



Steam and Condensate Piping

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Put most simply, steam is used as a medium to transfer heat energy from a point of generation to a point of use where the heat energy can be extracted to do work. Steam is an efficient heat-transfer medium and has the advantage of flowing by pressure differential to the point of use. Thus, no pumps are necessary to move the heat-transfer medium as in a hot water system, which reduces initial equipment costs and the associated maintenance expenses.

STEAM BASICS

Steam is produced when sufficient heat energy is added to change water from a liquid to a vapor. The heat energy inputs take two forms: sensible heat and latent heat.

Sensible heat (also referred to as heat of saturated liquid) is the amount of heat energy required to raise 1 pound of water from a temperature of 32°F to the boiling point, or saturation temperature, for any given system pressure. This heat energy input is referred to as sensible heat because every British thermal unit (Btu) of heat energy added to the water can be sensed by a thermometer from the fact that the water temperature rises by 1°F. (1 Btu is the amount of energy required to raise the temperature of 1 pound of water by 1°F.) As an example (refer to Table 8-1 on the next page), a steam system operating at 15.3 pounds per square inch gauge (psig) requires 218.82 Btu per pound of water of sensible heat energy input to raise the temperature of the water from 32°F to 250.33°F.

Latent heat content is the heat energy required to turn 1 pound of saturated water from a liquid to vapor steam. It is the heat energy available to be extracted from the steam to do work. When the latent heat content of a pound of steam has been extracted by any heat transfer process, the steam will condense back to saturated liquid. The amount of latent heat energy cannot be determined with a thermometer because the temperatures of saturated liquid and steam are identical for any given system pressure. Referring again to Table 8-1, at 15.3 psig, the latent heat content is 945.3 Btu per pound.

Specific Volume of Saturated Steam

The volume required per pound of steam at a given pressure (see Table 8-1, last column) is of great importance when installing a steam distribution system. The choice of the steam generation pressure influences both the required distribution pipe size and the steam velocity in the system. Pipe size directly impacts initial system cost, while steam velocity raises issues of erosion and noise. Steam distribution systems often are designed to generate steam at a relatively high pressure, requiring smaller-diameter, lower-cost piping and reducing the steam pressure prior to the point of use, thus increasing the available latent heat content.

Flash Steam

Condensed steam (condensate) is saturated liquid at the same temperature as the steam from which it was formed. If this condensate is discharged to an area of lower pressure, the excess sensible heat content of the condensate will cause a portion of the liquid to flash, or re-evaporate to vapor steam. This is an energy-saving measure that reclaims the heating value of high-pressure condensate rather than letting it vent to the atmosphere (to 0 psig) before being returned to the boiler.

Figure 8-1 provides information on flash steam formation for typical systems, while specific values of flash steam formation can be determined using the following equation:

Equation 8-1

$$\% \text{ of flash steam} = \frac{S_H - S_L}{H} \times 100$$

where:

S_H = Sensible heat in the condensate at the higher pressure before discharge

S_L = Sensible heat in the condensate at the lower pressure at which the discharge takes place

H = Latent heat in the steam at the lower pressure at which the condensate has been discharged

Example 8-1

The following example (courtesy of Armstrong International) illustrates the amount of recoverable heat energy in flash steam formation.

