

Thermodynamic Laws

Zeroth Law: When two systems are in thermal equilibrium with a third system, they must be in thermal equilibrium with each other.

First Law (closed system): $Q = m\Delta U + W / J$

Heat entering a system can either increase temperature (internal energy) or be used to perform work on the surroundings. It is the law of energy conservation, i.e., energy cannot be created or destroyed.

Second Law (isolated system): $m\Delta S_{total} \geq 0$

The entropy change of any system and its surroundings, considered together, is positive, and approaches zero for any process that approaches reversibility. It is considered the fundamental law of natural sciences.

The two classical statements of the Second Law:

Clausius statement: It is impossible to construct a device that operates in a cycle and produces no effect other than the transfer of heat from a cooler body to a hotter body.

Kelvin-Planck statement: It is impossible to construct a device that operates in a cycle and produces no effect other than the raising of a weight and the exchange of heat with a single reservoir.

Third Law: It is impossible to cool a body down to absolute zero.

Thermodynamic Laws (simplified)

First Law: You can't win, you can only break even.

Second Law: You can only break even at absolute zero.

Third Law: You can never reach absolute zero.

Thermodynamic Equations

Ideal Gas Law: $pV = nRT = NkT$; $V = mv$; $n = m/M$; $k = R/N_A$

Helmholtz Function: $f = u - Ts$

The four thermodynamic potentials:

Gibbs Function: $g = h - Ts$

$$\text{Equation of State: } p = -J \left(\frac{\partial f}{\partial v} \right)_T$$



Enthalpy:

$$h = u + pv / J = \int \left[c_v + \frac{v}{J} \left(\frac{\partial p}{\partial T} \right) \right] dT + \frac{1}{J} \int \left[v \left(\frac{\partial p}{\partial v} \right)_T + T \left(\frac{\partial p}{\partial T} \right)_v \right] dv$$

$$\text{Entropy: } s = - \left(\frac{\partial f}{\partial T} \right)_v = - \left(\frac{\partial g}{\partial T} \right)_p = \int \frac{c_v dT}{T} + \frac{1}{J} \int \left(\frac{\partial p}{\partial T} \right)_v dv$$

$$\text{Isochoric Specific Heat: } c_v = \left(\frac{\partial u}{\partial T} \right)_v = T \left(\frac{\partial s}{\partial T} \right)_v = c_v^0 + \int_{T^0}^T \left(\frac{\partial^2 p}{\partial T^2} \right)_v dT$$

$$\text{Isobaric Specific Heat: } c_p = \left(\frac{\partial h}{\partial T} \right)_p = T \left(\frac{\partial s}{\partial T} \right)_p = c_v - \frac{T \left(\frac{\partial p}{\partial v} \right)_T^2}{J \left(\frac{\partial^2 p}{\partial v^2} \right)_T}$$

$$\text{Specific Heat Ratio: } \gamma = c_p / c_v = \kappa / \kappa_s$$

Velocity of Sound:

$$a = v \sqrt{g_v \gamma \left(\frac{\partial^2 f}{\partial v^2} \right)_T} = v \sqrt{-g_v \gamma \left(\frac{\partial p}{\partial v} \right)_T} = v \sqrt{g_v \left[\frac{T \left(\frac{\partial p}{\partial T} \right)_v^2}{J c_v} - \left(\frac{\partial p}{\partial v} \right)_T \right]}$$

Nomenclature

| | | | |
|----------------------|---------------------------------|-------------------------------------------------|-----------------------|
| a | velocity of sound | ft/sec | m/sec |
| c_p | isobaric specific heat | Btu/lbm ^o -R | kJ/kg ^o -K |
| c_v | isochoric specific heat | Btu/lbm ^o -R | kJ/kg ^o -K |
| f | Helmholtz function | Btu/lbm | kJ/kg |
| g | Gibbs function | Btu/lbm | kJ/kg |
| g_v | gravitational conversion factor | 32.174 lbm-ft/lb _m -sec ² | 1.0 |
| h | enthalpy | Btu/lbm | kJ/kg |
| J | Joule's constant | 778.16926 ft-lb _m /Btu | 1.0 |
| m | mass | lbm | kg |
| M | molecular weight | --- | --- |
| N | no. of molecules | --- | --- |
| n | no. of moles | lb mol | kg mol |
| p | pressure | lb/ft ² | kPa |
| Q | heat | Btu | kJ |
| s | entropy | Btu/lbm ^o -R | kJ/kg ^o -K |
| T | temperature | °R | °K |
| u | internal energy | Btu/lbm | kJ/kg |
| v | specific volume | ft ³ /lbm | m ³ /kg |
| v | volume | ft ³ | m ³ |
| w | work | ft-lb _m | kJ |
| κ | isothermal compressibility | ft ³ /lb _m | (kPa) ⁻¹ |
| κ_s | adiabatic compressibility | ft ³ /lb _m | (kPa) ⁻¹ |
| γ | specific heat ratio | --- | --- |

Superscript: 0 = heat capacity at zero pressure

(Physical Constants on reverse side.)

