



BORGNAKKE • SONNTAG

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# Fundamentals of Thermodynamics

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8e



# Symbols

$a$	acceleration
$A$	area
$a, A$	specific Helmholtz function and total Helmholtz function
$AF$	air-fuel ratio
$B_S$	adiabatic bulk modulus
$B_T$	isothermal bulk modulus
$c$	velocity of sound
$c$	mass fraction
$C_D$	coefficient of discharge
$C_p$	constant-pressure specific heat
$C_v$	constant-volume specific heat
$C_{po}$	zero-pressure constant-pressure specific heat
$C_{vo}$	zero-pressure constant-volume specific heat
COP	coefficient of performance
CR	compression ratio
$e, E$	specific energy and total energy
EMF	electromotive force
$F$	force
$FA$	fuel-air ratio
$g$	acceleration due to gravity
$g, G$	specific Gibbs function and total Gibbs function
$h, H$	specific enthalpy and total enthalpy
HV	heating value
$i$	electrical current
$I$	irreversibility
$J$	proportionality factor to relate units of work to units of heat
$k$	specific heat ratio: $C_p/C_v$
$K$	equilibrium constant
KE	kinetic energy
$L$	length
$m$	mass
$\dot{m}$	mass flow rate
$M$	molecular mass
$M$	Mach number
$n$	number of moles
$n$	polytropic exponent
$P$	pressure
$P_i$	partial pressure of component $i$ in a mixture
PE	potential energy

$P_r$	reduced pressure $P/P_c$
$P_r$	relative pressure as used in gas tables
$q, Q$	heat transfer per unit mass and total heat transfer
$\dot{Q}$	rate of heat transfer
$Q_H, Q_L$	heat transfer with high-temperature body and heat transfer with low-temperature body; sign determined from context
$R$	gas constant
$\bar{R}$	universal gas constant
$s, S$	specific entropy and total entropy
$S_{\text{gen}}$	entropy generation
$\dot{S}_{\text{gen}}$	rate of entropy generation
$t$	time
$T$	temperature
$T_r$	reduced temperature $T/T_c$
$u, U$	specific internal energy and total internal energy
$v, V$	specific volume and total volume
$v_r$	relative specific volume as used in gas tables
$\mathbf{V}$	velocity
$w, W$	work per unit mass and total work
$\dot{W}$	rate of work, or power
$w^{\text{rev}}$	reversible work between two states
$x$	quality
$y$	gas-phase mole fraction
$y$	extraction fraction
$Z$	elevation
$Z$	compressibility factor
$Z$	electrical charge

## Script Letters

$\mathcal{E}$	electrical potential
$\mathcal{P}$	surface tension
$\mathcal{T}$	tension

## Greek Letters

$\alpha$	residual volume
$\alpha$	dimensionless Helmholtz function $a/RT$
$\alpha_p$	volume expansivity
$\beta$	coefficient of performance for a refrigerator
$\beta'$	coefficient of performance for a heat pump
$\beta_S$	adiabatic compressibility
$\beta_T$	isothermal compressibility
$\delta$	dimensionless density $\rho/\rho_c$
$\eta$	efficiency
$\mu$	chemical potential
$\nu$	stoichiometric coefficient
$\rho$	density
$\tau$	dimensionless temperature variable $T_c/T$
$\tau_0$	dimensionless temperature variable $1 - T_r$
$\Phi$	equivalence ratio
$\phi$	relative humidity

$\phi, \Phi$	exergy or availability for a control mass
$\psi$	exergy, flow availability
$\omega$	humidity ratio or specific humidity
$\omega$	acentric factor

## Subscripts

$c$	property at the critical point
c.v.	control volume
$e$	state of a substance leaving a control volume
$f$	formation
$f$	property of saturated liquid
$fg$	difference in property for saturated vapor and saturated liquid
$g$	property of saturated vapor
$i$	state of a substance entering a control volume
$i$	property of saturated solid
$if$	difference in property for saturated liquid and saturated solid
$ig$	difference in property for saturated vapor and saturated solid
$r$	reduced property
$s$	isentropic process
0	property of the surroundings
0	stagnation property

## Superscripts

—	bar over symbol denotes property on a molal basis (over $V, H, S, U, A, G$ , the bar denotes partial molal property)
°	property at standard-state condition
*	ideal gas
*	property at the throat of a nozzle
irr	irreversible
r	real gas part
rev	reversible



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# SI Units: Single-State Properties



TABLE A.1  
Conversion Factors

<b>Area (<i>A</i>)</b>	
1 mm <sup>2</sup> = 1.0 × 10 <sup>-6</sup> m <sup>2</sup>	1 ft <sup>2</sup> = 144 in. <sup>2</sup>
1 cm <sup>2</sup> = 1.0 × 10 <sup>-4</sup> m <sup>2</sup> = 0.1550 in. <sup>2</sup>	1 in. <sup>2</sup> = 6.4516 cm <sup>2</sup> = 6.4516 × 10 <sup>-4</sup> m <sup>2</sup>
1 m <sup>2</sup> = 10.7639 ft <sup>2</sup>	1 ft <sup>2</sup> = 0.092 903 m <sup>2</sup>
<b>Conductivity (<i>k</i>)</b>	
1 W/m-K = 1 J/s-m-K = 0.577 789 Btu/h-ft-°R	1 Btu/h-ft-R = 1.730 735 W/m-K
<b>Density (<i>ρ</i>)</b>	
1 kg/m <sup>3</sup> = 0.06242797 lbm/ft <sup>3</sup>	1 lbm/ft <sup>3</sup> = 16.018 46 kg/m <sup>3</sup>
1 g/cm <sup>3</sup> = 1000 kg/m <sup>3</sup>	
1 g/cm <sup>3</sup> = 1 kg/L	
<b>Energy (<i>E</i>, <i>U</i>)</b>	
1 J = 1 N-m = 1 kg-m <sup>2</sup> /s <sup>2</sup>	1 lbf-ft = 1.355 818 J
1 J = 0.737 562 lbf-ft	= 1.285 07 × 10 <sup>-3</sup> Btu
1 cal (Int.) = 4.186 81 J	1 Btu (Int.) = 1.055 056 kJ
	= 778.1693 lbf-ft
1 erg = 1.0 × 10 <sup>-7</sup> J	
1 eV = 1.602 177 33 × 10 <sup>-19</sup> J	
<b>Force (<i>F</i>)</b>	
1 N = 0.224 809 lbf	1 lbf = 4.448 222 N
1 kp = 9.806 65 N (1 kgf)	
<b>Gravitation</b>	
<i>g</i> = 9.806 65 m/s <sup>2</sup>	<i>g</i> = 32.174 05 ft/s <sup>2</sup>
<b>Heat capacity (<i>C<sub>p</sub></i>, <i>C<sub>v</sub></i>, <i>C</i>), specific entropy (<i>s</i>)</b>	
1 kJ/kg-K = 0.238 846 Btu/lbm-°R	1 Btu/lbm-°R = 4.1868 kJ/kg-K
<b>Heat flux (per unit area)</b>	
1 W/m <sup>2</sup> = 0.316 998 Btu/h-ft <sup>2</sup>	1 Btu/h-ft <sup>2</sup> = 3.154 59 W/m <sup>2</sup>



TABLE A.1 (continued)

## Conversion Factors

<b>Heat-transfer coefficient (<math>h</math>)</b>	
1 W/m <sup>2</sup> -K = 0.176 11 Btu/h-ft <sup>2</sup> -°R	1 Btu/h-ft <sup>2</sup> -°R = 5.678 26 W/m <sup>2</sup> -K
<b>Length (<math>L</math>)</b>	
1 mm = 0.001 m = 0.1 cm	1 ft = 12 in.
1 cm = 0.01 m = 10 mm = 0.3970 in.	1 in. = 2.54 cm = 0.0254 m
1 m = 3.280 84 ft = 39.370 in.	1 ft = 0.3048 m
1 km = 0.621 371 mi	1 mi = 1.609 344 km
1 mi = 1609.3 m (US statute)	1 yd = 0.9144 m
<b>Mass (<math>m</math>)</b>	
1 kg = 2.204 623 lbm	1 lbm = 0.453 592 kg
1 tonne = 1000 kg	1 slug = 14.5939 kg
1 grain = 6.479 89 × 10 <sup>-5</sup> kg	1 ton = 2000 lbm
<b>Moment (torque, <math>T</math>)</b>	
1 N-m = 0.737 562 lbf-ft	1 lbf-ft = 1.355 818 N-m
<b>Momentum (<math>mV</math>)</b>	
1 kg-m/s = 7.232 94 lbm-ft/s = 0.224 809 lbf-s	1 lbm-ft/s = 0.138 256 kg-m/s
<b>Power (<math>\dot{Q}</math>, <math>\dot{W}</math>)</b>	
1 W = 1 J/s = 1 N-m/s = 0.737 562 lbf-ft/s	1 lbf-ft/s = 1.355 818 W = 4.626 24 Btu/h
1 kW = 3412.14 Btu/h	1 Btu/s = 1.055 056 kW
1 hp (metric) = 0.735 499 kW	1 hp (UK) = 0.7457 kW = 550 lbf-ft/s = 2544.43 Btu/h
1 ton of refrigeration = 3.516 85 kW	1 ton of refrigeration = 12 000 Btu/h
<b>Pressure (<math>P</math>)</b>	
1 Pa = 1 N/m <sup>2</sup> = 1 kg/m-s <sup>2</sup>	1 lbf/in. <sup>2</sup> = 6.894 757 kPa
1 bar = 1.0 × 10 <sup>5</sup> Pa = 100 kPa	1 atm = 14.695 94 lbf/in. <sup>2</sup> = 29.921 in. Hg [32°F] = 33.8995 ft H <sub>2</sub> O [4°C]
1 atm = 101.325 kPa = 1.013 25 bar = 760 mm Hg [0°C] = 10.332 56 m H <sub>2</sub> O [4°C]	
1 torr = 1 mm Hg [0°C]	
1 mm Hg [0°C] = 0.133 322 kPa	1 in. Hg [0°C] = 0.491 15 lbf/in. <sup>2</sup>
1 m H <sub>2</sub> O [4°C] = 9.806 38 kPa	1 in. H <sub>2</sub> O [4°C] = 0.0361 26 lbf/in. <sup>2</sup>
<b>Specific energy (<math>e</math>, <math>u</math>)</b>	
1 kJ/kg = 0.429 92 Btu/lbm = 334.55 lbf-ft/lbm	1 Btu/lbm = 2.326 kJ/kg 1 lbf-ft/lbm = 2.989 07 × 10 <sup>-3</sup> kJ/kg = 1.285 07 × 10 <sup>-3</sup> Btu/lbm



TABLE A.1 (continued)

**Conversion Factors**

<b>Specific kinetic energy (<math>\frac{1}{2} V^2</math>)</b>	
$1 \text{ m}^2/\text{s}^2 = 0.001 \text{ kJ/kg}$	$1 \text{ ft}^2/\text{s}^2 = 3.9941 \times 10^{-5} \text{ Btu/lbm}$
$1 \text{ kJ/kg} = 1000 \text{ m}^2/\text{s}^2$	$1 \text{ Btu/lbm} = 250.37 \text{ ft}^2/\text{s}^2$
<b>Specific potential energy (<math>Zg</math>)</b>	
$1 \text{ m} \cdot g_{\text{std}} = 9.80665 \times 10^{-3} \text{ kJ/kg}$	$1 \text{ ft} \cdot g_{\text{std}} = 1.0 \text{ lbf} \cdot \text{ft/lbm}$
$= 4.21607 \times 10^{-3} \text{ Btu/lbm}$	$= 0.001285 \text{ Btu/lbm}$
	$= 0.002989 \text{ kJ/kg}$
<b>Specific volume (<math>v</math>)</b>	
$1 \text{ cm}^3/\text{g} = 0.001 \text{ m}^3/\text{kg}$	
$1 \text{ cm}^3/\text{g} = 1 \text{ L/kg}$	
$1 \text{ m}^3/\text{kg} = 16.01846 \text{ ft}^3/\text{lbm}$	$1 \text{ ft}^3/\text{lbm} = 0.062428 \text{ m}^3/\text{kg}$
<b>Temperature (<math>T</math>)</b>	
$1 \text{ K} = 1^\circ\text{C} = 1.8 \text{ R} = 1.8 \text{ F}$	$1 \text{ R} = (5/9) \text{ K}$
$\text{TC} = \text{TK} - 273.15$	$\text{TF} = \text{TR} - 459.67$
$= (\text{TF} - 32)/1.8$	$= 1.8 \text{ TC} + 32$
$\text{TK} = \text{TR}/1.8$	$\text{TR} = 1.8 \text{ TK}$
<b>Universal Gas Constant</b>	
$\bar{R} = N_0 k = 8.31451 \text{ kJ/kmol} \cdot \text{K}$	$\bar{R} = 1.98589 \text{ Btu/lbmol} \cdot \text{R}$
$= 1.98589 \text{ kcal/kmol} \cdot \text{K}$	$= 1545.36 \text{ lbf} \cdot \text{ft/lbmol} \cdot \text{R}$
$= 82.0578 \text{ atm} \cdot \text{L/kmol} \cdot \text{K}$	$= 0.73024 \text{ atm} \cdot \text{ft}^3/\text{lbmol} \cdot \text{R}$
	$= 10.7317 (\text{lbf/in.}^2) \cdot \text{ft}^3/\text{lbmol} \cdot \text{R}$
<b>Velocity (<math>V</math>)</b>	
$1 \text{ m/s} = 3.6 \text{ km/h}$	$1 \text{ ft/s} = 0.681818 \text{ mi/h}$
$= 3.28084 \text{ ft/s}$	$= 0.3048 \text{ m/s}$
$= 2.23694 \text{ mi/h}$	$= 1.09728 \text{ km/h}$
$1 \text{ km/h} = 0.27778 \text{ m/s}$	$1 \text{ mi/h} = 1.46667 \text{ ft/s}$
$= 0.91134 \text{ ft/s}$	$= 0.44704 \text{ m/s}$
$= 0.62137 \text{ mi/h}$	$= 1.60934 \text{ km/h}$
<b>Volume (<math>V</math>)</b>	
$1 \text{ m}^3 = 35.3147 \text{ ft}^3$	$1 \text{ ft}^3 = 2.831685 \times 10^{-2} \text{ m}^3$
$1 \text{ L} = 1 \text{ dm}^3 = 0.001 \text{ m}^3$	$1 \text{ in.}^3 = 1.6387 \times 10^{-5} \text{ m}^3$
$1 \text{ Gal (US)} = 3.785412 \text{ L}$	$1 \text{ Gal (UK)} = 4.546090 \text{ L}$
$= 3.785412 \times 10^{-3} \text{ m}^3$	$1 \text{ Gal (US)} = 231.00 \text{ in.}^3$

TABLE A.2  
*Critical Constants*

Substance	Formula	Molec. Mass	Temp. (K)	Press. (MPa)	Vol. (m <sup>3</sup> /kg)
Ammonia	NH <sub>3</sub>	17.031	405.5	11.35	0.00426
Argon	Ar	39.948	150.8	4.87	0.00188
Bromine	Br <sub>2</sub>	159.808	588	10.30	0.000796
Carbon dioxide	CO <sub>2</sub>	44.01	304.1	7.38	0.00212
Carbon monoxide	CO	28.01	132.9	3.50	0.00333
Chlorine	Cl <sub>2</sub>	70.906	416.9	7.98	0.00175
Fluorine	F <sub>2</sub>	37.997	144.3	5.22	0.00174
Helium	He	4.003	5.19	0.227	0.0143
Hydrogen (normal)	H <sub>2</sub>	2.016	33.2	1.30	0.0323
Krypton	Kr	83.80	209.4	5.50	0.00109
Neon	Ne	20.183	44.4	2.76	0.00206
Nitric oxide	NO	30.006	180	6.48	0.00192
Nitrogen	N <sub>2</sub>	28.013	126.2	3.39	0.0032
Nitrogen dioxide	NO <sub>2</sub>	46.006	431	10.1	0.00365
Nitrous oxide	N <sub>2</sub> O	44.013	309.6	7.24	0.00221
Oxygen	O <sub>2</sub>	31.999	154.6	5.04	0.00229
Sulfur dioxide	SO <sub>2</sub>	64.063	430.8	7.88	0.00191
Water	H <sub>2</sub> O	18.015	647.3	22.12	0.00317
Xenon	Xe	131.30	289.7	5.84	0.000902
Acetylene	C <sub>2</sub> H <sub>2</sub>	26.038	308.3	6.14	0.00433
Benzene	C <sub>6</sub> H <sub>6</sub>	78.114	562.2	4.89	0.00332
<i>n</i> -Butane	C <sub>4</sub> H <sub>10</sub>	58.124	425.2	3.80	0.00439
Chlorodifluoroethane (142b)	CH <sub>3</sub> CClF <sub>2</sub>	100.495	410.3	4.25	0.00230
Chlorodifluoromethane (22)	CHClF <sub>2</sub>	86.469	369.3	4.97	0.00191
Dichlorofluoroethane (141)	CH <sub>3</sub> CCl <sub>2</sub> F	116.95	481.5	4.54	0.00215
Dichlorotrifluoroethane (123)	CHCl <sub>2</sub> CF <sub>3</sub>	152.93	456.9	3.66	0.00182
Difluoroethane (152a)	CHF <sub>2</sub> CH <sub>3</sub>	66.05	386.4	4.52	0.00272
Difluoromethane (32)	CF <sub>2</sub> H <sub>2</sub>	52.024	351.3	5.78	0.00236
Ethane	C <sub>2</sub> H <sub>6</sub>	30.070	305.4	4.88	0.00493
Ethyl alcohol	C <sub>2</sub> H <sub>5</sub> OH	46.069	513.9	6.14	0.00363
Ethylene	C <sub>2</sub> H <sub>4</sub>	28.054	282.4	5.04	0.00465
<i>n</i> -Heptane	C <sub>7</sub> H <sub>16</sub>	100.205	540.3	2.74	0.00431
<i>n</i> -Hexane	C <sub>6</sub> H <sub>14</sub>	86.178	507.5	3.01	0.00429
Methane	CH <sub>4</sub>	16.043	190.4	4.60	0.00615
Methyl alcohol	CH <sub>3</sub> OH	32.042	512.6	8.09	0.00368
<i>n</i> -Octane	C <sub>8</sub> H <sub>18</sub>	114.232	568.8	2.49	0.00431
Pentafluoroethane (125)	CHF <sub>2</sub> CF <sub>3</sub>	120.022	339.2	3.62	0.00176
<i>n</i> -Pentane	C <sub>5</sub> H <sub>12</sub>	72.151	469.7	3.37	0.00421
Propane	C <sub>3</sub> H <sub>8</sub>	44.094	369.8	4.25	0.00454
Propene	C <sub>3</sub> H <sub>6</sub>	42.081	364.9	4.60	0.00430
Refrigerant mixture	R-410a	72.585	344.5	4.90	0.00218
Tetrafluoroethane (134a)	CF <sub>3</sub> CH <sub>2</sub> F	102.03	374.2	4.06	0.00197

TABLE A.3

*Properties of Selected Solids at 25°C*

Substance	$\rho$ (kg/m <sup>3</sup> )	$C_p$ (kJ/kg-K)
Asphalt	2120	0.92
Brick, common	1800	0.84
Carbon, diamond	3250	0.51
Carbon, graphite	2000–2500	0.61
Coal	1200–1500	1.26
Concrete	2200	0.88
Glass, plate	2500	0.80
Glass, wool	20	0.66
Granite	2750	0.89
Ice (0°C)	917	2.04
Paper	700	1.2
Plexiglass	1180	1.44
Polystyrene	920	2.3
Polyvinyl chloride	1380	0.96
Rubber, soft	1100	1.67
Sand, dry	1500	0.8
Salt, rock	2100–2500	0.92
Silicon	2330	0.70
Snow, firm	560	2.1
Wood, hard (oak)	720	1.26
Wood, soft (pine)	510	1.38
Wool	100	1.72
<b>Metals</b>		
Aluminum	2700	0.90
Brass, 60–40	8400	0.38
Copper, commercial	8300	0.42
Gold	19300	0.13
Iron, cast	7272	0.42
Iron, 304 St Steel	7820	0.46
Lead	11340	0.13
Magnesium, 2% Mn	1778	1.00
Nickel, 10% Cr	8666	0.44
Silver, 99.9% Ag	10524	0.24
Sodium	971	1.21
Tin	7304	0.22
Tungsten	19300	0.13
Zinc	7144	0.39

TABLE A.4

*Properties of Some Liquids at 25°C\**

Substance	$\rho$ (kg/m <sup>3</sup> )	$C_p$ (kJ/kg-K)
Ammonia	604	4.84
Benzene	879	1.72
Butane	556	2.47
CCl <sub>4</sub>	1584	0.83
CO <sub>2</sub>	680	2.9
Ethanol	783	2.46
Gasoline	750	2.08
Glycerine	1260	2.42
Kerosene	815	2.0
Methanol	787	2.55
<i>n</i> -Octane	692	2.23
Oil engine	885	1.9
Oil light	910	1.8
Propane	510	2.54
R-12	1310	0.97
R-22	1190	1.26
R-32	961	1.94
R-125	1191	1.41
R-134a	1206	1.43
R-410a	1059	1.69
Water	997	4.18
<b>Liquid metals</b>		
Bismuth, Bi	10040	0.14
Lead, Pb	10660	0.16
Mercury, Hg	13580	0.14
NaK (56/44)	887	1.13
Potassium, K	828	0.81
Sodium, Na	929	1.38
Tin, Sn	6950	0.24
Zinc, Zn	6570	0.50

\*Or  $T_{\text{melt}}$  if higher.

TABLE A.5

*Properties of Various Ideal Gases at 25°C, 100 kPa\* (SI Units)*

Gas	Chemical Formula	Molecular Mass (kg/kmol)	$R$ (kJ/kg-K)	$\rho$ (kg/m <sup>3</sup> )	$C_{p0}$ (kJ/kg-K)	$C_{v0}$ (kJ/kg-K)	$k = \frac{C_p}{C_v}$
Steam	H <sub>2</sub> O	18.015	0.4615	0.0231	1.872	1.410	1.327
Acetylene	C <sub>2</sub> H <sub>2</sub>	26.038	0.3193	1.05	1.699	1.380	1.231
Air	—	28.97	0.287	1.169	1.004	0.717	1.400
Ammonia	NH <sub>3</sub>	17.031	0.4882	0.694	2.130	1.642	1.297
Argon	Ar	39.948	0.2081	1.613	0.520	0.312	1.667
Butane	C <sub>4</sub> H <sub>10</sub>	58.124	0.1430	2.407	1.716	1.573	1.091
Carbon dioxide	CO <sub>2</sub>	44.01	0.1889	1.775	0.842	0.653	1.289
Carbon monoxide	CO	28.01	0.2968	1.13	1.041	0.744	1.399
Ethane	C <sub>2</sub> H <sub>6</sub>	30.07	0.2765	1.222	1.766	1.490	1.186
Ethanol	C <sub>2</sub> H <sub>5</sub> OH	46.069	0.1805	1.883	1.427	1.246	1.145
Ethylene	C <sub>2</sub> H <sub>4</sub>	28.054	0.2964	1.138	1.548	1.252	1.237
Helium	He	4.003	2.0771	0.1615	5.193	3.116	1.667
Hydrogen	H <sub>2</sub>	2.016	4.1243	0.0813	14.209	10.085	1.409
Methane	CH <sub>4</sub>	16.043	0.5183	0.648	2.254	1.736	1.299
Methanol	CH <sub>3</sub> OH	32.042	0.2595	1.31	1.405	1.146	1.227
Neon	Ne	20.183	0.4120	0.814	1.03	0.618	1.667
Nitric oxide	NO	30.006	0.2771	1.21	0.993	0.716	1.387
Nitrogen	N <sub>2</sub>	28.013	0.2968	1.13	1.042	0.745	1.400
Nitrous oxide	N <sub>2</sub> O	44.013	0.1889	1.775	0.879	0.690	1.274
<i>n</i> -Octane	C <sub>8</sub> H <sub>18</sub>	114.23	0.07279	0.092	1.711	1.638	1.044
Oxygen	O <sub>2</sub>	31.999	0.2598	1.292	0.922	0.662	1.393
Propane	C <sub>3</sub> H <sub>8</sub>	44.094	0.1886	1.808	1.679	1.490	1.126
R-12	CCl <sub>2</sub> F <sub>2</sub>	120.914	0.06876	4.98	0.616	0.547	1.126
R-22	CHClF <sub>2</sub>	86.469	0.09616	3.54	0.658	0.562	1.171
R-32	CF <sub>2</sub> H <sub>2</sub>	52.024	0.1598	2.125	0.822	0.662	1.242
R-125	CHF <sub>2</sub> CF <sub>3</sub>	120.022	0.06927	4.918	0.791	0.722	1.097
R-134a	CF <sub>3</sub> CH <sub>2</sub> F	102.03	0.08149	4.20	0.852	0.771	1.106
R-410a	—	72.585	0.11455	2.967	0.809	0.694	1.165
Sulfur dioxide	SO <sub>2</sub>	64.059	0.1298	2.618	0.624	0.494	1.263
Sulfur trioxide	SO <sub>3</sub>	80.053	0.10386	3.272	0.635	0.531	1.196

\*Or saturation pressure if it is less than 100 kPa.

TABLE A.6

*Constant-Pressure Specific Heats of Various Ideal Gases\**

		$C_{p0} = C_0 + C_1\theta + C_2\theta^2 + C_3\theta^3$ (kJ/kg K)		$\theta = T(\text{Kelvin})/1000$	
Gas	Formula	$C_0$	$C_1$	$C_2$	$C_3$
Steam	H <sub>2</sub> O	1.79	0.107	0.586	−0.20
Acetylene	C <sub>2</sub> H <sub>2</sub>	1.03	2.91	−1.92	0.54
Air	—	1.05	−0.365	0.85	−0.39
Ammonia	NH <sub>3</sub>	1.60	1.4	1.0	−0.7
Argon	Ar	0.52	0	0	0
Butane	C <sub>4</sub> H <sub>10</sub>	0.163	5.70	−1.906	−0.049
Carbon dioxide	CO <sub>2</sub>	0.45	1.67	−1.27	0.39
Carbon monoxide	CO	1.10	−0.46	1.0	−0.454
Ethane	C <sub>2</sub> H <sub>6</sub>	0.18	5.92	−2.31	0.29
Ethanol	C <sub>2</sub> H <sub>5</sub> OH	0.2	4.65	−1.82	0.03
Ethylene	C <sub>2</sub> H <sub>4</sub>	0.136	5.58	−3.0	0.63
Helium	He	5.193	0	0	0
Hydrogen	H <sub>2</sub>	13.46	4.6	−6.85	3.79
Methane	CH <sub>4</sub>	1.2	3.25	0.75	−0.71
Methanol	CH <sub>3</sub> OH	0.66	2.21	0.81	−0.89
Neon	Ne	1.03	0	0	0
Nitric oxide	NO	0.98	−0.031	0.325	−0.14
Nitrogen	N <sub>2</sub>	1.11	−0.48	0.96	−0.42
Nitrous oxide	N <sub>2</sub> O	0.49	1.65	−1.31	0.42
<i>n</i> -Octane	C <sub>8</sub> H <sub>18</sub>	−0.053	6.75	−3.67	0.775
Oxygen	O <sub>2</sub>	0.88	−0.0001	0.54	−0.33
Propane	C <sub>3</sub> H <sub>8</sub>	−0.096	6.95	−3.6	0.73
R-12 <sup>†</sup>	CCl <sub>2</sub> F <sub>2</sub>	0.26	1.47	−1.25	0.36
R-22 <sup>†</sup>	CHClF <sub>2</sub>	0.2	1.87	−1.35	0.35
R-32 <sup>†</sup>	CF <sub>2</sub> H <sub>2</sub>	0.227	2.27	−0.93	0.041
R-125 <sup>†</sup>	CHF <sub>2</sub> CF <sub>3</sub>	0.305	1.68	−0.284	0
R-134a <sup>†</sup>	CF <sub>3</sub> CH <sub>2</sub> F	0.165	2.81	−2.23	1.11
Sulfur dioxide	SO <sub>2</sub>	0.37	1.05	−0.77	0.21
Sulfur trioxide	SO <sub>3</sub>	0.24	1.7	−1.5	0.46

\*Approximate forms valid from 250 K to 1200 K.

<sup>†</sup>Formula limited to maximum 500 K.

TABLE A7.1

*Ideal Gas Properties of Air, Standard Entropy at 0.1-MPa (1-Bar) Pressure*

$T$ (K)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s_T^0$ (kJ/kg-K)	$T$ (K)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s_T^0$ (kJ/kg-K)
200	142.77	200.17	6.46260	1100	845.45	1161.18	8.24449
220	157.07	220.22	6.55812	1150	889.21	1219.30	8.29616
240	171.38	240.27	6.64535	1200	933.37	1277.81	8.34596
260	185.70	260.32	6.72562	1250	977.89	1336.68	8.39402
280	200.02	280.39	6.79998	1300	1022.75	1395.89	8.44046
290	207.19	290.43	6.83521	1350	1067.94	1455.43	8.48539
298.15	213.04	298.62	6.86305	1400	1113.43	1515.27	8.52891
300	214.36	300.47	6.86926	1450	1159.20	1575.40	8.57111
320	228.73	320.58	6.93413	1500	1205.25	1635.80	8.61208
340	243.11	340.70	6.99515	1550	1251.55	1696.45	8.65185
360	257.53	360.86	7.05276	1600	1298.08	1757.33	8.69051
380	271.99	381.06	7.10735	1650	1344.83	1818.44	8.72811
400	286.49	401.30	7.15926	1700	1391.80	1879.76	8.76472
420	301.04	421.59	7.20875	1750	1438.97	1941.28	8.80039
440	315.64	441.93	7.25607	1800	1486.33	2002.99	8.83516
460	330.31	462.34	7.30142	1850	1533.87	2064.88	8.86908
480	345.04	482.81	7.34499	1900	1581.59	2126.95	8.90219
500	359.84	503.36	7.38692	1950	1629.47	2189.19	8.93452
520	374.73	523.98	7.42736	2000	1677.52	2251.58	8.96611
540	389.69	544.69	7.46642	2050	1725.71	2314.13	8.99699
560	404.74	565.47	7.50422	2100	1774.06	2376.82	9.02721
580	419.87	586.35	7.54084	2150	1822.54	2439.66	9.05678
600	435.10	607.32	7.57638	2200	1871.16	2502.63	9.08573
620	450.42	628.38	7.61090	2250	1919.91	2565.73	9.11409
640	465.83	649.53	7.64448	2300	1968.79	2628.96	9.14189
660	481.34	670.78	7.67717	2350	2017.79	2692.31	9.16913
680	496.94	692.12	7.70903	2400	2066.91	2755.78	9.19586
700	512.64	713.56	7.74010	2450	2116.14	2819.37	9.22208
720	528.44	735.10	7.77044	2500	2165.48	2883.06	9.24781
740	544.33	756.73	7.80008	2550	2214.93	2946.86	9.27308
760	560.32	778.46	7.82905	2600	2264.48	3010.76	9.29790
780	576.40	800.28	7.85740	2650	2314.13	3074.77	9.32228
800	592.58	822.20	7.88514	2700	2363.88	3138.87	9.34625
850	633.42	877.40	7.95207	2750	2413.73	3203.06	9.36980
900	674.82	933.15	8.01581	2800	2463.66	3267.35	9.39297
950	716.76	989.44	8.07667	2850	2513.69	3331.73	9.41576
1000	759.19	1046.22	8.13493	2900	2563.80	3396.19	9.43818
1050	802.10	1103.48	8.19081	2950	2613.99	3460.73	9.46025
1100	845.45	1161.18	8.24449	3000	2664.27	3525.36	9.48198

TABLE A7.2

*The Isentropic Relative Pressure and Relative Volume Functions*

$T[\text{K}]$	$P_r$	$v_r$	$T[\text{K}]$	$P_r$	$v_r$	$T[\text{K}]$	$P_r$	$v_r$
200	0.2703	493.47	700	23.160	20.155	1900	1327.5	0.95445
220	0.3770	389.15	720	25.742	18.652	1950	1485.8	0.87521
240	0.5109	313.27	740	28.542	17.289	2000	1658.6	0.80410
260	0.6757	256.58	760	31.573	16.052	2050	1847.1	0.74012
280	0.8756	213.26	780	34.851	14.925	2100	2052.1	0.68242
290	0.9899	195.36	800	38.388	13.897	2150	2274.8	0.63027
298.15	1.0907	182.29	850	48.468	11.695	2200	2516.2	0.58305
300	1.1146	179.49	900	60.520	9.9169	2250	2777.5	0.54020
320	1.3972	152.73	950	74.815	8.4677	2300	3059.9	0.50124
340	1.7281	131.20	1000	91.651	7.2760	2350	3364.6	0.46576
360	2.1123	113.65	1050	111.35	6.2885	2400	3693.0	0.43338
380	2.5548	99.188	1100	134.25	5.4641	2450	4046.2	0.40378
400	3.0612	87.137	1150	160.73	4.7714	2500	4425.8	0.37669
420	3.6373	77.003	1200	191.17	4.1859	2550	4833.0	0.35185
440	4.2892	68.409	1250	226.02	3.6880	2600	5269.5	0.32903
460	5.0233	61.066	1300	265.72	3.2626	2650	5736.7	0.30805
480	5.8466	54.748	1350	310.74	2.8971	2700	6236.2	0.28872
500	6.7663	49.278	1400	361.62	2.5817	2750	6769.7	0.27089
520	7.7900	44.514	1450	418.89	2.3083	2800	7338.7	0.25443
540	8.9257	40.344	1500	483.16	2.0703	2850	7945.1	0.23921
560	10.182	36.676	1550	554.96	1.8625	2900	8590.7	0.22511
580	11.568	33.436	1600	634.97	1.6804	2950	9277.2	0.21205
600	13.092	30.561	1650	723.86	1.52007	3000	10007	0.19992
620	14.766	28.001	1700	822.33	1.37858			
640	16.598	25.713	1750	931.14	1.25330			
660	18.600	23.662	1800	1051.05	1.14204			
680	20.784	21.818	1850	1182.9	1.04294			
700	23.160	20.155	1900	1327.5	0.95445			

The relative pressure and relative volume are temperature functions calculated with two scaling constants  $A_1$ ,  $A_2$ .

$$P_r = \exp[s_T^0/R - A_1]; \quad v_r = A_2 T/P_r$$

such that for an isentropic process ( $s_1 = s_2$ )

$$\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}} = \frac{e^{s_{T_2}^0/R}}{e^{s_{T_1}^0/R}} \approx \left(\frac{T_2}{T_1}\right)^{C_p/R} \quad \text{and} \quad \frac{v_2}{v_1} = \frac{v_{r2}}{v_{r1}} \approx \left(\frac{T_1}{T_2}\right)^{C_v/R}$$

where the near equalities are for the constant heat capacity approximation.



TABLE A.8

*Ideal Gas Properties of Various Substances, Entropies at 0.1-MPa (1-Bar) Pressure, Mass Basis*

<i>T</i> (K)	Nitrogen, Diatomic (N <sub>2</sub> ) <i>R</i> = 0.2968 kJ/kg-K <i>M</i> = 28.013 kg/kmol			Oxygen, Diatomic (O <sub>2</sub> ) <i>R</i> = 0.2598 kJ/kg-K <i>M</i> = 31.999 kg/kmol		
	<i>u</i> (kJ/kg)	<i>h</i> (kJ/kg)	<i>s</i> <sub>T</sub> <sup>0</sup> (kJ/kg-K)	<i>u</i> (kJ/kg)	<i>h</i> (kJ/kg)	<i>s</i> <sub>T</sub> <sup>0</sup> (kJ/kg-K)
200	148.39	207.75	6.4250	129.84	181.81	6.0466
250	185.50	259.70	6.6568	162.41	227.37	6.2499
300	222.63	311.67	6.8463	195.20	273.15	6.4168
350	259.80	363.68	7.0067	228.37	319.31	6.5590
400	297.09	415.81	7.1459	262.10	366.03	6.6838
450	334.57	468.13	7.2692	296.52	413.45	6.7954
500	372.35	520.75	7.3800	331.72	461.63	6.8969
550	410.52	573.76	7.4811	367.70	510.61	6.9903
600	449.16	627.24	7.5741	404.46	560.36	7.0768
650	488.34	681.26	7.6606	441.97	610.86	7.1577
700	528.09	735.86	7.7415	480.18	662.06	7.2336
750	568.45	791.05	7.8176	519.02	713.90	7.3051
800	609.41	846.85	7.8897	558.46	766.33	7.3728
850	650.98	903.26	7.9581	598.44	819.30	7.4370
900	693.13	960.25	8.0232	638.90	872.75	7.4981
950	735.85	1017.81	8.0855	679.80	926.65	7.5564
1000	779.11	1075.91	8.1451	721.11	980.95	7.6121
1100	867.14	1193.62	8.2572	804.80	1090.62	7.7166
1200	957.00	1313.16	8.3612	889.72	1201.53	7.8131
1300	1048.46	1434.31	8.4582	975.72	1313.51	7.9027
1400	1141.35	1556.87	8.5490	1062.67	1426.44	7.9864
1500	1235.50	1680.70	8.6345	1150.48	1540.23	8.0649
1600	1330.72	1805.60	8.7151	1239.10	1654.83	8.1389
1700	1426.89	1931.45	8.7914	1328.49	1770.21	8.2088
1800	1523.90	2058.15	8.8638	1418.63	1886.33	8.2752
1900	1621.66	2185.58	8.9327	1509.50	2003.19	8.3384
2000	1720.07	2313.68	8.9984	1601.10	2120.77	8.3987
2100	1819.08	2442.36	9.0612	1693.41	2239.07	8.4564
2200	1918.62	2571.58	9.1213	1786.44	2358.08	8.5117
2300	2018.63	2701.28	9.1789	1880.17	2477.79	8.5650
2400	2119.08	2831.41	9.2343	1974.60	2598.20	8.6162
2500	2219.93	2961.93	9.2876	2069.71	2719.30	8.6656
2600	2321.13	3092.81	9.3389	2165.50	2841.07	8.7134
2700	2422.66	3224.03	9.3884	2261.94	2963.49	8.7596
2800	2524.50	3355.54	9.4363	2359.01	3086.55	8.8044
2900	2626.62	3487.34	9.4825	2546.70	3210.22	8.8478
3000	2729.00	3619.41	9.5273	2554.97	3334.48	8.8899

TABLE A.8 (continued)

*Ideal Gas Properties of Various Substances, Entropies at 0.1-MPa (1-Bar) Pressure, Mass Basis*

$T$ (K)	Carbon Dioxide (CO <sub>2</sub> ) $R = 0.1889 \text{ kJ/kg-K}$ $M = 44.010 \text{ kg/kmol}$			Water (H <sub>2</sub> O) $R = 0.4615 \text{ kJ/kg-K}$ $M = 18.015 \text{ kg/kmol}$		
	$u$ (kJ/kg)	$h$ (kJ/kg)	$s_T^0$ (kJ/kg-K)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s_T^0$ (kJ/kg-K)
200	97.49	135.28	4.5439	276.38	368.69	9.7412
250	126.21	173.44	4.7139	345.98	461.36	10.1547
300	157.70	214.38	4.8631	415.87	554.32	10.4936
350	191.78	257.90	4.9972	486.37	647.90	10.7821
400	228.19	303.76	5.1196	557.79	742.40	11.0345
450	266.69	351.70	5.2325	630.40	838.09	11.2600
500	307.06	401.52	5.3375	704.36	935.12	11.4644
550	349.12	453.03	5.4356	779.79	1033.63	11.6522
600	392.72	506.07	5.5279	856.75	1133.67	11.8263
650	437.71	560.51	5.6151	935.31	1235.30	11.9890
700	483.97	616.22	5.6976	1015.49	1338.56	12.1421
750	531.40	673.09	5.7761	1097.35	1443.49	12.2868
800	579.89	731.02	5.8508	1180.90	1550.13	12.4244
850	629.35	789.93	5.9223	1266.19	1658.49	12.5558
900	676.69	849.72	5.9906	1353.23	1768.60	12.6817
950	730.85	910.33	6.0561	1442.03	1880.48	12.8026
1000	782.75	971.67	6.1190	1532.61	1994.13	12.9192
1100	888.55	1096.36	6.2379	1719.05	2226.73	13.1408
1200	996.64	1223.34	6.3483	1912.42	2466.25	13.3492
1300	1106.68	1352.28	6.4515	2112.47	2712.46	13.5462
1400	1218.38	1482.87	6.5483	2318.89	2965.03	13.7334
1500	1331.50	1614.88	6.6394	2531.28	3223.57	13.9117
1600	1445.85	1748.12	6.7254	2749.24	3487.69	14.0822
1700	1561.26	1882.43	6.8068	2972.35	3756.95	14.2454
1800	1677.61	2017.67	6.8841	3200.17	4030.92	14.4020
1900	1794.78	2153.73	6.9577	3432.28	4309.18	14.5524
2000	1912.67	2290.51	7.0278	3668.24	4591.30	14.6971
2100	2031.21	2427.95	7.0949	3908.08	4877.29	14.8366
2200	2150.34	2565.97	7.1591	4151.28	5166.64	14.9712
2300	2270.00	2704.52	7.2206	4397.56	5459.08	15.1012
2400	2390.14	2843.55	7.2798	4646.71	5754.37	15.2269
2500	2510.74	2983.04	7.3368	4898.49	6052.31	15.3485
2600	2631.73	3122.93	7.3917	5152.73	6352.70	15.4663
2700	2753.10	3263.19	7.4446	5409.24	6655.36	15.5805
2800	2874.81	3403.79	7.4957	5667.86	6960.13	15.6914
2900	2996.84	3544.71	7.5452	5928.44	7266.87	15.7990
3000	3119.18	3685.95	7.5931	6190.86	7575.44	15.9036

TABLE A.9

*Ideal Gas Properties of Various Substances (SI Units), Entropies at 0.1-MPa (1-Bar) Pressure, Mole Basis*

<i>T</i> K	Nitrogen, Diatomic (N <sub>2</sub> ) $\bar{h}_{f,298}^0 = 0 \text{ kJ/kmol}$ $M = 28.013 \text{ kg/kmol}$		Nitrogen, Monatomic (N) $\bar{h}_{f,298}^0 = 472\,680 \text{ kJ/kmol}$ $M = 14.007 \text{ kg/kmol}$	
	$(\bar{h} - \bar{h}_{298}^0)$ kJ/kmol	$\bar{s}_T^0$ kJ/kmol K	$(\bar{h} - \bar{h}_{298}^0)$ kJ/kmol	$\bar{s}_T^0$ kJ/kmol
0	−8670	0	−6197	0
100	−5768	159.812	−4119	130.593
200	−2857	179.985	−2040	145.001
298	0	191.609	0	153.300
300	54	191.789	38	153.429
400	2971	200.181	2117	159.409
500	5911	206.740	4196	164.047
600	8894	212.177	6274	167.837
700	11937	216.865	8353	171.041
800	15046	221.016	10431	173.816
900	18223	224.757	12510	176.265
1000	21463	228.171	14589	178.455
1100	24760	231.314	16667	180.436
1200	28109	234.227	18746	182.244
1300	31503	236.943	20825	183.908
1400	34936	239.487	22903	185.448
1500	38405	241.881	24982	186.883
1600	41904	244.139	27060	188.224
1700	45430	246.276	29139	189.484
1800	48979	248.304	31218	190.672
1900	52549	250.234	33296	191.796
2000	56137	252.075	35375	192.863
2200	63362	255.518	39534	194.845
2400	70640	258.684	43695	196.655
2600	77963	261.615	47860	198.322
2800	85323	264.342	52033	199.868
3000	92715	266.892	56218	201.311
3200	100134	269.286	60420	202.667
3400	107577	271.542	64646	203.948
3600	115042	273.675	68902	205.164
3800	122526	275.698	73194	206.325
4000	130027	277.622	77532	207.437
4400	145078	281.209	86367	209.542
4800	160188	284.495	95457	211.519
5200	175352	287.530	104843	213.397
5600	190572	290.349	114550	215.195
6000	205848	292.984	124590	216.926