Gauge Pressure, psig	Absolute Pressure, psia	Steam Temperature, F°	Heat of Saturated Liquid, Btu/lb	Latent Heat, Btu/lb	Total Heat of Steam, Btu/lb	Specific Volume of Saturated Liquid, ft³/lb	Specific Volume of Saturated Steam, ft³/lb
0.0	14.696	212.00	180.07	970.3	1150.4	0.016715	26.80
1.3	16.0	216.32	184.42	967.6	1152.0	0.016746	24.75
2.3	17.0	219.44	187.56	965.5	1153.1	0.016768	23.39
5.3	20.0	227.96	196.16	960.1	1156.3	0.016830	20.09
10.3	25.0	240.07	208.42	952.1	1160.6	0.016922	16.30
15.3	30.0	250.33	218.82	945.3	1164.1	0.017004	13.75
20.3	35.0	259.28	227.91	939.2	1167.1	0.017078	11.90
25.3	40.0	267.25	236.03	933.7	1169.7	0.017146	10.50
30.3	45.0	274.44	243.36	928.6	1172.0	0.017209	9.40
40.3	55.0	287.07	256.30	919.6	1175.9	0.017325	7.79
50.3	65.0	297.97	267.50	911.6	1179.1	0.017429	6.66
60.3	75.0	307.60	277.43	904.5	1181.9	0.017524	5.82
70.3	85.0	316.25	286.39	897.8	1184.2	0.017613	5.17
80.3	95.0	324.12	294.56	891.7	1186.2	0.017696	4.65
90.3	105.0	331.36	302.10	886.0	1188.1	0.017775	4.23
100.0	114.7	337.90	308.80	880.0	1188.8	0.017850	3.88
110.3	125.0	344.33	315.68	875.4	1191.1	0.017922	3.59
120.3	135.0	350.21	321.85	870.6	1192.4	0.017991	3.33
125.3	140.0	353.02	324.82	868.2	1193.0	0.018024	3.22
130.3	145.0	355.76	327.70	865.8	1193.5	0.018057	3.11
140.3	155.0	360.50	333.24	861.3	1194.6	0.018121	2.92
150.3	165.0	365.99	338.53	857.1	1195.6	0.018183	2.75
160.3	175.0	370.75	343.57	852.8	1196.5	0.018244	2.60
180.3	195.0	379.67	353.10	844.9	1198.0	0.018360	2.34
200.3	215.0	387.89	361.91	837.4	1199.3	0.018470	2.13
225.3	240.0	397.37	372.12	828.5	1200.6	0.018602	1.92
250.3	265.0	406.11	381.60	820.1	1201.7	0.018728	1.74
	300.0	417.33	393.84	809.0	1202.8	0.018896	1.54
	400.0	444.59	424.00	780.5	1204.5	0.019340	1.16
	450.0	456.28	437.20	767.4	1204.6	0.019547	1.03
	500.0	467.01	449.40	755.0	1204.4	0.019748	0.93
	600.0	486.21	471.60	731.6	1203.2	0.02013	0.77
	900.0	531.98	526.60	668.8	1195.4	0.02123	0.50
	1200.0	567.22	571.70	611.7	1183.4	0.02232	0.36
	1500.0	596.23	611.60	556.3	1167.9	0.02346	0.28
	1700.0	613.15	636.30	519.6	1155.9	0.02428	0.24
	2000.0	635.82	671.70	463.4	1135.1	0.02565	0.19
	2500.0	668.13	730.60	360.5	1091.1	0.02860	0.13
	2700.0	679.55	756.20	312.1	1068.3	0.03027	0.11
	3206.2	705.40	902.70	0.0	902.7	0.05053	0.05

Source: Armstrong International Inc.

Condensate at steam temperature and 100-psig pressure has a heat content of 308.8 Btu per pound (see Table 8-1). If this condensate is discharged to atmospheric pressure (0 psig), its heat content instantly drops to 180 Btu per pound. The surplus of 128.8 Btu re-evaporates, or flashes, a portion of the condensate. Thus,

$$\% \text{ of flash steam} = \frac{308.9 - 180}{970.3} \times 100 = 13.3\%$$

The ability to recover usable heat content in the form of flash steam can greatly increase overall steam system efficiency. Consider a heat exchanger operating on 50-psig steam and condensing 2,000 pounds per hour of condensate:

$$\% \text{ of flash steam} = \frac{267.5 - 180.07}{970.3} \times 100 = 9.01\%$$

Thus, the flash steam produced is $0.0901 \times 2,000$, or 180 pounds per hour.

STEAM DISTRIBUTION PIPING

The purpose of any steam distribution system is to deliver clean, dry steam at the needed pressure to the eventual point of use. Two factors governing the design and sizing of steam distribution piping are steam velocity and the allowable pressure drop in the distribution system.

Steam Velocity

The velocity of the steam in a distribution system is a function of the mass rate of steam flow, steam pressure, and pipe size.

The steam velocity can be determined by the following equation:

Equation 8-2

$$V = \frac{2.4Q \times V_s}{A}$$

where:

V = Velocity, feet per minute (fpm)

Q = Flow of steam, pounds per hour

V_s = Specific volume of steam at the system pressure

A = Internal area of pipe, in^2

Steam velocities of 6,000 to 8,000 fpm are common in process steam systems. In heating systems where noise from flowing steam is an issue, velocities are typically 4,000 to 6,000 fpm.

Pressure Drop

One function of the steam distribution system is to deliver steam at the needed pressure. Friction losses in the piping, as well as flow through elbows, fittings, strainers, and valves, contribute to pressure drop between the boiler and the point of use. While steam velocity is a function of the mass flow rate, pressure drop is a function of the square of the mass flow rate. Table 8-2 provides an example of the relationship of mass flow rate, velocity, and pressure drop in a 2-inch steam line at 100 psig.

It is commonly accepted that the total pressure drop in a steam system should not exceed 20 percent of the steam supply pressure at the boiler.

One other factor to note in sizing steam distribution piping is the possibility of future expansion of the steam system. Generous sizing of the original distribution system can save costly retrofits in the future.

Figures 8-2 and 8-3 provide guidance on properly sizing steam distribution lines to take into account both steam velocity and pressure drop.

The following example (reprinted with permission from the *ASHRAE Handbook*) illustrates how to use the charts.

Example 8-2

Given a flow rate of 6,700 pounds per hour, an initial steam pressure of 100 psig, and a pressure drop of 11 psi per 100 feet, find the size of Schedule 40 pipe required and the velocity of steam in the pipe.

