Chapter Five

System Air Removal, Air Vent Valves and Steam Traps

We have grown up in an era and industry where most equipment and accompanying parts are of the finest design and quality. Things we need to know are the applications and installation procedures for what we may design, install, repair, and adjust. Think about what a serviceman or technician might have been faced with many years ago when instructions did not come with the things we installed. Think about a building owner who paid hard-earned money for a product or products that helped provide heat to a building. More importantly, think about anyone entering the heating industry where books on steam or water heating were very expensive or unavailable. Imagine all the years where on-the-job training was the only way a person could learn the trade.

Our heating industry is a cut-and-dry business. Heat is provided by burning a fuel in a boiler or using electrical resistance heaters to produce steam or heat water. From the 1700s to early 1900s, steam and water circulated by gravity. With the advent of electricity and pump motors, both steam and water were circulated by mechanical means. When fuel and electricity became expensive, heating controls became part of the heating plant. The control industry became quite sophisticated with the coming of the transistor and computer chip. These items caused the heating equipment manufacturers to design more efficient heating systems. The new heating control technology and the use of electrically-operated equipment was the only advancement in the heating industry since the 1800s. Basically, a boiler, pipe, and fittings have not changed much. Environmental and boiler controls moved forward by light-years, but proper education and schools are still far behind the technology advancements. Very few schools other than one-, two-, or three-day seminars are available and simply-written texts are scarce. In a multiple billion-dollar industry such as heating, one must ask this question: "How come?" *How Come?* is the title of a book written by Dan Holohan. It deals with the why and wherefores of hydronics. Additionally, Dan is a steam historian, teacher extraordinaire, and wrote many books on the subject. How come? means why are things done this way and can be expanded by thinking, *Do I know, or am I guessing?*

While doing research for this book, I came upon a reproduction of a text by the Hoffman Specialty Company, published in the *Architectural Review* somewhere about 1929, titled, "The Parts of Air Vents in Steam Heating Progress," By J.F. Musselman. For the sake of brevity, I am using excerpts from that article.

1. The history of steam heat is the history of the air valve and return valve (the precursor to the steam trap).
2. We know that without some means of relieving steam heating systems of units of air, we could not have efficient steam heat.
3. Credit is given to James Watt as the first designer and builder of heating systems (1784-1785).
4. Colonel William Cook, in *Gentleman's Magazine* (1847), described a method to warm rooms by the heat of boiling water. Both James Watt and Colonel William Cook used hand-operated petcocks to remove condensation. Unknowingly, the hand-operated petcocks also vented the air from the piping systems.
5. James Watt did not know he depended on pressure rather than good circulation to get heat into a radiator.

6. Steam heating by pressure continued for another fifty years. Air having no means of escape and remaining in a one-pipe system prevented good steam circulation. The failure to remove air at the start of a heating cycle and, under certain conditions, an additional 1/10 of a cubic inch of air per square foot of radiation per hour, air is brought in by steam. This system air caused air binding. Air is heavier than steam; air is a noncondensable and will not return to the boiler. Air must be eliminated from the system or air binding in piping or a radiator will retard the movement of steam.
7. Around 1799, Mr. Lee of Manchester, directed by James Watt and Robert Bolton, had the idea of using cast-iron pipe to convey steam to radiators. Additionally, cast-iron radiators were designed for use in heating. A cast-iron cylinder was encased in a brick enclosure. The cast-iron cylinder and the brick enclosure were separated by an air gap. System air in the piping and cylinder (radiator) escaped by a manually-opened stopcock while steam was entering the radiator.
8. No information is available as to the success of this system. Very little was done to improve any subsequent steam heating systems.
9. Many people invented items to improve steam circulation, syphons, and fittings to drain condensate, and strange piping arrangements were developed to help circulate steam through piping systems.

A quick story: A steam heating system was installed and it appeared that this heating system was the system to replace all other systems. Steam reached all the heating elements quickly. The system was quiet and heated uniformly. Nevertheless, a very annoying problem occurred. The steam had an objectionable odor and the piping stank. A steam heating system designer was called to find out what caused the problem. The designer found sand holes in the cast-iron pipe and radiators. After the sand holes were repaired, the steam heating system had poor circulation. Sand holes, in effect, were the automatic vent valves. This designer learned that removing air continuously is the key to a steam system operating at peak efficiency. Because automatic vent valves were not invented yet, air removal still had to be done at each radiator, by opening a petcock manually.

10. Between 1840 and 1860, nothing was done to improve the operation of steam systems. Gravity water heating systems had much better circulation and rapidly replaced steam heating systems.
11. During the 1860s, an automatic vent valve was invented. The new vent valves were equipped with a petcock in the event the vent valve malfunctioned.
12. Hot water heating systems (gravity, no pumps) in very large buildings did not work well, and that resulted in the resurgence of steam system installation. Around 1889, a working automatic vent valve was invented, and by 1901, five or six companies were making quality vent valves. A problem with some automatic vent valves occurred; they whistled, and others spit water and needed adjustment regularly. Additionally, the vent valves vented foul-smelling air.
13. Positive return line valves (steam traps) were developed along with the vent valve. Positive return line valves were used on two-pipe steam systems. A positive return line valve permits air to flow out of the radiator with the waters of condensate. Air and water flowed down the return pipes to a master vent valve in the basement, where system air was exhausted to the atmosphere.

