

## Thermodynamic Laws

**Zerth 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 science.

**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.

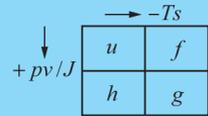
**Third Law:** You can never reach absolute zero.

## 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:**  $g = h - Ts$

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

**Enthalpy:**

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

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

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

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

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

**Velocity of Sound:**

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

### Nomenclature

	I-P	S-I	
<i>a</i>	velocity of sound	ft/sec	m/sec
<i>c<sub>p</sub></i>	isobaric specific heat	Btu/lb <sub>m</sub> ·°R	kJ/kg·°K
<i>c<sub>v</sub></i>	isochoric specific heat	Btu/lb <sub>m</sub> ·°R	kJ/kg·°K
<i>f</i>	Helmholtz function	Btu/lb <sub>m</sub>	kJ/kg
<i>g</i>	Gibbs function	Btu/lb <sub>m</sub>	kJ/kg
<i>g<sub>c</sub></i>	gravitational conversion factor	32.174 lb <sub>m</sub> ·ft/lb <sub>f</sub> ·sec <sup>2</sup>	1.0
<i>h</i>	enthalpy	Btu/lb <sub>m</sub>	kJ/kg
<i>J</i>	Joule's constant	778.16926 ft·lb <sub>f</sub> /Btu	1.0
<i>m</i>	mass	lb <sub>m</sub>	kg
<i>M</i>	molecular weight	---	---
<i>N</i>	no. of molecules	---	---
<i>n</i>	no. of moles	lb mol	kg mol
<i>p</i>	pressure	lb <sub>f</sub> /ft <sup>2</sup>	kPa
<i>Q</i>	heat	Btu	kJ
<i>s</i>	entropy	Btu/lb <sub>m</sub> ·°R	kJ/kg·°K
<i>T</i>	temperature	°R	°K
<i>u</i>	internal energy	Btu/lb <sub>m</sub>	kJ/kg
<i>v</i>	specific volume	ft <sup>3</sup> /lb <sub>m</sub>	m <sup>3</sup> /kg
<i>V</i>	volume	ft <sup>3</sup>	m <sup>3</sup>
<i>W</i>	work	ft·lb <sub>f</sub>	kJ
<i>κ</i>	isothermal compressibility	ft <sup>2</sup> /lb <sub>f</sub>	(kPa) <sup>-1</sup>
<i>κ<sub>s</sub></i>	adiabatic compressibility	ft <sup>2</sup> /lb <sub>f</sub>	(kPa) <sup>-1</sup>
<i>γ</i>	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 Type L Copper OD (Inches)	Suction Lines Velocity = 1500 fpm					Liquid Lines Velocity = 150 fpm					Discharge Lines Velocity = 150 fpm				
		Suction Temperature (°F)					Suction Temperature (°F)					Suction Temperature (°F)				
		-40	-20	0	20	40	-40	-20	0	20	40	-20	20	40	60	80
	3/8	0.09	0.14	0.22	0.33	0.02	0.04	0.06	0.09	0.14	2.27	2.40	0.94	0.98	0.39	0.42
	1/2	0.17	0.27	0.43	0.64	0.06	0.10	0.15	0.23	4.35	4.58	2.25	2.37	0.92	1.00	
	5/8	0.27	0.44	0.68	1.03	0.11	0.18	0.29	0.43	6.98	7.36	4.25	4.48	1.73	1.88	
	7/8	0.56	0.91	1.42	2.13	0.30	0.49	0.76	1.13	14.5	15.3	11.3	11.9	4.53	4.93	
	1-1/8	0.95	1.55	2.42	3.63	0.61	0.99	1.54	2.30	24.7	26.0	23.1	24.3	9.16	9.96	
	1-3/8	1.45	2.36	3.69	5.53	1.06	1.74	2.70	4.02	37.6	39.6	40.4	42.6	15.9	17.3	
	1-5/8	2.05	3.35	5.22	7.83	1.69	2.76	4.28	6.37	53.3	56.1	64.1	67.6	25.2	27.4	
	2-1/8	3.57	5.82	9.07	13.6	3.54	5.76	8.82	13.2	92.6	97.6	124	141	52.0	56.5	
	2-5/8	5.51	8.98	14.0	21.0	6.29	10.2	15.8	23.4	143	150	237	250	91.7	99.7	
	3-1/8	7.87	12.8	20.0	30.0	10.1	16.4	25.3	37.5	204	215	379	400	146	159	
	3-5/8	10.6	17.3	27.0	40.6	15.0	24.4	37.7	55.7	276	291	565	595	217	235	
	4-1/8	13.8	22.5	35.1	52.7	21.3	34.5	53.2	78.7	359	378	798	841	305	331	
	5-1/8	21.6	35.1	54.7	82.2	38.3	61.9	95.4	141	559	589	1430	1510	544	590	
	6-1/8	31.0	50.5	78.7	118	61.7	99.8	154	227	803	846	2310	2430	872	947	