Carrying Capacity of Refrigeration Lines - Tons of Refrigeration

| R-22 | Line Size | Suction Lines | | | | | Liquid Lines | | | | | Discharge Lines | | | | |
|---------------------------|--------------------------|---------------------|---------------|---------------|---------------|--------------------------|--------------------|--------------|----------|--------------|--------------------------|------------------------|------|------|------|--|
| | | Velocity = 1500 fpm | | | | | Velocity = 150 fpm | | | | | ΔT = 1°F, Δp = 3.0 psi | | | | |
| | | ΔT = 1°F | Δp = 0.39 psi | Δp = 0.57 psi | Δp = 0.81 psi | Δp = 1.1 psi | ΔT = 1°F | Δp = 1.9 psi | ΔT = 1°F | Δp = 3.0 psi | | | | | | |
| Type L Copper OD (Inches) | Suction Temperature (°F) | -40 | -20 | 0 | 20 | Suction Temperature (°F) | -20 | 20 | 20 | 20 | Suction Temperature (°F) | -20 | 20 | 20 | 20 | |
| 3/8 | 0.09 | 0.14 | 0.22 | 0.33 | 0.02 | 0.04 | 0.06 | 0.09 | 2.27 | 2.40 | 0.94 | 0.99 | 0.38 | 0.42 | 1.00 | |
| 1/2 | 0.17 | 0.27 | 0.43 | 0.64 | 0.06 | 0.11 | 0.18 | 0.28 | 4.35 | 4.58 | 2.25 | 2.37 | 0.92 | 1.00 | 1.88 | |
| 5/8 | 0.27 | 0.44 | 0.68 | 1.04 | 0.11 | 0.18 | 0.28 | 0.45 | 6.98 | 7.38 | 4.25 | 4.46 | 1.27 | 1.43 | 2.85 | |
| 7/8 | 0.56 | 0.91 | 1.42 | 2.13 | 0.30 | 0.49 | 0.76 | 1.13 | 11.9 | 15.3 | 11.3 | 11.9 | 4.53 | 4.83 | 9.65 | |
| 1-1/8 | 0.96 | 1.56 | 2.42 | 3.63 | 0.51 | 0.81 | 1.24 | 1.83 | 19.4 | 26.0 | 22.1 | 24.3 | 9.16 | 9.65 | 19.4 | |
| 1-3/8 | 1.65 | 2.59 | 3.89 | 5.83 | 0.86 | 1.29 | 1.96 | 2.70 | 32.6 | 43.2 | 37.6 | 39.9 | 15.3 | 16.1 | 32.6 | |
| 1-5/8 | 2.56 | 3.95 | 5.92 | 8.73 | 1.29 | 1.89 | 2.76 | 4.28 | 53.7 | 53.3 | 56.1 | 64.1 | 27.6 | 29.2 | 57.4 | |
| 2-1/8 | 4.11 | 6.22 | 9.07 | 13.6 | 2.14 | 3.24 | 4.78 | 7.02 | 93.2 | 132.2 | 92.6 | 97.2 | 45.4 | 48.1 | 97.2 | |
| 2-5/8 | 5.95 | 8.88 | 14.0 | 21.0 | 3.20 | 4.82 | 7.02 | 10.2 | 158 | 237 | 150 | 237 | 250 | 271 | 271 | |
| 3-1/8 | 7.87 | 12.3 | 20.0 | 30.0 | 4.64 | 6.94 | 10.1 | 16.4 | 253 | 375 | 204 | 215 | 379 | 400 | 146 | |
| 3-5/8 | 10.8 | 17.3 | 27.0 | 40.6 | 6.6 | 9.8 | 14.4 | 21.4 | 377 | 571 | 296 | 317 | 565 | 595 | 217 | |
| 4-1/8 | 13.8 | 22.5 | 35.1 | 52.7 | 9.15 | 13.5 | 20.1 | 29.1 | 537 | 789 | 389 | 411 | 788 | 841 | 305 | |
| 4-5/8 | 17.6 | 28.1 | 43.1 | 64.7 | 12.7 | 18.8 | 27.6 | 40.4 | 789 | 1173 | 589 | 620 | 1173 | 1244 | 450 | |
| 5-1/8 | 21.6 | 35.1 | 54.7 | 82.2 | 16.7 | 24.6 | 36.1 | 53.1 | 1113 | 1644 | 841 | 882 | 1644 | 1710 | 590 | |
| 6-1/8 | 31.0 | 50.5 | 76.7 | 116 | 23.6 | 35.1 | 51.4 | 74.7 | 1584 | 2310 | 1170 | 1244 | 2310 | 2430 | 841 | |

