STEAM UTILIZATION

# DESIGN OF FLUID SYSTEMS

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# PREFACE

**Recognizing the on-going need for education as it relates to the fundamentals of steam including the most efficient use of its heat content, Spirax Sarco has developed the Steam Utilization Course. This handbook represents over 80 years of steam experience in the proper selection, sizing and application of steam traps, pressure and temperature controls, and condensate recovery systems in major industrial plants throughout the world.**

**The Steam Utilization Course can be used in conjunction with "Design of Fluid Systems—Hook Ups" for a complete and concise knowledge of the use of steam for heat.**

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Spirax Sarco is the recognized industry standard for knowledge and products and for over 85 years has been committed to servicing the steam users worldwide. The existing and potential applications for steam, water and air are virtually unlimited. Beginning with steam generation, through distribution and utilization and ultimately returning condensate to the boiler, Spirax Sarco has the solutions to optimize steam system performance and increase productivity to save valuable time and money.

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For assistance with the installation or operation of any Spirax Sarco product or application, call toll free:

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# Contents

# Basic Steam Engineering Principals

## Introduction

This Spirax Sarco Steam Utilization Course is intended to cover the basic fundamentals and efficient usage of steam as a cost effective conveyor of energy (Fig. 2) to space heating or process heating equipment. The use of steam for power generation is a specialized subject, already well documented, and is outside the scope of this course.

This course has been designed and written for those engaged in the design, operation, maintenance and or general care of a steam system. A moderate knowledge of physics is assumed. The first part of this course attempts to define the basic terminology and principles involved in steam generation and system engineering.

## What Is Steam

Like many other substances, water can exist in the form of either a solid, liquid, or gas. We will focus largely on liquid and gas phases and the changes that occur during the transition between these two phases. Steam is the vaporized state of water which contains heat energy intended for transfer into a variety of processes from air heating to vaporizing liquids in the refining process.

Perhaps the first thing that we should do is define some of the basic terminology that will be used in this course.

## Definitions

### BTU

The basic unit of measurement for all types of heat energy is the British Thermal Unit or BTU. Specifically, it is the amount of heat energy necessary to raise one pound of water one degree Fahrenheit.

### Temperature

A degree of hot or cold mesured on a definite scale. For all practical purposes a measurement from a known starting point to a known ending point.

### Heat

Energy

### Saturation

The point where a substance can hold no more energy without changing phase (physical state).

### Enthalpy

The term given for the total energy, measured in BTU's, due to both pressure and temperature of a fluid or vapor, at any given time or condition.

### Gauge Pressure (PSIG)

Pressure shown on a standard gauge and indicated the presure above atmospheric pressure.

### Absolute Pressure (PSIA)

The pressure from and above perfect vacuum

### Sensible Heat (hf)

The heat energy that raises the water temperature from 32°F. The maximum amount of sensible heat the water can absorb is determined by the pressure of the liquid. (Fig 1 & 2)

### Latent Heat (hfg)

The enthalpy of evaporation. The heat input which produces a change of water from liquid to gas.

## Total Heat

Is the sum of sensible heat and latent heat ($h_t$=$h_f$+$h_{hfg}$). (Fig 1)

## The Formation of Steam

Steam is created from the boiling of water. As heat energy (BTU's) is added to water, the temperature rises accordingly. When water reaches its saturation point, it begins to change from a liquid to a gas. Let's investigate how this happens by placing a thermometer in one pound of water at a temperature of 32˚F, which is the coldest temperature water can exist at atmospheric pressure before changing from liquid to a solid.

Let's put this water into a pan on top of our stove and turn on the burner. Heat energy from the burner will be transferred through the pan into the water, causing the water's temperature to rise.

We can actually monitor the heat energy transfer (Fig.1) by watching the thermometer level rise - one BTU of heat energy will raise one pound of water by one degree Fahrenheit. As each degree of temperature rise is registered on the thermometer, we can read that as the addition of 1 BTU. Eventually, the water temperature will rise to its boiling point (saturation temperature) at atmospheric pressure, which is 212°F at sea level. Any additional heat energy that we add at this point will cause the water to begin changing state (phase) from a liquid to a gas (steam).

At atmospheric pressure and at sea level we have added 180 BTU's, changing the water temperature from 32°F to 212°F (212-32=180). This enthalpy is known as Sensible Heat (BTU per pound). If we continue to add heat energy to the water via the burner, we will notice that the thermometer will not change, but the water will begin to evaporate into steam. The heat energy that is being added which causes the water's change of phase from liquid to gas is known as Latent Heat. This latent heat content is the sole purpose of generating steam. Latent heat (BTU per pound) has a very high heat content that transfers to colder products/processes very rapidly without losing any temperature. As steam gives up its latent heat, it condenses and the water is the same temperature of the steam. The sum of the two heat contents, sensible and latent, are known as the Total Heat.

A very interesting thing happens when we go through this exercise and that is the change in volume that the gas (steam) occupies versus the volume that the water occupied. One pound of water at atmospheric pressure occupies only .016 cubic feet, but when we convert this water into steam at the same pressure, the steam occupies 26.8 cubic feet for the same one pound.

The steam that we have just created on our stove at home will provide humidification to the surrounding air space along with some temperature rise. Steam is also meant to be a flexible energy carrier to other types of processes. In order to make steam flow from the generation point to another point at which it will be utilized, there has to be a difference in pressure.

Therefore, our pan type steam generator will not create any significant force to move the steam. A boiler, for all practical purposes, is a pan with a lid. There are many types of boilers that are subjects of other courses. We will simply refer to them as boilers in this course. If we contain the steam within a boiler, pressure will begin to rise with the change of volume from liquid to gas. As this pressure rises, the boiling point of the water inside also rises. If the pressure of saturated steam is known, the temperature is also known. We will consider this relationship later when we look again at the saturated steam tables.

Another thing that happens when steam is created in a boiler is that the gas (steam) is compressed into a smaller volume (ft$^3$ per pound). This is because the non-compressible liquid (water) is now a compressible gas. The higher the pressure, the higher the temperature. The lower the latent heat content of the steam, the smaller the volume the steam occupies (Fig. 3). This allows the plant to generate steam at high pressures and distribute that steam in smaller piping to the point of usage in the plant. This higher pressure in the boiler provides for more driving force to make the steam flow.

The need for optimum efficiency increases with every rise in fuel costs. Steam and condensate systems must be carefully designed and maintained to ensure that unnecessary energy waste is kept at a minimum. For this reason, this course will deal with the practical aspects of energy conservation in steam systems, as we go through the system.

**Figure 1**

Steam Saturation Curve Graph at a Specific Boiler Pressure

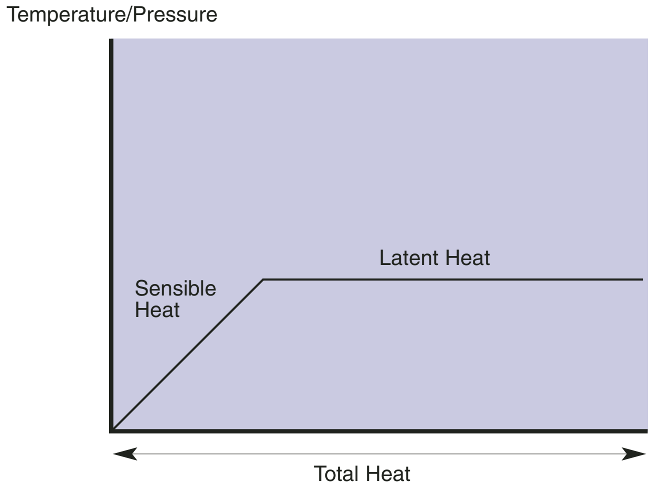
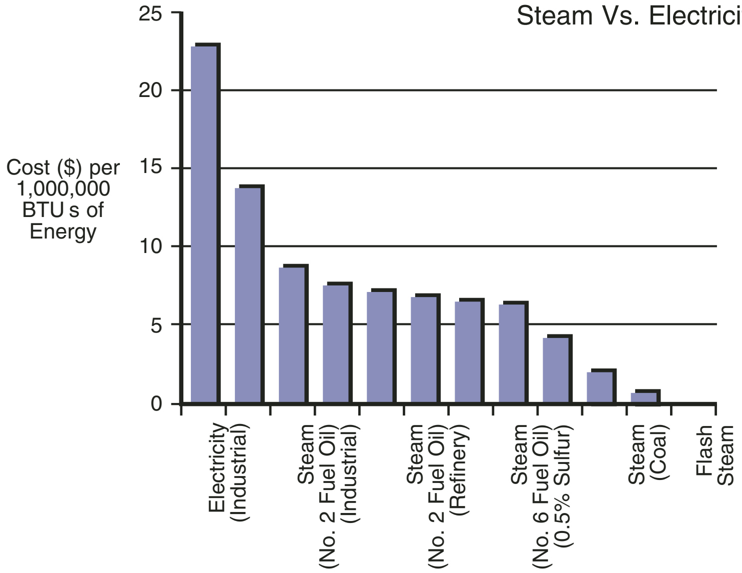


**Figure 2**

Steam Vs. Electricity



## Figure 3: Steam Saturation Table

| Gauge Press. in Hg. Vac. | Absolute Pressure psia | Temperature Degrees F | Sensible (hf) BTU/LB | Latent (hfg) BTU/lb | Total (hg) BTU/lb | Spec. Volume Steam (Vg) $ft^3$/lb |
|---|---|---|---|---|---|---|
| 27.96 | 1 | 101.7 | 69.5 | 1032.9 | 1102.4 | 333.0 |
| 25.91 | 2 | 126.1 | 93.9 | 1019.7 | 1113.6 | 173.5 |
| 23.81 | 3 | 141.5 | 109.3 | 1011.3 | 1120.6 | 118.6 |
| 21.83 | 4 | 153.0 | 120.8 | 1004.9 | 1125.7 | 90.52 |
| 19.79 | 5 | 162.3 | 130.1 | 999.7 | 1129.8 | 73.42 |
| 17.75 | 6 | 170.1 | 137.8 | 995.4 | 1133.2 | 61.89 |
| 15.7 | 7 | 176.9 | 144.6 | 991.5 | 1136.1 | 53.57 |
| 13.66 | 8 | 182.9 | 150.7 | 987.9 | 1138.6 | 47.26 |
| 11.62 | 9 | 188.3 | 156.2 | 984.7 | 1140.9 | 42.32 |
| 9.58 | 10 | 193.2 | 161.1 | 981.9 | 1143.0 | 38.37 |
| 7.54 | 11 | 197.8 | 165.7 | 979.2 | 1144.9 | 35.09 |
| 5.49 | 12 | 202.0 | 169.9 | 976.7 | 1146.6 | 32.35 |
| 3.45 | 13 | 205.9 | 173.9 | 974.3 | 1148.2 | 30.01 |
| 1.41 | 14 | 209.6 | 177.6 | 972.2 | 1149.8 | 28.0 |
| **Gauge Pressure psig** | | | | | | |
| 0 | 14.7 | 212.0 | 180.2 | 970.6 | 1150.8 | 26.8 |
| 1 | 15.7 | 215.4 | 183.6 | 968.4 | 1152.0 | 25.2 |
| 2 | 16.7 | 218.5 | 186.8 | 966.4 | 1153.2 | 23.8 |
| 3 | 17.7 | 221.5 | 189.8 | 964.5 | 1154.3 | 22.5 |
| 4 | 18.7 | 224.5 | 192.7 | 962.6 | 1155.3 | 21.4 |
| **5** | **19.7** | **227.4** | **195.5** | **960.8** | **1156.3** | **20.4** |
| 6 | 20.7 | 230.0 | 198.1 | 959.2 | 1157.3 | 19.4 |
| 7 | 21.7 | 232.4 | 200.6 | 957.6 | 1158.2 | 18.6 |
| 8 | 22.7 | 234.8 | 203.1 | 956.0 | 1159.1 | 17.9 |
| 9 | 23.7 | 237.1 | 205.5 | 954.5 | 1160.0 | 17.2 |
| **10** | **24.7** | **239.4** | **207.9** | **952.9** | **1160.8** | **16.5** |
| 11 | 25.7 | 241.6 | 210.1 | 951.5 | 1161.6 | 15.9 |
| 12 | 26.7 | 243.7 | 212.3 | 950.1 | 1162.3 | 15.3 |
| 13 | 27.7 | 245.8 | 214.4 | 948.6 | 1163.0 | 14.8 |
| 14 | 28.7 | 247.9 | 216.4 | 947.3 | 1163.7 | 14.3 |
| **15** | **29.7** | **249.8** | **218.4** | **946.0** | **1164.4** | **13.9** |
| 16 | 30.7 | 251.7 | 220.3 | 944.8 | 1165.1 | 13.4 |
| 17 | 31.7 | 253.6 | 222.2 | 943.5 | 1165.7 | 13 |
| 18 | 32.7 | 255.4 | 224.0 | 942.4 | 1166.4 | 12.7 |
| 19 | 33.7 | 257.2 | 225.8 | 941.2 | 1167.0 | 12.3 |
| **20** | **34.7** | **258.8** | **227.5** | **940.1** | **1167.6** | **12** |
| 22 | 36.7 | 262.3 | 230.9 | 937.8 | 1168.7 | 11.4 |
| 24 | 38.7 | 265.3 | 234.2 | 935.8 | 1170.0 | 10.8 |
| 26 | 40.7 | 268.3 | 237.3 | 933.5 | 1170.8 | 10.3 |
| 28 | 42.7 | 271.4 | 240.2 | 931.6 | 1171.8 | 9.87 |
| **30** | **44.7** | **274.0** | **243.0** | **929.7** | **1172.7** | **9.46** |
| 32 | 46.7 | 276.7 | 245.9 | 927.6 | 1173.5 | 9.08 |
| 34 | 48.7 | 279.4 | 248.5 | 925.8 | 1174.3 | 8.73 |
| 36 | 50.7 | 281.9 | 251.1 | 924.0 | 1175.1 | 8.40 |
| 38 | 52.7 | 284.4 | 253.7 | 922.1 | 1175.8 | 8.11 |
| **40** | **54.7** | **286.7** | **256.1** | **920.4** | **1176.5** | **7.83** |
| 42 | 56.7 | 289.0 | 258.5 | 918.6 | 1177.1 | 7.57 |
| 44 | 58.7 | 291.3 | 260.8 | 917.0 | 1177.8 | 7.33 |
| 46 | 60.7 | 293.5 | 263.0 | 915.4 | 1178.4 | 7.10 |
| 48 | 62.7 | 205.6 | 265.2 | 913.8 | 1179.0 | 6.89 |
| **50** | **64.7** | **297.7** | **267.4** | **912.2** | **1179.6** | **6.68** |
| 52 | 66.7 | 299.7 | 269.4 | 901.7 | 1180.1 | 6.50 |
| 54 | 68.7 | 301.7 | 271.5 | 909.2 | 1180.7 | 6.32 |
| 56 | 70.7 | 303.6 | 273.5 | 907.8 | 1181.3 | 6.16 |
| 58 | 72.7 | 305.5 | 275.3 | 906.5 | 1181.8 | 6.00 |
| **60** | **74.7** | **307.4** | **277.1** | **905.3** | **1182.4** | **5.84** |
| 62 | 76.7 | 309.2 | 279.0 | 904.0 | 1183.0 | 5.70 |
| 64 | 78.7 | 310.9 | 280.9 | 902.6 | 1183.5 | 5.56 |
| 66 | 80.7 | 312.7 | 282.8 | 901.2 | 1184.0 | 5.43 |
| 68 | 82.7 | 314.3 | 284.5 | 900.0 | 1184.5 | 5.31 |

## Figure 3 (Cont.): Steam Saturation Table

| Gauge Pressure psig | Absolute Pressure psia | Temperature Degrees F | Sensible (hf) BTU/LB | Latent (hfg) BTU/lb | Total (hg) BTU/lb | Specific Volume Steam (Vg) $ft^3/lb$ |
|---|---|---|---|---|---|---|
| **70** | **84.7** | **316.0** | **286.2** | **898.8** | **1185.0** | **5.19** |
| 72 | 86.7 | 317.7 | 288.0 | 897.5 | 1185.5 | 5.08 |
| 74 | 88.7 | 319.3 | 289.4 | 896.5 | 1185.9 | 4.97 |
| 76 | 90.7 | 320.9 | 291.2 | 895.1 | 1185.9 | 4.87 |
| 78 | 92.7 | 322.4 | 292.9 | 893.9 | 1186.8 | 4.77 |
| **80** | **94.7** | **323.9** | **294.5** | **892.7** | **1187.2** | **4.67** |
| 82 | 96.7 | 325.5 | 296.1 | 891.5 | 1187.6 | 4.58 |
| 84 | 98.7 | 326.9 | 297.6 | 890.3 | 1187.9 | 4.49 |
| 86 | 100.7 | 328.4 | 299.1 | 889.2 | 1188.3 | 4.41 |
| 88 | 102.7 | 329.9 | 300.6 | 888.1 | 1188.7 | 4.33 |
| **90** | **104.7** | **331.2** | **302.1** | **887.0** | **1189.1** | **4.25** |
| 92 | 106.7 | 332.6 | 303.5 | 885.8 | 1189.3 | 4.17 |
| 94 | 108.7 | 333.9 | 304.9 | 884.8 | 1189.7 | 4.10 |
| 96 | 110.7 | 335.3 | 306.3 | 883.7 | 1190.0 | 4.03 |
| 98 | 112.7 | 336.6 | 307.7 | 882.6 | 1190.3 | 3.96 |
| **100** | **114.7** | **337.9** | **309.0** | **881.6** | **1190.6** | **3.90** |
| 102 | 116.7 | 339.2 | 310.3 | 880.6 | 1190.9 | 3.83 |
| 104 | 118.7 | 340.5 | 311.6 | 879.6 | 1191.2 | 3.77 |
| 106 | 120.7 | 341.7 | 313.0 | 878.5 | 1191.5 | 3.71 |
| 108 | 122.7 | 343.0 | 314.3 | 877.5 | 1191.8 | 3.65 |
| **110** | **124.7** | **344.2** | **315.5** | **876.5** | **1192.0** | **3.60** |
| 112 | 126.7 | 345.4 | 316.8 | 875.5 | 1192.3 | 3.54 |
| 114 | 128.7 | 346.5 | 318.0 | 874.5 | 1192.5 | 3.49 |
| 116 | 130.7 | 347.7 | 319.3 | 873.5 | 1192.8 | 3.44 |
| 118 | 132.7 | 348.9 | 320.5 | 872.5 | 1193.0 | 3.39 |
| **120** | **134.7** | **350.1** | **321.8** | **871.5** | **1193.3** | **3.34** |
| 125 | 139.7 | 352.8 | 324.7 | 869.3 | 1194.0 | 3.23 |
| 130 | 144.7 | 355.6 | 327.6 | 866.9 | 1194.5 | 3.12 |
| 135 | 149.7 | 358.3 | 330.6 | 864.5 | 1195.1 | 3.02 |
| **140** | **154.7** | **360.9** | **333.2** | **862.5** | **1195.7** | **2.93** |
| 145 | 159.7 | 363.5 | 335.9 | 860.3 | 1196.2 | 2.84 |
| 150 | 164.7 | 365.9 | 338.6 | 858.0 | 1196.6 | 2.76 |
| 155 | 169.7 | 368.3 | 341.1 | 856.0 | 1197.1 | 2.68 |
| **160** | **174.7** | **370.7** | **343.6** | **853.9** | **1197.5** | **2.61** |
| 165 | 179.7 | 372.9 | 346.1 | 851.8 | 1197.9 | 2.54 |
| 170 | 184.7 | 375.2 | 348.5 | 849.8 | 1198.3 | 2.48 |
| 175 | 189.7 | 377.5 | 350.9 | 847.9 | 1198.8 | 2.41 |
| **180** | **194.7** | **379.6** | **353.2** | **845.9** | **1199.1** | **2.35** |
| 185 | 199.7 | 381.6 | 355.4 | 844.1 | 1195.5 | 2.30 |
| 190 | 204.7 | 383.7 | 357.6 | 842.2 | 1199.8 | 2.24 |
| 195 | 209.7 | 385.7 | 359.9 | 840.2 | 1200.1 | 2.18 |
| **200** | **214.7** | **387.7** | **362.0** | **838.4** | **1200.4** | **2.14** |
| 210 | 224.7 | 391.7 | 366.2 | 834.8 | 1201.0 | 2.04 |
| 220 | 234.7 | 395.5 | 370.3 | 831.2 | 1201.5 | 1.96 |
| 230 | 244.7 | 399.1 | 374.2 | 827.8 | 1202.0 | 1.88 |
| 240 | 254.7 | 402.7 | 378.0 | 824.5 | 1202.5 | 1.81 |
| **250** | **264.7** | **406.1** | **381.7** | **821.2** | **1202.9** | **1.74** |
| 260 | 274.7 | 409.3 | 385.3 | 817.9 | 1203.2 | 1.68 |
| 270 | 284.7 | 412.5 | 388.8 | 814.8 | 1203.6 | 1.62 |
| 280 | 294.7 | 415.8 | 392.3 | 811.6 | 1203.9 | 1.57 |
| 290 | 304.7 | 418.8 | 395.7 | 808.5 | 1204.2 | 1.52 |
| **300** | **314.7** | **421.7** | **398.9** | **805.5** | **1204.4** | **1.47** |
| 310 | 324.7 | 424.7 | 402.1 | 802.6 | 1204.7 | 1.43 |
| 320 | 334.7 | 427.5 | 405.2 | 799.7 | 1204.9 | 1.39 |
| 330 | 344.7 | 430.3 | 408.3 | 796.7 | 1205.0 | 1.35 |
| 340 | 354.7 | 433.0 | 411.3 | 793.8 | 1205.1 | 1.31 |
| **350** | **364.7** | **435.7** | **414.3** | **791.0** | **1205.3** | **1.27** |
| 360 | 374.7 | 438.3 | 417.2 | 788.2 | 1205.4 | 1.24 |
| 370 | 384.7 | 440.8 | 420.0 | 785.4 | 1205.4 | 1.21 |
| 380 | 394.7 | 443.3 | 422.8 | 782.7 | 1205.5 | 1.18 |
| 390 | 404.7 | 445.7 | 425.6 | 779.9 | 1205.5 | 1.15 |
| **400** | **414.7** | **448.1** | **428.2** | **777.4** | **1205.6** | **1.12** |
| 420 | 434.7 | 452.8 | 433.4 | 772.2 | 1205.6 | 1.07 |
| 440 | 454.7 | 457.3 | 438.5 | 767.1 | 1205.6 | 1.02 |

## Figure 3 (Cont.): Steam Saturation Table

| Gauge Pressure psig | Absolute Pressure psia | Temperature Degrees F | Sensible (hf) BTU/LB | Latent (hfg) BTU/lb | Total (hg) BTU/lb | Specific Volume Steam (Vg) $ft^3$/lb |
|---|---|---|---|---|---|---|
| 460 | 474.7 | 461.7 | 443.4 | 762.1 | 1205.5 | .98 |
| 480 | 494.7 | 465.9 | 448.3 | 757.1 | 1205.4 | .94 |
| **500** | **514.7** | **470.0** | **453.0** | **752.3** | **1205.3** | **.902** |
| 520 | 534.7 | 474.0 | 457.6 | 747.5 | 1205.1 | .868 |
| 540 | 554.7 | 477.8 | 462.0 | 742.8 | 1204.8 | .835 |
| 560 | 574.7 | 481.6 | 466.4 | 738.1 | 1205.5 | .805 |
| 580 | 594.7 | 485.2 | 470.7 | 733.5 | 1204.2 | .776 |
| **600** | **614.7** | **488.8** | **474.8** | **729.1** | **1203.9** | **.750** |
| 620 | 634.7 | 492.3 | 479.0 | 724.5 | 1203.5 | .726 |
| 640 | 654.7 | 495.7 | 483.0 | 720.1 | 1203.1 | .703 |
| 660 | 674.7 | 499.0 | 486.9 | 715.8 | 1202.7 | .681 |
| 680 | 694.7 | 502.2 | 490.7 | 711.5 | 1202.2 | .660 |
| **700** | **714.7** | **505.4** | **494.4** | **707.4** | **1201.8** | **.641** |
| 720 | 734.7 | 508.5 | 498.2 | 703.1 | 1201.3 | .623 |
| 740 | 754.7 | 51.5 | 501.9 | 698.9 | 1200.8 | .605 |
| 760 | 774.7 | 514.5 | 505.5 | 694.7 | 1200.2 | .588 |
| 780 | 794.7 | 517.5 | 509.0 | 690.7 | 0099.7 | .572 |
| **800** | **814.7** | **520.3** | **512.5** | **686.6** | **1199.1** | **.557** |

## Boilers & Boiler Efficiency

Boilers and the associated firing equipment should be designed and sized for maximum efficiency. Boiler manufacturers have improved their equipment designs to provide this maximum efficiency, when the equipment is new, sized correctly for the load conditions, and the firing equipment is properly tuned. There are many different efficiencies that are claimed when discussing boilers but the only true measure of a boiler's efficiency is the Fuel-to-Steam Efficiency. Fuel-To-Steam efficiency is calculated using either of two methods, as prescribed by the ASME Power Test Code, PTC4.1. The first method is input-output. This is the ratio of BTU's output divided by BTU's input, multiplied by 100. The second method is heat balance. This method considers stack temperature and losses, excess air levels, and radiation and convection losses. Therefore, the heat balance calculation for fuel-to-steam efficiency is 100 minus the total percent stack loss and minus the percent radiation and convection losses.

The sizing of a boiler for a particular application is not a simple task. Steam usages vary based upon the percentage of boiler load that is used for heating versus process and then combining those loads. These potentially wide load variations are generally overcome by installing not just one large boiler but possibly two smaller units or a large and a small boiler to accommodate the load variations. Boiler manufacturers usually will recommend that the turndown ratio from maximum load to low load not exceed 4:1. Turndown ratios exceeding 4:1 will increase the firing cycles and decrease efficiency.

A boiler operating at low load conditions can cycle as frequently as 12 times per hour, or 288 times a day. With each cycle, pre- and post-purge air flow removes heat from the boiler and sends it out the stack. This energy loss can be eliminated by keeping the boiler on at low firing rates. Every time the boiler cycles off, it must go through a specific start-up sequence for safety assurance. It requires about one to two minutes to place the boiler back on line. And, if there's a sudden load demand, the start-up sequence cannot be accelerated. Keeping the boiler on line assures the quickest response to load changes. Frequent cycling also accelerates wear of boiler components. Maintenance increases and, more importantly, the chance of component failure increases.

Once the boiler or boilers have been sized for their steam output, BTU's or lb./hr, then the operating pressures have to be determined. Boiler operating pressures are generally determined by the system needs as to product/process temperatures needed and/or the pressure losses in transmission of the steam in distribution throughout the facility. (Fig. 4)

## Selection of Working Pressure

The steam distribution system is an important link between the steam source and the steam user. It must supply good quality steam at the required rate and at the right pressure. It must do this with a minimum of heat loss, and be economical in capital cost.

The pressure at which the steam is to be distributed is determined by the point of usage in the plant needing the highest pressure. We must remember however that as the steam passes through the distribution pipework, it will lose some of its pressure due to resistance to flow, and the fact that some of it will condense due to loss of heat from the piping. Therefore, allowance should be made for this pressure loss when deciding upon the initial distribution pressure.

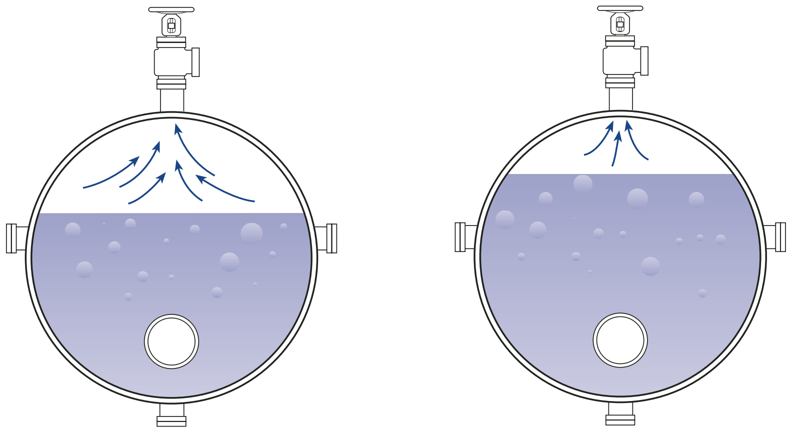
Summarizing, we need to consider when selecting our working pressure:

- Pressure required at point of usage
- Pressure drop along pipe due to resistance of flow (friction)
- Pipe heat losses

It is a recommended practice to select a boiler operating pressure greater than what is actually required.

This is an acceptable practice as long as it is understood that selecting a boiler with a much greater operating pressure than is required, then operating it at the lower pressure will cause a loss in efficiency of the boiler. This efficiency loss comes from the increased radiation and convection losses. Another area of efficiency loss comes from the lower quality (dryness) of the steam produced due to increased water level in the boiler and the increased steam bubble size because of the lower operating pressures internally. It is always recommended to operate the boiler at or as close to the maximum operating pressure that the vessel was designed for. The boilers operating pressure (Fig. 4) has a definite impact on the potential of priming and carry-over which can cause serious problems not only for the system but for the boiler also.