The following steps are illustrated by the broken lines on Figure 8-2 and Figure 8-3.

1. Enter Figure 8-2 at a flow rate of 6,700 pounds per hour, and move vertically to the horizontal line at 100 psig.

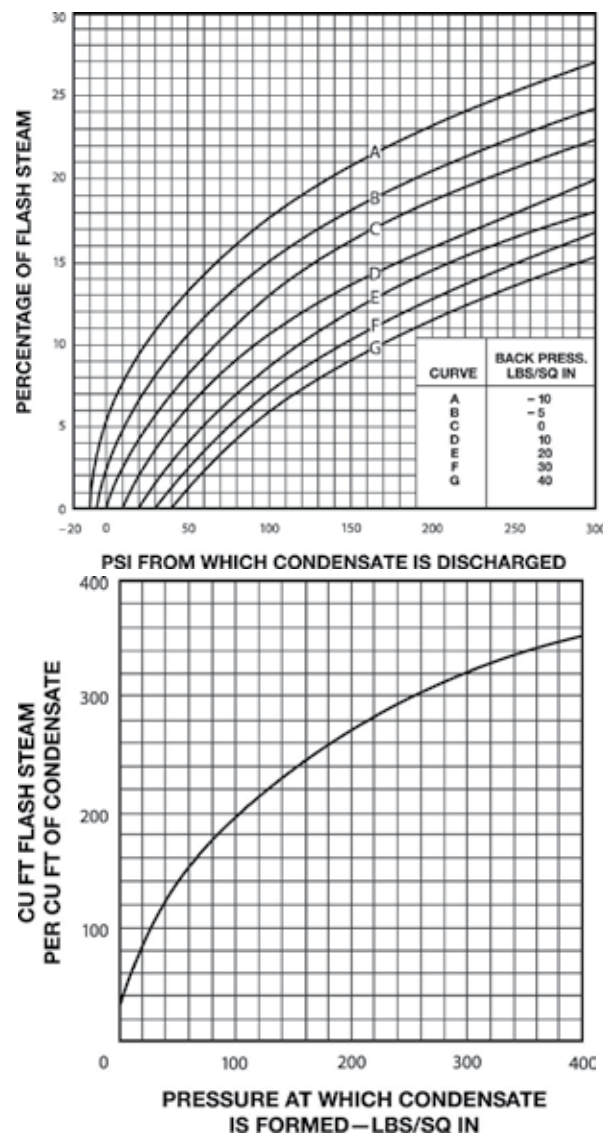


Figure 8-1 Flash Steam Formation Data
(top) Percentage of Flash Steam Formed When Discharging Condensate to Reduced Pressure; (bottom) Volume of Flash Steam Formed When 1 Cubic Foot of Condensate Is Discharged to Atmospheric Pressure
Source: Armstrong International Inc.

Table 8-2 Relationship of Mass Flow Rate, Velocity, and Pressure Drop in a 2-inch Steam Line at 100 psig

Mass Flow, lb/hour	Velocity, fpm	Pressure Drop
1,000	2,780	0.7 psi / 100 ft
2,000	5,560	2.7 psi / 100 ft
3,000	8,340	6.0 psi / 100 ft

2. Follow the inclined multiplier line (upward and to the left) to the horizontal 0-psig line. The equivalent mass flow at 0 psig is about 2,500 pounds per hour.
3. Follow the 2,500-pounds-per-hour line vertically until it intersects the horizontal line at 11 psi per 100 feet of pressure drop. The nominal pipe size is 2.5 inches. The equivalent steam velocity at 0 psig is about 32,700 fpm.
4. To find the steam velocity at 100 psig, locate the value of 32,700 fpm on the ordinate of the velocity multiplier chart (Figure 8-3) at 0 psig.
5. Move along the inclined multiplier line (downward and to the right) until it intersects the vertical 100-psig pressure line. The velocity as read from the right (or left) scale is about 13,000 fpm.

Note: Steps 1 through 5 would be rearranged or reversed if different data were given.

