SIZING STEAM TRAPS

HOW TO DETERMINE THE PROPER SIZE TRAP

Capacity tables that follow show maximum discharge rates in pounds per hour. To select the correct size trap from these tables, the normal condensing rate should be converted to a “pounds per hour” basis and multiplied by a safety factor.

REASON FOR SAFETY FACTORS

For steam applications, the condensation rate varies with:

(1) The starting or warming-up condition.
(2) The normal operating condition.
(3) Any abnormal operating condition.

Of these, the condensing rate for the normal condition is occasionally known, or it can be estimated with sufficient accuracy for trap selection; the loads imposed by warm-up and abnormal conditions are seldom known and practically impossible to predict.

During warm-up the trap load is heavy, since air as well as large quantities of condensate must be discharged. Condensate forms at a rapid rate as the cold equipment and connecting piping are brought up to temperature. This usually results in pressure drop at the trap inlet, thereby reducing its capacity during the period when the load is maximum.

Safety factors are therefore necessary, to compensate for start-up conditions, variation of steam pressure and product initial temperature, the process cycle speed required, and discrepancies between assumed and actual conditions which determine the normal condensing rate.

The selection of a safety factor depends on the type of trap and the operating conditions. If the known or calculated normal condensing rate is multiplied by the recommended factor from the pages which follow, efficient trapping will be assured.

EFFECT OF BACK PRESSURE ON TRAP CAPACITY

Most trap installations include piping to a common return system or to an available disposal location. In either case a constant static back pressure may exist, against which the trap must discharge. This back pressure may be unintentional or deliberately produced.

Unintentional back pressure in condensate return piping is caused by lifting the condensate to a higher level, piping which is too small for the volume of liquid conveyed, piping with insufficient or no pitch in the direction of flow, pipe and fittings clogged with rust, pipe scale or other debris, leaking steam traps, etc. In steam service an intentional back pressure is instigated by means of a pressure regulating or spring-loaded valve in the discharge system, when a supply of flash steam at a pressure less than the trap pressure is needed.

If very hot condensate is discharged to a pressure less than that existing in the trap body, some of it will flash into steam, with a tremendous increase in volume and consequent choking and build-up of pressure in the trap’s discharge orifice and the passages and piping adjacent thereto. For condensate at or close to steam temperature, this flash pressure is quite high, usually considerably higher than any static back pressure existing in the trap outlet piping.

For this reason, capacity tables for thermostatic and thermodynamic traps are based on gage pressure at the trap inlet, instead of on the difference between trap inlet and discharge pressures. Experiments have shown that, for the temperatures applying to these tables, unless the static back pressure in the return piping exceeds 25% of the trap inlet pressure, no reduction of the trap capacity results. For back pressures greater than 25% of the trap inlet pressure there is a progressive decrease of trap capacity.

Thus, if the return piping static pressure is less than 25% of the trap inlet pressure, the capacities shown in these tables should be utilized for trap selection. If the return piping pressure is greater than 25% of the trap inlet pressure, reduce the table capacities by the percentage indicated in second line of Table A on the following pages.

Above data does not apply to mechanical traps, capacities are based on differential pressure, obtained by subtracting any static back pressure from trap inlet pressure.

WHEN THE NORMAL CONDENSING RATE IS KNOWN

Normal condensing rate means the pounds of steam condensed per hour by the average conditions which prevail when the equipment drained is at operating temperature.

If this amount is known, simply multiply by the safety factor recommended for the service and conditions, obtained from the pages which follow, and determine size directly from the capacity tables for the type of trap selected.

WHEN THE NORMAL CONDENSING RATE IS UNKNOWN

Determine by utilizing proper formula for the service and equipment to be trapped. Multiply the result by safety factor recommended for the operating conditions. See examples on the following pages.
EXPLANATION OF SYMBOLS USED IN NORMAL CONDENSING RATE FORMULAS