**Figure 4**



**Boiler Operating at Design Pressure**

- Design Pressure
- Smaller Specific Volume
- Greater Separation Area
- Dry Steam
- Proper Steam Velocities (4 to 6,000 fpm)

**Boiler Operating at Reduced Pressure from Design**

- Lower Pressure
- Greater Specific Volume
- Decreased Separation Area
- Lower Quality of Steam
- Increased Steam Velocities

Many of the boiler manufacturers today design their equipment to provide 99.5% dry saturated steam to be generated and admitted into the distribution system. This means that less than 1/2 of 1% of the volume exiting the boiler will be water, not steam. In practice, steam often carries tiny droplets of water with it and cannot be described as dry saturated steam. Steam quality is described by its dryness fraction, the portion of completely dry steam present in the steam being considered. The steam becomes wet if water droplets in suspension are present in the steam space, carrying no latent heat content.

For example (Fig. 3), the latent heat energy of 100 PSIG steam is 881 BTU's (assuming 99.5% dryness) but, if this steam is only 95% dry, then the heat content of this steam is only .95 X 881 = 834 BTU's per pound. The small droplets of water in wet steam have weight but occupy negligible space. The volume of wet steam is less than that of dry saturated steam. Therefore, steam separators are used at boiler off takes to insure dry quality steam.

## Steam Velocity

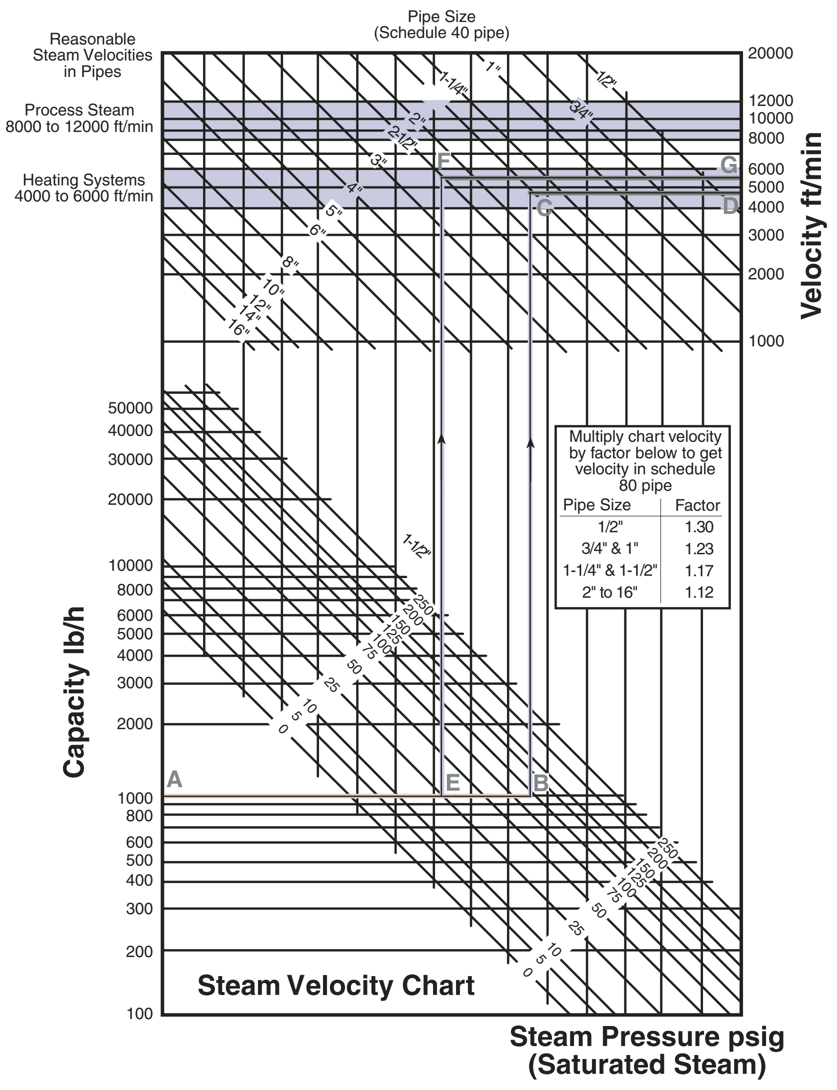
The velocity of the steam flow out of the boiler, at designed operating pressure, is established by the outlet nozzle of the boiler itself. Target velocities of 6,000 fpm or less have become commonplace as design criteria. These lower velocities provide for reduced pressure losses, more efficient condensate drainage, reduced waterhammer potential and piping erosion.

It is important that the steam velocity, piping and nozzle sizing, be considered when selecting the boiler operating pressure required.

Noise is not the only reason velocities in a steam system should be kept as low as practical. Steam is generated and distributed throughout the system and because of temperature differences in the surroundings and the insulation losses, the steam gives up its heat and condenses. Although it may not travel as fast as the steam, the condensate (water) is still going to erode the bottom of the pipe. This erosion is accelerated with the velocity of the steam, therefore the lower the steam velocity, the less erosion will take place.

The chart (Fig. 5) will be very helpful in sizing steam carrying pipes for proper velocities.

**Figure 5: Steam Velocity Chart**



EXAMPLE:

Steam flow is 1,000 lb/hr.

Find pipe size for 100 psig and 25 psig.

The steam system piping and associated equipment, containing this high heat energy source (steam), will constantly be a source of radiation losses. A simple but often overlooked energy savings is to insulate all the piping, steam and condensate, and all heat exchange equipment that can be insulated. A single foot of 3" pipe with 100 PSI steam in it exposed to an ambient temperature of 60°F will radiate 778 BTU's per hour of operation. The latent heat energy content of 100 PSI steam is 880 BTU's per pound.

Nearly a pound of steam per hour per foot of pipe is condensed just in distributing this valuable energy supply to the point of usage. Flanges, valves, strainers and equipment will waste much more energy than a single foot of pipe. The net effect is the consumption of more fuel to produce this lost energy. (Fig. 6)

## Figure 6: Pipeline Heat Loss Table - BTU's/Hr/Ft

| | | Process Pipeline Diameter and Insulation Thickness | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 4 | | 5" | | 6" | | 8" | | 10" | | 12" | | 14" | |
| Insulation Thickness | | 2" | 4" | 2" | 4" | 2" | 4" | 2" | 4" | 2" | 4" | 2" | 4" | 2" | 4" |
| Product/Ambient Temperature Difference Deg F° | **80** | 66 | 41 | 77 | 47 | 89 | 53 | 109 | 63 | 132 | 75 | 153 | 8 | 166 | 92 |
| | **150** | 123 | 77 | 14 | 87 | 166 | 99 | 205 | 120 | 247 | 140 | 286 | 161 | 311 | 173 |
| | **200** | 164 | 10 | 19 | 117 | 221 | 131 | 274 | 159 | 329 | 187 | 382 | 214 | 415 | 231 |
| | **250** | 205 | 12 | 240 | 146 | 276 | 164 | 342 | 199 | 412 | 235 | 477 | 268 | 519 | 288 |
| | **300** | 246 | 153 | 288 | 175 | 331 | 198 | 411 | 238 | 495 | 281 | 573 | 321 | 622 | 346 |
| | **350** | 288 | 178 | 336 | 205 | 386 | 230 | 478 | 278 | 576 | 328 | 668 | 375 | 726 | 404 |

## Air and Non-Condensable Gases In The Steam System

We know that when steam comes into contact with a cooler surface, it gives up its latent heat and condenses. As condensation takes place, the condensate begins to form a film of water (Fig. 7). It is a fact that water has a surprisingly high resistance to heat transfer. A film of water only 1/100 inch thick offers the same resistance to heat transfer as a 1/2 inch thick layer of iron or a 5 inch thick layer of copper. The air and other non-condensable gases in the steam cause a variety of problems to steam systems. Foremost is the reduction of area to deliver the steam. Air is a simple bi-product of steam generation. It is in all steam systems and should be dealt with accordingly. Where the air will collect in the system is the problem.

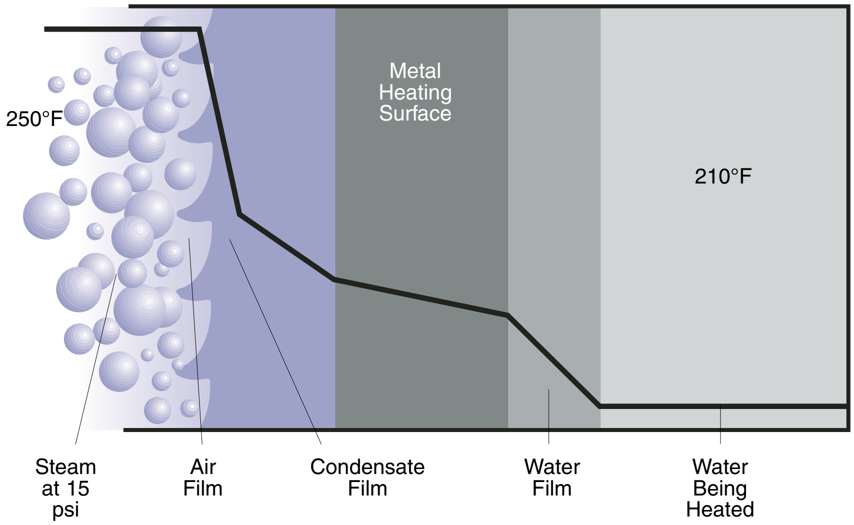
Air and other non-condensable gases are released when steam is generated and passes down the distribution with the steam. It will collect in areas of high steam consumption such as heat exchangers, but will also collect at high points and at the end of the steam piping. If a steam line feeds a series of heat exchangers, such as cooking kettles, the air collects at the end of the main line. The last kettle, therefore, would be fed with a mixture of steam and non-condensable gases.

Air cannot hold the temperature or latent heat of steam. It will, therefore, cause a reduction in temperature first of all. Air, it should be remembered, is an insulator. (Fig. 7) It is generally accepted that a thin layer of air only 0.04 inches thick can offer the same resistance to the flow of heat as a layer of water 1 inch thick, a layer of iron 4.3 feet thick or a layer of copper 43 feet thick. Even a small amount of air in a steam system will cause fairly drastic temperature losses, an example would be 100 PSIG saturated steam has a temperature of 338°F, if in this steam there existed a 10% by volume mixture of air the equivalent temperature of this mixture would be 331°F, or the steam temperature of 90 PSIG not 100 PSIG.

Another major problem with air in the steam system is that it will be absorbed into the condensate. This reduces the pH of the condensate and creates a substance known as carbonic acid. The acidity of the condensate will then attack the piping, heat exchange equipment or any other part of the steam system that it comes into contact with.

## Figure 7

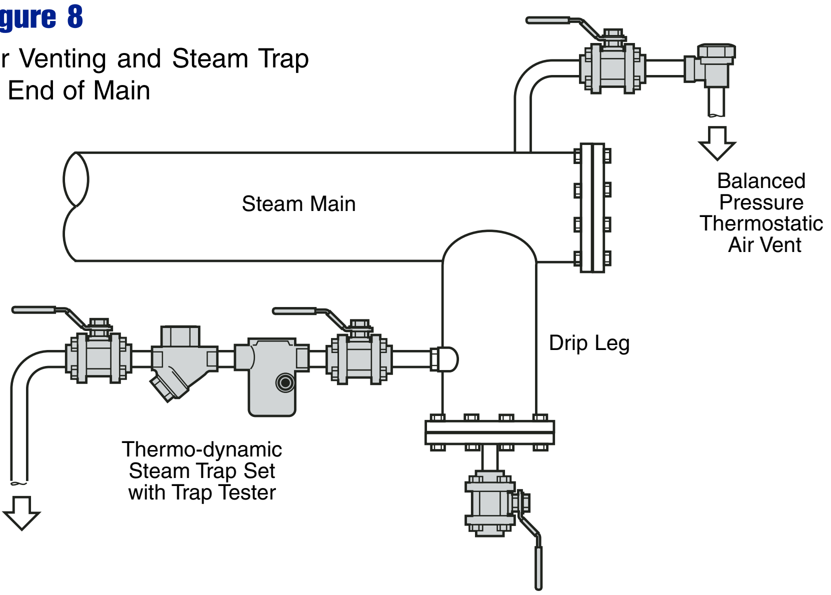
The Practical Effect of Air & Water Films



The use of Thermostatic Air Vents will help remove the accumulating air and rid the system of the adverse effects. Air Vents are nothing more than thermostatically-actuated steam traps positioned in the system where the air will collect. Proper design procedures require air vents to be located at high points, at the end of the steam main piping, (Fig. 8) and on all heat exchange equipment.

**Figure 8**

Air Venting and Steam Trap at End of Main



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## Steam System Basics

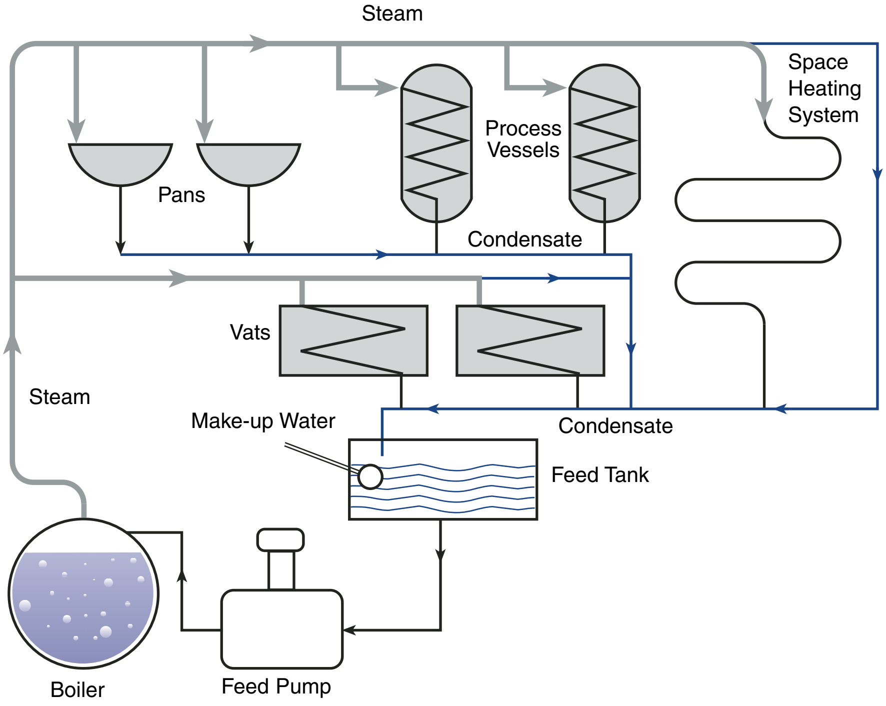
From the outset, an understanding of the basic steam circuit, 'steam and condensate loop' (Fig. 9) is required. The steam flow in a circuit is due to condensation of steam which causes a pressure drop. This induces the flow of steam through the piping.

The steam generated in the boiler must be conveyed through pipework to the point where it's heat energy is required. Initially there will be one or more main pipes or "steam mains" which carry the steam from the boiler in the direction of the steam using equipment. Smaller branch pipes can then carry the steam to the individual pieces of equipment.

When the boiler crown valve is opened admitting the steam into the distribution piping network, there immediately begins a process of heat loss. These losses of energy are in the heating up of the piping network to the steam temperature and natural losses to the ambient air conditions. The resulting condensate falls to the bottom of the piping and is carried along with the steam flow along the steam main. This condensate must be drained from this piping or severe damage will result.

**Figure 9**

A Typical Steam Circuit



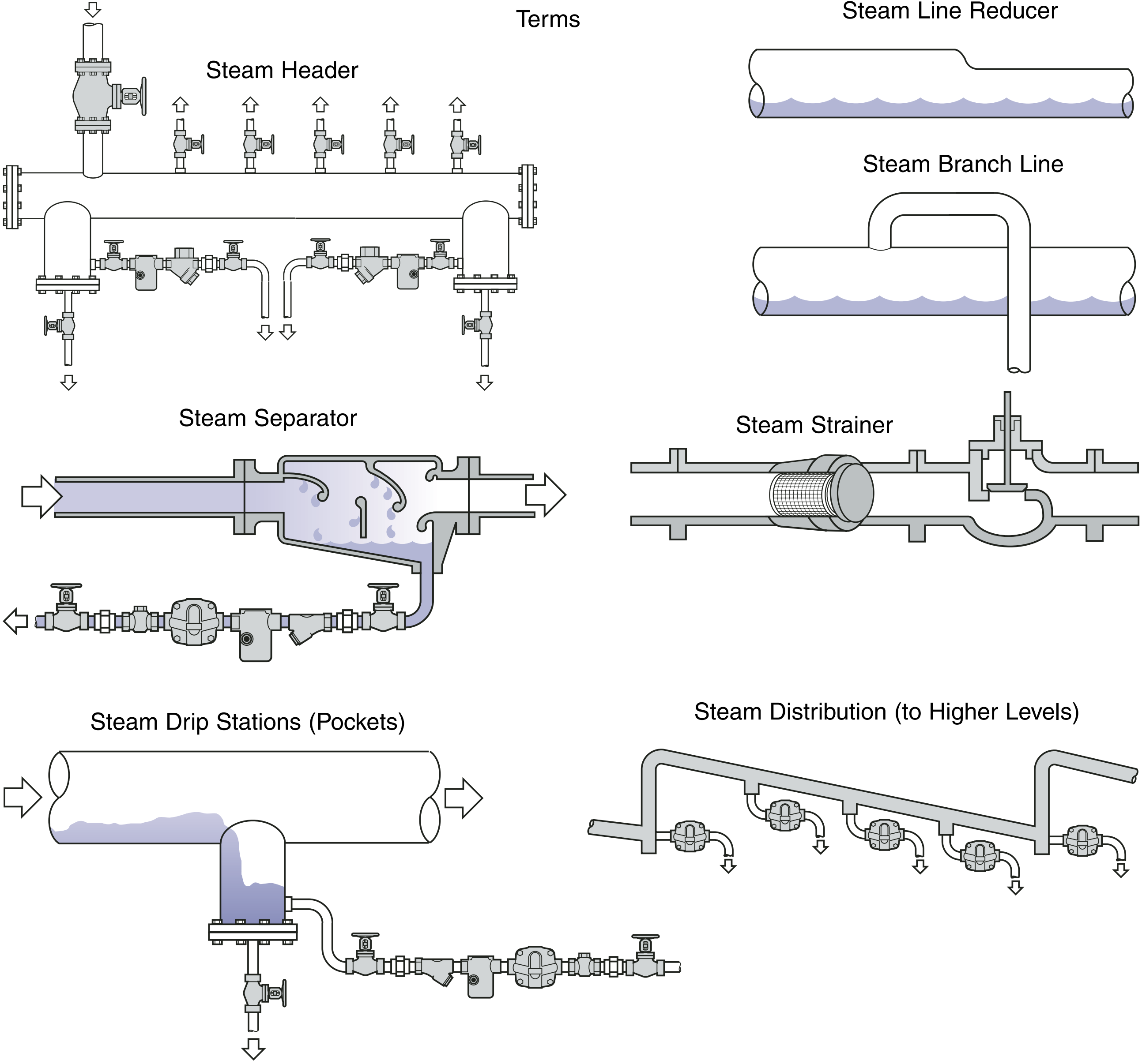
When the valves serving the individual pieces of equipment call for steam, the flow into the heat exchange equipment begins again causing condensation and the resultant pressure drop which induces even more flow.

## Steam Piping Design Considerations

Since we have already established that steams principle job is to give up its latent heat energy and re-condense to water, by doing so, we can assume that it will do so anywhere and everywhere (Fig. 10) because all heat flow is from hot to cold. When the steam is admitted into the distribution piping network, the steam immediately begins to heat the piping. This transfer of heat energy creates condensate, (Fig. 11 and 12) or if the piping is already at the same temperature as the steam, there are still loses to the ambient air conditions, even when insulated. This liquid condensate would continue to build up to the point of blocking all of the steam piping if it is not properly removed, and create waterhammer in the steam system. Periodically in a steam distribution main piping network, condensate “drip stations” need to be installed to remove this condensate from the system. These pockets should be designed with as much care as possible. This allows the condensate a low point in which to drop out of the steam flow and be removed by steam traps.

**Figure 10**

Terms



### Figure 11: Warm-Up Load in Pounds of Steam per 100 Ft. of Steam Main

Ambient Temperature 70°F. Based on Sch. 40 pipe to 250 psi
Sch. 80 above 250 except Sch. 120 5" and larger above 800 psi

| Steam Pressure psi | Main Size 2" | 2-1/2" | 3" | 4" | 5" | 6" | 8" | 10" | 12" | 14" | 16" | 18" | 20" | 24" | 0˚F Correction Factor * |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 6.2 | 9.7 | 12.8 | 18.2 | 24.6 | 31.9 | 48 | 68 | 90 | 107 | 140 | 176 | 207 | 308 | 1.50 |
| 5 | 6.9 | 11.0 | 14.4 | 20.4 | 27.7 | 35.9 | 48 | 77 | 101 | 120 | 157 | 198 | 233 | 324 | 1.44 |
| 10 | 7.5 | 11.8 | 15.5 | 22.0 | 29.9 | 38.8 | 58 | 83 | 109 | 130 | 169 | 213 | 251 | 350 | 1.41 |
| 20 | 8.4 | 13.4 | 17.5 | 24.9 | 33.8 | 44 | 66 | 93 | 124 | 146 | 191 | 241 | 284 | 396 | 1.37 |
| 40 | 9.9 | 15.8 | 20.6 | 90.3 | 39.7 | 52 | 78 | 110 | 145 | 172 | 225 | 284 | 334 | 465 | 1.32 |
| 60 | 11.0 | 17.5 | 22.9 | 32.6 | 44 | 57 | 86 | 122 | 162 | 192 | 250 | 316 | 372 | 518 | 1.29 |
| 80 | 12.0 | 19.0 | 24.9 | 35.3 | 48 | 62 | 93 | 132 | 175 | 208 | 271 | 342 | 403 | 561 | 1.27 |
| 100 | 12.8 | 20.3 | 26.6 | 37.8 | 51 | 67 | 100 | 142 | 188 | 222 | 290 | 366 | 431 | 600 | 1.26 |
| 125 | 13.7 | 21.7 | 28.4 | 40 | 55 | 71 | 107 | 152 | 200 | 238 | 310 | 391 | 461 | 642 | 1.25 |
| 150 | 14.5 | 23.0 | 30 | 43 | 58 | 75 | 113 | 160 | 212 | 251 | 328 | 414 | 487 | 679 | 1.24 |
| 175 | 15.3 | 24.2 | 31.7 | 45 | 61 | 79 | 119 | 169 | 224 | 265 | 347 | 437 | 514 | 716 | 1.23 |
| 200 | 16.0 | 25.3 | 33.1 | 47 | 64 | 83 | 125 | 177 | 234 | 277 | 362 | 456 | 537 | 748 | 1.22 |
| 250 | 17.2 | 27.3 | 35.8 | 51 | 69 | 89 | 134 | 191 | 252 | 299 | 390 | 492 | 579 | 807 | 1.21 |
| 300 | 25.0 | 38.3 | 51 | 75 | 104 | 143 | 217 | 322 | 443 | 531 | 682 | 854 | 1045 | 1182 | 1.20 |
| 400 | 27.8 | 43 | 57 | 83 | 116 | 159 | 241 | 358 | 493 | 590 | 759 | 971 | 1163 | 1650 | 1.18 |
| 500 | 30.2 | 46 | 62 | 91 | 126 | 173 | 262 | 389 | 535 | 642 | 825 | 1033 | 1263 | 1793 | 1.17 |
| 600 | 32.7 | 50 | 67 | 98 | 136 | 187 | 284 | 421 | 579 | 694 | 893 | 1118 | 1367 | 1939 | 1.16 |
| 800 | 38.0 | 58 | 77 | 113 | 203 | 274 | 455 | 670 | 943 | 1132 | 1445 | 1835 | 2227 | 3227 | 1.156 |
| 1000 | 45 | 64 | 86 | 126 | 227 | 305 | 508 | 748 | 1052 | 1263 | 1612 | 2047 | 2485 | 3601 | 1.147 |
| 1200 | 52 | 72 | 96 | 140 | 253 | 340 | 566 | 833 | 1172 | 1407 | 1796 | 2280 | 2767 | 4010 | 1.140 |
| 1400 | 62 | 79 | 106 | 155 | 280 | 376 | 626 | 922 | 1297 | 1558 | 1988 | 2524 | 3064 | 4440 | 1.135 |
| 1600 | 71 | 87 | 117 | 171 | 309 | 415 | 692 | 1018 | 1432 | 1720 | 2194 | 2786 | 3382 | 4901 | 1.130 |
| 1750 | 78 | 94 | 126 | 184 | 333 | 448 | 746 | 1098 | 1544 | 1855 | 2367 | 3006 | 3648 | 5285 | 1.128 |
| 1800 | 80 | 97 | 129 | 189 | 341 | 459 | 764 | 1125 | 1584 | 1902 | 2427 | 3082 | 3741 | 5420 | 1.127 |

** For outdoor temperature of 0°F, multiply load value in table for each main size by correction factor shown*

### Figure 12: Running Load in Pounds per Hour per 100 Ft. of Insulated Steam Main

Ambient Temperature 70°F. Insulation 80% efficient.
Load due to radiation and convection for saturated steam.

| Steam Pressure psi | Main Size 2" | 2-1/2" | 3" | 4" | 5" | 6" | 8" | 10" | 12" | 14" | 16" | 18" | 20" | 24" | 0°F Correction Factor * |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 6 | 7 | 9 | 11 | 13 | 16 | 20 | 24 | 29 | 32 | 36 | 39 | 44 | 53 | 1.58 |
| 30 | 8 | 9 | 11 | 14 | 17 | 20 | 26 | 32 | 38 | 42 | 48 | 51 | 57 | 68 | 1.50 |
| 60 | 10 | 12 | 14 | 18 | 24 | 27 | 33 | 41 | 49 | 54 | 62 | 67 | 74 | 89 | 1.45 |
| 100 | 12 | 15 | 18 | 22 | 28 | 33 | 41 | 51 | 61 | 67 | 77 | 83 | 93 | 111 | 1.41 |
| 125 | 13 | 16 | 20 | 24 | 30 | 36 | 45 | 56 | 66 | 73 | 84 | 90 | 101 | 121 | 1.39 |
| 175 | 16 | 19 | 23 | 26 | 33 | 38 | 53 | 66 | 78 | 86 | 98 | 107 | 119 | 142 | 1.38 |
| 250 | 18 | 22 | 27 | 34 | 42 | 50 | 62 | 77 | 92 | 101 | 116 | 126 | 140 | 168 | 1.36 |
| 300 | 20 | 25 | 30 | 37 | 46 | 54 | 68 | 85 | 101 | 111 | 126 | 138 | 154 | 184 | 1.35 |
| 400 | 23 | 28 | 34 | 43 | 53 | 63 | 80 | 99 | 118 | 130 | 148 | 162 | 180 | 216 | 1.33 |
| 500 | 27 | 33 | 39 | 49 | 61 | 73 | 91 | 114 | 135 | 148 | 170 | 185 | 206 | 246 | 1.32 |
| 600 | 30 | 37 | 44 | 55 | 68 | 82 | 103 | 128 | 152 | 167 | 191 | 208 | 232 | 277 | 1.31 |
| 800 | 36 | 44 | 53 | 69 | 85 | 101 | 131 | 164 | 194 | 214 | 244 | 274 | 305 | 365 | 1.30 |
| 1000 | 43 | 52 | 63 | 82 | 101 | 120 | 156 | 195 | 231 | 254 | 290 | 326 | 363 | 435 | 1.27 |
| 1200 | 51 | 62 | 75 | 97 | 119 | 142 | 185 | 230 | 274 | 301 | 343 | 386 | 430 | 515 | 1.26 |
| 1400 | 60 | 73 | 89 | 114 | 141 | 168 | 219 | 273 | 324 | 356 | 407 | 457 | 509 | 610 | 1.25 |
| 1600 | 69 | 85 | 103 | 132 | 163 | 195 | 253 | 315 | 375 | 412 | 470 | 528 | 588 | 704 | 1.22 |
| 1750 | 76 | 93 | 113 | 145 | 179 | 213 | 278 | 346 | 411 | 452 | 516 | 580 | 645 | 773 | 1.22 |
| 1800 | 79 | 96 | 117 | 150 | 185 | 221 | 288 | 358 | 425 | 467 | 534 | 600 | 667 | 800 | 1.21 |

** For outdoor temperature of 0°F, multiply load value in table for each main size by correction factor shown.*

The proper design of these drip stations is fairly simple. The most common rules to follow are:

1. Drip Stations on steam mains must be located at all low points in the system, elevation changes, directional changes, expansion loops and at all dead ends.
2. In the horizontal run of the steam main piping drip stations must be located at regular intervals of 100 to 200 feet.
3. The drip station itself is a section of piping connected to the bottom of the main piping. The diameter of the drip station pipe should be the same size as the steam main piping up to 6" piping. For steam main piping larger than 6" the drip station piping shall be 1/2 the nominal pipe size but no less than 6".
4. The vertical drop of the drip station shall be 1-1/2 times the diameter of the steam main but not less than 18 inches.
5. Horizontal run of the steam piping must fall 1/2" in 10 feet towards drip stations.

The reasoning behind these rules is simple. First, the diameter of the hole in the bottom of the steam main should be such that it can allow the water ample area to fall into. Gravity is our only force to allow this to happen. If the diameter of the drip station was too small, the velocity of the water would simply allow it to pass either on the side or over the top of the hole. The length of the drip station allows the water to fall far enough out of the steam flow as to not be pulled back out and forced on down the piping, and to provide the steam trap with some hydraulic head pressure for drainage of condensate during the low pressure times of shut down and start-up of the steam main. Remember, the intent of the distribution line is to deliver steam at as high a quality as possible to the heat process equipment. The equipment downstream will suffer severe damage if we don't do this step correctly.