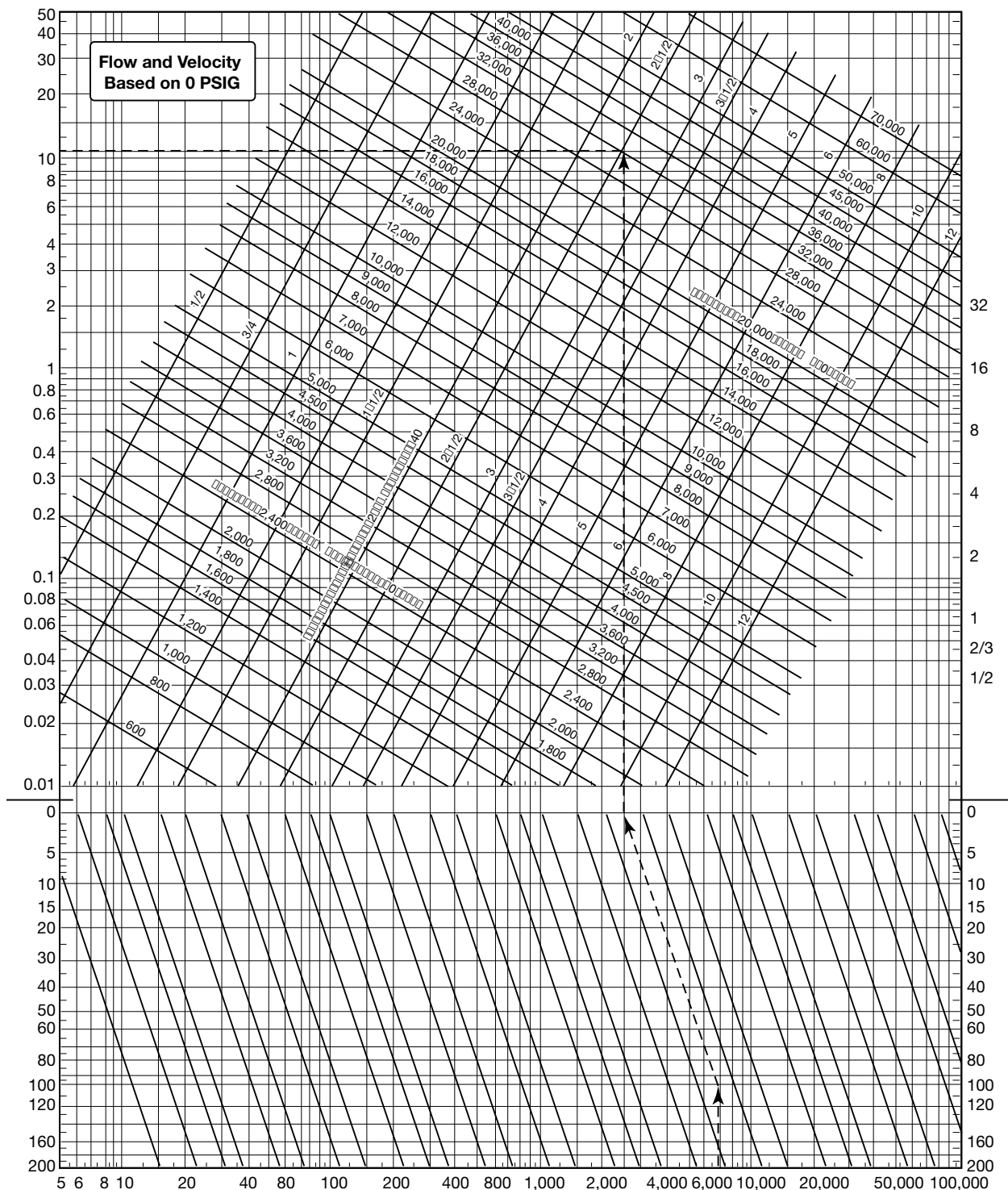


Figure 8-2 Flow Rate and Velocity of Steam in Schedule 40 Pipe at a Saturation Pressure of 0 psig

Source: ASHRAE Handbook

Erosion in Steam Distribution Systems

It is important to note that high steam velocity, especially with the presence of entrained droplets of condensate, will erode piping and fittings. This is most apparent at elbows, valves, and reducing fittings where flow direction or flow volume changes cause impingement on the piping.

CONDENSATE REMOVAL

Condensate is formed in steam systems when the latent heat of the steam is given up. This heat transfer can be intentional, such as in a space heater, radiator, or steam jacketed kettle, or unintentional (and unavoidable) due to radiation heat losses from piping and equipment.

In either case, it is imperative that the condensate, as well as any air or other noncondensable gases, be removed from the steam system as quickly as possible. Condensate and noncondensable gases contribute to decreased heat transfer efficiency, corrosion of piping and equipment, and an increased probability of dangerous water hammer.

The problems resulting from poor condensate drainage are as follows:

- A loss of heat transfer performance will result unless condensate is drained from the steam heating unit. Since heat transfer in a steam system is based on the large amount of latent heat that becomes available as the steam condenses, if the heating unit is flooded, only the sensible heat from the condensate will become available as it cools. Table 8-1 shows that the sensible heat is only a small fraction of the latent heat available in a pound of steam at any given pressure. The latent heat is transferred at a constant steam temperature as the steam condenses.
- Water hammer in an undrained or improperly drained steam main can be caused by the impact of a rapidly moving slug of water. Unless the condensate is removed from low points in the steam mains, it gradually accumulates until the high-velocity steam forms ripples. As condensate builds up, the area available for steam flow decreases, leading to even higher steam velocities to the point where water is entrained by the steam in the form of a wave. The slug of water accelerated by the steam can reach velocities in excess of 100 miles per hour before it hits some obstruction, such as an elbow or other fitting. The rapid change in speed can cause a loud noise or even severe damage to the system.
- Corrosion occurs in units that are not properly drained. Several corrosion processes have been defined: generalized corrosion, which removes metal more or less uniformly from the surface; oxygen pitting, which concentrates on small areas, rapidly creating holes; and condensate grooving, which etches away the metal along the path followed by the condensate, which has become acidic (carbonic acid) due to dissolved carbon dioxide.
- Corrosion is accelerated by the presence of carbon dioxide, which can form in the boiler as chemical components such as carbonates and bicarbonates decompose. Oxygen introduced by vacuum breakers or from makeup feed water also increases the corrosion rate.
- Fouling or scaling on heat transfer surfaces also is increased by inadequate condensate drainage and venting.