With the development of positive closure steam traps, graduated radiator valves, working vacuum vent valves, and automatic boiler return devices, it permitted James A. Donnelly to design and develop the gravity return steam vacuum system. Air vent valves were no longer needed on each radiator.

Steam vapors and foul air vented to a central location near the boiler. Exhaust piping could be added onto the vent fitting and all odoriferous steam vapors and air could be piped out of the building.

In 1905, positive return valves worked so well that James A. Donnelly's gravity two-pipe steam return systems could compete with the water heating systems of the day. Additionally, the graduated radiator steam control valve allowed the installer to meter the flow of steam to each radiator, thereby improving steam circulation in the building.

Graduated radiator valves (the precursor to a fixed orifice or built-in adjustable-type orifice valves) are valves that restrict how much steam enters a radiator. Graduated radiator control valves made it possible for vacuum pumps to draw the return side of a system into a deeper vacuum than the steam side of the system. That greater differential in pressure improved steam circulation.

14. Around 1919, steam traps, vent valves, boiler return traps, vacuum pumps, and many other devices produced by different manufacturers used in steam heating were tested and certified by independent laboratories. Steam heating became the heating medium of choice in many buildings, particularly in large buildings where water heating was not suitable.

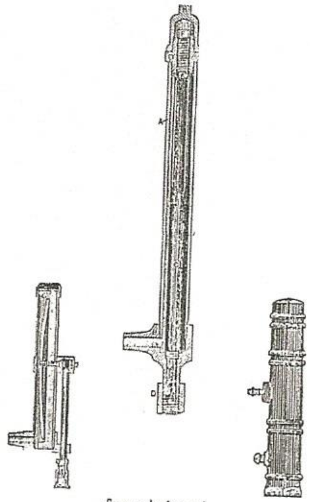
The key to comfortable steam heating is the removal of system air. Much has been written about proper venting and air removal. Unfortunately, little has been written on how to size vent valves. Many theories about system balance have been put into place, and for the most part, when air removal theory and proper vent valve placement was implemented, good results were obtained. Problems with air removal occurred some time after a building was built.

Vent valve replacement for a radiator was a simple repair with this exception. When a specific model of a vent valve was no longer available or a manufacturer went out of business, selecting a replacement valve could be problematic. Installing the wrong type or wrong capacity vent valves could cause the radiator or part of the heating system to be out of balance with the rest of the building. Because a vent valve replacement was such an easy repair, uninformed service people or home owners replaced the vent valves with what a counter person at the store offered as a replacement. Vent valves with different venting rates were used and steam circulation to some locations changed. Over time, as steam circulation became increasingly imbalanced due to the installation of the wrong type of vent valve, steam would reach the steam risers and radiators at different times. This resulted in system imbalances that generally resulted in over or under-heating of some spaces in a building.

Hoffman Specialty Company is a manufacturer with roots that go back to the era where steam heating began its development. Today, Hoffman Series, Bell and Gossett, a Zylem Brand and, in the twenty-first century, still manufactures air vent valves and a host of other products used in steam heating. This company has a rich history, provides technical information, and keeps a library about the development of all of its products. Because Hoffmann gave me technical publications and data when I was servicing heating systems, it pleases me to use the information so graciously provided me.

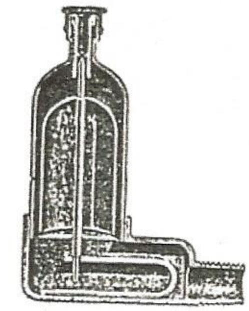
Vent Valves of History

1



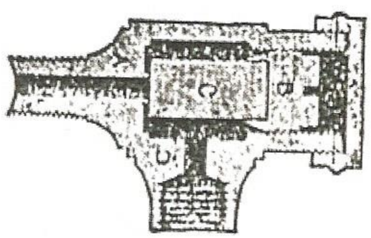
Some early forms of automatic air valves

2



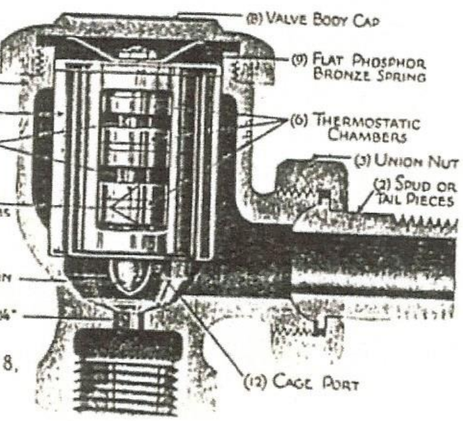
An early type of automatic air valve

3



Air valve with short expansion-post

4



Sectional view of No. 8, showing the all-metal construction

Shown in Figure 1 is one of the first automatic vent valves. These vent valves opened and closed in response to the movement of bimetallic elements that responded to the heat of steam. These vent valves collected water and, on occasion, had to be drained.

As time passed, vent valve technology progressed and the type valve shown in Figure 2 was developed. This vent valve had a bimetallic element shaped like a hairpin. Note the stem guide and valve seat at the outlet port of the valve. Additionally, water drained from the vent valve by gravity and little maintenance was required.