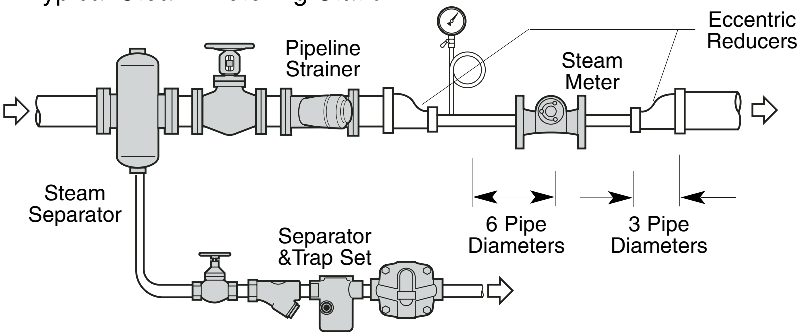
## Steam and Condensate Metering

Difficulties in energy management of steam arise from the fact that it is often a totally unmeasured service. Metering (Fig. 13) starting in the boiler house, is essential if savings are to be validated. Although fuel consumption is fairly easy to monitor, measurement of steam is a bit more difficult. A steam meter must compensate for quality as well as pressure, specific volume and temperature. Performance of different types of meters when used on steam will vary and the measurement may not always be accurate. Most meters depend on a measurement of volume. Since volume depends on pressure, measurements need to be taken at a constant pressure to the meter or else specific corrections have to be applied. Readings taken under fluctuating pressure conditions are inaccurate unless the meter can automatically compensate.

Steam metering should be done downstream of a good quality reducing valve which maintains a constant pressure. Readings should be interpreted using the meter factor and the meter calibration should be checked from time to time.

**Figure 13**

A Typical Steam Metering Station



Although steam metering is most often carried out in the boiler house, it is also important in order to determine:

1. Custody transfer. To measure steam usage and thus determine steam cost:
   a) Centrally at the boiler house
   b) At all major steam using areas
2. Equipment efficiency. Identifying major steam users, when loaded to capacity or idle; also peak load times, plant deterioration and cleaning requirements.
3. Process control. Meters indicate that the correct steam requirement and quantity is supplied to a process, when bypass lines are opened; and when valves and steam traps need attention.
4. Energy efficiency. Compare the efficiency of one process area with another; monitor the results of plant improvements and steam saving programs.

# Steam and Condensate Metering

## Why Measure Steam?

Steam is still the most widely used heat carrying medium in the world. It is used in the processes that make many of the foodstuffs we eat, the clothes we wear, components of the cars we ride in and the furniture we use. It is used in hospitals for sterilization of instruments and surgical packs, in the refining process for crude oil based products, in chemical production, and in the laundry that cleans our clothes.

Despite this, it is commonly regarded as an almost free service - easily available. Very few attempt to monitor its usage and costs, as they would for other raw materials in the process.

"But a steam meter won't save energy". This statement is sometimes used as a reason for not installing steam meters. It cannot be argued against if steam meters are evaluated in the same way as other pieces of energy saving equipment or schemes.

A statement such as the one quoted earlier does little to ease the frustration of the Energy Manager or Factory Manager trying to establish where steam is being used, how much is being used and whether it is being used wisely and effectively.

All too often, when the need for a steam meter is accepted, only central monitoring i.e. in the Boiler House or a major Plant Room is carried out. Monitoring at branch mains or at each plant room, a section of the process or major pieces of steam using equipment, are not considered.

While central monitoring will establish overall steam flow figures (and thus, costs), 'departmental' monitoring will give data which is much more useful. Such steam meters will enable checks to be kept on individual plant performance. Costs can be analyzed for each part of the process and 'pay-back' records can be established following the implementation of energy saving measures.

The steam meter is the first basic tool in good steam housekeeping - it provides the knowledge of steam usage and cost which is vital to an efficiently operated plant or building. The main reasons for using a steam meter are, therefore:-

## Plant Efficiency

A steam meter will indicate process efficiency. For example, whether idle machinery is switched off; whether plant is loaded to capacity and whether working practices are satisfactory. It will also show the deterioration of plant overtime, allowing optimal plant cleaning or even replacement, to be calculated. Further, it can establish peak steam usage times or identify sections or items of plant which are major steam users. This may lead to a change in production methods to even out steam usage and ease the peak load problems on boiler plant.

## Energy Efficiency

Steam meters can be used to monitor the results of energy saving schemes and to compare the efficiency of one piece of plant with another.

## Process Control

Steam meters can indicate that the correct quantity of steam is being supplied to a process and that it is at the correct temperature and pressure.

## Costing and Custody Transfer

Steam meters can measure steam usage and thus steam cost.

(a) Centrally

(b) At major steam using centers.

Steam can be costed as a 'raw material' at various stages of the production process thus allowing the true cost of individual product lines to be calculated.

## The Control and Regulation of Steam

The proper control and regulation of steam either in regards to steam pressure for equipment or for the flow of this valuable heat energy source to heat transfer equipment is mandatory for today's industrial and HVAC steam users for efficient usage of this energy source. The control of heat flow to product temperatures in process equipment is mandatory, otherwise production wastage becomes intolerable, which means lost profits.

The control of steam pressures and the regulation of steam flow to heat exchangers is accomplished by several different types of valves. This section is intended to describe the different types of valves used for these operations and the differences that will help the user in deciding which type of valve is necessary for his specific application. This section will not go into complete descriptions of these valves but just an overview of their operational characteristics and the benefits of that operation.

## Pressure Reducing Valves

Most steam boilers are designed to work at relatively high pressures, generally above the steam pressure required in equipment, and should not be operated at lower pressures. Operation at lowered pressures causes reduced efficiencies and increased potential for boiler carryover. For this reason, the highest efficiency is maintained by generating and distributing the highest steam pressures that the boiler is capable of producing. To produce lower pressure steam at the point of use, a building pressure reducing valve should be used. This system design allows for much smaller distribution piping, reducing costs and reducing heat losses from these pipes. Also every piece of steam using equipment has a maximum safe working pressure which cannot be exceeded in operation. Another energy efficiency reason for reducing steam pressures is the "latent" heat content is greater in lower pressure steam. More heat content per pound means less pounds of steam to do the work. These are not the only reasons for reducing steam pressure. Since the temperature of saturated steam is determined by its pressure, control of pressure is a simple but effective method of accurate temperature control. This fact is used in applications such as sterilizers and control of surface temperatures on contact dryers. Reducing steam pressure will also cut down on the losses of flash steam from vented condensate return receivers.

Most pressure reducing valves currently available can be divided into three groups and their operation is as follows:

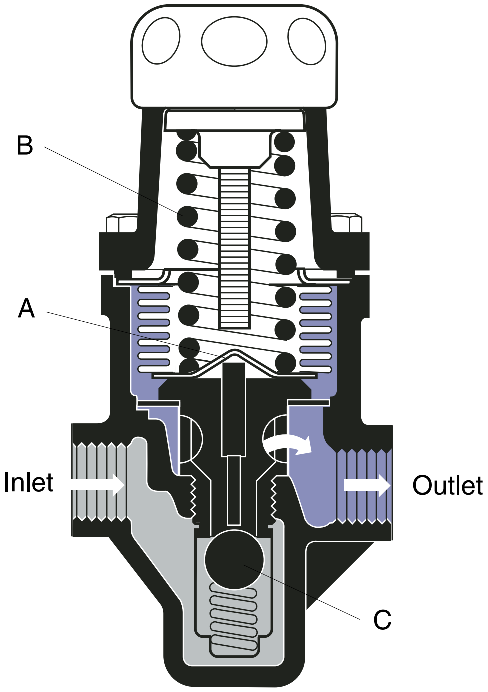
## Direct Acting Control Valves

The direct acting valve is the simplest design of reducing valve (Fig. 14a). Reduced pressure from downstream of the valve acts on the underside of the diaphragm "A", opposing the pressure applied by the control spring "B". This determines the opening of the main valve "C" and the flow through the reducing valve.

In order for the valve to move from open to the closed position, there must be a build up of pressure under the diaphragm "A". This overcomes the pressure exerted by the control spring "B". This action results in an inevitable variation of the downstream pressure. It will be the highest when the valve is closed, or nearly closed, and will "droop" as the load demand increases. The outlet pressure acting on the underside of the diaphragm tends to close the valve as does the inlet pressure acting on the underside of the main valve itself. The control spring must be capable of overcoming the effects of both the reduced and inlet pressures when the downstream pressure is set. Any variation in the inlet pressure will alter the force it produces on the main valve and so affect the downstream pressure. This type of valve has two main drawbacks in that it allows greater fluctuation of the downstream pressure, under unstable load demands, and these valves have relatively low capacity for their size. It is nevertheless perfectly adequate for a whole range of simple applications where accurate control is not essential and where the steam flow is fairly small and reasonably constant.

**Figure 14a**

Direct Acting Pressure Reducing Valve



## Pilot Operated Valves

Where accurate control of pressure or large capacity is required, a pilot operated reducing valve (Fig. 14b) should be used.

Reduced pressure acts on the underside of the pilot diaphragm “C”, either through the pressure control pipe “F”, so balancing the load produced on the top of the pilot diaphragm by the pressure of the adjustment spring “B”.

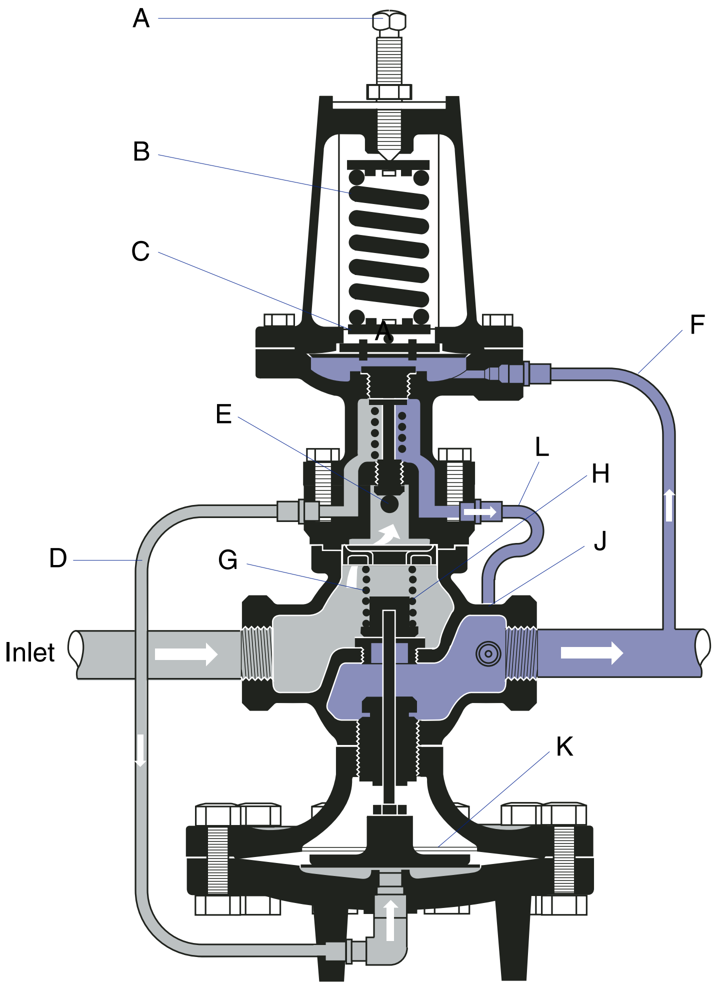
When the downstream reduced pressure falls, “F” the spring force overcomes the pressure acting below the pilot diaphragm and opens the pilot valve “E”, admitting steam through the pressure control piping “D” to the underside of the main diaphragm “K”. In turn, this opens the main valve “H” against its return spring “G” and allows more steam to pass until the downstream pressure returns to the preset value.

Any further rise in reduced pressure will act on the pilot diaphragm to close the pilot valve. Pressure from below the main diaphragm will then be relieved into the valve outlet back through the control pressure piping “D” and the orifice “J” as the return spring moves the main valve towards its seat, throttling the flow.

The pilot valve will settle down to an opening which is just sufficient to balance the flow through the orifice “J” and maintain the necessary pressure under the diaphragm to keep the main valve in the required position for the prevailing upstream and downstream pressure and load conditions. Any variation in pressure or load will be sensed immediately by the pilot diaphragm, which will act to adjust the position of the main valve.

**Figure 14b**

Pilot Operated Reducing Valve



The reduced pressure is set by the screw “A” which alters the compression of the adjustment spring “B”.

The pilot operated design offers a number of advantages over the direct acting valve. Only a very small amount of steam has to flow through the pilot valve to pressurize the main diaphragm chamber and fully open the main valve. Thus, only very small changes in downstream pressure are necessary to produce large changes in flow. The “droop” of pilot operated valves is, therefore, small. Although any rise in upstream pressure will apply an increased closing force on the main valve, this is offset by the force of the upstream pressure acting on the main diaphragm. The result is a valve which gives close control of downstream pressure regardless of variations on the upstream sides (Fig. 16).

## Pneumatically Operated Valves

Pneumatically operated control valves with actuators and positioners (Fig. 15) being piloted by controllers will provide pressure reduction with even more accurate control. Controllers sense downstream pressure fluctuations interpolate the signals and regulate an air supply signal to a pneumatic positioner which in turn supplies air to a diaphragm opening a valve. Springs are utilized as an opposing force causing the valves to close upon loss of or a reduction of air pressure applied on the diaphragm. Industry sophistication and control needs are demanding closer and more accurate control of steam pressures, making Pneumatic control valves much more popular today.

## Selection & Application

The first essential is to select the best type of valve for a given application and this follows logically from the descriptions already given. Small loads where accurate control is not vital should be met by using the simple direct acting valves. In all other cases, the pilot operated valves will be the best choice, particularly if there are periods of no demand when the downstream pressure must not be allowed to rise.

Oversizing, a common industry practice, should be avoided at all costs regardless of the type of control valve selected. A valve that is too large in capacity capabilities will have to work with minimum opening between the valve head and seat on less than maximum loads which can and does cause wire-drawing, valve cutting, and erosion. In addition, any small movement of the oversized head will produce a relatively large change in the flow through the valve orifice in an effort to accommodate load changes, almost always allowing more or less flow through the valve than was actually needed causing larger pressure fluctuations downstream.

**Figure 15**

Pneumatic Pressure Reducing Valve

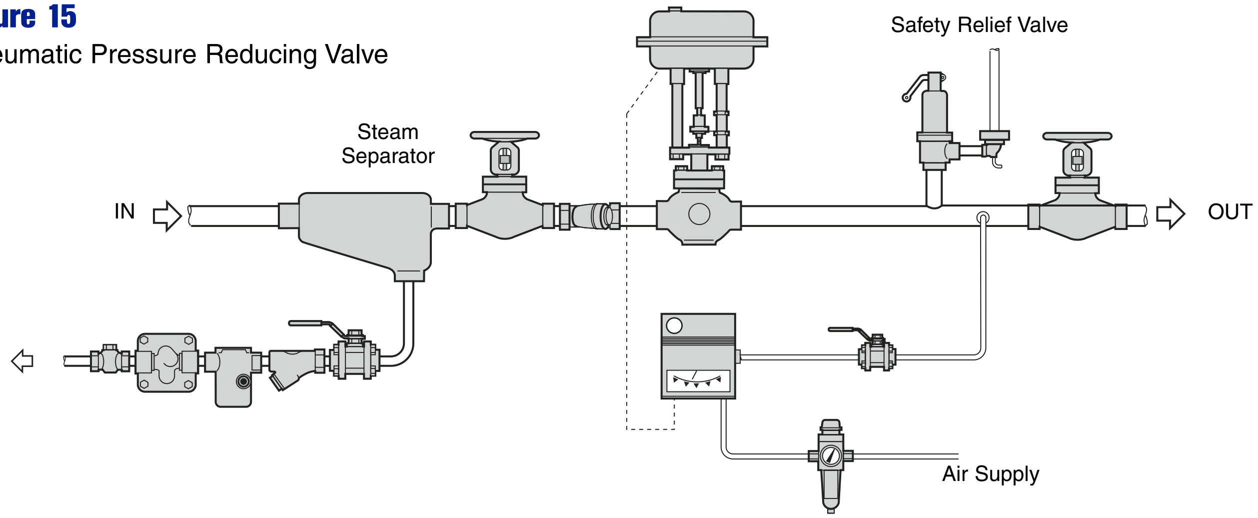
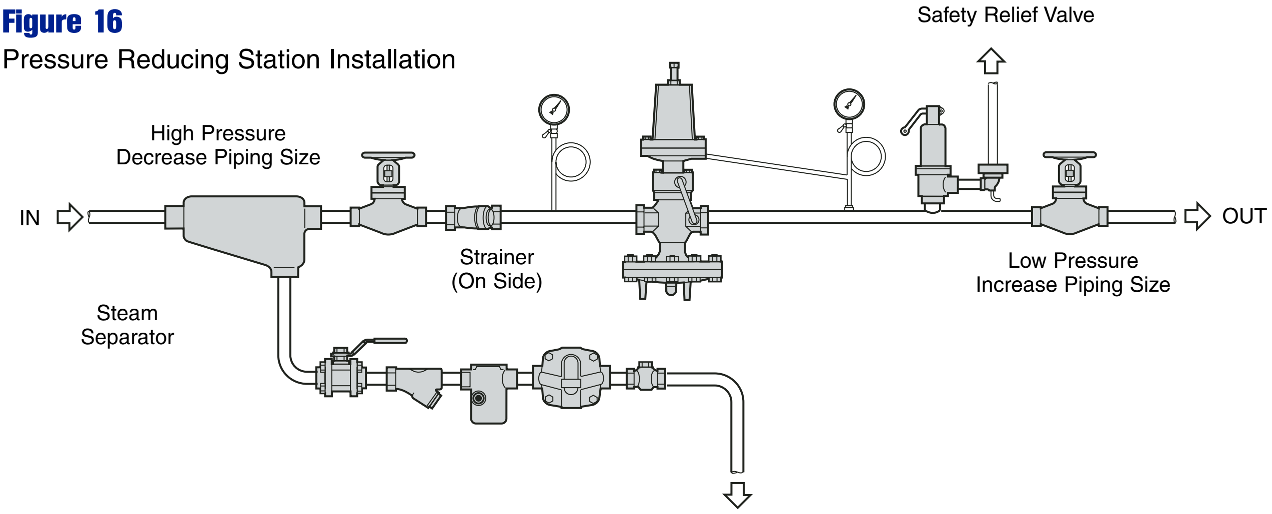


**Figure 16**

Pressure Reducing Station Installation



A smaller, correctly sized reducing valve will be less prone to wear and will give more accurate control. Where it is necessary to make bigger reductions in pressure or to cope with wide fluctuations in loads, it is recommended to use two or more valves in series or parallel to improve controllability and life expectancy of the valves.

Although reliability and accuracy depend on correct selection and sizing, they also depend on correct installation.

Since the majority of reducing valve problems are caused by the presence of wet steam and/or dirt, a steam separator and strainer with a fine mesh screen (100 mesh) are fitted before the valve. The strainer is installed with the "Y" portion of its body just below horizontal in a horizontal steam line to prevent the body from filling up with condensate during periods of shut down and to ensure that the full area of the screen is effective in preventing dirt from passing through. As a part of a Preventative Maintenance Program all strainers should be installed with blowdown valves for regular dirt removal. All upstream and downstream piping and fittings should be sized to handle the maximum steam flows at a reasonable velocity of not more than 6,000 feet per minute. Eccentric pipe reducers, with the flat side on the bottom, should be used to prevent any build up of condensate in the piping during shutdown.

If the downstream equipment is not capable of withstanding the full upstream steam pressure, then a safety relief valve must be fitted either on the downstream piping or the specific piece of equipment to be protected from over pressurization in case of a valve failure. This safety relief valve must be sized to handle the maximum steam flow of the reducing valve at the desired set relief pressure. ASME standards state that those set relief pressures are to be 5 PSI above the equipment maximum operating pressure for equipment operating up to 70 PSI, and not to exceed 10% greater than maximum operating pressures for equipment operating above 70 PSI but below 1000 PSI.

## Temperature Control Valves

Most types of steam equipment need to utilize some form of temperature control system. In process equipment, product quality is often dependent upon accurate temperature control, while heating systems need to be thermostatically controlled in order to maintain optimum comfort conditions. From an energy saving point of view, controlling the steam energy supply to a process piece of equipment to maintain the desired product temperature, whether air or any product, is mandatory. If process systems are not controlled to the desired temperatures then the system will run "wild" either not providing the required heat energy or over heating the product to unacceptable levels. A very important item to remember in the use of temperature control valves on systems is that in order to regulate the heat energy transferred to the process the control valve effectively regulates not only the flow rate of energy in pounds per hour, but, also accomplishes temperature control by regulating the saturated steam pressure/temperature levels admitted to the process heat exchange equipment. Temperature control can be accomplished by several methods and valves:

## Manual Control Valves

Manual valves can be applied to a piece of equipment to control the energy supplied to the process as simply as they are used to regulate the flow of other fluids. The major drawback of manual valves to control temperatures is that these valves will undoubtedly need frequent adjustments and monitoring to maintain just the correct temperatures under constantly changing load conditions, which is the case of most pieces of process equipment.

## Self Acting Control Valves

Self-Acting Control Valves (Fig. 17) are operated by a sensor system that senses the product temperatures, causing a heat sensitive fluid to expand or contract based on the product temperature transferring heat energy to the sensors fluid. This expansion and contraction of the heat sensitive fluid is transmitted up through a capillary tubing arrangement and the respective expansion and contraction of the fluid applies or relieves pressure to a valve head, causing the valve head to move. This movement allows the control valve to throttle the steam flow to the equipment. These control systems are calibrated by the amount of heat sensitive fluid to control within a given temperature range and can be set to any temperature between the upper and lower limits by means of an adjustment knob.

**Figure 17**

Self Acting Temperature Control

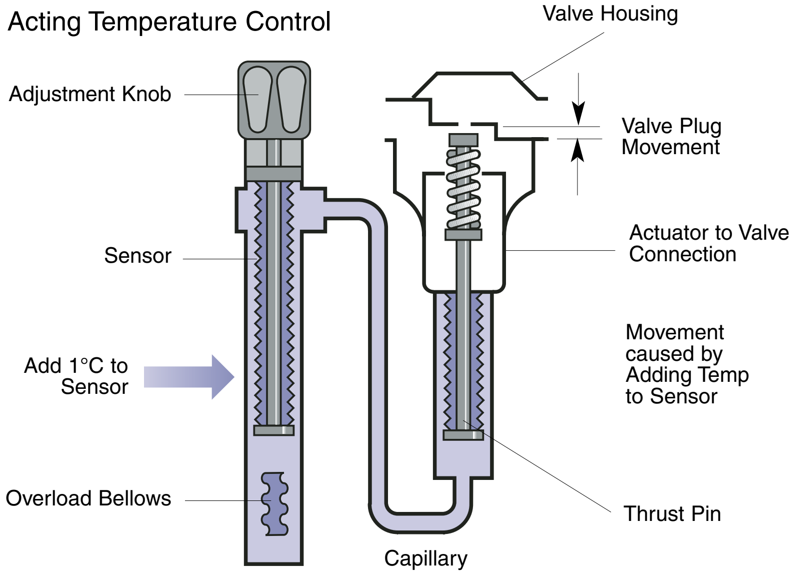
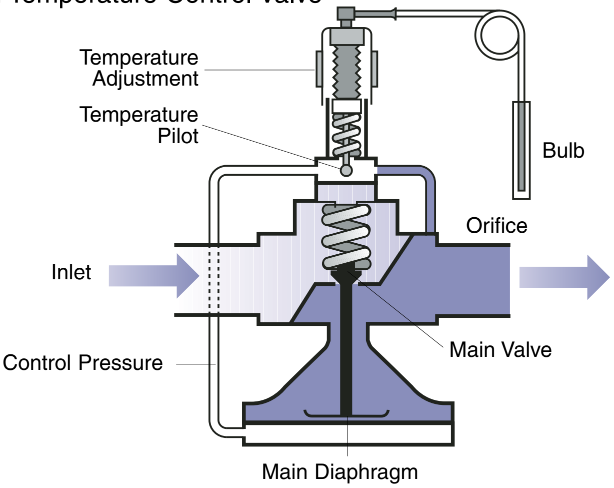


**Figure 18**

Pilot Operated Temperature Control Valve



## Pilot Operated Control Valves

Pilot Operated Temperature Control Valves (Fig. 18) operate on a similar design except instead of operating the control valve head movement directly, these units only control a small pilot device which in turn operates the main valve for throttling of the steam flow. Since on this device the heat sensitive fluid only operates a very small valve mechanism, which in turn operates the main throttling device, the sensing system is much smaller in physical size. These systems tend to control the required temperatures much closer to the desired levels and if and when a load change requirement occurs, the pilot operated valves are able to respond to these changes much more rapidly.

The normal position before starting up the system is with the main throttling valve closed and the pilot valve held open by spring force. Entering steam passes through the pilot valve into the diaphragm chamber and out through the control orifice. Control pressure increases in the diaphragm chamber, which opens the main valve. As the product being heated approaches the pre-selected desired temperature, the heat sensitive fluid in the sensor bulb expands through the capillary tubing into the bellows and throttles the pilot valve. The control pressure maintained in the diaphragm chamber positions the main valve to deliver the required steam flow. When heat is not required, the main valve closes tight to provide dead end shut off. The temperature setting can be changed by turning the calibrated adjustment dial on the pilot. This type of temperature control is known as “modulating control”, since the steam supply is gradually increased or decreased in response to any variation in the temperature of the medium being heated. Remember that this means that the steam pressure in the heating equipment can and will vary from relatively high pressure/temperature when the valve is wide open to practically nothing, or even potentially in vacuum conditions. NOTE: A vacuum can form as the residual steam in the coil or heat exchanger equipment condenses because the closed valve prevents any further steam from entering. The most common occurrence is coils and/or heat exchanger equipment running in vacuum, doing more work than what they were designed for, greater product flows through the equipment causing the steam to be condensed faster than it can be admitted.

## Pneumatic Control Valve

Pneumatic Control Valves (Fig. 19) are also pilot operated valves in that they receive their control signals from an external sensing system, converting this temperature signal into either a compressed air signal to actuate (throttle) the valve or from a temperature signal to an electrical signal (4-20 MA) which then regulates a compressed air signal to the valve actuator. Sensitivity and response time to changes of load condition are enhanced with this type of valve system. Another benefit of using this arrangement of control system is the ability to observe the valves opening position externally by either an indicator on the valve stem or by the compressed air signal applied to the actuator.

The deciding factors for the selection of the proper control valve system for a specific application is certainly the degree of accuracy required on the product's temperature and the response time to load changes if there are any.

## Proportional Control Bands

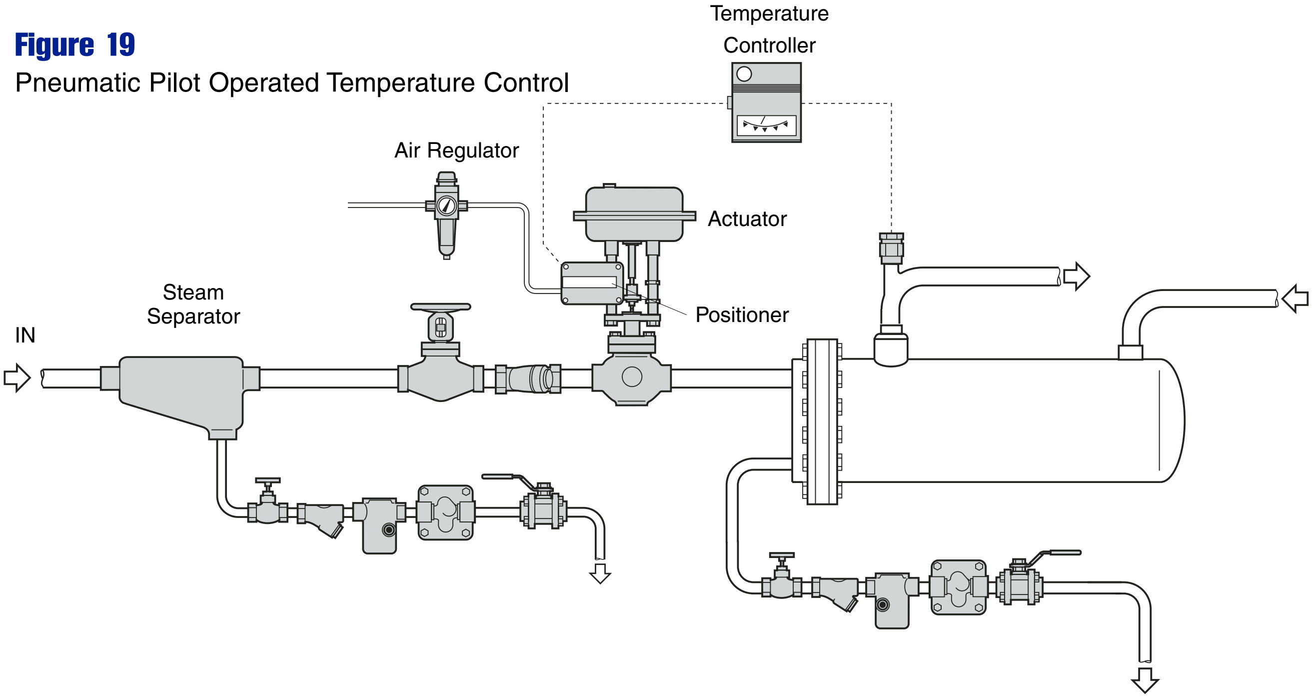
Since self-acting controls require a change in sensor temperature to effect a response in the amount of valve opening, they provide a set temperature value that is offset in proportion to the load change. The charts on the following page (Figs. 20a and 20b) show that the proportional band of the control describes the amount that the temperature setting "droops" at full load. Both set point accuracy and system stability result when the regulator valve is sized for the range of offset recommended. Main valves and pilots are matched so that typically on a 6°F sensor bulb change results in full opening of the high capacity main valve. Pneumatic control valve system's proportional bands are affected by the sensitivity of the sensor and the control signals received from the compressed air supply or electrical signal. Calibration of these valves also will dictate their sensitivity and certainly the use of a controller unit will enhance the proportional band characteristics.