A = Heating surface area, square feet (see Table B)
B = Heat output of coil or heater, BTU per hour
C = Condensate generated by submerged heating surfaces, lbs/hr/sq ft (Table F)
D = Weight of material processed per hour after drying, pounds
F = Steam flow, Ibs/hr
G = Gallons of liquid heated per unit time
H = Heat loss from bare iron or steel heating surface, BTU/sq ft/°F/hr
L = Latent heat of steam at pressure utilized, BTU/lb (see Table C or obtain from Steam Table)
M = Metal weight of autoclave, retort or other pressure vessel, pounds
Qh = Condensate generated, Ibs/hr
Qu = Condensate generated, Ibs/unit time (Always convert to Ibs/hr before applying safety factor. See Examples using formulas 7 and 10 on next page).
S = Specific heat of material processed, BTU/lb/°F
Ta = Ambient air temperature, °F
Tf = Final temperature of material processed, °F
Ti = Initial temperature of material processed, °F
Ts = Temperature of steam at pressure utilized, °F (see Table C or obtain from Steam Table)
U = Overall coefficient of heat transfer, BTU/sq ft/°F/hr (see Table E)
V = Volume of air heated, cubic feet/minute
Wg = Liquid weight, lbs/gallon
Wh = Weight of material processed per hour, lbs
Wu = Weight of material processed per unit time, lbs
X = Factor for \( \frac{Tf - Ti}{L} \) (obtain from Table D)
Y = Factor for \( \frac{H(Ts - Ta)}{L} \), lbs/hr/sq ft (obtain from Table C)

AIR HEATING

Steam Mains; Pipe Coil Radiation; Convectors; Radiators; etc. (Natural Air Circulation)

(1) \( Qh = A Y \)

Recommended Safety Factors

For Steam Mains

Ambient Air Above Freezing:
1st Trap After Boiler ................. 3
At End of Main ....................... 3
Other Traps .......................... 2

Ambient Air Below Freezing:
At End of Main ....................... 4
Other Traps .......................... 3

Steam mains should be trapped at all points where condensate can collect, such as at loops, risers, separators, end of mains, ahead of valves, where mains reduce to smaller diameters, etc., regardless of the condensate load. Installation of traps at these locations usually provides ample capacity.

For Pipe Coil Radiation, Convectors and Radiators

Single Continuous Coil ............. 2
Multiple Coil ........................ 4

Damp Space Pipe Coil Radiation; Dry Kilns; Greenhouses; Drying Rooms; etc. (Natural Air Circulation)

(2) \( Qh = 2.5 A Y \)

Recommended Safety Factors

Single Continuous Coil ............. 2
Multiple Coil ........................ 4

Steam Line Separators; Line Purifiers

(3) \( Qh = 0.1 U \)

Recommended Safety Factors

Indoor Pipe Line ..................... 2
Outdoor Pipe Line ................... 3
If Boiler Carry-Over Anticipated... 4 to 6 (Depending on probable severity of conditions)

Example: 11,500 cubic feet of air per minute heated by blast coil from 50°F to 170°F with 50 PSIG constant steam pressure.

Solution: By formula (6), \( Qh = 1.09 \times 11,500 \times 0.132 = 1655 \) lbs/hr. Recommended safety factor, 3 for intake air above freezing and constant steam pressure. 3 x 1655 = 4965 lbs/hr trap capacity required.
SIZING STEAM TRAPS CONT’D.

LIQUID HEATING
Submerged Coils; Heat Exchangers; Evaporators; Stills; Vats; Tanks; Jacketed Kettles; Cooking Pans; etc.

(7) When Quantity of Liquid to be Heated in a Given Time is Known:
\[ Q_u = \frac{G W g S X}{A U} \]

(8) When Quantity of Liquid to be Heated is Unknown:
\[ Q_h = A U X \]

(9) When Heating Surface Area is Larger than Required to Heat Known Quantity of Liquid in a Given Time:
\[ Q_h = A C \]

Recommended Safety Factors
For Submerged Coil Equipment; Heat Exchangers; Evaporators; etc.

Constant Steam Pressure:
- Single Coil, Gravity Drainage ....... 2
- Single Coil, Siphon Drainage ....... 3
- Multiple Coil, Gravity Drainage .... 4

Variable Steam Pressure:
- Single Coil, Gravity Drainage ....... 3
- Single Coil, Siphon Drainage ....... 4
- Multiple Coil, Gravity Drainage .... 5

For Siphon Drained Equipment, specify traps with “Steam Lock Release Valve”.

For Jacketed Equipment; Cooling Kettles; Pans; etc.

Slow Cooking:
- Gravity Drainage .................... 3
- Siphon Drainage ................. 4

Moderately Fast Cooking:
- Gravity Drainage .................... 4
- Siphon Drainage ................. 5

Very Fast Cooking:
- Gravity Drainage .................... 5
- Siphon Drainage ................. 6

For Siphon Drained Equipment, specify traps with “Steam Lock Release Valve”.

Example: Heat exchanger with single submerged coil, gravity drained, heating 1250 gallons of petroleum oil of 0.51 specific heat, weighing 7.3 lbs/gal, from 50°F to 190°F in 15 minutes, using steam at 100 PSIG.

