will rise to a height equal to the pressure drop of that zone. The system pressure drop is ½ psi. That means that a ½ psi differential exists at the end of the steam main. To find the height of the water in the drop leg when a zone valve is open, we need to multiply ½ psi by 2.31 feet (the height that 1 psi pressure can raise water). A ½ psi pressure will raise water for about 14 inches above the boiler waterline. Conversely, since the system has two zones and one zone valve can be closed, we need to find out how high the water will rise in the drop leg of the zone with the closed zone valve. To find the height water will rise in the drop leg, multiply .5 psi by 2.31 feet. The level the water will seek is 4.62 feet or about 55 inches above the boiler waterline.

In a zone where the zone valve is closed, water will be pushed out of the boiler and rise in the drop leg for about 55 inches above the boiler's waterline. Since the boiler pressure is 2 psi, water in the drop leg will not drain back to the boiler. Steam pressure in the boiler acts like a check valve. The pressure holds the water at 55 inches. Variations can occur in the height of the water in the drop legs. These variations in height are caused by varying steam pressure. Varying steam pressure can occur when a zone valve leaks, opens partway, or opens fully; boiler pressure will drop off and return to the set point. The water in the drop leg will rise and fall in direct proportion to the boiler pressure.

All steam systems do not operate at 2 psig. A steam system's operating pressure can be as low as ¼ psig. Generally, the operating steam pressure of a boiler is twice the pressure drop of the steam system. In this drawing, the operating pressure can be ½ psig pressure drop times 2, or 1 psig boiler operating pressure.

In a steam system equipped with a zone valve operating at 1 psig, the steam pressure in the boiler will push water out of the boiler into the drop leg for about 27 inches above the boiler waterline. Many steam systems have anomalies. One anomaly may be that one or more riser run-outs have several extra elbows installed. These additional elbows may have been installed in the riser run-out because of a structural impediment. The extra elbows will cause an increase in the pressure drop at that riser. Let us assume that the pressure drop increased to ¾ psig. At a ¾ psig pressure drop, the boiler operating pressure must be increased to 1½ psig; 1½ psig will assure that steam is supplied to all the radiators at that riser during any heating cycle. When a zone valve is closed and a boiler's operating pressure reaches 1½ psig, boiler water will be pushed into the drop leg of the closed zone and reach a height of 42 inches.

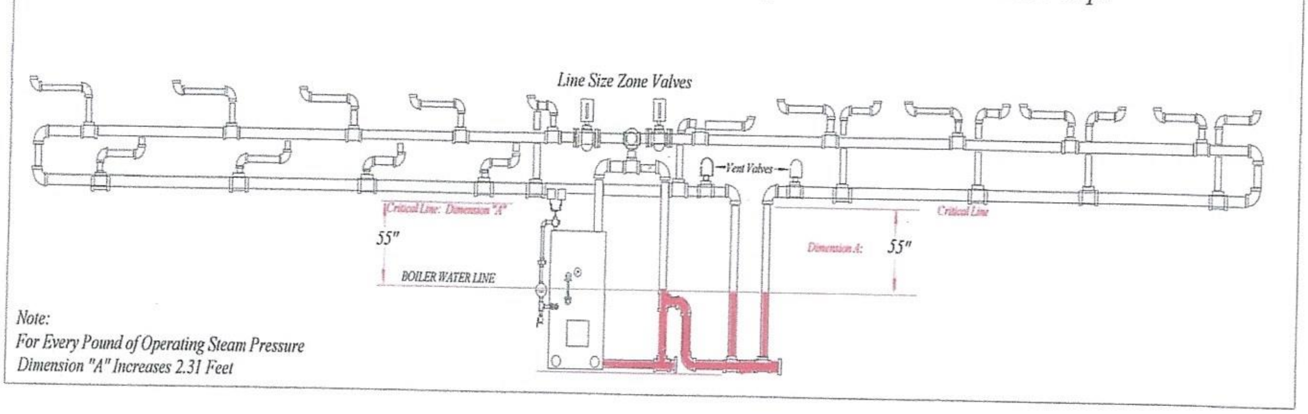
Remember, at 2 psig, when both zone valves are closed, water will be pushed into and up the drop legs to about 55 inches above the boiler waterline. At 1½ psig, water will be raised to 42 inches and the "A" dimension will have a safety margin of 13 inches.