Vent valve number 3 was used on radiators in a one-pipe steam system. Air was discharged from the vent valve and sometimes piped through the wall and vented to the atmosphere or separate air release piping that ended at a central location in the basement. Often, the vented air was discharged outside the building and foul air and some steam was not released inside the occupied spaces in the building.

Usually, the central location to vent air was is the boiler room. Air release occurred at a master venting device, and this devise's outlet was piped to the boiler's chimney or vented through a wall where the foul-smelling air exited the building spaces. Air vent piping could be connected to an air removal pump (Paul system). All air release piping risers were connected to a master header. When the master header was connected to a mechanical air exhauster, the discharge outlet of the air exhauster was piped outside the building where the odoriferous air was released.

Figure 4 was called a positive return line valve or steam trap. This valve, the number 8, was manufactured by the Hoffman Specialty Company and was of the first valves produced that did not use carbon posts or need mechanical adjustments. Positive return line valves were used on two-pipe steam systems, two-pipe gravity vacuum systems, and two-pipe induced vacuum systems.

Many manufactures, such as American Radiator Company (ARCO, air eliminators), Anderson Products Incorporated (Vent-Rite radiator air valves), Barnes & Jones, Broomell, Dole Valve Company, Donnelly, Dunham, Hoffman Specialty Company, Hutcheson, Ideal, Illinois Engineering Company, Imico, J.P. Marsh Company, Milwaukee Valve Company, Moline, Monash-Yonkers Company, Mouat, New York Air Valve Corporation, O-E Specialty Company, Richardson, Sarco, Stickle Steam Specialties, Trane, Vapor System, Veco, Warren Webster, William S. Hanes & Company, and others, produced vent valves for steam systems.

Some of these companies designed and installed proprietary heating systems with all the valves, traps, boiler return traps, and venting devices.

No matter what a manufacturer made, designed, or claimed, good steam circulation could not occur without proper system air removal. All steam systems, no matter how sophisticated, complex, or expensive, needed some type of air release valve, and for the most part, the vent valves' cost was minuscule in comparison to any part of the heating system.

We have established venting devices were inexpensive. The selection of an air vent valve for radiators and steam mains was so simple that we need to look at why so many different capacity vent valves are offered by the different manufacturers. Shown on pages 141 to 143 are two manufacturers of vent valves and some different vent valves that one can use. Pay close attention to the words used about the limits of the vent valve.

A Brief Explanation of What a Vent Valve Is and Does

Vent valves are used for venting heating elements such as convectors, radiators, unit heaters, steam mains, and pipes used as heating elements. Generally, a vent valve must permit air to leave the heating elements or pipes and must close when steam or water reaches the vent valve. The vent valve also must open when water has drained or the temperature inside the vent has lowered due to the presence of air inside the vent valve. A vent valve must be designed to allow water to drain out of the valve. Old-style vent valves had a long drain tube called a syphon. The syphon helped remove any water collected in the vent valve. Modern-style vent valves use a short tongue in place of the long drain tube.

When water drains from a vent valve or the surface temperature of a radiator and vent valve cools, the valve pin drops away from the port and air venting resumes. This cycle will repeat often during the duty cycle of an operating boiler.

Drop-away pressure needs to be considered when installing vent valves. When the steam system pressure exceeds the maximum drop-away pressure of a vent valve, the vent valve cannot open and all venting ceases. Therefore, the vent valve drop-away pressure must fit into the system's operating pressure. For vent valves to work properly, the steam pressure in the steam system should rise and fall during the heating cycles.

All boilers used for steam heating should be set to cycle. The primary control for many boilers is a thermostat. Thermostats call a boiler into operation to heat a building or selected spaces. Thermostats set the duty cycle of the boiler. To stop steam from being supplied at a constant pressure, a pressure-controlling device is needed. Typically, a pressure controller is set to the maximum steam pressure that a system requires. A boiler's operating pressure is determined by the system pressure drop. Additionally, the pressure controller must be set to maintain a differential of at least ½ psig. That means the fuel-burning equipment shuts down at a predetermined steam pressure. The burner restarts at ½ psig lower than the cutout pressure. The pressure controller, in effect, caused the system steam pressure to cycle. Cycling of the steam pressure assures that the operating steam pressure is not constant. By varying or allowing the steam pressure to rise and fall, condensed water can drain out of the vent valves. The floats can drop or the bimetallic elements can cool, allowing the vent valve to open and allow condensate to drain, break vacuum, and allow more air to be released from the system.

Assume a vent valve has a drop-away pressure of 6 psi; that means the vent valve will not open unless the system steam pressure drops below 6 psig. When that vent valve is installed in a steam system operating at less than 6 psig, the vent valve will open when steam pressure drops back or the vent valve cools, and condensate water will drain out of the valve.

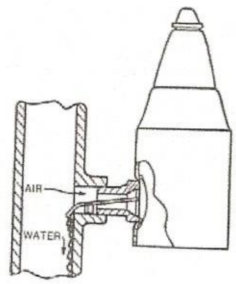
Vent valve capacities are determined by the size of the outlet port (orifice or hole in the valve) and the system's operating pressure. System pressure is variable. Therefore, a vent valve will discharge air at different rates. System operating pressures range from 0 to a set maximum steam pressure.