Solution: By formula (7), \( Q_u = 1250 \times 7.3 \times 0.51 \times 0.195 = 740 \) pounds of condensate in 15 minutes, or \( 4 \times 740 = 2960 \) lbs/hr. Recommended safety factor is 2 for single coil, gravity drained. 2 x 2960 = 5920 lbs/hr trap capacity required.

DIRECT STEAM CONTACT HEATING
Autoclaves; Retorts; Sterilizers; Reaction Chambers; etc.

(10) \[ Q_u = \frac{W S X}{0.12 M X} \]

Recommended Safety Factors
Slow Warm-up Permissible ........ 3
Fast Warm-up Desired ............. 5

Example: An autoclave which weighs 400 pounds before loading is charged with 270 pounds of material having a specific heat of .57 and an initial temperature of 70°F. Utilizing steam at 50 PSIG, it is desired to bring the temperature up 250°F in the shortest possible time.

Solution: By formula (10), \( Q_u = \frac{(270 \times 0.57 \times 0.195) + 0.12(400 \times 0.195)}{5} = 2400 \) lbs/hr is required.

INDIRECT STEAM CONTACT HEATING
Cylinder Dryers, Drum Dryers, Rotary Steam Tube Dryers, Calenders; etc.

(11) \[ Q_h = \frac{970 (W - D)}{L} + Wh X \]

Recommended Safety Factors
For Siphon or Bucket Drained Rotating Cylinder, Drum and Steam Tube Dryers; Cylinder Ironers; etc.

Small or Medium Size,
- Fast Rotation .......................... 6
- Large Size, Slow Rotation .......... 6
- Large Size, Fast Rotation .......... 8

For Siphon or Bucket Drained Equipment, specify traps with “Steam Lock Release Valve”. Each cylinder should be individually trapped.

For Gravity Drained Chest Type Dryers and Ironers
Each Chest Individually Trapped .... 2
Entire Machine Drained By
Single Trap ............................. 4 to 6
Depending on number of Chests

For Platen Presses
Each Platen Individually Trapped ... 2
*Entire Press Drained by Single Trap, Platens Piped in Series ..................... 3
*Entire Press Drained by Single Trap, Platens Piped in Parallel ...... 4 to 6
Depending on number of Platens

Example: A medium size rotary steam tube dryer with condensate lifted to a discharge passage in the trunion, dries 4000 lbs/hr of granular material to 3300 pounds, with 15 PSIG steam, initial temperature of material 70°F, final temperature 250°F.

Solution: By formula (11) \( Q_h = \frac{970 (4000 - 3300)}{4} (4000 \times 0.191) \]

= 1483 lbs/hr. Using safety factor of 4 recommended for medium size, slow rotation: \( 4 \times 1483 = 5932 \) lbs/hr trap capacity required.

*A separate trap for each heating surface (coil, chest, platen, etc.) is recommended for maximum heating efficiency. Sluggish removal of condensate and air is certain when more than one unit is drained by a single trap, resulting in reduced temperatures, slow heating and possible water-hammer damage.

<table>
<thead>
<tr>
<th>TABLE A — EFFECT OF BACK PRESSURE ON STEAM TRAP CAPACITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back Pressure as Percent of Inlet Pressure</td>
</tr>
<tr>
<td>Percent Reduction of Trap Capacity</td>
</tr>
</tbody>
</table>

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### TABLE B - SQUARE FEET OF SURFACE PER LINEAL FOOT OF PIPE

<table>
<thead>
<tr>
<th>Nominal Pipe Size (In.)</th>
<th>1/2</th>
<th>3/4</th>
<th>1 1⁄4</th>
<th>1 1⁄2</th>
<th>2 2⁄5</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area, Sq. Ft. per Lineal Ft.</td>
<td>.22</td>
<td>.28</td>
<td>.35</td>
<td>.44</td>
<td>.50</td>
<td>.63</td>
<td>.76</td>
<td>.92</td>
<td>1.18</td>
<td>1.46</td>
<td>1.74</td>
<td>2.26</td>
<td>2.81</td>
<td>3.34</td>
<td>3.67</td>
<td>4.19</td>
<td>4.71</td>
</tr>
</tbody>
</table>

### TABLE C - FACTOR X = (Tf - Ti)/L

| Steam Pressure - PSIG | 1 | 2 | 5 | 10 | 15 | 20 | 25 | 50 | 75 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 600 |
|-----------------------|---|---|---|----|----|----|----|----|----|-----|------|------|------|------|------|------|------|------|------|------|------|
| Steam Temperature - °F | 40 | .041 | .042 | .043 | .043 | .044 | .045 | .045 | .047 | .048 | .049 | .050 | .051 | .052 | .052 | .053 | .055 |
| Factor Y Cond - lbs/hr/sq.ft | .45 | .46 | .49 | .53 | .56 | .59 | .61 | .63 | .66 | .68 | .70 | .72 | .73 | .75 | .77 | .79 | .80 | .82 | .83 | .86 | .90 |

*Based on still air at 60°F, recommended safety factors compensate for air at other temperatures. Used for steam trap selection only.