| R-134a | Line Size | Suction Lines | | | | | Liquid Lines | | | | | Discharge Lines | | | | |
|---------------------------|--------------------------|---------------------|---------------|---------------|--------------------------|----------|--------------------|----------|--------------|--------------------------|--------------|------------------------|------|-------|--|--|
| | | Velocity = 1500 fpm | | | | | Velocity = 150 fpm | | | | | ΔT = 1°F, Δp = 1.3 psi | | | | |
| | | ΔT = 1°F | Δp = 0.33 psi | Δp = 0.49 psi | Δp = 0.70 psi | ΔT = 1°F | Δp = 1.3 psi | ΔT = 1°F | Δp = 2.2 psi | ΔT = 1°F | Δp = 3.6 psi | | | | | |
| Type L Copper OD (Inches) | Suction Temperature (°F) | -20 | 0 | 20 | Suction Temperature (°F) | -20 | 20 | 20 | 20 | Suction Temperature (°F) | -20 | 20 | 20 | 20 | | |
| 3/8 | 0.09 | 0.13 | 0.21 | 0.32 | 0.02 | 0.04 | 0.06 | 0.09 | 2.21 | 2.29 | 0.68 | 0.72 | 0.28 | 0.30 | | |
| 1/2 | 0.15 | 0.25 | 0.40 | 0.60 | 0.05 | 0.08 | 0.13 | 0.23 | 4.03 | 4.37 | 1.63 | 1.77 | 0.66 | 0.72 | | |
| 5/8 | 0.24 | 0.40 | 0.64 | 0.99 | 0.16 | 0.25 | 0.40 | 0.60 | 6.47 | 7.02 | 3.10 | 3.36 | 1.23 | 1.35 | | |
| 7/8 | 0.50 | 0.84 | 1.33 | 2.05 | 0.42 | 0.67 | 1.04 | 1.64 | 10.7 | 14.6 | 9.27 | 9.97 | 3.33 | 3.56 | | |
| 1-1/8 | 0.86 | 1.43 | 2.27 | 0.51 | 0.86 | 1.36 | 2.29 | 24.8 | 16.3 | 18.2 | 6.54 | 7.20 | 2.60 | 2.82 | | |
| 1-3/8 | 1.31 | 2.17 | 3.46 | 0.90 | 1.50 | 2.39 | 34.8 | 24.8 | 29.7 | 12.3 | 11.4 | 12.5 | 5.17 | 5.61 | | |
| 1-5/8 | 1.95 | 3.06 | 4.50 | 1.39 | 2.38 | 3.63 | 49.3 | 47.1 | 51.1 | 18.0 | 18.0 | 18.0 | 8.58 | 9.22 | | |
| 2-1/8 | 3.21 | 5.35 | 8.53 | 2.99 | 4.98 | 7.88 | 85.8 | 93.1 | 98.4 | 107 | 37.2 | 40.9 | 14.6 | 15.9 | | |
| 2-5/8 | 4.66 | 7.65 | 12.1 | 5.31 | 8.81 | 14.0 | 132 | 144 | 148 | 175 | 190 | 65.6 | 72.2 | 26.0 | | |
| 3-1/8 | 7.07 | 11.8 | 18.8 | 8.53 | 14.2 | 22.4 | 189 | 205 | 208 | 304 | 105 | 115 | 38.0 | 41.3 | | |
| 3-5/8 | 9.57 | 15.9 | 25.4 | 12.7 | 21.1 | 33.3 | 255 | 277 | 278 | 418 | 155 | 171 | 51.7 | 55.7 | | |
| 4-1/8 | 12.4 | 20.7 | 33.0 | 18.0 | 29.0 | 47.0 | 342 | 360 | 360 | 541 | 219 | 240 | 69.0 | 73.9 | | |
| 4-5/8 | 16.4 | 28.3 | 51.4 | 32.3 | 53.5 | 84.3 | 517 | 562 | 562 | 1060 | 390 | 429 | 94.0 | 100.0 | | |
| 6-1/8 | 27.9 | 46.4 | 73.9 | 52.2 | 86.3 | 136 | 744 | 807 | 807 | 1710 | 1860 | 625 | 688 | 186.0 | | |