Converting an Old Two-Pipe Vapor Vent System to a Zoned System

With the cost of fuel continually escalating, modifications to steam systems in old factories and loft buildings occurred when the buildings were converted to residential occupancy. Many of these old buildings were equipped with nineteenth- or early twentieth-century steam systems. Occupancy and usage changes caused modifications to existing one-pipe, two-pipe vapor, gravity vapor vacuum, and two-pipe gravity vacuum return systems with steam traps. In many buildings, the modifications created banging and steam distribution problems. Usually, the modifications could have been done economically and properly; what was needed was a basic understanding of the old steam systems. The system shown on page 12 is simplified, and the basic items and conditions needed are shown in the sketch. That system can be converted without installing condensate or boiler feed pump and tank sets.

The most important requirement is the height of dimension "A." We know that some vapor systems can operate at steam pressures as low as 4 inches on the water column or 1/8 psig. We also know the EDR unit is used to size radiators. To recap, an EDR (Equivalent Direct Radiation or square feet of steam) is a unit of measurement. By definition, 1 EDR equals 1 square foot of heating surface, and 1 square foot of heating surface equals 1 square foot of steam. An EDR equals 240 BTUH when a radiator, convector, or coil is internally at 1 pound of steam pressure (steam temperature at 215 degrees) and is surrounded by air at 70 degrees Fahrenheit. Steam tables show that 215-degree F steam is about 1 psig; that means radiators or other heating elements must be supplied with 1-psig steam pressure.

Zone Valve Installation for Two Pipe Vapor Steam Steam System Without Condensate Pumps



Dwng # 36

Typically, the maximum operating pressure of the boiler is set at 1 psig plus the system differential. A system differential of ½ psig was established for the system shown, and this makes for a boiler operating pressure of 1½ psig. Why do we add the system differential to the 1 psig operating pressure? In most steam heating systems, a pressure control is used to control the operation of the boiler. The pressure controllers are equipped with differential settings. We know that in most steam systems, a minimum of 1 pound pressure has to be supplied to each radiator. The operating pressure control should be set to supply no less than 1 psig of steam. Therefore, the system differential is added to the operating pressure and the pressure control is set to shut the burner down at 1½ psig, and restart the burner at 1 psig. In that sequence, the steam pressure in the system will vary from about ¾ to 1½ psig.

Why did the pressure drop to ¾ psi? Remember, the burner restarts at 1 psi; the burner goes through a pre-purge and post-purge cycle before ignition occurs. Additionally, the firebox cooled a bit and the steam pressure in the boiler drops below 1 psig. How far below 1 psig the pressure goes is dependent on the burner's ability to recover the lost BTUs.

Remember, system operating pressure is about twice the system's pressure drop. If we take a ½ psig and multiply it by 2, we get 1 psig as the operating pressure. Keep in mind, twice the pressure drop is the maximum operating pressure of a steam system, and this is a reliable thumb rule. To attain the proper steam circulation, the boiler pressure has to be a bit greater than the system operating pressure.

The thumb rule is based on technical information supplied in *Hoffman Steam Heating Systems Design Manual*, Bulletin TES-181, on page 42, Table 4, which deals with steam velocity.

Maximum Velocity in Steam Piping

The capacity of a steam pipe depends on these factors:

(1) The quantity of condensate in the pipe
(2) The direction of condensate flow
(3) The pressure drops of the pipe

The total pressure drop of a system should not exceed ½ the supply pressure when steam and condensate are flowing in the same direction.

As I have stated often, proper steam distribution is all about removing condensate water and air. Visualize steam and condensate flowing in a pipe, read lines 1, 2, and 3 again; think about the high speed of steam flowing over the slower-moving condensate water. Think about water damming in a pipe. The right-angled turns in a piping system and the changes in direction of horizontal pipe to vertical piping. See the condensate water possibly smashing into right-angle fittings, see the waters of condensate pushed into steam and return risers, and see the water smash the internal floats and thermostats in vent valves and steam traps. Think about how destructive condensate water can be in steam piping.