Assume the maximum operating pressure of the steam system is 2 psig with a drop back of ½ psig (set system differential). It is conceivable that the cycling pressures will be between 2 psig and 1 psig (the 1 psig occurs due to the time it takes for the burner to start and begin producing more steam in the boiler). As steam pressure increases, more air is forced out of the vent valves; when the burner shuts down and steam pressure drops, less air will be released from the vent valves.

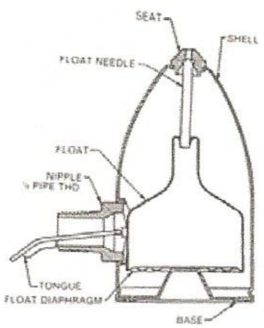
Another important function of a vent valve is to allow air to reenter the steam system. This function is very important, because reentering air prevents a vacuum from forming in the radiator and piping system. If a deep vacuum is formed in the radiator, any water remaining in the radiator can flash into steam and cause banging in the radiator or piping system.

Air vent valves in vacuum systems work a bit differently. They allow air to leave the system but will not allow air to reenter the system. Vent valves in steam vacuum systems are equipped with large orifices and air checks. The reason for the larger orifices is that the system operates at very low steam pressures. To increase a vent valve's capacity to vent air at lower steam pressures, a larger outlet hole is needed. The drop-away pressure for vent valves in vacuum systems should be equal to maximum operating steam pressure of the system, usually about 2 psig.

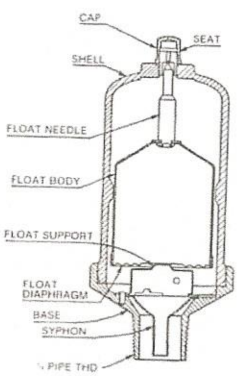
Hoffman Vent Valves



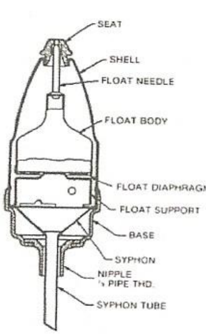
Shown is a vent valve inserted into a boss on a radiator section. Look carefully at the boss and the tongue of the vent valve. This boss is quite long and the tongue of the vent valve is just long enough to enter the section of the radiator. The tongue needs to be inside the radiator section, or the exiting water flow will be impeded. Each leaving droplet of water must flow along the bottom of the tongue, and the system air enters the vent valve from above the tongue. If the tongue were lying inside the boss, the tongue would be forced upwards and water would be trapped in the boss. Additionally, the air passage would be restricted and reduce the effectiveness of the vent valve



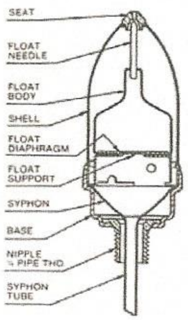
Shown is a cutaway of a Hoffman # 40 vent valve. This vent valve is a single-port open vent, and not for use in vacuum systems. The travel of the float needle is fixed and is not adjustable. Travel of the float needle is set at .022 inches. The drop-away pressure is 6 psi and may be used in systems operating up to 10 psi. This vent valve has a venting capacity from 150 to 800 cubic inches of air per minute, depending on the steam pressure. Valves with fixed ports cannot be used in systems where proportional venting is needed. Since most steam systems operate at 2 psig or less, the maximum venting capacity of this valve is about 500 cubic inches of air per minute.



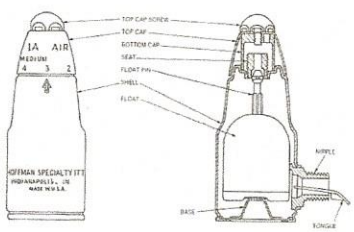
Shown is a cutaway of a Hoffman 71, a vent valve. Hoffman 71A vent valve is a straight pattern model valve and the 71A is the angle pattern model. These valves have a smaller port than the 40 series valves and are similar in use as the 40 series valves. The float travel is .0006 inches, and the smaller port and lower travel of the float needle cause this valve to have a lower capacity air release than the 40 series valves. Therefore, this vent valve is used in systems with a higher operating pressure than 40 vent valves. The drop-away pressure of this valve is 11 psi and its maximum operating pressure is 15 psig. Additionally, this valve is a federal specification vent valve and was subjected to rigid testing. As a result, this valve is more costly than the 40 series valves.



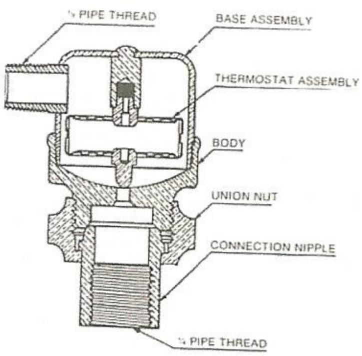
Shown is a cutaway of a Hoffman # 43 vent valve. The Hoffman # 43 vent valve is identical in all aspects of operation as the # 40. However, it is a straight pattern valve and can be used only in the vertical position. Look at the syphon tube. It is cut at an angle. The angle cut helps to promote drainage. In this valve, the syphon has two parts: a funnel and syphon tube. The funnel is designed to catch the droplets of water formed as steam condenses in the valve, and the syphon is to drain and direct the water out of the valve.