On certain applications such as hot water storage systems, periods of heavy steam demand alternate with periods of no demand. In such cases, it is possible to use the "on/off" type of temperature regulator. Here the control thermostat closes off the steam valve completely when the control temperature is reached and consequently the steam pressure in the primary side rapidly drops to zero. As soon as hot water is drawn off, cold make-up water enters and is sensed by the control system thermostat which opens the steam valve fully, giving a rapid build up of steam pressure in the primary side. This type of control system would only be recommended for applications when the hot water is being drawn off at intervals for cleaning usage then there would be a recovery time allowed before the next draw off of the system.

This section is essentially a brief introduction to the subject of temperature control, rather than a comprehensive coverage of the many types of control currently

**Figure 19**

Pneumatic Pilot Operated Temperature Control



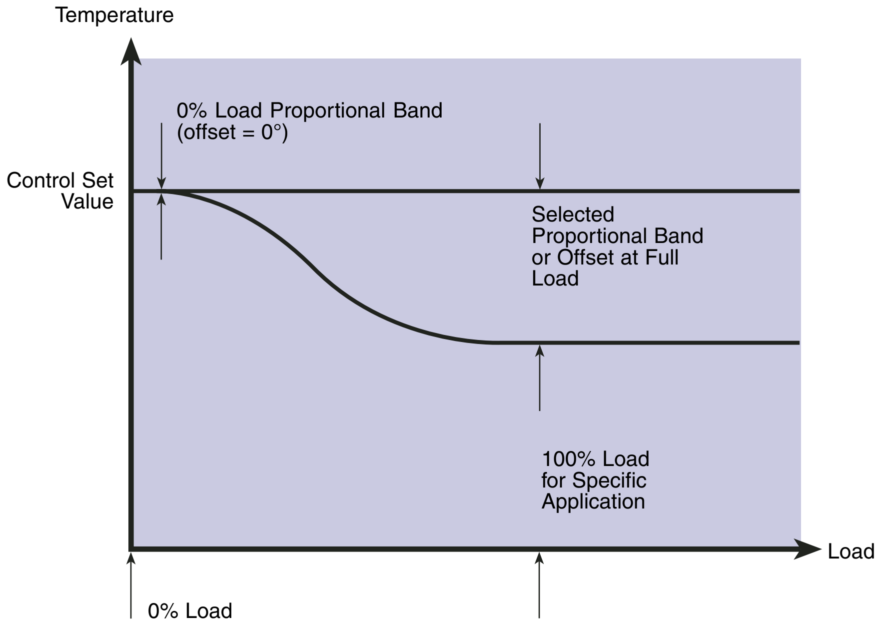


**Figure 20a**

Selected Proportional Band

| Application | °F P-Band |
|---|---|
| Hot Water Service Storage Calorifier | 7° - 14°F |
| Central Heating Non Storage Calorifiers | 4° - 7°F |
| Space Heating (Coils, Convectors, Radiators, etc.) | 2° - 5°F |
| Bulk Storage | 4° - 18°F |
| Plating Tanks | 4° - 11°F |

**Figure 20b**

Acceptable P-bands

available for use on steam heat exchange equipment.

When a modulating control is used, the steam trap should be capable of giving continuous condensate discharge over the full range of pressures. If maximum output is required from the unit, the trap used must be able to discharge condensate and air freely and must not be of a type which is prone to steam locking. A thermostatic trap is not suitable because it has a fixed discharge temperature that may cause condensate to be held back just when the control valve is wide open and the equipment is calling for maximum heat transfer.

Traps which give a heavy blast discharge, such as a large inverted bucket trap, may upset the accurate temperature control of certain units because of the sudden change in pressure in the steam space which occurs when they open. This effect is most likely to be noticeable in equipment where the steam space has a high output in relation to its volume.

The most suitable type of trap for temperature controlled applications is the continuous discharge float and thermostatic trap. This trap will discharge condensate immediately as it is formed without upsetting pressure conditions in the steam space. It will not steam lock, with proper installation, and will not air lock or attempt to control the discharge temperature of the condensate.

If waterhammer is likely to occur, the float and thermostatic trap is liable to become damaged, for this reason and for the longevity of the heat exchange equipment waterhammer situations should be corrected at all costs. In most cases waterhammer in heat exchange equipment is caused by water logging of the equipment. Note: Condensate must be allowed to drain freely by gravity at all times. If condensate has to be lifted up into a return system, then this lifting has to be done by a pumping device.

## Condensate Removal

Condensate should be properly disposed of from each of the three possible types of plant locations which are Drip, Tracer and Process. Condensate has been neglected in the past, but has a distinct monetary value which must be recaptured. It is becoming far too valuable to merely discard to the ground or a drain. Let us look at some of the important and valuable aspects of condensate.

First of all, condensate is purified water. It is distilled water. It may have some chemical treatment left in it which in itself is valuable. Most of all though, it is hot water. It is fairly obvious that it is less expensive to regenerate hot condensate back into steam than it would be to heat cold make up water into steam. Every BTU is valuable and that which remains in the condensate is no exception.

In the past, the focus of condensate removal was generally in main steam process areas only. Condensate from light load locations, such as Drip and Tracer, have not been widely returned. The loads at a drip station are low for each location, but when the number of locations are counted, it is shown the amount of returnable condensate is very high. For example, if we review the expected condensate load from the Steam Distribution Condensate Tables (Fig. 12), a six inch steam main at 100 psig will generate about 33 lbs. per hour per 100 ft. of insulated pipe. This initially does not seem like much, but if there are 100 drip locations, it calculates to approx. 3300 lbs. per hour of condensate. Multiply this number by 8760 hours in a year and you will see a substantial amount of usage.

CALCULATION:

3300 lbs./hour
x 8760 hrs/ year
**28,908,000** lbs/year
or **3,412,897** gal./year

Another factor to calculate is the monetary value of the condensate. Condensate contains heat, chemicals and water. It is usually as much as one third of the cost of generating steam. If our example were to assume a steam generation cost of $3.00 for each 1,000 lbs., our example of lost condensate and energy calculates as follows:

CALCULATION:

$$\frac{28{,}908{,}000 \text{ lbs/year}}{1{,}000} = 28{,}980$$

28,980 x $1.00 = $ **28,980**/year

Another small user in a steam system, where condensate is being created and discharged, is that of the tracer lines. Tracers are those lines that follow the flow of process liquids to prevent them from freezing or solidifying. Tracer lines, however, are not usually meant to be a type of heat exchanger. They merely follow the path of the process fluids to keep them hot and less viscous. One of the extreme costs which are hidden in everyday plant production is the cost of pumping liquids from one point to another. Heavy, viscous liquids are obviously more difficult to pump so amperage at the electrical pumps rises. As amperage rises, electrical use rises and so does the amount of money spent on pumping liquids.

If the tracer lines do their job, they allow heat to transfer into the product liquids as heat is lost through the insulation. If the efficiency of insulation is relatively good, the steam usage would be reasonably low. It would not be unusual for this type of tracing to generate only about 25 lbs/hour. Again, at first glance this seems to be only a small user of steam and not worth collecting and returning. It has much of the same characteristics as the drip station condensate in that it is hot, has been chemically treated and is good quality water. Again, if a plant had 100 tracer lines of this type, the usage would calculate as follows:

CALCULATION:

25 lbs./hour X 100 lines
= 2500 lbs/hour
2500 lbs./hour X 8760 hrs./year
= 21,900,000 lbs./year

It is easy to see that this is also a substantial amount. Our calculations assume that this type of tracing will be on year round. Not all tracing is on continuously, however. Some tracing is used primarily for winterizing. This type of tracing is for freeze protection of liquid lines, instrumentation, etc. Every section of the country usually turns on this type of tracing at various times, so calculations similar to the above could be used and a modification to the amount of hours per year should be made.

Process applications consume the vast majority of steam. Heat exchange equipment is used to transfer heat from steam to product, whether it is fluid or air. They are designed to consume all heat necessary to perform any particular task. Ideally, condensate removal from any source should flow downward. In many cases this is not practical. It is unique to heat exchangers that flow of steam and product varies and sometimes it is significant.

As well as the removal of condensate for the monetary reasons mentioned previously, related to the return of hot condensate to the boiler feedtank, there are other reasons equally as important to why steam traps should be utilized, these are:

## Air Venting

At start up the trap must be capable of discharging air. Unless air is displaced, steam cannot enter the steam space and warming up becomes a lengthy business. Standing losses increase and plant efficiency falls. Separate air vents may be required on larger or more awkward steam spaces, but in most cases air in a system is discharged through the steam traps. Here thermostatic traps have a clear advantage over other types since they are fully open at start up.

Float traps with inbuilt thermostatic air vents are especially useful, while many thermodynamic traps are quite capable of handling moderate amounts of air. The small bleed hole in the inverted bucket trap or the orifice plate generally leads to poor air venting capacity.

## Thermal Efficiency

Once the requirements of air and condensate removal have been considered we can turn our attention to thermal efficiency. This is often simplified into a consideration of how much heat is profitably used in a given weight of steam.

On this basis the thermostatic trap may appear to be the best choice. These traps hold back condensate until it has cooled to something below saturation temperature. Provided that the heat is given up in the plant itself, to the space being heated or to the process, then there is a real saving in steam consumption. Indeed, there is every inducement to discharge condensate at the lowest possible temperature.

On the other hand, if cool condensate is then returned to a feed tank which requires preheating, the ‘efficient’ trap has done little for the overall efficiency of the steam system.

Care must also be taken in evaluating any application involving a cooling leg. Draining through a bimetallic steam trap may look attractive in terms of lower temperature discharge and reduced loss of flash steam. On the other hand, if heat is being lost to atmosphere through an unlagged cooling leg, then the net gain in thermal efficiency is probably negligible.

Without a cooling leg condensate will be held back within the plant and the main reservation must be whether the plant itself will accept this waterlogging. It is permissible with non-critical tracer lines or oversized coils, but as already indicated, it can be disastrous in the case of heat exchangers.

## Reliability

It has been said that ‘good steam trapping’, means the avoidance of ‘trouble’. Undoubtedly, reliability is a major consideration. Reliability means the ability to perform under the prevailing conditions with the minimum of attention.

Given thought, the prevailing conditions can usually be predicted.

- *Corrosion due to the condition of the condensate or of the surrounding atmosphere may be known, and can be countered by using particular materials of construction.*
- *Waterhammer, often due to a lift after the trap, may be overlooked at the design stage and can mean unnecessary damage to otherwise reliable steam traps.*
- *Dirt is another factor. A trap selected to meet all the obvious criteria may be less reliable in a system where water treatment compound carried over from the boiler, or pipe dirt, is allowed to interfere with trap operation.*

The prime requirement however is the adequate removal of air and condensate. This requires a clear understanding of how traps operate.

NOTE: WATERHAMMER CONDITIONS IN A STEAM SYSTEM DAMAGE MORE THAN JUST STEAM TRAPS AND IS A VERY SERIOUS CONDITION WHICH SHOULD BE RESOLVED.

## Steam Traps

First, a definition of a steam trap may be in order to fully understand the function of this piece of equipment. A steam trap is an automatic valve designed to stop the flow of steam so that heat energy can be transferred, and the condensate and air can be discharged as required. If we break this definition down into sections, it is first of all an “automatic valve”.

This infers that there is some form of automatic motion that must take place. It is “designed to stop the flow of steam so that heat energy can be transferred”. This portion of the description is such that it would imply the transmission of energy whether by flowing down a distribution pipe or giving up energy to a product in a heat exchanger. The definition also continues to say “discharge condensate and air as required”. This portion of the definition implies that some types may handle differing amounts of either condensate or air, or even a combination of the two.

In the beginning, steam traps were manually operated valves.

The major problem with this type of condensate drainage system is the variation to changing condensate flows. Condensate, you will recall, is steam that has given up its enthalpy and reformed into water. The amount of condensate being created varies in many different ways. A fixed position of a block valve or fixed hole in a drilled plug cock valve cannot adjust automatically to the varying conditions of condensate load.

This method of condensate removal would warrant an operator be present much of the time to correct the setting of the valve. If condensate was allowed to back up, less heat transfer would take place, causing production to fall off. If, on the other hand, the condensing load was less, the operator would have to close the valve to the point that steam was not continuously being released. Because of the changing nature of condensing loads, this would be a full-time job.

True steam trap operation will fall under one of the following three categories:

1. Mechanical or Density
2. Thermostatic or Temperature Controlled
3. Thermodynamic or Velocity

These categories of traps have distinctive operating characteristics and work most efficiently when used for their designed purpose. It would stand to reason that steam traps evolved with industry and demand. There are really only three applications for steam traps: drip stations (located on steam delivery lines), tracing (steam lines designed to maintain a product temperature or keep a liquid system from freezing) and process (steam used specifically for heating products such as air, process fluids, foods etc.). These differing applications will be discussed later. Our purpose now is to explore the operating characteristics of traps and where they fall within each category.

## Mechanical Steam Traps

There are two basic designs of steam traps in this category. They are the “Float and Thermostatic” and the “Inverted Bucket” designs. The float and thermostatic design evolved primarily from a free floating ball design.

The first float type trap consisted of a free floating ball in an expanded area of pipe. It was a top in, bottom out type of system that required water to fill the expanded area and float the ball upwards, exposing the outlet piping and outlet orifice. As long as condensate was flowing to the trap, condensate would flow from the trap at the same rate. The floats were weighted slightly to require water to always be present in the trap and thereby stop steam from leaking into the condensate return line or to atmosphere. It was soon noted, however, that air would accumulate in the expanded area of pipe and form a bubble which kept condensate from flowing downward. A piece of pipe was added to the inlet piping to the trap and a manual valve attached to be periodically “blown down” to keep water flowing to the trap and air removed. When the thermostatic bellows steam trap was invented, it soon took the place of the manual valve and automated the procedure.

## Float And Thermostatic Trap

Modern Float and Thermostatic traps (Fig. 21) still have a ball type float, but it is now attached to a lever. The lever is attached to a valve head and pivot point. When condensate enters the trap, the float rises with the liquid level and mechanically pulls the valve off the seat to allow condensate to be discharged. A thermostatically operated air vent is still present but located inside the body on most modern day designs of F&T traps.

Some manufacturers locate the “air vent” externally, but the purpose is the same. This part of the trap is strictly there for automating the air venting procedure. It is also noteworthy to note here that this type of trap has one basic application point, and that is for process purposes. This is due to the fact that this trap type immediately removes air and non-condensables as they enter the trap and discharges condensate in the same manner, at saturation temperatures. There may be some limited uses other than process for this type of trap, but primarily it is used in this type of application.

The main advantages to this type of trap is its superior air removal capabilities either on start up or during the process procedure. It also has a continuous discharge characteristic that follows exactly the forming of condensate. In other words, what comes in goes out at the same rate. This type of steam trap adjusts automatically to either heavy or light loads of condensing and is not adversely affected by changes in pressure. Condensate removal is also done at steam temperature, so heat exchange takes place at constant temperatures, insuring maximum efficiency use of the energy supply.

A disadvantage is general to all mechanical type of traps and that is the power of the float is constant, so as steam pressure goes up, the size of the permissible discharge orifice goes down. In practice, mechanical traps must have different sizes of valves and seats for different pressure ranges. This is to ensure that the float and lever combination has the ability to generate enough energy to lift the valve head off of the seat at the design operating pressures. If it cannot, the trap mechanism is overcome by the steam pressure and the trap fails closed.

## Inverted Bucket Traps

The second mechanically operated steam trap is the Inverted Bucket type of trap (Fig. 22). In this trap, the operating force is provided by steam entering and being contained within an inverted bucket causing it to float in condensate that surrounds the bucket itself. The bucket is attached to a lever and pivot point similar to that in the F & T. The valve head and seat, however, are located at the top of the trap. It requires water being present within the body in order for the bucket to have something in which to float. This is called the "prime".

When steam is first turned on, air is allowed to flow to the trap. This air is captured within the bucket and flows out through a hole in the top of the bucket known as the "vent hole". Air passes upward through the hole, through the prime, and collects at the top of the trap. Since the system is building pressure, the air is at its most compressed state. This puts a downward force on the prime and pushes it back up into the bucket. As this bucket fills with water, it loses buoyancy

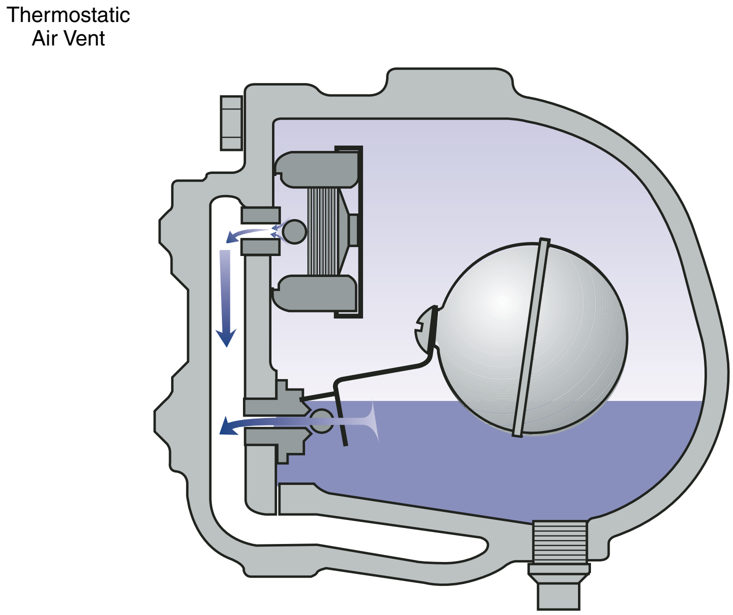
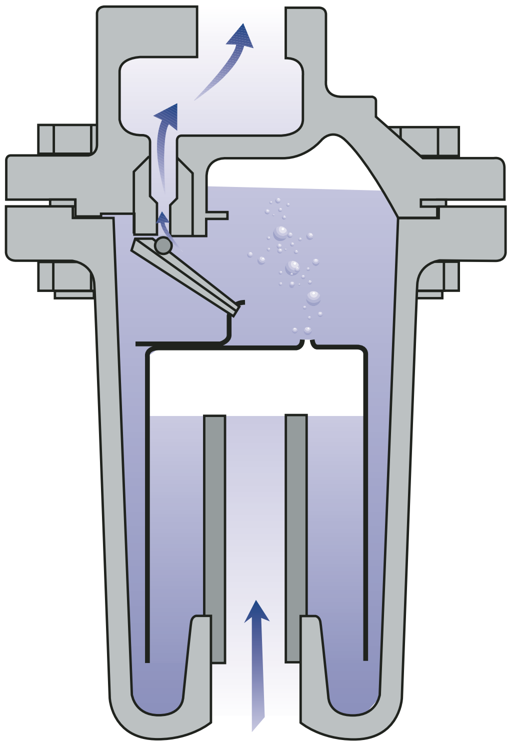


**Figure 21**

Float and Thermostatic Steam Trap

**Figure 22**

Inverted Bucket Trap



and sinks in the surrounding liquid. In doing so, it pulls the valve head off of the valve seat and allows the collected air to discharge. Flow from under the bucket starts again. This allows either more air or steam to begin to enter the trap body. If it is more air, the sequence is repeated.

If it is steam, however, the sequence is different. Steam passes through the bucket vent hole to the top of the trap and is condensed by heat losses from the trap body, in particular the cap or top. This loss is necessary to keep steam and condensate coming to the trap. As condensate enters under the bucket, it fills the space and again the bucket loses buoyancy and sinks. Discharge flow is first downward from under the bucket, and then upward to the discharge orifice.

The biggest advantage to this type of trap is its ability to withstand high pressures. It has a reasonable degree of tolerance to waterhammer damage but suffers from freeze damage. In the case of freezing, however, most of the damage is done to the body of the trap rather than to the mechanism or float.

The disadvantage to this trap type is its limited ability to discharge air and other non-condensable gases. This is due to the small vent hole and low differential pressure driving the air through it. It is suspect at times to rapid pressure changes in the system due to the requirement of a “prime” being maintained internally for proper operation. The “prime” water seal is at saturated steam pressure/temperatures and if the steam pressure drops rapidly due to load changes of equipment, the “prime” has a tendency to boil off (flash). Without the required “prime,” this type of trap fails open.

This type of trap is most appropriately suited for stable, steady load and pressure conditions such as one would find on a steam distribution system.

## Thermostatically or Temperature Controlled Traps

The balanced pressure or bellows type of steam trap was first manufactured with a bellows of copper design. This bellows (Fig. 23) had a liquid fill which, in the beginning, was distilled water. Modern thermostatic type traps still have a liquid fill but it is made up of a distilled water and alcohol mixture and they are contained within an enclosed capsule rather than a bellows. Alcohol was added to the fill to lower its boiling point.

The capsules work by exploiting the difference in the boiling point between the alcohol mixture and the surrounding condensate. As the temperature of the condensate gets closer to steam temperature, the mixture contained within the capsule gets closer to its boiling point at a set temperature below that of steam (before steam reaches the trap), the mixture evaporates. This results in an increase in internal pressure of the capsule, which is greater than that within the trap body so forcing the valve down onto its seat, and preventing the trap from blowing steam. As the steam condenses back to condensate, and the temperature drops accordingly, the alcohol mixture recondenses so relieving the internal pressure of the capsule and thus lifting the valve back off its seat, allowing condensate to flow through the trap.

The mixture of distilled water and alcohol in the bellows is the key to the operating temperatures of the balanced pressure trap. Most manufacturers provide thermostatic traps to operate within 20 to 40 degrees of saturated steam temperatures. An important point to remember is that all thermostatically operated steam traps will cause condensate to back up in the system. The amount of backup in the system is dependent upon the temperature that the trap is designed to operate at, along with the condensate loads coming to the trap.

The advantage to this type of trap is its ability to freely and

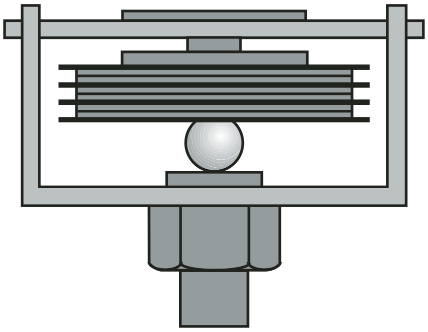


**Figure 23**

Stainless Steel Bellows for Thermostatic Trap immediately discharge air and non-condensables as soon as they enter the trap's body, as in the F & T. These traps have the ability to operate up to 600 PSIG and provide constant and consistent levels of subcooling of the condensate in relation to the saturated steam pressure/temperature curve. The most modern designs have overcome the earlier models' sensitivities of waterhammer and superheat damage by encapsulating the filling in a much more robust enclosure.

The disadvantages of thermostatically operated traps is that there is always a backup of condensate in the system, which could reduce heat transfer in some applications. These traps also will require a time period to adjust to load changes in the system. Balanced pressure steam traps are used very commonly in air venting, distribution, main drip drainage and in tracing applications.

## Bimetallic Thermostatic Traps

Bimetallic type traps have shown a lot of variation since their original design. The modern types of bimetal traps all are common in that the valve is located on the outlet side of the trap and the bimetal strips, or disks, are located inside the body. This means that the action of the trap is to pull the valve head into the valve seat opposing the steam pressure of the system, trying to drive the valve head off of the valve seat.

The bimetal strips or disks (Fig. 24) are made of two dissimilar metals, usually of 304 and 316 stainless steel. Because they are dissimilar metals, one expands more than the other at a given temperature. It is said to have different coefficients of expansion. A characteristic of this differing expansion rate is that the element has to bend or arch. This bending motion can then be used to open or close a valve accordingly.

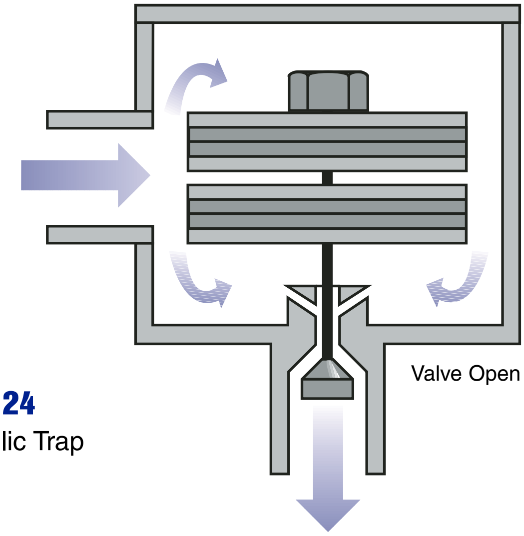


**Figure 24**

Bimetallic Trap

This type of trap has a very deep subcooling range. This range may be as much as 100°F below the saturation temperatures, thus causing excessive back up of condensate into the system. Extreme caution must be taken when applying a bimetal thermostatic trap to equipment so as not to cause equipment damage from this backup of condensate.

The advantages to this type of trap are its ability to withstand waterhammer and handle fairly large condensate loads for its small physical size. They do discharge air and non-condensable gases well, but because of their low temperature sensitivity (subcooling), they may fully close before all of these gases are removed. The trap drains freely upon drop in temperature or system shutdown, so freeze damage should not be a factor. Its primary use is for drip stations on superheated steam mains, where superheated steam and condensate cannot coexist. Another application in which these are used is for non-critical tracing (freeze protection) where energy efficiency is maximized.

A disadvantage to this type of trap is the lag time required when condensate loads change to open the trap. Response to changes are very slow. Another disadvantage to this type of trap is that they are highly susceptible to dirt being caught between the valve head and seat. Also, dirt attaches to the bimetal strips or disks and acts as and insulator, changing the discharge characteristics.

### Liquid Expansion Thermostatic

This type of trap is a variation to the standard thermostatic steam trap. The variation comes in the fill which is used and the location of that fill. There is a bellows but it is surrounded by a light mineral oil (Fig. 25). Another variation on this type of trap is an adjustment nut which allows adjustment of the stroke on the valve. The operational characteristics remain much the same as for the bellows type trap.

On start-up, the bellows is relaxed and the valve is wide open. Air is allowed to pass freely through and out of the trap. As condensate begins to flow to the trap, it surrounds the bellows and flows out as well. As the condensate temperature rises, it transfers its heat energy into the mineral oil filling which causes the mineral oil to begin changing its volume (expanding). The changing volume of the mineral oil exerts a force on the end of the bellows and forces a plunger valve toward the seat. This trap type has a substantial subcooling range. This range is variable and adjustable with the mineral oil which makes up this type of trap. It will back up condensate and regulate its flow by its temperature. Since the discharge temperature of this type of trap is adjustable, it is best used where inexpensive temperature control is needed. A primary application for this type of trap is on hot water or oil storage tanks where the temperature of the stored liquids needs to be kept below steam temperature of 0 PSIG (212°F).

The main advantage to this type of steam trap is its ability to adjust a discharge temperature to match that desired in the storage tank. This effectively reduces steam consumption on applications where controlled waterlogging can be tolerated. This trap can and is used also for freeze protection of float and thermostatic steam traps.

The major disadvantages to this trap are the amount of condensate back-up plus its inability to respond rapidly to condensate load changes and its sensitivity to dirt.

### Thermodynamic Steam Traps

This type of steam trap uses velocity to open and close a valve. The valve in this type of trap is a free floating disk which sits on two seating surface areas. One area is an inlet orifice and the other are multiple outlet orifices located in an adjacent ring. It is a fairly simple trap to understand. On start-up, the disk is forced upward and off the seating surface rings by the flow of air and condensate. Condensate and air are discharged from the trap. Condensate force is directed to the center and under the disk chamber and is exposed to the outlet ring of orifices. It recognizes a lower downstream pressure within the chamber and flashing of the condensate occurs.

Flashing is nature's way of cooling condensate back to the saturation temperature at which it can exist as liquid at the lower pressure. The excess heat energy in the condensate that cannot exist as liquid at the lower pressure and temperature generates steam at the lower pressure and expands. This expansion causes an increase in the velocity of flow between the bottom of the disk and the seating surfaces, which in turn causes a negative pressure to be sensed on the bottom of the disk beginning to pull it down onto the seating surfaces. Some of the flash steam that is being created flows around the sides of the disk to the top surface of the disk. This flash steam is trapped between the top of the disk and the cap of the trap and pressure develops in this space, pushing the disk down onto the seating surfaces.