Look at Drawing # 36 on page 97 again. Steam velocity and the removal of condensate water was accounted for when the piping was sized according to tables and charts developed and published by The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

Our major concern in the steam system is the "A" dimension. When zone valves are installed, the "A" dimension can be a limiting factor in some steam systems. Problems can occur in steam systems where the steam and return piping is not isolated from the boiler by steam traps and a pump with a condensate receiver. In one- and two-pipe steam systems, we must assume a minimum steam pressure of 2 psig. In most steam systems that operate above 2 psig, all steam and return piping will need to be isolated from the boiler by steam traps and a condensate receiver and pump set.

Drawing # 36 shows an "A" dimension of 55 inches; 55 inches is the maximum height boiler water can rise in the drop leg at the end of the steam main. Therefore, the steam main will not be flooded by boiler water and condensate water will drain and not collect in the steam main.

One-pipe and two-pipe vapor vent systems without steam traps may pose a problem. Return risers and dry returns will become pressurized with steam. Air venting in these systems is critical and the sizing of the main air removal vent at the end of the steam main play an important role. The main vents have to be high-capacity vents. Steam main vents and radiator vents create zones of lower pressure that help the steam flow to all the steam risers, radiators, and condensate water to drain to the return lines.

In two-pipe steam systems, radiators giving off the latent heat of steam help create a pressure differential. Steam condenses in each radiator, and as steam condenses, the steam pressure in the radiators drops. The cooler condensate water drains out of the radiator. Some steam follows the condensate to the return riser. In a one-pipe steam system, condensate will flow down the steam riser to the steam main, and eventually into the drop leg and return to the boiler.

Converting Large Vapor Systems Equipped with Steam Traps

Some vapor systems were modified and steam traps were installed at the radiators. Many vapor systems had wet returns and did not need an end-of-the-line steam trap. Additionally, vapor systems had dry returns and combination dry and wet returns. Since most vapor systems had coal-fired boilers and could heat a building at less than 8 ounces of pressure and where a proper dimension "A" could not be met, boiler return traps were installed to return system condensate to the boiler.

When existing boilers for these steam systems were converted from coal- to oil- or gas-fired boilers, some contractors removed the boiler return traps (boiler return traps were installed in systems with dry returns). Often, new main vent valves were installed at the end of the steam main. Installing new main vent valves at the end of the steam mains changed the operating characteristics of the steam system.

Why Was There a Change in the Way the System Operated?

Vapor systems with steam traps at the radiators had two separate returns. Occasionally, some systems had a second dry return that handled only system air besides the dry return from the radiators and the wet return. Condensate from the radiators drained to the boiler in the dry return. The second dry return discharged air and was connected to an air-separating fitting. Additionally, the wet return received the condensate from the end of the steam mains and riser drips, and kept the boiler and steam system in equilibrium. ***See the drawing on pages 75 and 77 in Chapter Three.***

Because air was released from the piping system, the system's operating characteristics changed. Look carefully at the drawing. Visualize the removal of the boiler return trap and the air separator. Look at the return piping from the radiators. Think about that part of the system no longer being open to the atmosphere (0 pressure throughout much of the heating cycle). The removal of the air check, which allowed air to leave the system quicker than any thermostatically-operated vent valve, caused this problem. The steam system would pressurize with air before steam could enter all the radiators, and as a result, all the radiators would not heat at the same time.

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When steam reached the air vent, the vent would stay closed for a long period of time, thereby increasing the pressure in the part of the piping system that supplied steam to the radiators, and that affected the way the system heated and operated.

Air checks released air all the time when steam left an air check; that indicated that one or more steam traps were defective. The release of steam from an air check was the telltale that showed the home owner a steam trap, or traps, was defective.

For this discussion, a contractor installed the same-size main vent valve at the end of the steam mains. In most buildings, the steam main is split at or near the boiler. The original installers split the steam mains to keep pressure drops low, and they tried to keep the pressure drops in the split steam mains equal. In reality, a slight difference in pressure drop occurs between both sides of the system. That part of the steam system with the lower pressure drop receives steam quicker and heats sooner.

Some buildings with split steam mains and different pressure drops had steam circulation problems. The steam main with the lower pressure drop heated that side of the building first. When multiple vent valves of the same capacity were installed on the steam mains, the venting of air caused a zone of lower pressure. Air and steam moved toward the end of the steam main quicker and the steam main with the lower pressure drop supplied steam to the steam risers and radiators faster. Because steam filled the steam piping with the lower pressure drop quicker, overheating at that section occurred.