Shown is a Hoffman # 74 unit heater vent valve. This vent valve is an open vent valve and designed for unit heater service. The travel of the float needle is .0006 inches and has a small port with a large float. This combination is needed so that the vent can release air at a higher steam pressure. The maximum drop-away pressure of this valve is 35 psi and will operate in systems up to that pressure, and the maximum capacity of this valve is about 800 cubic inches of air per minute.



Shown is a Hoffman 1-A vent valve and is a multi-ported non-vacuum vent valve. This valve has six carefully-drilled orifices. The drop-away pressure of the 1-A vent valve is 1.5 psi. The valve may be used in systems operating up to 10 psi, but the system pressure must drop to 1.5 psi or less for the valve to reopen. This valve can be gotten in a straight pattern design (fig. # 1-B), and this multi-ported valve can be used to balance steam systems.



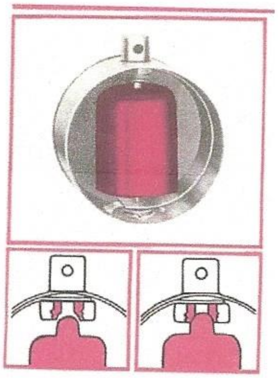
Shown is a cutaway of a Hoffman # 3 air line vent valve. This vent valve does not have a float in it. Air is released by the action of a thermostatic element. The # 3 vent valve was primarily used on air line or Paul systems. See the outlet port of the valve. It is equipped with a threaded connection and can be piped to a separate air release piping system. The separate air release piping can be directed to release system air to a central location in the basement or connect to an air removal pump. Drop-away pressure is not important with this valve, as it operates similarly to steam traps. This valve has not been used in new systems for many years. Today, the Hoffman # 3 is used primarily for replacement.

All the vent valve capacities are based on the *operating steam pressure*. Hoffman vent valves, except the number 3 air line vent valve, have a maximum discharge capacity of about 850 cubic inches of air per minute or about ½ a cubic foot of air per minute.

Hoffman # 75 and 76 main vent valves are not shown here. Hoffman # 75 and 76 are similar in shape to the # 74 vent valve. The # 75 vent valve is for pressure systems and the # 76 is for use in vacuum systems. Both valves will release about 4 cubic feet of air per minute.

Competitors Vent Valve

I chose Competitors Heating Corporation as the second manufacturer of vent valves to be included in this book, because like Hoffman, Competitors supplies information readily and honor their warrantee. Competitors uses bimetallic elements to open and close their vent valves.



Shown in the picture are the internal working parts of a Competitors vent valve. A semicircular bimetallic thermostatic actuator responds quickly when exposed to the hot steam.

The actuator lifts the valve stem into the seat and closes the outlet valve port, thereby holding steam in the radiator.

Additionally, a large open float prevents condensate water from collecting in the vent valve body. Competitors valves have large orifices that vent large volumes of air, and that results in fast system air removal.

This pattern radiator vent valve comes in five models and are called Competitors Vapor Equalizing Valves. Each valve comes with an instruction. Listed below are some instructions and venting capacities. Venting capacities are rated at 1 psig.

1. Number 4 – Install on radiators in the room with the thermostat or on radiators that will affect the operation of a thermostat. Venting capacity: .1485 CFM.
2. Number 5 – Install on radiators near or above the boiler room and in warm rooms. Venting capacity: .560 CFM. The # 5 vent valve equals four ordinary air vent valves.
3. Number 6 – Install on radiators farthest from the boiler and in cold rooms. Venting capacity: 1.179 CFM. The # 6 vent valve equals eight ordinary air vent valves.
4. Number C – Install on radiators farthest from the boiler or in the coldest rooms. Venting capacity: 2.26 CFM. The C vent valve equals fifteen ordinary air vents.
5. Number D – Install where a large amount of air must be vented. Venting capacity: 4.08 cubic feet of air per minute. Equals twenty-seven ordinary vent valves.

6.Competitors # 1 air eliminator – Use at the end of steam mains or where a high air removal rate is needed, such as large unit heaters. Venting capacity: 4.08 cubic feet of air per minute.

Venting capacities for Competitors vent valves are based at 1 psi operating pressure.

7. Competitors # 2 air eliminators – Use at the end of large, long steam mains or the steam main at the cold side of a building. Venting capacity: 16.32 cubic feet of air per minute.

Venting capacities for Competitors vent valves are based at 1 PSI operating pressure.

As we look at the venting capacities of vent valves, this question arises: "How much air must be vented from a steam system?" Since we can remove enormous amounts of air from a system by using larger vent valves, why not install the largest vent valves?

Two questions that plague some contractors and service technicians are:

1. What is the difference between different manufacturers' radiator vent valves?
2. How is the air removal capacity of a vent valve affected by the pressure of the steam system?

Some questions may be answered on pages 136 through 149. Pay attention to the venting capacities of Hoffman # 40 and the Competitors # 4 and # 5 vent valves. These vent valves or similar-type vent valves will be found on radiators where steam is used for heating. Most radiator vent valves expel up to ½ a cubic foot of air per minute.

The real question is: "How does one size a vent valve?" The answer to that question is we do not have to size vent valves; they have already been sized for us. We need to select the proper-size vent valve for the application and location of use.