Steam Traps

Properly installed steam traps can minimize the problems caused by poor condensate drainage by draining the condensate and venting noncondensable gases from steam piping and heat exchangers. A steam trap is an automatic valve that is open in the presence of condensate and noncondensable gases and closed in the presence of live steam.

All steam traps must:

- Vent air and other gases from the mains and heating units.
- Prevent the flow of steam into the condensate piping.
- Allow condensate to drain into the condensate piping.

Many steam trap designs have been developed, and the main difference between trap types is the method of actuation. The most commonly used traps fall into one of the following categories:

- **Thermostatic:** The trap opens and closes by sensing the difference in temperature between the steam and the condensate, which has been allowed to cool to a temperature lower than the steam temperature. Some examples of this type of trap include thermostatic bellows (see Figure 8-4) and bimetallic traps.
- **Mechanical:** These include inverted bucket (see Figure 8-5) and float and thermostatic (F&T) traps. These traps operate on the difference in density between the steam and the condensate, opening when a mixture of condensate

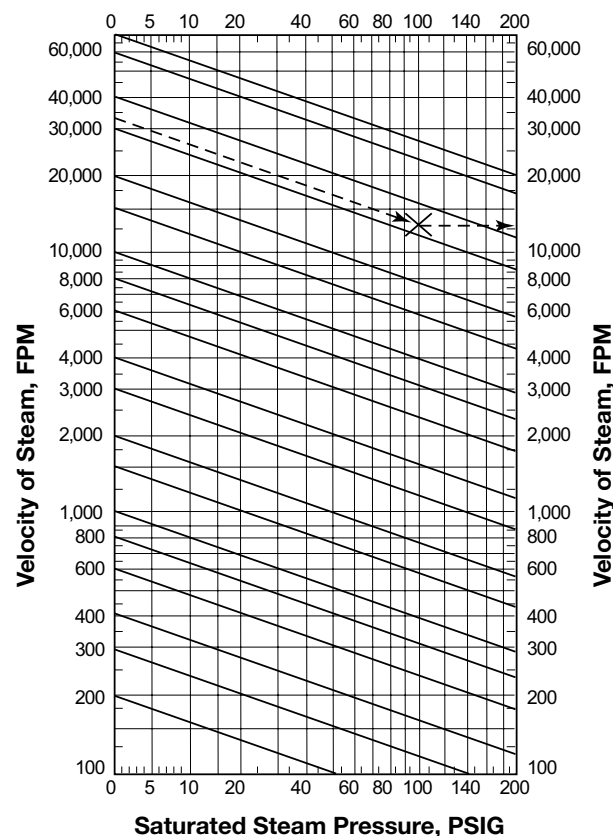


Figure 8-3 Velocity Multiplier Chart for Figure 8-2
Source: ASHRAE Handbook



Figure 8-4 Thermostatic Bellows Trap



Figure 8-5 Inverted Bucket Trap



Figure 8-6 Thermodynamic Disc Trap

and steam lifts the bucket (or condensate alone lifts the float) and closing when the condensate is discharged and live steam enters the trap.

- Thermodynamic disc (see Figure 8-6): This trap senses differences in flow velocity or pressure caused by relatively high-velocity steam compared to lower-velocity condensate.

Each trap design gives the trap its own set of characteristics.

Because of the variety of trap designs, one of the key decisions in condensate drainage design is the choice of the right type of trap. Often this choice is easy; for example, low-pressure heating system radiators are almost always equipped with thermostatic traps because the characteristics of that type of trap match the condensate drainage and air-venting requirements of low-pressure heating equipment. Sometimes, either of two different types of trap could be applied equally well to a given condensate drainage situation because the trap characteristics meet the drainage and venting requirements. For example, a high-pressure steam main could be equipped with either an inverted bucket trap or a thermodynamic disc trap. In some cases, a given kind of trap simply would not be able to do the job. For instance, since a thermodynamic trap requires a significant pressure drop between the steam-condensing device and the condensate pipe, such a trap installed in a low-pressure heating system would not have a sufficient pressure differential to operate.