TABLE A.9 (continued)

*Ideal Gas Properties of Various Substances (SI Units), Entropies at 0.1-MPa (1-Bar) Pressure, Mole Basis*

<i>T</i> K	Oxygen, Diatomic (O <sub>2</sub> ) $\bar{h}_{f,298}^0 = 0 \text{ kJ/kmol}$ $M = 31.999 \text{ kg/kmol}$		Oxygen, Monatomic (O) $\bar{h}_{f,298}^0 = 249\,170 \text{ kJ/kmol}$ $M = 16.00 \text{ kg/kmol}$	
	$(\bar{h} - \bar{h}_{298}^0)$ kJ/kmol	$\bar{s}_T^0$ kJ/kmol K	$(\bar{h} - \bar{h}_{298}^0)$ kJ/kmol	$\bar{s}_T^0$ kJ/kmol K
0	−8683	0	−6725	0
100	−5777	173.308	−4518	135.947
200	−2868	193.483	−2186	152.153
298	0	205.148	0	161.059
300	54	205.329	41	161.194
400	3027	213.873	2207	167.431
500	6086	220.693	4343	172.198
600	9245	226.450	6462	176.060
700	12499	231.465	8570	179.310
800	15836	235.920	10671	182.116
900	19241	239.931	12767	184.585
1000	22703	243.579	14860	186.790
1100	26212	246.923	16950	188.783
1200	29761	250.011	19039	190.600
1300	33345	252.878	21126	192.270
1400	36958	255.556	23212	193.816
1500	40600	258.068	25296	195.254
1600	44267	260.434	27381	196.599
1700	47959	262.673	29464	197.862
1800	51674	264.797	31547	199.053
1900	55414	266.819	33630	200.179
2000	59176	268.748	35713	201.247
2200	66770	272.366	39878	203.232
2400	74453	275.708	44045	205.045
2600	82225	278.818	48216	206.714
2800	90080	281.729	52391	208.262
3000	98013	284.466	56574	209.705
3200	106022	287.050	60767	211.058
3400	114101	289.499	64971	212.332
3600	122245	291.826	69190	213.538
3800	130447	294.043	73424	214.682
4000	138705	296.161	77675	215.773
4400	155374	300.133	86234	217.812
4800	172240	303.801	94873	219.691
5200	189312	307.217	103592	221.435
5600	206618	310.423	112391	223.066
6000	224210	313.457	121264	224.597

**TABLE A.9** (continued)  
**Ideal Gas Properties of Various Substances (SI Units), Entropies at 0.1-MPa (1-Bar)**  
**Pressure, Mole Basis**

<i>T</i> K	Carbon Dioxide (CO <sub>2</sub> ) $\bar{h}_{f,298}^0 = -393\,522 \text{ kJ/kmol}$ $M = 44.01 \text{ kg/kmol}$		Carbon Monoxide (CO) $\bar{h}_{f,298}^0 = -110\,527 \text{ kJ/kmol}$ $M = 28.01 \text{ kg/kmol}$	
	$(\bar{h} - \bar{h}_{298}^0)$ kJ/kmol	$\bar{s}_T^0$ kJ/kmol K	$(\bar{h} - \bar{h}_{298}^0)$ kJ/kmol	$\bar{s}_T^0$ kJ/kmol K
0	-9364	0	-8671	0
100	-6457	179.010	-5772	165.852
200	-3413	199.976	-2860	186.024
298	0	213.794	0	197.651
300	69	214.024	54	197.831
400	4003	225.314	2977	206.240
500	8305	234.902	5932	212.833
600	12906	243.284	8942	218.321
700	17754	250.752	12021	223.067
800	22806	257.496	15174	227.277
900	28030	263.646	18397	231.074
1000	33397	269.299	21686	234.538
1100	38885	274.528	25031	237.726
1200	44473	279.390	28427	240.679
1300	50148	283.931	31867	243.431
1400	55895	288.190	35343	246.006
1500	61705	292.199	38852	248.426
1600	67569	295.984	42388	250.707
1700	73480	299.567	45948	252.866
1800	79432	302.969	49529	254.913
1900	85420	306.207	53128	256.860
2000	91439	309.294	56743	258.716
2200	103562	315.070	64012	262.182
2400	115779	320.384	71326	265.361
2600	128074	325.307	78679	268.302
2800	140435	329.887	86070	271.044
3000	152853	334.170	93504	273.607
3200	165321	338.194	100962	276.012
3400	177836	341.988	108440	278.279
3600	190394	345.576	115938	280.422
3800	202990	348.981	123454	282.454
4000	215624	352.221	130989	284.387
4400	240992	358.266	146108	287.989
4800	266488	363.812	161285	291.290
5200	292112	368.939	176510	294.337
5600	317870	373.711	191782	297.167
6000	343782	378.180	207105	299.809

TABLE A.9 (continued)

*Ideal Gas Properties of Various Substances (SI Units), Entropies at 0.1-MPa (1-Bar) Pressure, Mole Basis*

<i>T</i> K	Water (H <sub>2</sub> O)		Hydroxyl (OH)	
	$\bar{h}_{f,298}^0 = -241\,826 \text{ kJ/kmol}$ $M = 18.015 \text{ kg/kmol}$		$\bar{h}_{f,298}^0 = 38\,987 \text{ kJ/kmol}$ $M = 17.007 \text{ kg/kmol}$	
	$(\bar{h} - \bar{h}_{298}^0)$ kJ/kmol	$\bar{s}_T^0$ kJ/kmol K	$(\bar{h} - \bar{h}_{298}^0)$ kJ/kmol	$\bar{s}_T^0$ kJ/kmol K
0	−9904	0	−9172	0
100	−6617	152.386	−6140	149.591
200	−3282	175.488	−2975	171.592
298	0	188.835	0	183.709
300	62	189.043	55	183.894
400	3450	198.787	3034	192.466
500	6922	206.532	5991	199.066
600	10499	213.051	8943	204.448
700	14190	218.739	11902	209.008
800	18002	223.826	14881	212.984
900	21937	228.460	17889	216.526
1000	26000	232.739	20935	219.735
1100	30190	236.732	24024	222.680
1200	34506	240.485	27159	225.408
1300	38941	244.035	30340	227.955
1400	43491	247.406	33567	230.347
1500	48149	250.620	36838	232.604
1600	52907	253.690	40151	234.741
1700	57757	256.631	43502	236.772
1800	62693	259.452	46890	238.707
1900	67706	262.162	50311	240.556
2000	72788	264.769	53763	242.328
2200	83153	269.706	60751	245.659
2400	93741	274.312	67840	248.743
2600	104520	278.625	75018	251.614
2800	115463	282.680	82268	254.301
3000	126548	286.504	89585	256.825
3200	137756	290.120	96960	259.205
3400	149073	293.550	104388	261.456
3600	160484	296.812	111864	263.592
3800	171981	299.919	119382	265.625
4000	183552	302.887	126940	267.563
4400	206892	308.448	142165	271.191
4800	230456	313.573	157522	274.531
5200	254216	318.328	173002	277.629
5600	278161	322.764	188598	280.518
6000	302295	326.926	204309	283.227

TABLE A.9 (continued)

*Ideal Gas Properties of Various Substances (SI Units), Entropies at 0.1-MPa (1-Bar) Pressure, Mole Basis*

<i>T</i> K	Hydrogen (H <sub>2</sub> ) $\bar{h}_{f,298}^0 = 0 \text{ kJ/kmol}$ $M = 2.016 \text{ kg/kmol}$		Hydrogen, Monatomic (H) $\bar{h}_{f,298}^0 = 217\,999 \text{ kJ/kmol}$ $M = 1.008 \text{ kg/kmol}$	
	$(\bar{h} - \bar{h}_{298}^0)$ kJ/kmol	$\bar{s}_T^0$ kJ/kmol K	$(\bar{h} - \bar{h}_{298}^0)$ kJ/kmol	$\bar{s}_T^0$ kJ/kmol K
0	−8467	0	−6197	0
100	−5467	100.727	−4119	92.009
200	−2774	119.410	−2040	106.417
298	0	130.678	0	114.716
300	53	130.856	38	114.845
400	2961	139.219	2117	120.825
500	5883	145.738	4196	125.463
600	8799	151.078	6274	129.253
700	11730	155.609	8353	132.457
800	14681	159.554	10431	135.233
900	17657	163.060	12510	137.681
1000	20663	166.225	14589	139.871
1100	23704	169.121	16667	141.852
1200	26785	171.798	18746	143.661
1300	29907	174.294	20825	145.324
1400	33073	176.637	22903	146.865
1500	36281	178.849	24982	148.299
1600	39533	180.946	27060	149.640
1700	42826	182.941	29139	150.900
1800	46160	184.846	31218	152.089
1900	49532	186.670	33296	153.212
2000	52942	188.419	35375	154.279
2200	59865	191.719	39532	156.260
2400	66915	194.789	43689	158.069
2600	74082	197.659	47847	159.732
2800	81355	200.355	52004	161.273
3000	88725	202.898	56161	162.707
3200	96187	205.306	60318	164.048
3400	103736	207.593	64475	165.308
3600	111367	209.773	68633	166.497
3800	119077	211.856	72790	167.620
4000	126864	213.851	76947	168.687
4400	142658	217.612	85261	170.668
4800	158730	221.109	93576	172.476
5200	175057	224.379	101890	174.140
5600	191607	227.447	110205	175.681
6000	208332	230.322	118519	177.114



TABLE A.9 (continued)

*Ideal Gas Properties of Various Substances (SI Units), Entropies at 0.1-MPa (1-Bar) Pressure, Mole Basis*

<i>T</i> K	Nitric Oxide (NO) $\bar{h}_{f,298}^0 = 90\,291 \text{ kJ/kmol}$ $M = 30.006 \text{ kg/kmol}$		Nitrogen Dioxide (NO <sub>2</sub> ) $\bar{h}_{f,298}^0 = 33\,100 \text{ kJ/kmol}$ $M = 46.005 \text{ kg/kmol}$	
	$(\bar{h} - \bar{h}_{298}^0)$ kJ/kmol	$\bar{s}_T^0$ kJ/kmol K	$(\bar{h} - \bar{h}_{298}^0)$ kJ/kmol	$\bar{s}_T^0$ kJ/kmol K
0	−9192	0	−10186	0
100	−6073	177.031	−6861	202.563
200	−2951	198.747	−3495	225.852
298	0	210.759	0	240.034
300	55	210.943	68	240.263
400	3040	219.529	3927	251.342
500	6059	226.263	8099	260.638
600	9144	231.886	12555	268.755
700	12308	236.762	17250	275.988
800	15548	241.088	22138	282.513
900	18858	244.985	27180	288.450
1000	22229	248.536	32344	293.889
1100	25653	251.799	37606	298.904
1200	29120	254.816	42946	303.551
1300	32626	257.621	48351	307.876
1400	36164	260.243	53808	311.920
1500	39729	262.703	59309	315.715
1600	43319	265.019	64846	319.289
1700	46929	267.208	70414	322.664
1800	50557	269.282	76008	325.861
1900	54201	271.252	81624	328.898
2000	57859	273.128	87259	331.788
2200	65212	276.632	98578	337.182
2400	72606	279.849	109948	342.128
2600	80034	282.822	121358	346.695
2800	87491	285.585	132800	350.934
3000	94973	288.165	144267	354.890
3200	102477	290.587	155756	358.597
3400	110000	292.867	167262	362.085
3600	117541	295.022	178783	365.378
3800	125099	297.065	190316	368.495
4000	132671	299.007	201860	371.456
4400	147857	302.626	224973	376.963
4800	163094	305.940	248114	381.997
5200	178377	308.998	271276	386.632
5600	193703	311.838	294455	390.926
6000	209070	314.488	317648	394.926

TABLE A.10

*Enthalpy of Formation and Absolute Entropy of Various Substances at 25°C, 100 kPa Pressure*

Substance	Formula	$M$ kg/kmol	State	$\bar{h}_f^0$ kJ/kmol	$\bar{s}_f^0$ kJ/kmol K
Acetylene	C <sub>2</sub> H <sub>2</sub>	26.038	gas	+226 731	200.958
Ammonia	NH <sub>3</sub>	17.031	gas	−45 720	192.572
Benzene	C <sub>6</sub> H <sub>6</sub>	78.114	gas	+82 980	269.562
Carbon dioxide	CO <sub>2</sub>	44.010	gas	−393 522	213.795
Carbon (graphite)	C	12.011	solid	0	5.740
Carbon monoxide	CO	28.011	gas	−110 527	197.653
Ethane	C <sub>2</sub> H <sub>6</sub>	30.070	gas	−84 740	229.597
Ethene	C <sub>2</sub> H <sub>4</sub>	28.054	gas	+52 467	219.330
Ethanol	C <sub>2</sub> H <sub>5</sub> OH	46.069	gas	−235 000	282.444
Ethanol	C <sub>2</sub> H <sub>5</sub> OH	46.069	liq	−277 380	160.554
Heptane	C <sub>7</sub> H <sub>16</sub>	100.205	gas	−187 900	427.805
Hexane	C <sub>6</sub> H <sub>14</sub>	86.178	gas	−167 300	387.979
Hydrogen peroxide	H <sub>2</sub> O <sub>2</sub>	34.015	gas	−136 106	232.991
Methane	CH <sub>4</sub>	16.043	gas	−74 873	186.251
Methanol	CH <sub>3</sub> OH	32.042	gas	−201 300	239.709
Methanol	CH <sub>3</sub> OH	32.042	liq	−239 220	126.809
<i>n</i> -Butane	C <sub>4</sub> H <sub>10</sub>	58.124	gas	−126 200	306.647
Nitrogen oxide	N <sub>2</sub> O	44.013	gas	+82 050	219.957
Nitromethane	CH <sub>3</sub> NO <sub>2</sub>	61.04	liq	−113 100	171.80
<i>n</i> -Octane	C <sub>8</sub> H <sub>18</sub>	114.232	gas	−208 600	466.514
<i>n</i> -Octane	C <sub>8</sub> H <sub>18</sub>	114.232	liq	−250 105	360.575
Ozone	O <sub>3</sub>	47.998	gas	+142 674	238.932
Pentane	C <sub>5</sub> H <sub>12</sub>	72.151	gas	−146 500	348.945
Propane	C <sub>3</sub> H <sub>8</sub>	44.094	gas	−103 900	269.917
Propene	C <sub>3</sub> H <sub>6</sub>	42.081	gas	+20 430	267.066
Sulfur	S	32.06	solid	0	32.056
Sulfur dioxide	SO <sub>2</sub>	64.059	gas	−296 842	248.212
Sulfur trioxide	SO <sub>3</sub>	80.058	gas	−395 765	256.769
<i>T-T</i> -Diesel	C <sub>14.4</sub> H <sub>24.9</sub>	198.06	liq	−174 000	525.90
Water	H <sub>2</sub> O	18.015	gas	−241 826	188.834
Water	H <sub>2</sub> O	18.015	liq	−285 830	69.950

TABLE A.11

Logarithms to the Base  $e$  of the Equilibrium Constant  $K$ 

For the reaction  $\nu_A A + \nu_B B \rightleftharpoons \nu_C C + \nu_D D$ , the equilibrium constant  $K$  is defined as

$$K = \frac{y_C^{\nu_C} y_D^{\nu_D}}{y_A^{\nu_A} y_B^{\nu_B}} \left( \frac{P}{P^0} \right)^{\nu_C + \nu_D - \nu_A - \nu_B}, \quad P^0 = 0.1 \text{ MPa}$$

Temp K	$\text{H}_2 \rightleftharpoons 2\text{H}$	$\text{O}_2 \rightleftharpoons 2\text{O}$	$\text{N}_2 \rightleftharpoons 2\text{N}$	$2\text{H}_2\text{O} \rightleftharpoons 2\text{H}_2 + \text{O}_2$	$2\text{H}_2\text{O} \rightleftharpoons \text{H}_2 + 2\text{OH}$	$2\text{CO}_2 \rightleftharpoons 2\text{CO} + \text{O}_2$	$\text{N}_2 + \text{O}_2 \rightleftharpoons 2\text{NO}$	$\text{N}_2 + 2\text{O}_2 \rightleftharpoons 2\text{NO}_2$
298	-164.003	-186.963	-367.528	-184.420	-212.075	-207.529	-69.868	-41.355
500	-92.830	-105.623	-213.405	-105.385	-120.331	-115.234	-40.449	-30.725
1000	-39.810	-45.146	-99.146	-46.321	-51.951	-47.052	-18.709	-23.039
1200	-30.878	-35.003	-80.025	-36.363	-40.467	-35.736	-15.082	-21.752
1400	-24.467	-27.741	-66.345	-29.222	-32.244	-27.679	-12.491	-20.826
1600	-19.638	-22.282	-56.069	-23.849	-26.067	-21.656	-10.547	-20.126
1800	-15.868	-18.028	-48.066	-19.658	-21.258	-16.987	-9.035	-19.577
2000	-12.841	-14.619	-41.655	-16.299	-17.406	-13.266	-7.825	-19.136
2200	-10.356	-11.826	-36.404	-13.546	-14.253	-10.232	-6.836	-18.773
2400	-8.280	-9.495	-32.023	-11.249	-11.625	-7.715	-6.012	-18.470
2600	-6.519	-7.520	-28.313	-9.303	-9.402	-5.594	-5.316	-18.214
2800	-5.005	-5.826	-25.129	-7.633	-7.496	-3.781	-4.720	-17.994
3000	-3.690	-4.356	-22.367	-6.184	-5.845	-2.217	-4.205	-17.805
3200	-2.538	-3.069	-19.947	-4.916	-4.401	-0.853	-3.755	-17.640
3400	-1.519	-1.932	-17.810	-3.795	-3.128	0.346	-3.359	-17.496
3600	-0.611	-0.922	-15.909	-2.799	-1.996	1.408	-3.008	-17.369
3800	0.201	-0.017	-14.205	-1.906	-0.984	2.355	-2.694	-17.257
4000	0.934	0.798	-12.671	-1.101	-0.074	3.204	-2.413	-17.157
4500	2.483	2.520	-9.423	0.602	1.847	4.985	-1.824	-16.953
5000	3.724	3.898	-6.816	1.972	3.383	6.397	-1.358	-16.797
5500	4.739	5.027	-4.672	3.098	4.639	7.542	-0.980	-16.678
6000	5.587	5.969	-2.876	4.040	5.684	8.488	-0.671	-16.588

Source: Consistent with thermodynamic data in *JANAF Thermochemical Tables*, third edition, Thermal Group, Dow Chemical U.S.A., Midland, MI, 1985.

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# SI Units: Thermodynamic Tables



TABLE B.1

*Thermodynamic Properties of Water*

TABLE B.1.1

*Saturated Water*

Temp. (°C)	Press. (kPa)	Specific Volume, m <sup>3</sup> /kg			Internal Energy, kJ/kg		
		Sat. Liquid $v_f$	Evap. $v_{fg}$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Evap. $u_{fg}$	Sat. Vapor $u_g$
0.01	0.6113	0.001000	206.131	206.132	0	2375.33	2375.33
5	0.8721	0.001000	147.117	147.118	20.97	2361.27	2382.24
10	1.2276	0.001000	106.376	106.377	41.99	2347.16	2389.15
15	1.705	0.001001	77.924	77.925	62.98	2333.06	2396.04
20	2.339	0.001002	57.7887	57.7897	83.94	2318.98	2402.91
25	3.169	0.001003	43.3583	43.3593	104.86	2304.90	2409.76
30	4.246	0.001004	32.8922	32.8932	125.77	2290.81	2416.58
35	5.628	0.001006	25.2148	25.2158	146.65	2276.71	2423.36
40	7.384	0.001008	19.5219	19.5229	167.53	2262.57	2430.11
45	9.593	0.001010	15.2571	15.2581	188.41	2248.40	2436.81
50	12.350	0.001012	12.0308	12.0318	209.30	2234.17	2443.47
55	15.758	0.001015	9.56734	9.56835	230.19	2219.89	2450.08
60	19.941	0.001017	7.66969	7.67071	251.09	2205.54	2456.63
65	25.03	0.001020	6.19554	6.19656	272.00	2191.12	2463.12
70	31.19	0.001023	5.04114	5.04217	292.93	2176.62	2469.55
75	38.58	0.001026	4.13021	4.13123	313.87	2162.03	2475.91
80	47.39	0.001029	3.40612	3.40715	334.84	2147.36	2482.19
85	57.83	0.001032	2.82654	2.82757	355.82	2132.58	2488.40
90	70.14	0.001036	2.35953	2.36056	376.82	2117.70	2494.52
95	84.55	0.001040	1.98082	1.98186	397.86	2102.70	2500.56
100	101.3	0.001044	1.67185	1.67290	418.91	2087.58	2506.50
105	120.8	0.001047	1.41831	1.41936	440.00	2072.34	2512.34
110	143.3	0.001052	1.20909	1.21014	461.12	2056.96	2518.09
115	169.1	0.001056	1.03552	1.03658	482.28	2041.44	2523.72
120	198.5	0.001060	0.89080	0.89186	503.48	2025.76	2529.24
125	232.1	0.001065	0.76953	0.77059	524.72	2009.91	2534.63
130	270.1	0.001070	0.66744	0.66850	546.00	1993.90	2539.90
135	313.0	0.001075	0.58110	0.58217	567.34	1977.69	2545.03
140	361.3	0.001080	0.50777	0.50885	588.72	1961.30	2550.02
145	415.4	0.001085	0.44524	0.44632	610.16	1944.69	2554.86
150	475.9	0.001090	0.39169	0.39278	631.66	1927.87	2559.54
155	543.1	0.001096	0.34566	0.34676	653.23	1910.82	2564.04
160	617.8	0.001102	0.30596	0.30706	674.85	1893.52	2568.37
165	700.5	0.001108	0.27158	0.27269	696.55	1875.97	2572.51
170	791.7	0.001114	0.24171	0.24283	718.31	1858.14	2576.46
175	892.0	0.001121	0.21568	0.21680	740.16	1840.03	2580.19
180	1002.2	0.001127	0.19292	0.19405	762.08	1821.62	2583.70
185	1122.7	0.001134	0.17295	0.17409	784.08	1802.90	2586.98
190	1254.4	0.001141	0.15539	0.15654	806.17	1783.84	2590.01

TABLE B.1.1 (continued)

*Saturated Water*

Temp. (°C)	Press. (kPa)	Enthalpy, kJ/kg			Entropy, kJ/kg-K		
		Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$
0.01	0.6113	0.00	2501.35	2501.35	0	9.1562	9.1562
5	0.8721	20.98	2489.57	2510.54	0.0761	8.9496	9.0257
10	1.2276	41.99	2477.75	2519.74	0.1510	8.7498	8.9007
15	1.705	62.98	2465.93	2528.91	0.2245	8.5569	8.7813
20	2.339	83.94	2454.12	2538.06	0.2966	8.3706	8.6671
25	3.169	104.87	2442.30	2547.17	0.3673	8.1905	8.5579
30	4.246	125.77	2430.48	2556.25	0.4369	8.0164	8.4533
35	5.628	146.66	2418.62	2565.28	0.5052	7.8478	8.3530
40	7.384	167.54	2406.72	2574.26	0.5724	7.6845	8.2569
45	9.593	188.42	2394.77	2583.19	0.6386	7.5261	8.1647
50	12.350	209.31	2382.75	2592.06	0.7037	7.3725	8.0762
55	15.758	230.20	2370.66	2600.86	0.7679	7.2234	7.9912
60	19.941	251.11	2358.48	2609.59	0.8311	7.0784	7.9095
65	25.03	272.03	2346.21	2618.24	0.8934	6.9375	7.8309
70	31.19	292.96	2333.85	2626.80	0.9548	6.8004	7.7552
75	38.58	313.91	2321.37	2635.28	1.0154	6.6670	7.6824
80	47.39	334.88	2308.77	2643.66	1.0752	6.5369	7.6121
85	57.83	355.88	2296.05	2651.93	1.1342	6.4102	7.5444
90	70.14	376.90	2283.19	2660.09	1.1924	6.2866	7.4790
95	84.55	397.94	2270.19	2668.13	1.2500	6.1659	7.4158
100	101.3	419.02	2257.03	2676.05	1.3068	6.0480	7.3548
105	120.8	440.13	2243.70	2683.83	1.3629	5.9328	7.2958
110	143.3	461.27	2230.20	2691.47	1.4184	5.8202	7.2386
115	169.1	482.46	2216.50	2698.96	1.4733	5.7100	7.1832
120	198.5	503.69	2202.61	2706.30	1.5275	5.6020	7.1295
125	232.1	524.96	2188.50	2713.46	1.5812	5.4962	7.0774
130	270.1	546.29	2174.16	2720.46	1.6343	5.3925	7.0269
135	313.0	567.67	2159.59	2727.26	1.6869	5.2907	6.9777
140	361.3	589.11	2144.75	2733.87	1.7390	5.1908	6.9298
145	415.4	610.61	2129.65	2740.26	1.7906	5.0926	6.8832
150	475.9	632.18	2114.26	2746.44	1.8417	4.9960	6.8378
155	543.1	653.82	2098.56	2752.39	1.8924	4.9010	6.7934
160	617.8	675.53	2082.55	2758.09	1.9426	4.8075	6.7501
165	700.5	697.32	2066.20	2763.53	1.9924	4.7153	6.7078
170	791.7	719.20	2049.50	2768.70	2.0418	4.6244	6.6663
175	892.0	741.16	2032.42	2773.58	2.0909	4.5347	6.6256
180	1002.2	763.21	2014.96	2778.16	2.1395	4.4461	6.5857
185	1122.7	785.36	1997.07	2782.43	2.1878	4.3586	6.5464
190	1254.4	807.61	1978.76	2786.37	2.2358	4.2720	6.5078



TABLE B.1.1 (continued)

## Saturated Water

Temp. (°C)	Press. (kPa)	Specific Volume, m <sup>3</sup> /kg			Internal Energy, kJ/kg		
		Sat. Liquid $v_f$	Evap. $v_{fg}$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Evap. $u_{fg}$	Sat. Vapor $u_g$
195	1397.8	0.001149	0.13990	0.14105	828.36	1764.43	2592.79
200	1553.8	0.001156	0.12620	0.12736	850.64	1744.66	2595.29
205	1723.0	0.001164	0.11405	0.11521	873.02	1724.49	2597.52
210	1906.3	0.001173	0.10324	0.10441	895.51	1703.93	2599.44
215	2104.2	0.001181	0.09361	0.09479	918.12	1682.94	2601.06
220	2317.8	0.001190	0.08500	0.08619	940.85	1661.49	2602.35
225	2547.7	0.001199	0.07729	0.07849	963.72	1639.58	2603.30
230	2794.9	0.001209	0.07037	0.07158	986.72	1617.17	2603.89
235	3060.1	0.001219	0.06415	0.06536	1009.88	1594.24	2604.11
240	3344.2	0.001229	0.05853	0.05976	1033.19	1570.75	2603.95
245	3648.2	0.001240	0.05346	0.05470	1056.69	1546.68	2603.37
250	3973.0	0.001251	0.04887	0.05013	1080.37	1522.00	2602.37
255	4319.5	0.001263	0.04471	0.04598	1104.26	1496.66	2600.93
260	4688.6	0.001276	0.04093	0.04220	1128.37	1470.64	2599.01
265	5081.3	0.001289	0.03748	0.03877	1152.72	1443.87	2596.60
270	5498.7	0.001302	0.03434	0.03564	1177.33	1416.33	2593.66
275	5941.8	0.001317	0.03147	0.03279	1202.23	1387.94	2590.17
280	6411.7	0.001332	0.02884	0.03017	1227.43	1358.66	2586.09
285	6909.4	0.001348	0.02642	0.02777	1252.98	1328.41	2581.38
290	7436.0	0.001366	0.02420	0.02557	1278.89	1297.11	2575.99
295	7992.8	0.001384	0.02216	0.02354	1305.21	1264.67	2569.87
300	8581.0	0.001404	0.02027	0.02167	1331.97	1230.99	2562.96
305	9201.8	0.001425	0.01852	0.01995	1359.22	1195.94	2555.16
310	9856.6	0.001447	0.01690	0.01835	1387.03	1159.37	2546.40
315	10547	0.001472	0.01539	0.01687	1415.44	1121.11	2536.55
320	11274	0.001499	0.01399	0.01549	1444.55	1080.93	2525.48
325	12040	0.001528	0.01267	0.01420	1474.44	1038.57	2513.01
330	12845	0.001561	0.01144	0.01300	1505.24	993.66	2498.91
335	13694	0.001597	0.01027	0.01186	1537.11	945.77	2482.88
340	14586	0.001638	0.00916	0.01080	1570.26	894.26	2464.53
345	15525	0.001685	0.00810	0.00978	1605.01	838.29	2443.30
350	16514	0.001740	0.00707	0.00881	1641.81	776.58	2418.39
355	17554	0.001807	0.00607	0.00787	1681.41	707.11	2388.52
360	18651	0.001892	0.00505	0.00694	1725.19	626.29	2351.47
365	19807	0.002011	0.00398	0.00599	1776.13	526.54	2302.67
370	21028	0.002213	0.00271	0.00493	1843.84	384.69	2228.53
374.1	22089	0.003155	0	0.00315	2029.58	0	2029.58

TABLE B.1.1 (continued)  
Saturated Water

Temp. (°C)	Press. (kPa)	Enthalpy, kJ/kg			Entropy, kJ/kg-K		
		Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$
195	1397.8	829.96	1959.99	2789.96	2.2835	4.1863	6.4697
200	1553.8	852.43	1940.75	2793.18	2.3308	4.1014	6.4322
205	1723.0	875.03	1921.00	2796.03	2.3779	4.0172	6.3951
210	1906.3	897.75	1900.73	2798.48	2.4247	3.9337	6.3584
215	2104.2	920.61	1879.91	2800.51	2.4713	3.8507	6.3221
220	2317.8	943.61	1858.51	2802.12	2.5177	3.7683	6.2860
225	2547.7	966.77	1836.50	2803.27	2.5639	3.6863	6.2502
230	2794.9	990.10	1813.85	2803.95	2.6099	3.6047	6.2146
235	3060.1	1013.61	1790.53	2804.13	2.6557	3.5233	6.1791
240	3344.2	1037.31	1766.50	2803.81	2.7015	3.4422	6.1436
245	3648.2	1061.21	1741.73	2802.95	2.7471	3.3612	6.1083
250	3973.0	1085.34	1716.18	2801.52	2.7927	3.2802	6.0729
255	4319.5	1109.72	1689.80	2799.51	2.8382	3.1992	6.0374
260	4688.6	1134.35	1662.54	2796.89	2.8837	3.1181	6.0018
265	5081.3	1159.27	1634.34	2793.61	2.9293	3.0368	5.9661
270	5498.7	1184.49	1605.16	2789.65	2.9750	2.9551	5.9301
275	5941.8	1210.05	1574.92	2784.97	3.0208	2.8730	5.8937
280	6411.7	1235.97	1543.55	2779.53	3.0667	2.7903	5.8570
285	6909.4	1262.29	1510.97	2773.27	3.1129	2.7069	5.8198
290	7436.0	1289.04	1477.08	2766.13	3.1593	2.6227	5.7821
295	7992.8	1316.27	1441.78	2758.05	3.2061	2.5375	5.7436
300	8581.0	1344.01	1404.93	2748.94	3.2533	2.4511	5.7044
305	9201.8	1372.33	1366.38	2738.72	3.3009	2.3633	5.6642
310	9856.6	1401.29	1325.97	2727.27	3.3492	2.2737	5.6229
315	10547	1430.97	1283.48	2714.44	3.3981	2.1821	5.5803
320	11274	1461.45	1238.64	2700.08	3.4479	2.0882	5.5361
325	12040	1492.84	1191.13	2683.97	3.4987	1.9913	5.4900
330	12845	1525.29	1140.56	2665.85	3.5506	1.8909	5.4416
335	13694	1558.98	1086.37	2645.35	3.6040	1.7863	5.3903
340	14586	1594.15	1027.86	2622.01	3.6593	1.6763	5.3356
345	15525	1631.17	964.02	2595.19	3.7169	1.5594	5.2763
350	16514	1670.54	893.38	2563.92	3.7776	1.4336	5.2111
355	17554	1713.13	813.59	2526.72	3.8427	1.2951	5.1378
360	18651	1760.48	720.52	2481.00	3.9146	1.1379	5.0525
365	19807	1815.96	605.44	2421.40	3.9983	0.9487	4.9470
370	21028	1890.37	441.75	2332.12	4.1104	0.6868	4.7972
374.1	22089	2099.26	0	2099.26	4.4297	0	4.4297

TABLE B.1.2

*Saturated Water Pressure Entry*

Press. (kPa)	Temp. (°C)	Specific Volume, m <sup>3</sup> /kg			Internal Energy, kJ/kg		
		Sat. Liquid $v_f$	Evap. $v_{fg}$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Evap. $u_{fg}$	Sat. Vapor $u_g$
0.6113	0.01	0.001000	206.131	206.132	0	2375.3	2375.3
1	6.98	0.001000	129.20702	129.20802	29.29	2355.69	2384.98
1.5	13.03	0.001001	87.97913	87.98013	54.70	2338.63	2393.32
2	17.50	0.001001	67.00285	67.00385	73.47	2326.02	2399.48
2.5	21.08	0.001002	54.25285	54.25385	88.47	2315.93	2404.40
3	24.08	0.001003	45.66402	45.66502	101.03	2307.48	2408.51
4	28.96	0.001004	34.79915	34.80015	121.44	2293.73	2415.17
5	32.88	0.001005	28.19150	28.19251	137.79	2282.70	2420.49
7.5	40.29	0.001008	19.23674	19.23775	168.76	2261.74	2430.50
10	45.81	0.001010	14.67254	14.67355	191.79	2246.10	2437.89
15	53.97	0.001014	10.02117	10.02218	225.90	2222.83	2448.73
20	60.06	0.001017	7.64835	7.64937	251.35	2205.36	2456.71
25	64.97	0.001020	6.20322	6.20424	271.88	2191.21	2463.08
30	69.10	0.001022	5.22816	5.22918	289.18	2179.22	2468.40
40	75.87	0.001026	3.99243	3.99345	317.51	2159.49	2477.00
50	81.33	0.001030	3.23931	3.24034	340.42	2143.43	2483.85
75	91.77	0.001037	2.21607	2.21711	394.29	2112.39	2496.67
100	99.62	0.001043	1.69296	1.69400	417.33	2088.72	2506.06
125	105.99	0.001048	1.37385	1.37490	444.16	2069.32	2513.48
150	111.37	0.001053	1.15828	1.15933	466.92	2052.72	2519.64
175	116.06	0.001057	1.00257	1.00363	486.78	2038.12	2524.90
200	120.23	0.001061	0.88467	0.88573	504.47	2025.02	2529.49
225	124.00	0.001064	0.79219	0.79325	520.45	2013.10	2533.56
250	127.43	0.001067	0.71765	0.71871	535.08	2002.14	2537.21
275	130.60	0.001070	0.65624	0.65731	548.57	1991.95	2540.53
300	133.55	0.001073	0.60475	0.60582	561.13	1982.43	2543.55
325	136.30	0.001076	0.56093	0.56201	572.88	1973.46	2546.34
350	138.88	0.001079	0.52317	0.52425	583.93	1964.98	2548.92
375	141.32	0.001081	0.49029	0.49137	594.38	1956.93	2551.31
400	143.63	0.001084	0.46138	0.46246	604.29	1949.26	2553.55
450	147.93	0.001088	0.41289	0.41398	622.75	1934.87	2557.62
500	151.86	0.001093	0.37380	0.37489	639.66	1921.57	2561.23
550	155.48	0.001097	0.34159	0.34268	655.30	1909.17	2564.47
600	158.85	0.001101	0.31457	0.31567	669.88	1897.52	2567.40
650	162.01	0.001104	0.29158	0.29268	683.55	1886.51	2570.06
700	164.97	0.001108	0.27176	0.27286	696.43	1876.07	2572.49
750	167.77	0.001111	0.25449	0.25560	708.62	1866.11	2574.73
800	170.43	0.001115	0.23931	0.24043	720.20	1856.58	2576.79

TABLE B.1.2 (continued)

## Saturated Water Pressure Entry

Press. (kPa)	Temp. (°C)	Enthalpy, kJ/kg			Entropy, kJ/kg-K		
		Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$
0.6113	0.01	0.00	2501.3	2501.3	0	9.1562	9.1562
1.0	6.98	29.29	2484.89	2514.18	0.1059	8.8697	8.9756
1.5	13.03	54.70	2470.59	2525.30	0.1956	8.6322	8.8278
2.0	17.50	73.47	2460.02	2533.49	0.2607	8.4629	8.7236
2.5	21.08	88.47	2451.56	2540.03	0.3120	8.3311	8.6431
3.0	24.08	101.03	2444.47	2545.50	0.3545	8.2231	8.5775
4.0	28.96	121.44	2432.93	2554.37	0.4226	8.0520	8.4746
5.0	32.88	137.79	2423.66	2561.45	0.4763	7.9187	8.3950
7.5	40.29	168.77	2406.02	2574.79	0.5763	7.6751	8.2514
10	45.81	191.81	2392.82	2584.63	0.6492	7.5010	8.1501
15	53.97	225.91	2373.14	2599.06	0.7548	7.2536	8.0084
20	60.06	251.38	2358.33	2609.70	0.8319	7.0766	7.9085
25	64.97	271.90	2346.29	2618.19	0.8930	6.9383	7.8313
30	69.10	289.21	2336.07	2625.28	0.9439	6.8247	7.7686
40	75.87	317.55	2319.19	2636.74	1.0258	6.6441	7.6700
50	81.33	340.47	2305.40	2645.87	1.0910	6.5029	7.5939
75	91.77	384.36	2278.59	2662.96	1.2129	6.2434	7.4563
100	99.62	417.44	2258.02	2675.46	1.3025	6.0568	7.3593
125	105.99	444.30	2241.05	2685.35	1.3739	5.9104	7.2843
150	111.37	467.08	2226.46	2693.54	1.4335	5.7897	7.2232
175	116.06	486.97	2213.57	2700.53	1.4848	5.6868	7.1717
200	120.23	504.68	2201.96	2706.63	1.5300	5.5970	7.1271
225	124.00	520.69	2191.35	2712.04	1.5705	5.5173	7.0878
250	127.43	535.34	2181.55	2716.89	1.6072	5.4455	7.0526
275	130.60	548.87	2172.42	2721.29	1.6407	5.3801	7.0208
300	133.55	561.45	2163.85	2725.30	1.6717	5.3201	6.9918
325	136.30	573.23	2155.76	2728.99	1.7005	5.2646	6.9651
350	138.88	584.31	2148.10	2732.40	1.7274	5.2130	6.9404
375	141.32	594.79	2140.79	2735.58	1.7527	5.1647	6.9174
400	143.63	604.73	2133.81	2738.53	1.7766	5.1193	6.8958
450	147.93	623.24	2120.67	2743.91	1.8206	5.0359	6.8565
500	151.86	640.21	2108.47	2748.67	1.8606	4.9606	6.8212
550	155.48	655.91	2097.04	2752.94	1.8972	4.8920	6.7892
600	158.85	670.54	2086.26	2756.80	1.9311	4.8289	6.7600
650	162.01	684.26	2076.04	2760.30	1.9627	4.7704	6.7330
700	164.97	697.20	2066.30	2763.50	1.9922	4.7158	6.7080
750	167.77	709.45	2056.98	2766.43	2.0199	4.6647	6.6846
800	170.43	721.10	2048.04	2769.13	2.0461	4.6166	6.6627

TABLE B.1.2 (continued)

## Saturated Water Pressure Entry

Press. (kPa)	Temp. (°C)	Specific Volume, m <sup>3</sup> /kg			Internal Energy, kJ/kg		
		Sat. Liquid $v_f$	Evap. $v_{fg}$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Evap. $u_{fg}$	Sat. Vapor $u_g$
850	172.96	0.001118	0.22586	0.22698	731.25	1847.45	2578.69
900	175.38	0.001121	0.21385	0.21497	741.81	1838.65	2580.46
950	177.69	0.001124	0.20306	0.20419	751.94	1830.17	2582.11
1000	179.91	0.001127	0.19332	0.19444	761.67	1821.97	2583.64
1100	184.09	0.001133	0.17639	0.17753	780.08	1806.32	2586.40
1200	187.99	0.001139	0.16220	0.16333	797.27	1791.55	2588.82
1300	191.64	0.001144	0.15011	0.15125	813.42	1777.53	2590.95
1400	195.07	0.001149	0.13969	0.14084	828.68	1764.15	2592.83
1500	198.32	0.001154	0.13062	0.13177	843.14	1751.3	2594.5
1750	205.76	0.001166	0.11232	0.11349	876.44	1721.39	2597.83
2000	212.42	0.001177	0.09845	0.09963	906.42	1693.84	2600.26
2250	218.45	0.001187	0.08756	0.08875	933.81	1668.18	2601.98
2500	223.99	0.001197	0.07878	0.07998	959.09	1644.04	2603.13
2750	229.12	0.001207	0.07154	0.07275	982.65	1621.16	2603.81
3000	233.90	0.001216	0.06546	0.06668	1004.76	1599.34	2604.10
3250	238.38	0.001226	0.06029	0.06152	1025.62	1578.43	2604.04
3500	242.60	0.001235	0.05583	0.05707	1045.41	1558.29	2603.70
4000	250.40	0.001252	0.04853	0.04978	1082.28	1519.99	2602.27
5000	263.99	0.001286	0.03815	0.03944	1147.78	1449.34	2597.12
6000	275.64	0.001319	0.03112	0.03244	1205.41	1384.27	2589.69
7000	285.88	0.001351	0.02602	0.02737	1257.51	1322.97	2580.48
8000	295.06	0.001384	0.02213	0.02352	1305.54	1264.25	2569.79
9000	303.40	0.001418	0.01907	0.02048	1350.47	1207.28	2557.75
10000	311.06	0.001452	0.01657	0.01803	1393.00	1151.40	2544.41
11000	318.15	0.001489	0.01450	0.01599	1433.68	1096.06	2529.74
12000	324.75	0.001527	0.01274	0.01426	1472.92	1040.76	2513.67
13000	330.93	0.001567	0.01121	0.01278	1511.09	984.99	2496.08
14000	336.75	0.001611	0.00987	0.01149	1548.53	928.23	2476.76
15000	342.24	0.001658	0.00868	0.01034	1585.58	869.85	2455.43
16000	347.43	0.001711	0.00760	0.00931	1622.63	809.07	2431.70
17000	352.37	0.001770	0.00659	0.00836	1660.16	744.80	2404.96
18000	357.06	0.001840	0.00565	0.00749	1698.86	675.42	2374.28
19000	361.54	0.001924	0.00473	0.00666	1739.87	598.18	2338.05
20000	365.81	0.002035	0.00380	0.00583	1785.47	507.58	2293.05
21000	369.89	0.002206	0.00275	0.00495	1841.97	388.74	2230.71
22000	373.80	0.002808	0.00072	0.00353	1973.16	108.24	2081.39
22089	374.14	0.003155	0	0.00315	2029.58	0	2029.58

TABLE B.1.2 (continued)