### TABLE D — FACTOR X = (Tf - Ti)/L

<table>
<thead>
<tr>
<th>Tf-Ti</th>
<th>40</th>
<th>60</th>
<th>80</th>
<th>100</th>
<th>120</th>
<th>140</th>
<th>160</th>
<th>180</th>
<th>200</th>
<th>220</th>
<th>240</th>
<th>260</th>
<th>280</th>
<th>300</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTU/HR/SQ FT/°F TEMP. DIFFERENTIAL STEAM PRESSURE - PSIG</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>50</td>
<td>75</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>250</td>
<td>300</td>
</tr>
<tr>
<td>Iron or Steel</td>
<td>1.6</td>
<td>1.8</td>
<td>2.0</td>
<td>2.2</td>
<td>2.4</td>
<td>2.6</td>
<td>2.8</td>
<td>3.0</td>
<td>3.2</td>
<td>3.4</td>
<td>3.6</td>
<td>3.8</td>
<td>4.0</td>
<td>4.2</td>
</tr>
<tr>
<td>Brass</td>
<td>2.6</td>
<td>2.8</td>
<td>3.0</td>
<td>3.2</td>
<td>3.4</td>
<td>3.6</td>
<td>3.8</td>
<td>4.0</td>
<td>4.2</td>
<td>4.4</td>
<td>4.6</td>
<td>4.8</td>
<td>5.0</td>
<td>5.2</td>
</tr>
<tr>
<td>Copper</td>
<td>3.2</td>
<td>3.4</td>
<td>3.6</td>
<td>3.8</td>
<td>4.0</td>
<td>4.2</td>
<td>4.4</td>
<td>4.6</td>
<td>4.8</td>
<td>5.0</td>
<td>5.2</td>
<td>5.4</td>
<td>5.6</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Coefficients shown are suggested average design values. Higher or lower figures will be realized for many conditions. Use for steam trap selection only.

### TABLE E — FACTOR U, HEAT TRANSFER COEFFICIENTS

<table>
<thead>
<tr>
<th>TYPE OF HEAT EXCHANGER</th>
<th>STEAM TO WATER</th>
<th>STEAM TO OIL</th>
<th>STEAM TO MILK</th>
<th>STEAM TO PARAFFIN WAX</th>
<th>STEAM TO SUGAR &amp; MOLASSES SOLUTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTU/HR/SQ FT/°F TEMP. DIFFERENTIAL</td>
<td>125</td>
<td>20</td>
<td>125</td>
<td>25</td>
<td>75</td>
</tr>
<tr>
<td>NATURAL CIRCULATION</td>
<td>300</td>
<td>45</td>
<td>300</td>
<td>80</td>
<td>150</td>
</tr>
</tbody>
</table>

Coefficients shown are suggested average design values. Higher or lower figures will be realized for many conditions. Use for steam trap selection only.

### TABLE F — FACTOR C, APPROXIMATE CONDENSING RATE FOR SUBMERGED SURFACES, LBS/HR/SQ FT

<table>
<thead>
<tr>
<th>HEATING SURFACE</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>100</th>
<th>125</th>
<th>150</th>
<th>175</th>
<th>200</th>
<th>225</th>
<th>250</th>
<th>275</th>
<th>300</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron or Steel</td>
<td>1.6</td>
<td>5</td>
<td>10</td>
<td>17</td>
<td>25</td>
<td>34</td>
<td>45</td>
<td>57</td>
<td>70</td>
<td>84</td>
<td>99</td>
<td>114</td>
</tr>
<tr>
<td>Brass</td>
<td>2.6</td>
<td>8</td>
<td>16</td>
<td>27</td>
<td>40</td>
<td>54</td>
<td>72</td>
<td>91</td>
<td>112</td>
<td>134</td>
<td>158</td>
<td>182</td>
</tr>
<tr>
<td>Copper</td>
<td>3.2</td>
<td>10</td>
<td>20</td>
<td>34</td>
<td>50</td>
<td>68</td>
<td>90</td>
<td>114</td>
<td>140</td>
<td>168</td>
<td>198</td>
<td>228</td>
</tr>
</tbody>
</table>