Problems occurred in some buildings because some installers and service people raised the system operating steam pressure in an attempt to supply more steam. I serviced buildings with steam pressures as high as 10 psig and differential settings at the pressure controller ranged from 1 to 4 psig. Some operational problems in these buildings were banging, boiler short cycling, and poor steam circulation. Usually, the corrective work required the lowering of the steam pressure and changing the pressure differential. In some buildings built before 1940, the existing pressure controllers were replaced with a Vaporstat™.

When the steam pressure was lowered to 2 psig or less, most of the banging went away. In buildings with vapor systems where the operating steam pressure was lowered to 1 psig, the burner off and a differential of 4 ounces (burner on at 12 ounces), all the problems went away. Depending on some of my customers' needs, when I returned to some buildings, I reset the boiler operating pressure to the boiler off at 8-ounce pressure and retained the 4-ounce differential.

Remember, vapor systems have very large steam piping. Piping that seems larger than needed was installed to allow the system to have a low pressure drop. Lower pressure drops permit steam systems to operate at low steam pressure. Steam piping in vapor systems carries a higher volume of steam at lower pressures than piping in steam systems designed to operate at higher steam pressures. Steam systems that were designed with pressure drops of 1/8 of a pound or less per 100 feet of installed pipe could operate at less than ½-pound steam pressure.

When buildings with vapor systems are zoned, wet returns may have to be abandoned and replaced with dry returns. When a dry return is installed, the dry return will need to be isolated from the boiler. Steam traps and a condensate receiver with a pump will need to be installed.

A potential problem is sizing the zone valve. We have an option here about what needs to be done. Assume that the steam requirement is 1,000 pounds of steam per hour or 4,000 EDR or 1,000,000 BTUH. We need to look at the valve manufacturer's sizing charts to figure out the size of the zone valve.

Steam capacities shown are in ***pounds*** of steam per hour and the valve trim is full port.

	Vacuum Return System			Atmospheric Return System		
	2 Psi Supply Pressure 3.2 Psi Pressure Drop	5 Psi Supply Pressure 5.6 Psi Pressure Drop	10 Psi Supply Pressure 9.6 Psi Pressure Drop	2 Psi Supply Pressure 1.6 Psi Pressure Drop	5 Psi Supply Pressure 4.0 Pressure Drop	10 Psi Supply Pressure 8.0 Psi Pressure Drop
1" Valve	232	332	485	164	281	441
1 ¼" Valve	370	531	776	268	450	706
1 ½" Valve	582	829	1,212	419	702	1,102
2" Valve	932	1,322	1,940	679	1,124	1,764
2 ½" Valve	1,460	2,090	3,056	1,043	1,770	2,778
3" Valve	2,330	3,319	4,850	1,640	2,816	4,410
4" Valve	3,709	5,310	7,760	2,680	4,500	7,060

In a vapor vacuum steam heating system that needs 1,000 pounds of steam per hour, we will find a 6-inch steam main. Try to establish what the designer had in mind when the system was installed. In researching the capacity of that steam main, I found, at 0-psig steam pressure, the steam piping will supply 1,000 pounds of steam per hour. Steam velocity in the piping system will be about 3,000 feet per minute or about 34 miles per hour. The pressure drop of this steam piping system is barely measurable. When we select a zone valve for a piping system, we can install a line-sized zone valve, or reduce the zone valve size to 2½ inch.

Although the capacity is not shown, a 6-inch zone valve can be used. The 6-inch zone valve will permit a boiler to operate at a steam pressure of less than ½ pound. At the time of this writing, a 6-inch zone valve with a modulating motor costs about $4,200.00 and about $2,000.00 for installation. A 2½-inch zone valve with a modulating motor costs about $1,200.00 and about $700.00 for installation. Controls and wiring are extra. Installing zone valves on pipe requires flanges or unions, welded or screwed onto the pipe.

Installing a 6-inch zone valve will allow the boiler to operate at 0 psig. If we install the 2½-inch zone valve, the boiler will need to operate at 2 psig. Always remember that the capacity of a zone valve is based on the inlet steam pressure.