*Saturated Water Pressure Entry*

Press. (kPa)	Temp. (°C)	Enthalpy, kJ/kg			Entropy, kJ/kg-K		
		Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$
850	172.96	732.20	2039.43	2771.63	2.0709	4.5711	6.6421
900	175.38	742.82	2031.12	2773.94	2.0946	4.5280	6.6225
950	177.69	753.00	2023.08	2776.08	2.1171	4.4869	6.6040
1000	179.91	762.79	2015.29	2778.08	2.1386	4.4478	6.5864
1100	184.09	781.32	2000.36	2781.68	2.1791	4.3744	6.5535
1200	187.99	798.64	1986.19	2784.82	2.2165	4.3067	6.5233
1300	191.64	814.91	1972.67	2787.58	2.2514	4.2438	6.4953
1400	195.07	830.29	1959.72	2790.00	2.2842	4.1850	6.4692
1500	198.32	844.87	1947.28	2792.15	2.3150	4.1298	6.4448
1750	205.76	878.48	1917.95	2796.43	2.3851	4.0044	6.3895
2000	212.42	908.77	1890.74	2799.51	2.4473	3.8935	6.3408
2250	218.45	936.48	1865.19	2801.67	2.5034	3.7938	6.2971
2500	223.99	962.09	1840.98	2803.07	2.5546	3.7028	6.2574
2750	229.12	985.97	1817.89	2803.86	2.6018	3.6190	6.2208
3000	233.90	1008.41	1795.73	2804.14	2.6456	3.5412	6.1869
3250	238.38	1029.60	1774.37	2803.97	2.6866	3.4685	6.1551
3500	242.60	1049.73	1753.70	2803.43	2.7252	3.4000	6.1252
4000	250.40	1087.29	1714.09	2801.38	2.7963	3.2737	6.0700
5000	263.99	1154.21	1640.12	2794.33	2.9201	3.0532	5.9733
6000	275.64	1213.32	1571.00	2784.33	3.0266	2.8625	5.8891
7000	285.88	1266.97	1505.10	2772.07	3.1210	2.6922	5.8132
8000	295.06	1316.61	1441.33	2757.94	3.2067	2.5365	5.7431
9000	303.40	1363.23	1378.88	2742.11	3.2857	2.3915	5.6771
10000	311.06	1407.53	1317.14	2724.67	3.3595	2.2545	5.6140
11000	318.15	1450.05	1255.55	2705.60	3.4294	2.1233	5.5527
12000	324.75	1491.24	1193.59	2684.83	3.4961	1.9962	5.4923
13000	330.93	1531.46	1130.76	2662.22	3.5604	1.8718	5.4323
14000	336.75	1571.08	1066.47	2637.55	3.6231	1.7485	5.3716
15000	342.24	1610.45	1000.04	2610.49	3.6847	1.6250	5.3097
16000	347.43	1650.00	930.59	2580.59	3.7460	1.4995	5.2454
17000	352.37	1690.25	856.90	2547.15	3.8078	1.3698	5.1776
18000	357.06	1731.97	777.13	2509.09	3.8713	1.2330	5.1044
19000	361.54	1776.43	688.11	2464.54	3.9387	1.0841	5.0227
20000	365.81	1826.18	583.56	2409.74	4.0137	0.9132	4.9269
21000	369.89	1888.30	446.42	2334.72	4.1073	0.6942	4.8015
22000	373.80	2034.92	124.04	2158.97	4.3307	0.1917	4.5224
22089	374.14	2099.26	0	2099.26	4.4297	0	4.4297

TABLE B.1.3

*Superheated Vapor Water*

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg·K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg·K)
$P = 10 \text{ kPa (45.81°C)}$					$P = 50 \text{ kPa (81.33°C)}$			
Sat.	14.67355	2437.89	2584.63	8.1501	3.24034	2483.85	2645.87	7.5939
50	14.86920	2443.87	2592.56	8.1749	—	—	—	—
100	17.19561	2515.50	2687.46	8.4479	3.41833	2511.61	2682.52	7.6947
150	19.51251	2587.86	2782.99	8.6881	3.88937	2585.61	2780.08	7.9400
200	21.82507	2661.27	2879.52	8.9037	4.35595	2659.85	2877.64	8.1579
250	24.13559	2735.95	2977.31	9.1002	4.82045	2734.97	2975.99	8.3555
300	26.44508	2812.06	3076.51	9.2812	5.28391	2811.33	3075.52	8.5372
400	31.06252	2968.89	3279.51	9.6076	6.20929	2968.43	3278.89	8.8641
500	35.67896	3132.26	3489.05	9.8977	7.13364	3131.94	3488.62	9.1545
600	40.29488	3302.45	3705.40	10.1608	8.05748	3302.22	3705.10	9.4177
700	44.91052	3479.63	3928.73	10.4028	8.98104	3479.45	3928.51	9.6599
800	49.52599	3663.84	4159.10	10.6281	9.90444	3663.70	4158.92	9.8852
900	54.14137	3855.03	4396.44	10.8395	10.82773	3854.91	4396.30	10.0967
1000	58.75669	4053.01	4640.58	11.0392	11.75097	4052.91	4640.46	10.2964
1100	63.37198	4257.47	4891.19	11.2287	12.67418	4257.37	4891.08	10.4858
1200	67.98724	4467.91	5147.78	11.4090	13.59737	4467.82	5147.69	10.6662
1300	72.60250	4683.68	5409.70	14.5810	14.52054	4683.58	5409.61	10.8382
$100 \text{ kPa (99.62°C)}$					$200 \text{ kPa (120.23°C)}$			
Sat.	1.69400	2506.06	2675.46	7.3593	0.88573	2529.49	2706.63	7.1271
150	1.93636	2582.75	2776.38	7.6133	0.95964	2576.87	2768.80	7.2795
200	2.17226	2658.05	2875.27	7.8342	1.08034	2654.39	2870.46	7.5066
250	2.40604	2733.73	2974.33	8.0332	1.19880	2731.22	2970.98	7.7085
300	2.63876	2810.41	3074.28	8.2157	1.31616	2808.55	3071.79	7.8926
400	3.10263	2967.85	3278.11	8.5434	1.54930	2966.69	3276.55	8.2217
500	3.56547	3131.54	3488.09	8.8341	1.78139	3130.75	3487.03	8.5132
600	4.02781	3301.94	3704.72	9.0975	2.01297	3301.36	3703.96	8.7769
700	4.48986	3479.24	3928.23	9.3398	2.24426	3478.81	3927.66	9.0194
800	4.95174	3663.53	4158.71	9.5652	2.47539	3663.19	4158.27	9.2450
900	5.41353	3854.77	4396.12	9.7767	2.70643	3854.49	4395.77	9.4565
1000	5.87526	4052.78	4640.31	9.9764	2.93740	4052.53	4640.01	9.6563
1100	6.33696	4257.25	4890.95	10.1658	3.16834	4257.01	4890.68	9.8458
1200	6.79863	4467.70	5147.56	10.3462	3.39927	4467.46	5147.32	10.0262
1300	7.26030	4683.47	5409.49	10.5182	3.63018	4683.23	5409.26	10.1982
$300 \text{ kPa (133.55°C)}$					$400 \text{ kPa (143.63°C)}$			
Sat.	0.60582	2543.55	2725.30	6.9918	0.46246	2553.55	2738.53	6.8958
150	0.63388	2570.79	2760.95	7.0778	0.47084	2564.48	2752.82	6.9299
200	0.71629	2650.65	2865.54	7.3115	0.53422	2646.83	2860.51	7.1706



**TABLE B.1.3** (continued)  
**Superheated Vapor Water**

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
300 kPa (133.55°C)					400 kPa (143.63°C)			
250	0.79636	2728.69	2967.59	7.5165	0.59512	2726.11	2964.16	7.3788
300	0.87529	2806.69	3069.28	7.7022	0.65484	2804.81	3066.75	7.5661
400	1.03151	2965.53	3274.98	8.0329	0.77262	2964.36	3273.41	7.8984
500	1.18669	3129.95	3485.96	8.3250	0.88934	3129.15	3484.89	8.1912
600	1.34136	3300.79	3703.20	8.5892	1.00555	3300.22	3702.44	8.4557
700	1.49573	3478.38	3927.10	8.8319	1.12147	3477.95	3926.53	8.6987
800	1.64994	3662.85	4157.83	9.0575	1.23722	3662.51	4157.40	8.9244
900	1.80406	3854.20	4395.42	9.2691	1.35288	3853.91	4395.06	9.1361
1000	1.95812	4052.27	4639.71	9.4689	1.46847	4052.02	4639.41	9.3360
1100	2.11214	4256.77	4890.41	9.6585	1.58404	4256.53	4890.15	9.5255
1200	2.26614	4467.23	5147.07	9.8389	1.69958	4466.99	5146.83	9.7059
1300	2.42013	4682.99	5409.03	10.0109	1.81511	4682.75	5408.80	9.8780
500 kPa (151.86°C)					600 kPa (158.85°C)			
Sat.	0.37489	2561.23	2748.67	6.8212	0.31567	2567.40	2756.80	6.7600
200	0.42492	2642.91	2855.37	7.0592	0.35202	2638.91	2850.12	6.9665
250	0.47436	2723.50	2960.68	7.2708	0.39383	2720.86	2957.16	7.1816
300	0.52256	2802.91	3064.20	7.4598	0.43437	2801.00	3061.63	7.3723
350	0.57012	2882.59	3167.65	7.6328	0.47424	2881.12	3165.66	7.5463
400	0.61728	2963.19	3271.83	7.7937	0.51372	2962.02	3270.25	7.7078
500	0.71093	3128.35	3483.82	8.0872	0.59199	3127.55	3482.75	8.0020
600	0.80406	3299.64	3701.67	8.3521	0.66974	3299.07	3700.91	8.2673
700	0.89691	3477.52	3925.97	8.5952	0.74720	3477.08	3925.41	8.5107
800	0.98959	3662.17	4156.96	8.8211	0.82450	3661.83	4156.52	8.7367
900	1.08217	3853.63	4394.71	9.0329	0.90169	3853.34	4394.36	8.9485
1000	1.17469	4051.76	4639.11	9.2328	0.97883	4051.51	4638.81	9.1484
1100	1.26718	4256.29	4889.88	9.4224	1.05594	4256.05	4889.61	9.3381
1200	1.35964	4466.76	5146.58	9.6028	1.13302	4466.52	5146.34	9.5185
1300	1.45210	4682.52	5408.57	9.7749	1.21009	4682.28	5408.34	9.6906
800 kPa (170.43°C)					1000 kPa (179.91°C)			
Sat.	0.24043	2576.79	2769.13	6.6627	0.19444	2583.64	2778.08	6.5864
200	0.26080	2630.61	2839.25	6.8158	0.20596	2621.90	2827.86	6.6939
250	0.29314	2715.46	2949.97	7.0384	0.23268	2709.91	2942.59	6.9246
300	0.32411	2797.14	3056.43	7.2327	0.25794	2793.21	3051.15	7.1228
350	0.35439	2878.16	3161.68	7.4088	0.28247	2875.18	3157.65	7.3010
400	0.38426	2959.66	3267.07	7.5715	0.30659	2957.29	3263.88	7.4650
500	0.44331	3125.95	3480.60	7.8672	0.35411	3124.34	3478.44	7.7621
600	0.50184	3297.91	3699.38	8.1332	0.40109	3296.76	3697.85	8.0289

TABLE B.1.3 (continued)  
Superheated Vapor Water

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
800 kPa (170.43°C)					1000 kPa (179.91°C)			
700	0.56007	3476.22	3924.27	8.3770	0.44779	3475.35	3923.14	8.2731
800	0.61813	3661.14	4155.65	8.6033	0.49432	3660.46	4154.78	8.4996
900	0.67610	3852.77	4393.65	8.8153	0.54075	3852.19	4392.94	8.7118
1000	0.73401	4051.00	4638.20	9.0153	0.58712	4050.49	4637.60	8.9119
1100	0.79188	4255.57	4889.08	9.2049	0.63345	4255.09	4888.55	9.1016
1200	0.84974	4466.05	5145.85	9.3854	0.67977	4465.58	5145.36	9.2821
1300	0.90758	4681.81	5407.87	9.5575	0.72608	4681.33	5407.41	9.4542
1200 kPa (187.99°C)					1400 kPa (195.07°C)			
Sat.	0.16333	2588.82	2784.82	6.5233	0.14084	2592.83	2790.00	6.4692
200	0.16930	2612.74	2815.90	6.5898	0.14302	2603.09	2803.32	6.4975
250	0.19235	2704.20	2935.01	6.8293	0.16350	2698.32	2927.22	6.7467
300	0.21382	2789.22	3045.80	7.0316	0.18228	2785.16	3040.35	6.9533
350	0.23452	2872.16	3153.59	7.2120	0.20026	2869.12	3149.49	7.1359
400	0.25480	2954.90	3260.66	7.3773	0.21780	2952.50	3257.42	7.3025
500	0.29463	3122.72	3476.28	7.6758	0.25215	3121.10	3474.11	7.6026
600	0.33393	3295.60	3696.32	7.9434	0.28596	3294.44	3694.78	7.8710
700	0.37294	3474.48	3922.01	8.1881	0.31947	3473.61	3920.87	8.1160
800	0.41177	3659.77	4153.90	8.4149	0.35281	3659.09	4153.03	8.3431
900	0.45051	3851.62	4392.23	8.6272	0.38606	3851.05	4391.53	8.5555
1000	0.48919	4049.98	4637.00	8.8274	0.41924	4049.47	4636.41	8.7558
1100	0.52783	4254.61	4888.02	9.0171	0.45239	4254.14	4887.49	8.9456
1200	0.56646	4465.12	5144.87	9.1977	0.48552	4464.65	5144.38	9.1262
1300	0.60507	4680.86	5406.95	9.3698	0.51864	4680.39	5406.49	9.2983
1600 kPa (201.40°C)					1800 kPa (207.15°C)			
Sat.	0.12380	2595.95	2794.02	6.4217	0.11042	2598.38	2797.13	6.3793
250	0.14184	2692.26	2919.20	6.6732	0.12497	2686.02	2910.96	6.6066
300	0.15862	2781.03	3034.83	6.8844	0.14021	2776.83	3029.21	6.8226
350	0.17456	2866.05	3145.35	7.0693	0.15457	2862.95	3141.18	7.0099
400	0.19005	2950.09	3254.17	7.2373	0.16847	2947.66	3250.90	7.1793
500	0.22029	3119.47	3471.93	7.5389	0.19550	3117.84	3469.75	7.4824
600	0.24998	3293.27	3693.23	7.8080	0.22199	3292.10	3691.69	7.7523
700	0.27937	3472.74	3919.73	8.0535	0.24818	3471.87	3918.59	7.9983
800	0.30859	3658.40	4152.15	8.2808	0.27420	3657.71	4151.27	8.2258
900	0.33772	3850.47	4390.82	8.4934	0.30012	3849.90	4390.11	8.4386
1000	0.36678	4048.96	4635.81	8.6938	0.32598	4048.45	4635.21	8.6390
1100	0.39581	4253.66	4886.95	8.8837	0.35180	4253.18	4886.42	8.8290
1200	0.42482	4464.18	5143.89	9.0642	0.37761	4463.71	5143.40	9.0096
1300	0.45382	4679.92	5406.02	9.2364	0.40340	4679.44	5405.56	9.1817

TABLE B.1.3 (continued)  
*Superheated Vapor Water*

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
2000 kPa (212.42°C)					2500 kPa (223.99°C)			
Sat.	0.09963	2600.26	2799.51	6.3408	0.07998	2603.13	2803.07	6.2574
250	0.11144	2679.58	2902.46	6.5452	0.08700	2662.55	2880.06	6.4084
300	0.12547	2772.56	3023.50	6.7663	0.09890	2761.56	3008.81	6.6437
350	0.13857	2859.81	3136.96	6.9562	0.10976	2851.84	3126.24	6.8402
400	0.15120	2945.21	3247.60	7.1270	0.12010	2939.03	3239.28	7.0147
450	0.16353	3030.41	3357.48	7.2844	0.13014	3025.43	3350.77	7.1745
500	0.17568	3116.20	3467.55	7.4316	0.13998	3112.08	3462.04	7.3233
600	0.19960	3290.93	3690.14	7.7023	0.15930	3287.99	3686.25	7.5960
700	0.22323	3470.99	3917.45	7.9487	0.17832	3468.80	3914.59	7.8435
800	0.24668	3657.03	4150.40	8.1766	0.19716	3655.30	4148.20	8.0720
900	0.27004	3849.33	4389.40	8.3895	0.21590	3847.89	4387.64	8.2853
1000	0.29333	4047.94	4634.61	8.5900	0.23458	4046.67	4633.12	8.4860
1100	0.31659	4252.71	4885.89	8.7800	0.25322	4251.52	4884.57	8.6761
1200	0.33984	4463.25	5142.92	8.9606	0.27185	4462.08	5141.70	8.8569
1300	0.36306	4678.97	5405.10	9.1328	0.29046	4677.80	5403.95	9.0291
3000 kPa (233.90°C)					4000 kPa (250.40°C)			
Sat.	0.06668	2604.10	2804.14	6.1869	0.04978	2602.27	2801.38	6.0700
250	0.07058	2644.00	2855.75	6.2871	—	—	—	—
300	0.08114	2750.05	2993.48	6.5389	0.05884	2725.33	2960.68	6.3614
350	0.09053	2843.66	3115.25	6.7427	0.06645	2826.65	3092.43	6.5820
400	0.09936	2932.75	3230.82	6.9211	0.07341	2919.88	3213.51	6.7689
450	0.10787	3020.38	3344.00	7.0833	0.08003	3010.13	3330.23	6.9362
500	0.11619	3107.92	3456.48	7.2337	0.08643	3099.49	3445.21	7.0900
600	0.13243	3285.03	3682.34	7.5084	0.09885	3279.06	3674.44	7.3688
700	0.14838	3466.59	3911.72	7.7571	0.11095	3462.15	3905.94	7.6198
800	0.16414	3653.58	4146.00	7.9862	0.12287	3650.11	4141.59	7.8502
900	0.17980	3846.46	4385.87	8.1999	0.13469	3843.59	4382.34	8.0647
1000	0.19541	4045.40	4631.63	8.4009	0.14645	4042.87	4628.65	8.2661
1100	0.21098	4250.33	4883.26	8.5911	0.15817	4247.96	4880.63	8.4566
1200	0.22652	4460.92	5140.49	8.7719	0.16987	4458.60	5138.07	8.6376
1300	0.24206	4676.63	5402.81	8.9442	0.18156	4674.29	5400.52	8.8099

TABLE B.1.3 (continued)  
Superheated Vapor Water

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
5000 kPa (263.99°C)					6000 kPa (275.64°C)			
Sat.	0.03944	2597.12	2794.33	5.9733	0.03244	2589.69	2784.33	5.8891
300	0.04532	2697.94	2924.53	6.2083	0.03616	2667.22	2884.19	6.0673
350	0.05194	2808.67	3068.39	6.4492	0.04223	2789.61	3042.97	6.3334
400	0.05781	2906.58	3195.64	6.6458	0.04739	2892.81	3177.17	6.5407
450	0.06330	2999.64	3316.15	6.8185	0.05214	2988.90	3301.76	6.7192
500	0.06857	3090.92	3433.76	6.9758	0.05665	3082.20	3422.12	6.8802
550	0.07368	3181.82	3550.23	7.1217	0.06101	3174.57	3540.62	7.0287
600	0.07869	3273.01	3666.47	7.2588	0.06525	3266.89	3658.40	7.1676
700	0.08849	3457.67	3900.13	7.5122	0.07352	3453.15	3894.28	7.4234
800	0.09811	3646.62	4137.17	7.7440	0.08160	3643.12	4132.74	7.6566
900	0.10762	3840.71	4378.82	7.9593	0.08958	3837.84	4375.29	7.8727
1000	0.11707	4040.35	4625.69	8.1612	0.09749	4037.83	4622.74	8.0751
1100	0.12648	4245.61	4878.02	8.3519	0.10536	4243.26	4875.42	8.2661
1200	0.13587	4456.30	5135.67	8.5330	0.11321	4454.00	5133.28	8.4473
1300	0.14526	4671.96	5398.24	8.7055	0.12106	4669.64	5395.97	8.6199
8000 kPa (295.06°C)					10000 kPa (311.06°C)			
Sat.	0.02352	2569.79	2757.94	5.7431	0.01803	2544.41	2724.67	5.6140
300	0.02426	2590.93	2784.98	5.7905	—	—	—	—
350	0.02995	2747.67	2987.30	6.1300	0.02242	2699.16	2923.39	5.9442
400	0.03432	2863.75	3138.28	6.3633	0.02641	2832.38	3096.46	6.2119
450	0.03817	2966.66	3271.99	6.5550	0.02975	2943.32	3240.83	6.4189
500	0.04175	3064.30	3398.27	6.7239	0.03279	3045.77	3373.63	6.5965
550	0.04516	3159.76	3521.01	6.8778	0.03564	3144.54	3500.92	6.7561
600	0.04845	3254.43	3642.03	7.0205	0.03837	3241.68	3625.34	6.9028
700	0.05481	3444.00	3882.47	7.2812	0.04358	3434.72	3870.52	7.1687
800	0.06097	3636.08	4123.84	7.5173	0.04859	3628.97	4114.91	7.4077
900	0.06702	3832.08	4368.26	7.7350	0.05349	3826.32	4361.24	7.6272
1000	0.07301	4032.81	4616.87	7.9384	0.05832	4027.81	4611.04	7.8315
1100	0.07896	4238.60	4870.25	8.1299	0.06312	4233.97	4865.14	8.0236
1200	0.08489	4449.45	5128.54	8.3115	0.06789	4444.93	5123.84	8.2054
1300	0.09080	4665.02	5391.46	8.4842	0.07265	4660.44	5386.99	8.3783

TABLE B.1.3 (continued)  
*Superheated Vapor Water*

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
15000 kPa (342.24°C)					20000 kPa (365.81°C)			
Sat.	0.01034	2455.43	2610.49	5.3097	0.00583	2293.05	2409.74	4.9269
350	0.01147	2520.36	2692.41	5.4420	—	—	—	—
400	0.01565	2740.70	2975.44	5.8810	0.00994	2619.22	2818.07	5.5539
450	0.01845	2879.47	3156.15	6.1403	0.01270	2806.16	3060.06	5.9016
500	0.02080	2996.52	3308.53	6.3442	0.01477	2942.82	3238.18	6.1400
550	0.02293	3104.71	3448.61	6.5198	0.01656	3062.34	3393.45	6.3347
600	0.02491	3208.64	3582.30	6.6775	0.01818	3174.00	3537.57	6.5048
650	0.02680	3310.37	3712.32	6.8223	0.01969	3281.46	3675.32	6.6582
700	0.02861	3410.94	3840.12	6.9572	0.02113	3386.46	3809.09	6.7993
800	0.03210	3610.99	4092.43	7.2040	0.02385	3592.73	4069.80	7.0544
900	0.03546	3811.89	4343.75	7.4279	0.02645	3797.44	4326.37	7.2830
1000	0.03875	4015.41	4596.63	7.6347	0.02897	4003.12	4582.45	7.4925
1100	0.04200	4222.55	4852.56	7.8282	0.03145	4211.30	4840.24	7.6874
1200	0.04523	4433.78	5112.27	8.0108	0.03391	4422.81	5100.96	7.8706
1300	0.04845	4649.12	5375.94	8.1839	0.03636	4637.95	5365.10	8.0441
30000 kPa					40000 kPa			
375	0.001789	1737.75	1791.43	3.9303	0.001641	1677.09	1742.71	3.8289
400	0.002790	2067.34	2151.04	4.4728	0.001908	1854.52	1930.83	4.1134
425	0.005304	2455.06	2614.17	5.1503	0.002532	2096.83	2198.11	4.5028
450	0.006735	2619.30	2821.35	5.4423	0.003693	2365.07	2512.79	4.9459
500	0.008679	2820.67	3081.03	5.7904	0.005623	2678.36	2903.26	5.4699
550	0.010168	2970.31	3275.36	6.0342	0.006984	2869.69	3149.05	5.7784
600	0.011446	3100.53	3443.91	6.2330	0.008094	3022.61	3346.38	6.0113
650	0.012596	3221.04	3598.93	6.4057	0.009064	3158.04	3520.58	6.2054
700	0.013661	3335.84	3745.67	6.5606	0.009942	3283.63	3681.29	6.3750
800	0.015623	3555.60	4024.31	6.8332	0.011523	3517.89	3978.80	6.6662
900	0.017448	3768.48	4291.93	7.0717	0.012963	3739.42	4257.93	6.9150
1000	0.019196	3978.79	4554.68	7.2867	0.014324	3954.64	4527.59	7.1356
1100	0.020903	4189.18	4816.28	7.4845	0.015643	4167.38	4793.08	7.3364
1200	0.022589	4401.29	5078.97	7.6691	0.016940	4380.11	5057.72	7.5224
1300	0.024266	4615.96	5343.95	7.8432	0.018229	4594.28	5323.45	7.6969

TABLE B.1.4

*Compressed Liquid Water*

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
500 kPa (151.86°C)					2000 kPa (212.42°C)			
Sat.	0.001093	639.66	640.21	1.8606	0.001177	906.42	908.77	2.4473
0.01	0.000999	0.01	0.51	0.0000	0.000999	0.03	2.03	0.0001
20	0.001002	83.91	84.41	0.2965	0.001001	83.82	85.82	.2962
40	0.001008	167.47	167.98	0.5722	0.001007	167.29	169.30	.5716
60	0.001017	251.00	251.51	0.8308	0.001016	250.73	252.77	.8300
80	0.001029	334.73	335.24	1.0749	0.001028	334.38	336.44	1.0739
100	0.001043	418.80	419.32	1.3065	0.001043	418.36	420.45	1.3053
120	0.001060	503.37	503.90	1.5273	0.001059	502.84	504.96	1.5259
140	0.001080	588.66	589.20	1.7389	0.001079	588.02	590.18	1.7373
160	—	—	—	—	0.001101	674.14	676.34	1.9410
180	—	—	—	—	0.001127	761.46	763.71	2.1382
200	—	—	—	—	0.001156	850.30	852.61	2.3301
5000 kPa (263.99°C)					10000 kPa (311.06°C)			
Sat	0.001286	1147.78	1154.21	2.9201	0.001452	1393.00	1407.53	3.3595
0	0.000998	0.03	5.02	0.0001	0.000995	0.10	10.05	0.0003
20	0.001000	83.64	88.64	0.2955	0.000997	83.35	93.32	0.2945
40	0.001006	166.93	171.95	0.5705	0.001003	166.33	176.36	0.5685
60	0.001015	250.21	255.28	0.8284	0.001013	249.34	259.47	0.8258
80	0.001027	333.69	338.83	1.0719	0.001025	332.56	342.81	1.0687
100	0.001041	417.50	422.71	1.3030	0.001039	416.09	426.48	1.2992
120	0.001058	501.79	507.07	1.5232	0.001055	500.07	510.61	1.5188
140	0.001077	586.74	592.13	1.7342	0.001074	584.67	595.40	1.7291
160	0.001099	672.61	678.10	1.9374	0.001195	670.11	681.07	1.9316
180	0.001124	759.62	765.24	2.1341	0.001120	756.63	767.83	2.1274
200	0.001153	848.08	853.85	2.3254	0.001148	844.49	855.97	2.3178
220	0.001187	938.43	944.36	2.5128	0.001181	934.07	945.88	2.5038
240	0.001226	1031.34	1037.47	2.6978	0.001219	1025.94	1038.13	2.6872
260	0.001275	1127.92	1134.30	2.8829	0.001265	1121.03	1133.68	2.8698
280					0.001322	1220.90	1234.11	3.0547
300					0.001397	1328.34	1342.31	3.2468

TABLE B.1.4 (continued)  
Compressed Liquid Water

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
15000 kPa (342.24°C)					20000 kPa (365.81°C)			
Sat.	0.001658	1585.58	1610.45	3.6847	0.002035	1785.47	1826.18	4.0137
0	0.000993	0.15	15.04	0.0004	0.000990	0.20	20.00	0.0004
20	0.000995	83.05	97.97	0.2934	0.000993	82.75	102.61	0.2922
40	0.001001	165.73	180.75	0.5665	0.000999	165.15	185.14	0.5646
60	0.001011	248.49	263.65	0.8231	0.001008	247.66	267.82	0.8205
80	0.001022	331.46	346.79	1.0655	0.001020	330.38	350.78	1.0623
100	0.001036	414.72	430.26	1.2954	0.001034	413.37	434.04	1.2917
120	0.001052	498.39	514.17	1.5144	0.001050	496.75	517.74	1.5101
140	0.001071	582.64	598.70	1.7241	0.001068	580.67	602.03	1.7192
160	0.001092	667.69	684.07	1.9259	0.001089	665.34	687.11	1.9203
180	0.001116	753.74	770.48	2.1209	0.001112	750.94	773.18	2.1146
200	0.001143	841.04	858.18	2.3103	0.001139	837.70	860.47	2.3031
220	0.001175	929.89	947.52	2.4952	0.001169	925.89	949.27	2.4869
240	0.001211	1020.82	1038.99	2.6770	0.001205	1015.94	1040.04	2.6673
260	0.001255	1114.59	1133.41	2.8575	0.001246	1108.53	1133.45	2.8459
280	0.001308	1212.47	1232.09	3.0392	0.001297	1204.69	1230.62	3.0248
300	0.001377	1316.58	1337.23	3.2259	0.001360	1306.10	1333.29	3.2071
320	0.001472	1431.05	1453.13	3.4246	0.001444	1415.66	1444.53	3.3978
340	0.001631	1567.42	1591.88	3.6545	0.001568	1539.64	1571.01	3.6074
360					0.001823	1702.78	1739.23	3.8770
30000 kPa					50000 kPa			
0	0.000986	0.25	29.82	0.0001	0.000977	0.20	49.03	-0.0014
20	0.000989	82.16	111.82	0.2898	0.000980	80.98	130.00	0.2847
40	0.000995	164.01	193.87	0.5606	0.000987	161.84	211.20	0.5526
60	0.001004	246.03	276.16	0.8153	0.000996	242.96	292.77	0.8051
80	0.001016	328.28	358.75	1.0561	0.001007	324.32	374.68	1.0439
100	0.001029	410.76	441.63	1.2844	0.001020	405.86	456.87	1.2703
120	0.001044	493.58	524.91	1.5017	0.001035	487.63	539.37	1.4857
140	0.001062	576.86	608.73	1.7097	0.001052	569.76	622.33	1.6915
160	0.001082	660.81	693.27	1.9095	0.001070	652.39	705.91	1.8890
180	0.001105	745.57	778.71	2.1024	0.001091	735.68	790.24	2.0793
200	0.001130	831.34	865.24	2.2892	0.001115	819.73	875.46	2.2634
220	0.001159	918.32	953.09	2.4710	0.001141	904.67	961.71	2.4419
240	0.001192	1006.84	1042.60	2.6489	0.001170	990.69	1049.20	2.6158
260	0.001230	1097.38	1134.29	2.8242	0.001203	1078.06	1138.23	2.7860
280	0.001275	1190.69	1228.96	2.9985	0.001242	1167.19	1229.26	2.9536
300	0.001330	1287.89	1327.80	3.1740	0.001286	1258.66	1322.95	3.1200
320	0.001400	1390.64	1432.63	3.3538	0.001339	1353.23	1420.17	3.2867
340	0.001492	1501.71	1546.47	3.5425	0.001403	1451.91	1522.07	3.4556
360	0.001627	1626.57	1675.36	3.7492	0.001484	1555.97	1630.16	3.6290
380	0.001869	1781.35	1837.43	4.0010	0.001588	1667.13	1746.54	3.8100

TABLE B.1.5

*Saturated Solid-Saturated Vapor, Water*

Temp. (°C)	Press. (kPa)	Specific Volume, m <sup>3</sup> /kg			Internal Energy, kJ/kg		
		Sat. Solid $v_i$	Evap. $v_{ig}$	Sat. Vapor $v_g$	Sat. Solid $u_i$	Evap. $u_{ig}$	Sat. Vapor $u_g$
0.01	0.6113	0.0010908	206.152	206.153	−333.40	2708.7	2375.3
0	0.6108	0.0010908	206.314	206.315	−333.42	2708.7	2375.3
−2	0.5177	0.0010905	241.662	241.663	−337.61	2710.2	2372.5
−4	0.4376	0.0010901	283.798	283.799	−341.78	2711.5	2369.8
−6	0.3689	0.0010898	334.138	334.139	−345.91	2712.9	2367.0
−8	0.3102	0.0010894	394.413	394.414	−350.02	2714.2	2364.2
−10	0.2601	0.0010891	466.756	466.757	−354.09	2715.5	2361.4
−12	0.2176	0.0010888	553.802	553.803	−358.14	2716.8	2358.7
−14	0.1815	0.0010884	658.824	658.824	−362.16	2718.0	2355.9
−16	0.1510	0.0010881	785.906	785.907	−366.14	2719.2	2353.1
−18	0.1252	0.0010878	940.182	940.183	−370.10	2720.4	2350.3
−20	0.10355	0.0010874	1128.112	1128.113	−374.03	2721.6	2347.5
−22	0.08535	0.0010871	1357.863	1357.864	−377.93	2722.7	2344.7
−24	0.07012	0.0010868	1639.752	1639.753	−381.80	2723.7	2342.0
−26	0.05741	0.0010864	1986.775	1986.776	−385.64	2724.8	2339.2
−28	0.04684	0.0010861	2415.200	2415.201	−389.45	2725.8	2336.4
−30	0.03810	0.0010858	2945.227	2945.228	−393.23	2726.8	2333.6
−32	0.03090	0.0010854	3601.822	3601.823	−396.98	2727.8	2330.8
−34	0.02499	0.0010851	4416.252	4416.253	−400.71	2728.7	2328.0
−36	0.02016	0.0010848	5430.115	5430.116	−404.40	2729.6	2325.2
−38	0.01618	0.0010844	6707.021	6707.022	−408.06	2730.5	2322.4
−40	0.01286	0.0010841	8366.395	8366.396	−411.70	2731.3	2319.6



TABLE B.1.5 (continued)

*Saturated Solid-Saturated Vapor, Water*

Temp. (°C)	Press. (kPa)	Enthalpy, kJ/kg			Entropy, kJ/kg-K		
		Sat. Solid $h_i$	Evap. $h_{ig}$	Sat. Vapor $h_g$	Sat. Solid $s_i$	Evap. $s_{ig}$	Sat. Vapor $s_g$
0.01	0.6113	−333.40	2834.7	2501.3	−1.2210	10.3772	9.1562
0	0.6108	−333.42	2834.8	2501.3	−1.2211	10.3776	9.1565
−2	0.5177	−337.61	2835.3	2497.6	−1.2369	10.4562	9.2193
−4	0.4376	−341.78	2835.7	2494.0	−1.2526	10.5358	9.2832
−6	0.3689	−345.91	2836.2	2490.3	−1.2683	10.6165	9.3482
−8	0.3102	−350.02	2836.6	2486.6	−1.2839	10.6982	9.4143
−10	0.2601	−354.09	2837.0	2482.9	−1.2995	10.7809	9.4815
−12	0.2176	−358.14	2837.3	2479.2	−1.3150	10.8648	9.5498
−14	0.1815	−362.16	2837.6	2475.5	−1.3306	10.9498	9.6192
−16	0.1510	−366.14	2837.9	2471.8	−1.3461	11.0359	9.6898
−18	0.1252	−370.10	2838.2	2468.1	−1.3617	11.1233	9.7616
−20	0.10355	−374.03	2838.4	2464.3	−1.3772	11.2120	9.8348
−22	0.08535	−377.93	2838.6	2460.6	−1.3928	11.3020	9.9093
−24	0.07012	−381.80	2838.7	2456.9	−1.4083	11.3935	9.9852
−26	0.05741	−385.64	2838.9	2453.2	−1.4239	11.4864	10.0625
−28	0.04684	−389.45	2839.0	2449.5	−1.4394	11.5808	10.1413
−30	0.03810	−393.23	2839.0	2445.8	−1.4550	11.6765	10.2215
−32	0.03090	−396.98	2839.1	2442.1	−1.4705	11.7733	10.3028
−34	0.02499	−400.71	2839.1	2438.4	−1.4860	11.8713	10.3853
−36	0.02016	−404.40	2839.1	2434.7	−1.5014	11.9704	10.4690
−38	0.01618	−408.06	2839.0	2431.0	−1.5168	12.0714	10.5546
−40	0.01286	−411.70	2838.9	2427.2	−1.5321	12.1768	10.6447

TABLE B.2

*Thermodynamic Properties of Ammonia*

TABLE B.2.1

*Saturated Ammonia*

Temp. (°C)	Press. (kPa)	Specific Volume, m <sup>3</sup> /kg			Internal Energy, kJ/kg		
		Sat. Liquid $v_f$	Evap. $v_{fg}$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Evap. $u_{fg}$	Sat. Vapor $u_g$
−50	40.9	0.001424	2.62557	2.62700	−43.82	1309.1	1265.2
−45	54.5	0.001437	2.00489	2.00632	−22.01	1293.5	1271.4
−40	71.7	0.001450	1.55111	1.55256	−0.10	1277.6	1277.4
−35	93.2	0.001463	1.21466	1.21613	21.93	1261.3	1283.3
−30	119.5	0.001476	0.96192	0.96339	44.08	1244.8	1288.9
−25	151.6	0.001490	0.76970	0.77119	66.36	1227.9	1294.3
−20	190.2	0.001504	0.62184	0.62334	88.76	1210.7	1299.5
−15	236.3	0.001519	0.50686	0.50838	111.30	1193.2	1304.5
−10	290.9	0.001534	0.41655	0.41808	133.96	1175.2	1309.2
−5	354.9	0.001550	0.34493	0.34648	156.76	1157.0	1313.7
0	429.6	0.001566	0.28763	0.28920	179.69	1138.3	1318.0
5	515.9	0.001583	0.24140	0.24299	202.77	1119.2	1322.0
10	615.2	0.001600	0.20381	0.20541	225.99	1099.7	1325.7
15	728.6	0.001619	0.17300	0.17462	249.36	1079.7	1329.1
20	857.5	0.001638	0.14758	0.14922	272.89	1059.3	1332.2
25	1003.2	0.001658	0.12647	0.12813	296.59	1038.4	1335.0
30	1167.0	0.001680	0.10881	0.11049	320.46	1016.9	1337.4
35	1350.4	0.001702	0.09397	0.09567	344.50	994.9	1339.4
40	1554.9	0.001725	0.08141	0.08313	368.74	972.2	1341.0
45	1782.0	0.001750	0.07073	0.07248	393.19	948.9	1342.1
50	2033.1	0.001777	0.06159	0.06337	417.87	924.8	1342.7
55	2310.1	0.001804	0.05375	0.05555	442.79	899.9	1342.7
60	2614.4	0.001834	0.04697	0.04880	467.99	874.2	1342.1
65	2947.8	0.001866	0.04109	0.04296	493.51	847.4	1340.9
70	3312.0	0.001900	0.03597	0.03787	519.39	819.5	1338.9
75	3709.0	0.001937	0.03148	0.03341	545.70	790.4	1336.1
80	4140.5	0.001978	0.02753	0.02951	572.50	759.9	1332.4
85	4608.6	0.002022	0.02404	0.02606	599.90	727.8	1327.7
90	5115.3	0.002071	0.02093	0.02300	627.99	693.7	1321.7
95	5662.9	0.002126	0.01815	0.02028	656.95	657.4	1314.4
100	6253.7	0.002188	0.01565	0.01784	686.96	618.4	1305.3
105	6890.4	0.002261	0.01337	0.01564	718.30	575.9	1294.2
110	7575.7	0.002347	0.01128	0.01363	751.37	529.1	1280.5
115	8313.3	0.002452	0.00933	0.01178	786.82	476.2	1263.1
120	9107.2	0.002589	0.00744	0.01003	825.77	414.5	1240.3
125	9963.5	0.002783	0.00554	0.00833	870.69	337.7	1208.4
130	10891.6	0.003122	0.00337	0.00649	929.29	226.9	1156.2
132.3	11333.2	0.004255	0	0.00426	1037.62	0	1037.6

TABLE B.2.1 (continued)

*Saturated Ammonia*

Temp. (°C)	Press. (kPa)	Enthalpy, kJ/kg			Entropy, kJ/kg-K		
		Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$
−50	40.9	−43.76	1416.3	1372.6	−0.1916	6.3470	6.1554
−45	54.5	−21.94	1402.8	1380.8	−0.0950	6.1484	6.0534
−40	71.7	0	1388.8	1388.8	0	5.9567	5.9567
−35	93.2	22.06	1374.5	1396.5	0.0935	5.7715	5.8650
−30	119.5	44.26	1359.8	1404.0	0.1856	5.5922	5.7778
−25	151.6	66.58	1344.6	1411.2	0.2763	5.4185	5.6947
−20	190.2	89.05	1329.0	1418.0	0.3657	5.2498	5.6155
−15	236.3	111.66	1312.9	1424.6	0.4538	5.0859	5.5397
−10	290.9	134.41	1296.4	1430.8	0.5408	4.9265	5.4673
−5	354.9	157.31	1279.4	1436.7	0.6266	4.7711	5.3977
0	429.6	180.36	1261.8	1442.2	0.7114	4.6195	5.3309
5	515.9	203.58	1243.7	1447.3	0.7951	4.4715	5.2666
10	615.2	226.97	1225.1	1452.0	0.8779	4.3266	5.2045
15	728.6	250.54	1205.8	1456.3	0.9598	4.1846	5.1444
20	857.5	274.30	1185.9	1460.2	1.0408	4.0452	5.0860
25	1003.2	298.25	1165.2	1463.5	1.1210	3.9083	5.0293
30	1167.0	322.42	1143.9	1466.3	1.2005	3.7734	4.9738
35	1350.4	346.80	1121.8	1468.6	1.2792	3.6403	4.9196
40	1554.9	371.43	1098.8	1470.2	1.3574	3.5088	4.8662
45	1782.0	396.31	1074.9	1471.2	1.4350	3.3786	4.8136
50	2033.1	421.48	1050.0	1471.5	1.5121	3.2493	4.7614
55	2310.1	446.96	1024.1	1471.0	1.5888	3.1208	4.7095
60	2614.4	472.79	997.0	1469.7	1.6652	2.9925	4.6577
65	2947.8	499.01	968.5	1467.5	1.7415	2.8642	4.6057
70	3312.0	525.69	938.7	1464.4	1.8178	2.7354	4.5533
75	3709.0	552.88	907.2	1460.1	1.8943	2.6058	4.5001
80	4140.5	580.69	873.9	1454.6	1.9712	2.4746	4.4458
85	4608.6	609.21	838.6	1447.8	2.0488	2.3413	4.3901
90	5115.3	638.59	800.8	1439.4	2.1273	2.2051	4.3325
95	5662.9	668.99	760.2	1429.2	2.2073	2.0650	4.2723
100	6253.7	700.64	716.2	1416.9	2.2893	1.9195	4.2088
105	6890.4	733.87	668.1	1402.0	2.3740	1.7667	4.1407
110	7575.7	769.15	614.6	1383.7	2.4625	1.6040	4.0665
115	8313.3	807.21	553.8	1361.0	2.5566	1.4267	3.9833
120	9107.2	849.36	482.3	1331.7	2.6593	1.2268	3.8861
125	9963.5	898.42	393.0	1291.4	2.7775	0.9870	3.7645
130	10892	963.29	263.7	1227.0	2.9326	0.6540	3.5866
132.3	11333	1085.85	0	1085.9	3.2316	0	3.2316