When the pressure in the cap chamber is great enough to overcome the inlet pressure of the condensate on the bottom of the disk, the trap snaps closed. The

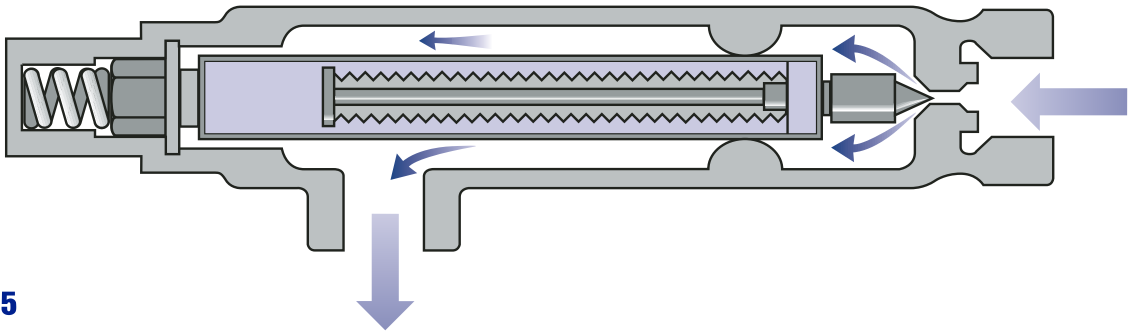


**Figure 25**

Liquid Expansion Thermostatic Trap

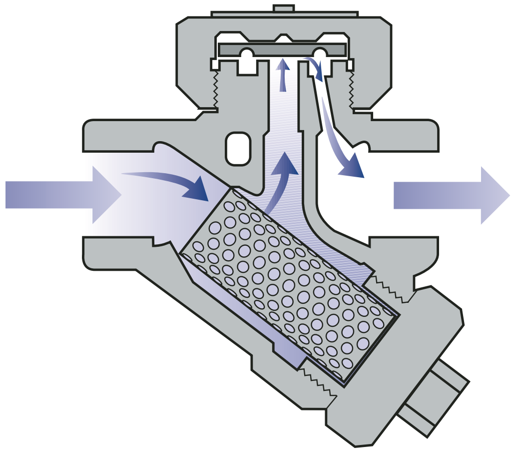


**Figure 26**

Thermodynamic Steam Trap

trap will remain closed until the pressure in the cap chamber has dropped to below the inlet pressure. Then the cycle will repeat itself. The cap chamber pressure drops due to natural heat losses from the cap to the ambient conditions, condensing this steam. This type of trap operates on a cyclical pattern, either open or closed. Because the trap is closed by flash steam created from hot condensate, there is a small amount of subcooling of the condensate and back up of condensate in the system. The subcooling ranges between 2 to 10°F below saturated steam pressure and temperature relationship.

The advantages of this type of trap are they are not damaged by waterhammer or freezing and will work consistently throughout their pressure range (up to 1750 PSIG). They can be utilized on superheated steam systems without any problems, and they are easily tested, installed and maintained. This is the only type of steam trap that will give an indication of wear before final failure occurs. The cycling rate increases with wear and gives a distinct audible clicking sound (rapid cycling).

The disadvantages to this trap are that it does not operate well at extremely low pressures (below 3.5 PSIG) or extremely high percentages of back pressure (around 80%). They are also limited in their air handling capability.

This type trap is ideally suited for steam main distribution drainage and tracing applications.

## Conclusion

The three catagories of steam traps discussed above are the most commonly used and widely known trap types. There are obviously variations to almost all of the traps described in this section. Some of those variations can be seen in the following descriptions and operating characteristics.

## Variations on Steam Traps

If we begin reviewing some of the variations of steam traps in the mechanical grouping, we note first the float type trap (Fig. 27). This type of design operates more like a liquid drain type trap that has no real balance line. You will see a small petcock valve located on top of the trap. This valve would be left open slightly to allow air and other non-condensables to be discharged. It probably worked fairly well for its day, but in today's world of expensive steam, would not be acceptable. Even a small steam bypass or leak may cost hundreds of dollars per year.

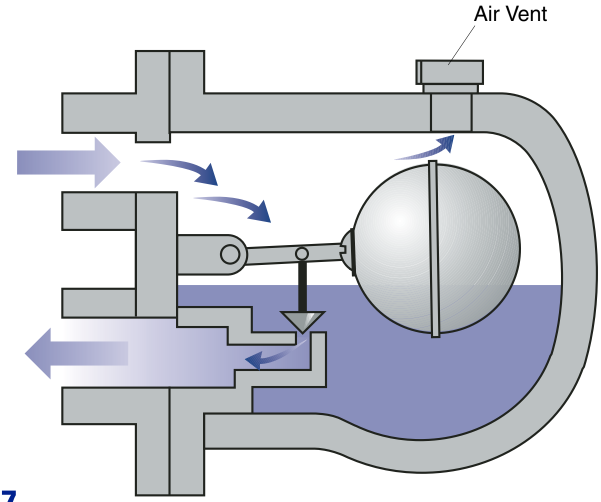


**Figure 27**

Float Trap

Another variation to the Float and Thermostatic trap is a free floating ball (Fig. 28) with the addition of a bimetal disk located at the top of the trap for air venting purposes. The outlet orifice is located on the lower section of the trap. The idea behind this type of trap valve and seat is basically the same as the ancient design of the original float type trap. The one big difference is that the seat is extended slightly outward from its position inside the trap body. This extension would cause dents to be created on the ball float that would not allow it to properly seat off when it was required. Another special note of attention should be paid to the operating (closing and opening) temperature of the bimetal disk for air venting purposes. The disk is a bimetal design that may close prematurely and not allow for proper air venting to take place. It may not open again until the subcooling range allows it to do so and air bind the trap. A special screwed stem is installed on the trap top to allow an operator to force the bimetal disk off the seat and again allow some steam to pass to prevent air binding of the trap.

The upright bucket trap (Fig. 29) uses siphon and float operation. As you can see by the design, the upright bucket allows condensate to flow over the float and fill from the top. This weighs down the bucket to the point that it sinks in the surrounding fluid. As it sinks, the valve is pulled out of the seat and line pressure forces the condensate inside the bucket to flow. It is fairly obvious that this type of design would have a lot of difficulty in ridding itself of air. Air binding was a main source of problem for this trap.

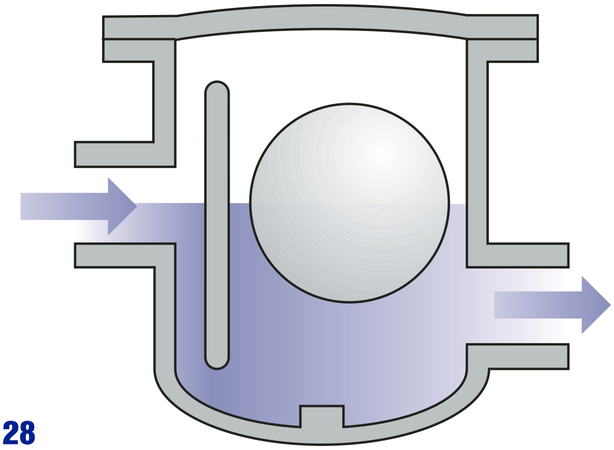


**Figure 28**
Free Float Trap

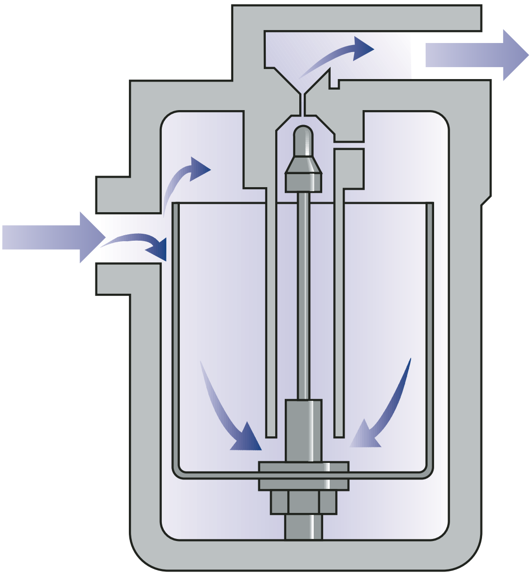


**Figure 29**
Open Top Bucket Trap

In the Thermostatic category of traps we see the most activity in attempts to redesign some of the elements themselves. In the beginning, you may remember that a balanced pressure bellows type of trap was originally made of copper. Bellows still exist today but are now made of stainless steel. This allows the manufacturers to use a more robust material and also allow them to use welds on the edges of disks for more strength (Fig. 30). The disks have a hole in the center to allow a hollow space to be created when they are welded together. This creates a bellows for fill just like the extruded copper bellows. It is said that these bellows are filled under vacuum, but in reality they are just com-

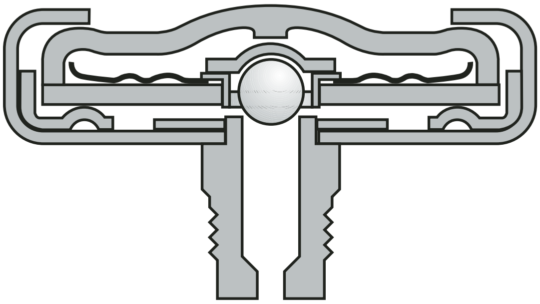


**Figure 30**
Balanced Pressure Capsule
for Thermostatic Trap

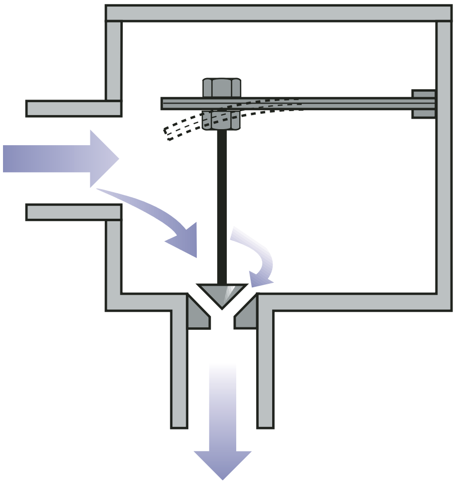


**Figure 31**
Simple Bimetallic Trap

pressed when filled and sealed.

The problem with having a liquid fill on the inside of a bellows still exists. That problem being the fill over expanding and rupturing the bellows when a small amount of superheat may be allowed to reach the trap internals. There have been two attempts to try to correct for this. As mentioned earlier, thermostatic type traps usually (but not always) reach a point where the inside pressure balances to the outside pressure of the bellows. This causes them to basically average the pressure temperature and constantly dribble. One attempt to solve the over expansion problem and dribble discharge was to create a single wafer type of capsule where the center portion containing the valve was forced in during the filling procedure of manufacturing. This created a bowing type of appearance and caused the capsule to operate more like the bottom of an oil can. As the fill vaporized it “popped” the portion of the capsule outward and forced the valve head on to the seat. As the fill cooled and contracted it popped again to the original position and opened the valve to allow discharge. This popping action meant that it would insure the trapping of some condensate around the capsule at all times and prevent over expansion. Superheat has no condensate, as you know, and also has a tendency of vaporizing any condensate in a system once it is up to full temperature. This still created over expansion, but the trap now had a more distinct on and off type of operation when used on saturated steam lines.

The problem with this type of trap was the design and location of the liquid fill that causes the trap to operate. Later design of the capsule put the liquid fill on the outside of the moving part of the wafer. The result of the fill vaporizing and forcing the valve to the seat in part then doubles the thickness of the wafer at its weakest point. It is also apparent that the fill then be encased in a thicker shell to prevent water hammer damage to the element. As you can see, the operation of this type of design improvement for the thermostatic trap is much more resistant to damage by either superheat or water hammer.

There have been many design changes over the evolution of the bimetal type of steam trap. They started off by the strip of metal expanding and pushing the valve into the seat. The obvious problem with that was aligning the valve head to the seat. Then it evolved to pull the valve into the seat (Fig. 31). In either case though, a single strip of very heavy metal could only create a linear tracking of the steam curve. Close inspection of this shows that the deepest subcooling range occurred at about the highest point in the steam curve. This meant that there was a lot of condensate backed up into the lines. A point to remember is that these traps can be adjusted by adjustment nuts on the stem. This controls the valve stem stroke and discharge temperature.

The next step in evolution was to “stack” strips that were of different thickness to both add power to draw on the valve stem and also operate at differing levels of the steam curve. This change, as can be seen in the curve, creates the effect of bending the straight line discharge of single metal strips. It follows the steam curve closer than just a single heavy metal strip. This made the trap more acceptable for use on some saturated steam lines but still kept a problem that exists with the design. This problem is how to draw a straight valve stem up through an outlet orifice with a arched draw. Typically, these two designs bind the valve stem within the orifice itself and can cause it to hang up and continuously leak.

As this trap was developed, it needed to maintain: A) closing force, B) operation to steam curve, and C) valve steam position through trap orifice. As you can see by this newer design, the differing lengths of bimetal strips would follow the steam curve adding force as the temperature and pressure rises. Also, the hole through the center allowed the manufacturer to create a straight pull on the valve stem to draw the valve directly through the center of the orifice. The second example of this type of new design stacked disks of bimetals opposing each other on the stem which results in the same type of action as the newer cross design. It should be mentioned that the job of the steam trap is to remove condensate which these designs will do, but should do so with regard to subcooling temperature of operation. All designs offer the adjustability of the stem stroke, but time is required to set them properly. With all of the down sizing of plants today, this probably does not occur that often.

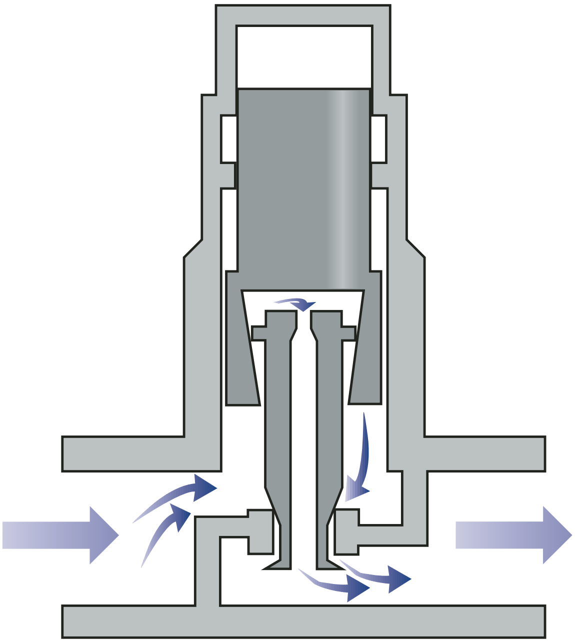


**Figure 32**
Impulse Trap

Thermodynamic traps are either of the flat disk design discussed earlier or of the piston design. The piston design (Fig. 32) as you can see, incorporates a constant bleed hole through the piston stem and seating disk. This relieves the pressure above and allows the disk to open to discharge. This hole is very small and easily plugged rendering it ineffective. Other design differences in TD traps is location and sizes of outlet orifices. Some types use two different sized orifices located on opposite sides of the trap and in line with the piping. This causes the disk to operate in a tilting fashion rather than straight up and down as with the three symmetrically spaced and same sized orifices. The tilting action causes the disk to spin during the closing sequence and cause wear on the outside edge of the seating surface and disk itself. Wear on this type of trap should be kept as even as possible to prolong the life expectancy. Another variation to disk traps is the inlet flow directions. Some traps are designed to flow the condensate and steam over the control chamber and create a barrier to ambient conditions. In order for the trap to work if surrounded by steam or hot condensate, a groove is cut into the disk that crosses the seating surface to bleed the steam from the top of the disk when closed. In this case, the trap uses steam as the gas to force closure of the trap and not flash to do the work.

With all of the types of traps and variations to each, how does one effectively choose a trap for application to their specific plant use? The following chart, “Steam Trap Selection Guide” (Fig. 34), may help in the selection process. You must first determine the factors required from your own plant size and age. You must determine the needs for condensate and air removal.

## Steam Trap Testing Methods

There is virtually no point in spending the time and money in creating a highly efficient steam system and then failing to maintain it at this same level. However, all too often leaking joints and valve stems are accepted as a normal operating condition of both steam and condensate systems.

Even a 1/8" diameter hole can discharge as much as 65 lb/hr of steam at 150 PSIG which represents a waste of approximately 30 tons of coal, 4,800 gallons of fuel oil or 7,500 therms of natural gas in a year (8400 hours).

Elimination of the visible leaks already mentioned is obviously reasonably straight forward. It is the invisible steam leaks through faulty steam traps that present a far more taxing problem. We know that the basic function of a steam trap is to discharge condensate and non-condensable gases in our systems and prevent live steam from escaping. Steam trap testing has brought about four different methods of testing. Let's look at all four methods and see what each will tell us about the condition of the steam trap.

## Visual Testing

The first point that has to be understood when visually testing a steam trap is that it will be a very rare occasion where the only matter coming out of a steam trap will be water!! Almost always, there will be varying mixtures of flash steam and water and in some cases the visual discharge will be all flash steam. So the first thing to remember is that we do not want to look for water only, nor do we want to attempt to decide if we are seeing the appropriate amount of flash steam and water mixture.

Visual testing of steam traps works best on two types of trap operation due to the trap's inherent discharge characteristics. Those two traps are the Inverted Bucket (Density) and Thermodynamic (Kinetic Energy). These two traps operate in a cyclical manner being fully open, discharging, or fully closed. The open/closed operation is the key to correct visual testing and what the tester should be looking for to indicate a properly operating steam trap.

If there is installed in the piping ahead of the steam trap a wye ("Y") strainer with a blowdown valve, opening the blowdown valve and diverting all of the condensate away from the steam trap allows only steam into the trap.

Any steam trap type should close positively when it senses only steam. This additional step, diverting the condensate away from the trap's inlet, allows the tester to test any type of trap operation and receive 100% positive answers to the trap's condition.

## Ultrasonic Trap Testing

Ultrasonic trap testing began with a screwdriver and has progressed to electronic sensing devices which amplify vibrations of flow. Flow of water and steam set up vibrations which are what we are looking for with ultrasonic testing. This form of testing works very well on traps that have cyclical discharge characteristics, like the kinetic energy Thermodynamic and the density operated Inverted Bucket. The open/closed operation provides a very positive answer to the trap's operation.

When testing other traps, like Float & Thermostatic and Thermostatic types which provide continuous modulating discharge, the tester again has to open the strainer blowdown valve and divert condensate away from the trap inlet so that the trap sees only steam. Again, if it is a properly operating trap, it will shut off completely. The ultrasonic testing device must be calibrated to eliminate external piping noises or other steam traps' discharge. When testing traps that are in close proximity, all traps except the one being tested must be isolated to remove any false signals from the other traps.

The ultrasonic testing method can provide very positive answers to a trap's operating condition as long as the operator doing the test has been trained, has developed some experience with the testing instrument and is able to identify the type of trap operation by visual inspection.

## Temperature Testing

Temperature testing of traps involves measuring the temperature at, or close to, the inlet and outlet of the steam trap. Pyrometers, temperature sensitive crayons, paint, band-aids and thermocouples all have their advocates. Unfortunately, these methods are of limited use since the temperatures of condensate and flash steam on the downstream side of a correctly working steam trap are controlled by the pressure in the condensate return system. A very large percentage of steam traps in the USA are thought to discharge into "0" PSIG, atmospheric gravity returns, which means that the maximum temperature that could be expected is 212°F, regardless of the trap's operating condition.

It does not necessarily mean that a trap has failed when an elevated temperature above 212°F is recorded downstream of a steam trap. More likely it means that the condensate return line is under a positive pressure, which means that the pressure/temperature relationship of steam must exist.

Thus if we were to record a temperature of 227°F on the outlet side of a trap, this tells the tester that the return system is at 5 PSIG saturated steam conditions, even though it was thought to be a "0" PSIG return system. There could be a failed open steam trap in the system that is causing this pressure or it could be purely the fact that the condensate return line was sized for water only and is not able to accommodate the flash steam volume without becoming pressurized. Temperature testing will identify a "failed closed" steam trap due to very low temperatures at the inlet of the steam trap. Temperature testing of traps to find failed open traps is by far the least accurate of all the testing methods available to users.

## Conductivity Testing

A more recent development in trap testing uses the electrical conductivity of condensate. This involves the installation of a chamber (Fig. 33) containing an inverted weir upstream of the steam trap shown as follows.

With the trap working normally, condensate flows under this weir and out through the trap. There is a small hole at the top of the weir that equalizes the pressure on each side. A sensor is inserted in the chamber on the upstream side which detects the presence of condensate by completing an electrical circuit with the condensate. A portable indicator is plugged into the sensor and the indicator provides the ability to read a completed circuit on the sensor. If the trap becomes defective and begins blowing steam, equilibrium on either side of the weir becomes disturbed and the steam pressure on the inlet side of the chamber displaces the condensate below the sensor. The sensor is no longer surrounded by the conductive condensate and the electrical circuit is broken, providing a failed signal on the indicator.

A major advantage to this method is the very positive signal which can be interpreted without resorting to experience or personal judgment. It is possible to wire a number of sensor chambers to one remote testing point for ease of quickly testing larger numbers of traps. The latest designs of conductivity testing equipment have added a temperature sensor in the same chamber that will provide the ability to determine a failed closed trap.

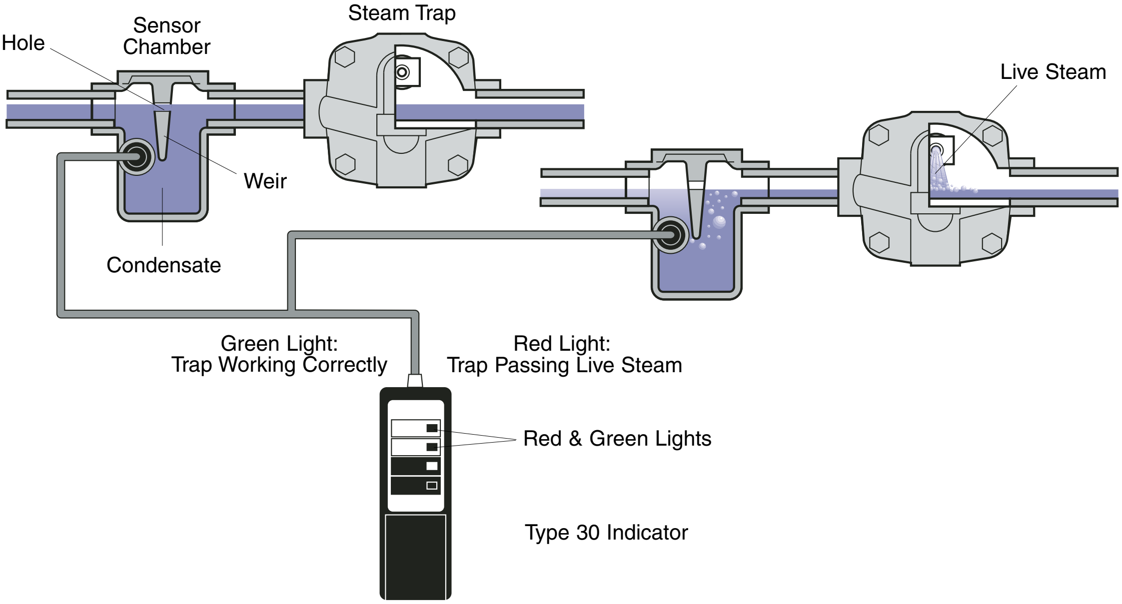


**Figure 33**

Conductivity Trap Testing System

## By-Passes Around Steam Traps

The habitual use of by-pass valves around steam traps can result in significant waste and loss of steam energy. Although a by-pass can be a very useful emergency device, it should never be regarded as a normal means of discharging condensate or air. Some trapping points still incorporate by-passes due to the misguided belief that they are essential to cope with start-up conditions. The operator may also be tempted to leave the by-passes cracked open during normal running. A valve used in this way will rapidly become wire-drawn and incapable of giving a tight shut-off. Once this has occurred, greater steam losses are inevitable. Steam traps are fully automatic devices which should be properly sized so that by-passes are unnecessary.

## Preventive Maintenance Programs

In order to ensure that pressure reducing valves, temperature controls, steam traps, etc. give long life and trouble-free service, it is essential to carry out a program of planned preventive maintenance. In general, this will mean regular cleaning of strainer screens and replacement of any internals which are beginning to show signs of wear. It is always advisable to hold a stock of spares recommended by the relevant manufacturer and a number of standby valves and traps which are on hand for use in an emergency.

Most steam system maintenance will have to be carried out during an annual shutdown, but it is usually easier to spread the work evenly over the course of an entire year. Most items will only need attention once every twelve months, although strainer screens may need more frequent cleaning, especially in the case of newly installed systems. In conclusion, it may be useful to list some of the causes of problems commonly experienced with the various patterns of steam traps which are available.

## Steam Trap Fault Finding

### Thermodynamic Disc Trap

*Symptom-Trap Blows Steam*

The trap will probably give a series of abrupt discharges (machine gunning). Check for dirt, including the strainer, and wipe the disc and seat. If no improvement, it is probable that the seating face and disc have become worn. The extent of this wear is evident by the normal crosshatching of machining. This can be dealt with by:

1. Re-lapping the seating face and disc in accordance with the manufacturer's instructions.
2. Installing a new disc if the trap seat is in good condition.
3. If both seating face and disc are not repairable, then the complete trap must be replaced.

If historical records show that thermodynamic traps on one particular application suffer repeatedly from rapid wear, suspect either an oversized trap, undersized associated pipe work or excessive back pressure.

*Symptom-Trap will not pass condensate*

While the trap's discharge orifices may be plugged shut with dirt, this symptom is most likely due to air binding, particularly if it occurs regularly during start up. Look at the air venting requirements of the steam using equipment in general.

### Balanced Pressure Thermostatic Trap

*Symptom-Trap blows steam*

Isolate the trap and allow it to cool before inspecting for dirt. If the seat is wire-drawn, replace all the internals including the thermostatic element. The original has probably been strained by the continuous steam blow. If the valve and seat seem to be in good order, then check the element. To check the element remove the complete element and holder assembly from the trap. Place the complete assembly in a pan of boiling water below the water level in the pan with the discharge end pointing up. Leave the assembly submerged in the boiling water for 5 minutes then carefully lift the assembly out of the water, as the element is removed from the water there should be a water accumulation in the discharge of the element. Set the element assembly on a table, still with the discharge end up and observe the water in the discharge side of the element. If the element is working correctly, the water will remain in the discharge until the element cools then the water will drain out onto the table. If the element has failed, the water will leak out of the immediately.

*Symptom-Trap will not pass condensate*

The element may be overextended due to excessive internal pressure making it impossible for the valve to lift off its seat. An over-expanded element could be caused by super heat, or perhaps by someone opening the trap while the element was still very hot, so that the liquid fill boiled as the pressure in the body was released.

### Liquid Expansion Thermostatic Trap

*Symptom-Trap blows steam*

Check for dirt or wear on the valve and seat. If wear has occurred, change the complete set of internals. It must be remembered that this type of trap is adjustable in the temperature of discharge, check to see if inadvertently the trap's adjustment has been turned out too far for it to close. Try adjusting the trap to a cooler setting. If it does not appear to react to temperature, a complete new set of internals should be fitted.

*Symptom-Trap will not pass condensate*

Check that the trap's adjustment has not been turned in too far to a setting that's too cold.

### Bimetallic Thermostatic Trap

*Symptom-Trap blows steam*

Check as usual for dirt and wear on the valve and seat. A bimetallic trap has only limited power to close by virtue of its method of operation and the valve may be held off its seat by an accumulation of quite soft deposits. This type of trap is usually supplied pre-set to a specific amount of subcooling. Check to see that the locking device on the manual adjustment is still secure. If this seems suspect, see if the trap will respond to adjustment. If cleaning has no effect, a complete new set of internals should be installed.

*Symptom-Trap will not pass condensate*

Bimetallic traps have the valve on the downstream side of the valve orifice which means that they tend to fail in the open position. Failure to pass cold condensate indicates either gross mis-adjustment or complete blockage of the valve orifice or built in strainer.

### Float & Thermostatic Trap

*Symptom-Trap blows steam*

Check the trap for dirt fouling either the main valve and seat or the thermostatic air vent valve and seat. If a steam lock release is installed in the trap, check to insure that it is not open causing a leak. Make sure that the float and valve mechanism has not been knocked out of line either by rough handling or waterhammer, preventing the valve from seating. Check that the float ball has not been damaged by waterhammer and developed a leak which would not allow the float ball to float or bind in its operation. The air vent assembly should be tested in the same manner as the Balanced Pressure Thermostatic trap element. When replacing the main float mechanism and valve assembly, these should be replaced as a complete set.

*Symptom-Trap will not pass condensate*

Check that the maximum operating pressure rating of the trap mechanism has not been exceeded. If this has happened, the mechanism will not have the power to open the valve against the higher steam pressure. A leaking or damaged float is almost certainly the result of waterhammer damage and the problem should be corrected.

### Inverted Bucket Trap

*Symptom-Trap blows steam*

Check for loss of the water seal "prime". Isolate the trap, wait for condensate to accumulate and start up the trap again. If this cures the trouble, try to discover the cause of the loss of the water seal "prime". This could be due to superheat, sudden pressure fluctuations or the trap being installed in such a way that the water seal can drain out by gravity. Try fitting a check valve before the trap to prevent this loss.

If steam blow persists, check for dirt or wear on the valve head and seat or failed mechanism. Replace the complete valve mechanism and linkage as a complete set.

Check the bucket to determine if it is distorted from waterhammer.

*Symptom-Trap will not pass condensate*

Check that the maximum operating pressure of the mechanism has not been exceeded causing the trap to lock shut. While checking the internals, insure that the air vent hole in the bucket is not obstructed, as this could cause the trap to fail closed. Air venting could also be a cause of a failed closed trap, especially in systems that start up and shut down frequently. Look at the air venting arrangements of the steam using equipment in general.

## Conclusion

It is important to know the type of trap discharge (Fig. 34) which should be expected when making maintenance checks or trap testing. The table on the following page sets out the usual discharge characteristics of the most commonly used traps.