Here we have to look at a qualifier. Honeywell's chart shows two types of steam systems, a vacuum return system and an atmospheric return system. Additionally, we need to know the pressure drop across the zone valve and piping system.

The chart shows that a 2½-inch zone valve with an inlet steam pressure of 2 psi at a 1.6 pressure drop can supply 1,043 pounds of steam per hour. Look at the valve chart again; 2½-inch zone valves with an inlet pressure of 5 psi can supply 1,770 pounds of steam per hour. This valve chart shows that increasing the inlet pressure to a zone valve increases the capacity of the zone valve dramatically. Occasionally, 2 pounds of pressure at the boiler may not be enough to heat the building. The boiler operating steam pressure can be increased, and that increase in pressure will make more steam available to heat the building.

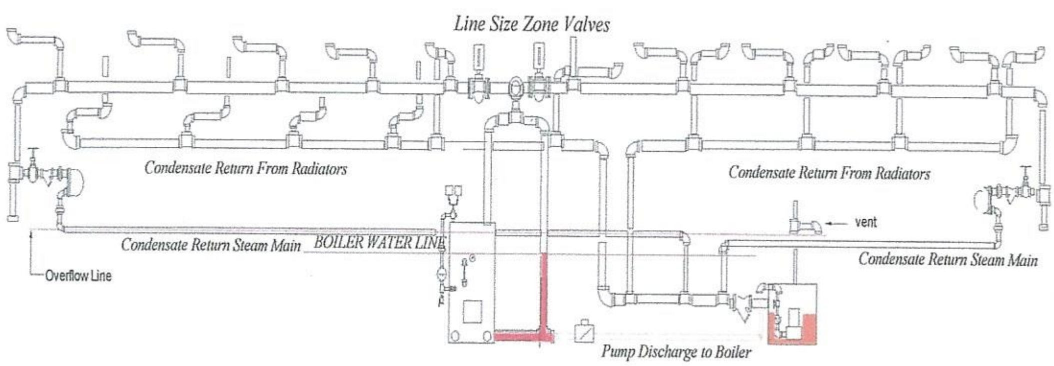
To assure a zone valve will not supply more steam and greater steam pressure than the system requires, we can install a Vaporstat™ after the zone valve. The Vaporstat™ will control steam pressure the same way a Vaporstat™ controls a boiler's operating pressures. A start point setting for the Vaporstat™ is 2 psig with an 8-ounce subtractive differential. Under most operating conditions, a vapor system will operate at less than 1 psig.

A Vaporstat™ operates like a traffic control device. Extreme cold weather can cause a boiler to operate much longer because the thermostat takes longer to reach set point. Because of the extended boiler run time, the steam pressure can increase above 2 psig. At that juncture, the Vaporstat™ causes the zone valve to close. Remember, the subtractive setting, when the steam pressure drops to 1½ psi, the zone valve begins to reopen and steam is supplied continuously. Keep in mind that gravity vapor systems are equipped with either a master vent valve and steam traps or vent valves on each radiator. Vent valves need a drop in pressure to allow air back into the system. Again, bear in mind, we need to assure that a vacuum does not form in a vapor vent system. Look at Drawing # 37.

Drawing # 37 shows that air release valves were not installed. *Air removal occurs as system air passes through the end of steam main and radiator steam traps*. All system air flows with the condensate to the condensate receiver.

System water is retained in the condensate tank and pumped into the boiler. System air leaves the condensate receiver via vent piping on top of the condensate receiver.

Zone Valve Installation for Two Pipe Vapor Steam Steam System With Condensate Pumps



Dwng # 37

When modifying steam and condensate pipes, all horizontal condensate discharge piping in the basement must be piped above the boiler's waterline and the inlet to the condensate receiver. Condensate water cannot be allowed to become trapped. Water collecting in the main return system can prevent system air from venting from the vent on the condensate receiver.

In buildings where condensate receivers, vacuum tanks, and pumps were installed, the placement of an end of the steam main steam trap is important. The trap's location is determined by measuring its height from top of the condensate receiver to the outlet port of the steam trap, including the slope of the pipe to the condensate tank. The steam trap must be above the height of the overflow pipe of the condensate receiver. Additionally, if any horizontal discharge pipe from a steam main steam trap enters a condensate receiver beneath the waterline of the condensate receiver, system air will not be removed quietly or quickly.