| R-404A | Line Size | Suction Lines | | | | | Liquid Lines | | | | | Discharge Lines | | | | |
|---------------------------|--------------------------|---------------------|---------------|---------------|--------------------------|--------------|--------------------|--------------|----------|--------------------------|-------|------------------------|-------|-------|-----|--|
| | | Velocity = 1500 fpm | | | | | Velocity = 150 fpm | | | | | ΔT = 1°F, Δp = 2.2 psi | | | | |
| | | ΔT = 1°F | Δp = 0.48 psi | Δp = 0.70 psi | Δp = 0.97 psi | Δp = 1.3 psi | ΔT = 1°F | Δp = 2.2 psi | ΔT = 1°F | Δp = 3.6 psi | | | | | | |
| Type L Copper OD (Inches) | Suction Temperature (°F) | -40 | -20 | 0 | Suction Temperature (°F) | -20 | 20 | 20 | 20 | Suction Temperature (°F) | -20 | 20 | 20 | 20 | | |
| 3/8 | 0.09 | 0.15 | 0.24 | 0.37 | 0.02 | 0.04 | 0.06 | 0.10 | 1.47 | 1.61 | 0.72 | 0.79 | 0.40 | 0.44 | | |
| 1/2 | 0.26 | 0.43 | 0.68 | 1.02 | 0.06 | 0.10 | 0.15 | 0.24 | 2.61 | 2.91 | 1.12 | 1.24 | 0.59 | 0.64 | | |
| 5/8 | 0.46 | 0.75 | 1.12 | 1.71 | 0.11 | 0.18 | 0.29 | 0.44 | 4.52 | 4.96 | 3.27 | 3.59 | 1.77 | 1.96 | | |
| 7/8 | 0.96 | 1.59 | 2.42 | 3.63 | 0.23 | 0.39 | 0.60 | 0.91 | 9.38 | 10.3 | 8.69 | 9.53 | 4.63 | 5.12 | | |
| 1-1/8 | 1.54 | 2.59 | 3.89 | 5.83 | 0.39 | 0.63 | 0.96 | 1.45 | 15.6 | 16.9 | 17.5 | 18.4 | 8.53 | 10.3 | | |
| 1-3/8 | 2.10 | 3.49 | 5.35 | 8.05 | 0.55 | 0.90 | 1.35 | 2.04 | 24.7 | 26.7 | 31.0 | 34.0 | 16.2 | 18.0 | | |
| 1-5/8 | 2.93 | 4.83 | 7.27 | 10.7 | 0.79 | 1.27 | 1.92 | 2.76 | 42.3 | 45.0 | 49.1 | 53.9 | 25.6 | 28.3 | | |
| 2-1/8 | 4.96 | 8.13 | 12.1 | 17.8 | 1.19 | 1.90 | 2.84 | 4.19 | 69.9 | 73.5 | 80.0 | 85.8 | 45.4 | 50.4 | | |
| 2-5/8 | 7.0 | 11.5 | 17.1 | 25.0 | 1.71 | 2.61 | 3.91 | 5.53 | 115.5 | 123.0 | 132.0 | 141.0 | 72.9 | 79.9 | | |
| 3-1/8 | 11.4 | 18.5 | 27.4 | 40.6 | 2.59 | 3.92 | 5.81 | 8.31 | 192 | 204 | 215 | 229 | 114.0 | 124.0 | | |
| 3-5/8 | 15.6 | 25.4 | 38.5 | 56.7 | 3.85 | 5.79 | 8.53 | 12.2 | 259 | 277 | 295 | 308 | 158.0 | 171.0 | | |
| 4-1/8 | 20.7 | 33.0 | 50.5 | 74.7 | 5.67 | 8.51 | 12.7 | 18.4 | 429 | 462 | 495 | 519 | 249.0 | 270.0 | | |
| 4-5/8 | 28.3 | 43.1 | 64.7 | 97.0 | 8.43 | 12.7 | 19.0 | 28.2 | 534 | 579 | 608 | 637 | 308 | 341 | | |
| 6-1/8 | 46.4 | 73.9 | 112.4 | 167.0 | 12.7 | 19.0 | 28.2 | 42.0 | 960 | 1040 | 1090 | 1150 | 540 | 600 | | |
| | | | | | | | | | 1500 | 1500 | 1500 | 1500 | 880 | 974 | 341 | |

| R-507 | Line Size | Suction Lines | | | | | Liquid Lines | | | | | Discharge Lines | | | | |
|---------------------------|--------------------------|---------------------|---------------|---------------|--------------------------|--------------|--------------------|--------------|----------|--------------------------|-------|------------------------|------|------|--|--|
| | | Velocity = 1500 fpm | | | | | Velocity = 150 fpm | | | | | ΔT = 1°F, Δp = 2.2 psi | | | | |
| | | ΔT = 1°F | Δp = 0.50 psi | Δp = 0.72 psi | Δp = 1.0 psi | Δp = 1.3 psi | ΔT = 1°F | Δp = 2.2 psi | ΔT = 1°F | Δp = 3.6 psi | | | | | | |
| Type L Copper OD (Inches) | Suction Temperature (°F) | -40 | -20 | 0 | Suction Temperature (°F) | -20 | 20 | 20 | 20 | Suction Temperature (°F) | -20 | 20 | 20 | 20 | | |
| 3/8 | 0.10 | 0.16 | 0.25 | 0.38 | 0.03 | 0.04 | 0.07 | 0.10 | 1.44 | 1.58 | 0.71 | 0.78 | 0.40 | 0.45 | | |
| 1/2 | 0.18 | 0.30 | 0.47 | 0.72 | 0.06 | 0.10 | 0.16 | 0.24 | 2.75 | 3.02 | 1.71 | 1.88 | 0.95 | 1.05 | | |
| 5/8 | 0.29 | 0.46 | 0.70 | 1.16 | 0.11 | 0.19 | 0.30 | 0.45 | 4.42 | 4.85 | 3.23 | 3.55 | 1.78 | 1.97 | | |
| 7/8 | 0.61 | 1.00 | 1.50 | 2.21 | 0.20 | 0.35 | 0.52 | 0.79 | 9.18 | 9.90 | 10.1 | 10.9 | 5.38 | 5.85 | | |
| 1-1/8 | 0.93 | 1.70 | 2.69 | 4.11 | 0.32 | 0.52 | 0.80 | 1.20 | 15.6 | 17.2 | 17.5 | 19.2 | 9.38 | 10.4 | | |
| 1-3/8 | 1.31 | 2.59 | 4.10 | 6.26 | 0.49 | 0.80 | 1.20 | 1.89 | 26.6 | 29.6 | 29.5 | 33.6 | 16.2 | 18.1 | | |
| 1-5/8 | 1.82 | 3.67 | 5.81 | 8.86 | 0.73 | 1.24 | 1.84 | 2.84 | 44.3 | 48.4 | 53.2 | 57.5 | 28.7 | 31.5 | | |
| 2-1/8 | 2.87 | 6.39 | 10.1 | 15.4 | 1.12 | 1.92 | 2.84 | 4.32 | 72.2 | 78.6 | 84.4 | 101 | 53.0 | 58.8 | | |
| 2-5/8 | 3.95 | 9.85 | 15.6 | 23.6 | 1.62 | 2.84 | 4.32 | 6.63 | 123.0 | 134.0 | 141.0 | 158.0 | 72.9 | 79.9 | | |
| 3-1/8 | 6.2 | 14.1 | 22.2 | 33.9 | 2.49 | 4.32 | 6.63 | 9.9 | 199 | 214 | 222</ | | | | | |