TABLE B.2.2

*Superheated Ammonia*

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
50 kPa (−46.53°C)					100 kPa (−33.60°C)			
Sat.	2.1752	1269.6	1378.3	6.0839	1.1381	1284.9	1398.7	5.8401
−30	2.3448	1296.2	1413.4	6.2333	1.1573	1291.0	1406.7	5.8734
−20	2.4463	1312.3	1434.6	6.3187	1.2101	1307.8	1428.8	5.9626
−10	2.5471	1328.4	1455.7	6.4006	1.2621	1324.6	1450.8	6.0477
0	2.6474	1344.5	1476.9	6.4795	1.3136	1341.3	1472.6	6.1291
10	2.7472	1360.7	1498.1	6.5556	1.3647	1357.9	1494.4	6.2073
20	2.8466	1377.0	1519.3	6.6293	1.4153	1374.5	1516.1	6.2826
30	2.9458	1393.3	1540.6	6.7008	1.4657	1391.2	1537.7	6.3553
40	3.0447	1409.8	1562.0	6.7703	1.5158	1407.9	1559.5	6.4258
50	3.1435	1426.3	1583.5	6.8379	1.5658	1424.7	1581.2	6.4943
60	3.2421	1443.0	1605.1	6.9038	1.6156	1441.5	1603.1	6.5609
70	3.3406	1459.9	1626.9	6.9682	1.6653	1458.5	1625.1	6.6258
80	3.4390	1476.9	1648.8	7.0312	1.7148	1475.6	1647.1	6.6892
100	3.6355	1511.4	1693.2	7.1533	1.8137	1510.3	1691.7	6.8120
120	3.8318	1546.6	1738.2	7.2708	1.9124	1545.7	1736.9	6.9300
140	4.0280	1582.5	1783.9	7.3842	2.0109	1581.7	1782.8	7.0439
160	4.2240	1619.2	1830.4	7.4941	2.1093	1618.5	1829.4	7.1540
180	4.4199	1656.7	1877.7	7.6008	2.2075	1656.0	1876.8	7.2609
200	4.6157	1694.9	1925.7	7.7045	2.3057	1694.3	1924.9	7.3648
150 kPa (−25.22°C)					200 kPa (−18.86°C)			
Sat.	0.7787	1294.1	1410.9	5.6983	0.5946	1300.6	1419.6	5.5979
−20	0.7977	1303.3	1422.9	5.7465	—	—	—	—
−10	0.8336	1320.7	1445.7	5.8349	0.6193	1316.7	1440.6	5.6791
0	0.8689	1337.9	1468.3	5.9189	0.6465	1334.5	1463.8	5.7659
10	0.9037	1355.0	1490.6	5.9992	0.6732	1352.1	1486.8	5.8484
20	0.9382	1372.0	1512.8	6.0761	0.6995	1369.5	1509.4	5.9270
30	0.9723	1389.0	1534.9	6.1502	0.7255	1386.8	1531.9	6.0025
40	1.0062	1406.0	1556.9	6.2217	0.7513	1404.0	1554.3	6.0751
50	1.0398	1423.0	1578.9	6.2910	0.7769	1421.3	1576.6	6.1453
60	1.0734	1440.0	1601.0	6.3583	0.8023	1438.5	1598.9	6.2133
70	1.1068	1457.2	1623.2	6.4238	0.8275	1455.8	1621.3	6.2794
80	1.1401	1474.4	1645.4	6.4877	0.8527	1473.1	1643.7	6.3437
100	1.2065	1509.3	1690.2	6.6112	0.9028	1508.2	1688.8	6.4679
120	1.2726	1544.8	1735.6	6.7297	0.9527	1543.8	1734.4	6.5869
140	1.3386	1580.9	1781.7	6.8439	1.0024	1580.1	1780.6	6.7015
160	1.4044	1617.8	1828.4	6.9544	1.0519	1617.0	1827.4	6.8123
180	1.4701	1655.4	1875.9	7.0615	1.1014	1654.7	1875.0	6.9196
200	1.5357	1693.7	1924.1	7.1656	1.1507	1693.2	1923.3	7.0239
220	1.6013	1732.9	1973.1	7.2670	1.2000	1732.4	1972.4	7.1255

TABLE B.2.2 (continued)  
Superheated Ammonia

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
300 kPa (−9.24°C)					400 kPa (−1.89°C)			
Sat.	0.40607	1309.9	1431.7	5.4565	0.30942	1316.4	1440.2	5.3559
0	0.42382	1327.5	1454.7	5.5420	0.31227	1320.2	1445.1	5.3741
10	0.44251	1346.1	1478.9	5.6290	0.32701	1339.9	1470.7	5.4663
20	0.46077	1364.4	1502.6	5.7113	0.34129	1359.1	1495.6	5.5525
30	0.47870	1382.3	1526.0	5.7896	0.35520	1377.7	1519.8	5.6338
40	0.49636	1400.1	1549.0	5.8645	0.36884	1396.1	1543.6	5.7111
50	0.51382	1417.8	1571.9	5.9365	0.38226	1414.2	1567.1	5.7850
60	0.53111	1435.4	1594.7	6.0060	0.39550	1432.2	1590.4	5.8560
70	0.54827	1453.0	1617.5	6.0732	0.40860	1450.1	1613.6	5.9244
80	0.56532	1470.6	1640.2	6.1385	0.42160	1468.0	1636.7	5.9907
100	0.59916	1506.1	1685.8	6.2642	0.44732	1503.9	1682.8	6.1179
120	0.63276	1542.0	1731.8	6.3842	0.47279	1540.1	1729.2	6.2390
140	0.66618	1578.5	1778.3	6.4996	0.49808	1576.8	1776.0	6.3552
160	0.69946	1615.6	1825.4	6.6109	0.52323	1614.1	1823.4	6.4671
180	0.73263	1653.4	1873.2	6.7188	0.54827	1652.1	1871.4	6.5755
200	0.76572	1692.0	1921.7	6.8235	0.57321	1690.8	1920.1	6.6806
220	0.79872	1731.3	1970.9	6.9254	0.59809	1730.3	1969.5	6.7828
240	0.83167	1771.4	2020.9	7.0247	0.62289	1770.5	2019.6	6.8825
260	0.86455	1812.2	2071.6	7.1217	0.64764	1811.4	2070.5	6.9797
500 kPa (4.13°C)					600 kPa (9.28°C)			
Sat.	0.25035	1321.3	1446.5	5.2776	0.21038	1325.2	1451.4	5.2133
10	0.25757	1333.5	1462.3	5.3340	0.21115	1326.7	1453.4	5.2205
20	0.26949	1353.6	1488.3	5.4244	0.22154	1347.9	1480.8	5.3156
30	0.28103	1373.0	1513.5	5.5090	0.23152	1368.2	1507.1	5.4037
40	0.29227	1392.0	1538.1	5.5889	0.24118	1387.8	1532.5	5.4862
50	0.30328	1410.6	1562.2	5.6647	0.25059	1406.9	1557.3	5.5641
60	0.31410	1429.0	1586.1	5.7373	0.25981	1425.7	1581.6	5.6383
70	0.32478	1447.3	1609.6	5.8070	0.26888	1444.3	1605.7	5.7094
80	0.33535	1465.4	1633.1	5.8744	0.27783	1462.8	1629.5	5.7778
100	0.35621	1501.7	1679.8	6.0031	0.29545	1499.5	1676.8	5.9081
120	0.37681	1538.2	1726.6	6.1253	0.31281	1536.3	1724.0	6.0314
140	0.39722	1575.2	1773.8	6.2422	0.32997	1573.5	1771.5	6.1491
160	0.41748	1612.7	1821.4	6.3548	0.34699	1611.2	1819.4	6.2623
180	0.43764	1650.8	1869.6	6.4636	0.36389	1649.5	1867.8	6.3717
200	0.45771	1689.6	1918.5	6.5691	0.38071	1688.5	1916.9	6.4776
220	0.47770	1729.2	1968.1	6.6717	0.39745	1728.2	1966.6	6.5806
240	0.49763	1769.5	2018.3	6.7717	0.41412	1768.6	2017.0	6.6808
260	0.51749	1810.6	2069.3	6.8692	0.43073	1809.8	2068.2	6.7786

TABLE B.2.2 (continued)  
Superheated Ammonia

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
800 kPa (17.85°C)					1000 kPa (24.90°C)			
Sat.	0.15958	1330.9	1458.6	5.1110	0.12852	1334.9	1463.4	5.0304
20	0.16138	1335.8	1464.9	5.1328	—	—	—	—
30	0.16947	1358.0	1493.5	5.2287	0.13206	1347.1	1479.1	5.0826
40	0.17720	1379.0	1520.8	5.3171	0.13868	1369.8	1508.5	5.1778
50	0.18465	1399.3	1547.0	5.3996	0.14499	1391.3	1536.3	5.2654
60	0.19189	1419.0	1572.5	5.4774	0.15106	1412.1	1563.1	5.3471
70	0.19896	1438.3	1597.5	5.5513	0.15695	1432.2	1589.1	5.4240
80	0.20590	1457.4	1622.1	5.6219	0.16270	1451.9	1614.6	5.4971
100	0.21949	1495.0	1670.6	5.7555	0.17389	1490.5	1664.3	5.6342
120	0.23280	1532.5	1718.7	5.8811	0.18477	1528.6	1713.4	5.7622
140	0.24590	1570.1	1766.9	6.0006	0.19545	1566.8	1762.2	5.8834
160	0.25886	1608.2	1815.3	6.1150	0.20597	1605.2	1811.2	5.9992
180	0.27170	1646.8	1864.2	6.2254	0.21638	1644.2	1860.5	6.1105
200	0.28445	1686.1	1913.6	6.3322	0.22669	1683.7	1910.4	6.2182
220	0.29712	1726.0	1963.7	6.4358	0.23693	1723.9	1960.8	6.3226
240	0.30973	1766.7	2014.5	6.5367	0.24710	1764.8	2011.9	6.4241
260	0.32228	1808.1	2065.9	6.6350	0.25720	1806.4	2063.6	6.5229
280	0.33477	1850.2	2118.0	6.7310	0.26726	1848.8	2116.0	6.6194
300	0.34722	1893.1	2170.9	6.8248	0.27726	1891.8	2169.1	6.7137
1200 kPa (30.94°C)					1400 kPa (36.26°C)			
Sat.	0.10751	1337.8	1466.8	4.9635	0.09231	1339.8	1469.0	4.9060
40	0.11287	1360.0	1495.4	5.0564	0.09432	1349.5	1481.6	4.9463
50	0.11846	1383.0	1525.1	5.1497	0.09942	1374.2	1513.4	5.0462
60	0.12378	1404.8	1553.3	5.2357	0.10423	1397.2	1543.1	5.1370
70	0.12890	1425.8	1580.5	5.3159	0.10882	1419.2	1571.5	5.2209
80	0.13387	1446.2	1606.8	5.3916	0.11324	1440.3	1598.8	5.2994
100	0.14347	1485.8	1658.0	5.5325	0.12172	1481.0	1651.4	5.4443
120	0.15275	1524.7	1708.0	5.6631	0.12986	1520.7	1702.5	5.5775
140	0.16181	1563.3	1757.5	5.7860	0.13777	1559.9	1752.8	5.7023
160	0.17071	1602.2	1807.1	5.9031	0.14552	1599.2	1802.9	5.8208
180	0.17950	1641.5	1856.9	6.0156	0.15315	1638.8	1853.2	5.9343
200	0.18819	1681.3	1907.1	6.1241	0.16068	1678.9	1903.8	6.0437
220	0.19680	1721.8	1957.9	6.2292	0.16813	1719.6	1955.0	6.1495
240	0.20534	1762.9	2009.3	6.3313	0.17551	1761.0	2006.7	6.2523
260	0.21382	1804.7	2061.3	6.4308	0.18283	1803.0	2059.0	6.3523
280	0.22225	1847.3	2114.0	6.5278	0.19010	1845.8	2111.9	6.4498
300	0.23063	1890.6	2167.3	6.6225	0.19732	1889.3	2165.5	6.5450
320	0.23897	1934.6	2221.3	6.7151	0.20450	1933.5	2219.8	6.6380

TABLE B.2.2 (continued)  
Superheated Ammonia

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
1600 kPa (41.03°C)					2000 kPa (49.37°C)			
Sat.	0.08079	1341.2	1470.5	4.8553	0.06444	1342.6	1471.5	4.7680
50	0.08506	1364.9	1501.0	4.9510	0.06471	1344.5	1473.9	4.7754
60	0.08951	1389.3	1532.5	5.0472	0.06875	1372.3	1509.8	4.8848
70	0.09372	1412.3	1562.3	5.1351	0.07246	1397.8	1542.7	4.9821
80	0.09774	1434.3	1590.6	5.2167	0.07595	1421.6	1573.5	5.0707
100	0.10539	1476.2	1644.8	5.3659	0.08248	1466.1	1631.1	5.2294
120	0.11268	1516.6	1696.9	5.5018	0.08861	1508.3	1685.5	5.3714
140	0.11974	1556.4	1748.0	5.6286	0.09447	1549.3	1738.2	5.5022
160	0.12662	1596.1	1798.7	5.7485	0.10016	1589.9	1790.2	5.6251
180	0.13339	1636.1	1849.5	5.8631	0.10571	1630.6	1842.0	5.7420
200	0.14005	1676.5	1900.5	5.9734	0.11116	1671.6	1893.9	5.8540
220	0.14663	1717.4	1952.0	6.0800	0.11652	1713.1	1946.1	5.9621
240	0.15314	1759.0	2004.1	6.1834	0.12182	1755.2	1998.8	6.0668
260	0.15959	1801.3	2056.7	6.2839	0.12705	1797.9	2052.0	6.1685
280	0.16599	1844.3	2109.9	6.3819	0.13224	1841.3	2105.8	6.2675
300	0.17234	1888.0	2163.7	6.4775	0.13737	1885.4	2160.1	6.3641
320	0.17865	1932.4	2218.2	6.5710	0.14246	1930.2	2215.1	6.4583
340	0.18492	1977.5	2273.4	6.6624	0.14751	1975.6	2270.7	6.5505
360	0.19115	2023.3	2329.1	6.7519	0.15253	2021.8	2326.8	6.6406
5000 kPa (88.90°C)					10000 kPa (125.20°C)			
Sat.	0.02365	1323.2	1441.4	4.3454	0.00826	1206.8	1289.4	3.7587
100	0.02636	1369.7	1501.5	4.5091	—	—	—	—
120	0.03024	1435.1	1586.3	4.7306	—	—	—	—
140	0.03350	1489.8	1657.3	4.9068	0.01195	1341.8	1461.3	4.1839
160	0.03643	1539.5	1721.7	5.0591	0.01461	1432.2	1578.3	4.4610
180	0.03916	1586.9	1782.7	5.1968	0.01666	1500.6	1667.2	4.6617
200	0.04174	1633.1	1841.8	5.3245	0.01842	1560.3	1744.5	4.8287
220	0.04422	1678.9	1900.0	5.4450	0.02001	1615.8	1816.0	4.9767
240	0.04662	1724.8	1957.9	5.5600	0.02150	1669.2	1884.2	5.1123
260	0.04895	1770.9	2015.6	5.6704	0.02290	1721.6	1950.6	5.2392
280	0.05123	1817.4	2073.6	5.7771	0.02424	1773.6	2015.9	5.3596
300	0.05346	1864.5	2131.8	5.8805	0.02552	1825.5	2080.7	5.4746
320	0.05565	1912.1	2190.3	5.9809	0.02676	1877.6	2145.2	5.5852
340	0.05779	1960.3	2249.2	6.0786	0.02796	1930.0	2209.6	5.6921
360	0.05990	2009.1	2308.6	6.1738	0.02913	1982.8	2274.1	5.7955
380	0.06198	2058.5	2368.4	6.2668	0.03026	2036.1	2338.7	5.8960
400	0.06403	2108.4	2428.6	6.3576	0.03137	2089.8	2403.5	5.9937
420	0.06606	2159.0	2489.3	6.4464	0.03245	2143.9	2468.5	6.0888
440	0.06806	2210.1	2550.4	6.5334	0.03351	2198.5	2533.7	6.1815

TABLE B.3

*Thermodynamic Properties of Carbon Dioxide*

TABLE B.3.1

*Saturated Carbon Dioxide*

Temp. (°C)	Press. (kPa)	Specific Volume, m <sup>3</sup> /kg			Internal Energy, kJ/kg		
		Sat. Liquid $v_f$	Evap. $v_{fg}$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Evap. $u_{fg}$	Sat. Vapor $u_g$
−50.0	682.3	0.000866	0.05492	0.05579	−20.55	302.26	281.71
−48	739.5	0.000872	0.05075	0.05162	−16.64	298.86	282.21
−46	800.2	0.000878	0.04694	0.04782	−12.72	295.42	282.69
−44	864.4	0.000883	0.04347	0.04435	−8.80	291.94	283.15
−42	932.5	0.000889	0.04029	0.04118	−4.85	288.42	283.57
−40	1004.5	0.000896	0.03739	0.03828	−0.90	284.86	283.96
−38	1080.5	0.000902	0.03472	0.03562	3.07	281.26	284.33
−36	1160.7	0.000909	0.03227	0.03318	7.05	277.60	284.66
−34	1245.2	0.000915	0.03002	0.03093	11.05	273.90	284.95
−32	1334.2	0.000922	0.02794	0.02886	15.07	270.14	285.21
−30	1427.8	0.000930	0.02603	0.02696	19.11	266.32	285.43
−28	1526.1	0.000937	0.02425	0.02519	23.17	262.45	285.61
−26	1629.3	0.000945	0.02261	0.02356	27.25	258.51	285.75
−24	1737.5	0.000953	0.02110	0.02205	31.35	254.50	285.85
−22	1850.9	0.000961	0.01968	0.02065	35.48	250.41	285.89
−20	1969.6	0.000969	0.01837	0.01934	39.64	246.25	285.89
−18	2093.8	0.000978	0.01715	0.01813	43.82	242.01	285.84
−16	2223.7	0.000987	0.01601	0.01700	48.04	237.68	285.73
−14	2359.3	0.000997	0.01495	0.01595	52.30	233.26	285.56
−12	2501.0	0.001007	0.01396	0.01497	56.59	228.73	285.32
−10	2648.7	0.001017	0.01303	0.01405	60.92	224.10	285.02
−8	2802.7	0.001028	0.01216	0.01319	65.30	219.35	284.65
−6	2963.2	0.001040	0.01134	0.01238	69.73	214.47	284.20
−4	3130.3	0.001052	0.01057	0.01162	74.20	209.46	283.66
−2	3304.2	0.001065	0.00985	0.01091	78.74	204.29	283.03
0	3485.1	0.001078	0.00916	0.01024	83.34	198.96	282.30
2	3673.3	0.001093	0.00852	0.00961	88.01	193.44	281.46
4	3868.8	0.001108	0.00790	0.00901	92.76	187.73	280.49
6	4072.0	0.001124	0.00732	0.00845	97.60	181.78	279.38
8	4283.1	0.001142	0.00677	0.00791	102.54	175.57	278.11
10	4502.2	0.001161	0.00624	0.00740	107.60	169.07	276.67
12	4729.7	0.001182	0.00573	0.00691	112.79	162.23	275.02
14	4965.8	0.001205	0.00524	0.00645	118.14	154.99	273.13
16	5210.8	0.001231	0.00477	0.00600	123.69	147.26	270.95
18	5465.1	0.001260	0.00431	0.00557	129.48	138.95	268.43
20	5729.1	0.001293	0.00386	0.00515	135.56	129.90	265.46
22	6003.1	0.001332	0.00341	0.00474	142.03	119.89	261.92
24	6287.7	0.001379	0.00295	0.00433	149.04	108.55	257.59
26	6583.7	0.001440	0.00247	0.00391	156.88	95.20	252.07
28	6891.8	0.001526	0.00193	0.00346	166.20	78.26	244.46
30	7213.7	0.001685	0.00121	0.00290	179.49	51.83	231.32
31.0	7377.3	0.002139	0.0	0.00214	203.56	0.0	203.56



TABLE B.3.1 (continued)  
Saturated Carbon Dioxide

Temp. (°C)	Press. (kPa)	Enthalpy, kJ/kg			Entropy, kJ/kg-K		
		Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$
-50.0	682.3	-19.96	339.73	319.77	-0.0863	1.5224	1.4362
-48	739.5	-16.00	336.38	320.38	-0.0688	1.4940	1.4252
-46	800.2	-12.02	332.98	320.96	-0.0515	1.4659	1.4144
-44	864.4	-8.03	329.52	321.49	-0.0342	1.4380	1.4038
-42	932.5	-4.02	326.00	321.97	-0.0171	1.4103	1.3933
-40	1004.5	0	322.42	322.42	0	1.3829	1.3829
-38	1080.5	4.04	318.78	322.82	0.0170	1.3556	1.3726
-36	1160.7	8.11	315.06	323.17	0.0339	1.3285	1.3624
-34	1245.2	12.19	311.28	323.47	0.0507	1.3016	1.3523
-32	1334.2	16.30	307.42	323.72	0.0675	1.2748	1.3423
-30	1427.8	20.43	303.48	323.92	0.0842	1.2481	1.3323
-28	1526.1	24.60	299.46	324.06	0.1009	1.2215	1.3224
-26	1629.3	28.78	295.35	324.14	0.1175	1.1950	1.3125
-24	1737.5	33.00	291.15	324.15	0.1341	1.1686	1.3026
-22	1850.9	37.26	286.85	324.11	0.1506	1.1421	1.2928
-20	1969.6	41.55	282.44	323.99	0.1672	1.1157	1.2829
-18	2093.8	45.87	277.93	323.80	0.1837	1.0893	1.2730
-16	2223.7	50.24	273.30	323.53	0.2003	1.0628	1.2631
-14	2359.3	54.65	268.54	323.19	0.2169	1.0362	1.2531
-12	2501.0	59.11	263.65	322.76	0.2334	1.0096	1.2430
-10	2648.7	63.62	258.61	322.23	0.2501	0.9828	1.2328
-8	2802.7	68.18	253.43	321.61	0.2668	0.9558	1.2226
-6	2963.2	72.81	248.08	320.89	0.2835	0.9286	1.2121
-4	3130.3	77.50	242.55	320.05	0.3003	0.9012	1.2015
-2	3304.2	82.26	236.83	319.09	0.3173	0.8734	1.1907
0	3485.1	87.10	230.89	317.99	0.3344	0.8453	1.1797
2	3673.3	92.02	224.73	316.75	0.3516	0.8167	1.1683
4	3868.8	97.05	218.30	315.35	0.3690	0.7877	1.1567
6	4072.0	102.18	211.59	313.77	0.3866	0.7580	1.1446
8	4283.1	107.43	204.56	311.99	0.4045	0.7276	1.1321
10	4502.2	112.83	197.15	309.98	0.4228	0.6963	1.1190
12	4729.7	118.38	189.33	307.72	0.4414	0.6640	1.1053
14	4965.8	124.13	181.02	305.15	0.4605	0.6304	1.0909
16	5210.8	130.11	172.12	302.22	0.4802	0.5952	1.0754
18	5465.1	136.36	162.50	298.86	0.5006	0.5581	1.0588
20	5729.1	142.97	152.00	294.96	0.5221	0.5185	1.0406
22	6003.1	150.02	140.34	290.36	0.5449	0.4755	1.0203
24	6287.7	157.71	127.09	284.80	0.5695	0.4277	0.9972
26	6583.7	166.36	111.45	277.80	0.5971	0.3726	0.9697
28	6891.8	176.72	91.58	268.30	0.6301	0.3041	0.9342
30	7213.7	191.65	60.58	252.23	0.6778	0.1998	0.8776
31.0	7377.3	219.34	0.0	219.34	0.7680	0.0	0.7680

TABLE B.3.2

*Superheated Carbon Dioxide*

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
400 kPa (NA)					800 kPa (−46.00°C)			
Sat.	—	—	—	—	0.04783	282.69	320.95	1.4145
−40	0.10499	292.46	334.46	1.5947	0.04966	287.05	326.78	1.4398
−20	0.11538	305.30	351.46	1.6646	0.05546	301.13	345.49	1.5168
0	0.12552	318.31	368.51	1.7295	0.06094	314.92	363.67	1.5859
20	0.13551	331.57	385.77	1.7904	0.06623	328.73	381.72	1.6497
40	0.14538	345.14	403.29	1.8482	0.07140	342.70	399.82	1.7094
60	0.15518	359.03	421.10	1.9033	0.07648	356.90	418.09	1.7660
80	0.16491	373.25	439.21	1.9561	0.08150	371.37	436.57	1.8199
100	0.17460	387.80	457.64	2.0069	0.08647	386.11	455.29	1.8714
120	0.18425	402.67	476.37	2.0558	0.09141	401.15	474.27	1.9210
140	0.19388	417.86	495.41	2.1030	0.09631	416.47	493.52	1.9687
160	0.20348	433.35	514.74	2.1487	0.10119	432.07	513.03	2.0148
180	0.21307	449.13	534.36	2.1930	0.10606	447.95	532.80	2.0594
200	0.22264	465.20	554.26	2.2359	0.11090	464.11	552.83	2.1027
220	0.23219	481.55	574.42	2.2777	0.11573	480.52	573.11	2.1447
240	0.24173	498.16	594.85	2.3183	0.12056	497.20	593.64	2.1855
260	0.25127	515.02	615.53	2.3578	0.12537	514.12	614.41	2.2252
1000 kPa (−40.12°C)					1400 kPa (−30.58°C)			
Sat.	0.03845	283.94	322.39	1.3835	0.02750	285.37	323.87	1.3352
−20	0.04342	298.89	342.31	1.4655	0.02957	294.04	335.44	1.3819
0	0.04799	313.15	361.14	1.5371	0.03315	309.42	355.83	1.4595
20	0.05236	327.27	379.63	1.6025	0.03648	324.23	375.30	1.5283
40	0.05660	341.46	398.05	1.6633	0.03966	338.90	394.42	1.5914
60	0.06074	355.82	416.56	1.7206	0.04274	353.62	413.45	1.6503
80	0.06482	370.42	435.23	1.7750	0.04575	368.48	432.52	1.7059
100	0.06885	385.26	454.11	1.8270	0.04870	383.54	451.72	1.7588
120	0.07284	400.38	473.22	1.8768	0.05161	398.83	471.09	1.8093
140	0.07680	415.77	492.57	1.9249	0.05450	414.36	490.66	1.8579
160	0.08074	431.43	512.17	1.9712	0.05736	430.14	510.44	1.9046
180	0.08465	447.36	532.02	2.0160	0.06020	446.17	530.45	1.9498
200	0.08856	463.56	552.11	2.0594	0.06302	462.45	550.68	1.9935
220	0.09244	480.01	572.46	2.1015	0.06583	478.98	571.14	2.0358
240	0.09632	496.72	593.04	2.1424	0.06863	495.76	591.83	2.0770
260	0.10019	513.67	613.86	2.1822	0.07141	512.77	612.74	2.1169
280	0.10405	530.86	634.90	2.2209	0.07419	530.01	633.88	2.1558

TABLE B.3.2 (continued)  
*Superheated Carbon Dioxide*

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
2000 kPa (−19.50°C)					3000 kPa (−5.55°C)			
Sat.	0.01903	285.88	323.95	1.2804	0.01221	284.09	320.71	1.2098
0	0.02193	303.24	347.09	1.3684	0.01293	290.52	329.32	1.2416
20	0.02453	319.37	368.42	1.4438	0.01512	310.21	355.56	1.3344
40	0.02693	334.88	388.75	1.5109	0.01698	327.61	378.55	1.4104
60	0.02922	350.19	408.64	1.5725	0.01868	344.14	400.19	1.4773
80	0.03143	365.49	428.36	1.6300	0.02029	360.30	421.16	1.5385
100	0.03359	380.90	448.07	1.6843	0.02182	376.35	441.82	1.5954
120	0.03570	396.46	467.85	1.7359	0.02331	392.42	462.35	1.6490
140	0.03777	412.22	487.76	1.7853	0.02477	408.57	482.87	1.6999
160	0.03982	428.18	507.83	1.8327	0.02619	424.87	503.44	1.7485
180	0.04186	444.37	528.08	1.8784	0.02759	441.34	524.12	1.7952
200	0.04387	460.79	548.53	1.9226	0.02898	457.99	544.92	1.8401
220	0.04587	477.43	569.17	1.9653	0.03035	474.83	565.88	1.8835
240	0.04786	494.31	590.02	2.0068	0.03171	491.88	587.01	1.9255
260	0.04983	511.41	611.08	2.0470	0.03306	509.13	608.30	1.9662
280	0.05180	528.73	632.34	2.0862	0.03440	526.59	629.78	2.0057
300	0.05377	546.26	653.80	2.1243	0.03573	544.25	651.43	2.0442
6000 kPa (21.98°C)					10 000 kPa			
Sat.	0.00474	261.97	290.42	1.0206	—	—	—	—
20	—	—	—	—	0.00117	118.12	129.80	0.4594
40	0.00670	298.62	338.82	1.1806	0.00159	184.23	200.14	0.6906
60	0.00801	322.51	370.54	1.2789	0.00345	277.63	312.11	1.0389
80	0.00908	342.74	397.21	1.3567	0.00451	312.82	357.95	1.1728
100	0.01004	361.47	421.69	1.4241	0.00530	338.20	391.24	1.2646
120	0.01092	379.47	445.02	1.4850	0.00598	360.19	419.96	1.3396
140	0.01176	397.10	467.68	1.5413	0.00658	380.54	446.38	1.4051
160	0.01257	414.56	489.97	1.5939	0.00715	399.99	471.46	1.4644
180	0.01335	431.97	512.06	1.6438	0.00768	418.94	495.73	1.5192
200	0.01411	449.40	534.04	1.6913	0.00819	437.61	519.49	1.5705
220	0.01485	466.91	556.01	1.7367	0.00868	456.12	542.91	1.6190
240	0.01558	484.52	578.00	1.7804	0.00916	474.58	566.14	1.6652
260	0.01630	502.27	600.05	1.8226	0.00962	493.03	589.26	1.7094
280	0.01701	520.15	622.19	1.8634	0.01008	511.53	612.32	1.7518
300	0.01771	538.18	644.44	1.9029	0.01053	530.11	635.37	1.7928
320	0.01840	556.37	666.80	1.9412	0.01097	548.77	658.46	1.8324

TABLE B.4

*Thermodynamic Properties of R-410a*

TABLE B.4.1

*Saturated R-410a*

Temp. (°C)	Press. (kPa)	Specific Volume, m <sup>3</sup> /kg			Internal Energy, kJ/kg		
		Sat. Liquid $v_f$	Evap. $v_{fg}$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Evap. $u_{fg}$	Sat. Vapor $u_g$
−60	64.1	0.000727	0.36772	0.36845	−27.50	256.41	228.91
−55	84.0	0.000735	0.28484	0.28558	−20.70	251.89	231.19
−51.4	101.3	0.000741	0.23875	0.23949	−15.78	248.59	232.81
−50	108.7	0.000743	0.22344	0.22418	−13.88	247.31	233.43
−45	138.8	0.000752	0.17729	0.17804	−7.02	242.67	235.64
−40	175.0	0.000762	0.14215	0.14291	−0.13	237.95	237.81
−35	218.4	0.000771	0.11505	0.11582	6.80	233.14	239.94
−30	269.6	0.000781	0.09392	0.09470	13.78	228.23	242.01
−25	329.7	0.000792	0.07726	0.07805	20.82	223.21	244.03
−20	399.6	0.000803	0.06400	0.06480	27.92	218.07	245.99
−15	480.4	0.000815	0.05334	0.05416	35.08	212.79	247.88
−10	573.1	0.000827	0.04470	0.04553	42.32	207.36	249.69
−5	678.9	0.000841	0.03764	0.03848	49.65	201.75	251.41
0	798.7	0.000855	0.03182	0.03267	57.07	195.95	253.02
5	933.9	0.000870	0.02699	0.02786	64.60	189.93	254.53
10	1085.7	0.000886	0.02295	0.02383	72.24	183.66	255.90
15	1255.4	0.000904	0.01955	0.02045	80.02	177.10	257.12
20	1444.2	0.000923	0.01666	0.01758	87.94	170.21	258.16
25	1653.6	0.000944	0.01420	0.01514	96.03	162.95	258.98
30	1885.1	0.000968	0.01208	0.01305	104.32	155.24	259.56
35	2140.2	0.000995	0.01025	0.01124	112.83	147.00	259.83
40	2420.7	0.001025	0.00865	0.00967	121.61	138.11	259.72
45	2728.3	0.001060	0.00723	0.00829	130.72	128.41	259.13
50	3065.2	0.001103	0.00597	0.00707	140.27	117.63	257.90
55	3433.7	0.001156	0.00482	0.00598	150.44	105.34	255.78
60	3836.9	0.001227	0.00374	0.00497	161.57	90.70	252.27
65	4278.3	0.001338	0.00265	0.00399	174.59	71.59	246.19
70	4763.1	0.001619	0.00124	0.00286	194.53	37.47	232.01
71.3	4901.2	0.00218	0	0.00218	215.78	0	215.78

TABLE B.4.1 (continued)  
Saturated R-410a

Temp. (°C)	Press. (kPa)	Enthalpy, kJ/kg			Entropy, kJ/kg-K		
		Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$
−60	64.1	−27.45	279.96	252.51	−0.1227	1.3135	1.1907
−55	84.0	−20.64	275.83	255.19	−0.0912	1.2644	1.1732
−51.4	101.3	−15.70	272.78	257.08	−0.0688	1.2301	1.1613
−50	108.7	−13.80	271.60	257.80	−0.0603	1.2171	1.1568
−45	138.8	−6.92	267.27	260.35	−0.0299	1.1715	1.1416
−40	175.0	0	262.83	262.83	0	1.1273	1.1273
−35	218.4	6.97	258.26	265.23	0.0294	1.0844	1.1139
−30	269.6	13.99	253.55	267.54	0.0585	1.0428	1.1012
−25	329.7	21.08	248.69	269.77	0.0871	1.0022	1.0893
−20	399.6	28.24	243.65	271.89	0.1154	0.9625	1.0779
−15	480.4	35.47	238.42	273.90	0.1435	0.9236	1.0671
−10	573.1	42.80	232.98	275.78	0.1713	0.8854	1.0567
−5	678.9	50.22	227.31	277.53	0.1989	0.8477	1.0466
0	798.7	57.76	221.37	279.12	0.2264	0.8104	1.0368
5	933.9	65.41	215.13	280.55	0.2537	0.7734	1.0272
10	1085.7	73.21	208.57	281.78	0.2810	0.7366	1.0176
15	1255.4	81.15	201.64	282.79	0.3083	0.6998	1.0081
20	1444.2	89.27	194.28	283.55	0.3357	0.6627	0.9984
25	1653.6	97.59	186.43	284.02	0.3631	0.6253	0.9884
30	1885.1	106.14	178.02	284.16	0.3908	0.5872	0.9781
35	2140.2	114.95	168.94	283.89	0.4189	0.5482	0.9671
40	2420.7	124.09	159.04	283.13	0.4473	0.5079	0.9552
45	2728.3	133.61	148.14	281.76	0.4765	0.4656	0.9421
50	3065.2	143.65	135.93	279.58	0.5067	0.4206	0.9273
55	3433.7	154.41	121.89	276.30	0.5384	0.3715	0.9099
60	3836.9	166.28	105.04	271.33	0.5729	0.3153	0.8882
65	4278.3	180.32	82.95	263.26	0.6130	0.2453	0.8583
70	4763.1	202.24	43.40	245.64	0.6752	0.1265	0.8017
71.3	4901.2	226.46	0	226.46	0.7449	0	0.7449

TABLE B.4.2

*Superheated R-410a*

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg·K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg·K)
50 kPa (−64.34°C)					100 kPa (−51.65°C)			
Sat.	0.46484	226.90	250.15	1.2070	0.24247	232.70	256.94	1.1621
−60	0.47585	229.60	253.40	1.2225	—	—	—	—
−40	0.52508	241.94	268.20	1.2888	0.25778	240.40	266.18	1.2027
−20	0.57295	254.51	283.16	1.3504	0.28289	253.44	281.73	1.2667
0	0.62016	267.52	298.53	1.4088	0.30723	266.72	297.44	1.3265
20	0.66698	281.05	314.40	1.4649	0.33116	280.42	313.54	1.3833
40	0.71355	295.15	330.83	1.5191	0.35483	294.64	330.12	1.4380
60	0.75995	309.84	347.83	1.5717	0.37833	309.40	347.24	1.4910
80	0.80623	325.11	365.43	1.6230	0.40171	324.75	364.92	1.5425
100	0.85243	340.99	383.61	1.6731	0.42500	340.67	383.17	1.5928
120	0.89857	357.46	402.38	1.7221	0.44822	357.17	401.99	1.6419
140	0.94465	374.50	421.74	1.7701	0.47140	374.25	421.39	1.6901
160	0.99070	392.12	441.65	1.8171	0.49453	391.89	441.34	1.7372
180	1.03671	410.28	462.12	1.8633	0.51764	410.07	461.84	1.7835
200	1.08270	428.98	483.11	1.9087	0.54072	428.79	482.86	1.8289
220	1.12867	448.19	504.63	1.9532	0.56378	448.02	504.40	1.8734
240	1.17462	467.90	526.63	1.9969	0.58682	467.74	526.42	1.9172
150 kPa (−43.35°C)					200 kPa (−37.01°C)			
Sat.	0.16540	236.36	261.17	1.1368	0.12591	239.09	264.27	1.1192
−40	0.16851	238.72	263.99	1.1489	—	—	—	—
−20	0.18613	252.34	280.26	1.2159	0.13771	251.18	278.72	1.1783
0	0.20289	265.90	296.33	1.2770	0.15070	265.06	295.20	1.2410
20	0.21921	279.78	312.66	1.3347	0.16322	279.13	311.78	1.2995
40	0.23525	294.12	329.40	1.3899	0.17545	293.59	328.68	1.3553
60	0.25112	308.97	346.64	1.4433	0.18750	308.53	346.03	1.4090
80	0.26686	324.37	364.40	1.4950	0.19943	324.00	363.89	1.4610
100	0.28251	340.35	382.72	1.5455	0.21127	340.02	382.28	1.5117
120	0.29810	356.89	401.60	1.5948	0.22305	356.60	401.21	1.5611
140	0.31364	374.00	421.04	1.6430	0.23477	373.74	420.70	1.6094
160	0.32915	391.66	441.03	1.6902	0.24645	391.43	440.72	1.6568
180	0.34462	409.87	461.56	1.7366	0.25810	409.66	461.28	1.7032
200	0.36006	428.60	482.61	1.7820	0.26973	428.41	482.35	1.7487
220	0.37548	447.84	504.16	1.8266	0.28134	447.67	503.93	1.7933
240	0.39089	467.58	526.21	1.8705	0.29293	467.41	526.00	1.8372
260	0.40628	487.78	548.73	1.9135	0.30450	487.63	548.53	1.8803

TABLE B.4.2 (continued)  
Superheated R-410a

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
300 kPa (−27.37°C)					400 kPa (−19.98°C)			
Sat.	0.08548	243.08	268.72	1.0949	0.06475	246.00	271.90	1.0779
−20	0.08916	248.71	275.46	1.1219	—	—	—	—
0	0.09845	263.33	292.87	1.1881	0.07227	261.51	290.42	1.1483
20	0.10720	277.81	309.96	1.2485	0.07916	276.44	308.10	1.2108
40	0.11564	292.53	327.22	1.3054	0.08571	291.44	325.72	1.2689
60	0.12388	307.65	344.81	1.3599	0.09207	306.75	343.58	1.3242
80	0.13200	323.25	362.85	1.4125	0.09828	322.49	361.80	1.3773
100	0.14003	339.37	381.38	1.4635	0.10440	338.72	380.48	1.4288
120	0.14798	356.03	400.43	1.5132	0.11045	355.45	399.64	1.4788
140	0.15589	373.23	420.00	1.5617	0.11645	372.72	419.30	1.5276
160	0.16376	390.97	440.10	1.6093	0.12241	390.51	439.47	1.5752
180	0.17159	409.24	460.72	1.6558	0.12834	408.82	460.16	1.6219
200	0.17940	428.03	481.85	1.7014	0.13424	427.64	481.34	1.6676
220	0.18719	447.31	503.47	1.7462	0.14012	446.96	503.01	1.7125
240	0.19496	467.09	525.58	1.7901	0.14598	466.76	525.15	1.7565
260	0.20272	487.33	548.15	1.8332	0.15182	487.03	547.76	1.7997
280	0.21046	508.02	571.16	1.8756	0.15766	507.74	570.81	1.8422
500 kPa (−13.89°C)					600 kPa (−8.67°C)			
Sat.	0.05208	248.29	274.33	1.0647	0.04351	250.15	276.26	1.0540
0	0.05651	259.59	287.84	1.1155	0.04595	257.54	285.12	1.0869
20	0.06231	275.02	306.18	1.1803	0.05106	273.56	304.20	1.1543
40	0.06775	290.32	324.20	1.2398	0.05576	289.19	322.64	1.2152
60	0.07297	305.84	342.32	1.2959	0.06023	304.91	341.05	1.2722
80	0.07804	321.72	360.74	1.3496	0.06455	320.94	359.67	1.3265
100	0.08302	338.05	379.56	1.4014	0.06877	337.38	378.65	1.3787
120	0.08793	354.87	398.84	1.4517	0.07292	354.29	398.04	1.4294
140	0.09279	372.20	418.60	1.5007	0.07701	371.68	417.89	1.4786
160	0.09760	390.05	438.85	1.5486	0.08106	389.58	438.22	1.5266
180	0.10238	408.40	459.59	1.5954	0.08508	407.98	459.03	1.5736
200	0.10714	427.26	480.83	1.6413	0.08907	426.88	480.32	1.6196
220	0.11187	446.61	502.55	1.6862	0.09304	446.26	502.08	1.6646
240	0.11659	466.44	524.73	1.7303	0.09700	466.11	524.31	1.7088
260	0.12129	486.73	547.37	1.7736	0.10093	486.42	546.98	1.7521
280	0.12598	507.46	570.45	1.8161	0.10486	507.18	570.09	1.7947
300	0.13066	528.62	593.95	1.8578	0.10877	528.36	593.62	1.8365

TABLE B.4.2 (continued)  
Superheated R-410a

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
800 kPa (0.05°C)					1000 kPa (7.25°C)			
Sat.	0.03262	253.04	279.14	1.0367	0.02596	255.16	281.12	1.0229
20	0.03693	270.47	300.02	1.1105	0.02838	267.11	295.49	1.0730
40	0.04074	286.83	319.42	1.1746	0.03170	284.35	316.05	1.1409
60	0.04429	303.01	338.44	1.2334	0.03470	301.04	335.75	1.2019
80	0.04767	319.36	357.49	1.2890	0.03753	317.73	355.27	1.2588
100	0.05095	336.03	376.79	1.3421	0.04025	334.65	374.89	1.3128
120	0.05415	353.11	396.42	1.3934	0.04288	351.91	394.79	1.3648
140	0.05729	370.64	416.47	1.4431	0.04545	369.58	415.04	1.4150
160	0.06039	388.65	436.96	1.4915	0.04798	387.70	435.68	1.4638
180	0.06345	407.13	457.90	1.5388	0.05048	406.28	456.76	1.5113
200	0.06649	426.10	479.30	1.5850	0.05294	425.33	478.27	1.5578
220	0.06951	445.55	501.15	1.6302	0.05539	444.84	500.23	1.6032
240	0.07251	465.46	523.46	1.6746	0.05781	464.80	522.62	1.6477
260	0.07549	485.82	546.21	1.7181	0.06023	485.21	545.43	1.6914
280	0.07846	506.61	569.38	1.7607	0.06262	506.05	568.67	1.7341
300	0.08142	527.83	592.97	1.8026	0.06501	527.30	592.31	1.7761
1200 kPa (13.43°C)					1400 kPa (18.88°C)			
Sat.	0.02145	256.75	282.50	1.0111	0.01819	257.94	283.40	1.0006
20	0.02260	263.39	290.51	1.0388	0.01838	259.18	284.90	1.0057
40	0.02563	281.72	312.48	1.1113	0.02127	278.93	308.71	1.0843
60	0.02830	299.00	332.96	1.1747	0.02371	296.88	330.07	1.1505
80	0.03077	316.06	352.98	1.2331	0.02593	314.35	350.64	1.2105
100	0.03311	333.24	372.97	1.2881	0.02801	331.80	371.01	1.2666
120	0.03537	350.69	393.13	1.3408	0.03000	349.46	391.46	1.3199
140	0.03756	368.51	413.59	1.3915	0.03192	367.43	412.13	1.3712
160	0.03971	386.75	434.40	1.4407	0.03380	385.79	433.12	1.4208
180	0.04183	405.43	455.62	1.4886	0.03565	404.56	454.47	1.4690
200	0.04391	424.55	477.24	1.5353	0.03746	423.77	476.21	1.5160
220	0.04597	444.12	499.29	1.5809	0.03925	443.41	498.36	1.5618
240	0.04802	464.14	521.77	1.6256	0.04102	463.49	520.92	1.6066
260	0.05005	484.60	544.66	1.6693	0.04278	483.99	543.88	1.6505
280	0.05207	505.48	567.96	1.7122	0.04452	504.91	567.25	1.6936
300	0.05407	526.77	591.66	1.7543	0.04626	526.25	591.01	1.7358
320	0.05607	548.47	615.75	1.7956	0.04798	547.97	615.14	1.7772