R-134a	Line Size Type L Copper OD (Inches)	Suction Lines Velocity = 1500 fpm					Liquid Lines Velocity = 150 fpm					Discharge Lines Velocity = 150 fpm				
		Suction Temperature (°F)					Suction Temperature (°F)					Suction Temperature (°F)				
		-20	0	20	40	60	-20	0	20	40	60	-20	20	40	60	80
	3/8	0.08	0.13	0.21	0.32	0.03	0.06	0.10	0.16	0.23	0.68	0.73	0.28	0.30	0.40	0.44
	1/2	0.15	0.25	0.40	0.60	0.08	0.13	0.21	0.33	1.63	1.77	0.66	0.72	0.94	1.05	
	5/8	0.24	0.40	0.64	0.99	0.16	0.26	0.43	0.67	3.10	3.36	1.23	1.35	1.77	1.96	
	7/8	0.50	0.84	1.33	2.05	0.42	0.67	1.06	1.66	9.38	10.3	8.69	9.53	4.63	5.12	
	1-1/8	0.86	1.43	2.27	3.46	0.76	1.23	2.00	3.06	16.0	17.5	17.7	19.4	9.33	10.3	
	1-3/8	1.31	2.17	3.46	5.30	1.15	1.90	3.06	4.61	24.4	26.7	31.0	34.0	16.2	18.0	
	1-5/8	1.85	3.09	4.90	7.38	1.65	2.76	4.32	6.50	34.5	37.8	49.1	53.9	25.6	28.3	
	2-1/8	3.21	5.35	8.53	12.9	3.49	5.74	8.99	13.5	60.0	65.8	102	112	52.8	58.4	
	2-5/8	4.96	8.25	13.1	20.0	5.19	8.49	12.7	19.0	92.5	101	181	199	92.9	103	
	3-1/8	7.07	11.8	18.8	28.5	7.52	12.1	18.6	28.1	132	145	289	317	148	164	
	3-5/8	9.57	15.9	25.4	38.8	10.1	16.6	25.5	38.8	179	196	431	472	219	243	
	4-1/8	12.4	20.7	33.0	50.7	13.4	22.1	34.2	51.4	232	255	608	667	308	341	
	5-1/8	19.4	32.3	51.4	77.3	20.3	34.2	51.4	77.3	387	425	1080	1200	549	606	
	6-1/8	27.9	46.4	73.9	111	29.2	48.8	74.4	111	570	615	1750	1920	880	974	