Fluid Flow Equations

Bernoulli equation:

$$\frac{P_1 \rho_c}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2 \rho_c}{\gamma} + \frac{V_2^2}{2g} + z_2; \quad \gamma = \rho g$$

Reynolds Number:

$$Re = \frac{vD}{\nu} = \frac{vD\rho}{\mu}$$

Colebrook's equation:

$$\frac{1}{\sqrt{f}} = -2 \log_{10} \left[\frac{\epsilon/D}{3.7} + \frac{2.51}{Re \sqrt{f}} \right]$$

Darcy-Weisbach equation:

$$h_f = f \frac{L_c}{D} \frac{v^2}{2g}$$

Orifice equation (incompressible flow):

$$m = C_f A_o \sqrt{2g \rho \Delta P}; \quad R_c > 250$$

Orifice equation (vapor flow):

$$m = C_f A_o \sqrt{\frac{2k}{k-1} P_o g_c v_o \left(\frac{P_d}{P_o} \right) \left[1 - \left(\frac{P_d}{P_o} \right)^{(k-1)/k} \right]}$$

where $\frac{P_d}{P_o} >$ critical pressure ratio

Critical pressure ratio:

$$\frac{P_d}{P_o} = \left(\frac{2}{k+1} \right)^{k/(k-1)}$$

Nomenclature

| | | | |
|----------|---------------------------------|---------------------------------------|---------------------|
| A_o | orifice area | ft ² | m ² |
| C_f | flow coefficient | --- | --- |
| D | diameter | ft | m |
| f | friction factor | --- | --- |
| g_c | gravitational conversion factor | 32.174 lbm-ft/lbf-sec ² | 1.0 |
| k | specific heat ratio | --- | --- |
| h_f | head loss due to friction | ft | m |
| L_c | equivalent length | ft | m |
| m | mass flow rate | lbm/sec | kg/sec |
| p | pressure | lbf/ft ² | Pa |
| Re | Reynold's Number | --- | --- |
| v | velocity | ft/sec | m/sec |
| z | height | ft | m |
| e | effective roughness | ft | m |
| γ | specific weight | lbm/ft ³ -sec ² | N/m ³ |
| μ | absolute viscosity | lb-sec/ft ² | Pa-sec |
| ν | kinematic viscosity | ft ² /sec | m ² /sec |
| ρ | density | lbm/ft ³ | kg/m ³ |

Subscripts: m = upstream; d = downstream

Physical Constants

| | | | |
|-------|--------------------------------------|--------------------------------------|------------------------------------|
| g | standard acceleration due to gravity | 32.1740 ft/sec ² | 9.80665 m/sec ² |
| k | Boltzmann's constant | 5.6573066x10 ⁻²⁴ ft-lbf/R | 1.380658x10 ⁻²³ kJ/K |
| N_A | Avogadro's constant | 2.71510576x10 ²³ lb/mol | 6.0221419x10 ²³ /kg mol |
| R | universal gas constant | 1545.349 ft-lbf/lb-mol-R | 8.314471 kJ/kg-mol-K |