TABLE B.4.2 (continued)  
*Superheated R-410a*

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
1800 kPa (28.22°C)					2000 kPa (32.31°C)			
Sat.	0.01376	259.38	284.15	0.9818	0.01218	259.72	284.09	0.9731
40	0.01534	272.67	300.29	1.0344	0.01321	269.07	295.49	1.0099
60	0.01754	292.34	323.92	1.1076	0.01536	289.90	320.62	1.0878
80	0.01945	310.76	345.77	1.1713	0.01717	308.88	343.22	1.1537
100	0.02119	328.84	366.98	1.2297	0.01880	327.30	364.91	1.2134
120	0.02283	346.93	388.03	1.2847	0.02032	345.64	386.29	1.2693
140	0.02441	365.24	409.17	1.3371	0.02177	364.12	407.66	1.3223
160	0.02593	383.85	430.51	1.3875	0.02317	382.86	429.20	1.3732
180	0.02741	402.82	452.16	1.4364	0.02452	401.94	450.99	1.4224
200	0.02886	422.19	474.14	1.4839	0.02585	421.40	473.10	1.4701
220	0.03029	441.97	496.49	1.5301	0.02715	441.25	495.55	1.5166
240	0.03170	462.16	519.22	1.5753	0.02844	461.50	518.37	1.5619
260	0.03309	482.77	542.34	1.6195	0.02970	482.16	541.56	1.6063
280	0.03447	503.78	565.83	1.6627	0.03095	503.21	565.12	1.6497
300	0.03584	525.19	589.70	1.7051	0.03220	524.66	589.05	1.6922
320	0.03720	546.98	613.94	1.7467	0.03343	546.49	613.35	1.7338
340	0.03855	569.15	638.54	1.7875	0.03465	568.69	637.99	1.7747
3000 kPa (49.07°C)					4000 kPa (61.90°C)			
Sat.	0.00729	258.19	280.06	0.9303	0.00460	250.37	268.76	0.8782
60	0.00858	274.96	300.70	0.9933	—	—	—	—
80	0.01025	298.38	329.12	1.0762	0.00661	285.02	311.48	1.0028
100	0.01159	319.07	353.84	1.1443	0.00792	309.62	341.29	1.0850
120	0.01277	338.84	377.16	1.2052	0.00897	331.39	367.29	1.1529
140	0.01387	358.32	399.92	1.2617	0.00990	352.14	391.75	1.2136
160	0.01489	377.80	422.49	1.3150	0.01076	372.51	415.53	1.2698
180	0.01588	397.46	445.09	1.3661	0.01156	392.82	439.05	1.3229
200	0.01683	417.37	467.85	1.4152	0.01232	413.25	462.52	1.3736
220	0.01775	437.60	490.84	1.4628	0.01305	433.88	486.10	1.4224
240	0.01865	458.16	514.11	1.5091	0.01377	454.79	509.85	1.4696
260	0.01954	479.08	537.69	1.5541	0.01446	475.99	533.83	1.5155
280	0.02041	500.37	561.59	1.5981	0.01514	497.51	558.08	1.5601
300	0.02127	522.01	585.81	1.6411	0.01581	519.37	582.60	1.6037
320	0.02212	544.02	610.37	1.6833	0.01647	541.55	607.42	1.6462
340	0.02296	566.37	635.25	1.7245	0.01712	564.06	632.54	1.6879
360	0.02379	589.07	660.45	1.7650	0.01776	586.90	657.95	1.7286

TABLE B.5

*Thermodynamic Properties of R-134a*

TABLE B.5.1

*Saturated R-134a*

Temp. (°C)	Press. (kPa)	Specific Volume, m <sup>3</sup> /kg			Internal Energy, kJ/kg		
		Sat. Liquid $v_f$	Evap. $v_{fg}$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Evap. $u_{fg}$	Sat. Vapor $u_g$
−70	8.3	0.000675	1.97207	1.97274	119.46	218.74	338.20
−65	11.7	0.000679	1.42915	1.42983	123.18	217.76	340.94
−60	16.3	0.000684	1.05199	1.05268	127.52	216.19	343.71
−55	22.2	0.000689	0.78609	0.78678	132.36	214.14	346.50
−50	29.9	0.000695	0.59587	0.59657	137.60	211.71	349.31
−45	39.6	0.000701	0.45783	0.45853	143.15	208.99	352.15
−40	51.8	0.000708	0.35625	0.35696	148.95	206.05	355.00
−35	66.8	0.000715	0.28051	0.28122	154.93	202.93	357.86
−30	85.1	0.000722	0.22330	0.22402	161.06	199.67	360.73
−26.3	101.3	0.000728	0.18947	0.19020	165.73	197.16	362.89
−25	107.2	0.000730	0.17957	0.18030	167.30	196.31	363.61
−20	133.7	0.000738	0.14576	0.14649	173.65	192.85	366.50
−15	165.0	0.000746	0.11932	0.12007	180.07	189.32	369.39
−10	201.7	0.000755	0.09845	0.09921	186.57	185.70	372.27
−5	244.5	0.000764	0.08181	0.08257	193.14	182.01	375.15
0	294.0	0.000773	0.06842	0.06919	199.77	178.24	378.01
5	350.9	0.000783	0.05755	0.05833	206.48	174.38	380.85
10	415.8	0.000794	0.04866	0.04945	213.25	170.42	383.67
15	489.5	0.000805	0.04133	0.04213	220.10	166.35	386.45
20	572.8	0.000817	0.03524	0.03606	227.03	162.16	389.19
25	666.3	0.000829	0.03015	0.03098	234.04	157.83	391.87
30	771.0	0.000843	0.02587	0.02671	241.14	153.34	394.48
35	887.6	0.000857	0.02224	0.02310	248.34	148.68	397.02
40	1017.0	0.000873	0.01915	0.02002	255.65	143.81	399.46
45	1160.2	0.000890	0.01650	0.01739	263.08	138.71	401.79
50	1318.1	0.000908	0.01422	0.01512	270.63	133.35	403.98
55	1491.6	0.000928	0.01224	0.01316	278.33	127.68	406.01
60	1681.8	0.000951	0.01051	0.01146	286.19	121.66	407.85
65	1889.9	0.000976	0.00899	0.00997	294.24	115.22	409.46
70	2117.0	0.001005	0.00765	0.00866	302.51	108.27	410.78
75	2364.4	0.001038	0.00645	0.00749	311.06	100.68	411.74
80	2633.6	0.001078	0.00537	0.00645	319.96	92.26	412.22
85	2926.2	0.001128	0.00437	0.00550	329.35	82.67	412.01
90	3244.5	0.001195	0.00341	0.00461	339.51	71.24	410.75
95	3591.5	0.001297	0.00243	0.00373	351.17	56.25	407.42
100	3973.2	0.001557	0.00108	0.00264	368.55	28.19	396.74
101.2	4064.0	0.001969	0	0.00197	382.97	0	382.97

TABLE B.5.1 (continued)  
Saturated R-134a

Temp. (°C)	Press. (kPa)	Enthalpy, kJ/kg			Entropy, kJ/k-K		
		Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$
−70	8.3	119.47	235.15	354.62	0.6645	1.1575	1.8220
−65	11.7	123.18	234.55	357.73	0.6825	1.1268	1.8094
−60	16.3	127.53	233.33	360.86	0.7031	1.0947	1.7978
−55	22.2	132.37	231.63	364.00	0.7256	1.0618	1.7874
−50	29.9	137.62	229.54	367.16	0.7493	1.0286	1.7780
−45	39.6	143.18	227.14	370.32	0.7740	0.9956	1.7695
−40	51.8	148.98	224.50	373.48	0.7991	0.9629	1.7620
−35	66.8	154.98	221.67	376.64	0.8245	0.9308	1.7553
−30	85.1	161.12	218.68	379.80	0.8499	0.8994	1.7493
−26.3	101.3	165.80	216.36	382.16	0.8690	0.8763	1.7453
−25	107.2	167.38	215.57	382.95	0.8754	0.8687	1.7441
−20	133.7	173.74	212.34	386.08	0.9007	0.8388	1.7395
−15	165.0	180.19	209.00	389.20	0.9258	0.8096	1.7354
−10	201.7	186.72	205.56	392.28	0.9507	0.7812	1.7319
−5	244.5	193.32	202.02	395.34	0.9755	0.7534	1.7288
0	294.0	200.00	198.36	398.36	1.0000	0.7262	1.7262
5	350.9	206.75	194.57	401.32	1.0243	0.6995	1.7239
10	415.8	213.58	190.65	404.23	1.0485	0.6733	1.7218
15	489.5	220.49	186.58	407.07	1.0725	0.6475	1.7200
20	572.8	227.49	182.35	409.84	1.0963	0.6220	1.7183
25	666.3	234.59	177.92	412.51	1.1201	0.5967	1.7168
30	771.0	241.79	173.29	415.08	1.1437	0.5716	1.7153
35	887.6	249.10	168.42	417.52	1.1673	0.5465	1.7139
40	1017.0	256.54	163.28	419.82	1.1909	0.5214	1.7123
45	1160.2	264.11	157.85	421.96	1.2145	0.4962	1.7106
50	1318.1	271.83	152.08	423.91	1.2381	0.4706	1.7088
55	1491.6	279.72	145.93	425.65	1.2619	0.4447	1.7066
60	1681.8	287.79	139.33	427.13	1.2857	0.4182	1.7040
65	1889.9	296.09	132.21	428.30	1.3099	0.3910	1.7008
70	2117.0	304.64	124.47	429.11	1.3343	0.3627	1.6970
75	2364.4	313.51	115.94	429.45	1.3592	0.3330	1.6923
80	2633.6	322.79	106.40	429.19	1.3849	0.3013	1.6862
85	2926.2	332.65	95.45	428.10	1.4117	0.2665	1.6782
90	3244.5	343.38	82.31	425.70	1.4404	0.2267	1.6671
95	3591.5	355.83	64.98	420.81	1.4733	0.1765	1.6498
100	3973.2	374.74	32.47	407.21	1.5228	0.0870	1.6098
101.2	4064.0	390.98	0	390.98	1.5658	0	1.5658

TABLE B.5.2

*Superheated R-134a*

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
50 kPa (−40.67°C)					100 kPa (−26.54°C)			
Sat.	0.36889	354.61	373.06	1.7629	0.19257	362.73	381.98	1.7456
−20	0.40507	368.57	388.82	1.8279	0.19860	367.36	387.22	1.7665
−10	0.42222	375.53	396.64	1.8582	0.20765	374.51	395.27	1.7978
0	0.43921	382.63	404.59	1.8878	0.21652	381.76	403.41	1.8281
10	0.45608	389.90	412.70	1.9170	0.22527	389.14	411.67	1.8578
20	0.47287	397.32	420.96	1.9456	0.23392	396.66	420.05	1.8869
30	0.48958	404.90	429.38	1.9739	0.24250	404.31	428.56	1.9155
40	0.50623	412.64	437.96	2.0017	0.25101	412.12	437.22	1.9436
50	0.52284	420.55	446.70	2.0292	0.25948	420.08	446.03	1.9712
60	0.53941	428.63	455.60	2.0563	0.26791	428.20	454.99	1.9985
70	0.55595	436.86	464.66	2.0831	0.27631	436.47	464.10	2.0255
80	0.57247	445.26	473.88	2.1096	0.28468	444.89	473.36	2.0521
90	0.58896	453.82	483.26	2.1358	0.29302	453.47	482.78	2.0784
100	0.60544	462.53	492.81	2.1617	0.30135	462.21	492.35	2.1044
110	0.62190	471.41	502.50	2.1874	0.30967	471.11	502.07	2.1301
120	0.63835	480.44	512.36	2.2128	0.31797	480.16	511.95	2.1555
130	0.65479	489.63	522.37	2.2379	0.32626	489.36	521.98	2.1807
150 kPa (−17.29°C)					200 kPa (−10.22°C)			
Sat.	0.13139	368.06	387.77	1.7372	0.10002	372.15	392.15	1.7320
−10	0.13602	373.44	393.84	1.7606	0.10013	372.31	392.34	1.7328
0	0.14222	380.85	402.19	1.7917	0.10501	379.91	400.91	1.7647
10	0.14828	388.36	410.60	1.8220	0.10974	387.55	409.50	1.7956
20	0.15424	395.98	419.11	1.8515	0.11436	395.27	418.15	1.8256
30	0.16011	403.71	427.73	1.8804	0.11889	403.10	426.87	1.8549
40	0.16592	411.59	436.47	1.9088	0.12335	411.04	435.71	1.8836
50	0.17168	419.60	445.35	1.9367	0.12776	419.11	444.66	1.9117
60	0.17740	427.76	454.37	1.9642	0.13213	427.31	453.74	1.9394
70	0.18308	436.06	463.53	1.9913	0.13646	435.65	462.95	1.9666
80	0.18874	444.52	472.83	2.0180	0.14076	444.14	472.30	1.9935
90	0.19437	453.13	482.28	2.0444	0.14504	452.78	481.79	2.0200
100	0.19999	461.89	491.89	2.0705	0.14930	461.56	491.42	2.0461
110	0.20559	470.80	501.64	2.0963	0.15355	470.50	501.21	2.0720
120	0.21117	479.87	511.54	2.1218	0.15777	479.58	511.13	2.0976
130	0.21675	489.08	521.60	2.1470	0.16199	488.81	521.21	2.1229
140	0.22231	498.45	531.80	2.1720	0.16620	498.19	531.43	2.1479

TABLE B.5.2 (continued)  
*Superheated R-134a*

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
300 kPa (0.56°C)					400 kPa (8.84°C)			
Sat.	0.06787	378.33	398.69	1.7259	0.05136	383.02	403.56	1.7223
10	0.07111	385.84	407.17	1.7564	0.05168	383.98	404.65	1.7261
20	0.07441	393.80	416.12	1.7874	0.05436	392.22	413.97	1.7584
30	0.07762	401.81	425.10	1.8175	0.05693	400.45	423.22	1.7895
40	0.08075	409.90	434.12	1.8468	0.05940	408.70	432.46	1.8195
50	0.08382	418.09	443.23	1.8755	0.06181	417.03	441.75	1.8487
60	0.08684	426.39	452.44	1.9035	0.06417	425.44	451.10	1.8772
70	0.08982	434.82	461.76	1.9311	0.06648	433.95	460.55	1.9051
80	0.09277	443.37	471.21	1.9582	0.06877	442.58	470.09	1.9325
90	0.09570	452.07	480.78	1.9850	0.07102	451.34	479.75	1.9595
100	0.09861	460.90	490.48	2.0113	0.07325	460.22	489.52	1.9860
110	0.10150	469.87	500.32	2.0373	0.07547	469.24	499.43	2.0122
120	0.10437	478.99	510.30	2.0631	0.07767	478.40	509.46	2.0381
130	0.10723	488.26	520.43	2.0885	0.07985	487.69	519.63	2.0636
140	0.11008	497.66	530.69	2.1136	0.08202	497.13	529.94	2.0889
150	0.11292	507.22	541.09	2.1385	0.08418	506.71	540.38	2.1139
160	0.11575	516.91	551.64	2.1631	0.08634	516.43	550.97	2.1386
500 kPa (15.66°C)					600 kPa (21.52°C)			
Sat.	0.04126	386.82	407.45	1.7198	0.03442	390.01	410.66	1.7179
20	0.04226	390.52	411.65	1.7342	—	—	—	—
30	0.04446	398.99	421.22	1.7663	0.03609	397.44	419.09	1.7461
40	0.04656	407.44	430.72	1.7971	0.03796	406.11	428.88	1.7779
50	0.04858	415.91	440.20	1.8270	0.03974	414.75	438.59	1.8084
60	0.05055	424.44	449.72	1.8560	0.04145	423.41	448.28	1.8379
70	0.05247	433.06	459.29	1.8843	0.04311	432.13	457.99	1.8666
80	0.05435	441.77	468.94	1.9120	0.04473	440.93	467.76	1.8947
90	0.05620	450.59	478.69	1.9392	0.04632	449.82	477.61	1.9222
100	0.05804	459.53	488.55	1.9660	0.04788	458.82	487.55	1.9492
110	0.05985	468.60	498.52	1.9924	0.04943	467.94	497.59	1.9758
120	0.06164	477.79	508.61	2.0184	0.05095	477.18	507.75	2.0019
130	0.06342	487.13	518.83	2.0440	0.05246	486.55	518.03	2.0277
140	0.06518	496.59	529.19	2.0694	0.05396	496.05	528.43	2.0532
150	0.06694	506.20	539.67	2.0945	0.05544	505.69	538.95	2.0784
160	0.06869	515.95	550.29	2.1193	0.05692	515.46	549.61	2.1033
170	0.07043	525.83	561.04	2.1438	0.05839	525.36	560.40	2.1279

TABLE B.5.2 (continued)  
Superheated R-134a

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
800 kPa (31.30°C)					1000 kPa (39.37°C)			
Sat.	0.02571	395.15	415.72	1.7150	0.02038	399.16	419.54	1.7125
40	0.02711	403.17	424.86	1.7446	0.02047	399.78	420.25	1.7148
50	0.02861	412.23	435.11	1.7768	0.02185	409.39	431.24	1.7494
60	0.03002	421.20	445.22	1.8076	0.02311	418.78	441.89	1.7818
70	0.03137	430.17	455.27	1.8373	0.02429	428.05	452.34	1.8127
80	0.03268	439.17	465.31	1.8662	0.02542	437.29	462.70	1.8425
90	0.03394	448.22	475.38	1.8943	0.02650	446.53	473.03	1.8713
100	0.03518	457.35	485.50	1.9218	0.02754	455.82	483.36	1.8994
110	0.03639	466.58	495.70	1.9487	0.02856	465.18	493.74	1.9268
120	0.03758	475.92	505.99	1.9753	0.02956	474.62	504.17	1.9537
130	0.03876	485.37	516.38	2.0014	0.03053	484.16	514.69	1.9801
140	0.03992	494.94	526.88	2.0271	0.03150	493.81	525.30	2.0061
150	0.04107	504.64	537.50	2.0525	0.03244	503.57	536.02	2.0318
160	0.04221	514.46	548.23	2.0775	0.03338	513.46	546.84	2.0570
170	0.04334	524.42	559.09	2.1023	0.03431	523.46	557.77	2.0820
180	0.04446	534.51	570.08	2.1268	0.03523	533.60	568.83	2.1067
1200 kPa (46.31°C)					1400 kPa (52.42°C)			
Sat.	0.01676	402.37	422.49	1.7102	0.01414	404.98	424.78	1.7077
50	0.01724	406.15	426.84	1.7237	—	—	—	—
60	0.01844	416.08	438.21	1.7584	0.01503	413.03	434.08	1.7360
70	0.01953	425.74	449.18	1.7908	0.01608	423.20	445.72	1.7704
80	0.02055	435.27	459.92	1.8217	0.01704	433.09	456.94	1.8026
90	0.02151	444.74	470.55	1.8514	0.01793	442.83	467.93	1.8333
100	0.02244	454.20	481.13	1.8801	0.01878	452.50	478.79	1.8628
110	0.02333	463.71	491.70	1.9081	0.01958	462.17	489.59	1.8914
120	0.02420	473.27	502.31	1.9354	0.02036	471.87	500.38	1.9192
130	0.02504	482.91	512.97	1.9621	0.02112	481.63	511.19	1.9463
140	0.02587	492.65	523.70	1.9884	0.02186	491.46	522.05	1.9730
150	0.02669	502.48	534.51	2.0143	0.02258	501.37	532.98	1.9991
160	0.02750	512.43	545.43	2.0398	0.02329	511.39	543.99	2.0248
170	0.02829	522.50	556.44	2.0649	0.02399	521.51	555.10	2.0502
180	0.02907	532.68	567.57	2.0898	0.02468	531.75	566.30	2.0752

TABLE B.5.2 (continued)  
Superheated R-134a

Temp. (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
1600 kPa (57.90°C)					2000 kPa (67.48°C)			
Sat.	0.01215	407.11	426.54	1.7051	0.00930	410.15	428.75	1.6991
60	0.01239	409.49	429.32	1.7135	—	—	—	—
70	0.01345	420.37	441.89	1.7507	0.00958	413.37	432.53	1.7101
80	0.01438	430.72	453.72	1.7847	0.01055	425.20	446.30	1.7497
90	0.01522	440.79	465.15	1.8166	0.01137	436.20	458.95	1.7850
100	0.01601	450.71	476.33	1.8469	0.01211	446.78	471.00	1.8177
110	0.01676	460.57	487.39	1.8762	0.01279	457.12	482.69	1.8487
120	0.01748	470.42	498.39	1.9045	0.01342	467.34	494.19	1.8783
130	0.01817	480.30	509.37	1.9321	0.01403	477.51	505.57	1.9069
140	0.01884	490.23	520.38	1.9591	0.01461	487.68	516.90	1.9346
150	0.01949	500.24	531.43	1.9855	0.01517	497.89	528.22	1.9617
160	0.02013	510.33	542.54	2.0115	0.01571	508.15	539.57	1.9882
170	0.02076	520.52	553.73	2.0370	0.01624	518.48	550.96	2.0142
180	0.02138	530.81	565.02	2.0622	0.01676	528.89	562.42	2.0398
3000 kPa (86.20°C)					4000 kPa (100.33°C)			
Sat.	0.00528	411.83	427.67	1.6759	0.00252	394.86	404.94	1.6036
90	0.00575	418.93	436.19	1.6995	—	—	—	—
100	0.00665	433.77	453.73	1.7472	—	—	—	—
110	0.00734	446.48	468.50	1.7862	0.00428	429.74	446.84	1.7148
120	0.00792	458.27	482.04	1.8211	0.00500	445.97	465.99	1.7642
130	0.00845	469.58	494.91	1.8535	0.00556	459.63	481.87	1.8040
140	0.00893	480.61	507.39	1.8840	0.00603	472.19	496.29	1.8394
150	0.00937	491.49	519.62	1.9133	0.00644	484.15	509.92	1.8720
160	0.00980	502.30	531.70	1.9415	0.00683	495.77	523.07	1.9027
170	0.01021	513.09	543.71	1.9689	0.00718	507.19	535.92	1.9320
180	0.01060	523.89	555.69	1.9956	0.00752	518.51	548.57	1.9603
6000 kPa					10000 kPa			
90	0.001059	328.34	334.70	1.4081	0.000991	320.72	330.62	1.3856
100	0.001150	346.71	353.61	1.4595	0.001040	336.45	346.85	1.4297
110	0.001307	368.06	375.90	1.5184	0.001100	352.74	363.73	1.4744
120	0.001698	396.59	406.78	1.5979	0.001175	369.69	381.44	1.5200
130	0.002396	426.81	441.18	1.6843	0.001272	387.44	400.16	1.5670
140	0.002985	448.34	466.25	1.7458	0.001400	405.97	419.98	1.6155
150	0.003439	465.19	485.82	1.7926	0.001564	424.99	440.63	1.6649
160	0.003814	479.89	502.77	1.8322	0.001758	443.77	461.34	1.7133
170	0.004141	493.45	518.30	1.8676	0.001965	461.65	481.30	1.7589
180	0.004435	506.35	532.96	1.9004	0.002172	478.40	500.12	1.8009

TABLE B.6

*Thermodynamic Properties of Nitrogen*

TABLE B.6.1

*Saturated Nitrogen*

Temp. (K)	Press. (kPa)	Specific Volume, m <sup>3</sup> /kg			Internal Energy, kJ/kg		
		Sat. Liquid $v_f$	Evap. $v_{fg}$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Evap. $u_{fg}$	Sat. Vapor $u_g$
63.1	12.5	0.001150	1.48074	1.48189	−150.92	196.86	45.94
65	17.4	0.001160	1.09231	1.09347	−147.19	194.37	47.17
70	38.6	0.001191	0.52513	0.52632	−137.13	187.54	50.40
75	76.1	0.001223	0.28052	0.28174	−127.04	180.47	53.43
77.3	101.3	0.001240	0.21515	0.21639	−122.27	177.04	54.76
80	137.0	0.001259	0.16249	0.16375	−116.86	173.06	56.20
85	229.1	0.001299	0.10018	0.10148	−106.55	165.20	58.65
90	360.8	0.001343	0.06477	0.06611	−96.06	156.76	60.70
95	541.1	0.001393	0.04337	0.04476	−85.35	147.60	62.25
100	779.2	0.001452	0.02975	0.03120	−74.33	137.50	63.17
105	1084.6	0.001522	0.02066	0.02218	−62.89	126.18	63.29
110	1467.6	0.001610	0.01434	0.01595	−50.81	113.11	62.31
115	1939.3	0.001729	0.00971	0.01144	−37.66	97.36	59.70
120	2513.0	0.001915	0.00608	0.00799	−22.42	76.63	54.21
125	3208.0	0.002355	0.00254	0.00490	−0.83	40.73	39.90
126.2	3397.8	0.003194	0	0.00319	18.94	0	18.94
Temp. (K)	Press. (kPa)	Enthalpy, kJ/kg			Entropy, kJ/kg-K		
		Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$
63.1	12.5	−150.91	215.39	64.48	2.4234	3.4109	5.8343
65	17.4	−147.17	213.38	66.21	2.4816	3.2828	5.7645
70	38.6	−137.09	207.79	70.70	2.6307	2.9684	5.5991
75	76.1	−126.95	201.82	74.87	2.7700	2.6909	5.4609
77.3	101.3	−122.15	198.84	76.69	2.8326	2.5707	5.4033
80	137.0	−116.69	195.32	78.63	2.9014	2.4415	5.3429
85	229.1	−106.25	188.15	81.90	3.0266	2.2135	5.2401
90	360.8	−95.58	180.13	84.55	3.1466	2.0015	5.1480
95	541.1	−84.59	171.07	86.47	3.2627	1.8007	5.0634
100	779.2	−73.20	160.68	87.48	3.3761	1.6068	4.9829
105	1084.6	−61.24	148.59	87.35	3.4883	1.4151	4.9034
110	1467.6	−48.45	134.15	85.71	3.6017	1.2196	4.8213
115	1939.3	−34.31	116.19	81.88	3.7204	1.0104	4.7307
120	2513.0	−17.61	91.91	74.30	3.8536	0.7659	4.6195
125	3208.0	6.73	48.88	55.60	4.0399	0.3910	4.4309
126.2	3397.8	29.79	0	29.79	4.2193	0	4.2193



TABLE B.6.2

*Superheated Nitrogen*

Temp. (K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
100 kPa (77.24 K)					200 kPa (83.62 K)			
Sat.	0.21903	54.70	76.61	5.4059	0.11520	58.01	81.05	5.2673
100	0.29103	72.84	101.94	5.6944	0.14252	71.73	100.24	5.4775
120	0.35208	87.94	123.15	5.8878	0.17397	87.14	121.93	5.6753
140	0.41253	102.95	144.20	6.0501	0.20476	102.33	143.28	5.8399
160	0.47263	117.91	165.17	6.1901	0.23519	117.40	164.44	5.9812
180	0.53254	132.83	186.09	6.3132	0.26542	132.41	185.49	6.1052
200	0.59231	147.74	206.97	6.4232	0.29551	147.37	206.48	6.2157
220	0.65199	162.63	227.83	6.5227	0.32552	162.31	227.41	6.3155
240	0.71161	177.51	248.67	6.6133	0.35546	177.23	248.32	6.4064
260	0.77118	192.39	269.51	6.6967	0.38535	192.14	269.21	6.4900
280	0.83072	207.26	290.33	6.7739	0.41520	207.04	290.08	6.5674
300	0.89023	222.14	311.16	6.8457	0.44503	221.93	310.94	6.6393
350	1.03891	259.35	363.24	7.0063	0.51952	259.18	363.09	6.8001
400	1.18752	296.66	415.41	7.1456	0.59392	296.52	415.31	6.9396
450	1.33607	334.16	467.77	7.2690	0.66827	334.04	467.70	7.0630
500	1.48458	371.95	520.41	7.3799	0.74258	371.85	520.37	7.1740
600	1.78154	448.79	626.94	7.5741	0.89114	448.71	626.94	7.3682
700	2.07845	527.74	735.58	7.7415	1.03965	527.68	735.61	7.5357
800	2.37532	609.07	846.60	7.8897	1.18812	609.02	846.64	7.6839
900	2.67217	692.79	960.01	8.0232	1.33657	692.75	960.07	7.8175
1000	2.96900	778.78	1075.68	8.1451	1.48501	778.74	1075.75	7.9393

TABLE B.6.2 (continued)  
Superheated Nitrogen

Temp. (K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
400 kPa (91.22 K)					600 kPa (96.37 K)			
Sat.	0.05992	61.13	85.10	5.1268	0.04046	62.57	86.85	5.0411
100	0.06806	69.30	96.52	5.2466	0.04299	66.41	92.20	5.0957
120	0.08486	85.48	119.42	5.4556	0.05510	83.73	116.79	5.3204
140	0.10085	101.06	141.40	5.6250	0.06620	99.75	139.47	5.4953
160	0.11647	116.38	162.96	5.7690	0.07689	115.34	161.47	5.6422
180	0.13186	131.55	184.30	5.8947	0.08734	130.69	183.10	5.7696
200	0.14712	146.64	205.49	6.0063	0.09766	145.91	204.50	5.8823
220	0.16228	161.68	226.59	6.1069	0.10788	161.04	225.76	5.9837
240	0.17738	176.67	247.62	6.1984	0.11803	176.11	246.92	6.0757
260	0.19243	191.64	268.61	6.2824	0.12813	191.13	268.01	6.1601
280	0.20745	206.58	289.56	6.3600	0.13820	206.13	289.05	6.2381
300	0.22244	221.52	310.50	6.4322	0.14824	221.11	310.06	6.3105
350	0.25982	258.85	362.78	6.5934	0.17326	258.52	362.48	6.4722
400	0.29712	296.25	415.10	6.7331	0.19819	295.97	414.89	6.6121
450	0.33437	333.81	467.56	6.8567	0.22308	333.57	467.42	6.7359
500	0.37159	371.65	520.28	6.9678	0.24792	371.45	520.20	6.8471
600	0.44595	448.55	626.93	7.1622	0.29755	448.40	626.93	7.0416
700	0.52025	527.55	735.65	7.3298	0.34712	527.43	735.70	7.2093
800	0.59453	608.92	846.73	7.4781	0.39666	608.82	846.82	7.3576
900	0.66878	692.67	960.19	7.6117	0.44618	692.59	960.30	7.4912
1000	0.74302	778.68	1075.89	7.7335	0.49568	778.61	1076.02	7.6131
800 kPa (100.38 K)					1000 kPa (103.73 K)			
Sat.	0.03038	63.21	87.52	4.9768	0.02416	63.35	87.51	4.9237
120	0.04017	81.88	114.02	5.2191	0.03117	79.91	111.08	5.1357
140	0.04886	98.41	137.50	5.4002	0.03845	97.02	135.47	5.3239
160	0.05710	114.28	159.95	5.5501	0.04522	113.20	158.42	5.4772
180	0.06509	129.82	181.89	5.6793	0.05173	128.94	180.67	5.6082
200	0.07293	145.17	203.51	5.7933	0.05809	144.43	202.52	5.7234
220	0.08067	160.40	224.94	5.8954	0.06436	159.76	224.11	5.8263
240	0.08835	175.54	246.23	5.9880	0.07055	174.98	245.53	5.9194
260	0.09599	190.63	267.42	6.0728	0.07670	190.13	266.83	6.0047
280	0.10358	205.68	288.54	6.1511	0.08281	205.23	288.04	6.0833
300	0.11115	220.70	309.62	6.2238	0.08889	220.29	309.18	6.1562
350	0.12998	258.19	362.17	6.3858	0.10401	257.86	361.87	6.3187
400	0.14873	295.69	414.68	6.5260	0.11905	295.42	414.47	6.4591
500	0.18609	371.25	520.12	6.7613	0.14899	371.04	520.04	6.6947
600	0.22335	448.24	626.93	6.9560	0.17883	448.09	626.92	6.8895
700	0.26056	527.31	735.76	7.1237	0.20862	527.19	735.81	7.0573
800	0.29773	608.73	846.91	7.2721	0.23837	608.63	847.00	7.2057
900	0.33488	692.52	960.42	7.4058	0.26810	692.44	960.54	7.3394
1000	0.37202	778.55	1076.16	7.5277	0.29782	778.49	1076.30	7.4614

TABLE B.6.2 (continued)  
Superheated Nitrogen

Temp. (K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
1500 kPa (110.38 K)					2000 kPa (115.58 K)			
Sat.	0.01555	62.17	85.51	4.8148	0.01100	59.25	81.25	4.7193
120	0.01899	74.26	102.75	4.9650	0.01260	66.90	92.10	4.8116
140	0.02452	93.36	130.15	5.1767	0.01752	89.37	124.40	5.0618
160	0.02937	110.44	154.50	5.3394	0.02144	107.55	150.43	5.2358
180	0.03393	126.71	177.60	5.4755	0.02503	124.42	174.48	5.3775
200	0.03832	142.56	200.03	5.5937	0.02844	140.66	197.53	5.4989
220	0.04260	158.14	222.05	5.6987	0.03174	156.52	219.99	5.6060
240	0.04682	173.57	243.80	5.7933	0.03496	172.15	242.08	5.7021
260	0.05099	188.87	265.36	5.8796	0.03814	187.62	263.90	5.7894
280	0.05512	204.10	286.78	5.9590	0.04128	202.97	285.53	5.8696
300	0.05922	219.27	308.10	6.0325	0.04440	218.24	307.03	5.9438
350	0.06940	257.03	361.13	6.1960	0.05209	256.21	360.39	6.1083
400	0.07949	294.73	413.96	6.3371	0.05971	294.05	413.47	6.2500
450	0.08953	332.53	466.82	6.4616	0.06727	331.95	466.49	6.3750
500	0.09953	370.54	519.84	6.5733	0.07480	370.05	519.65	6.4870
600	0.11948	447.71	626.92	6.7685	0.08980	447.33	626.93	6.6825
700	0.13937	526.89	735.94	6.9365	0.10474	526.59	736.07	6.8507
800	0.15923	608.39	847.22	7.0851	0.11965	608.14	847.45	6.9994
900	0.17906	692.24	960.83	7.2189	0.13454	692.04	961.13	7.1333
1000	0.19889	778.32	1076.65	7.3409	0.14942	778.16	1077.01	7.2553
3000 kPa (123.61 K)					10000 kPa			
Sat.	0.00582	46.03	63.47	4.5032	—	—	—	—
140	0.01038	79.98	111.13	4.8706	0.00200	0.84	20.87	4.0373
160	0.01350	101.35	141.85	5.0763	0.00291	47.44	76.52	4.4088
180	0.01614	119.68	168.09	5.2310	0.00402	82.44	122.65	4.6813
200	0.01857	136.78	192.49	5.3596	0.00501	108.21	158.35	4.8697
220	0.02088	153.24	215.88	5.4711	0.00590	129.86	188.88	5.0153
240	0.02312	169.30	238.66	5.5702	0.00672	149.42	216.64	5.1362
260	0.02531	185.10	261.02	5.6597	0.00749	167.77	242.72	5.2406
280	0.02746	200.72	283.09	5.7414	0.00824	185.34	267.69	5.3331
300	0.02958	216.21	304.94	5.8168	0.00895	202.38	291.90	5.4167
350	0.03480	254.57	358.96	5.9834	0.01067	243.57	350.26	5.5967
400	0.03993	292.70	412.50	6.1264	0.01232	283.59	406.79	5.7477
500	0.05008	369.06	519.29	6.3647	0.01551	362.42	517.48	5.9948
600	0.06013	446.57	626.95	6.5609	0.01861	441.47	627.58	6.1955
700	0.07012	525.99	736.35	6.7295	0.02167	521.96	738.65	6.3667
800	0.08008	607.67	847.92	6.8785	0.02470	604.42	851.43	6.5172
900	0.09003	691.65	961.73	7.0125	0.02771	689.02	966.15	6.6523
1000	0.09996	777.85	1077.72	7.1347	0.03072	775.68	1082.84	6.7753

TABLE B.7

*Thermodynamic Properties of Methane*

TABLE B.7.1

*Saturated Methane*

Temp. (K)	P (kPa)	Specific Volume, m <sup>3</sup> /kg			Internal Energy, kJ/kg		
		$v_f$	$v_{fg}$	$v_g$	$u_f$	$u_{fg}$	$u_g$
90.7	11.7	0.002215	3.97941	3.98163	−358.10	496.59	138.49
95	19.8	0.002243	2.44845	2.45069	−343.79	488.62	144.83
100	34.4	0.002278	1.47657	1.47885	−326.90	478.96	152.06
105	56.4	0.002315	0.93780	0.94012	−309.79	468.89	159.11
110	88.2	0.002353	0.62208	0.62443	−292.50	458.41	165.91
111.7	101.3	0.002367	0.54760	0.54997	−286.74	454.85	168.10
115	132.3	0.002395	0.42800	0.43040	−275.05	447.48	172.42
120	191.6	0.002439	0.30367	0.30610	−257.45	436.02	178.57
125	269.0	0.002486	0.22108	0.22357	−239.66	423.97	184.32
130	367.6	0.002537	0.16448	0.16701	−221.65	411.25	189.60
135	490.7	0.002592	0.12458	0.12717	−203.40	397.77	194.37
140	641.6	0.002653	0.09575	0.09841	−184.86	383.42	198.56
145	823.7	0.002719	0.07445	0.07717	−165.97	368.06	202.09
150	1040.5	0.002794	0.05839	0.06118	−146.65	351.53	204.88
155	1295.6	0.002877	0.04605	0.04892	−126.82	333.61	206.79
160	1592.8	0.002974	0.03638	0.03936	−106.35	314.01	207.66
165	1935.9	0.003086	0.02868	0.03177	−85.06	292.30	207.24
170	2329.3	0.003222	0.02241	0.02563	−62.67	267.81	205.14
175	2777.6	0.003393	0.01718	0.02058	−38.75	239.47	200.72
180	3286.4	0.003623	0.01266	0.01629	−12.43	205.16	192.73
185	3863.2	0.003977	0.00846	0.01243	18.47	159.49	177.96
190	4520.5	0.004968	0.00300	0.00797	69.10	67.01	136.11
190.6	4599.2	0.006148	0	0.00615	101.46	0	101.46

TABLE B.7.1 (continued)

*Saturated Methane*

Temp. (K)	P (kPa)	Enthalpy, kJ/kg			Entropy, kJ/kg-K		
		$h_f$	$h_{fg}$	$h_g$	$s_f$	$s_{fg}$	$s_g$
90.7	11.7	−358.07	543.12	185.05	4.2264	5.9891	10.2155
95	19.8	−343.75	537.18	193.43	4.3805	5.6545	10.0350
100	34.4	−326.83	529.77	202.94	4.5538	5.2977	9.8514
105	56.4	−309.66	521.82	212.16	4.7208	4.9697	9.6905
110	88.2	−292.29	513.29	221.00	4.8817	4.6663	9.5480
111.7	101.3	−286.50	510.33	223.83	4.9336	4.5706	9.5042
115	132.3	−274.74	504.12	229.38	5.0368	4.3836	9.4205
120	191.6	−256.98	494.20	237.23	5.1867	4.1184	9.3051
125	269.0	−238.99	483.44	244.45	5.3321	3.8675	9.1996
130	367.6	−220.72	471.72	251.00	5.4734	3.6286	9.1020
135	490.7	−202.13	458.90	256.77	5.6113	3.3993	9.0106
140	641.6	−183.16	444.85	261.69	5.7464	3.1775	8.9239
145	823.7	−163.73	429.38	265.66	5.8794	2.9613	8.8406
150	1040.5	−143.74	412.29	268.54	6.0108	2.7486	8.7594
155	1295.6	−123.09	393.27	270.18	6.1415	2.5372	8.6787
160	1592.8	−101.61	371.96	270.35	6.2724	2.3248	8.5971
165	1935.9	−79.08	347.82	268.74	6.4046	2.1080	8.5126
170	2329.3	−55.17	320.02	264.85	6.5399	1.8824	8.4224
175	2777.6	−29.33	287.20	257.87	6.6811	1.6411	8.3223
180	3286.4	−0.53	246.77	246.25	6.8333	1.3710	8.2043
185	3863.2	33.83	192.16	226.00	7.0095	1.0387	8.0483
190	4520.5	91.56	80.58	172.14	7.3015	0.4241	7.7256
190.6	4599.2	129.74	0	129.74	7.4999	0	7.4999

TABLE B.7.2

*Superheated Methane*

Temp. (K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
	100 kPa (111.50K)				200 kPa (120.61 K)			
Sat.	0.55665	167.90	223.56	9.5084	0.29422	179.30	238.14	9.2918
125	0.63126	190.21	253.33	9.7606	0.30695	186.80	248.19	9.3736
150	0.76586	230.18	306.77	10.1504	0.37700	227.91	303.31	9.7759
175	0.89840	269.72	359.56	10.4759	0.44486	268.05	357.02	10.1071
200	1.02994	309.20	412.19	10.7570	0.51165	307.88	410.21	10.3912
225	1.16092	348.90	464.99	11.0058	0.57786	347.81	463.38	10.6417
250	1.29154	389.12	518.27	11.2303	0.64370	388.19	516.93	10.8674
275	1.42193	430.17	572.36	11.4365	0.70931	429.36	571.22	11.0743
300	1.55215	472.36	627.58	11.6286	0.77475	471.65	626.60	11.2670
325	1.68225	516.00	684.23	11.8100	0.84008	515.37	683.38	11.4488
350	1.81226	561.34	742.57	11.9829	0.90530	560.77	741.83	11.6220
375	1.94220	608.58	802.80	12.1491	0.97046	608.07	802.16	11.7885
400	2.07209	657.89	865.10	12.3099	1.03557	657.41	864.53	11.9495
425	2.20193	709.36	929.55	12.4661	1.10062	708.92	929.05	12.1059

TABLE B.7.2 (continued)  
Superheated Methane

Temp. (K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
400 kPa (131.42 K)					600 kPa (138.72 K)			
Sat.	0.15427	191.01	252.72	9.0754	0.10496	197.54	260.51	8.9458
150	0.18233	223.16	296.09	9.3843	0.11717	218.08	288.38	9.1390
175	0.21799	264.61	351.81	9.7280	0.14227	261.03	346.39	9.4970
200	0.25246	305.19	406.18	10.0185	0.16603	302.44	402.06	9.7944
225	0.28631	345.61	460.13	10.2726	0.18911	343.37	456.84	10.0525
250	0.31978	386.32	514.23	10.5007	0.21180	384.44	511.52	10.2830
275	0.35301	427.74	568.94	10.7092	0.23424	426.11	566.66	10.4931
300	0.38606	470.23	624.65	10.9031	0.25650	468.80	622.69	10.6882
325	0.41899	514.10	681.69	11.0857	0.27863	512.82	680.00	10.8716
350	0.45183	559.63	740.36	11.2595	0.30067	558.48	738.88	11.0461
375	0.48460	607.03	800.87	11.4265	0.32264	605.99	799.57	11.2136
400	0.51731	656.47	863.39	11.5879	0.34456	655.52	862.25	11.3754
425	0.54997	708.05	928.04	11.7446	0.36643	707.18	927.04	11.5324
450	0.58260	761.85	994.89	11.8974	0.38826	761.05	994.00	11.6855
475	0.61520	817.89	1063.97	12.0468	0.41006	817.15	1063.18	11.8351
500	0.64778	876.18	1135.29	12.1931	0.43184	875.48	1134.59	11.9816
525	0.68033	936.67	1208.81	12.3366	0.45360	936.03	1208.18	12.1252
800 kPa (144.40 K)					1000 kPa (149.13 K)			
Sat.	0.07941	201.70	265.23	8.8505	0.06367	204.45	268.12	8.7735
150	0.08434	212.53	280.00	8.9509	0.06434	206.28	270.62	8.7902
175	0.10433	257.30	340.76	9.3260	0.08149	253.38	334.87	9.1871
200	0.12278	299.62	397.85	9.6310	0.09681	296.73	393.53	9.5006
225	0.14050	341.10	453.50	9.8932	0.11132	338.79	450.11	9.7672
250	0.15781	382.53	508.78	10.1262	0.12541	380.61	506.01	10.0028
275	0.17485	424.47	564.35	10.3381	0.13922	422.82	562.04	10.2164
300	0.19172	467.36	620.73	10.5343	0.15285	465.91	618.76	10.4138
325	0.20845	511.55	678.31	10.7186	0.16635	510.26	676.61	10.5990
350	0.22510	557.33	737.41	10.8938	0.17976	556.18	735.94	10.7748
375	0.24167	604.95	798.28	11.0617	0.19309	603.91	797.00	10.9433
400	0.25818	654.57	861.12	11.2239	0.20636	653.62	859.98	11.1059
425	0.27465	706.31	926.03	11.3813	0.21959	705.44	925.03	11.2636
450	0.29109	760.24	993.11	11.5346	0.23279	759.44	992.23	11.4172
475	0.30749	816.40	1062.40	11.6845	0.24595	815.66	1061.61	11.5672
500	0.32387	874.79	1133.89	11.8311	0.25909	874.10	1133.19	11.7141
525	0.34023	935.38	1207.56	11.9749	0.27221	934.73	1206.95	11.8580
550	0.35657	998.14	1283.45	12.1161	0.28531	997.53	1282.84	11.9992

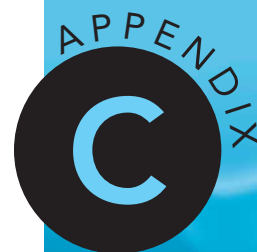
TABLE B.7.2 (continued)  
Superheated Methane

Temp. (K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)	$s$ (kJ/kg-K)
	1500 kPa (158.52 K)				2000 kPa (165.86 K)			
Sat.	0.04196	207.53	270.47	8.6215	0.03062	207.01	268.25	8.4975
175	0.05078	242.64	318.81	8.9121	0.03504	229.90	299.97	8.6839
200	0.06209	289.13	382.26	9.2514	0.04463	280.91	370.17	9.0596
225	0.07239	332.85	441.44	9.5303	0.05289	326.64	432.43	9.3532
250	0.08220	375.70	499.00	9.7730	0.06059	370.67	491.84	9.6036
275	0.09171	418.65	556.21	9.9911	0.06796	414.40	550.31	9.8266
300	0.10103	462.27	613.82	10.1916	0.07513	458.59	608.85	10.0303
325	0.11022	507.04	672.37	10.3790	0.08216	503.80	668.12	10.2200
350	0.11931	553.30	732.26	10.5565	0.08909	550.40	728.58	10.3992
375	0.12832	601.30	793.78	10.7263	0.09594	598.69	790.57	10.5703
400	0.13728	651.24	857.16	10.8899	0.10274	648.87	854.34	10.7349
425	0.14619	703.26	922.54	11.0484	0.10949	701.08	920.06	10.8942
450	0.15506	757.43	990.02	11.2027	0.11620	755.43	987.84	11.0491
475	0.16391	813.80	1059.66	11.3532	0.12289	811.94	1057.72	11.2003
500	0.17273	872.37	1131.46	11.5005	0.12955	870.64	1129.74	11.3480
525	0.18152	933.12	1205.41	11.6448	0.13619	931.51	1203.88	11.4927
550	0.19031	996.02	1281.48	11.7864	0.14281	994.51	1280.13	11.6346
	4000 kPa (186.10 K)				8000 kPa			
Sat.	0.01160	172.96	219.34	8.0035	—	—	—	—
200	0.01763	237.70	308.23	8.4675	0.00412	55.58	88.54	7.2069
225	0.02347	298.52	392.39	8.8653	0.00846	217.30	284.98	8.1344
250	0.02814	349.08	461.63	9.1574	0.01198	298.05	393.92	8.5954
275	0.03235	396.67	526.07	9.4031	0.01469	357.88	475.39	8.9064
300	0.03631	443.48	588.73	9.6212	0.01705	411.71	548.15	9.1598
325	0.04011	490.62	651.07	9.8208	0.01924	463.52	617.40	9.3815
350	0.04381	538.70	713.93	10.0071	0.02130	515.02	685.39	9.5831
375	0.04742	588.18	777.86	10.1835	0.02328	567.12	753.34	9.7706
400	0.05097	639.34	843.24	10.3523	0.02520	620.38	821.95	9.9477
425	0.05448	692.38	910.31	10.5149	0.02707	675.14	891.71	10.1169
450	0.05795	747.43	979.23	10.6725	0.02891	731.63	962.92	10.2796
475	0.06139	804.55	1050.12	10.8258	0.03072	789.99	1035.75	10.4372
500	0.06481	863.78	1123.01	10.9753	0.03251	850.28	1110.34	10.5902
525	0.06820	925.11	1197.93	11.1215	0.03428	912.54	1186.74	10.7393
550	0.07158	988.53	1274.86	11.2646	0.03603	976.77	1264.99	10.8849
575	0.07495	1053.98	1353.77	11.4049	0.03776	1042.96	1345.07	11.0272





# Ideal Gas Specific Heat



Three types of energy storage or possession were identified in Section 1.8, of which two, translation and intramolecular energy, are associated with the individual molecules. These comprise the ideal gas model, with the third type, the system intermolecular potential energy, then accounting for the behavior of real (nonideal gas) substances. This appendix deals with the ideal gas contributions. Since these contribute to the energy, and therefore also the enthalpy, they also contribute to the specific heat of each gas. The different possibilities can be grouped according to the intramolecular energy contributions as follows:

## C.1 MONATOMIC GASES (INERT GASES AR, HE, NE, XE, KR; ALSO N, O, H, CL, F, ...)

$$h = h_{\text{translation}} + h_{\text{electronic}} = h_t + h_e$$

$$\frac{dh}{dT} = \frac{dh_t}{dT} + \frac{dh_e}{dT}, \quad C_{P0} = C_{P0t} + C_{P0e} = \frac{5}{2}R + f_e(T)$$

where the electronic contribution,  $f_e(T)$ , is usually small, except at very high  $T$  (common exceptions are O, Cl, F).