**Figure 34**

Steam Trap Discharge Characteristics

| TRAP TYPE | USUAL DISCHARGE PATTERN |
|---|---|
| Thermodynamic Disc | Blast action. Cyclical Open/Closed |
| Balanced Pressure Thermostatic | Blast action. Cyclical Open/Closed on Light loads<br>Continuous Modulating on Heavier loads |
| Bimetallic Thermostatic | Continuous dribble discharge |
| Liquid Expansion Thermostatic | Continuous dribble discharge |
| Float and Thermostatic | Continuous discharge-varies with loads |
| Inverted Bucket | Blast action. Cyclical Open/Closed on Light loads<br>Modulating on Heavier loads no definite closure |

## Steam Trap Selection

It can be claimed that the majority of steam trap types will "work" on any application (provided that the operating conditions fall within the pressure range and condensate discharge capacity of the trap) (Fig. 35). However, we do not just want steam traps to "work" moderately well. We must aim to achieve maximum output and efficiency from all steam using equipment. This means selecting the best trap to suit each particular application (Fig. 36).

The following list contains a number of important questions which should be considered when choosing a steam trap for a particular application:

1. Will condensate be discharged immediately as it forms?
2. Is there condensate back pressure or a return line higher than the steam heated equipment?
3. Are there waterhammer conditions in the steam supply line?
4. Is there vibration or excessive movement in the equipment?
5. Does the condensate contain corrosive substances?
6. Will the trap be in an exposed position?
7. Is the steam supply super heated?
8. Is air likely to be present in any quantity?
9. Is steam locking a possibility?
10. Is the installation made up of several steam heated units?

## Waterlogging

With most steam heated equipment it is desirable, and very frequently essential, to discharge condensate as soon as it forms in the steam space. Although sensible heat in the condensate is usable heat, a much greater rate of heat transfer will be obtained if only the steam is in contact with the heat transfer surface.

Steam traps of the mechanical type should always be chosen for applications which require rapid condensate removal. Thermostatic type traps cannot release condensate until it has cooled a set number of degrees below steam temperature, resulting in waterlogging the steam space. There are, however, a number of occasions when such waterlogging may be perfectly acceptable and even desirable.

As an example, let us consider the difference in trapping requirements of a steam radiator and a unit heater. While the steam space of the radiator is great compared with its heating surface, the steam capacity of the unit heater is small compared with its heat output. The radiator can make good use of the sensible heat in the condensate before it is discharged, but the unit heater cannot. For this reason, the radiator should be fitted with a thermostatic trap that will hold back condensate until its temperature has dropped a predetermined number of degrees below that of the steam.

On the other hand, the unit heater must be fitted with a trap that will discharge condensate immediately as it forms. The slightest waterlogging in this case would reduce heat output and cause the heater to blow cool air. Condensate held back in the unit heater will also promote corrosion and unnecessarily reduce the life of the heater tubes.

The extent to which waterlogging of a steam space can be tolerated is clearly a significant factor in steam trap selection. The wrong choice of trap is at the root of many instances of poor plant performance.

## Lifting Of Condensate

The rate at which a steam trap can discharge condensate depends on the size of the valve orifice and the “differential pressure”, the difference in pressure between the inlet and the outlet of the trap.

If a steam trap discharges to atmosphere, the differential pressure across the trap will be the same as the upstream steam pressure. The same will be true if the trap discharges into a return line at a lower level which allows the condensate to gravitate back to the boiler feed tank. Unfortunately, such an arrangement is often ruled out because either the boiler feed tank is higher than the traps or the return main has to run at high level to clear obstructions. In these cases, the condensate must be lifted either directly by steam pressure in the apparatus or by a pump. In this section we are particularly concerned with the problems which may arise from lifting condensate by the steam pressure at the trap inlet.

For every 1 psi of steam pressure at the trap, condensate can be lifted to a height of approximately 2.3 feet. In order to lift condensate, the trap must have positive steam pressure at all times. There are disadvantages to lifting condensate in this manner. In the first place, the necessary steam pressure may not always be available at the trap inlet. If, for example, the normal operating pressure is 25 psi, it is theoretically possible to lift the condensate 57.5 feet. However, on a cold start up, the steam pressure may for a time drop to, or even below, zero. Until this pressure builds up, condensate cannot be removed from the equipment and will collect in the steam space. This will result in a greatly extended heat up period. The condensate will also prevent any air from escaping through the steam trap which makes the problem even worse.

If the equipment is temperature controlled, the very action of the control may reduce the steam pressure below the point at which it can successfully lift condensate to an overhead return line. Once again the steam space will waterlog until the control valve opens, resulting in poor temperature control and the possibility of waterhammer as the steam rushes into the waterlogged steam space. Additionally, if the steam space is a coil, considerable erosion and corrosion may take place.

It must be remembered that certain types of steam traps are limited as to the amount of “back pressure” against which they will satisfactorily operate.

**Figure 35**

Requirements for Steam Trap/Applications

| ***REQUIREMENTS FOR STEAM TRAP/APPLICATIONS*** | | | |
|---|---|---|---|
| TYPES | DISCHARGE | DISCHARGE TEMPERATURE | AIR HANDLING |
| Balanced Pressure | Continuous (Dribble) | 20 - 40 deg. F Subcool | Excellent |
| Bi-metallic | Continuous (Dribble) | 50 - 100 deg. F Subcool | Excellent (but may close too quickly due to subcooling) |
| Inverted Bucket | Intermittent | Saturated Steam Temperature | Limited |
| Float and Thermostatic | Continuous | Saturated Steam Temperature | Excellent |
| Disk (TD) | Intermittent | 2 to 10 deg. F Subcool | Limited |

| ***APPLICATION REQUIREMENTS*** | | | |
|---|---|---|---|
| APPLICATION | DISCHARGE | SUB-COOL | AIR HANDLING |
| Drip | Continuous or Intermittent | Little | Little |
| Tracer/Critical | Continuous or Intermittent | Little | Little |
| Tracer/Non-Critical | Continuous | Some | None |
| Process | Continuous | None | Much |

## Figure 36: Steam Trap Selection Guide

As the USA's leading provider of steam system solutions, Spirax Sarco recognizes that no two steam trapping systems are identical. Because of the wide array of steam trap applications with inherently different characteristics, choosing the correct steam trap for optimum performance is difficult. Waterhammer, superheat, corrosive condensate, or other damaging operating characteristics dramatically affect performance of a steam trap. With over 80 years of experience in steam technology, Spirax Sarco is committed to helping its customers design, operate and maintain an efficient steam system. You have our word on it!

| Application | 1st Choice | | | | | | 2nd Choice | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Float & Thermostatic | Thermo-Dynamic® | Balanced Pressure | Bimetallic | Liquid Expansion | Inverted Bucket | Float & Thermostatic | Thermo-Dynamic® | Balanced Pressure | Bimetallic | Liquid Expansion | Inverted Bucket |
| **Steam Mains** to 30 psig | ✓ | | | | | | | | | | | ✓ |
| 30-400 psig | | ✓ | | | | | | | | | | ✓ |
| to 600 psig | | ✓ | | | | | | | | | | ✓ |
| to 900 psig | | ✓ | | | | | | | | | | ✓ |
| to 2000 psig | | ✓ | | | | | | | | | | ✓ |
| with Superheat | | ✓ | | | | | | | | ✓ | | |
| **Separators** | ✓ | | | | | | | | | | | ✓ |
| **Steam Tracers** Critical | | ✓ | | | | | | | ✓ | | | |
| Non-Critical | | | ✓ | | | | | ✓ | | | | |
| **Heating Equipment** | | | | | | | | | | | | |
| Shell & Tube Heat Exchangers | ✓ | | | | | | | | | | | ✓* |
| Heating Coils | ✓ | | | | | | | | | | | ✓* |
| Unit Heaters | ✓ | | | | | | | | | | | ✓* |
| Plate & Frame Heat Exchangers | ✓ | | | | | | | | | | | ✓* |
| Radiators | | | ✓ | | | | | | | | | |
| **General Process Equipment** | | | | | | | | | | | | |
| to 30 psig | ✓ | | | | | | | | | | | ✓* |
| to 200 psig | ✓ | | | | | | | | | | | ✓* |
| to 465 psig | ✓ | | | | | | | | | | | ✓* |
| to 600 psig | | | | | | ✓ | | | | | | |
| to 900 psig | | | | | | ✓ | | | | | | |
| to 2000 psig | | | | | | ✓ | | | | | | |
| **Hospital Equipment** | | | | | | | | | | | | |
| Autoclaves | ✓ | | | | | | | | ✓ | | | |
| Sterilizers | ✓ | | | | | | | | ✓ | | | |
| **Fuel Oil Heating** | | | | | | | | | | | | |
| Bulk Storage Tanks | | | ✓ | | | | ✓ | | | | | |
| Line Heaters | ✓ | | | | | | | | | | | |
| **Tanks & Vats** | | | | | | | | | | | | |
| Bulk Storage Tanks | | | ✓ | | | | ✓ | | | | | |
| Process Vats | ✓ | | | | | | | ✓ | | | | |
| **Vulcanizers** | | ✓ | | | | | ✓ | | | | | |
| **Evaporators** | ✓ | | | | | | | | | | | ✓ |
| **Reboilers** | ✓ | | | | | | | | | | | ✓ |
| **Rotating Cylinders** | ✓ | | | | | | | | | | | ✓ |
| **Freeze Protection** | | | | | ✓ | | | | | | | |

* With the addition of thermostatic air vent device

## Steam Trap Sizing

The benefits of selecting the best type of steam trap for a given application (Fig. 35 & 36) will be wasted if the trap is not correctly sized. It is bad practice to choose a 3/4" trap simply because it has to go on a 3/4" drain line. In order to size a steam trap, we obviously need to know the quantity of condensate to be handled in a given time. The makers of most standard kinds of steam equipment usually supply reliable figures on the condensation rates of their equipment. If such information is not available, it has to be acquired either by calculation or practical measurement of the condensate produced. A test procedure which will give reasonably accurate results is set out at the end of this section.

Reference has already been made to "start-up" loads and "running" loads in this course. We know that steam will condense most rapidly on start up when the system is cold. It is for this reason that it is common practice to size traps using a safety factor. The trap selected should be able to handle twice the normal running load, or as much as 3 times the running load following an automatic temperature control. An undersized trap will cause waterlogging of the steam space when it can be least afforded.

## Steam Pressure and Trap Capacity

We know that for a steam trap to operate, there must be a higher pressure at its inlet than there is at its outlet. The actual amount of condensate which the trap can discharge is governed by the following three factors:

1. The differential pressure
2. The size of the trap discharge orifice.
3. The temperature of the condensate.

We must now examine these factors in more detail.

### 1. Differential Pressure

The maximum amount of condensate the trap will discharge will increase as the differential pressure (the difference in pressure between the inlet and outlet of the trap) increases. In other words, the capacity of a trap discharging to atmosphere with steam at 75 psi will be greater than that of the same trap with steam at 30 psi. The capacity does not, however, increase in proportion to the pressure.

It is not wise to assume that the pressure at which steam is supplied to a piece of equipment will be the pressure on the inlet to its steam trap. Pressure losses often mean that the steam pressure at the trap will be considerably less than the steam supply pressure.

If a steam trap is discharging condensate to atmosphere, the outlet pressure will be atmospheric and, therefore, the differential pressure will be the same as the gauge pressure at the trap inlet. However, if the trap discharges into a main which is under pressure, the differential pressure will be reduced by an amount which can be determined by subtracting the outlet pressure from the trap inlet pressure. The quantity of condensate which the trap is capable of passing in a given time will be reduced accordingly.

### 2. Size of Discharge Orifice

The size of the discharge orifice not only helps to determine the capacity of the trap but also often fixes the maximum pressure at which the trap will operate. Reference to the steam trap section reveals that the vast majority of the traps described have the valve on the pressure side (the inlet side) of the valve seat. The only notable exception to this arrangement occurs in the bimetallic type of traps where the valve is on the outlet side of the valve seat. In the case of traps with the valve on the pressure side of the valve seat, the valve, when closed, will be held on its seat by the steam pressure. According to the type of trap in question, the thermostatic element, ball float or bucket must have enough force to pull the valve away from its seat against this pressure.

In any given trap, the force is a fixed amount. Force Required = pressure x area.

The maximum pressure at which the valve of the trap can open is the pressure at which this operating force is just greater than the valve seat area multiplied by the pressure in the trap body.

In the case of traps with the valve at the outlet side of the valve seat, the situation is different. In this type, the steam pressure tends to open the valve, so the maximum pressure at which the trap can close is when the operating force is just greater than the steam pressure multiplied by the valve seat area.

### 3. The Temperature Of The Condensate.

The capacity of a trap should never be based on the amount of cold water the trap will pass at any given differential pressure. Condensate in a steam trap is usually at a temperature above atmospheric boiling point. When the condensate is passing through the valve seat of the trap, its pressure is quickly reduced and a certain amount of flash steam is generated. This flash steam tends to choke the discharge orifice, reducing its effective area. As the condensate temperature rises, the amount of flash steam generated will increase and the discharge capacity of the trap will decrease. The extent of which condensate temperature affects the trap's discharge capacity is relative to its temperature below saturation temperature -- lower temperatures, lower flashing rates.

## Steam Tracing

There are two typical applications of tracing. They are typically referred to as either process fluid (critical) or freeze protection (non-critical) tracing. There are different requirements for each as far as heat is concerned, so we will separate their requirements prior to discussing how to attach tracing to the application.

Tracing is as its name implies, a pipe or tube following either process fluid lines or lines where it is desirable to prevent freezing during the winter months. Steam tracing is the distribution of steam through small bore tubing or pipes which basically transfer heat to a larger pipe to keep fluids from becoming viscous, solidifying or freezing.

## Process (Critical) Tracing

Typically, process fluids are already at as high a temperature as desired. They have passed through heat exchange equipment and absorbed as much heat as necessary to keep the viscosity to a level that they flow smoothly through the piping. Tracing is installed running along the fluid lines mainly to keep the product at the specific temperature it already has. It is, therefore, a heat maintainer, and not a heat exchanger. Because of this, the consumption of the steam is usually very low. In fact, it is one of the smallest steam consumers in a given plant. The fact is however, that in some plants (such as Hydrocarbon Processing facilities), they account for as much as 70% of the steam using locations. The fact that they consume very little steam is then overshadowed by the sheer numbers of lines.

## Freeze Protection (Non-Critical)

In areas of the country where freezing conditions prevail during winter months, many different types of systems require protection from freeze-up. Obviously, these lines are water lines or perhaps metering equipment that use water in sensor tubes to detect flow of gases, etc. Tracing lines keep the water from freezing which will in turn possibly rupture piping, tubing or equipment. Sometimes, liquids that will not necessarily freeze become very thick if not heated and kept heated throughout their processing. An example usually used is "thick as molasses".

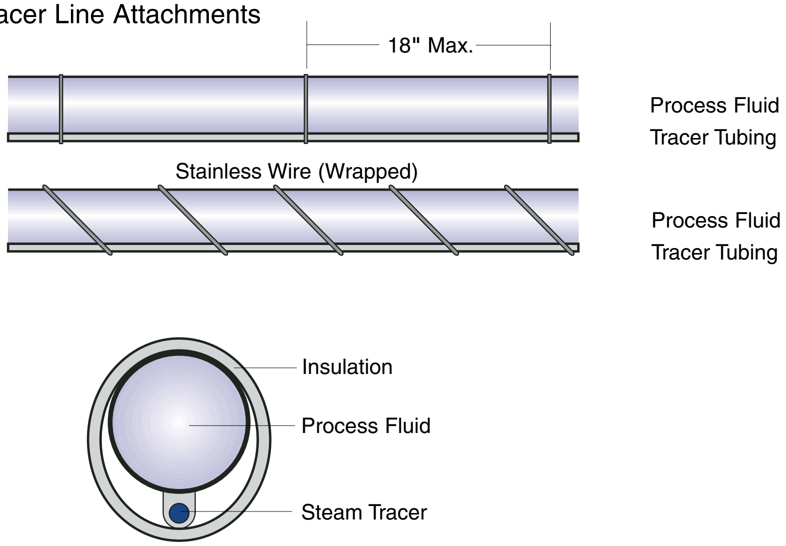
There are many different ways of attaching tracing and there are many different types or methods of using the tracing concept. The following discusses these.

Typically, tracing is copper tubing attached to a pipe filled with some type of liquid (Fig. 37).

The method of attaching also varies from plant to plant and spec to spec. The lines themselves can be banded or strapped, (when temperature differences between the steam and product fluid are low and steel pipe is used), attached using Heat Conducting Paste (Fig. 38) and Channels and straight wiring them in place. The placement of the tracer tubing is more important in most cases than the method used for attachment. In whichever method of attaching is selected, it is most important to avoid crimping the tubing.

### Figure 37

Tracer Line Attachments



# Steam Tracing

**Figure 38**

Tracer Using Heat Transfer Paste

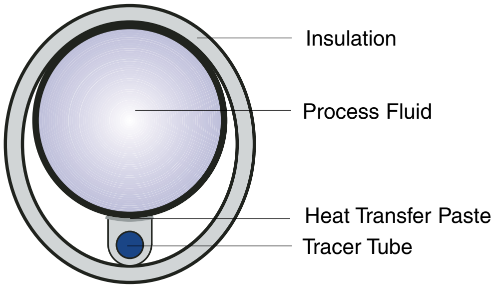
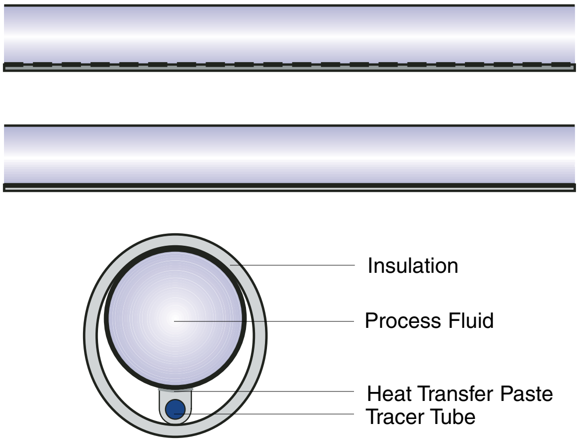


**Figure 39**

Welded Steam Tracer Pipe



Another popular method of tracing is the use of jacketed pipe (Fig. 40). This method of tracing is used particularly when there is need to keep a fluid (such as Sulfur) from solidifying in the pipes. We will look at each of the methods mentioned above and discuss some do's and don'ts.

## Attaching Tracers

The easiest method of tracing is by attaching copper tubing to the pipe. It is used mostly because of the abundance of copper tubing and the cost which is relatively low. The tubing is attached in the lower quadrant of the pipe being traced (Fig. 41). Another important consideration in tracing is to oppose the two flows, fluids in the process piping and steam in the tracer tubes. This may not always be practiced, however, but there are some solid reasons why one would want to consider this. Think about what the tracer job is - maintain heat already absorbed by the process fluid. As it transfers from point "A" to point "B" in the plant, heat will naturally be lost through the insulation. The job of the tracer then is to allow transfer of the heat of the steam into the flowing fluids as it is lost to the atmosphere.

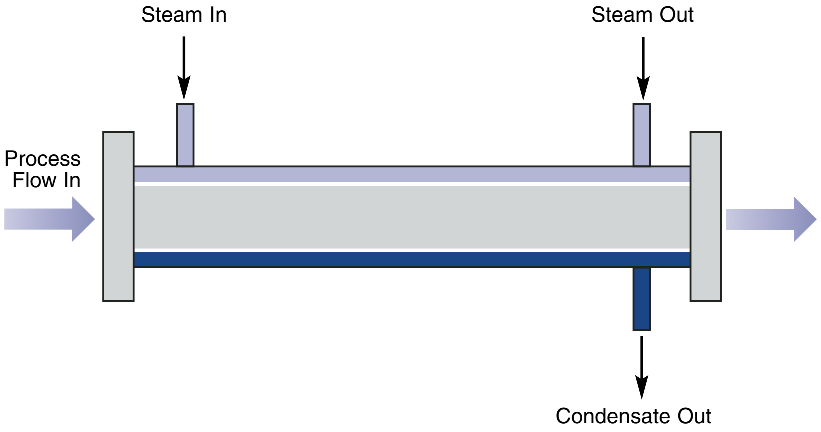
The tracer line then should also be installed running in a straight line as far toward the bottom of the piping as is possible (Fig. 42). The tracer is housed inside the insulation wrapping on the pipe, and we gain much benefit from attaching it in this manner. Heat, which you may recall, rises naturally and surrounds the piping allowing for as much natural conduction of BTU's as possible. This heat barrier also reduces the heat losses from the process fluids.

On some occasions, the amount of heat available and temperature of the steam is such that spacers are used to prevent burning the liquids on the inside of the process lines. This could cause coking (burning) of the lines and also restrict flow of the process. When spacers are used, it is important that the insulation be sized to allow for the extra space required. It may also be advisable to label the outside of the insulation with information such as "traced" and maybe even the number of tracer lines attached along with the pressures being used. This may help in future maintenance of the system itself. It may also help in using the numbers of tracers as they are needed.

*There may be times when the number of tracer lines being used can be reduced. For example, a process pipe during the winter months may require multiple tracer lines to insure that the fluids remain at the proper temperature. However, during the summer months, the numbers of tracer lines may be reduced because of less heat loss through the insulation. Some plants list the steam manifold header number where the on/off valves may be found to help with reducing the amount of steam being consumed unnecessarily.*

## Figure 40

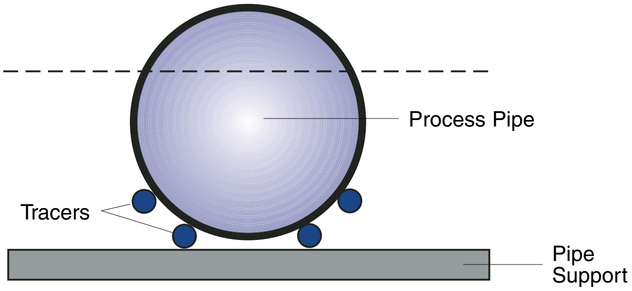
Single Section of Jacketed Pipe



## Figure 41

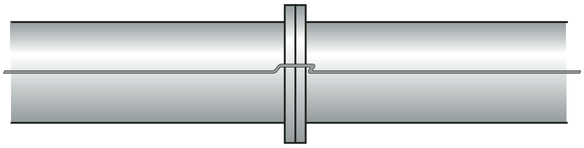
Pipe Support

Multiple tracer lines attached to lower half of process fluid lines. Insulation not shown



## Figure 42

Horizontal Tracing



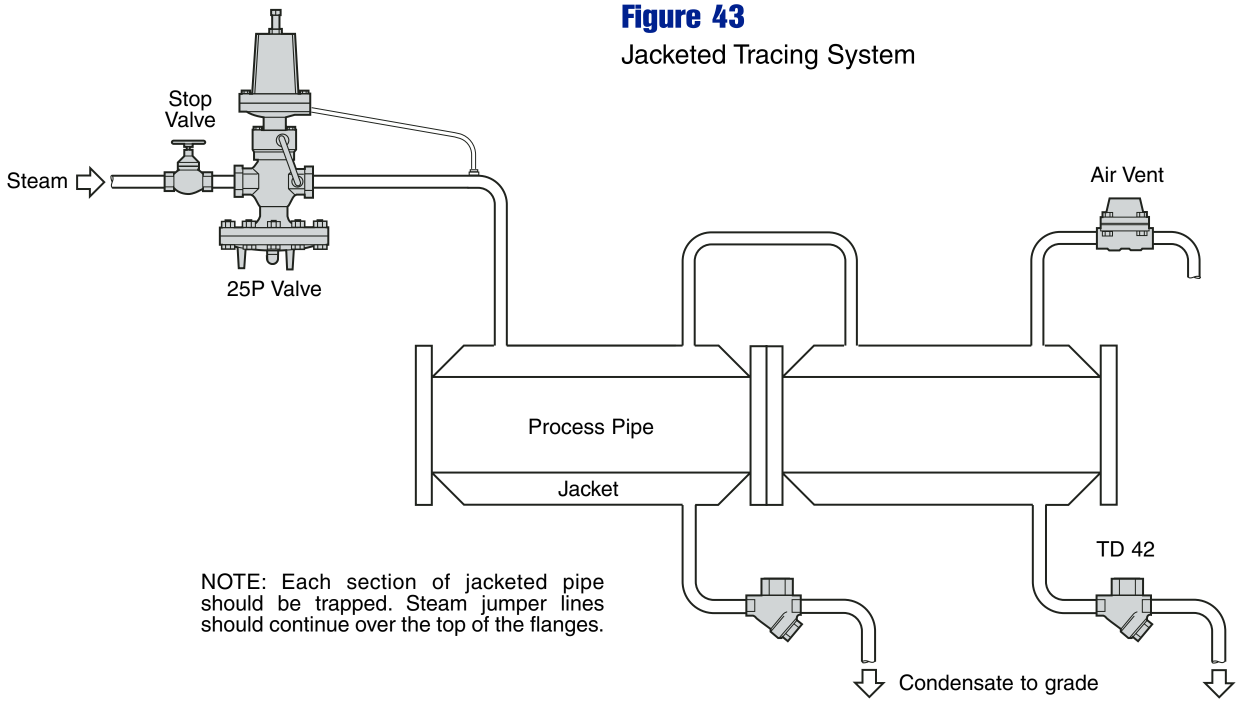
Tracing lines that must pass over flanges should pass in the horizontal. If it is required to place a connection fitting along side of flanges, they should also be placed horizontally.

## Jacketed Pipe

Jacketed pipe (Fig. 43 on the following page) may be an alternative method of tracing used when the process fluids require a high temperature to stay flowing with the least amount of resistance. These liquid lines are usually fluids that set up at very high temperatures such as sulfur. They are very specialized tracer lines as the steam jacket completely encircles the process fluid line. This pipe within a pipe requires special attention and will require specialized traps to ensure the proper drainage. Jacketed pipe obviously transfers a lot of heat in comparison to steam tracer lines made of copper or stainless steel. This type of tracer line usually is used when the temperature of the process fluid is about the same temperature as the steam being used. The lines are usually flange fitted and the passing of steam from one line to the next requires steam flow to ensure the passage of steam on down the lines. The chart (Fig. 44 on the following page) will help in sizing the steam connection line size for the size of jacketed pipe being used. Each jacketed line has a connection at the bottom on the downstream line that is used to drain each section individually. This is important because this particular type of specialized tracer is truly acting like a heat exchanger. The steam consumption of this type of tracing may be much higher than the smaller tubing type tracers used in plants.

## Figure 43

Jacketed Tracing System



NOTE: Each section of jacketed pipe should be trapped. Steam jumper lines should continue over the top of the flanges.

## Figure 44

Steam Connection Line Sizing for Jacketed Pipe

| STEAM CONNECTION LINE SIZING FOR JACKETED PIPE | | |
|---|---|---|
| Product Line | Jacket Diameter | Steam Connection |
| 2-1/2" | 4" | 1/2" |
| 3" | 6" | 3/4" |
| 4" | 6" | 3/4" |
| 6" | 8" | 3/4" |
| 8" | 10" | 1" |
| 10" | 12" | 1" |

### Steam Manifolds

Steam manifolds are most helpful in running the steam to the system. Manifolds are easily maintained and located as opposed to individually valving areas of a plant. A centralized location for manifolds (Fig. 45a) ensure operators of turning on and off the correct valves for tracing. Manifolds should be fitted with a tag that identifies what lines are traced and how many lines are going to that particular process line. Other considerations for manifolding steam lines is the ability to control automatic valves on and off. If the tracing on a particular manifold is used for freeze protection, ambient sensors on control valves will automatically turn the steam on when needed. This ensures that the steam is turned on and off properly. The important word here is “off”. It is not unusual to see steam lines turned on during a particular time of year. The conditions may change at any given time and the steam may not be required. If the steam is always on, then it is always used even in small quantities. This is wasteful and should be avoided. As this course has mentioned, it is important to conserve this precious and costly commodity called steam. Even though tracing systems individually use small amounts of steam, remember the sheer numbers of lines that may be involved.

### Condensate Manifolds

Condensate manifolds (Fig. 45b) are also very useful in any typical plant that uses tracing. The condensate manifold itself locates traps and tracers in a small given area. The condensate from the tracer lines is usually very high quality condensate and should be collected and returned to the boiler. There is normally no cross contamination of product fluids to tracer lines. Condensate manifolds also make it very easy to find and monitor the tracing traps being used. Each trap station on a manifold should be tagged with a number that identifies the trap, size, pressure, etc. so that a maintenance program can help determine the correctness of either the traps being selected or size of trap being used. These manifolds can be either horizontally or vertically designed depending on the space available and the specification of any given plant.

The following charts (Fig. 46) and illustrations (Fig. 47) may be helpful in sizing, selecting and specifying tracers and their types.