R-404A	Line Size Type L Copper OD (Inches)	Suction Lines Velocity = 1500 fpm					Liquid Lines Velocity = 150 fpm					Discharge Lines Velocity = 150 fpm				
		Suction Temperature (°F)					Suction Temperature (°F)					Suction Temperature (°F)				
		-40	-20	0	20	40	-40	-20	0	20	40	-20	20	40	60	80
	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	0.17	0.29	0.46	0.70	0.06	0.10	0.15	0.23	2.81	3.09	1.73	1.90	0.94	1.05	
	5/8	0.28	0.46	0.73	1.12	0.11	0.18	0.29	0.44	4.52	4.96	3.27	3.59	1.77	1.96	
	7/8	0.58	0.96	1.52	2.33	0.29	0.49	0.77	1.16	9.38	10.3	8.69	9.53	4.63	5.12	
	1-1/8	0.99	1.64	2.60	3.98	0.60	0.99	1.56	2.35	16.0	17.5	17.7	19.4	9.33	10.3	
	1-3/8	1.50	2.49	3.95	6.05	1.05	1.74	2.73	4.10	24.4	26.7	31.0	34.0	16.2	18.0	
	1-5/8	2.13	3.53	5.80	8.57	1.67	2.76	4.32	6.50	34.5	37.8	49.1	53.9	25.6	28.3	
	2-1/8	3.70	6.13	9.74	14.9	3.49	5.74	8.99	13.5	60.0	65.8	102	112	52.8	58.4	
	2-5/8	5.70	9.46	15.0	23.0	5.19	8.49	12.7	19.0	92.5	101	181	199	92.9	103	
	3-1/8	8.14	13.5	21.4	32.8	7.52	12.1	18.6	28.1	132	145	289	317	148	164	
	3-5/8	11.0	18.3	29.0	44.4	10.1	16.6	25.5	38.8	179	196	431	472	219	243	
	4-1/8	14.3	23.7	37.7	57.7	13.4	22.1	34.2	51.4	232	255	608	667	308	341	
	5-1/8	22.3	37.0	58.7	88.9	20.3	34.2	51.4	77.3	387	425	1080	1200	549	606	
	6-1/8	32.1	53.2	84.4	129	29.2	48.8	74.4	111	570	615	1750	1920	880	974	

R-507	Line Size Type L Copper OD (Inches)	Suction Lines Velocity = 1500 fpm					Liquid Lines Velocity = 150 fpm					Discharge Lines Velocity = 150 fpm				
		Suction Temperature (°F)					Suction Temperature (°F)					Suction Temperature (°F)				
		-40	-20	0	20	40	-40	-20	0	20	40	-20	20	40	60	80
	3/8	0.10	0.16	0.25	0.38	0.03	0.04	0.07	0.10	1.44	1.58	0.71	0.79	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	0.48	0.76	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	1.58	2.41	0.30	0.50	0.79	1.16	9.16	10.1	8.58	9.43	4.65	5.16	
	1-1/8	1.03	1.70	2.69	4.11	0.62	1.02	1.60	2.40	15.6	17.2	17.5	19.2	9.38	10.4	
	1-3/8	1.57	2.59	4.10	6.26	1.09	1.79	2.80	4.20	23.8	26.1	30.6	33.6	16.3	18.1	
	1-5/8	2.22	3.67	5.81	8.86	1.73	2.84	4.43	6.64	33.7	37.0	48.4	53.2	25.7	28.5	
	2-1/8	3.87	6.39	10.1	15.4	3.61	5.92	9.22	13.8	58.6	64.4	101	111	53.0	58.8	
	2-5/8	5.97	9.85	15.6	23.8	5.42	9.0	13.8	20.4	90.3	99.2	179	196	93.4	104	
	3-1/8	8.52	14.1	22.2	33.9	8.03	13.1	20.0	30.0	129	142	286	314	149	165	
	3-5/8	11.5	19.0	30.1	45.9	10.9	18.0	27.0	40.0	174	192	425	467	220	244	
	4															

## Fluid Flow Equations

**Bernoulli equation:**

$$\frac{P_1 \rho g_c}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{P_2 \rho g_c}{\gamma} + \frac{v_2^2}{2g} + z_2; \quad \gamma = \rho g$$

**Reynolds Number:**

$$R_e = \frac{vD}{\nu} = \frac{vD\rho}{\mu g_c}$$

**Colebrook's equation:**

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

**Darcy-Weisbach equation:**

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

**Orifice equation (incompressible flow):**

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

**Orifice equation (vapor flow):**

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

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

**Critical pressure ratio:**

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

### Nomenclature

	I-P	S-I	
$A_o$	orifice area	ft <sup>2</sup>	m <sup>2</sup>
$C_f$	flow coefficient	---	---
$D$	diameter	ft	m
$f$	friction factor	---	---
$g_c$	gravitational conversion factor	32.174 lb <sub>m</sub> -ft/lb <sub>f</sub> -sec <sup>2</sup>	1.0
$h$	specific heat ratio	---	---
$h_f$	head loss due to friction	ft	m
$L_e$	equivalent length	ft	m
$m$	mass flow rate	lb <sub>m</sub> /sec	kg/sec
$p$	pressure	lb <sub>f</sub> /ft <sup>2</sup>	Pa
$R_e$	Reynold's Number	---	---
$v$	velocity	ft/sec	m/sec
$z$	height	ft	m
$\epsilon$	effective roughness	ft	m
$\gamma$	specific weight	lb <sub>m</sub> /ft <sup>2</sup> -sec <sup>2</sup>	N/m <sup>3</sup>
$\mu$	absolute viscosity	lb <sub>f</sub> -sec/ft <sup>2</sup>	Pa-sec
$\nu$	kinematic viscosity	ft <sup>2</sup> /sec	m <sup>2</sup> /sec
$\rho$	density	lb <sub>m</sub> /ft <sup>3</sup>	kg/m <sup>3</sup>