Proper Condensate Drainage from System Piping

Properly drained mains and care taken in starting up a cold system not only prevent water hammer damage but also improve the quality of the steam and reduce the maintenance required on pressure-reducing valves, temperature controls, and other components.

Startup Loads

When bringing a steam distribution system up to operating pressure and temperature from a cold state, large amounts of latent heat are given up to the piping and fittings. This heat loss causes condensate formation on a scale much greater than that encountered in normal system operation. Table 8-3 gives values for warming-up loads to different saturation temperatures for various sizes of pipe.

Take as an example 300 feet of 10-inch line being brought up to 125-psi system pressure or ~353°F, assuming a warm-up time of one hour. The warming-up load of the line would be 450 pounds per hour of condensate. When at the operating pressure/temperature, this same line only loses latent heat through radiation and creates only 88 pounds per hour of condensate in still air at 70°F with 90 percent efficient insulation, or a factor of more than 5:1.

A liberal steam trap load safety factor and oversized steam traps do not always provide an efficient and safe steam main drain installation. The following points should also be considered:

- The method of heat up to be employed
- Providing suitable reservoirs, or drip legs, for the condensate
- Ensuring an adequate pressure differential across the steam trap
- Selecting and sizing the steam trap

Table 8-3 Warming-Up Loads for 70°F Schedule 40 Pipe, Pounds of Water Per Lineal Foot

Pipe Size, in.	Weight of Pipe per Foot, lbs	Steam Pressure, psig						
		2	15	30	60	125	180	250
1	1.69	.030	.037	.043	.051	.063	.071	.079
1¼	2.27	.040	.050	.057	.068	.085	.095	.106
1½	2.72	.048	.059	.069	.082	.101	.114	.127
2	3.65	.065	.080	.092	.110	.136	.153	.171
2½	5.79	.104	.126	.146	.174	.215	.262	.271
3	7.57	.133	.165	.190	.227	.282	.316	.354
3½	9.11	.162	.198	.229	.273	.339	.381	.426
4	10.79	.190	.234	.271	.323	.400	.451	.505
5	14.62	.258	.352	.406	.439	.544	.612	.684
6	18.97	.335	.413	.476	.569	.705	.795	.882
8	28.55	.504	.620	.720	.860	1.060	1.190	1.340
10	40.48	.714	.880	1.020	1.210	1.500	1.690	1.890
12	53.60	.945	1.170	1.350	1.610	2.000	2.240	2.510
14	63.00	1.110	1.370	1.580	1.890	2.340	2.640	2.940
16	83.00	1.460	1.810	2.080	2.490	3.080	3.470	3.880
18	105.00	1.850	2.280	2.630	3.150	3.900	4.400	4.900
20	123.00	2.170	2.680	3.080	3.690	4.570	5.150	5.750
24	171.00	3.020	3.720	4.290	5.130	6.350	7.150	8.000

- Proper trap installation

Heat-Up Methods

The type and size of the steam trap used to drain steam mains depend on the method used to bring the system up to normal operating pressure and temperature. The two methods of system heat up commonly used are the supervised and the automatic.

In the supervised heat-up method, manual drain valves are installed at all drainage points in the steam main system. The valves are fully opened to the condensate return or to drain before steam is admitted to the system. After most of the heat-up condensate has been discharged, the drain valves are closed, allowing the steam traps to drain the normal operating load. Therefore, the steam traps are sized to handle only the condensate formed due to radiation losses at the system's operating pressure. This heat-up method generally is used for large installations with steam mains of appreciable size and length and where the heat up generally occurs only once a year, such as in large systems where the system pressure is maintained at a constant level after startup and is not shut down except in emergencies.

In the automatic heat-up method, the steam boiler brings the system up to full steam pressure and temperature without supervision or manual drainage. This method relies on the traps to drain the warm-up load of condensate automatically as soon as it forms. This heat-up method generally is used in small installations that are shut down and started up at regular intervals, as occurs in heating systems or dry-cleaning plants where the boiler is usually shut down at night and started up again the following morning. To prevent system shock, steam system warm up also can be done with a ¾-foot line with a ½-inch valve to gradually warm up the main for a fixed amount of time before the main control valve is opened.

Steam Main Size, in.	Drip Leg Diameter, in.	Minimum Drip Leg Length, in.	
		Supervised Warm Up	Automatic Warm Up
½	½	10	28
¾	¾	10	28
1	1	10	28
2	2	10	28
3	3	10	28
4	4	10	28
6	4	10	28
8	4	12	28
10	6	15	28
12	6	18	28
14	6	21	28
16	8	24	28
18	10	27	28
20	10	30	30
24	12	36	36

Drip Legs

A reservoir, or drip leg, must be provided for the steam trap to be effective, since a steam trap can discharge only the condensate that is brought into it. Drip legs should be provided at all low points in the system and wherever the condensate can collect, such as at the ends of mains, at the bottoms of risers, and ahead of expansion joints, separators, pressure-reducing valves, and temperature regulators.