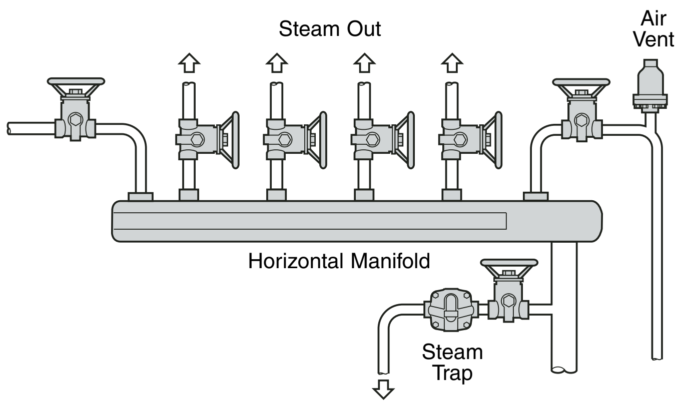


**Figure 45a**
Steam Manifolds

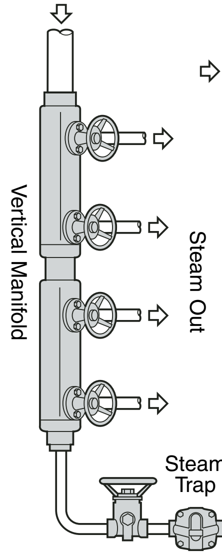


**Figure 45b**
Condensate Manifolds

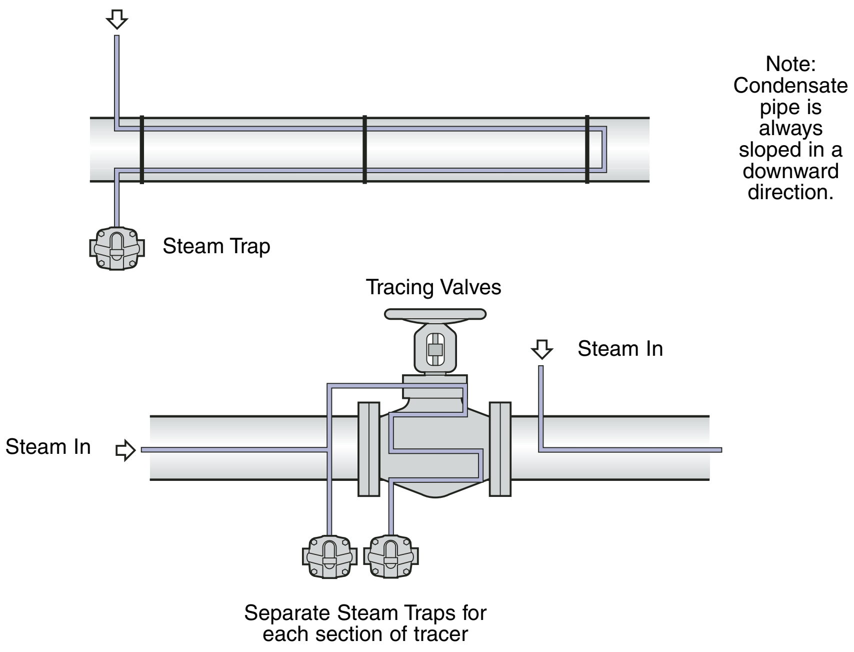
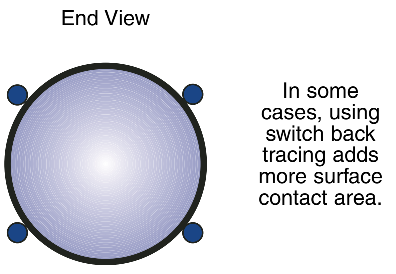
**Figure 46**

| NUMBER OF 1/2" TRACERS USED WITH DIFFERENT SIZES OF PRODUCT LINES | | | |
|---|---|---|---|
| | Type A<br>General Frost protection or where solidification may occur at temps below 75°F | Type B<br>Where solidification may occur at temps between 75-150°F | Type C<br>Where solidification may occur at temps between 150-300°F |
| Product Line Size | Number of 1/2" Tracers | Number of 1/2" Tracers | Number of 1/2" Tracers |
| 1" | 1 | 1 | 1 |
| 1-1/2" | 1 | 1 | 2 |
| 2" | 1 | 1 | 2 |
| 3" | 1 | 1 | 3 |
| 4" | 1 | 2 | 3 |
| 6" | 2 | 2 | 3 |
| 8" | 2 | 2 | 3 |
| 10-12" | 2 | 3 | 6 |
| 14-16" | 2 | 3 | 8 |
| 18-20" | 2 | 3 | 10 |

| RECOMMENDED HEADER SIZE FOR CONDENSATE LINES | |
|---|---|
| Header Size | Number of 1/2" Tracers |
| 1" | Up to 5 |
| 1-1/2" | 6 to 10 |
| 2" | 11 to 25 |

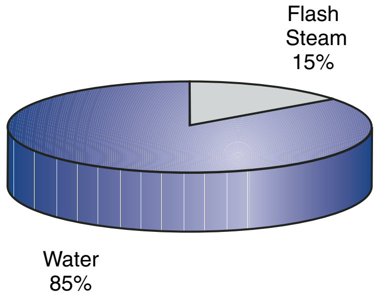
### Figure 47

Switch Back Tracing Line

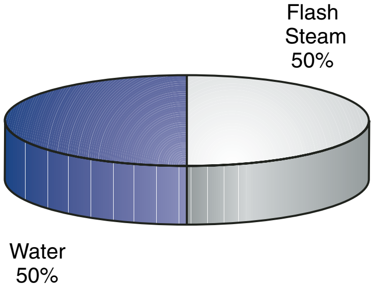
### Figure 48

Approximate amount of flash steam in Condensate



### Figure 49

Approximate amount of energy in Condensate



## Condensate Management

When steam condenses, energy is transferred to the cooler material to be heated. This accounts for only around 75% of the energy supplied in the boiler to produce the steam. The remainder, about 25%, is still held by the condensed water.

As well as having heat content, the condensate is distilled water: ideal for use as boiler feed water. An efficient installation will collect every drop of condensate it economically can, and either return it to the deaerator or boiler feed tank, or use it in the process.

Condensate is discharged through steam traps from a higher to a lower pressure. As a result of this drop in pressure, some of the condensate will then re-evaporate, and is referred to as flash steam. The proportion that will flash off differs according to the level of pressure reduction between the 'steam' and 'condensate' sides of the system, but a figure of 10-15% by mass is typical (Fig. 48).

About half of the energy mentioned above (i.e. 12.5% of the total energy supplied) could be lost through flash steam (Fig. 49).

Flash Steam Recovery is, therefore, an essential part of achieving an energy efficient system.

This section will bring together Condensate Recovery, Condensate Removal and Flash Steam Recovery under the heading of Condensate Management. The objective is to examine the technical aspects for the benefit of the expert and then to use this as a basis to provide simple guide lines for the occasional user.

Condensate line sizing plays an important role in successfully controlling and collecting condensate. Sizing condensate lines requires much planning to control velocities of liquids and gases. It should be remembered that condensate lines are, in fact, bi-phase systems that require proper planning. Review the Condensate Line Sizing Chart for assistance in this area (Fig. 50).

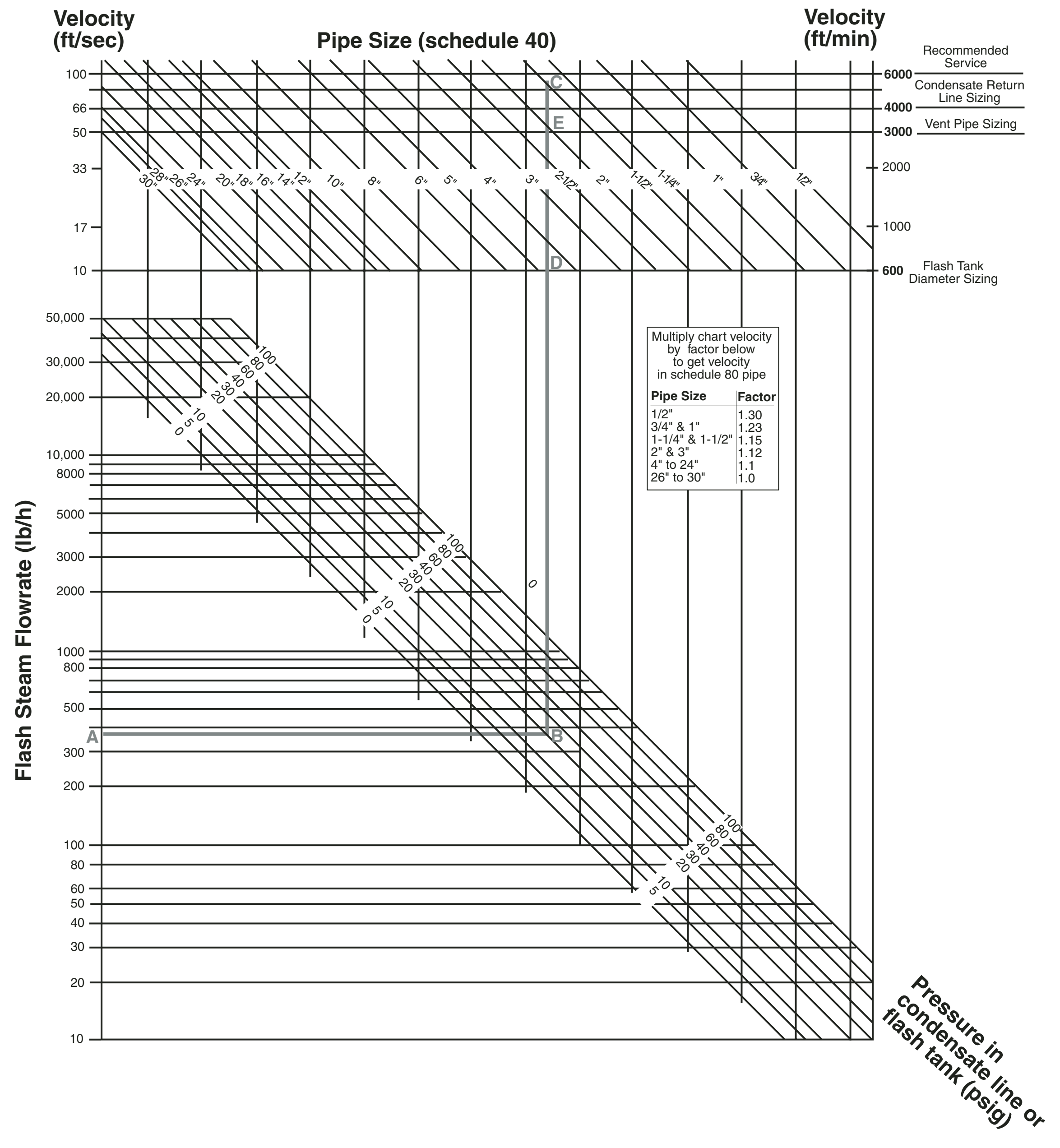
You will note that it is recommended to increase the line size on the discharge of all steam traps. This is intended to allow for the flashing that will be expected when steam traps discharge condensate into lower pressure systems. A chart is provided to assist in quickly estimating the amount of flash that can be produced. The volumetric change of condensate flashing into steam may cause substantial increasing velocities that may damage existing condensate recovery systems.

## Flash Steam Recovery

When hot condensate under pressure is released to a lower pressure, its temperature must very quickly drop to the boiling point for the lower pressure as shown in the steam tables. The surplus heat is utilized by the condensate as latent heat causing some of it to re-evaporate into steam.

The quantity of "flash steam" available from each pound of condensate can be calculated using this formula:

**Figure 50: Condensate Line Sizing Chart**



Multiply chart velocity by factor below to get velocity in schedule 80 pipe

| Pipe Size | Factor |
|---|---|
| 1/2" | 1.30 |
| 3/4" & 1" | 1.23 |
| 1-1/4" & 1-1/2" | 1.15 |
| 2" & 3" | 1.12 |
| 4" to 24" | 1.1 |
| 26" to 30" | 1.0 |

**Percentage Quantity of Flash Steam**

= *Sensible Heat at*
*the Higher Pressure*
\- *Sensible Heat at*
*the Lower Pressure*
÷ *Latent Heat of*
*the Lower Pressure*

To simplify this procedure we can use the chart (Fig. 51) to read off the percentage of flash steam produced by this pressure drop. An example would be if we had 100 PSIG saturated steam/condensate being discharged from a steam trap to an atmospheric, gravity flow condensate return system (0 PSIG), the flash percentage of the condensate would be 13.3% of the volume discharged.

Conversely, if we had 15 PSIG saturated steam discharging to the same (0 PSIG) atmospheric gravity flow return system, the percentage of flash steam would be only 4% by volume. These examples clearly show that the amount of flash released depends upon the difference between the pressures upstream and downstream of the trap and the corresponding temperatures of those pressures in saturated steam. The higher the initial pressure and the lower the flash recovery pressure, the greater the quantity of flash steam produced.

It must be noted here that the chart is based upon saturated steam pressure/temperature conditions at the trap inlet, and that the condensate is discharged as rapidly as it appears at the trap. Steam traps that subcool the condensate, such as balanced pressure thermostatic and bimetallic traps, hold condensate back in the system allowing it to give up sensible heat energy and causing it to cool below the saturated steam temperature for that pressure. Under those circumstances, we must calculate from the formula above the percentage of flash steam produced, but the amount of subcooling (the condensate temperature) must be known before calculating.

**Figure 51: Percent Flash**

| Steam Pressure (psig) | Atmosphere | Flash Tank Pressure (psig) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 2 | 5 | 10 | 15 | 20 | 30 | 40 | 60 | 80 | 100 |
| 5 | 1.7 | 1.0 | 0 | | | | | | | | |
| 10 | 2.9 | 2.2 | 1.4 | 0 | | | | | | | |
| 15 | 4.0 | 3.2 | 2.4 | 1.1 | 0 | | | | | | |
| 20 | 4.9 | 4.2 | 3.4 | 2.1 | 1.1 | 0 | | | | | |
| 30 | 6.5 | 5.8 | 5.0 | 3.8 | 2.6 | 1.7 | 0 | | | | |
| 40 | 7.8 | 7.1 | 6.4 | 5.1 | 4.0 | 3.1 | 1.3 | 0 | | | |
| 60 | 10.0 | 9.3 | 8.6 | 7.3 | 6.3 | 5.4 | 3.6 | 2.2 | 0 | | |
| 80 | 11.7 | 11.1 | 10.3 | 9.0 | 8.1 | 7.1 | 5.5 | 4.0 | 1.9 | 0 | |
| 100 | 13.3 | 12.6 | 11.8 | 10.6 | 9.7 | 8.8 | 7.0 | 5.7 | 3.5 | 1.7 | 0 |
| 125 | 14.8 | 14.2 | 13.4 | 12.2 | 11.3 | 10.3 | 8.6 | 7.4 | 5.2 | 3.4 | 1.8 |
| 160 | 16.8 | 16.2 | 15.4 | 14.1 | 13.2 | 12.4 | 10.6 | 9.5 | 7.4 | 5.6 | 4.0 |
| 200 | 18.6 | 18.0 | 17.3 | 16.1 | 15.2 | 14.3 | 12.8 | 11.5 | 9.3 | 7.5 | 5.9 |
| 250 | 20.6 | 20.0 | 19.3 | 18.1 | 17.2 | 16.3 | 14.7 | 13.6 | 11.2 | 9.8 | 8.2 |
| 300 | 22.7 | 21.8 | 21.1 | 19.9 | 19.0 | 18.2 | 16.7 | 15.4 | 13.4 | 11.8 | 10.1 |
| 350 | 24.0 | 23.3 | 22.6 | 21.6 | 20.5 | 19.8 | 18.3 | 17.2 | 15.1 | 13.5 | 11.9 |
| 400 | 25.3 | 24.7 | 24.0 | 22.9 | 22.0 | 21.1 | 19.7 | 18.5 | 16.5 | 15.0 | 13.4 |

Percent flash for various initial steam pressures and flash tank pressures.

Before discussing the ways of recovering flash steam and why we want to recover it, there are two important practical points which should be noted:

First, one pound of steam has a specific volume of 26.8 cubic feet at atmospheric pressure. It also contains 970 BTU's of latent heat energy. This means that if a trap discharges 100 pounds per hour of condensate from 100 PSIG to atmosphere, the weight of flash steam released will be 13.3 pounds per hour, having a specific volume of 356.4 cubic feet. It will also have 12,901 BTU's of latent heat energy. This will appear to be a very large quantity of steam and may well lead to the erroneous conclusion that the trap is passing live steam (failed open).

Another factor to be considered is that we have just released 13.3 pounds of water to the atmosphere that should have gone back to the boiler house for recycling as boiler feed water. Since we just wasted it, we now have to supply 13.3 pounds of fresh city water that has been softened, chemically treated and preheated to the feedwater system's temperature before putting this new water back into the boiler.

Secondly, the actual formation of flash steam takes place within and downstream of the steam trap orifice where pressure drop occurs. From this point onward, the condensate return system must be capable of carrying this flash steam, as well as condensate. Unfortunately, during the past 80 years, condensate return lines have been sized using water volume only and did not include the flash steam volume that is present.

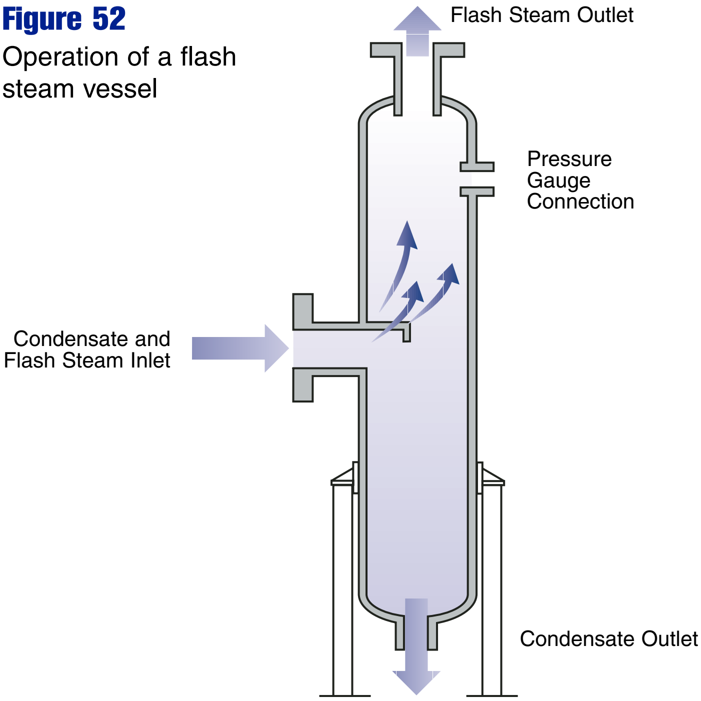
The specific volume of water at 0 PSIG is .016 cubic feet per pound, compared to 26.8 cubic feet per pound for flash steam at the same pressure. Sizing of condensate return lines from trap discharges based totally on water is a gross error and causes lines to be drastically undersized for the flash steam. This causes condensate lines to become pressurized, not atmospheric, which in turn causes a backpressure to be applied to the trap's discharge which can cause equipment failure and flooding.

This undersizing explains why the majority of 0 PSI atmospheric condensate return systems in the United States do not operate at 0 PSIG. To take this thought one step further for those people who perform temperature tests on steam traps to determine if the trap has failed, the instant we cause a positive pressure to develop in the condensate return system by flash steam, the condensate return line now must follow the pressure/temperature relationship of saturated steam. So, trap testing by temperature identifies only that we have a return system at a certain temperature above 212°F (0 PSIG) and we can then determine by that temperature the system pressure at which it is operating. Elevated condensate return temperatures do not necessarily mean a trap has failed.

If the flash steam is to be recovered and utilized, it obviously has to be separated from the condensate. This is best achieved by passing the mixture of flash steam and condensate through what is known as a "flash tank" or "flash vessel" (Fig. 52). A typical arrangement is shown.

**Figure 52**

Operation of a flash steam vessel



The size of the vessel has to be designed to allow for a reduced velocity so that the separation of the flash steam and condensate can be accomplished adequately, so as not to have carry-over of condensate out into the flash steam recovery system. This target velocity is ten feet per second per ASHRAE standards to ensure proper separation. The condensate drops to the bottom of the flash tank where it is removed by a float and thermostatic steam trap.

A number of basic requirements and considerations have to be met before flash steam recovery is a viable and economical proposition:

1. It is first essential to have a sufficient supply of condensate, from loads at sufficiently higher pressures, to ensure that enough flash steam will be released to make recovery economically effective. The steam traps, and the equipment from which they are draining condensate, must be able to function satisfactorily while accepting the new back pressure applied to them by the flash recovery system.

   In particular, care is needed when attempting flash steam recovery from condensate, which is leaving temperature controlled equipment. At less than full loads, the steam space pressure will be lowered by the action of the temperature control valve. If the steam space pressure approaches or even falls below the flash steam vessel pressure, condensate drainage from this equipment becomes impractical by a steam trap alone, and the equipment becomes "stalled" and water logging will most definitely occur. We will look at this problem in much further detail in our next section "Condensate Recovery".

2. The second requirement is a suitable use for low pressure flash steam. Ideally, low pressure load(s) requires at all times a supply of steam

which either equals or exceeds the available flash steam supply. The deficit can then be made up through a pressure reducing valve set. If the supply of flash steam exceeds the demand for it, the surplus may have to be vented to waste through a backpressure relief valve.

Thus it is possible to utilize the flash steam from process condensate on a space heating installation, but the savings will only be achieved during the heating season. When heating is not required, the recovery system becomes ineffective.

Wherever possible, the better arrangement is to use flash steam from process condensate to supply process loads, and that from heating condensate to supply heating loads. Supply and demand are then more likely to remain "in step".

When all else fails, in many facilities there is always a need for hot water, especially in the boiler house. This can be supplied via a heat exchanger and the use of flash steam.

3. It is also preferable to select an application for the flash steam which is reasonably close in proximity to the high pressure condensate source. Piping for low pressure steam is inevitably of larger diameter. This makes it somewhat costly to install. Furthermore, the heat loss from large diameter pipes reduces the benefits obtained from flash steam recovery and in the worst cases could outweigh them.

Flash steam recovery is simplest when being recovered from a single piece of equipment that condenses a large amount of steam, such as a large steam to water converter or a large air handling coil bank, but we cannot forget that flash steam recovery systems by design will apply a backpressure to the equipment that is being drained or to the flash steam source. Another very common area from which flash steam is recovered is boiler blowdown. Dissolved solids that create the need for boiler blowdown drop out and will produce usable flash steam and condensate.

Boiler blowdown flash steam recovery (Fig. 53) is a very efficient method for recovery. It not only is a continuous supply of valuable heat energy to be utilized, but it is in close proximity to an area of definite need as in the boiler feed or deaerator system that demands a constant source of low pressure heat energy for preheating the boiler make up water supply. This simple installation is shown below.

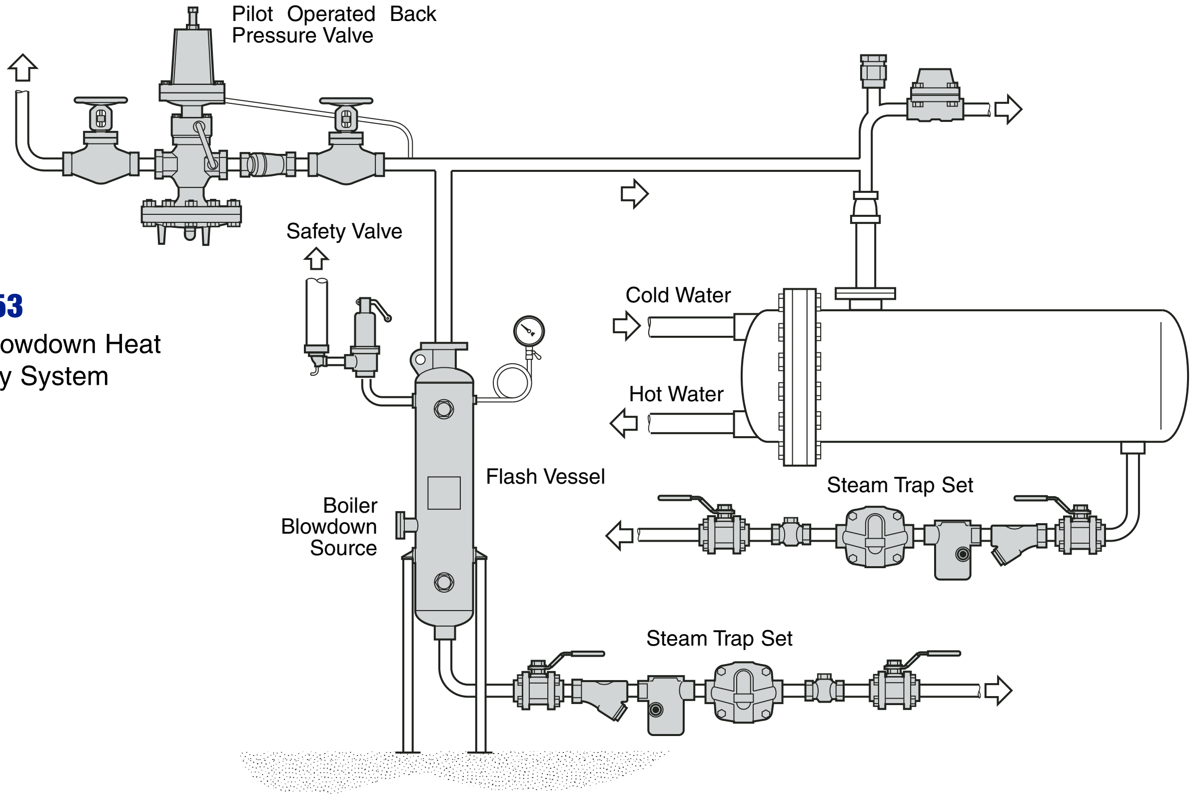


**Figure 53**
Boiler Blowdown Heat Recovery System

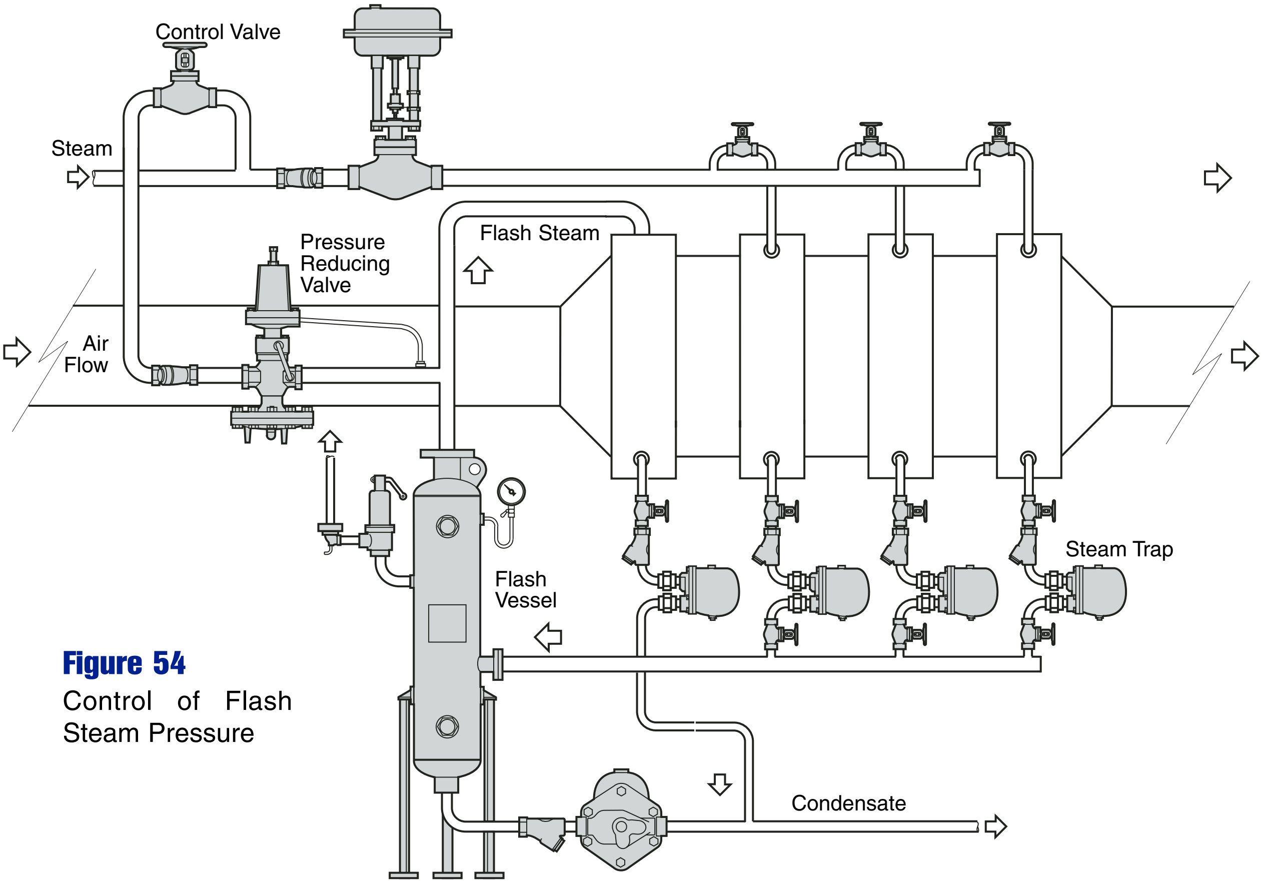


**Figure 54**
Control of Flash Steam Pressure

Another area that works very well in the utilization of flash steam recovery is large multi-section air heating coils (Fig. 54). Many times flash steam can be supplied to a coil added to the system to maximize use of the flash steam supplied by the primary coils in the system. An example is shown in the following sketch. This example clearly fulfills the basic requirements of having a flash steam recovery system which is in step with demand.

Only when air coils are called upon to supply heat does the flash steam recovery system become available, and it can then be condensed in the first air coil which is essentially a pre-heater. This simple arrangement ensures that higher pressure traps are not subjected to any backpressure on start up of the system.