## C.2 DIATOMIC AND LINEAR POLYATOMIC GASES (N<sub>2</sub>, O<sub>2</sub>, CO, OH, ..., CO<sub>2</sub>, N<sub>2</sub>O, ...)

In addition to translational and electronic contributions to specific heat, these also have molecular rotation (about the center of mass of the molecule) and also  $(3a - 5)$  independent modes of molecular vibration of the  $a$  atoms in the molecule relative to one another, such that

$$C_{P0} = C_{P0t} + C_{P0r} + C_{P0v} + C_{P0e} = \frac{5}{2}R + R + f_v(T) + f_e(T)$$

where the vibrational contribution is

$$f_v(T) = R \sum_{i=1}^{3a-5} [x_i^2 e^{x_i} / (e^{x_i} - 1)^2], \quad x_i = \frac{\theta_i}{T}$$

and the electronic contribution,  $f_e(T)$ , is usually small, except at very high  $T$  (common exceptions are O<sub>2</sub>, NO, OH).

### Example C.1

$\text{N}_2$ ,  $3a - 5 = 1$  vibrational mode, with  $\theta_i = 3392$  K.

At  $T = 300$  K,  $C_{P0} = 0.742 + 0.2968 + 0.0005 + \approx 0 = 1.0393$  kJ/kg K.

At  $T = 1000$  K,  $C_{P0} = 0.742 + 0.2968 + 0.123 + \approx 0 = 1.1618$  kJ/kg K.

(an increase of 11.8% from 300 K).

### Example C.2

$\text{CO}_2$ ,  $3a - 5 = 4$  vibrational modes, with  $\theta_i = 960$  K, 960 K, 1993 K, 3380 K

At  $T = 300$  K,  $C_{P0} = 0.4723 + 0.1889 + 0.1826 + \approx 0 = 0.8438$  kJ/kg K.

At  $T = 1000$  K,  $C_{P0} = 0.4723 + 0.1889 + 0.5659 + \approx 0 = 1.2271$  kJ/kg K.

(an increase of 45.4% from 300 K).

## C.3

### NONLINEAR POLYATOMIC MOLECULES ( $\text{H}_2\text{O}$ , $\text{NH}_3$ , $\text{CH}_4$ , $\text{C}_2\text{H}_6$ , ...)

Contributions to specific heat are similar to those for linear molecules, except that the rotational contribution is larger and there are  $(3a - 6)$  independent vibrational modes, such that

$$C_{P0} = C_{P0t} + C_{P0r} + C_{P0v} + C_{P0e} = \frac{5}{2} R + \frac{3}{2} R + f_v(T) + f_e(T)$$

where the vibrational contribution is

$$f_v(T) = R \sum_{i=1}^{3a-6} [x_i^2 e^{x_i} / (e^{x_i} - 1)^2], \quad x_i = \frac{\theta_i}{T}$$

and  $f_e(T)$  is usually small, except at very high temperatures.

### Example C.3

$\text{CH}_4$ ,  $3a - 6 = 9$  vibrational modes, with  $\theta_i = 4196$  K, 2207 K (two modes), 1879 K (three), 4343 K (three)

At  $T = 300$  K,  $C_{P0} = 1.2958 + 0.7774 + 0.1527 + \approx 0 = 2.2259$  kJ/kg K.

At  $T = 1000$  K,  $C_{P0} = 1.2958 + 0.7774 + 2.4022 + \approx 0 = 4.4754$  kJ/kg K.

(an increase of 101.1% from 300 K).



# Equations of State

## APPENDIX D

Some of the most used pressure-explicit equations of state can be shown in a form with two parameters. This form is known as a cubic equation of state and contains as a special case the ideal-gas law:

$$P = \frac{RT}{v - b} - \frac{a}{v^2 + cbv + db^2}$$

where  $(a, b)$  are parameters and  $(c, d)$  define the model as shown in the following table with the acentric factor  $(\omega)$  and

$$b = b_0 RT_c / P_c \quad \text{and} \quad a = a_0 R^2 T_c^2 / P_c$$

The acentric factor is defined by the saturation pressure at a reduced temperature  $T_r = 0.7$

$$\omega = -\frac{\ln P_r^{\text{sat}} \text{ at } T_r = 0.7}{\ln 10} - 1$$

TABLE D.1  
Equations of State

Model	$c$	$d$	$b_0$	$a_0$
Ideal gas	0	0	0	0
van der Waals	0	0	1/8	27/64
Redlich–Kwong	1	0	0.08664	$0.42748 T_r^{-1/2}$
Soave	1	0	0.08664	$0.42748[1 + f(1 - T_r^{1/2})]^2$
Peng–Robinson	2	−1	0.0778	$0.45724[1 + f(1 - T_r^{1/2})]^2$

$$f = 0.48 + 1.574\omega - 0.176\omega^2$$

for Soave

$$f = 0.37464 + 1.54226\omega - 0.26992\omega^2$$

for Peng–Robinson

TABLE D.2

*The Lee–Kesler Equation of State*

The Lee–Kesler generalized equation of state is

$$Z = \frac{P_r v_r'}{T_r} = 1 + \frac{B}{v_r'} + \frac{C}{v_r'^2} + \frac{D}{v_r'^5} + \frac{c_4}{T_r^3 v_r'^2} \left( \beta + \frac{\gamma}{v_r'^2} \right) \exp \left( -\frac{\gamma}{v_r'^2} \right)$$

$$B = b_1 - \frac{b_2}{T_r} - \frac{b_3}{T_r^2} - \frac{b_4}{T_r^3}$$

$$C = c_1 - \frac{c_2}{T_r} + \frac{c_3}{T_r^3}$$

$$D = d_1 + \frac{d_2}{T_r}$$

in which

$$T_r = \frac{T}{T_c}, \quad P_r = \frac{P}{P_c}, \quad v_r' = \frac{v}{RT_c/P_c}$$

The set of constants is as follows:

Constant	Simple Fluids	Constant	Simple Fluids
$b_1$	0.118 119 3	$c_3$	0.0
$b_2$	0.265 728	$c_4$	0.042 724
$b_3$	0.154 790	$d_1 \times 10^4$	0.155 488
$b_4$	0.030 323	$d_2 \times 10^4$	0.623 689
$c_1$	0.023 674 4	$\beta$	0.653 92
$c_2$	0.018 698 4	$\gamma$	0.060 167

TABLE D.3

*Saturated Liquid–Vapor Compressibilities, Lee–Kesler Simple Fluid*

$T_r$	0.40	0.50	0.60	0.70	0.80	0.85	0.90	0.95	1
$P_r$ sat	2.7E-4	4.6E-3	0.028	0.099	0.252	0.373	0.532	0.737	1
$Z_f$	6.5E-5	9.5E-4	0.0052	0.017	0.042	0.062	0.090	0.132	0.29
$Z_g$	0.999	0.988	0.957	0.897	0.807	0.747	0.673	0.569	0.29

TABLE D.4

*Acentric Factor for Some Substances*

Substance			$\omega$	Substance			$\omega$
Ammonia	NH <sub>3</sub>		0.25	Water	H <sub>2</sub> O		0.344
Argon	Ar		0.001	<i>n</i> -Butane	C <sub>4</sub> H <sub>10</sub>		0.199
Bromine	Br <sub>2</sub>		0.108	Ethane	C <sub>2</sub> H <sub>6</sub>		0.099
Helium	He		−0.365	Methane	CH <sub>4</sub>		0.011
Neon	Ne		−0.029	R-32	CF <sub>2</sub> H <sub>2</sub>		0.277
Nitrogen	N <sub>2</sub>		0.039	R-125	CHF <sub>2</sub> CF <sub>3</sub>		0.305

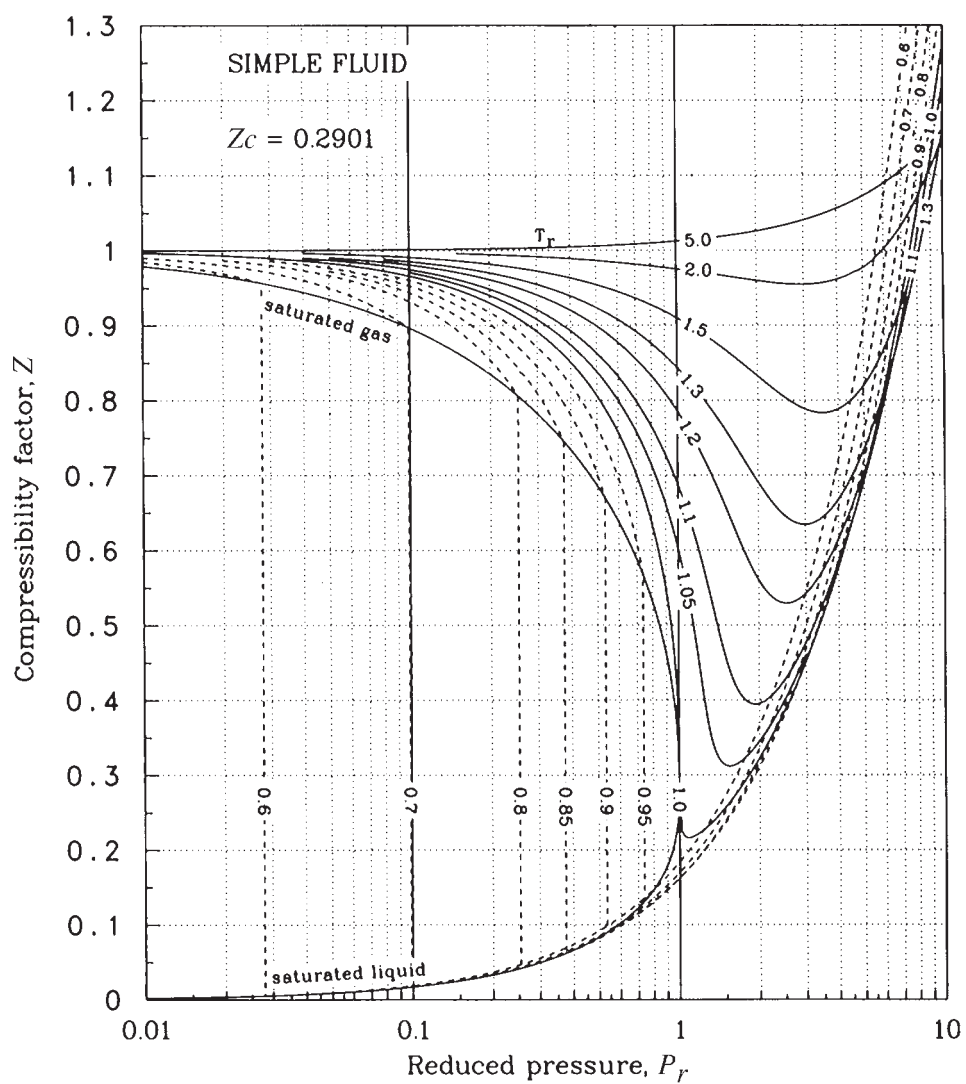


FIGURE D.1 Lee-Kesler simple fluid compressibility factor.

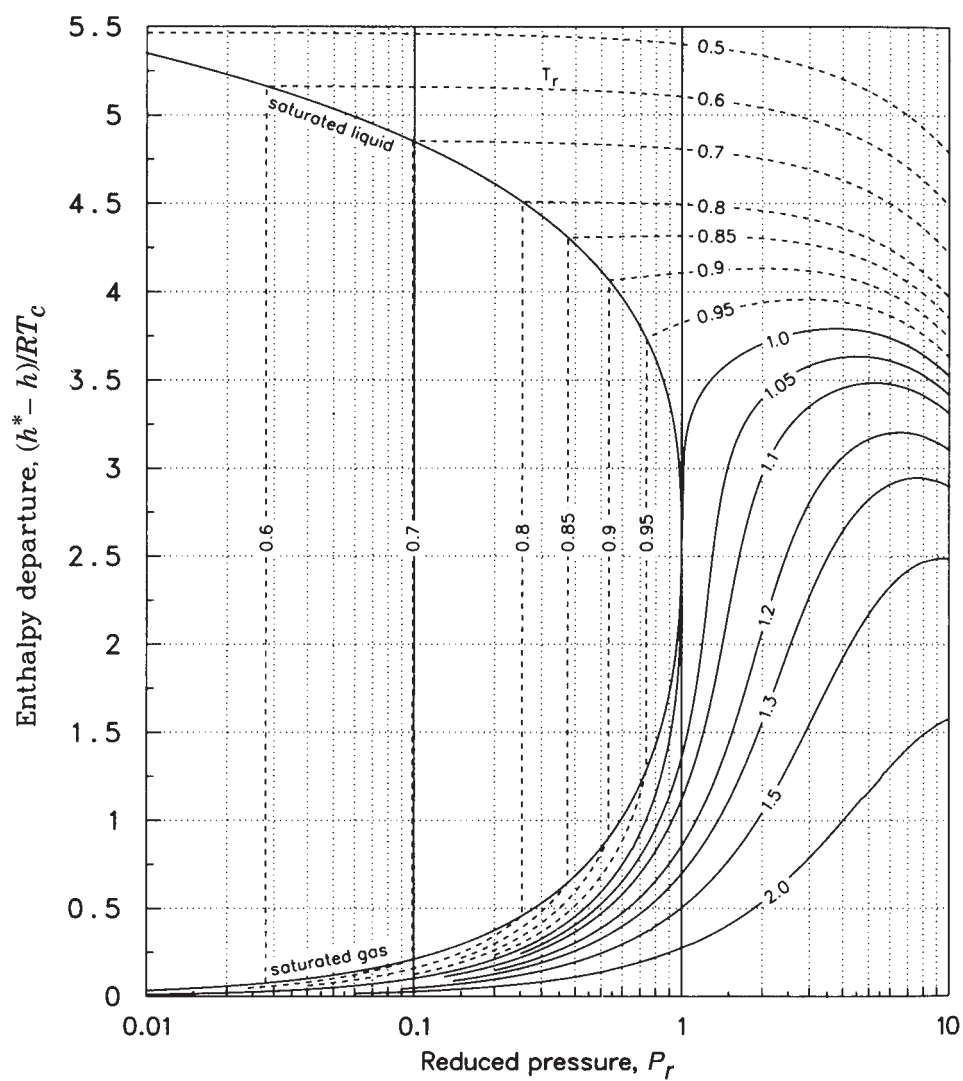
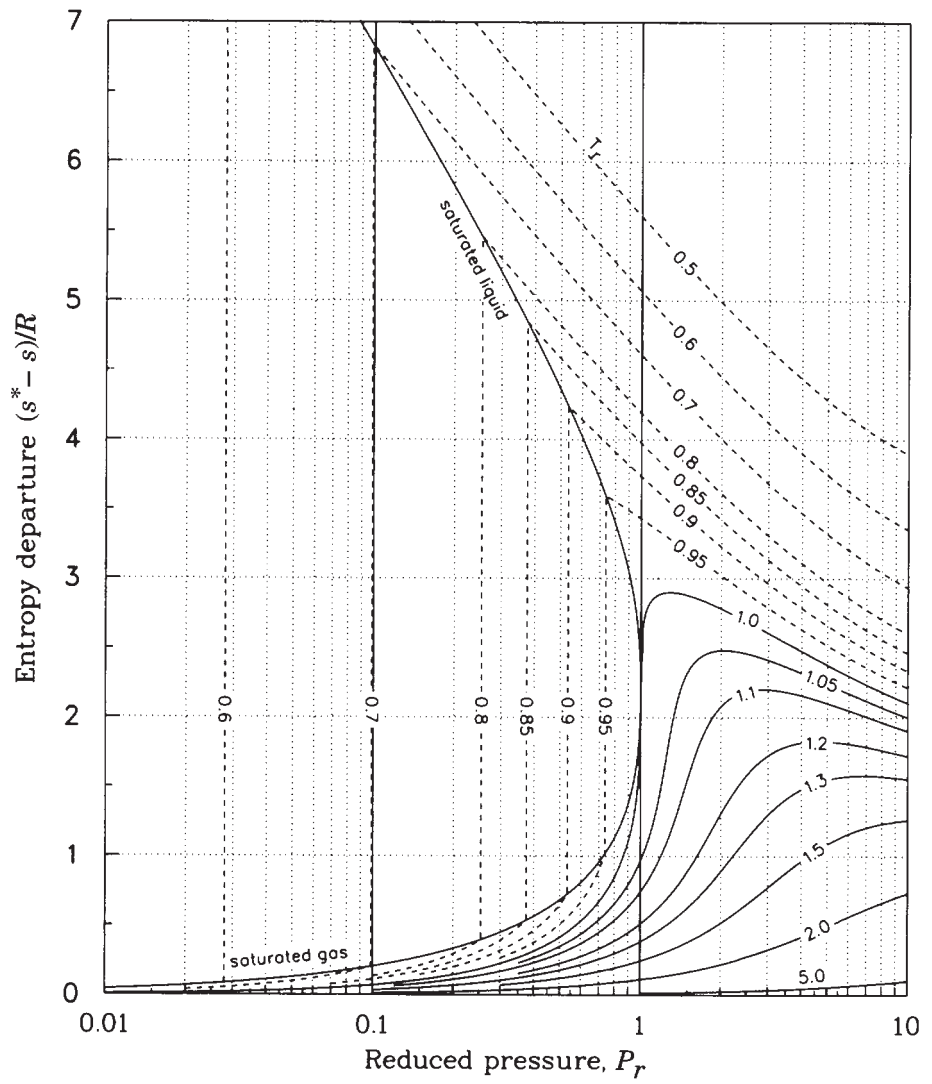


FIGURE D.2 Lee-Kesler simple fluid enthalpy departure.



**FIGURE D.3** Lee-Kesler simple fluid entropy departure.

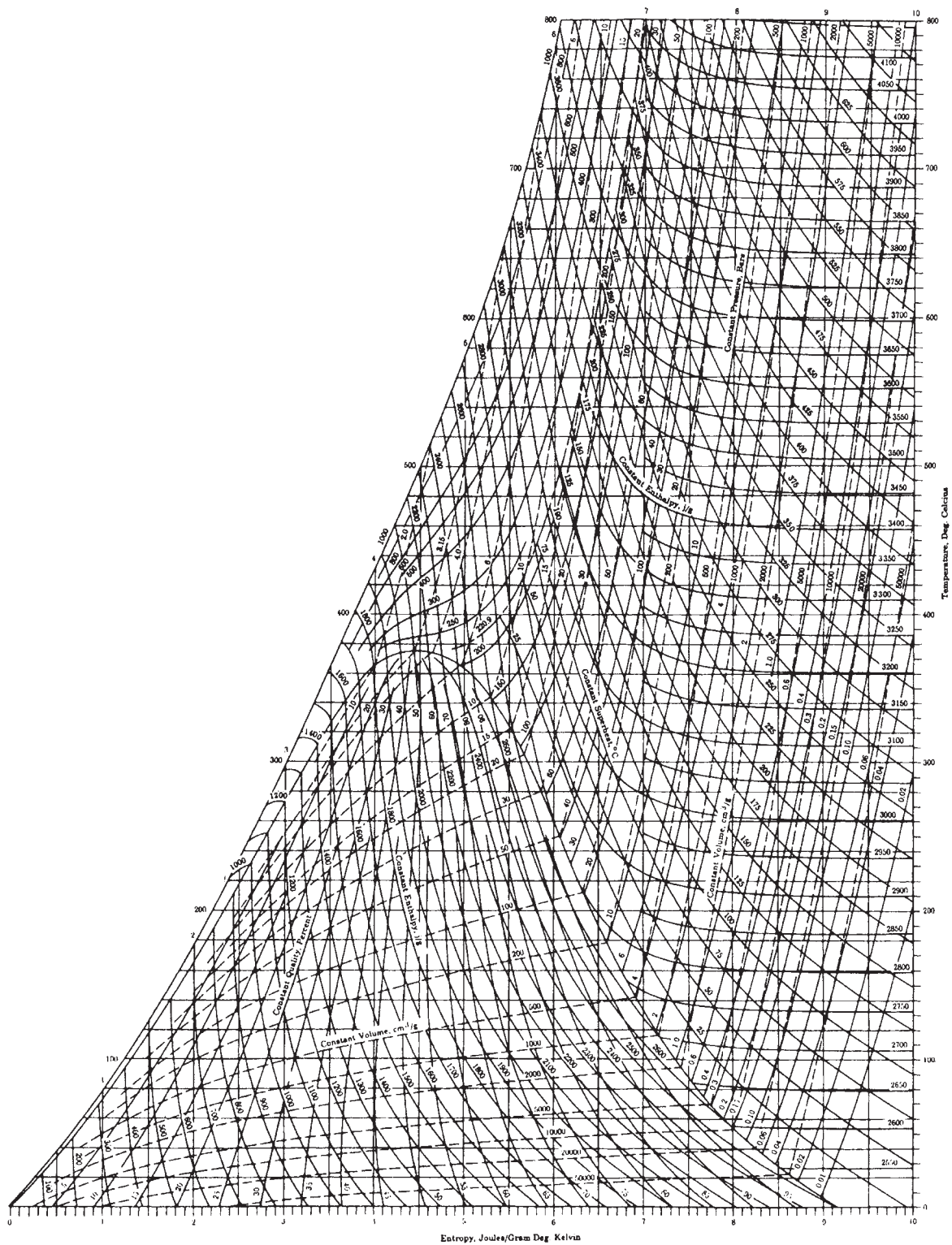
APPENDIX

E

# Figures







**FIGURE E.1** Temperature–entropy diagram for water.

Keenan, Keyes, Hill, & Moore. STEAM TABLES (International Edition–Metric Units). Copyright © 1969, John Wiley & Sons, Inc.

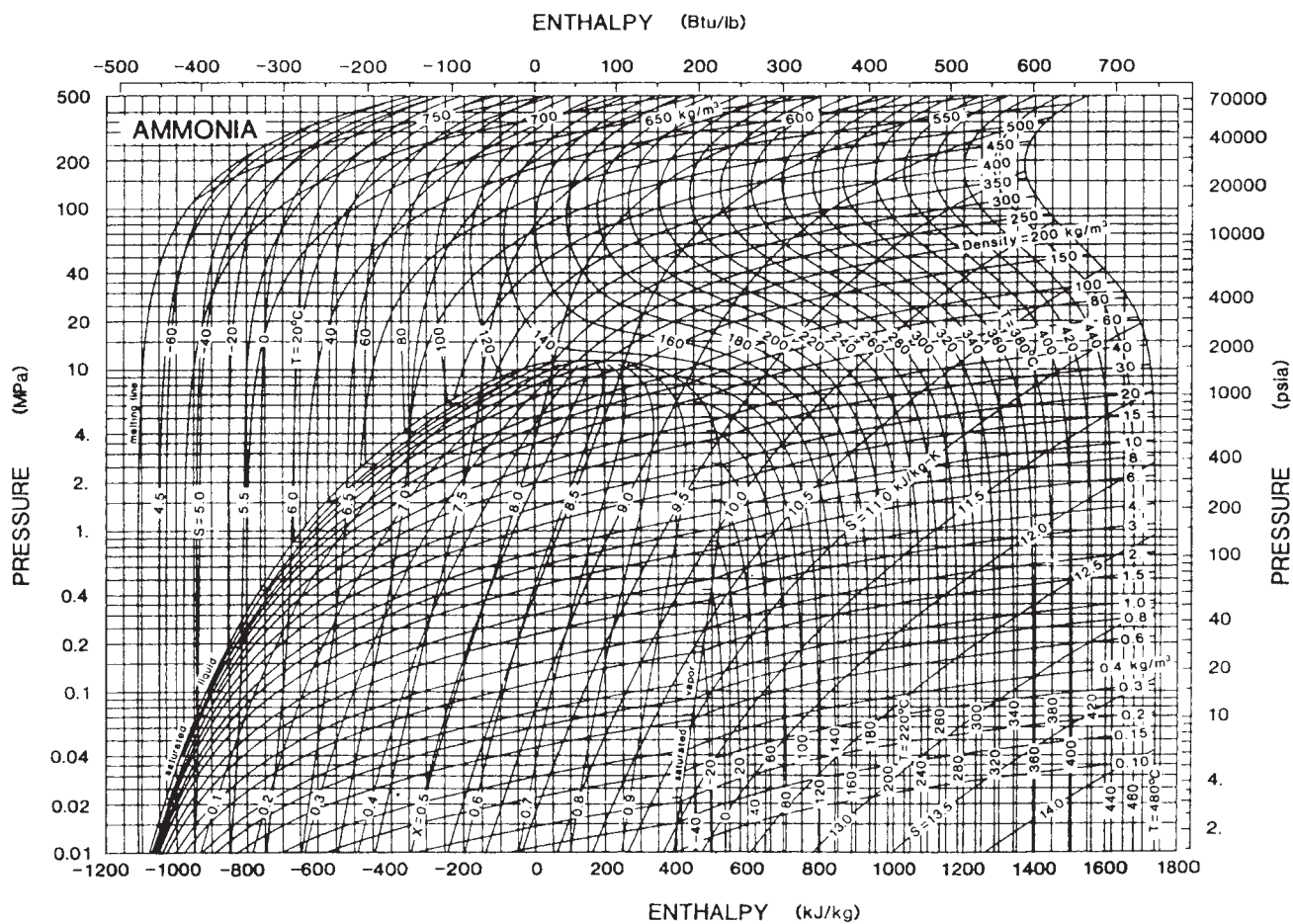
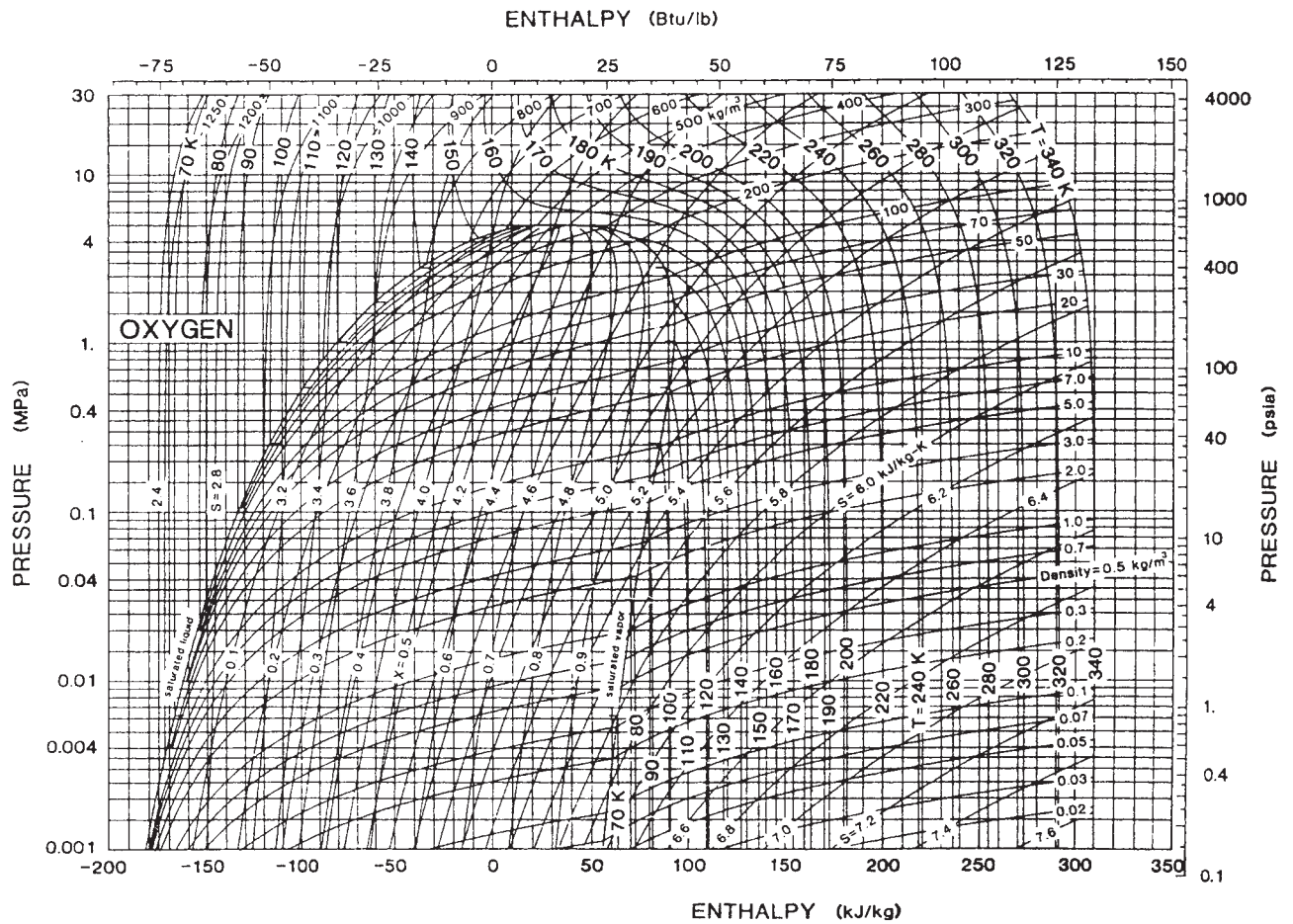


FIGURE E.2 Pressure–enthalpy diagram for ammonia.



**FIGURE E.3** Pressure-enthalpy diagram for oxygen.

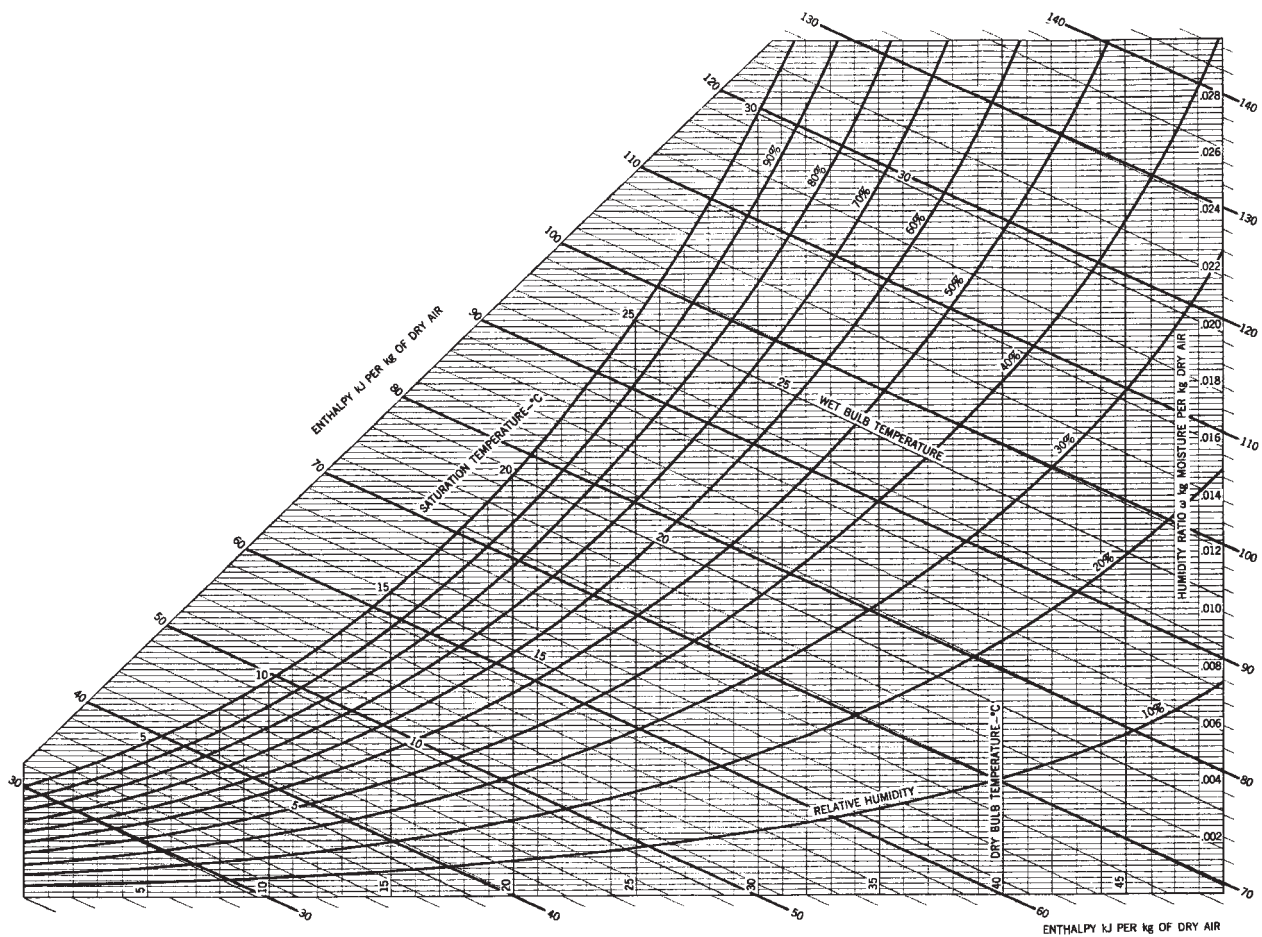


FIGURE E.4 Psychrometric chart.



# English Unit Tables





TABLE F.1

*Critical Constants (English Units)*

Substance	Formula	Molec. Mass	Temp. (R)	Pressure (lbf/in. <sup>2</sup> )	Volume (ft <sup>3</sup> /lbm)
Ammonia	NH <sub>3</sub>	17.031	729.9	1646	0.0682
Argon	Ar	39.948	271.4	706	0.0300
Bromine	Br <sub>2</sub>	159.808	1058.4	1494	0.0127
Carbon dioxide	CO <sub>2</sub>	44.010	547.4	1070	0.0342
Carbon monoxide	CO	28.010	239.2	508	0.0533
Chlorine	Cl <sub>2</sub>	70.906	750.4	1157	0.0280
Fluorine	F <sub>2</sub>	37.997	259.7	757	0.0279
Helium	He	4.003	9.34	32.9	0.2300
Hydrogen (normal)	H <sub>2</sub>	2.016	59.76	188.6	0.5170
Krypton	Kr	83.800	376.9	798	0.0174
Neon	Ne	20.183	79.92	400	0.0330
Nitric oxide	NO	30.006	324.0	940	0.0308
Nitrogen	N <sub>2</sub>	28.013	227.2	492	0.0514
Nitrogen dioxide	NO <sub>2</sub>	46.006	775.8	1465	0.0584
Nitrous oxide	N <sub>2</sub> O	44.013	557.3	1050	0.0354
Oxygen	O <sub>2</sub>	31.999	278.3	731	0.0367
Sulfur dioxide	SO <sub>2</sub>	64.063	775.4	1143	0.0306
Water	H <sub>2</sub> O	18.015	1165.1	3208	0.0508
Xenon	Xe	131.300	521.5	847	0.0144
Acetylene	C <sub>2</sub> H <sub>2</sub>	26.038	554.9	891	0.0693
Benzene	C <sub>6</sub> H <sub>6</sub>	78.114	1012.0	709	0.0531
<i>n</i> -Butane	C <sub>4</sub> H <sub>10</sub>	58.124	765.4	551	0.0703
Chlorodifluoroethane (142b)	CH <sub>3</sub> CClF <sub>2</sub>	100.495	738.5	616	0.0368
Chlorodifluoromethane (22)	CHClF <sub>2</sub>	86.469	664.7	721	0.0307
Dichlorodifluoroethane (141)	CH <sub>3</sub> CCl <sub>2</sub> F	116.950	866.7	658	0.0345
Dichlorotrifluoroethane (123)	CHCl <sub>2</sub> CF <sub>3</sub>	152.930	822.4	532	0.0291
Difluoroethane (152a)	CHF <sub>2</sub> CH <sub>3</sub>	66.050	695.5	656	0.0435
Difluoromethane (32)	CH <sub>2</sub> F <sub>2</sub>	52.024	632.3	838	0.0378
Ethane	C <sub>2</sub> H <sub>6</sub>	30.070	549.7	708	0.0790
Ethyl alcohol	C <sub>2</sub> H <sub>5</sub> OH	46.069	925.0	891	0.0581
Ethylene	C <sub>2</sub> H <sub>4</sub>	28.054	508.3	731	0.0744
<i>n</i> -Heptane	C <sub>7</sub> H <sub>16</sub>	100.205	972.5	397	0.0691
<i>n</i> -Hexane	C <sub>6</sub> H <sub>14</sub>	86.178	913.5	437	0.0688
Methane	CH <sub>4</sub>	16.043	342.7	667	0.0990
Methyl alcohol	CH <sub>3</sub> OH	32.042	922.7	1173	0.0590
<i>n</i> -Octane	C <sub>8</sub> H <sub>18</sub>	114.232	1023.8	361	0.0690
Pentafluoroethane (125)	CHF <sub>2</sub> CF <sub>3</sub>	120.022	610.6	525	0.0282
<i>n</i> -Pentane	C <sub>5</sub> H <sub>12</sub>	72.151	845.5	489	0.0675
Propane	C <sub>3</sub> H <sub>8</sub>	44.094	665.6	616	0.0964
Propene	C <sub>3</sub> H <sub>6</sub>	42.081	656.8	667	0.0689
Refrigerant mixture	R-410a	72.585	620.1	711	0.0349
Tetrafluoroethane (134a)	CF <sub>3</sub> CH <sub>2</sub> F	102.030	673.6	589	0.0311

TABLE F.2

*Properties of Selected Solids at 77 F*

Substance	$\rho$ (lbm/ft <sup>3</sup> )	$C_p$ (Btu/lbm R)
Asphalt	132.3	0.225
Brick, common	112.4	0.20
Carbon, diamond	202.9	0.122
Carbon, graphite	125–156	0.146
Coal	75–95	0.305
Concrete	137	0.21
Glass, plate	156	0.191
Glass, wool	1.25	0.158
Granite	172	0.212
Ice (32°F)	57.2	0.487
Paper	43.7	0.287
Plexiglas	73.7	0.344
Polystyrene	57.4	0.549
Polyvinyl chloride	86.1	0.229
Rubber, soft	68.7	0.399
Sand, dry	93.6	0.191
Salt, rock	130–156	0.2196
Silicon	145.5	0.167
Snow, firm	35	0.501
Wood, hard (oak)	44.9	0.301
Wood, soft (pine)	31.8	0.33
Wool	6.24	0.411
<b>Metals</b>		
Aluminum, duralumin	170	0.215
Brass, 60–40	524	0.0898
Copper, commercial	518	0.100
Gold	1205	0.03082
Iron, cast	454	0.100
Iron, 304 St Steel	488	0.110
Lead	708	0.031
Magnesium, 2% Mn	111	0.239
Nickel, 10% Cr	541	0.1066
Silver, 99.9% Ag	657	0.0564
Sodium	60.6	0.288
Tin	456	0.0525
Tungsten	1205	0.032
Zinc	446	0.0927

TABLE F.3

*Properties of Some Liquids at 77 F*

Substance	$\rho$ (lbm/ft <sup>3</sup> )	$C_p$ (Btu/lbm R)
Ammonia	37.7	1.151
Benzene	54.9	0.41
Butane	34.7	0.60
CCl <sub>4</sub>	98.9	0.20
CO <sub>2</sub>	42.5	0.69
Ethanol	48.9	0.59
Gasoline	46.8	0.50
Glycerine	78.7	0.58
Kerosene	50.9	0.48
Methanol	49.1	0.61
<i>n</i> -octane	43.2	0.53
Oil, engine	55.2	0.46
Oil, light	57	0.43
Propane	31.8	0.61
R-12	81.8	0.232
R-22	74.3	0.30
R-32	60	0.463
R-125	74.4	0.337
R-134a	75.3	0.34
R-410a	66.1	0.40
Water	62.2	1.00
<b>Liquid Metals</b>		
Bismuth, Bi	627	0.033
Lead, Pb	665	0.038
Mercury, Hg	848	0.033
NaK (56/44)	55.4	0.27
Potassium, K	51.7	0.193
Sodium, Na	58	0.33
Tin, Sn	434	0.057
Zinc, Zn	410	0.12

TABLE F.4

*Properties of Various Ideal Gases at 77 F, 1 atm\* (English Units)*

Gas	Chemical Formula	Mol. Mass (lbm/lbmol)	$R$ (ft-lbf/lbm R)	$\rho \times 10^3$ (lbm/ft <sup>3</sup> )	$C_{p0}$ (Btu/lbm R)	$C_{v0}$	$k$ $C_{p0}/C_{v0}$
Steam	H <sub>2</sub> O	18.015	85.76	1.442	0.447	0.337	1.327
Acetylene	C <sub>2</sub> H <sub>2</sub>	26.038	59.34	65.55	0.406	0.330	1.231
Air	—	28.97	53.34	72.98	0.240	0.171	1.400
Ammonia	NH <sub>3</sub>	17.031	90.72	43.325	0.509	0.392	1.297
Argon	Ar	39.948	38.68	100.7	0.124	0.0745	1.667
Butane	C <sub>4</sub> H <sub>10</sub>	58.124	26.58	150.3	0.410	0.376	1.091
Carbon dioxide	CO <sub>2</sub>	44.01	35.10	110.8	0.201	0.156	1.289
Carbon monoxide	CO	28.01	55.16	70.5	0.249	0.178	1.399
Ethane	C <sub>2</sub> H <sub>6</sub>	30.07	51.38	76.29	0.422	0.356	1.186
Ethanol	C <sub>2</sub> H <sub>5</sub> OH	46.069	33.54	117.6	0.341	0.298	1.145
Ethylene	C <sub>2</sub> H <sub>4</sub>	28.054	55.07	71.04	0.370	0.299	1.237
Helium	He	4.003	386.0	10.08	1.240	0.744	1.667
Hydrogen	H <sub>2</sub>	2.016	766.5	5.075	3.394	2.409	1.409
Methane	CH <sub>4</sub>	16.043	96.35	40.52	0.538	0.415	1.299
Methanol	CH <sub>3</sub> OH	32.042	48.22	81.78	0.336	0.274	1.227
Neon	Ne	20.183	76.55	50.81	0.246	0.148	1.667
Nitric oxide	NO	30.006	51.50	75.54	0.237	0.171	1.387
Nitrogen	N <sub>2</sub>	28.013	55.15	70.61	0.249	0.178	1.400
Nitrous oxide	N <sub>2</sub> O	44.013	35.10	110.8	0.210	0.165	1.274
<i>n</i> -octane	C <sub>8</sub> H <sub>18</sub>	114.23	13.53	5.74	0.409	0.391	1.044
Oxygen	O <sub>2</sub>	31.999	48.28	80.66	0.220	0.158	1.393
Propane	C <sub>3</sub> H <sub>8</sub>	44.094	35.04	112.9	0.401	0.356	1.126
R-12	CCl <sub>2</sub> F <sub>2</sub>	120.914	12.78	310.9	0.147	0.131	1.126
R-22	CHClF <sub>2</sub>	86.469	17.87	221.0	0.157	0.134	1.171
R-32	CF <sub>2</sub> H <sub>2</sub>	52.024	29.70	132.6	0.196	0.158	1.242
R-125	CHF <sub>2</sub> CF <sub>3</sub>	120.022	12.87	307.0	0.189	0.172	1.097
R-134a	CF <sub>3</sub> CH <sub>2</sub> F	102.03	15.15	262.2	0.203	0.184	1.106
R-410a	—	72.585	21.29	185.2	0.193	0.166	1.165
Sulfur dioxide	SO <sub>2</sub>	64.059	24.12	163.4	0.149	0.118	1.263
Sulfur trioxide	SO <sub>3</sub>	80.053	19.30	204.3	0.152	0.127	1.196

\*Or saturation pressure if it is less than 1 atm.