Subscripts:  $u$  = upstream;  $d$  = downstream

### Physical Constants

	I-P	S-I	
$g$	standard acceleration due to gravity	32.1740 ft/sec <sup>2</sup>	9.80665 m/sec <sup>2</sup>
$k$	Boltzmann's constant	5.657308x10 <sup>-24</sup> ft-lb <sub>f</sub> /°R	1.380650x10 <sup>-28</sup> kJ/°K
$N_A$	Avogadro's constant	2.73159766x10 <sup>26</sup> / lb mol	6.02214199x10 <sup>26</sup> / kg mol
$R$	universal gas constant	1545.349 ft-lb <sub>f</sub> /lb mol-°R	8.314471 kJ/kg mol-°K

## Refrigerant Data

ASHRAE Number	Chemical Name	Sporlan Letter Designation	Color Designation (PMS No.) <sup>1</sup>	ASHRAE 34 Safety Group	CAS Registry Number	Critical Values <sup>2</sup>			Molecular Weight
						Temperature (°F)	Pressure (psia)	Specific Vol (ft <sup>3</sup> /lb <sub>m</sub> )	
R-10	tetrachloromethane (carbon tetrachloride)			B1	56-23-5	542.03	661.37	0.0287	153.82
R-11	trichlorofluoromethane	H	Orange (021)	A1	75-69-4	398.27	659.27	0.0289	137.37
R-12	dichlorodifluoromethane	F	White (N/A)	A1	75-71-8	233.55	599.89	0.0284	120.91
R-12B1	bromochlorodifluoromethane (halon 1211)				353-59-3	308.84	594.94	0.0225	165.36
R-13	chlorotrifluoromethane	E	Light Blue (2975)	A1	75-72-9	83.71	562.31	0.0275	104.46
R-13B1	bromotrifluoromethane (halon 1301)	T	Pinkish-Red/Coral (177)	A1	75-63-8	152.60	574.90	0.0215	148.91
R-14	tetrafluoromethane (carbon tetrafluoride)		Yellow-Brown/Mustard (124)	A1	75-73-0	-50.15	543.89	0.0256	88.01
R-20	trichloromethane (chloroform)				67-66-3	504.23	794.81	0.0324	119.38
R-21	dichlorofluoromethane				75-43-4	353.21	751.30	0.0306	102.92
R-22	chlorodifluoromethane	V	Light Green (352)	A1	75-45-6	205.06	723.74	0.0306	86.47
R-22B1	bromodifluoromethane (halon 1201)				1511-62-2	281.89	744.33	0.0204	130.92
R-23	trifluoromethane	G	Light Blue-Gray (428)	A1	75-46-7	78.66	701.40	0.0305	70.01
R-30	dichloromethane (methylene chloride)				75-09-2	455.27	861.63	0.0357	84.93
R-31	chlorofluoromethane				593-70-4	305.17	744.20	0.0371	68.48
R-32	difluoromethane (methylene fluoride)				172-59	172.59	838.61	0.0378	52.02
R-40	chloromethane (methyl chloride)				74-87-3	289.49	965.95	0.0446	50.49
R-41	fluoromethane (methyl fluoride)				593-53-3	111.43	855.29	0.0506	34.03
R-50	methane	A3	74-82-8	-116.70	666.40	0.0988	16.04	0.0284	236.74
R-110	hexachloroethane				67-72-1	808.3	571	0.0286	187.37
R-113	1,1,2-trichloro-1,2,2-trifluoroethane		Dark Purple/Violet (266)	A1	76-13-1	417.31	492.00	0.0276	170.92
R-114	1,2-dichloro-1,1,2,2-tetrafluoroethane	B	Dark Blue/Navy (302)	A1	76-14-2	294.22	472.39	0.0261	154.47
R-115	chloropentafluoroethane				76-15-3	175.91	452.52	0.0258	138.01
R-116	hexafluoroethane		Dark Grey (424)	A1	76-16-4	67.78	441.20	0.0291	152.93
R-123	2,2-dichloro-1,1,1-trifluoroethane		Light Blue-Gray (428)	B1	306-83-2	362.63	531.10	0.0286	136.48
R-124	2-chloro-1,1,1,2-tetrafluoroethane	M	Deep Green (335)	A1	2837-89-0	252.10	525.66	0.0280	120.02
R-125	pentafluoroethane		Medium Brown/Tan (465)	A1	354-33-6	151.12	526.34	0.0280	120.02
R-130	1,1,2,2-tetrachloroethane				79-34-5	738.5	847.0	0.0291	152.04
R-134a	1,1,1,2-tetrafluoroethane	J	Light Blue (2975)	A1	811-97-2	213.91	588.75	0.0313	102.03