An excerpt from an article, written in 1946, by the director of engineering of Hoffman Specialty Company, Ferdinand Jehle, M.E., will provide some insight into what vent valve installation is all about.

Mr. Jehle wrote that if the port size of a vent is within reason, then the boiler capacity and not the venting capacity determines the heat-up time.

An example explaining the statement: a steam system has 800 square feet of radiation and is equipped with twenty radiators. The steam main in the basement is a 3-inch pipe and is 150 feet long. Each radiator has 23 cubic inches of internal area per square foot of heating surface.

To find the cubic inches of air in the radiators, we must multiply 23 cubic inches of space (1 EDR) in the radiators by 800 square feet of heating surface; 23 × 800 = 18,400 cubic inches of air is in all the radiators.

To find the cubic inches of air in the steam main, we must find the surface area of a 3-inch circle and then multiply that by 150 feet × 12 inches.

Diameters of pipe times	3.1414 = surface area of a 3-inch circle; 3.1414 × 3 = 9.42 sq. in.
Length of pipe times 12 inches	150 feet × 12 inches = 1,800 sq. in.

Area of the diameter multiplied by the length = cubic inches of space in the pipe.

1,800 × 9.42 = 16, 956 cubic inches of space in the 3-inch pipe

Total cubic inches of air in the system:

Total cubic inches of air in the twenty radiators = 18,400 cubic inches
Total cubic inches of air in the pipe = 16,956 cubic inches

Total cubic inches in the system = 35,356 cubic inches of air in the system

The math is not exact; 23 cubic inches of air per square foot of heating surfaces in radiators are the average number of different types of radiators. The 23 cubic inches of air could be more or less, depending on which manufacturer made the cast-iron radiators. Consequently, heating elements could be steel pipe and pipes with fins or finned convectors. Therefore, the estimated 23 cubic inches of air space per EDR will be far in excess, and any mathematical errors made, these calculations will favor the conservative side of the example.

We know that the quicker air leaves a system, the sooner steam will reach the radiators and provide heat, so how do we size the vent valves for each radiator?

Before sizing vent valves, we need to know and understand this fact. It will take the boiler 1 hour to deliver 800 EDR of steam to heat the building on the coldest design day.

Let us divide 35,356 cubic inches plus an additional 5,184 cubic inches of air contained in the boiler. A total of 40,540 cubic inches of air is in the entire system. Divide 40,540 cubic inches of air by twenty radiators. Therefore, each radiator vent valve should vent 2,027 cubic inches of air in 1 hour. Since vent valve capacity ratings are in minutes, we need to divide 2,027 cubic inches of air by 60 minutes, which means each vent valve will expel 33.78 cubic inches of air per minute.

Look at the capacities of these open port vent valves.

Competitors # 4 = .1485 CFM or about 247 cubic inches of air per minute
Competitors # 5 = .560 CFM or about 800 cubic inches of air per minute
Hoffman # 40 = valve vents about 380 cubic inches of air per minute

A vent valve needs to vent 33.78 cubic inches of air each minute; any one of the above vent valves can vent much more air than required. Remember, each vent valve vents air until steam or water reaches the vent valve.

To find out how long it would take to vent all the air from the system, divide the venting capacity of twenty vent valves combined by 40,540 cubic inches.

Manufacturer	Valve Type	Valves	Venting rate	Total capacity	Divide by	Venting Time
Competitors	# 4 vent valves	20	247 CIM	4,940	40,540/4940	= 8.20 minutes
Competitors	# 5 vent valves	20	800 CIM	16,000	40,540/16,000	= 2.53 minutes
Hoffman	# 40 vent valves	20	380 CIM	7,600	40,540/7,600	= 5.33 minutes

In the example, system venting occurs without using a main vent on the steam main. Additionally, not factored in was the system operating pressure. The venting capacity of vent valves with fixed orifices is based on the operating steam pressure. Competitors vent capacity to vent air is based on a system pressure of 1 psig, and ITT Hoffman rates its valves on a pressure curve. At 1 psig, the # 40 valve vents about 380 CIM.

Boilers do not produce steam immediately. The steaming rate of a boiler is based on the size of the boiler in relation to the system it serves. Additionally, when a boiler pressurizes a system, the piping becomes charged with air. System air is vented by the vent valves and steam replaces the vented air.

ITT Hoffman's venting chart shows that their vent valves begin venting air at 4 ounces of pressure. At 4 ounces of pressure, the # 40 vent expels about 150 cubic inches of air per minute; as the pressure increases, the venting rate of the vent valve increases in proportion to the steam pressure.

Assume a steam system operates at 4 ounces of steam pressure and the twenty radiator vent valves discharge 150 cubic inches of air per minute, all the vent valves will release 3,000 CIM of air. A total of 40,540 cubic inches of air will be released at 4 ounces of steam pressure and it will take 13 minutes to release the air in the pipes plus 1.7 minutes for the air contained in the boiler. Remember, a boiler must operate for one full hour to supply 800 EDR of steam.

Note: The Hoffman # 40 radiator vent valve is a regular, low capacity vent valve. Above, in the examples, all the system air was removed in less than 15 minutes, and without a vent on the end of the steam main.