TABLE F.5

*Ideal Gas Properties of Air (English Units), Standard Entropy at 1 atm = 101.325 kPa = 14.696 lbf/in.<sup>2</sup>*

<i>T</i> (R)	<i>u</i> (Btu/lbm)	<i>h</i> (Btu/lbm)	<i>s</i> <sub><i>T</i></sub> <sup>0</sup> (Btu/lbm R)	<i>T</i> (R)	<i>u</i> (Btu/lbm)	<i>h</i> (Btu/lbm)	<i>s</i> <sub><i>T</i></sub> <sup>0</sup> (Btu/lbm R)
400	68.212	95.634	1.56788	1950	357.243	490.928	1.96404
440	75.047	105.212	1.59071	2000	367.642	504.755	1.97104
480	81.887	114.794	1.61155	2050	378.096	518.636	1.97790
520	88.733	124.383	1.63074	2100	388.602	532.570	1.98461
536.67	91.589	128.381	1.63831	2150	399.158	546.554	1.99119
540	92.160	129.180	1.63979	2200	409.764	560.588	1.99765
560	95.589	133.980	1.64852	2300	431.114	588.793	2.01018
600	102.457	143.590	1.66510	2400	452.640	617.175	2.02226
640	109.340	153.216	1.68063	2500	474.330	645.721	2.03391
680	116.242	162.860	1.69524	2600	496.175	674.421	2.04517
720	123.167	172.528	1.70906	2700	518.165	703.267	2.05606
760	130.118	182.221	1.72216	2800	540.286	732.244	2.06659
800	137.099	191.944	1.73463	2900	562.532	761.345	2.07681
840	144.114	201.701	1.74653	3000	584.895	790.564	2.08671
880	151.165	211.494	1.75791	3100	607.369	819.894	2.09633
920	158.255	221.327	1.76884	3200	629.948	849.328	2.10567
960	165.388	231.202	1.77935	3300	652.625	878.861	2.11476
1000	172.564	241.121	1.78947	3400	675.396	908.488	2.12361
1040	179.787	251.086	1.79924	3500	698.257	938.204	2.13222
1080	187.058	261.099	1.80868	3600	721.203	968.005	2.14062
1120	194.378	271.161	1.81783	3700	744.230	997.888	2.14880
1160	201.748	281.273	1.82670	3800	767.334	1027.848	2.15679
1200	209.168	291.436	1.83532	3900	790.513	1057.882	2.16459
1240	216.640	301.650	1.84369	4000	813.763	1087.988	2.17221
1280	224.163	311.915	1.85184	4100	837.081	1118.162	2.17967
1320	231.737	322.231	1.85977	4200	860.466	1148.402	2.18695
1360	239.362	332.598	1.86751	4300	883.913	1178.705	2.19408
1400	247.037	343.016	1.87506	4400	907.422	1209.069	2.20106
1440	254.762	353.483	1.88243	4500	930.989	1239.492	2.20790
1480	262.537	364.000	1.88964	4600	954.613	1269.972	2.21460
1520	270.359	374.565	1.89668	4700	978.292	1300.506	2.22117
1560	278.230	385.177	1.90357	4800	1002.023	1331.093	2.22761
1600	286.146	395.837	1.91032	4900	1025.806	1361.732	2.23392
1650	296.106	409.224	1.91856	5000	1049.638	1392.419	2.24012
1700	306.136	422.681	1.92659	5100	1073.518	1423.155	2.24621
1750	316.232	436.205	1.93444	5200	1097.444	1453.936	2.25219
1800	326.393	449.794	1.94209	5300	1121.414	1484.762	2.25806
1850	336.616	463.445	1.94957	5400	1145.428	1515.632	2.26383
1900	346.901	477.158	1.95689				

TABLE F.6

*Ideal Gas Properties of Various Substances (English Units), Entropies at 1 atm Pressure*

<i>T</i> R	Nitrogen, Diatomic (N <sub>2</sub> ) $\bar{h}_{f,537}^0 = 0$ Btu/lbmol $M = 28.013$ lbm/lbmol		Nitrogen, Monatomic (N) $\bar{h}_{f,537}^0 = 203\,216$ Btu/lbmol $M = 14.007$ lbm/lbmol	
	$\bar{h} - \bar{h}_{537}^0$	$\bar{s}_T^0$	$\bar{h} - \bar{h}_{537}^0$	$\bar{s}_T^0$
	Btu/lbmol	Btu/lbmol R	Btu/lbmol	Btu/lbmol R
0	−3727	0	−2664	0
200	−2341	38.877	−1671	31.689
400	−950	43.695	−679	35.130
537	0	45.739	0	36.589
600	441	46.515	314	37.143
800	1837	48.524	1307	38.571
1000	3251	50.100	2300	39.679
1200	4693	51.414	3293	40.584
1400	6169	52.552	4286	41.349
1600	7681	53.561	5279	42.012
1800	9227	54.472	6272	42.597
2000	10804	55.302	7265	43.120
2200	12407	56.066	8258	43.593
2400	14034	56.774	9251	44.025
2600	15681	57.433	10244	44.423
2800	17345	58.049	11237	44.791
3000	19025	58.629	12230	45.133
3200	20717	59.175	13223	45.454
3400	22421	59.691	14216	45.755
3600	24135	60.181	15209	46.038
3800	25857	60.647	16202	46.307
4000	27587	61.090	17195	46.562
4200	29324	61.514	18189	46.804
4400	31068	61.920	19183	47.035
4600	32817	62.308	20178	47.256
4800	34571	62.682	21174	47.468
5000	36330	63.041	22171	47.672
5500	40745	63.882	24670	48.148
6000	45182	64.654	27186	48.586
6500	49638	65.368	29724	48.992
7000	54109	66.030	32294	49.373
7500	58595	66.649	34903	49.733
8000	63093	67.230	37559	50.076
8500	67603	67.777	40270	50.405
9000	72125	68.294	43040	50.721
9500	96658	68.784	45875	51.028
10000	81203	69.250	48777	51.325

TABLE F.6 (continued)

*Ideal Gas Properties of Various Substances (English Units), Entropies at 1 atm Pressure*

<i>T</i> <i>R</i>	Oxygen, Diatomic (O <sub>2</sub> ) $\bar{h}_{f,537}^0 = 0 \text{ Btu/lbmol}$ $M = 31.999 \text{ lbm/lbmol}$		Oxygen, Monatomic (O) $\bar{h}_{f,537}^0 = 107\,124 \text{ Btu/lbmol}$ $M = 16.00 \text{ lbm/lbmol}$	
	$\bar{h} - \bar{h}_{537}^0$ Btu/lbmol	$\bar{s}_T^0$ Btu/lbmol R	$\bar{h} - \bar{h}_{537}^0$ Btu/lbmol	$\bar{s}_T^0$ Btu/lbmol R
0	−3733	0	−2891	0
200	−2345	42.100	−1829	33.041
400	−955	46.920	−724	36.884
537	0	48.973	0	38.442
600	446	49.758	330	39.023
800	1881	51.819	1358	40.503
1000	3366	53.475	2374	41.636
1200	4903	54.876	3383	42.556
1400	6487	56.096	4387	43.330
1600	8108	57.179	5389	43.999
1800	9761	58.152	6389	44.588
2000	11438	59.035	7387	45.114
2200	13136	59.844	8385	45.589
2400	14852	60.591	9381	46.023
2600	16584	61.284	10378	46.422
2800	18329	61.930	11373	46.791
3000	20088	62.537	12369	47.134
3200	21860	63.109	13364	47.455
3400	23644	63.650	14359	47.757
3600	25441	64.163	15354	48.041
3800	27250	64.652	16349	48.310
4000	29071	65.119	17344	48.565
4200	30904	65.566	18339	48.808
4400	32748	65.995	19334	49.039
4600	34605	66.408	20330	49.261
4800	36472	66.805	21327	49.473
5000	38350	67.189	22325	49.677
5500	43091	68.092	24823	50.153
6000	47894	68.928	27329	50.589
6500	52751	69.705	29847	50.992
7000	57657	70.433	32378	51.367
7500	62608	71.116	34924	51.718
8000	67600	71.760	37485	52.049
8500	72633	72.370	40063	52.362
9000	77708	72.950	42658	52.658
9500	82828	73.504	45270	52.941
10000	87997	74.034	47897	53.210

TABLE F.6 (continued)

*Ideal Gas Properties of Various Substances (English Units), Entropies at 1 atm Pressure*

<i>T</i> R	Carbon Dioxide (CO <sub>2</sub> )		Carbon Monoxide (CO)	
	$\bar{h}_{f,537}^0 = -169\,184 \text{ Btu/lbmol}$ $M = 44.01 \text{ lbm/lbmol}$		$\bar{h}_{f,537}^0 = -47\,518 \text{ Btu/lbmol}$ $M = 28.01 \text{ lbm/lbmol}$	
	$\bar{h} - \bar{h}_{537}^0$ Btu/lbmol	$\bar{s}_T^0$ Btu/lbmol R	$\bar{h} - \bar{h}_{537}^0$ Btu/lbmol	$\bar{s}_T^0$ Btu/lbmol R
0	−4026	0	−3728	0
200	−2636	43.466	−2343	40.319
400	−1153	48.565	−951	45.137
537	0	51.038	0	47.182
600	573	52.047	441	47.959
800	2525	54.848	1842	49.974
1000	4655	57.222	3266	51.562
1200	6927	59.291	4723	52.891
1400	9315	61.131	6220	54.044
1600	11798	62.788	7754	55.068
1800	14358	64.295	9323	55.992
2000	16982	65.677	10923	56.835
2200	19659	66.952	12549	57.609
2400	22380	68.136	14197	58.326
2600	25138	69.239	15864	58.993
2800	27926	70.273	17547	59.616
3000	30741	71.244	19243	60.201
3200	33579	72.160	20951	60.752
3400	36437	73.026	22669	61.273
3600	39312	73.847	24395	61.767
3800	42202	74.629	26128	62.236
4000	45105	75.373	27869	62.683
4200	48021	76.084	29614	63.108
4400	50948	76.765	31366	63.515
4600	53885	77.418	33122	63.905
4800	56830	78.045	34883	64.280
5000	59784	78.648	36650	64.641
5500	67202	80.062	41089	65.487
6000	74660	81.360	45548	66.263
6500	82155	82.560	50023	66.979
7000	89682	83.675	54514	67.645
7500	97239	84.718	59020	68.267
8000	104823	85.697	63539	68.850
8500	112434	86.620	68069	69.399
9000	120071	87.493	72610	69.918
9500	127734	88.321	77161	70.410
10000	135426	89.110	81721	70.878

TABLE F.6 (continued)

*Ideal Gas Properties of Various Substances (English Units), Entropies at 1 atm Pressure*

<i>T</i> R	Water (H <sub>2</sub> O)		Hydroxyl (OH)	
	$\bar{h}_{f,537}^0 = -103\,966 \text{ Btu/lbmol}$ $M = 18.015 \text{ lbm/lbmol}$		$\bar{h}_{f,537}^0 = 16\,761 \text{ Btu/lbmol}$ $M = 17.007 \text{ lbm/lbmol}$	
	$\bar{h} - \bar{h}_{537}^0$ Btu/lbmol	$\bar{s}_T^0$ Btu/lbmol R	$\bar{h} - \bar{h}_{537}^0$ Btu/lbmol	$\bar{s}_T^0$ Btu/lbmol R
0	−4528	0	−3943	0
200	−2686	37.209	−2484	36.521
400	−1092	42.728	−986	41.729
537	0	45.076	0	43.852
600	509	45.973	452	44.649
800	2142	48.320	1870	46.689
1000	3824	50.197	3280	48.263
1200	5566	51.784	4692	49.549
1400	7371	53.174	6112	50.643
1600	9241	54.422	7547	51.601
1800	11178	55.563	9001	52.457
2000	13183	56.619	10477	53.235
2200	15254	57.605	11978	53.950
2400	17388	58.533	13504	54.614
2600	19582	59.411	15054	55.235
2800	21832	60.245	16627	55.817
3000	24132	61.038	18220	56.367
3200	26479	61.796	19834	56.887
3400	28867	62.520	21466	57.382
3600	31293	63.213	23114	57.853
3800	33756	63.878	24777	58.303
4000	36251	64.518	26455	58.733
4200	38774	65.134	28145	59.145
4400	41325	65.727	29849	59.542
4600	43899	66.299	31563	59.922
4800	46496	66.852	33287	60.289
5000	49114	67.386	35021	60.643
5500	55739	68.649	39393	61.477
6000	62463	69.819	43812	62.246
6500	69270	70.908	48272	62.959
7000	76146	71.927	52767	63.626
7500	83081	72.884	57294	64.250
8000	90069	73.786	61851	64.838
8500	97101	74.639	66434	65.394
9000	104176	75.448	71043	65.921
9500	111289	76.217	75677	66.422
10000	118440	76.950	80335	66.900

TABLE F.6 (continued)

*Ideal Gas Properties of Various Substances (English Units), Entropies at 1 atm Pressure*

<i>T</i> R	Hydrogen (H <sub>2</sub> ) $\bar{h}_{f,537}^0 = 0 \text{ Btu/lbmol}$ $M = 2.016 \text{ lbm/lbmol}$		Hydrogen, Monatomic (H) $\bar{h}_{f,537}^0 = 93\,723 \text{ Btu/lbmol}$ $M = 1.008 \text{ lbm/lbmol}$	
	$\bar{h} - \bar{h}_{537}^0$ Btu/lbmol	$\bar{s}_T^0$ Btu/lbmol R	$\bar{h} - \bar{h}_{537}^0$ Btu/lbmol	$\bar{s}_T^0$ Btu/lbmol R
0	−3640	0	−2664	0
200	−2224	24.703	−1672	22.473
400	−927	29.193	−679	25.914
537	0	31.186	0	27.373
600	438	31.957	314	27.927
800	1831	33.960	1307	29.355
1000	3225	35.519	2300	30.463
1200	4622	36.797	3293	31.368
1400	6029	37.883	4286	32.134
1600	7448	38.831	5279	32.797
1800	8884	39.676	6272	33.381
2000	10337	40.441	7265	33.905
2200	11812	41.143	8258	34.378
2400	13309	41.794	9251	34.810
2600	14829	42.401	10244	35.207
2800	16372	42.973	11237	35.575
3000	17938	43.512	12230	35.917
3200	19525	44.024	13223	36.238
3400	21133	44.512	14215	36.539
3600	22761	44.977	15208	36.823
3800	24407	45.422	16201	37.091
4000	26071	45.849	17194	37.346
4200	27752	46.260	18187	37.588
4400	29449	46.655	19180	37.819
4600	31161	47.035	20173	38.040
4800	32887	47.403	21166	38.251
5000	34627	47.758	22159	38.454
5500	39032	48.598	24641	38.927
6000	43513	49.378	27124	39.359
6500	48062	50.105	29606	39.756
7000	52678	50.789	32088	40.124
7500	57356	51.434	34571	40.467
8000	62094	52.045	37053	40.787
8500	66889	52.627	39535	41.088
9000	71738	53.182	42018	41.372
9500	76638	53.712	44500	41.640
10000	81581	54.220	46982	41.895

TABLE F.6 (continued)

*Ideal Gas Properties of Various Substances (English Units), Entropies at 1 atm Pressure*

<i>T</i> <i>R</i>	Nitric Oxide (NO) $\bar{h}_{f,537}^0 = 38\,818 \text{ Btu/lbmol}$ $M = 30.006 \text{ lbm/lbmol}$		Nitrogen Dioxide (NO <sub>2</sub> ) $\bar{h}_{f,537}^0 = 14\,230 \text{ Btu/lbmol}$ $M = 46.005 \text{ lbm/lbmol}$	
	$\bar{h} - \bar{h}_{537}^0$ Btu/lbmol	$\bar{s}_T^0$ Btu/lbmol R	$\bar{h} - \bar{h}_{537}^0$ Btu/lbmol	$\bar{s}_T^0$ Btu/lbmol R
0	−3952	0	−4379	0
200	−2457	43.066	−2791	49.193
400	−979	48.207	−1172	54.789
537	0	50.313	0	57.305
600	451	51.107	567	58.304
800	1881	53.163	2469	61.034
1000	3338	54.788	4532	63.333
1200	4834	56.152	6733	65.337
1400	6372	57.337	9044	67.118
1600	7948	58.389	11442	68.718
1800	9557	59.336	13905	70.168
2000	11193	60.198	16421	71.493
2200	12853	60.989	18978	72.712
2400	14532	61.719	21567	73.838
2600	16228	62.397	24182	74.885
2800	17937	63.031	26819	75.861
3000	19657	63.624	29473	76.777
3200	21388	64.183	32142	77.638
3400	23128	64.710	34823	78.451
3600	24875	65.209	37515	79.220
3800	26629	65.684	40215	79.950
4000	28389	66.135	42923	80.645
4200	30154	66.565	45637	81.307
4400	31924	66.977	48358	81.940
4600	33698	67.371	51083	82.545
4800	35476	67.750	53813	83.126
5000	37258	68.113	56546	83.684
5500	41726	68.965	63395	84.990
6000	46212	69.746	70260	86.184
6500	50714	70.467	77138	87.285
7000	55229	71.136	84026	88.306
7500	59756	71.760	90923	89.258
8000	64294	72.346	97826	90.149
8500	68842	72.898	104735	90.986
9000	73401	73.419	111648	91.777
9500	77968	73.913	118565	92.525
10000	82544	74.382	125485	93.235

TABLE F.7

*Thermodynamic Properties of Water*

TABLE F.7.1

*Saturated Water*

Temp. (F)	Press. (psia)	Specific Volume, ft <sup>3</sup> /lbm			Internal Energy, Btu/lbm		
		Sat. Liquid $v_f$	Evap. $v_{fg}$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Evap. $u_{fg}$	Sat. Vapor $u_g$
32	0.0887	0.01602	3301.6545	3301.6705	0	1021.21	1021.21
35	0.100	0.01602	2947.5021	2947.5181	2.99	1019.20	1022.19
40	0.122	0.01602	2445.0713	2445.0873	8.01	1015.84	1023.85
45	0.147	0.01602	2036.9527	2036.9687	13.03	1012.47	1025.50
50	0.178	0.01602	1703.9867	1704.0027	18.05	1009.10	1027.15
60	0.256	0.01603	1206.7283	1206.7443	28.08	1002.36	1030.44
70	0.363	0.01605	867.5791	867.5952	38.09	995.64	1033.72
80	0.507	0.01607	632.6739	632.6900	48.08	988.91	1036.99
90	0.699	0.01610	467.5865	467.6026	58.06	982.18	1040.24
100	0.950	0.01613	349.9602	349.9764	68.04	975.43	1043.47
110	1.276	0.01617	265.0548	265.0709	78.01	968.67	1046.68
120	1.695	0.01620	203.0105	203.0267	87.99	961.88	1049.87
130	2.225	0.01625	157.1419	157.1582	97.96	955.07	1053.03
140	2.892	0.01629	122.8567	122.8730	107.95	948.21	1056.16
150	3.722	0.01634	96.9611	96.9774	117.94	941.32	1059.26
160	4.745	0.01639	77.2079	77.2243	127.94	934.39	1062.32
170	5.997	0.01645	61.9983	62.0148	137.94	927.41	1065.35
180	7.515	0.01651	50.1826	50.1991	147.96	920.38	1068.34
190	9.344	0.01657	40.9255	40.9421	157.99	913.29	1071.29
200	11.530	0.01663	33.6146	33.6312	168.03	906.15	1074.18
210	14.126	0.01670	27.7964	27.8131	178.09	898.95	1077.04
212.0	14.696	0.01672	26.7864	26.8032	180.09	897.51	1077.60
220	17.189	0.01677	23.1325	23.1492	188.16	891.68	1079.84
230	20.781	0.01685	19.3677	19.3846	198.25	884.33	1082.58
240	24.968	0.01692	16.3088	16.3257	208.36	876.91	1085.27
250	29.823	0.01700	13.8077	13.8247	218.48	869.41	1087.90
260	35.422	0.01708	11.7503	11.7674	228.64	861.82	1090.46
270	41.848	0.01717	10.0483	10.0655	238.81	854.14	1092.95
280	49.189	0.01726	8.6325	8.6498	249.02	846.35	1095.37
290	57.535	0.01735	7.4486	7.4660	259.25	838.46	1097.71
300	66.985	0.01745	6.4537	6.4712	269.51	830.45	1099.96
310	77.641	0.01755	5.6136	5.6312	279.80	822.32	1102.13
320	89.609	0.01765	4.9010	4.9186	290.13	814.07	1104.20
330	103.00	0.01776	4.2938	4.3115	300.50	805.68	1106.17
340	117.94	0.01787	3.7742	3.7921	310.90	797.14	1108.04
350	134.54	0.01799	3.3279	3.3459	321.35	788.45	1109.80



TABLE F.7.1 (continued)  
Saturated Water

Temp. (F)	Press. (psia)	Enthalpy, Btu/lbm			Entropy, Btu/lbm R		
		Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$
32	0.0887	0	1075.38	1075.39	0	2.1869	2.1869
35	0.100	2.99	1073.71	1076.70	0.0061	2.1703	2.1764
40	0.122	8.01	1070.89	1078.90	0.0162	2.1430	2.1591
45	0.147	13.03	1068.06	1081.10	0.0262	2.1161	2.1423
50	0.178	18.05	1065.24	1083.29	0.0361	2.0898	2.1259
60	0.256	28.08	1059.59	1087.67	0.0555	2.0388	2.0943
70	0.363	38.09	1053.95	1092.04	0.0746	1.9896	2.0642
80	0.507	48.08	1048.31	1096.39	0.0933	1.9423	2.0356
90	0.699	58.06	1042.65	1100.72	0.1116	1.8966	2.0083
100	0.950	68.04	1036.98	1105.02	0.1296	1.8526	1.9822
110	1.276	78.01	1031.28	1109.29	0.1473	1.8101	1.9574
120	1.695	87.99	1025.55	1113.54	0.1646	1.7690	1.9336
130	2.225	97.97	1019.78	1117.75	0.1817	1.7292	1.9109
140	2.892	107.96	1013.96	1121.92	0.1985	1.6907	1.8892
150	3.722	117.95	1008.10	1126.05	0.2150	1.6533	1.8683
160	4.745	127.95	1002.18	1130.14	0.2313	1.6171	1.8484
170	5.997	137.96	996.21	1134.17	0.2473	1.5819	1.8292
180	7.515	147.98	990.17	1138.15	0.2631	1.5478	1.8109
190	9.344	158.02	984.06	1142.08	0.2786	1.5146	1.7932
200	11.530	168.07	977.87	1145.94	0.2940	1.4822	1.7762
210	14.126	178.13	971.61	1149.74	0.3091	1.4507	1.7599
212	14.696	180.13	970.35	1150.49	0.3121	1.4446	1.7567
220	17.189	188.21	965.26	1153.47	0.3240	1.4201	1.7441
230	20.781	198.31	958.81	1157.12	0.3388	1.3901	1.7289
240	24.968	208.43	952.27	1160.70	0.3533	1.3609	1.7142
250	29.823	218.58	945.61	1164.19	0.3677	1.3324	1.7001
260	35.422	228.75	938.84	1167.59	0.3819	1.3044	1.6864
270	41.848	238.95	931.95	1170.90	0.3960	1.2771	1.6731
280	49.189	249.17	924.93	1174.10	0.4098	1.2504	1.6602
290	57.535	259.43	917.76	1177.19	0.4236	1.2241	1.6477
300	66.985	269.73	910.45	1180.18	0.4372	1.1984	1.6356
310	77.641	280.06	902.98	1183.03	0.4507	1.1731	1.6238
320	89.609	290.43	895.34	1185.76	0.4640	1.1483	1.6122
330	103.00	300.84	887.52	1188.36	0.4772	1.1238	1.6010
340	117.94	311.29	879.51	1190.80	0.4903	1.0997	1.5900
350	134.54	321.80	871.30	1193.10	0.5033	1.0760	1.5793

TABLE F.7.1 (continued)

## Saturated Water

Temp. (F)	Press. (psia)	Specific Volume, ft <sup>3</sup> /lbm			Internal Energy, Btu/lbm		
		Sat. Liquid $v_f$	Evap. $v_{fg}$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Evap. $u_{fg}$	Sat. Vapor $u_g$
360	152.93	0.01811	2.9430	2.9611	331.83	779.60	1111.43
370	173.24	0.01823	2.6098	2.6280	342.37	770.57	1112.94
380	195.61	0.01836	2.3203	2.3387	352.95	761.37	1114.31
390	220.17	0.01850	2.0680	2.0865	363.58	751.97	1115.55
400	347.08	0.01864	1.8474	1.8660	374.26	742.37	1116.63
410	276.48	0.01878	1.6537	1.6725	385.00	732.56	1117.56
420	308.52	0.01894	1.4833	1.5023	395.80	722.52	1118.32
430	343.37	0.01909	1.3329	1.3520	406.67	712.24	1118.91
440	381.18	0.01926	1.1998	1.2191	417.61	701.71	1119.32
450	422.13	0.01943	1.0816	1.1011	428.63	690.90	1119.53
460	466.38	0.01961	0.9764	0.9961	439.73	679.82	1119.55
470	514.11	0.01980	0.8826	0.9024	450.92	668.43	1119.35
480	565.50	0.02000	0.7986	0.8186	462.21	656.72	1118.93
490	620.74	0.02021	0.7233	0.7435	473.60	644.67	1118.28
500	680.02	0.02043	0.6556	0.6761	485.11	632.26	1117.37
510	743.53	0.02066	0.5946	0.6153	496.75	619.46	1116.21
520	811.48	0.02091	0.5395	0.5604	508.53	606.23	1114.76
530	884.07	0.02117	0.4896	0.5108	520.46	592.56	1113.02
540	961.51	0.02145	0.4443	0.4658	532.56	578.39	1110.95
550	1044.02	0.02175	0.4031	0.4249	544.85	563.69	1108.54
560	1131.85	0.02207	0.3656	0.3876	557.35	548.42	1105.76
570	1225.21	0.02241	0.3312	0.3536	570.07	532.50	1102.56
580	1324.37	0.02278	0.2997	0.3225	583.05	515.87	1098.91
590	1429.58	0.02318	0.2707	0.2939	596.31	498.44	1094.76
600	1541.13	0.02362	0.2440	0.2676	609.91	480.11	1090.02
610	1659.32	0.02411	0.2193	0.2434	623.87	460.76	1084.63
620	1784.48	0.02465	0.1963	0.2209	638.26	440.20	1078.46
630	1916.96	0.02525	0.1747	0.2000	653.17	418.22	1071.38
640	2057.17	0.02593	0.1545	0.1804	668.68	394.52	1063.20
650	2205.54	0.02673	0.1353	0.1620	684.96	368.66	1053.63
660	2362.59	0.02766	0.1169	0.1446	702.24	340.02	1042.26
670	2528.88	0.02882	0.0990	0.1278	720.91	307.52	1028.43
680	2705.09	0.03031	0.0809	0.1112	741.70	269.26	1010.95
690	2891.99	0.03248	0.0618	0.0943	766.34	220.82	987.16
700	3090.47	0.03665	0.0377	0.0743	801.66	145.92	947.57
705.4	3203.79	0.05053	0	0.0505	872.56	0	872.56

TABLE F.7.1 (continued)  
Saturated Water

Temp. (F)	Press. (psia)	Enthalpy, Btu/lbm			Entropy, Btu/lbm R		
		Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$
360	152.93	332.35	862.88	1195.23	0.5162	1.0526	1.5688
370	173.24	342.95	854.24	1197.19	0.5289	1.0295	1.5584
380	195.61	353.61	845.36	1198.97	0.5416	1.0067	1.5483
390	220.17	364.33	836.23	1200.56	0.5542	0.9841	1.5383
400	247.08	375.11	826.84	1201.95	0.5667	0.9617	1.5284
410	276.48	385.96	817.17	1203.13	0.5791	0.9395	1.5187
420	308.52	396.89	807.20	1204.09	0.5915	0.9175	1.5090
430	343.37	407.89	796.93	1204.82	0.6038	0.8957	1.4995
440	381.18	418.97	786.34	1205.31	0.6160	0.8740	1.4900
450	422.13	430.15	775.40	1205.54	0.6282	0.8523	1.4805
460	466.38	441.42	764.09	1205.51	0.6404	0.8308	1.4711
470	514.11	452.80	752.40	1205.20	0.6525	0.8093	1.4618
480	565.50	464.30	740.30	1204.60	0.6646	0.7878	1.4524
490	620.74	475.92	727.76	1203.68	0.6767	0.7663	1.4430
500	680.02	487.68	714.76	1202.44	0.6888	0.7447	1.4335
510	743.53	499.59	701.27	1200.86	0.7009	0.7232	1.4240
520	811.48	511.67	687.25	1198.92	0.7130	0.7015	1.4144
530	884.07	523.93	672.66	1196.58	0.7251	0.6796	1.4048
540	961.51	536.38	657.45	1193.83	0.7374	0.6576	1.3950
550	1044.02	549.05	641.58	1190.63	0.7496	0.6354	1.3850
560	1131.85	561.97	624.98	1186.95	0.7620	0.6129	1.3749
570	1225.21	575.15	607.59	1182.74	0.7745	0.5901	1.3646
580	1324.37	588.63	589.32	1177.95	0.7871	0.5668	1.3539
590	1429.58	602.45	570.06	1172.51	0.7999	0.5431	1.3430
600	1541.13	616.64	549.71	1166.35	0.8129	0.5187	1.3317
610	1659.32	631.27	528.08	1159.36	0.8262	0.4937	1.3199
620	1784.48	646.40	505.00	1151.41	0.8397	0.4677	1.3075
630	1916.96	662.12	480.21	1142.33	0.8537	0.4407	1.2943
640	2057.17	678.55	453.33	1131.89	0.8681	0.4122	1.2803
650	2205.54	695.87	423.89	1119.76	0.8831	0.3820	1.2651
660	2362.59	714.34	391.13	1105.47	0.8990	0.3493	1.2483
670	2528.88	734.39	353.83	1088.23	0.9160	0.3132	1.2292
680	2705.09	756.87	309.77	1066.64	0.9350	0.2718	1.2068
690	2891.99	783.72	253.88	1037.60	0.9575	0.2208	1.1783
700	3090.47	822.61	167.47	990.09	0.9901	0.1444	1.1345
705.4	3203.79	902.52	0	902.52	1.0580	0	1.0580

TABLE F.7.2

*Superheated Vapor Water*

Temp. (F)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)
1 psia (101.70 F)					5 psia (162.20 F)			
Sat.	333.58	1044.02	1105.75	1.9779	73.531	1062.99	1131.03	1.8441
200	392.51	1077.49	1150.12	2.0507	78.147	1076.25	1148.55	1.8715
240	416.42	1091.22	1168.28	2.0775	83.001	1090.25	1167.05	1.8987
280	440.32	1105.02	1186.50	2.1028	87.831	1104.27	1185.53	1.9244
320	464.19	1118.92	1204.82	2.1269	92.645	1118.32	1204.04	1.9487
360	488.05	1132.92	1223.23	2.1499	97.447	1132.42	1222.59	1.9719
400	511.91	1147.02	1241.75	2.1720	102.24	1146.61	1241.21	1.9941
440	535.76	1161.23	1260.37	2.1932	107.03	1160.89	1259.92	2.0154
500	571.53	1182.77	1288.53	2.2235	114.21	1182.50	1288.17	2.0458
600	631.13	1219.30	1336.09	2.2706	126.15	1219.10	1335.82	2.0930
700	690.72	1256.65	1384.47	2.3142	138.08	1256.50	1384.26	2.1367
800	750.30	1294.86	1433.70	2.3549	150.01	1294.73	1433.53	2.1774
900	809.88	1333.94	1483.81	2.3932	161.94	1333.84	1483.68	2.2157
1000	869.45	1373.93	1534.82	2.4294	173.86	1373.85	1534.71	2.2520
1100	929.03	1414.83	1586.75	2.4638	185.78	1414.77	1586.66	2.2864
1200	988.60	1456.67	1639.61	2.4967	197.70	1456.61	1639.53	2.3192
1300	1048.17	1499.43	1693.40	2.5281	209.62	1499.38	1693.33	2.3507
1400	1107.74	1543.13	1748.12	2.5584	221.53	1543.09	1748.06	2.3809
10 psia (193.19 F)					14.696 psia (211.99 F)			
Sat.	38.424	1072.21	1143.32	1.7877	26.803	1077.60	1150.49	1.7567
200	38.848	1074.67	1146.56	1.7927	—	—	—	—
240	41.320	1089.03	1165.50	1.8205	27.999	1087.87	1164.02	1.7764
280	43.768	1103.31	1184.31	1.8467	29.687	1102.40	1183.14	1.8030
320	46.200	1117.56	1203.05	1.8713	31.359	1116.83	1202.11	1.8280
360	48.620	1131.81	1221.78	1.8948	33.018	1131.22	1221.01	1.8516
400	51.032	1146.10	1240.53	1.9171	34.668	1145.62	1239.90	1.8741
440	53.438	1160.46	1259.34	1.9385	36.313	1160.05	1258.80	1.8956
500	57.039	1182.16	1287.71	1.9690	38.772	1181.83	1287.27	1.9262
600	63.027	1218.85	1335.48	2.0164	42.857	1218.61	1335.16	1.9737
700	69.006	1256.30	1384.00	2.0601	46.932	1256.12	1383.75	2.0175
800	74.978	1294.58	1433.32	2.1009	51.001	1294.43	1433.13	2.0584
900	80.946	1333.72	1483.51	2.1392	55.066	1333.60	1483.35	2.0967
1000	86.912	1373.74	1534.57	2.1755	59.128	1373.65	1534.44	2.1330
1100	92.875	1414.68	1586.54	2.2099	63.188	1414.60	1586.44	2.1674
1200	98.837	1456.53	1639.43	2.2428	67.247	1456.47	1639.34	2.2003
1300	104.798	1499.32	1693.25	2.2743	71.304	1499.26	1693.17	2.2318
1400	110.759	1543.03	1747.99	2.3045	75.361	1542.98	1747.92	2.2620
1500	116.718	1587.67	1803.66	2.3337	79.417	1587.63	1803.60	2.2912
1600	122.678	1633.24	1860.25	2.3618	83.473	1633.20	1860.20	2.3194

**TABLE F.7.2** (continued)  
**Superheated Vapor Water**

Temp. (F)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)
20 psia (227.96 F)					40 psia (267.26 F)			
Sat.	20.091	1082.02	1156.38	1.7320	10.501	1092.27	1170.00	1.6767
240	20.475	1086.54	1162.32	1.7405	—	—	—	—
280	21.734	1101.36	1181.80	1.7676	10.711	1097.31	1176.59	1.6857
320	22.976	1116.01	1201.04	1.7929	11.360	1112.81	1196.90	1.7124
360	24.206	1130.55	1220.14	1.8168	11.996	1127.98	1216.77	1.7373
400	25.427	1145.06	1239.17	1.8395	12.623	1142.95	1236.38	1.7606
440	26.642	1159.59	1258.19	1.8611	13.243	1157.82	1255.84	1.7827
500	28.456	1181.46	1286.78	1.8919	14.164	1180.06	1284.91	1.8140
600	31.466	1218.35	1334.80	1.9395	15.685	1217.33	1333.43	1.8621
700	34.466	1255.91	1383.47	1.9834	17.196	1255.14	1382.42	1.9063
800	37.460	1294.27	1432.91	2.0243	18.701	1293.65	1432.08	1.9474
900	40.450	1333.47	1483.17	2.0626	20.202	1332.96	1482.50	1.9859
1000	43.437	1373.54	1534.30	2.0989	21.700	1373.12	1533.74	2.0222
1100	46.422	1414.51	1586.32	2.1334	23.196	1414.16	1585.86	2.0568
1200	49.406	1456.39	1639.24	2.1663	24.690	1456.09	1638.85	2.0897
1300	52.389	1499.19	1693.08	2.1978	26.184	1498.94	1692.75	2.1212
1400	55.371	1542.92	1747.85	2.2280	27.677	1542.70	1747.56	2.1515
1500	58.352	1587.58	1803.54	2.2572	29.169	1587.38	1803.29	2.1807
1600	61.333	1633.15	1860.14	2.2854	30.660	1632.97	1859.92	2.2089
60 psia (292.73 F)					80 psia (312.06 F)			
Sat.	7.177	1098.33	1178.02	1.6444	5.474	1102.56	1183.61	1.6214
320	7.485	1109.46	1192.56	1.6633	5.544	1105.95	1188.02	1.6270
360	7.924	1125.31	1213.29	1.6893	5.886	1122.53	1209.67	1.6541
400	8.353	1140.77	1233.52	1.7134	6.217	1138.53	1230.56	1.6790
440	8.775	1156.01	1253.44	1.7360	6.541	1154.15	1250.98	1.7022
500	9.399	1178.64	1283.00	1.7678	7.017	1177.19	1281.07	1.7346
600	10.425	1216.31	1332.06	1.8165	7.794	1215.28	1330.66	1.7838
700	11.440	1254.35	1381.37	1.8609	8.561	1253.57	1380.31	1.8285
800	12.448	1293.03	1431.24	1.9022	9.322	1292.41	1430.40	1.8700
900	13.452	1332.46	1481.82	1.9408	10.078	1331.95	1481.14	1.9087
1000	14.454	1372.71	1533.19	1.9773	10.831	1372.29	1532.63	1.9453
1100	15.454	1413.81	1585.39	2.0119	11.583	1413.46	1584.93	1.9799
1200	16.452	1455.80	1638.46	2.0448	12.333	1455.51	1638.08	2.0129
1300	17.449	1498.69	1692.42	2.0764	13.082	1498.43	1692.09	2.0445
1400	18.445	1542.48	1747.28	2.1067	13.830	1542.26	1746.99	2.0749
1500	19.441	1587.18	1803.04	2.1359	14.577	1586.99	1802.79	2.1041
1600	20.436	1632.79	1859.70	2.1641	15.324	1632.62	1859.48	2.1323
1800	22.426	1726.69	1975.69	2.2178	16.818	1726.54	1975.50	2.1861
2000	24.415	1824.02	2095.10	2.2685	18.310	1823.88	2094.94	2.2367