R-141b	1,1-dichloro-1-fluoroethane				1717-00-6	399.56	616.41	0.0348	116.95
R-142b	1-chloro-1,1-difluoroethane	A2	75-68-3	278.78	597.99	0.0368	100.50	0.0370	84.04
R-143a	1,1,1-trifluoroethane	A2	420-46-2	163.20	547.60	0.0370	84.04	0.0364	98.96
R-150	1,2-dichloroethane				107-06-2	559.1	778.3	0.0435	98.96
R-150a	1,1-dichloroethane				75-34-3	481.7	735.3	0.0435	66.05
R-152a	1,1-difluoroethane	A2	75-37-6	235.87	655.10	0.0435	66.05	0.0435	64.51
R-160	chloroethane (ethyl chloride)				75-00-3	369.1	764	0.0435	108.96
R-160B1	ethyl bromide (halon 2001)				74-96-4	447.3	903.6	0.0435	108.96
R-161	fluoroethane (ethyl fluoride)				353-36-6	216.0	682	0.0435	48.06
R-170	ethane	K			74-84-0	89.92	706.59	0.0435	30.07
R-227ea	1,1,1,2,3,3,3-heptafluoropropane				431-89-0	217.04	432.21	0.0276	170.03
R-236ea	1,1,1,2,3,3-hexafluoropropane				431-63-0	282.72	507.92	0.0285	152.04
R-236fa	1,1,1,3,3,3-hexafluoropropane				690-39-1	256.86	464.12	0.0291	152.04
R-245ca	1,1,2,2,3-pentafluoropropane				679-86-7	345.96	569.27	0.0306	134.05
R-245fa	1,1,1,3,3-pentafluoropropane	A1	460-73-11	309.29	527.94	0.0310	134.05	0.0617	42.08
R-C270	cyclopropane				75-19-4	257.27	809.23	0.0706	44.10
R-290	propane	A3	74-98-6	206.06	616.07	0.0258	200.04	0.0703	58.12
R-C318	octafluorocyclobutane	A1	115-25-3	239.41	402.84	0.0714	58.12	0.0714	58.12
R-600	n-butane	A3	106-97-8	305.62	550.56	0.0714	58.12	0.0714	58.12
R-600a	2-methyl propane (isobutane)	A3	75-28-5	274.46	527.94	0.0714	58.12	0.0714	58.12
R-601	n-pentane				109-66-0	385.8	487	0.0690	72.15
R-601a	2-methyl butane (isopentane)				78-78-4	370.0	490	0.0679	72.15
R-610	ethyl ether				60-29-7	380.57	527.94	0.0690	74.12
R-611	methyl formate	B2	107-31-3	416.29	870.23	0.0459	60.05	0.0714	31.06
R-630	methyl amine				74-89-5	314.4	1082.0	0.0632	45.08
R-631	ethyl amine				75-04-7	361.4	815.11	0.0632	45.08
R-702n	normal hydrogen	A3	1333-74-0	-399.93	190.75	0.5320	2.02	0.2300	4.00
R-704	helium	A1	7440-59-7	-450.31	32.99	0.0682	17.03	0.0497	18.02
R-717	ammonia	A	Silver	B2	7664-41-7	269.99	1643.7	0.0332	20.18
R-718	water/steam	A1			7732-18-5	705.18	3199.2	0.0332	20.18
R-720	neon	A1	7440-01-9	-379.58	388.50	0.0510	28.01	0.0529	28.97
R-728	nitrogen	A1	7727-37-9	-232.52	492.81	0.0367	32.00	0.0302	39.95
R-729	air				-220.96	548.97	0.0302	39.95	44.01
R-732	oxygen				7782-44-7	-181.42	731.42	0.0302	39.95
R-740	argon	A1	7440-37-1	-188.48	704.68	0.0353	44.01	0.0353	44.01
R-744	carbon dioxide	A1	1273-76-3	31.1	878.0	0.0353	44.01	0.0353	44.01
R-744A	nitrous oxide				10024-97-2	97.61	1050.1	0.0305	64.06
R-764	sulfur dioxide	B1	7446-09-5	315.77	1142.9	0.0312	131.39	0.0312	96.95
R-1120	trichloroethene (trielene)				79-01-6	568	712	0.0385	64.04
R-1130	trans-1,2-dichloroethene (dielene)				156-60-5	469.9	795	0.0385	64.04
R-1132a	1,1-difluoroethene (vinylidene fluoride)				75-38-7	85.46	746.9	0.0748	28.05
R-1140	chloroethene (vinyl chloride)	B3	75-01-4	305.3	746.9	0.0717	58.12	0.0717	58.12
R-1150	ethene (ethylene)	A3	74-85-1	48.55	731.00	0.0717	58.12	0.0717	58.12
R-1270	propene (propylene)	A3	115-07-1	198.36	676.54	0.0717	58.12	0.0717	58.12