System condensate water retained in steam trap discharge piping below the inlet of a condensate tank is trapped! Water held in this piping creates a water seal. This water seal will prevent system air from flowing with the condensate water into the condensate tank. Additionally, unreleased air can block or retard condensate flow. Water removal can only occur when the pressure in the discharge piping increases above the height of the water below the waterline. Most of the system air will be trapped in the piping as air cannot pass through the water seal. Should the pressure in the condensate discharge piping become great enough to push both air and water into the condensate receiver, loud bubbling or water hammering can occur in the trapped discharge piping and condensate receiver.

When planning modifications, repairs, or installing steam heating systems, what must be remembered is that a steam heating system has separate parts, and each part has to be considered individually.

The parts of the steam heating system are as follows:

1. Boilers and near boiler piping
2. Steam main piping
   a. One zone
   b. Multiple zones
   - A zone is a section of steam main piping taken off the steam header in the boiler room. Many steam systems have multiple steam mains that supply steam to different parts of the building. When zone valves are installed in any steam system, the operating characteristics of that steam system changes. Installing zone valves in steam systems can cause problems if condensate and air removal are not tended to properly. In steam systems without condensate receivers and pumps, the "A" and "B" dimensions must be considered. "A" dimensions are critical in systems without steam traps at the end of the steam main. "B" dimensions are critical to any steam system that uses steam traps.
3. Main condensate piping
4. Steam risers and their run-outs from the steam main
5. Radiator placement and the run-outs from the steam riser
6. In two-pipe systems, the return risers and their connection to the main return line
7. Dry returns with or without steam traps
8. Wet return piping (must always be below the operating waterline of a boiler)
9. Hartford loop connections or the discharge pipe from condensate or boiler feed pumps connected to the bottom inlet of a boiler
10. Last but not the least, improperly-sized fuel-burning equipment, misapplication of the boiler's controls, under- or over-fired fuel-burning equipment will affect the way a boiler makes steam.

Before beginning work, consideration must be given to the boiler's operation, capacity, and differences in pressure drops that may occur because of piping changes to steam distribution piping or adding heating capacity to building.

Unlike water in a water heating system, ***steam is not a forgiving heating medium***. All departures from proper piping installations, misapplication of equipment, and things as simple as not reaming all cut piping will create problems. An analogy for steam is that "***steam is water looking to happen***." Our problem is to keep steam in the appropriate parts of the piping system as steam and remove the condensate water.

Steam cannot be made to stay in a piping system; steam wants to be water and will always become water. We can keep steam in a gaseous state a bit longer. This can be accomplished by insulating all the steam piping. To heat any building, steam must be produced continuously during the heating cycle. New steam must replace the spent steam (steam that gave up its latent heat). All the spent steam (water) must be removed from the steam piping quickly.

After the initial start of a boiler, the boiler must fill the piping system with steam. In the first steam cycle, condensate will be voluminous as the entire piping system is cold. Water (spent steam) must return to the boiler or fresh makeup water will be added to the boiler.

"Condensate lag" is a condition often overlooked by some designers and installers.

Definition: *Condensate lag* is how much time it takes for water (condensate) to return to the boiler from the steam piping system. Why should we consider the condensate lag?

Steam boilers have five different waterlines and a normal boiler operating waterline:

A. Low waterline. The low waterline is the minimum height of water in the boiler. A boiler must not be fired at or operated at or below the minimum waterline.
B. Cutout waterline. A cutout waterline is where a boiler manufacturer recommends a low water cut-off, which shuts off the fuel-burning equipment.
C. Fill line. Fill line is that point when makeup water is added to the boiler.
D. Normal operating waterline. The normal operating waterline is the waterline a boiler will find and operate at after the condensate water returns to a boiler in the same proportion that steam left the boiler. A boiler's waterline can fluctuate between the cutout line and above the fill line.
E. Maximum water level. The maximum water level is the highest water level that a boiler can operate at without hurling water into the external steam header. Usually, the maximum water level is not set unless a boiler is equipped with a domestic hot water coil.