*Mean water temperature is 1⁄2 the sum of inlet temperature plus outlet temperature. Table based on heating surfaces submerged in water with natural circulation. Safety factor of 50% has been included to allow for moderate scaling. If surface will remain bright, multiply above figures by 2. Use for steam trap selection only.
SIZING STEAM LINES

SIMPLE SIZING CRITERIA

Proper detailed design of a steam system should be done using detailed calculations for frictional losses in steam piping. The following examples and rules are meant to provide simple guidelines to see if steam pipe sizes are possibly undersized. They do not imply any design liability by Nicholson. Undersizing of steam lines can lead to reduced pressure to process equipment and impaired performance of valves, heat exchangers and steam traps. Steam line sizing along with condensate return line sizing should always be checked when a system is not performing up to expectations.

EXAMPLE: The system shown in Figure 3.1 will be used as our example. The Supply “S” at the right is 120 psig steam which is branching off to steam users A, B, C, D & E. The equipment usage is indicated in lbs/hr. The segments of piping will be addressed going backwards from the furthest end user A. The steam flow going through the pipe segment from the intersection X to equipment A is 1000 lb/hr (the usage of A). A simple rule of thumb for smaller steam piping (6” and below) is to keep steam velocities below 10,000 feet/minute (165 feet/second) for short lengths of pipe only.

The length of the steam line between X and A is 1000 feet, so the simple rule of thumb can not be applied here because the pressure drop will be too high. The pressure drop should be kept to a minimum, or supply pressure to the equipment will droop.

SOLUTION BY CHART: The chart is a graphic solution to help select pipe sizes. The pressure values used for this chart are in psia (absolute). For values given in gage pressure (psig), you must add 15 psi (14.7 psi actual). The example we will use is for saturated steam flow, but this chart does have corrections for superheat. There will be an overall system pressure drop, so that the pressure is assumed to be 5 to 10 psig below the supply pressure of 120 psig (135 psia). Enter the chart at the top at a point representing 130 psia and proceed vertically downward. Enter the chart at the right at the value of the steam flow in Lb/minute (1000 lb/hr = 16.7 lb/min) and move horizontally across until the horizontal line intersects the vertical line. You will proceed along the diagonal, downward and to the right, parallel with the other diagonal lines.

This chart can be used two ways: either to determine the pressure drop of an existing pipe or to determine the correct pipe size for a specific pressure drop.

TO SIZE LINES: On the bottom of the chart is a pressure drop per 100 feet of pipe, select a value of 0.25 psi per 100 feet. This indicates 2.5 psi as the total loss for 1000 feet. Enter the chart at the bottom at .25 and move upward until you intersect the diagonal line. Proceed from the intersection horizontally left until you reach the actual pipe diameter to determine the pipe size. In this example, the pipe size for section X to A should be 2 1/2” pipe.

TO FIGURE PRESSURE DROP: Enter the chart on the left side at your pipe size and proceed horizontally until you intersect with the diagonal line. Proceed vertically downward to determine the pressure drop per 100 feet of pipe. The next section of pipe to determine would be X to B. This would have the same pressure, but the intersection of the vertical line would be at the horizontal steam flow of 33 lb/min (2000 lb/hr) for user B. The choice of pipe sizes can be argued, a 4” will yield 0.1 psi/100 feet pressure drop (1.0 psi per 1000 feet), but the more economical solution of a 3” pipe yields a 0.4psi/100 feet pressure drop. Note: when selecting the smaller more economical pipe size, there is less room for expansion and pressure drops will increase should additional process capacity arise.

For common sections of header such as Y to X, the steam flow for both steam users A and B must be combined. The vertical line will now intersect with the horizontal steam flow line coming across at 50 lb/min (3000 lb/hr). Using a 4” line will bring the pressure drop to a value of 0.22 psi/100 feet, or 2.2 psi for the 1000 foot section.

Remember that pressure drop figures from the bottom of the chart are per 100 feet, so segments such as Y to C have a larger total pressure drop because the distance is longer. Similarly, the total pressure drop from Z to Y is less because the distance is only 500 feet. The values for steam flow continue to be additive for each steam user; Z to Y is 3700 lb/hr (61.7 lb/min), W to Z is 6200 lb/hr (103.3 lb/min) and S to W is 7200 lb/hr (120 lb/min). Pipe sizes in Figure 3.1 are given for your reference and provide the user with reasonable pressure drops in the steam lines.
SIZING STEAM LINES CONT’D.