When a heating cycle starts, most boilers take longer than 12 minutes to produce steam. The speed vent valves remove air from the system will not help a boiler to make steam quicker.

In this example, a boiler has to supply sufficient steam to the radiators to increase temperature in a room, and this is what happens:

A room and a radiator are at 70 degrees F. The temperature drops and a thermostat starts the boiler. Steam is produced to heat all the radiators and piping, and to maintain a 70-degree room temperature. Steam at 215 degrees F has to enter the radiators so they can supply the EDR (estimated demand ratio) needed to heat the rooms. The calculations used for an 800 EDR steam system are rough but are sufficiently accurate for this example.

A cast-iron radiator weighs about 5.4 pounds per EDR, and all the piping weighs in at 1,140 pounds.

Eight hundred square feet of radiation 800 × 5.4 pounds = 4,320 pounds

3-inch pipe weighs 1,140 pounds

Approximate weight of the metal equals 5,460 pounds

To heat the metal from 70 degrees F to 215 degrees, assuming the specific heat of the iron is .12, requires 95,004 BTUs.

Five thousand four hundred and sixty pounds of metal multiplied by a 145 Delta T = 791,700 BTUs. Then multiply 791,700 BTUs by .12 (specific heat). The warm-up requirements are 95,004 BTUs.

The house needs 800 EDR or 192,000 BTUH for heating. A boiler's capacity is determined by adding the connected radiation load (twenty radiators = 192,000 BTUH) plus 95,004 BTUH to overcome the start-up losses. This boiler must have an output capacity of 287,004 BTUH.

Because this boiler can produce 1½ times more pounds of steam per hour than the system needs, the additional BTU capacity will result in the system reaching the 2 psig set operating pressures faster. The boiler will reach set pressure in about .69 hours or 36 minutes. In 36 minutes, all the piping and the inside tubes of the radiators will reach about 215 degrees. No matter how creative we get with vent valves, no one can make the boiler produce the set steam pressure quicker unless more fuel is put into the burner.

All of the above calculations are based on a 0 degree outdoor temperature. When the outdoor temperatures are higher, the system will heat quicker and, of course, the set steam pressure will be reached proportionally faster. Additionally, the start-up load, 94,000 BTUH, will produce nearly 2 gallons of domestic hot water per minute when a submersed coil or storage tank with a coil is used to produce domestic hot water without affecting the boiler's ability to heat the building.

Small vent valves are more than sufficient to vent system air. Nevertheless, 150 feet of steam main supplies steam to the supply take-offs for twenty radiators. The radiators closest to the boiler will heat up quicker and hotter than the radiators at the end of the piping system. By installing a main vent on the end of the steam main, steam will reach the peripherals of the piping system quicker. The question is: How big should the main vent valve be at the end of the piping system?

Remember, a 150-foot long, 3-inch steam main has 17,000 cubic inches of air in it. The piping system has 18,000 cubic inches of air in it and the boiler has 5,184 cubic inches of air in it; therefore, the total amount of air in the entire system is about 40,540 cubic inches of air. All twenty of number 40 Hoffman vent valves at 4 ounces of pressure can vent all system air in about 13 minutes.

When steam enters the radiators closest to the boiler, the vent valves close. Steam progresses toward the radiators farther down the steam main and more vent valves close. Closed vent valves cannot release air. This causes the remaining system air to be vented by fewer vent valves as steam flows toward the end of the piping system and limits the venting of air to fewer and fewer vent valves.

Remember, each of the remaining open vent valves expel 150 cubic inches of air per minute. Fewer vent valves, venting air will increase the length of time to remove the system air and will result in the radiators at the end of the steam main taking longer to heat. Additionally, a thermostat controls the operation of the boiler; when the thermostat is satisfied, the burner shuts down and no steam will be produced. I stated before that the radiators closest to the boiler would reach temperature sooner and the radiators farthest from the boiler may not reach proper temperature. This condition will create uneven temperatures in the building. The installation of a main vent valve at the end of the steam main will help balance the steam supply and heat the building quicker and more uniformly.

At the end of the steam main, the main vent valve needs to vent 17,000 cubic inches of air plus 5,184 cubic inches of air in the boiler, the amount of air in the 3-inch pipe and boiler. That translates to a total of 13 cubic feet of air in both the steam main and the boiler. Hoffman # 40 vent valves, at 1 pound of steam pressure, can remove all the system air in about 6 minutes, and at 4 ounces of pressure, they will vent all the system air in about 13½ minutes.

Boilers produce steam pressure gradually; therefore, the vent valves start venting air at lower rates and gradually increase in capacity proportional to the rise in steam pressure. It takes about 5 to 12 minutes to vent the system (a variable venting rate based on system pressure). That is very quick in relation to the 36 minutes it takes for the boiler to fill the system with 2 pounds of steam pressure. Steam pressure builds up slowly, and as result, the vent valves vent air slowly. Due to the slower venting rate, a safety factor of two should be used in estimating how long the system air will be released.

The boiler and steam main, together, hold about 13 cubic feet of air in it, and a Competitors # 1 or a Hoffman # 75 vent valve can remove 4 cubic feet of air per minute at 1 psig. By installing either vent valve, the steam main can be free of air in about 3 minutes. One thing we need to remember about the steam mains, main vent valves close and stay closed once the set steam pressure is reached. Steam main vent valves normally vent air once, at the start of each heating cycle.