For long horizontal runs of steam mains and where there are no low drainage points, the drip legs should be provided at intervals of approximately 300 feet, but never more than 500 feet.

Table 8-4 provides guidelines for drip leg sizing. A properly sized drip leg will capture condensate. An inadequately sized drip leg can actually cause a vertical piccolo effect in which pressure drop pulls condensate out of the trap. The diameter of the drip leg should be the same as that of the steam main up to 4 inches in diameter and half the steam main diameter (but not less than 4 inches) on larger lines.

Adequate Pressure Differential Across the Trap

The trap cannot discharge condensate unless a pressure differential exists across it—that is, unless the pressure at the inlet is higher than that in the condensate line. The drip leg should be of sufficient length to provide a hydrostatic head at the trap inlet so the condensate can be discharged during warm up, before a positive steam pressure develops in the steam main.

For mechanical traps, the minimum differential plus the maximum allowable differential (the trap operating pressure rating) must be considered. In draining devices such as heat exchangers that are controlled by temperature-regulating valves that could possibly operate in a vacuum at part load, install a vacuum breaker to ensure that pressure upstream of the trap cannot fall below atmospheric pressure and that adequate hydrostatic head is available.

Running Loads

As noted earlier, condensate formation is significantly lower after the system has come up to temperature, since it is due only to radiation heat losses from the system through the insulation. Table 8-5 provides condensate loads for various pressures and line sizes.

Piping Layout

Since the condensate in the steam line flows to the drip leg by gravity, it is important that the piping be pitched to properly direct that flow. Figure 8-7 provides guidelines for proper pipe pitch.

Trap Installation

The following recommendations should be observed when installing a steam trap:

- The steam trap should be installed as close as possible to the drip leg.
- The need to lift condensate to the return system requires special consideration. If the equipment being drained is under modulating pressure, as in a temperature-controlled heat exchanger, the inlet pressure to the trap could fall below that needed to lift the condensate. As a rule of thumb, the trap needs approximately 1 psig at the inlet for every 2 feet of lift to the return (0.43 psig per 1 foot, more precisely). When sufficient lift pressure cannot be guaranteed, the condensate should be drained to a reservoir/pump system and pumped to the return. A check valve should be piped in the trap outlet line if condensate is being lifted to the return.
- Pipe connections to and from the steam trap should be at least equal to the pipe size of the trap connection, and full-size isolation valves should be installed on each side of the trap to allow service.
- A strainer equipped with a blowdown valve should be installed before the steam trap, and a test valve should be installed downstream of the trap. (Some traps combine isolation valves, strainers, and test valves in a single package.)
- All low points of the steam main and wherever condensate can collect, such as before pressure-reducing valves and temperature regulators, should be drained.

Flashing Flow and High-Pressure Condensate Piping

Flash tanks play an important role in condensate drainage. They get their name from the sudden evaporation, or flashing, that occurs when condensate at high pressure is suddenly released to low pressure. The production of flash steam also is influenced by other components in the system. For example, thermostatic steam traps open only after the condensate has cooled to below the saturation temperature for the given pressure.

In sizing condensate returns for high-pressure systems, this flash steam must be considered, since it provides more friction loss than would be the case if the flashing did not occur and the pipe was carrying only liquid. Flash steam lines typically are sized for the pressure at which the main is operating. Low-pressure steam requires a larger pipe size than high-pressure steam.

To size condensate pipes to carry flashing condensate, determine the percentage of flash steam using Figure 8-1, and then multiply the total high-pressure condensate flow by the flash steam percentage to determine the flash steam flow rate. This procedure will oversize the condensate pipe to accommodate the flash steam without generating excess return line pressures.

Table 8-5 Condensation in Insulated Pipes* Carrying Saturated Steam in Quiet Air at 70°F, Pounds of Condensate Per Hour Per Lineal Foot

Pipe Size, in.	ft ² per Lineal Foot	Pressure, psi								
		15	30	60	125	180	250	450	600	800
1	.344	.05	.06	.07	.10	.12	.14	.186	.221	.289
1¼	.434	.06	.07	.09	.12	.14	.17	.231	.273	.359
1½	.497	.07	.08	.10	.14	.16	.19	.261	.310	.406
2	.622	.08	.10	.13	.17	.20	.23	.320	.379	.498
2½	.753	.10	.12	.15	.20	.24	.28	.384	.454	.596
3	.916	.12	.14	.18	.24	.28	.33	.460	.546	.714
3½	1.047	.13	.16	.20	.27	.32	.38	.520	.617	.807
4	1.178	.15	.18	.22	.30	.36	.43	.578	.686	.897
5	1.456	.18	.22	.27	.37	.44	.51	.698	.826	1.078
6	1.735	.20	.25	.32	.44	.51	.59	.809	.959	1.253
8	2.260	.27	.32	.41	.55	.66	.76	1.051	1.244	1.628
10	2.810	.32	.39	.51	.68	.80	.94	1.301	1.542	2.019
12	3.340	.38	.46	.58	.80	.92	1.11	1.539	1.821	2.393
14	3.670	.42	.51	.65	.87	1.03	1.21	1.688	1.999	2.624
16	4.200	.47	.57	.74	.99	1.19	1.38	1.927	2.281	2.997
18	4.710	.53	.64	.85	1.11	1.31	1.53	2.151	2.550	3.351
20	5.250	.58	.71	.91	1.23	1.45	1.70	2.387	2.830	3.725
24	6.280	.68	.84	1.09	1.45	1.71	2.03	2.833	3.364	4.434