Refrigerant Data

| ASHRAE Number | Chemical Name | Sporlan Letter Designation | Color Designation (PMS No.) | ASHRAE 34 Safety Group | CAS Registry Number | Critical Values ² Temperature (°F) | Pressure (psia) | Specific Vol (ft ³ /lb.) | Molecular Weight |
|---------------|-------------------------------------------|----------------------------|-----------------------------|------------------------|---------------------|-----------------------------------------------|-----------------|-------------------------------------|------------------|
| R-10 | tetrachloromethane (carbon tetrachloride) | | | B1 | 56-23-5 | 542.03 | 661.27 | 0.0287 | 153.82 |
| R-11 | trichlorofluoromethane | H | Orange (021) | A1 | 75-29-4 | 538.33 | 639.27 | 0.028 | 137.27 |
| R-12 | dichlorodifluoromethane | F | White (N/A) | A1 | 75-71-8 | 233.55 | 599.89 | 0.0284 | 120.91 |
| R-12B1 | bromochlorodifluoromethane (halon 1211) | | | A1 | 353-59-3 | 398.94 | 594.94 | 0.0225 | 165.36 |
| R-13 | trichlorofluoromethane | E | Light Blue (2975) | A1 | 75-79-9 | 83.71 | 592.31 | 0.0275 | 104.46 |
| R-13B1 | bromotrifluoromethane (halon 1301) | T | Pinkish-Red/Coral (177) | A1 | 75-63-8 | 152.80 | 574.90 | 0.0215 | 148.91 |
| R-14 | tetrafluoromethane (carbon tetrafluoride) | | | A1 | 75-73-9 | -50.15 | 543.89 | 0.0296 | 88.01 |
| R-20 | trichloroethane (chlorofom) | | | B1 | 75-69-3 | 504.23 | 734.61 | 0.0234 | 119.39 |
| R-21 | dichlorodifluoroethane | | | B1 | 75-43-4 | 353.21 | 751.30 | 0.0306 | 102.92 |
| R-22 | chlorodifluoroethane | V | Light Green (352) | A1 | 75-45-6 | 205.06 | 723.74 | 0.0306 | 86.47 |
| R-22B1 | bromochlorodifluoroethane (halon 1201) | | | A1 | 353-81-2 | 281.88 | 714.33 | 0.0232 | 120.92 |
| R-23 | trifluoroethane | G | Light Blue-Gray (428) | A1 | 75-46-7 | 78.66 | 701.40 | 0.0305 | 70.01 |
| R-30 | dichloromethane (methylene chloride) | | | B2 | 75-45-6 | 455.27 | 881.83 | 0.037 | 84.93 |
| R-31 | chlorodifluoroethane | | | B1 | 593-70-4 | 320.17 | 734.20 | 0.0275 | 104.46 |
| R-32 | difluoroethane (methylene fluoride) | | | A2 | 75-10-5 | 172.59 | 638.61 | 0.0378 | 52.02 |
| R-40 | chloromethane (methyl chloride) | | | B2 | 74-87-3 | 289.49 | 665.95 | 0.0446 | 50.49 |
| R-410 | fluoromethane (methyl fluoride) | | | A3 | 593-53-3 | 111.43 | 655.29 | 0.0968 | 34.03 |
| R-50 | methane | | | A3 | 74-82-8 | -118.70 | 666.40 | 0.0906 | 16.04 |
| R-60 | hexachloroethane | | | B3 | 67-72-1 | 808.3 | 571 | 0.0284 | 236.74 |
| R-113 | 1,1,2-trichloro-1,2,2-trifluoroethane | | | A1 | 76-13-1 | 417.31 | 492.00 | 0.0286 | 167.37 |
| R-134 | 1,2-dichloro-1,1,2,2-tetrafluoroethane | B | Dark Purple/Violet (266) | A1 | 76-14-2 | 294.22 | 472.39 | 0.0276 | 170.92 |
| R-115 | chloropentafluoroethane | | | A1 | 76-15-3 | 175.91 | 452.52 | 0.0261 | 154.47 |
| R-116 | hexafluoroethane | | | A1 | 76-16-4 | 67.78 | 441.20 | 0.0298 | 138.01 |
| R-122 | 2,2-dichloro-1,1,1-trifluoroethane | | | B1 | 366-83-2 | 262.63 | 531.10 | 0.0291 | 152.93 |
| R-124 | 2-chloro-1,1,1,2-tetrafluoroethane | M | Deep Green (335) | A1 | 2837-89-0 | 252.10 | 525.66 | 0.0286 | 136.48 |
| R-125 | pentafluoroethane | | | A1 | 354-33-6 | 151.12 | 526.34 | 0.0280 | 120.02 |
| R-133 | 1,1,1-tetrafluoroethane | | | A1 | 75-72-5 | 78.65 | 720.55 | 0.0315 | 84.16 |
| R-134a | 1,1,2,2-tetrafluoroethane | J | Light Blue (2975) | A1 | 811-97-2 | 213.91 | 588.75 | 0.0283 | 102.03 |
| R-141b | 1,1-dichloro-1,1-fluoroethane | | | A1 | 1717-00-6 | 399.56 | 616.41 | 0.0348 | 116.95 |
| R-142b | 1,1-chloro-1,1-difluoroethane | | | A2 | 75-46-3 | 278.76 | 597.89 | 0.0388 | 100.50 |