Another method of flash steam recovery is through a vent condenser on a receiver (Fig. 55 on following page). Flash steam is allowed to flow up through the condenser (heat exchanger), that has a supply of fluid flowing through it, to capture the heat energy contained in the flash steam. This type of system is an “atmospheric” pressure system, which allows condensate from the flash steam to flow by gravity back into the original condensate receiver. This provides the user with recovery of heat energy and the complete recovery of all condensate from that system, and enables the user to accomplish this without presenting all of the equipment in that system with any backpressure.

## Condensate Recovery Systems

The importance of effective condensate removal from steam spaces has been stressed throughout this course. If maximum steam system efficiency is to be achieved, the best type of steam trap must be fitted in the most suitable position for the application in question. Having considered how to best utilize any flash steam which may be available, we must now decide what to do with the condensate which remains.

There are a number of reasons why condensate should not be allowed to discharge to drain. The most important consideration is the valuable heat which it contains even after flash steam has been recovered. It is possible to use condensate as hot process

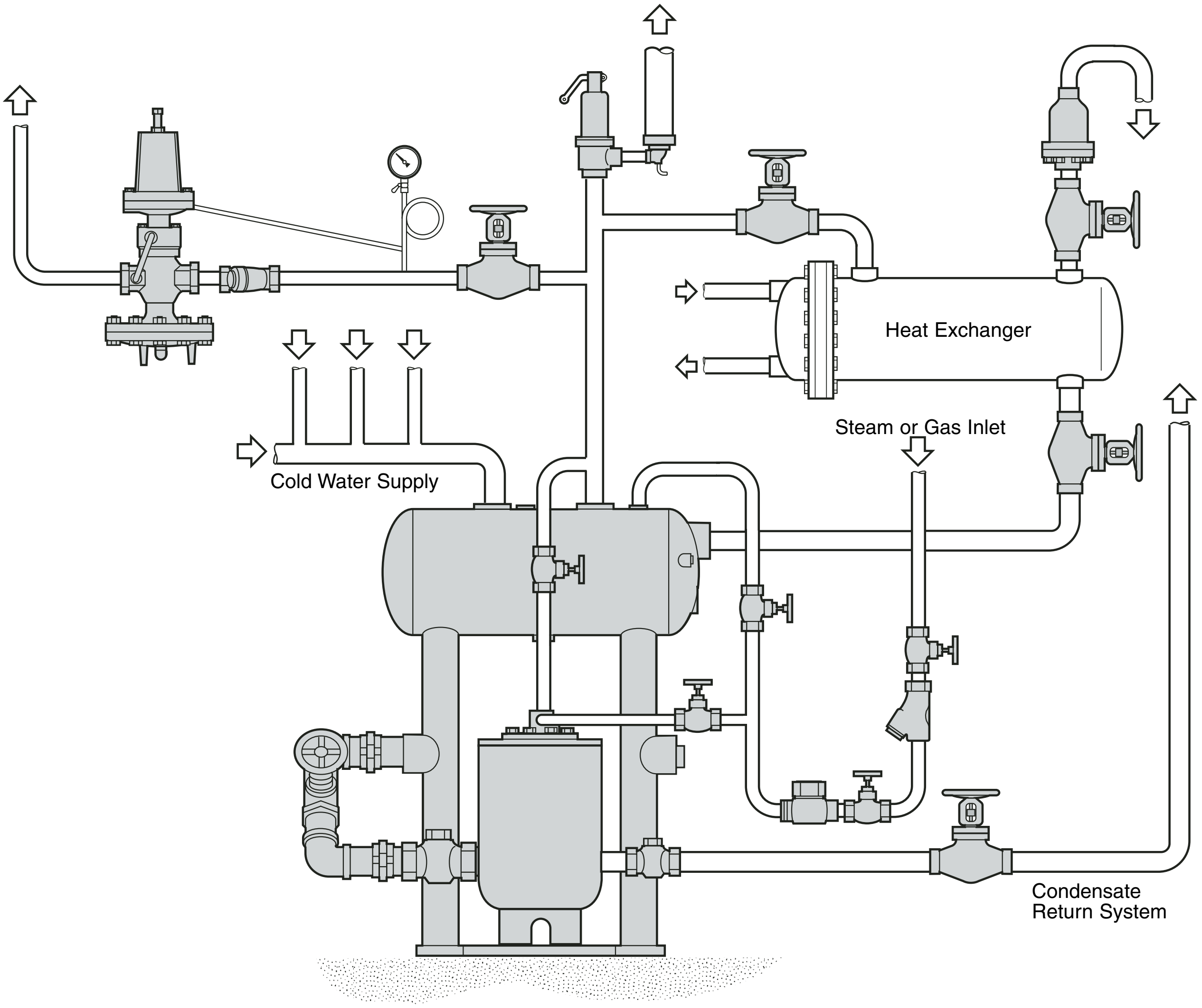


**Figure 55**

Flash Steam Condensor or Heater

water but the best arrangement is to return it to the boiler house, where it can be re-used as boiler feed water without further treatment, saving preheating fuel, raw water and the chemicals needed for boiler feed treatment. These savings will be even greater in cases where effluent charges have to be paid for the discharge of valuable hot condensate down the drain.

Condensate recovery savings can add up to 25 to 30% of the plant's steam generating costs. One justifiable reason for not returning condensate is the risk of contamination. Perforated coils in process vessels and heat exchangers do exist and the cross contamination of condensate and process fluids is always a danger. If there is any possibility that the condensate is contaminated, it must not be returned to the boiler. These problems have been lessened by the application of sensing systems monitoring the quality of condensate in different holding areas of a plant to determine condensate quality and providing a means to re-route the condensate if contaminated.

***Vented "open" return systems have been utilized for 80 plus years where the condensate is allowed to flow by gravity to a central collection receiver and then the use of electrically driven pumps return it to the boiler house when these receivers are full.***

## Electrically Driven Pumps

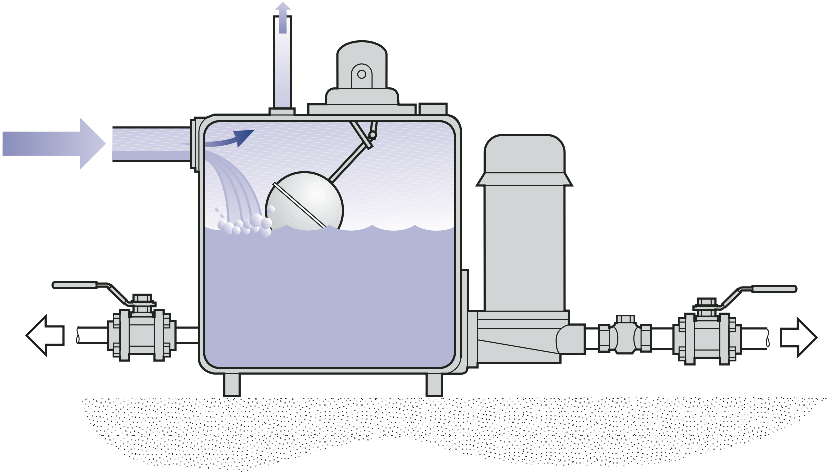
Electrical driven pumps (Fig. 56) have been used to collect and return this condensate. When utilized on radiation heating applications, condensate usually returns at relatively low temperatures, 160-180°F, which does not provide any great difficulty for the electric pumps. When condensate temperatures approach 200°F or above, the electrically driven pumps begin to experience a phenomenon known as "cavitation". Cavitation is the flashing of higher temperature condensate as it enters the eye of the impeller, where the pressure drops to below atmospheric pressure. The pump becomes vapor (steam) bound. These pumps must have a flooded impeller chamber in order to maintain a constant flow of water to cleanse and cool the "mechanical seals" of the pump.

If the mechanical seals are allowed to run dry for any amount of time, the maximum operating temperature of the seal is reached in a very short time. This causes permanent mechanical seal damage, which in turn causes leakage of condensate to the floor or even worse, up into the electrical motor.

Many years ago, electric pump manufacturers supplied their pumps with restrictions in the pump discharges in order to provide the customer with the precise discharge pressure and flow conditions that he requested. Those same manufacturers have since stopped installing throttling orifices in these pumps and have only informed the users via the installation and maintenance manuals, which never get delivered to the job site. The installing contractor installs, in the discharge of the pump unit, an isolation valve and a check valve.

**Figure 56**

Electric Pump Operation



Isolation valves have only two positions in this industry, either fully open or fully closed. This is not the required throttling valve that the manufacturer recommended in his installation manual. Since these isolation valves are usually fully open during service, the pump will search up and down its performance curve until it finds the operating point, which just overcomes the true system backpressure. When this is allowed to happen, the pump will not have the same operating characteristics as was designed. This will change the NPSH required of the pump, which determines the maximum pumpable temperature of the condensate that can be handled without cavitation. Hence, the continuous replacement of mechanical seals of these pumps. These pumps need to be throttled to the designed operating conditions, which means a throttling valve must be installed downstream of the pump with a pressure gauge between the pump discharge and the throttling valve, and the valve should be closed until the designed operating pressure is achieved on the pressure gauge.

If cavitation problems still exist due to elevated temperatures, the only recourse is to cool the condensate down to a pumpable temperature. This sounds like a simple cure, but if we look at the oxygen solubility chart (Fig. 57 on the following page), we see that as condensate cools down, the ability of that water to contain oxygen goes up. The more oxygen contained in condensate when it reaches the boiler house, the more chemicals that have to be added to remove that oxygen.

Sodium Sulfite is the chemical added to condensate to remove this dissolved, contained oxygen and it takes 8 PPM of Sodium Sulfite to remove 1 PPM of oxygen. So cooling down the condensate is certainly an answer to pumping problems, but it causes the usage of more chemicals, increased heat energy to preheat this condensate back up and certainly will cause decreased life of the condensate return piping system due to the increased corrosion attack.

**Figure 57**

Solubility of Oxygen in Condensate

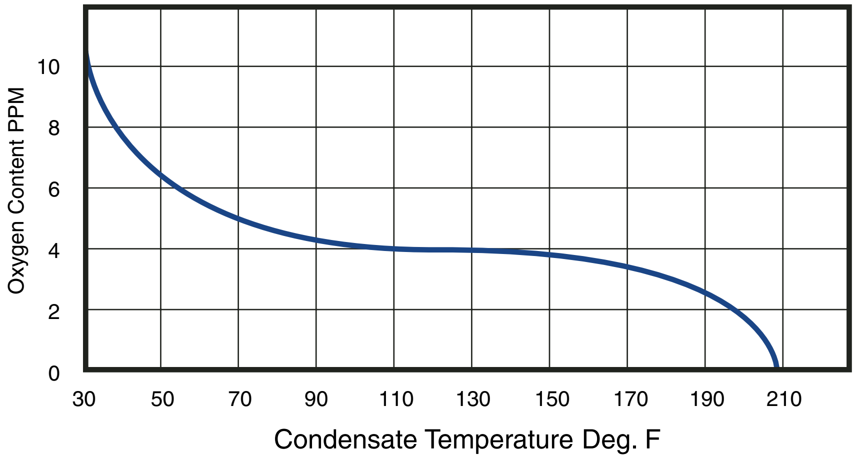
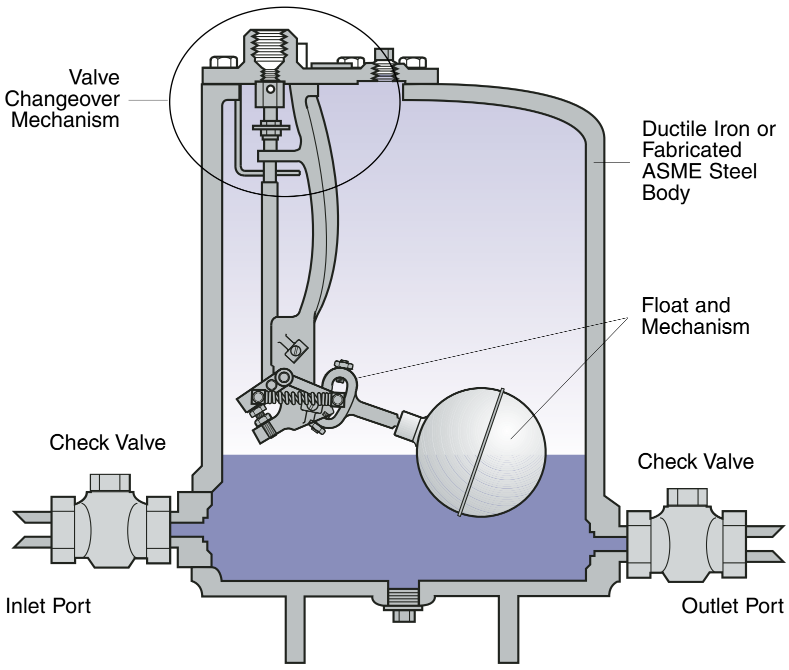


**Figure 58**

PPF/PPC Features



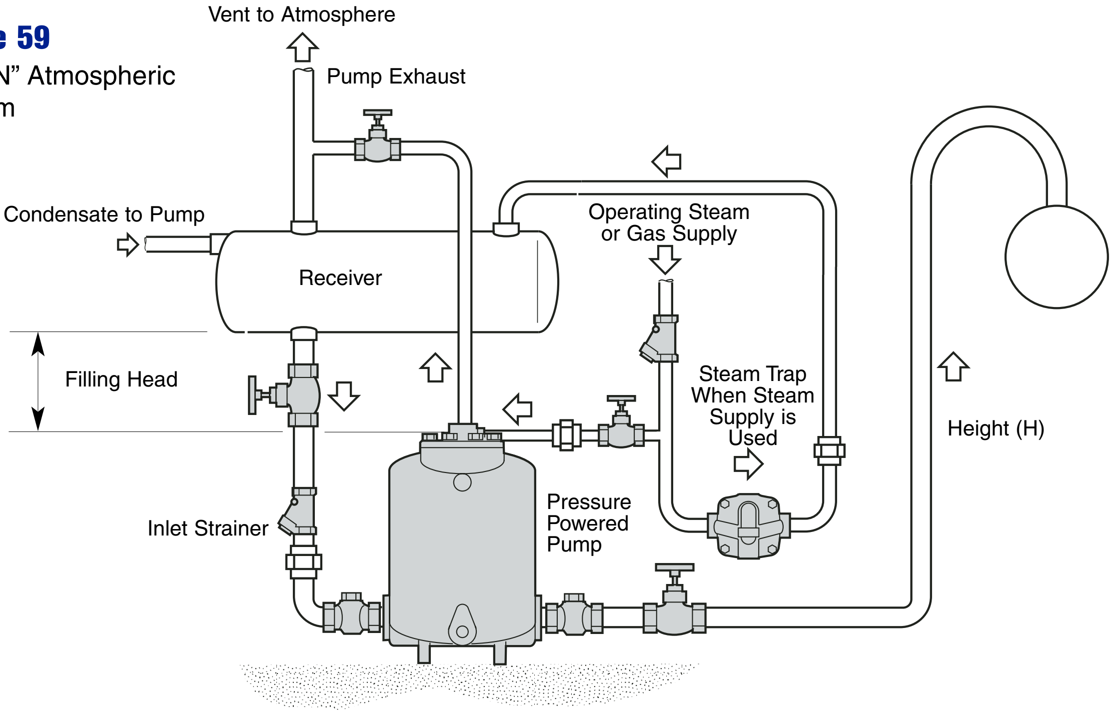
## Non Electric Pressure Powered Pumps

Non Electric Pressure Powered Pumps have become the state of art method of condensate pumping in industry today. This type of pump does not require any electrical connections, has no high speed rotating impellers, no temperature sensitive mechanical seals or large oversized receivers for storage of condensate (Fig. 58). The non-electric pressure powered pump can operate on steam, compressed air or any inert gas with pressures up to 300 PSIG.

In "open" atmospheric systems (Fig. 59), there are several benefits to using this pumping system. Receivers are not as large, condensate does not have to cool down before pumping, the pump can be installed directly below heat exchange equipment and will handle the condensate at 212°F without any cavitation or mechanical problems. There is still a need for a small receiver to allow steam traps that are discharging into it to sense a common pressure of 0 PSIG so as not to apply any backpressure to any of the steam traps. The condensate is then pumped back to the boiler house for re-use.

Industry requirements for more efficient usage of steam energy is demanding that condensate not only be returned at the highest possible temperatures, but that there are less and less atmospheric vents allowing flash steam to be lost. To accommodate this need for efficient usage and the need for increasing equipment life expectancy of all heat exchange equipment, the "closed" system (Fig. 60) of removal and recovery of condensate is becoming the design criteria. In "closed" systems

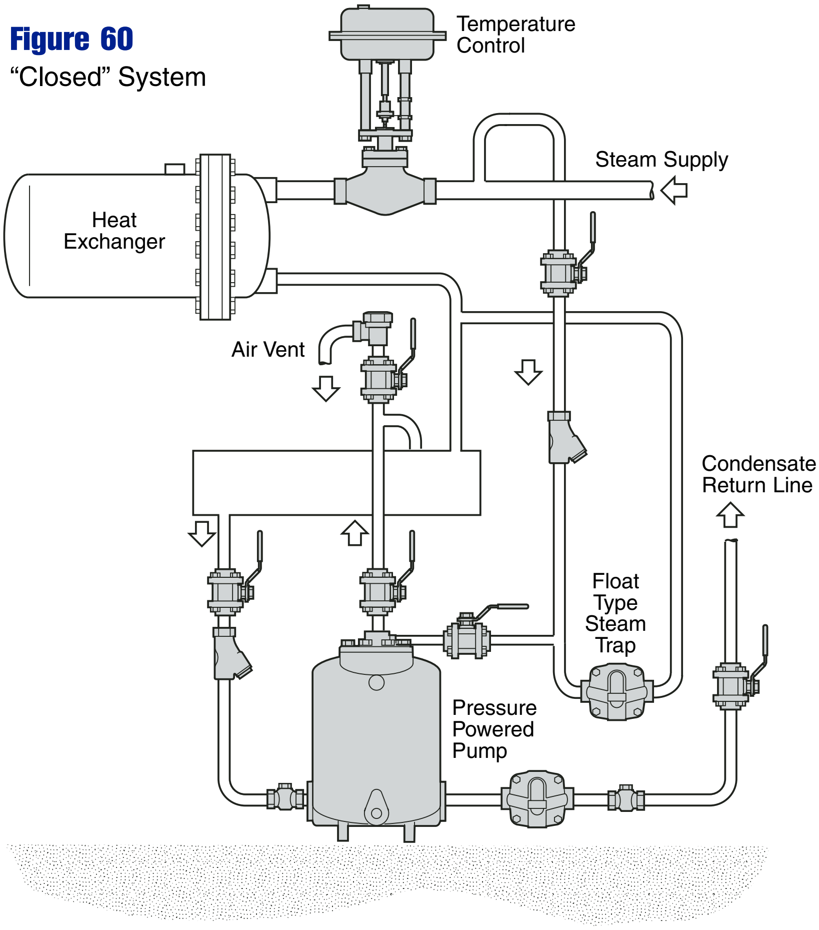
**Figure 59**
"OPEN" Atmospheric System



condensate is removed, recovered at saturation temperatures and returned directly back to the deaerator in the boiler house.

The return of saturated temperature condensate in this manner allows the boiler house to reduce the steam demand to the deaerator to re-heat the condensate, reduces the need for more chemicals to be added to the condensate, and ensures that the heat exchange equipment is kept dry at all times which eliminates corrosion attack and potential coil freezing. In the majority of applications, these "closed" systems are dedicated systems to a single piece of equipment.

**Figure 60**
"Closed" System



All temperature controlled equipment, as discussed earlier, has fluctuating steam pressures inside the equipment based upon equipment load demands. Historically, we have depended upon steam pressure to “lift” condensate out of a piece of equipment via the steam trap into the condensate return system. Because of the operation of the temperature control valves, there would be times that there would be sufficient steam pressure at the trap inlet to overcome the condensate return line pressure or the required lift.

At other times during operation, there would not be enough steam pressure supplied to the equipment to lift condensate. At those times we would begin to flood the heat exchange equipment, causing either product temperature fluctuations or even worse, freezing of the air coils, because we were unable to effectively remove the condensate. Installing a pumping device between the equipment and the trap (Fig. 61) allows for condensate to be recovered and removed from the steam equipment at all times during operation, whenever the steam pressure is sensed in the equipment.

When the steam pressure is greater than the condensate return pressure or lift, steam pressure alone lifts the condensate out through the steam trap. However, when steam pressure in the equipment is equal to or lower than that of the condensate return system or lift, condensate completely fills the pump body, steam pressure is supplied to the pump and the condensate is pumped out through the steam trap into the condensate return system.

When the pump is pumping condensate, the condensate being produced in the equipment is allowed to fall by gravity into the reservoir pipe, again ensuring that the equipment is kept dry. Upon completion of the pumping cycle, the pressure inside the pump body is equalized back to the reservoir piping and the collected condensate in the reservoir pipe falls by gravity into the pump body, starting the cycle all over again.

Because this system of condensate removal and recovery is designed to be a “closed” system, there is no need for vacuum breakers as we have used in the past. In fact, the equipment is encouraged to work into a vacuum condition if it is required by the temperature control system. Even in vacuum conditions, condensate is allowed to fall by gravity into the pump because the pump is equalized in pressure to the outlet of the equipment through the exhaust of the pump.

## Waterhammer In Condensate Return Lines

Waterhammer in condensate return lines is an indication of two possible problems. In “open” systems, atmospheric returns, the causes of waterhammer are air pockets and/or steam traps discharging into a flooded section of piping. Air pockets in the line are easily remedied by adding an air venting device for water systems, a float actuated device that will remain open until it is full of water and air eliminated. These devices are mounted on the high points of the return line and vent to atmosphere. Steam traps discharging into a water line should be avoided at all costs.

As we mentioned earlier in the flash steam recovery section, condensate lines have historically been sized for water volume only and not for the volume of flash steam produced from traps discharging to a lower pressure. If there is no other possible area to discharge a steam trap into except a condensate return line, the installation shown above should be followed. This breaks away from the tradition of discharging steam traps into condensate return lines at 90° to the condensate return line by literally injecting the steam trap discharge into the condensate return line so that the actual outlet of the trap discharge is below the normal water level in the return line and discharging in the direction of condensate flow.

This prevents sections of flash steam being trapped by walls of water on both sides which, when steam condenses, causes a vacuum and violently pulls the two walls of water together. These shock waves are transmitted down the return piping causing hammering noises and pipe movement.

In “closed” systems, condensate return piping must be sized for two phase flow at low velocities or the same situation will occur.

**Figure 61**

Closed System

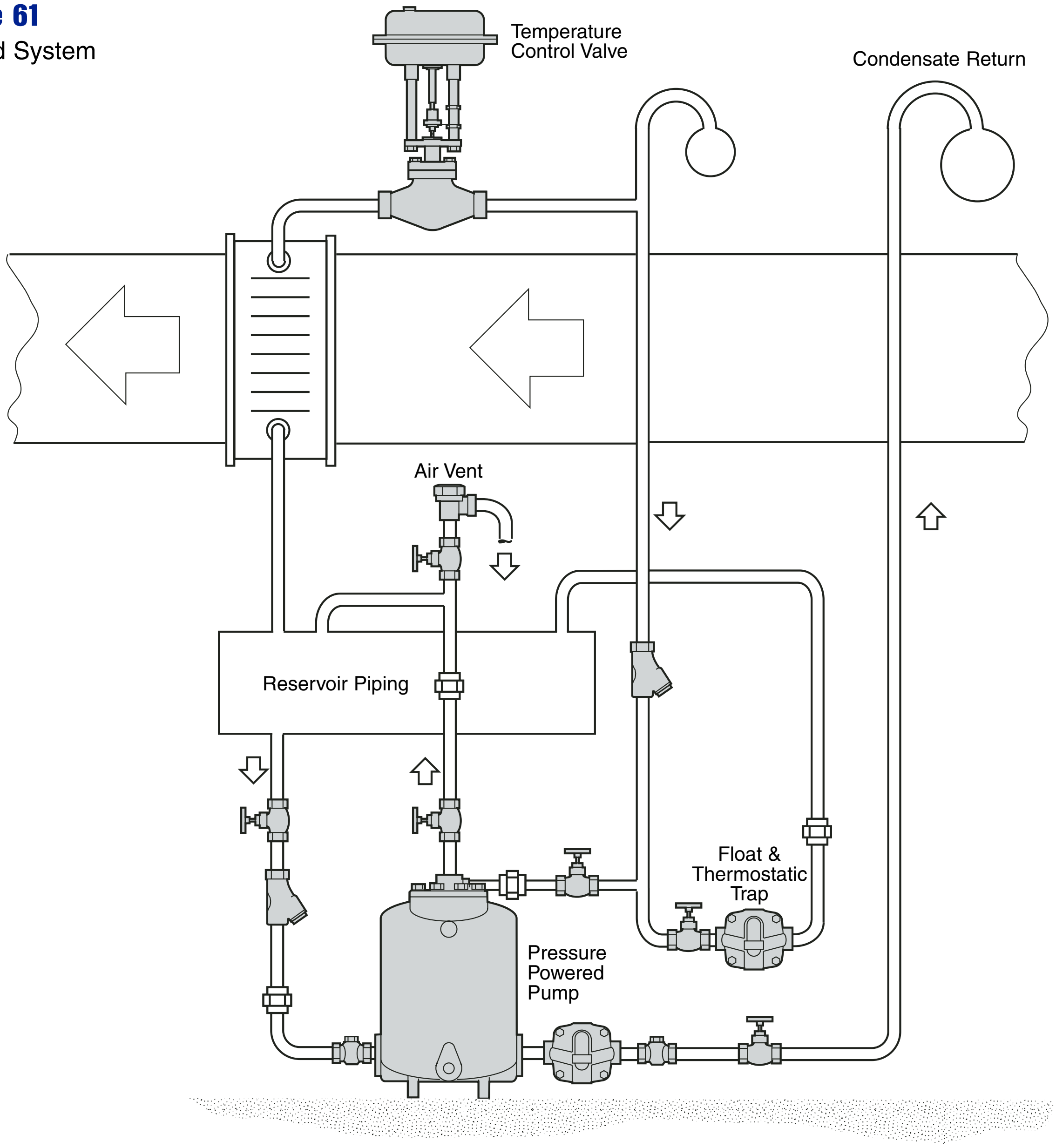
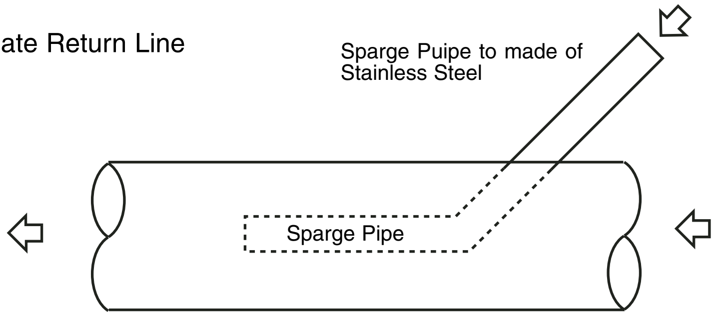


**Figure 62**

Discharging Into Condensate Return Line



Enlarge Condensate return, if necessary, to accommodate Sparge Pipe

# Steam Utilization Course Review

1. Steam is created by ______________________ __________________________.
2. A typical target velocity for steam is ____________________________________.
3. Why is steam velocity important?
    1. ____________________________________________________________ _____
    2. _________________________________________________________________
    3. _________________________________________________________________
4. Four common rules in designing steam main drip stations are:
    1. _________________________________________________________________
    2. _________________________________________________________________
    3. _________________________________________________________________
    4. _________________________________________________________________
5. A normal byproduct of steam generation is the release of ___________________.
6. How much condensate is created in a steam main of 8" diameter at 125 psig for every 100 feet?_______________________________________________________
7. What 3 categories do steam traps fall under?
    1. _________________________________________________________________
    2. _________________________________________________________________
    3. _________________________________________________________________
8. List the types of steam traps for each category.
    1. _________________________________________________________________
    2. _________________________________________________________________
    3. _________________________________________________________________
    4. _________________________________________________________________
    5. _________________________________________________________________
    6. _________________________________________________________________
9. List the 4 methods used for testing steam traps.
    1. _________________________________________________________________
    2. _________________________________________________________________
    3. _________________________________________________________________
    4. _________________________________________________________________
10. When lifting condensate, how much pressure is exerted for every 2.3 feet of lift?

    ___________________________________________________________________

11. Properly sized steam traps are sized to ______________________________ and not to

__________________________________ __________________________________________.

12. How many tracer lines are recommended for an 8” product pipe to keep temperatures at or above 150*F?

___________________________________________________________________________

13. Into what two groups can pressure reducing valves be divided?

1. _________________________________________________________________________
2. _________________________________________________________________________

14. What 3 factors attribute to proper reliability and accuracy of control valves?

1. _________________________________________________________________________
2. _________________________________________________________________________
3. _________________________________________________________________________

15. The term used when condensate is discharged to a lower pressure and partially vaporizes is ______________________________________________________________.

16. Calculate the percent of flash steam created when 100 psig condensate is discharged to atmosphere (Sh L.P. - SH H.P.) ) Lh L.P.)

17. List 3 important reasons to recover condensate.

1. _________________________________________________________________________
2. _________________________________________________________________________
3. _________________________________________________________________________

18. List 3 considerations that must be met before flash steam recovery is viable and economical.

1. _________________________________________________________________________
2. _________________________________________________________________________
3. _________________________________________________________________________

19. Condensate lines should be sized for handling what two factors?

1. _________________________________________________________________________
2. _________________________________________________________________________

20. Shock waves created in condensate return lines are known as

___________________________________________________________________________

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