Is a vent valve that vents 4 cubic inches of air per minute needed? This is a subjective question, and my answer is, "I do not think so." At 1 pound of steam pressure, the air to be released from the steam main should be equal to the total amount of air released from all the twenty Hoffman # 40 vent valves, 7,600 cubic inches of air. Remember that the steam main and boiler has about 22,184 cubic inches of air in it. Additionally, a steam main, main vent that releases half the 7,600 cubic inches of air per minute or 2 cubic feet of air per minute will clear the steam main of air in about 3 minutes. Remember that the vent valves release less air at lower pressures and the rate of air release increases proportionately with the rise in steam pressure. The boiler in the above example takes 36 minutes to reach the set pressure. Steam flows through the steam main, starting at 0 pressure and gradually increasing in pressure.

Vent valves and end-of-the-line vent valves vent the system air in about half the time it takes a boiler to reach set pressure. Releasing air out of a steam main quicker than needed does not improve the system's efficiency.

Many boilers in buildings are oversized and can reach set operating pressure in less than 15 minutes. Because time to calculate the size of a main vent in existing systems is limited and installing a larger vent valve on a steam main will not cause problems, most service people opt for installing large vent valves. Clearing the steam main of air expeditiously causes the steam to circulate and reach all the radiators uniformly, and helps the radiator vent valves to operate quietly and lessen strain on the radiator vent valve internals.

Overheating or under-heating problems may occur in rooms above or near a boiler, or in the room where the thermostat is found. If excess heat is supplied to the room with the thermostat, the boiler can shut down before the entire building is heated. Sometimes, installing a smaller capacity vent valve on that radiator or radiators in other hot rooms can correct some under-heating or overheating problems.

Selecting vent valves for heating systems does not just happen. Many vent valve manufacturers make many vent valves from which to choose. Before selecting vent valves, try to decide how much air needs to be removed from the heating system. Then try to calculate how quickly steam will reach the radiators. Most of us are not engineers, but we can do some basic math. If we figure out how long it takes for a boiler to reach set pressure, we will know about how long it takes for steam to reach the farthest radiator.

Suppose it takes 10 minutes for a boiler to reach set pressure, we would want to make sure that system air is out of the piping sooner than 10 minutes. The reason for this is that steam should be in the radiators before the boiler reaches set pressure.

Count all the radiators on the system, select the vent valves by its capacity, and do not exceed a venting capacity of 500 cubic inches per minute at 2 psig (very fast for a radiator). Multiply all the vent valves by their capacity and that will give the total amount of system air the radiator vent valves will remove.

Find the cubic inches of air in the steam main and select a main vent valve large enough to vent all the air out of the steam main in half the time it takes for the boiler to reach set pressure. Very large capacity main vents are not needed, unless the building is very large. Additionally, several smaller vent valves can be placed at the end of the main to equal a super-capacity vent valve.

Often, large buildings have many different sizes of radiators, and some rooms may overheat or under-heat. If a room is overheated, lowering the venting rate of a vent valve will make the radiator take longer to heat that space and may alleviate the condition. Conversely, if under-heating occurs, venting air faster may bring the room up to temperature sooner. Here, a multi-ported vent valve may alleviate the condition. Multi-ported vent valves have six or more settings, where the installer can experiment with the proper setting to get the best results.

When steam heating systems were engineered and built as specified, an engineer selected and specified the vent valves. For the most part, heating was uniform throughout the building and a reasonable comfort was maintained. With the passing of time, vent valves failed and the proper capacity vent valve might not have been replaced in kind or replaced at all. Some buildings operated so poorly that owners had to replace all the vent valves in the building. In large jobs, price is often the governing factor, and all the vent valves may have been replaced without regard to capacity or quality.

In retrospect, we need to check the system's operating steam pressure. Determine the size of the radiators and establish a proper vent valve for each radiator; determine the size of the steam main vent valves and amount of steam main vent valves. Then add the capacities of all the vent valves. Calculate the total cubic inch or cubic foot space of the piping in the heating system and divide that by the total of the vent valve capacity. These calculations will provide an approximate amount of time that it takes to discharge the system air. Since system air is removed faster than a boiler can supply steam for heating, will the vent valve sizing be correct?

Remember this: steam systems were designed with a specific steam velocity; installing larger vent valves will not affect the velocity of steam. Larger vent valves will not overcome the frictional resistance of the piping system.

Assume the steam velocity is about 35 miles per hour. Steam will flow about 3,000 feet per minute. That means in most buildings, steam should be present in all the radiators in seconds, not the 10 to 30 minutes it takes a boiler to fill the system with steam. Air and steam flow together. The colder piping removes heat from the steam, and that, in part, causes some delay in establishing heat in a building.

Steam Traps

Steam traps can be special piping patterns or mechanical devices that prevent the passage of steam and allow the passage of air and condensate water.

Steam traps can be installed in a one-pipe steam system and are installed on two-pipe systems. A steam trap's primary function is to hold steam in a radiator or piping. Additionally, the steam trap drains condensate water (spent steam) and permits the passage of air out of the steam piping, heating elements, or equipment powered by steam.