| R-143a | 1,1,1-trifluoroethane | | | A2 | 429-46-2 | 163.20 | 547.60 | 0.0370 | 84.04 |
| R-150 | 1,2-dichloroethane | | | A2 | 107-06-2 | 55.1 | 778.9 | 0.0384 | 98.96 |
| R-150a | 1,1-dichloroethane | | | A2 | 75-34-3 | 481.7 | 735.3 | 0.0378 | 96.95 |
| R-152a | 1,1-difluoroethane | | | A2 | 75-07-6 | 228.07 | 655.10 | 0.0435 | 69.69 |
| R-160 | chloroethane (ethyl chloride) | | | A3 | 75-00-3 | 369.1 | 764 | 0.0434 | 64.51 |
| R-160B1 | ethyl bromide (halon 2001) | | | A3 | 74-48-4 | 447.3 | 903.6 | 0.036 | 108.96 |
| R-161 | fluoroethane (ethyl fluoride) | | | A3 | 353-36-5 | 216.9 | 662 | 0.0378 | 48.06 |
| R-170 | ethane | K | | A3 | 74-84-0 | 89.22 | 705.59 | 0.1120 | 30.07 |
| R-227ea | 1,1,1,2,3,3,3-heptafluoropropane | | | A1 | 431-89-0 | 217.04 | 632.21 | 0.0276 | 170.03 |
| R-229ea | 1,1,2,2,3,3,3-heptafluoropropane | | | A1 | 431-89-0 | 217.04 | 632.21 | 0.0276 | 170.03 |
| R-236fa | 1,1,1,3,3,3-hexafluoropropane | | | A1 | 690-39-1 | 256.86 | 464.12 | 0.0291 | 152.04 |
| R-245ca | 1,1,2,2,2-pentafluoropropane | | | A1 | 678-98-7 | 345.96 | 569.27 | 0.0306 | 134.05 |
| R-245fa | 1,1,1,3,3,3-pentafluoropropane | | | A1 | 409-73-11 | 309.28 | 577.94 | 0.0310 | 134.05 |
| R-C270 | cyclopentane | | | A3 | 75-19-4 | 257.27 | 869.23 | 0.0617 | 42.08 |
| R-290 | propane | | | A3 | 74-88-6 | 206.06 | 616.07 | 0.0706 | 44.10 |
| R-C318 | octafluorocyclobutane | | | A1 | 115-25-3 | 239.41 | 402.84 | 0.0278 | 200.04 |
| R-600a | n-butane | | | A3 | 186-97-8 | 305.62 | 509.66 | 0.0478 | 58.12 |
| R-600a | 2-methyl propane (isobutane) | | | A3 | 75-28-5 | 274.46 | 527.94 | 0.0714 | 58.12 |
| R-601 | n-pentane | | | A3 | 109-66-0 | 305.8 | 467 | 0.0630 | 72.15 |
| R-601a | 2-methyl butane (isopentane) | | | A3 | 76-74-4 | 370.0 | 490 | 0.0679 | 72.15 |
| R-610 | ethyl ether | | | A3 | 60-29-7 | 380.57 | 527.94 | 0.0669 | 74.12 |
| R-611 | methyl formate | | | B2 | 107-31-3 | 416.29 | 670.23 | 0.0459 | 60.05 |
| R-612 | ethyl amine | | | B2 | 74-89-5 | 314.4 | 1062.0 | 0.0714 | 31.06 |
| R-631 | ethyl amine | | | B2 | 75-04-7 | 361.4 | 815.11 | 0.0832 | 45.08 |
| R-702n | normal hydrogen | | | A3 | 1332-74-0 | -399.93 | 190.75 | 0.5230 | 2.02 |
| R-704 | helium | | | A1 | 7440-39-7 | -452.31 | 4.00 | 0.2280 | 4.00 |
| R-717 | ammonia | A | Silver | A3 | 7669-11-7 | 269.99 | 1943.7 | 0.1643 | 17.03 |
| R-718 | water/steam | | | A1 | 7732-18-5 | 705.18 | 3199.2 | 0.0497 | 18.02 |
| R-720 | neon | | | A1 | 7448-01-9 | -379.58 | 388.50 | 0.0332 | 20.18 |
| R-728 | nitrogen | | | A1 | 7727-37-9 | -252.52 | 572.91 | 0.5710 | 28.01 |
| R-729 | air | | | A1 | 7727-37-9 | -220.86 | 548.97 | 0.0529 | 28.07 |
| R-732 | oxygen | | | A1 | 7782-44-7 | -181.42 | 731.42 | 0.0367 | 32.00 |
| R-740 | argon | | | A1 | 7449-39-1 | -188.48 | 714.68 | 0.0332 | 39.95 |
| R-744 | carbon dioxide | | | A1 | 124-38-9 | 87.76 | 1069.9 | 0.0342 | 44.01 |
| R-744A | nitrous oxide | | | A1 | 10028-97-2 | 97.61 | 1050.1 | 0.0353 | 44.01 |
| R-764 | sulfur dioxide | | | B1 | 7448-09-5 | 315.77 | 1142.9 | 0.0305 | 64.06 |
| R-1120 | trichloroethane (trialeane) | | | B1 | 78-01-6 | 568 | 712 | 0.0312 | 131.39 |
| R-1130 | trans-1,2-dichloroethane (dielene) | | | B3 | 156-60-5 | 489.9 | 795 | 0.0365 | 96.95 |
| R-1132a | 1,2-difluoroethane (vinylidene fluoride) | | | B3 | 75-36-7 | 65.46 | 646.62 | 0.0285 | 64.04 |
| R-1140 | chloroethane (vinyl chloride) | | | B3 | 75-01-4 | 305.3 | 746.9 | 0.0362 | 62.50 |
| R-1150 | ethene (ethylene) | | | A3 | 74-85-1 | 485.5 | 731.00 | 0.0748 | 28.05 |
| R-1270 | propene (propylene) | | | A3 | 115-07-1 | 198.36 | 676.54 | 0.0717 | 42.08 |