* Insulation assumed to be 75% efficient

Branch Lines

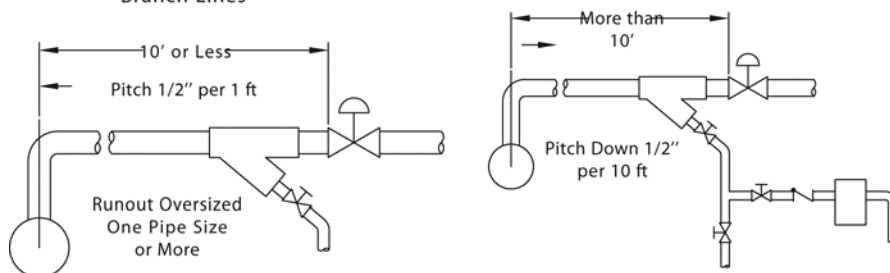


Figure 8-7 Pipe Pitch for Condensate Removal by Gravity

(left) Piping for runouts less than 10 feet: No trap is required unless the pitch back to the supply header is less than ½ inch per foot. (right) Piping for runouts greater than 10 feet: Drip leg and trap are required ahead of the control valve. A strainer ahead of the control valve can serve as the drip leg if the blowdown connection runs to an inverted bucket trap. This will also minimize strainer cleaning problems. An internal check valve or a swing check should be installed ahead of the trap.

ASPE Read, Learn, Earn Continuing Education

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Notice for North Carolina Professional Engineers: State regulations for registered PEs in North Carolina now require you to complete ASPE's online CEU validation form to be eligible for continuing education credits. After successfully completing this quiz, just visit ASPE's CEU Validation Center at aspe.org/CEUValidationCenter.

Expiration date: Continuing education credit will be given for this examination through **February 28, 2017**.

CE Questions — "Steam and Condensate Piping" (CEU 232)

1. What is the heat energy required to turn 1 pound of saturated water from a liquid to vapor steam?
 - a. heat of saturated liquid
 - b. latent heat
 - c. specific heat
 - d. sensible heat
2. What is saturated liquid at the same temperature as the steam from which it was formed?
 - a. condensate
 - b. flash steam
 - c. sensible steam
 - d. vapor steam
3. For a steam system operating at 110.3 psig, how many Btu's per pound of water of sensible heat energy input are required to raise the temperature of the water from 32°F to 344.33°F?
 - a. 218.82
 - b. 308.80
 - c. 315.68
 - d. 321.85
4. Which of the following governs the design and sizing of steam distribution piping?
 - a. mass rate of steam flow
 - b. allowable pressure drop in the distribution system
 - c. steam velocity
 - d. both b and c
5. The total pressure drop in a steam system should not exceed _____ percent of the steam supply pressure at the boiler.
 - a. 10
 - b. 20
 - c. 30
 - d. 40
6. Which of the following can be caused by condensate in a steam system?
 - a. corrosion
 - b. increased heat transfer efficiency
 - c. water hammer
 - d. both a and c
7. The _____ steam trap works by sensing differences in flow velocity or pressure caused by relatively high-velocity steam compared to lower-velocity condensate.
 - a. thermostatic bellows
 - b. inverted bucket
 - c. thermodynamic disc
 - d. float and thermostatic
8. Assuming a warm-up time of one hour, what is the warming-up load of 100 feet of 6-inch line being brought up to 60-psi system pressure?
 - a. 5.69 pounds per hour
 - b. 56.9 pounds per hour
 - c. 113.8 pounds per hour
 - d. 1,897 pounds per hour
9. The supervised heat-up method typically is used _____.
 - a. in small installations
 - b. where heat-up occurs every day
 - c. in dry-cleaning plants
 - d. where heat-up occurs once a year
10. A drip leg should be provided _____.
 - a. at the ends of mains
 - b. at the bottoms of risers
 - c. ahead of expansion joints
 - d. all of the above
11. Drip legs should be provided at intervals of approximately _____ feet.
 - a. 200
 - b. 300
 - c. 500
 - d. 600
12. A steam trap needs approximately _____ psig at the inlet for every 2 feet of lift to the return.
 - a. 0.43
 - b. 1
 - c. 1.43
 - d. none of the above