## Refrigerant Blends

ASHRAE Number	Composition (mass percentages)	Sporlan Letter Designation	Color Designation (PMS No.) <sup>1</sup>	ASHRAE 34 Safety Group	Trade Name	Critical Values <sup>2</sup>			Molecular Weight
						Temperature (°F)	Pressure (psia)	Specific Vol (ft <sup>3</sup> /lb <sub>m</sub> )	
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 (61/11/28)	F	Yellow-Brown/Mustard (124)	A1	MP66	218.38	679.07	0.0322	92.84
R-402A	R-125/R-290/R-22 (60/2/38)	L	Light Brown/Sand (461)	A1	HP80	168.85	614.11	0.0294	101.55
R-402B	R-125/R-290/R-22 (38/2/60)	R	Green-Brown/Olive (385)	A1	HP91	181.45	656.35	0.0299	94.71
R-403A	R-290/R-22/R-218 (5/75/20)				ISCEON® 69-S	191.7	638	0.0326	91.99
R-403B	R-290/R-22/R-218 (5/56/39)				ISCEON® 69-L	191.7	638	0.0326	103.26
R-404A	R-125/R-143a/R-134a (44/52/4)	S	Orange (021)	A1	HP62, FX-70	161.86	541.71	0.0328	97.60
R-405A	R-22/R-152a/R-142b/R-C318 (45/7/5/42.5)				GREENCOOL G2015	222.8	622	0.0328	111.91
R-406A	R-22/R-600a/R-142b (55/4/41)				GHG	241.7	708	0.0328	89.86
R-406B	R-22/R-600a/R-142b (65/4/31)				GHG-HP	241.7	708	0.0328	88.58
R-407A	R-32/R-125/R-134a (20/40/40)	V	Lime Green (368)	A1	Klea® 60	179.44	650.77	0.0302	90.11
R-407B	R-32/R-125/R-134a (10/70/20)				Klea® 61	165.88	592.21	0.0285	102.94
R-407C	R-32/R-125/R-134a (23/25/52)	N	Medium Brown (471)	A1	Klea® 66, Suva 9000	186.89	672.11	0.0312	86.20
R-407D	R-32/R-125/R-134a (15/15/70)				196.82	650.21	0.0315	90.96	
R-407E	R-32/R-125/R-134a (25/15/60)				191.78	686.59	0.0320	83.78	
R-408A	R-125/R-143a/R-22 (7/46/47)	R	Medium Purple (248)	A1	FX-10	162.30	629.46	0.0325	87.02
R-408B	R-22/R-124/R-142b (60/25/15)	F	Medium Brown/Tan (465)	A1	FX-56	224.46	667.17	0.0318	97.43
R-409B	R-22								