Refrigerant Blends

| ASHRAE Number | Composition (mass percentages) | Sporlan Letter Designation | Color Designation (PMS No.) | ASHRAE 34 Safety Group | Trade Name | Critical Values ² Temperature (°F) | Pressure (psia) | Specific Vol (ft ³ /lb.) | Molecular Weight |
|---------------|------------------------------------------|----------------------------|-----------------------------|------------------------|----------------------------|-----------------------------------------------|-----------------|-------------------------------------|------------------|
| R-401A | R-22/R-152a/R-124 (53/13/34) | X | Pinkish-Red/Coral (177) | A1 | MP39 | 221.48 | 669.03 | 0.0324 | 94.44 |
| R-401B | R-22/R-152a/R-124 (61/17/28) | F | Yellow-Brown/Mustard (124) | A1 | MP66 | 218.28 | 679.07 | 0.0322 | 92.84 |
| R-402A | R-125/R-290/R-2 (80/2/18) | L | Light Brown/Gand (461) | A1 | HP81 | 182.85 | 614.11 | 0.0241 | 101.50 |
| R-402B | R-125/R-290/R-2 (38/2/60) | R | Green-Brown/Olive (385) | A1 | HP81 | 181.45 | 656.35 | 0.0299 | 94.71 |
| R-402A | R-22/R-290/R-218 (5/75/20) | | | A1 | 1SC20N® 69-S | 196.2 | 660 | 0.0320 | 91.99 |
| R-404A | R-22/R-220/R-142b (65/6/28) | | | A1 | 1SC20N® 69-L | 191.7 | 638 | 0.0320 | 91.99 |
| R-404A | R-125/R-143a/R-134a (44/52/4) | S | Orange (021) | A1 | HPR2, FX-70 | 161.86 | 541.71 | 0.0328 | 97.60 |
| R-405A | R-22/R-152a/R-142b/R-C218 (49/75/5/42.5) | | | A1 | GREENCOOL G2015 | 222.8 | 622 | 0.0322 | 111.91 |
| R-405B | R-22/R-600a/R-142b (55/41/4) | | | A2 | GHG | 241.7 | 708 | 0.0322 | 100.26 |
| R-406B | R-22/R-600a/R-142b (65/4/31) | | | A2 | GHG-HP | | | 0.0322 | 88.58 |
| R-407A | R-32/R-125/R-134a (20/40/40) | V | Line Green (368) | A1 | Klea® 69 | 179.44 | 650.77 | 0.0302 | 90.11 |
| R-407B | R-32/R-125/R-134a (18/70/28) | | | A1 | Klea® 61 | 185.68 | 630.21 | 0.0295 | 102.94 |
| R-407C | R-32/R-125/R-134a (23/25/52) | N | Medium Brown (471) | A1 | Klea® 66, Sava 9000 | 186.89 | 672.11 | 0.0312 | 86.20 |
| R-407D | R-32/R-125/R-134a (15/15/70) | | | A1 | Dark Brown/Chocolate (450) | 186.82 | 650.21 | 0.0315 | 90.96 |
| R-407E | R-32/R-125/R-134a (25/15/60) | | | A1 | | 181.78 | 686.59 | 0.0320 | 83.78 |
| R-408A | R-125/R-143a/R-22 (7/46/47) | | | A1 | | 162.30 | 632.40 | 0.0292 | 96.46 |
| R-408A | R-22/R-124/R-142b (80/25/15) | | | A1 | FX-5 | 224.46 | 667.17 | 0.0316 | 97.43 |
| R-408B | R-22/R-124/R-142b (85/25/10) | | | A1 | FX-57 | 219.84 | 683.24 | 0.0313 | 96.67 |
| R-410A | R-32/R-125 (50/50) | | | A1 | AC-20, Sava® 9100, Puron® | 198.20 | 639.81 | 0.0320 | 91.91 |
| R-411A | R-127/R-22/R-152a (11/5/87.5/11) | | | A2 | GREENCOOL G2018A | 210.31 | 718.46 | 0.0329 | 82.36 |
| R-411B | R-127/R-22/R-152a (3/94/3) | | | A2 | GREENCOOL G2018B | 204.71 | 717.54 | 0.0322 | 83.07 |
| R-411C | R-22/R-152a (3/98.5/1.5) | | | A2 | GREENCOOL G2018C | 203.9 | 718 | 0.0322 | 83.44 |
| R-412A | R-22/R-218/R-142b (70/5/25) | | | A2 | Acton TFRS | 225.5 | 708 | 0.0322 | 92.17 |
| R-412A | R-218/R-134a/R-600a (9/8/3) | | | A2 | 1SC20N® 49 | 214.5 | 615 | 0.0322 | 103.95 |
| R-414A</ | | | | | | | | | |