TABLE F.7.2 (continued)  
Superheated Vapor Water

Temp. (F)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)
100 psia (327.85 F)					150 psia (358.47 F)			
Sat.	4.4340	1105.76	1187.81	1.6034	3.0163	1111.19	1194.91	1.5704
350	4.5917	1115.39	1200.36	1.6191	—	—	—	—
400	4.9344	1136.21	1227.53	1.6517	3.2212	1130.10	1219.51	1.5997
450	5.2646	1156.20	1253.62	1.6812	3.4547	1151.47	1247.36	1.6312
500	5.5866	1175.72	1279.10	1.7085	3.6789	1171.93	1274.04	1.6598
550	5.9032	1195.02	1304.25	1.7340	3.8970	1191.88	1300.05	1.6862
600	6.2160	1214.23	1329.26	1.7582	4.1110	1211.58	1325.69	1.7110
700	6.8340	1252.78	1379.24	1.8033	4.5309	1250.78	1376.55	1.7568
800	7.4455	1291.78	1429.56	1.8449	4.9441	1290.21	1427.44	1.7989
900	8.0528	1331.45	1480.47	1.8838	5.3529	1330.18	1478.76	1.8381
1000	8.6574	1371.87	1532.08	1.9204	5.7590	1370.83	1530.68	1.8750
1100	9.2599	1413.12	1584.47	1.9551	6.1630	1412.24	1583.31	1.9098
1200	9.8610	1455.21	1637.69	1.9882	6.5655	1454.47	1636.71	1.9430
1300	10.4610	1498.18	1691.76	2.0198	6.9670	1497.55	1690.93	1.9747
1400	11.0602	1542.04	1746.71	2.0502	7.3677	1541.49	1745.99	2.0052
1500	11.6588	1586.79	1802.54	2.0794	7.7677	1586.30	1801.91	2.0345
1600	12.2570	1632.44	1859.25	2.1076	8.1673	1632.00	1858.70	2.0627
1800	13.4525	1726.38	1975.32	2.1614	8.9657	1726.00	1974.86	2.1165
2000	14.6472	1823.74	2094.78	2.2120	9.7633	1823.38	2094.38	2.1672
200 psia (381.86 F)					300 psia (417.42 F)			
Sat.	2.2892	1114.55	1199.28	1.5464	1.5441	1118.14	1203.86	1.5115
400	2.3609	1123.45	1210.83	1.5600	—	—	—	—
450	2.5477	1146.44	1240.73	1.5938	1.6361	1135.37	1226.20	1.5365
500	2.7238	1167.96	1268.77	1.6238	1.7662	1159.47	1257.52	1.5701
550	2.8932	1188.65	1295.72	1.6512	1.8878	1181.85	1286.65	1.5997
600	3.0580	1208.87	1322.05	1.6767	2.0041	1203.24	1314.50	1.6266
700	3.3792	1248.76	1373.82	1.7234	2.2269	1244.63	1368.26	1.6751
800	3.6932	1288.62	1425.31	1.7659	2.4421	1285.41	1420.99	1.7187
900	4.0029	1328.90	1477.04	1.8055	2.6528	1326.31	1473.58	1.7589
1000	4.3097	1369.77	1529.28	1.8425	2.8604	1367.65	1526.45	1.7964
1100	4.6145	1411.36	1582.15	1.8776	3.0660	1409.60	1579.80	1.8317
1200	4.9178	1453.73	1635.74	1.9109	3.2700	1452.24	1633.77	1.8653
1300	5.2200	1496.91	1690.10	1.9427	3.4730	1495.63	1688.43	1.8972
1400	5.5214	1540.93	1745.28	1.9732	3.6751	1539.82	1743.84	1.9279
1500	5.8222	1585.81	1801.29	2.0025	3.8767	1584.82	1800.03	1.9573
1600	6.1225	1631.55	1858.15	2.0308	4.0777	1630.66	1857.04	1.9857
1800	6.7223	1725.62	1974.41	2.0847	4.4790	1724.85	1973.50	2.0396
2000	7.3214	1823.02	2093.99	2.1354	4.8794	1822.32	2093.20	2.0904

**TABLE F.7.2** (continued)  
**Superheated Vapor Water**

Temp. (F)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)
400 psia (444.69 F)					600 psia (486.33 F)			
Sat.	1.1619	1119.44	1205.45	1.4856	0.7702	1118.54	1204.06	1.4464
450	1.1745	1122.63	1209.57	1.4901	—	—	—	—
500	1.2843	1150.11	1245.17	1.5282	0.7947	1127.97	1216.21	1.4592
550	1.3834	1174.56	1276.95	1.5605	0.8749	1158.23	1255.36	1.4990
600	1.4760	1197.33	1306.58	1.5892	0.9456	1184.50	1289.49	1.5320
700	1.6503	1240.38	1362.54	1.6396	1.0728	1231.51	1350.62	1.5871
800	1.8163	1282.14	1416.59	1.6844	1.1900	1275.42	1407.55	1.6343
900	1.9776	1323.69	1470.07	1.7252	1.3021	1318.36	1462.92	1.6766
1000	2.1357	1365.51	1523.59	1.7632	1.4108	1361.15	1517.79	1.7155
1100	2.2917	1407.81	1577.44	1.7989	1.5173	1404.20	1572.66	1.7519
1200	2.4462	1450.73	1631.79	1.8327	1.6222	1447.68	1627.80	1.7861
1300	2.5995	1494.34	1686.76	1.8648	1.7260	1491.74	1683.38	1.8186
1400	2.7520	1538.70	1742.40	1.8956	1.8289	1536.44	1739.51	1.8497
1500	2.9039	1583.83	1798.78	1.9251	1.9312	1581.84	1796.26	1.8794
1600	3.0553	1629.77	1855.93	1.9535	2.0330	1627.98	1853.71	1.9080
1700	3.2064	1676.52	1913.86	1.9810	2.1345	1674.88	1911.87	1.9355
1800	3.3573	1724.08	1972.59	2.0076	2.2357	1722.55	1970.78	1.9622
2000	3.6585	1821.61	2092.41	2.0584	2.4375	1820.20	2090.84	2.0131
800 psia (518.36 F)					1000 psia (544.74 F)			
Sat.	0.5691	1115.02	1199.26	1.4160	0.4459	1109.86	1192.37	1.3903
550	0.6154	1138.83	1229.93	1.4469	0.4534	1114.77	1198.67	1.3965
600	0.6776	1170.10	1270.41	1.4861	0.5140	1153.66	1248.76	1.4450
650	0.7324	1197.22	1305.64	1.5186	0.5637	1184.74	1289.06	1.4822
700	0.7829	1222.08	1337.98	1.5471	0.6080	1212.03	1324.54	1.5135
800	0.8764	1268.45	1398.19	1.5969	0.6878	1261.21	1388.49	1.5664
900	0.9640	1312.88	1455.60	1.6408	0.7610	1307.26	1448.08	1.6120
1000	1.0482	1356.71	1511.88	1.6807	0.8305	1352.17	1505.86	1.6530
1100	1.1300	1400.52	1567.81	1.7178	0.8976	1396.77	1562.88	1.6908
1200	1.2102	1444.60	1623.76	1.7525	0.9630	1441.46	1619.67	1.7260
1300	1.2892	1489.11	1679.97	1.7854	1.0272	1486.45	1676.53	1.7593
1400	1.3674	1534.17	1736.59	1.8167	1.0905	1531.88	1733.67	1.7909
1500	1.4448	1579.85	1793.74	1.8467	1.1531	1577.84	1791.21	1.8210
1600	1.5218	1626.19	1851.49	1.8754	1.2152	1624.40	1849.27	1.8499
1700	1.5985	1673.25	1909.89	1.9031	1.2769	1671.61	1907.91	1.8777
1800	1.6749	1721.03	1968.98	1.9298	1.3384	1719.51	1967.18	1.9046
2000	1.8271	1818.80	2089.28	1.9808	1.4608	1817.41	2087.74	1.9557

TABLE F.7.2 (continued)  
Superheated Vapor Water

Temp. (F)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)
1500 psia (596.38 F)					2000 psia (635.99 F)			
Sat.	0.2769	1091.81	1168.67	1.3358	0.1881	1066.63	1136.25	1.2861
650	0.3329	1146.95	1239.34	1.4012	0.2057	1091.06	1167.18	1.3141
700	0.3716	1183.44	1286.60	1.4429	0.2487	1147.74	1239.79	1.3782
750	0.4049	1214.13	1326.52	1.4766	0.2803	1187.32	1291.07	1.4216
800	0.4350	1241.79	1362.53	1.5058	0.3071	1220.13	1333.80	1.4562
850	0.4631	1267.69	1396.23	1.5321	0.3312	1249.46	1372.03	1.4860
900	0.4897	1292.53	1428.46	1.5562	0.3534	1276.78	1407.58	1.5126
1000	0.5400	1340.43	1490.32	1.6001	0.3945	1328.10	1474.09	1.5598
1100	0.5876	1387.16	1550.26	1.6398	0.4325	1377.17	1537.23	1.6017
1200	0.6334	1433.45	1609.25	1.6765	0.4685	1425.19	1598.58	1.6398
1300	0.6778	1479.68	1667.82	1.7108	0.5031	1472.74	1658.95	1.6751
1400	0.7213	1526.06	1726.28	1.7431	0.5368	1520.15	1718.81	1.7082
1500	0.7641	1572.77	1784.86	1.7738	0.5697	1567.64	1778.48	1.7395
1600	0.8064	1619.90	1843.72	1.8301	0.6020	1615.37	1838.18	1.7692
1700	0.8482	1667.53	1902.98	1.8312	0.6340	1663.45	1898.08	1.7976
1800	0.8899	1715.73	1962.73	1.8582	0.6656	1711.97	1958.32	1.8248
1900	0.9313	1764.53	2023.03	1.8843	0.6971	1760.99	2018.99	1.8511
2000	0.9725	1813.97	2083.91	1.9096	0.7284	1810.56	2080.15	1.8765
4000 psia					8000 psia			
650	0.02447	657.71	675.82	0.8574	0.02239	627.01	660.16	0.8278
700	0.02867	742.13	763.35	0.9345	0.02418	688.59	724.39	0.8844
750	0.06332	960.69	1007.56	1.1395	0.02671	755.67	795.21	0.9441
800	0.10523	1095.04	1172.93	1.2740	0.03061	830.67	875.99	1.0095
850	0.12833	1156.47	1251.46	1.3352	0.03706	915.81	970.67	1.0832
900	0.14623	1201.47	1309.71	1.3789	0.04657	1003.68	1072.63	1.1596
950	0.16152	1239.20	1358.75	1.4143	0.05721	1079.59	1164.28	1.2259
1000	0.17520	1272.94	1402.62	1.4449	0.06722	1141.04	1240.55	1.2791
1100	0.19954	1333.90	1481.60	1.4973	0.08445	1236.84	1361.85	1.3595
1200	0.22129	1390.11	1553.91	1.5423	0.09892	1314.18	1460.62	1.4210
1300	0.24137	1443.72	1622.38	1.5823	0.11161	1382.27	1547.50	1.4718
1400	0.26029	1495.73	1688.39	1.6188	0.12309	1444.85	1627.08	1.5158
1500	0.27837	1546.73	1752.78	1.6525	0.13372	1503.78	1701.74	1.5549
1600	0.29586	1597.12	1816.11	1.6841	0.14373	1560.12	1772.89	1.5904
1700	0.31291	1647.17	1878.79	1.7138	0.15328	1614.58	1841.49	1.6229
1800	0.32964	1697.11	1941.11	1.7420	0.16251	1667.69	1908.27	1.6531
1900	0.34616	1747.10	2003.32	1.7689	0.17151	1719.85	1973.75	1.6815
2000	0.36251	1797.27	2065.60	1.7948	0.18034	1771.38	2038.36	1.7083



**TABLE F.7.3**  
**Compressed Liquid Water**

Temp. (F)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)
500 psia (467.12 F)					1000 psia (544.74 F)			
Sat.	0.01975	447.69	449.51	0.6490	0.02159	538.37	542.36	0.74318
32	0.01599	0.00	1.48	0.0000	0.01597	0.02	2.98	0.0000
50	0.01599	18.02	19.50	0.0360	0.01599	17.98	20.94	0.0359
75	0.0160	42.98	44.46	0.0838	0.0160	42.87	45.83	0.0836
100	0.0161	67.87	69.36	0.1293	0.0161	67.70	70.67	0.1290
125	0.0162	92.75	94.24	0.1728	0.0162	92.52	95.51	0.1724
150	0.0163	117.66	119.17	0.2146	0.0163	117.37	120.39	0.2141
175	0.0165	142.62	144.14	0.2547	0.0164	142.28	145.32	0.2542
200	0.0166	167.64	168.18	0.2934	0.0166	167.25	170.32	0.2928
225	0.0168	192.76	194.31	0.3308	0.0168	192.30	195.40	0.3301
250	0.0170	217.99	219.56	0.3670	0.0169	217.46	220.60	0.3663
275	0.0172	243.36	244.95	0.4022	0.0171	242.77	245.94	0.4014
300	0.0174	268.91	270.52	0.4364	0.0174	268.24	271.45	0.4355
325	0.0177	294.68	296.32	0.4698	0.0176	293.91	297.17	0.4688
350	0.0180	320.70	322.36	0.5025	0.0179	319.83	323.14	0.5014
375	0.0183	347.01	348.70	0.5345	0.0182	346.02	349.39	0.5333
400	0.0186	373.68	375.40	0.5660	0.0185	372.55	375.98	0.5647
425	0.0190	400.77	402.52	0.5971	0.0189	399.47	402.97	0.5957
450	0.0194	428.39	430.19	0.6280	0.0193	426.89	430.47	0.6263
2000 psia (635.99 F)					8000 psia			
Sat.	0.02565	662.38	671.87	0.8622	—	—	—	—
50	0.01592	17.91	23.80	0.0357	0.01563	17.38	40.52	0.0342
75	0.0160	42.66	48.57	0.0832	0.0157	41.42	64.65	0.0804
100	0.0160	67.36	73.30	0.1284	0.01577	65.49	88.83	0.1246
125	0.0161	92.07	98.04	0.1716	0.01586	89.62	113.10	0.1670
150	0.0162	116.82	122.84	0.2132	0.01597	113.81	137.45	0.2078
175	0.0164	141.62	147.68	0.2531	0.01610	138.04	161.87	0.2471
200	0.0165	166.48	172.60	0.2916	0.01623	162.31	186.34	0.2849
225	0.0167	191.42	197.59	0.3288	0.01639	186.61	210.87	0.3214
250	0.0169	216.45	222.69	0.3648	0.01655	210.97	235.47	0.3567
275	0.0171	241.61	247.93	0.3998	0.01675	235.39	260.16	0.3909
300	0.0173	266.92	273.33	0.4337	0.01693	259.91	284.97	0.4241
325	0.0176	292.42	298.92	0.4669	0.01714	284.53	309.91	0.4564
350	0.0178	318.14	324.74	0.4993	0.01737	309.29	335.01	0.4878
400	0.0184	370.38	377.20	0.5621	0.01788	359.26	385.73	0.5486
450	0.0192	424.03	431.13	0.6231	0.01848	409.94	437.30	0.6069
500	0.0201	479.84	487.29	0.6832	0.01918	461.56	489.95	0.6633
600	0.0233	605.37	613.99	0.8086	0.02106	569.36	600.53	0.7728

TABLE F.7.4

*Saturated Solid–Saturated Vapor, Water (English Units)*

Temp. (F)	Press. (lbf/in. <sup>2</sup> )	Specific Volume, ft <sup>3</sup> /lbm		Internal Energy, Btu/lbm		
		Sat. Solid $v_i$	Sat. Vapor $v_g \times 10^{-3}$	Sat. Solid $u_i$	Evap. $u_{ig}$	Sat. Vapor $u_g$
32.02	0.08866	0.017473	3.302	−143.34	1164.5	1021.2
32	0.08859	0.01747	3.305	−143.35	1164.5	1021.2
30	0.08083	0.01747	3.607	−144.35	1164.9	1020.5
25	0.06406	0.01746	4.505	−146.84	1165.7	1018.9
20	0.05051	0.01745	5.655	−149.31	1166.5	1017.2
15	0.03963	0.01745	7.133	−151.75	1167.3	1015.6
10	0.03093	0.01744	9.043	−154.16	1168.1	1013.9
5	0.02402	0.01743	11.522	−156.56	1168.8	1012.2
0	0.01855	0.01742	14.761	−158.93	1169.5	1010.6
−5	0.01424	0.01742	19.019	−161.27	1170.2	1008.9
−10	0.01086	0.01741	24.657	−163.59	1170.8	1007.3
−15	0.00823	0.01740	32.169	−165.89	1171.5	1005.6
−20	0.00620	0.01740	42.238	−168.16	1172.1	1003.9
−25	0.00464	0.01739	55.782	−170.40	1172.7	1002.3
−30	0.00346	0.01738	74.046	−172.63	1173.2	1000.6
−35	0.00256	0.01737	98.890	−174.82	1173.8	998.9
−40	0.00187	0.01737	134.017	−177.00	1174.3	997.3

Temp. (F)	Press. (lbf/in. <sup>2</sup> )	Enthalpy, Btu/lbm			Entropy, Btu/lbm R		
		Sat. Solid $h_i$	Evap. $h_{ig}$	Sat. Vapor $h_g$	Sat. Liquid $s_i$	Evap. $s_{ig}$	Sat. Vapor $s_g$
32.02	0.08866	−143.34	1218.7	1075.4	−0.2916	2.4786	2.1869
32	0.08859	−143.35	1218.7	1075.4	−0.2917	2.4787	2.1870
30	0.08083	−144.35	1218.8	1074.5	−0.2938	2.4891	2.1953
25	0.06406	−146.84	1219.1	1072.3	−0.2990	2.5154	2.2164
20	0.05051	−149.31	1219.4	1070.1	−0.3042	2.5422	2.2380
15	0.03963	−151.75	1219.6	1067.9	−0.3093	2.5695	2.2601
10	0.03093	−154.16	1219.8	1065.7	−0.3145	2.5973	2.2827
5	0.02402	−156.56	1220.0	1063.5	−0.3197	2.6256	2.3059
0	0.01855	−158.93	1220.2	1061.2	−0.3248	2.6544	2.3296
−5	0.01424	−161.27	1220.3	1059.0	−0.3300	2.6839	2.3539
−10	0.01086	−163.59	1220.4	1056.8	−0.3351	2.7140	2.3788
−15	0.00823	−165.89	1220.5	1054.6	−0.3403	2.7447	2.4044
−20	0.00620	−168.16	1220.5	1052.4	−0.3455	2.7761	2.4307
−25	0.00464	−170.40	1220.6	1050.2	−0.3506	2.8081	2.4575
−30	0.00346	−172.63	1220.6	1048.0	−0.3557	2.8406	2.4849
−35	0.00256	−174.82	1220.6	1045.7	−0.3608	2.8737	2.5129
−40	0.00187	−177.00	1220.5	1043.5	−0.3659	2.9084	2.5425

TABLE F.8

*Thermodynamic Properties of Ammonia*

TABLE F.8.1

*Saturated Ammonia*

Temp. (F)	Press. (psia)	Specific Volume, ft <sup>3</sup> /lbm			Internal Energy, Btu/lbm		
		Sat. Liquid $v_f$	Evap. $v_{fg}$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Evap. $u_{fg}$	Sat. Vapor $u_g$
−60	5.547	0.02277	44.7397	44.7625	−20.92	564.27	543.36
−50	7.663	0.02299	33.0702	33.0932	−10.51	556.84	546.33
−40	10.404	0.02322	24.8464	24.8696	−0.04	549.25	549.20
−30	13.898	0.02345	18.9490	18.9724	10.48	541.50	551.98
−28.0	14.696	0.02350	17.9833	18.0068	12.59	539.93	552.52
−20	18.289	0.02369	14.6510	14.6747	21.07	533.57	554.64
−10	23.737	0.02394	11.4714	11.4953	31.73	252.47	557.20
0	30.415	0.02420	9.0861	9.1103	42.46	517.18	559.64
10	38.508	0.02446	7.2734	7.2979	53.26	508.71	561.96
20	48.218	0.02474	5.8792	5.9039	64.12	500.04	564.16
30	59.756	0.02502	4.7945	4.8195	75.06	491.17	566.23
40	73.346	0.02532	3.9418	3.9671	86.07	482.09	568.15
50	89.226	0.02564	3.2647	3.2903	97.16	472.78	569.94
60	107.641	0.02597	2.7221	2.7481	108.33	463.24	571.56
70	128.849	0.02631	2.2835	2.3098	119.58	453.44	573.02
80	153.116	0.02668	1.9260	1.9526	130.92	443.37	574.30
90	180.721	0.02706	1.6323	1.6594	142.36	433.01	573.37
100	211.949	0.02747	1.3894	1.4168	153.89	422.34	576.23
110	247.098	0.02790	1.1870	1.2149	165.53	411.32	576.85
120	286.473	0.02836	1.0172	1.0456	177.28	399.92	577.20
130	330.392	0.02885	0.8740	0.9028	189.17	388.10	577.27
140	379.181	0.02938	0.7524	0.7818	201.20	375.82	577.02
150	433.181	0.02995	0.6485	0.6785	213.40	363.01	576.41
160	492.742	0.03057	0.5593	0.5899	225.80	349.61	575.41
170	558.231	0.03124	0.4822	0.5135	238.42	335.53	573.95
180	630.029	0.03199	0.4153	0.4472	251.33	320.66	571.99
190	708.538	0.03281	0.3567	0.3895	264.58	304.87	569.45
200	794.183	0.03375	0.3051	0.3388	278.24	287.96	566.20
210	887.424	0.03482	0.2592	0.2941	292.43	269.70	562.13
220	988.761	0.03608	0.2181	0.2542	307.28	249.72	557.00
230	1098.766	0.03759	0.1807	0.2183	323.03	227.47	550.50
240	1218.113	0.03950	0.1460	0.1855	340.05	202.02	542.06
250	1347.668	0.04206	0.1126	0.1547	359.03	171.57	530.60
260	1488.694	0.04599	0.0781	0.1241	381.74	131.74	513.48
270.1	1643.742	0.06816	0	0.0682	446.09	0	446.09

TABLE F.8.1 (continued)  
Saturated Ammonia

Temp. (F)	Press. (psia)	Enthalpy, Btu/lbm			Entropy, Btu/lbm R		
		Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$
−60	5.547	−20.89	610.19	589.30	−0.0510	1.5267	1.4758
−50	7.663	−10.48	603.73	593.26	−0.0252	1.4737	1.4485
−40	10.404	0	597.08	597.08	0	1.4227	1.4227
−30	13.898	10.54	590.23	600.77	0.0248	1.3737	1.3985
−28.0	14.696	12.65	588.84	601.49	0.0297	1.3641	1.3938
−20	18.289	21.15	583.15	604.31	0.0492	1.3263	1.3755
−10	23.737	31.84	575.85	607.69	0.0731	1.2806	1.3538
0	30.415	42.60	568.32	610.92	0.0967	1.2364	1.3331
10	38.508	53.43	560.54	613.97	0.1200	1.1935	1.3134
20	48.218	64.34	552.50	616.84	0.1429	1.1518	1.2947
30	59.756	75.33	544.18	619.52	0.1654	1.1113	1.2768
40	73.346	86.41	535.59	622.00	0.1877	1.0719	1.2596
50	89.226	97.58	526.68	624.26	0.2097	1.0334	1.2431
60	107.641	108.84	517.46	626.30	0.2314	0.9957	1.2271
70	128.849	120.21	507.89	628.09	0.2529	0.9589	1.2117
80	153.116	131.68	497.94	629.62	0.2741	0.9227	1.1968
90	180.721	143.26	487.60	630.86	0.2951	0.8871	1.1822
100	211.949	154.97	476.83	631.80	0.3159	0.8520	1.1679
110	247.098	166.80	465.59	632.40	0.3366	0.8173	1.1539
120	286.473	178.79	453.84	632.63	0.3571	0.7829	1.1400
130	330.392	190.93	441.54	632.47	0.3774	0.7488	1.1262
140	379.181	203.26	428.61	631.87	0.3977	0.7147	1.1125
150	433.181	215.80	415.00	630.80	0.4180	0.6807	1.0987
160	492.742	228.58	400.61	629.19	0.4382	0.6465	1.0847
170	558.231	241.65	385.35	627.00	0.4586	0.6120	1.0705
180	630.029	255.06	369.08	624.14	0.4790	0.5770	1.0560
190	708.538	268.88	351.63	620.51	0.4997	0.5412	1.0410
200	794.183	283.20	332.80	616.00	0.5208	0.5045	1.0253
210	887.424	298.14	312.27	610.42	0.5424	0.4663	1.0087
220	988.761	313.88	289.63	603.51	0.5647	0.4261	0.9909
230	1098.766	330.67	264.21	594.89	0.5882	0.3831	0.9713
240	1218.113	348.95	234.93	583.87	0.6132	0.3358	0.9490
250	1347.668	369.52	199.65	569.17	0.6410	0.2813	0.9224
260	1488.694	394.41	153.25	547.66	0.6743	0.2129	0.8872
270.1	1643.742	466.83	0	466.83	0.7718	0	0.7718

**TABLE F.8.2**  
**Superheated Ammonia**

Temp. F	$v$ ft <sup>3</sup> /lbm	$h$ Btu/lbm	$s$ Btu/lbm R	$v$ ft <sup>3</sup> /lbm	$h$ Btu/lbm	$s$ Btu/lbm R	$v$ ft <sup>3</sup> /lbm	$h$ Btu/lbm	$s$ Btu/lbm R
5 psia (−63.09 F)			10 psia (−41.33 F)			15 psia (−27.27 F)			
Sat.	49.32002	588.05	1.4846	25.80648	596.58	1.4261	17.66533	601.75	1.3921
−40	52.3487	599.56	1.5128	25.8962	597.27	1.4277	—	—	
−20	54.9506	609.53	1.5360	27.2401	607.60	1.4518	17.9999	605.63	1.4010
0	57.5366	619.51	1.5582	28.5674	617.88	1.4746	18.9086	616.22	1.4245
20	60.1099	629.50	1.5795	29.8814	628.12	1.4964	19.8036	626.72	1.4469
40	62.6732	639.52	1.5999	31.1852	638.34	1.5173	20.6880	637.15	1.4682
60	65.2288	649.57	1.6197	32.4809	648.56	1.5374	21.5641	647.54	1.4886
80	67.7782	659.67	1.6387	33.7703	658.80	1.5567	22.4338	657.91	1.5082
100	70.3228	669.84	1.6572	35.0549	669.07	1.5754	23.2985	668.29	1.5271
120	72.8637	680.06	1.6752	36.3356	679.38	1.5935	24.1593	678.70	1.5453
140	75.4015	690.36	1.6926	37.6133	689.75	1.6111	25.0170	689.14	1.5630
160	77.9370	700.74	1.7097	38.8886	700.19	1.6282	25.8723	699.64	1.5803
180	80.4706	711.20	1.7263	40.1620	710.70	1.6449	26.7256	710.21	1.5970
200	83.0026	721.75	1.7425	41.4338	721.30	1.6612	27.5774	720.84	1.6134
220	85.5334	732.39	1.7584	42.7043	731.98	1.6771	28.4278	731.56	1.6294
240	88.0631	743.13	1.7740	43.9737	742.74	1.6928	29.2772	742.36	1.6451
260	90.5918	753.96	1.7892	45.2422	753.61	1.7081	30.1256	753.24	1.6604
280	93.1199	764.90	1.8042	46.5100	764.56	1.7231	30.9733	764.23	1.6755
20 psia (−16.63 F)			25 psia (−7.95 F)			30 psia (−0.57 F)			
Sat.	13.49628	605.47	1.3680	10.95013	608.37	1.3494	9.22850	610.74	1.3342
0	14.0774	614.54	1.3881	11.1771	612.82	1.3592	9.2423	611.06	1.3349
20	14.7635	625.30	1.4111	11.7383	623.86	1.3827	9.7206	622.39	1.3591
40	15.4385	635.94	1.4328	12.2881	634.72	1.4049	10.1872	633.49	1.3817
60	16.1051	646.51	1.4535	12.8291	645.46	1.4260	10.6447	644.41	1.4032
80	16.7651	657.02	1.4734	13.3634	656.12	1.4461	11.0954	655.21	1.4236
100	17.4200	667.51	1.4925	13.8926	666.73	1.4654	11.5407	665.93	1.4431
120	18.0709	678.01	1.5109	14.4176	677.32	1.4840	11.9820	676.62	1.4618
140	18.7187	688.53	1.5287	14.9395	687.91	1.5020	12.4200	687.29	1.4799
160	19.3640	699.09	1.5461	15.4589	698.54	1.5194	12.8554	697.98	1.4975
180	20.0073	709.71	1.5629	15.9763	709.20	1.5363	13.2888	708.70	1.5145
200	20.6491	720.39	1.5794	16.4920	719.93	1.5528	13.7206	719.47	1.5311
220	21.2895	731.14	1.5954	17.0065	730.72	1.5689	14.1511	730.29	1.5472
240	21.9288	741.97	1.6111	17.5198	741.58	1.5847	14.5804	741.19	1.5630
260	22.5673	752.88	1.6265	18.0322	752.52	1.6001	15.0088	752.16	1.5785
280	23.2049	763.89	1.6416	18.5439	763.55	1.6152	15.4365	763.21	1.5936
300	23.8419	774.99	1.6564	19.0548	774.67	1.6301	15.8634	774.36	1.6085
320	24.4783	786.18	1.6709	19.5652	785.89	1.6446	16.2898	785.59	1.6231

TABLE F.8.2 (continued)  
Superheated Ammonia

Temp. F	$v$ ft <sup>3</sup> /lbm	$h$ Btu/lbm	$s$ Btu/lbm R	$v$ ft <sup>3</sup> /lbm	$h$ Btu/lbm	$s$ Btu/lbm R	$v$ ft <sup>3</sup> /lbm	$h$ Btu/lbm	$s$ Btu/lbm R
	35 psia (5.89 F)			40 psia (11.66 F)			50 psia (21.66 F)		
Sat.	7.98414	612.73	1.3214	7.04135	614.45	1.3103	5.70491	617.30	1.2917
20	8.2786	620.90	1.3387	7.1964	619.39	1.3206	—	—	—
40	8.6860	632.23	1.3618	7.5596	630.96	1.3443	5.9814	628.37	1.3142
60	9.0841	643.34	1.3836	7.9132	642.26	1.3665	6.2731	640.07	1.3372
80	9.4751	654.29	1.4043	8.2596	653.37	1.3874	6.5573	651.49	1.3588
100	9.8606	665.14	1.4240	8.6004	664.33	1.4074	6.8356	662.70	1.3792
120	10.2420	675.92	1.4430	8.9370	675.21	1.4265	7.1096	673.79	1.3986
140	10.6202	686.67	1.4612	9.2702	686.04	1.4449	7.3800	684.78	1.4173
160	10.9957	697.42	1.4788	9.6008	696.86	1.4626	7.6478	695.73	1.4352
180	11.3692	708.19	1.4959	9.9294	707.69	1.4798	7.9135	706.67	1.4526
200	11.7410	719.01	1.5126	10.2562	718.54	1.4965	8.1775	717.61	1.4695
220	12.1115	729.87	1.5288	10.5817	729.44	1.5128	8.4400	728.59	1.4859
240	12.4808	740.80	1.5447	10.9061	741.40	1.5287	8.7014	739.62	1.5018
260	12.8493	751.80	1.5602	11.2296	751.43	1.5442	8.9619	750.70	1.5175
280	13.2169	762.88	1.5753	11.5522	762.54	1.5594	9.2216	761.86	1.5327
300	13.5838	774.04	1.5902	11.8741	773.72	1.5744	9.4805	773.09	1.5477
320	13.9502	785.29	1.6049	12.1955	785.00	1.5890	9.7389	784.40	1.5624
340	14.3160	796.64	1.6192	12.5163	796.36	1.6034	9.9967	795.80	1.5769
	60 psia (30.19 F)			70 psia (37.68 F)			80 psia (44.38 F)		
Sat.	4.80091	619.57	1.2764	4.14732	621.44	1.2635	3.65200	623.02	1.2523
40	4.9277	625.69	1.2888	4.1738	622.94	1.2665	—	—	—
60	5.1787	637.82	1.3126	4.3961	635.52	1.2912	3.8083	633.16	1.2721
80	5.4217	649.57	1.3348	4.6099	647.62	1.3140	4.0005	645.63	1.2956
100	5.6586	661.05	1.3557	4.8174	659.37	1.3354	4.1861	657.66	1.3175
120	5.8909	672.34	1.3755	5.0201	670.88	1.3556	4.3667	669.39	1.3381
140	6.1197	683.50	1.3944	5.2191	682.21	1.3749	4.5435	680.90	1.3577
160	6.3456	694.59	1.4126	5.4153	693.44	1.3933	4.7174	692.27	1.3763
180	6.5694	705.64	1.4302	5.6093	704.60	1.4110	4.8890	703.55	1.3942
200	6.7915	716.68	1.4472	5.8014	715.73	1.4281	5.0588	714.79	1.4115
220	7.0121	727.73	1.4637	5.9921	726.87	1.4448	5.2270	726.00	1.4283
240	7.2316	738.83	1.4798	6.1816	738.03	1.4610	5.3941	737.23	1.4446
260	7.4501	749.97	1.4955	6.3702	749.23	1.4767	5.5602	748.50	1.4604
280	7.6678	761.17	1.5108	6.5579	760.49	1.4922	5.7254	759.80	1.4759
300	7.8848	772.45	1.5259	6.7449	771.81	1.5073	5.8900	771.17	1.4911
320	8.1011	783.80	1.5406	6.9313	783.21	1.5221	6.0538	782.61	1.5059
340	8.3169	795.24	1.5551	7.1171	794.68	1.5366	6.2172	794.12	1.5205
360	8.5323	806.77	1.5693	7.3025	806.24	1.5509	6.3801	805.71	1.5348

**TABLE F.8.2** (continued)  
**Superheated Ammonia**

Temp. F	$v$ ft <sup>3</sup> /lbm	$h$ Btu/lbm	$s$ Btu/lbm R	$v$ ft <sup>3</sup> /lbm	$h$ Btu/lbm	$s$ Btu/lbm R	$v$ ft <sup>3</sup> /lbm	$h$ Btu/lbm	$s$ Btu/lbm R
	90 psia (50.45 F)			100 psia (56.02 F)			125 psia (68.28 F)		
Sat.	3.26324	624.36	1.2423	2.94969	625.52	1.2334	2.37866	627.80	1.2143
60	3.3503	630.74	1.2547	2.9831	628.25	1.2387	—	—	—
80	3.5260	643.59	1.2790	3.1459	641.51	1.2637	2.4597	636.11	1.2299
100	3.6947	655.92	1.3014	3.3013	654.16	1.2867	2.5917	649.59	1.2544
120	3.8583	667.88	1.3224	3.4513	666.36	1.3082	2.7177	662.44	1.2770
140	4.0179	679.58	1.3423	3.5972	678.24	1.3283	2.8392	674.83	1.2980
160	4.1745	691.10	1.3612	3.7400	689.91	1.3475	2.9574	686.90	1.3178
180	4.3287	702.50	1.3793	3.8804	701.44	1.3658	3.0730	698.74	1.3366
200	4.4811	713.83	1.3967	4.0188	712.87	1.3834	3.1865	710.44	1.3546
220	4.6319	725.13	1.4136	4.1558	724.25	1.4004	3.2985	722.04	1.3720
240	4.7816	736.43	1.4300	4.2915	735.63	1.4169	3.4091	733.59	1.3887
260	4.9302	747.75	1.4459	4.4261	747.01	1.4329	3.5187	745.13	1.4050
280	5.0779	759.11	1.4615	4.5599	758.42	1.4485	3.6274	756.68	1.4208
300	5.2250	770.53	1.4767	4.6930	769.88	1.4638	3.7353	768.27	1.4362
320	5.3714	782.01	1.4916	4.8254	781.40	1.4788	3.8426	779.89	1.4514
340	5.5173	793.56	1.5063	4.9573	792.99	1.4935	3.9493	791.58	1.4662
360	5.6626	805.18	1.5206	5.0887	804.66	1.5079	4.0555	803.33	1.4807
380	5.8076	816.90	1.5348	5.2196	816.40	1.5220	4.1613	815.15	1.4949
	150 psia (78.79 F)			175 psia (88.03 F)			200 psia (96.31 F)		
Sat.	1.99226	629.45	1.1986	1.71282	630.64	1.1850	1.50102	631.49	1.1731
80	1.9997	630.36	1.2003	—	—	—	—	—	—
100	2.1170	644.81	1.2265	1.7762	639.77	1.2015	1.5190	634.45	1.1785
120	2.2275	658.37	1.2504	1.8762	654.13	1.2267	1.6117	649.71	1.2052
140	2.3331	671.31	1.2723	1.9708	667.67	1.2497	1.6984	663.90	1.2293
160	2.4351	683.80	1.2928	2.0614	680.62	1.2710	1.7807	677.36	1.2514
180	2.5343	695.99	1.3122	2.1491	693.17	1.2909	1.8598	690.30	1.2719
200	2.6313	707.96	1.3306	2.2345	705.44	1.3098	1.9365	702.87	1.2913
220	2.7267	719.79	1.3483	2.3181	717.51	1.3278	2.0114	715.20	1.3097
240	2.8207	731.54	1.3653	2.4002	729.46	1.3451	2.0847	727.35	1.3273
260	2.9136	743.24	1.3818	2.4813	741.33	1.3619	2.1569	739.39	1.3443
280	3.0056	754.93	1.3978	2.5613	753.16	1.3781	2.2280	751.38	1.3607
300	3.0968	766.63	1.4134	2.6406	764.99	1.3939	2.2984	763.33	1.3767
320	3.1873	778.37	1.4287	2.7192	776.84	1.4092	2.3680	775.30	1.3922
340	3.2772	790.15	1.4436	2.7972	788.72	1.4243	2.4370	787.28	1.4074
360	3.3667	801.99	1.4582	2.8746	800.65	1.4390	2.5056	799.30	1.4223
380	3.4557	813.90	1.4726	2.9516	812.64	1.4535	2.5736	811.38	1.4368
400	3.5442	825.88	1.4867	3.0282	824.70	1.4677	2.6412	823.51	1.4511

TABLE F.8.2 (continued)  
Superheated Ammonia

Temp. F	$v$ ft <sup>3</sup> /lbm	$h$ Btu/lbm	$s$ Btu/lbm R	$v$ ft <sup>3</sup> /lbm	$h$ Btu/lbm	$s$ Btu/lbm R	$v$ ft <sup>3</sup> /lbm	$h$ Btu/lbm	$s$ Btu/lbm R
	250 psia (110.78 F)			300 psia (123.20 F)			350 psia (134.14 F)		
Sat.	1.20063	632.43	1.1528	0.99733	632.63	1.1356	0.85027	632.28	1.1205
120	1.2384	640.21	1.1663	—	—	—	—	—	—
140	1.3150	655.95	1.1930	1.0568	647.32	1.1605	0.8696	637.87	1.1299
160	1.3863	670.53	1.2170	1.1217	663.27	1.1866	0.9309	655.48	1.1588
180	1.4539	684.34	1.2389	1.1821	678.07	1.2101	0.9868	671.46	1.1842
200	1.5188	697.59	1.2593	1.2394	692.08	1.2317	1.0391	686.34	1.2071
220	1.5815	710.45	1.2785	1.2943	705.55	1.2518	1.0886	700.47	1.2282
240	1.6426	723.05	1.2968	1.3474	718.63	1.2708	1.1362	714.08	1.2479
260	1.7024	735.46	1.3142	1.3991	731.44	1.2888	1.1822	727.32	1.2666
280	1.7612	747.76	1.3311	1.4497	744.07	1.3062	1.2270	740.31	1.2844
300	1.8191	759.98	1.3474	1.4994	756.58	1.3228	1.2708	753.12	1.3015
320	1.8762	772.18	1.3633	1.5482	769.02	1.3390	1.3138	765.82	1.3180
340	1.9328	784.37	1.3787	1.5965	781.43	1.3547	1.3561	778.46	1.3340
360	1.9887	796.59	1.3938	1.6441	793.84	1.3701	1.3979	791.07	1.3496
380	2.0442	808.83	1.4085	1.6913	806.27	1.3850	1.4391	803.67	1.3648
400	2.0993	821.13	1.4230	1.7380	818.72	1.3997	1.4798	816.30	1.3796
420	2.1540	833.48	1.4372	1.7843	831.23	1.4141	1.5202	828.95	1.3942
440	2.2083	845.90	1.4512	1.8302	843.78	1.4282	1.5602	841.65	1.4085
	400 psia (143.97 F)			600 psia (175.93 F)			800 psia (200.65 F)		
Sat.	0.73876	631.50	1.1070	0.47311	625.39	1.0620	0.33575	615.67	1.0242
160	0.7860	647.06	1.1324	—	—	—	—	—	—
180	0.8392	664.44	1.1601	0.4834	630.48	1.0700	—	—	—
200	0.8880	680.32	1.1845	0.5287	652.67	1.1041	—	—	—
220	0.9338	695.21	1.2067	0.5680	671.78	1.1327	0.3769	642.62	1.0645
240	0.9773	709.40	1.2273	0.6035	689.03	1.1577	0.4115	665.08	1.0971
260	1.0192	723.10	1.2466	0.6366	705.06	1.1803	0.4419	684.62	1.1246
280	1.0597	736.47	1.2650	0.6678	720.26	1.2011	0.4694	702.36	1.1489
300	1.0992	749.60	1.2825	0.6976	734.88	1.2206	0.4951	718.93	1.1710
320	1.1379	762.58	1.2993	0.7264	749.09	1.2391	0.5193	734.69	1.1915
340	1.1758	775.45	1.3156	0.7542	763.02	1.2567	0.5425	749.89	1.2108
360	1.2131	788.27	1.3315	0.7814	776.75	1.2737	0.5648	764.68	1.2290
380	1.2499	801.06	1.3469	0.8079	790.34	1.2901	0.5864	779.19	1.2465
400	1.2862	813.85	1.3619	0.8340	803.86	1.3060	0.6074	793.50	1.2634
420	1.3221	826.66	1.3767	0.8595	817.32	1.3215	0.6279	807.68	1.2797
440	1.3576	839.51	1.3911	0.8847	830.76	1.3366	0.6480	821.76	1.2955
460	1.3928	852.39	1.4053	0.9095	844.21	1.3514	0.6677	835.80	1.3109
480	1.4277	865.34	1.4192	0.9340	857.67	1.3658	0.6871	849.80	1.3260



TABLE F.9

*Thermodynamic Properties of R-410a*

TABLE F.9.1

*Saturated R-410a*

Temp. (F)	Press. (psia)	Specific Volume, ft <sup>3</sup> /lbm			Internal Energy, Btu/lbm		
		Sat. Liquid $v_f$	Evap. $v_{fg}$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Evap. $u_{fg}$	Sat. Vapor $u_g$
−80	8.196	0.01158	6.6272	6.6388	−13.12	111.09	97.97
−70	11.152	0.01173	4.9609	4.9726	−9.88	108.94	99.07
−60.5	14.696	0.01187	3.8243	3.8362	−6.78	106.88	100.09
−60	14.905	0.01188	3.7736	3.7855	−6.62	106.77	100.15
−50	19.598	0.01204	2.9123	2.9243	−3.35	104.55	101.20
−40	25.387	0.01220	2.2770	2.2892	−0.06	102.30	102.24
−30	32.436	0.01237	1.8011	1.8135	3.26	100.00	103.25
−20	40.923	0.01255	1.4397	1.4522	6.60	97.65	104.24
−10	51.034	0.01275	1.1615	1.1742	9.96	95.23	105.20
0	62.967	0.01295	0.9448	0.9578	13.37	92.75	106.12
10	76.926	0.01316	0.7741	0.7873	16.81	90.20	107.00
20	93.128	0.01339	0.6382	0.6516	20.29	87.55	107.84
30	111.796	0.01364	0.5289	0.5426	23.82	84.81	108.63
40	133.163	0.01391	0.4402	0.4541	27.41	81.95	109.36
50	157.473	0.01420	0.3676	0.3818	31.06	78.96	110.02
60	184.980	0.01451	0.3076	0.3221	34.78	75.82	110.59
70	215.951	0.01486	0.2576	0.2724	38.57	72.50	111.07
80	250.665	0.01525	0.2156	0.2308	42.46	68.97	111.44
90	289.421	0.01569	0.1800	0.1957	46.46	65.20	111.66
100	332.541	0.01619	0.1495	0.1657	50.59	61.12	111.70
110	380.377	0.01679	0.1231	0.1399	54.88	56.64	111.52
120	433.323	0.01750	0.1000	0.1175	59.37	51.65	111.02
130	491.841	0.01841	0.0792	0.0976	64.18	45.92	110.09
140	556.488	0.01966	0.0599	0.0796	69.46	38.99	108.46
150	627.997	0.02170	0.0405	0.0622	75.78	29.65	105.43
160	707.371	0.03054	0.0080	0.0385	88.87	6.57	95.44
160.4	710.859	0.03490	0	0.0349	92.77	0	92.77

TABLE F.9.1 (continued)  
Saturated R-410a

Temp. (F)	Press. (psia)	Enthalpy, Btu/lbm			Entropy, Btu/lbm R		
		Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$
-80	8.196	-13.10	121.14	108.04	-0.0327	0.3191	0.2864
-70	11.152	-9.85	119.18	109.33	-0.0243	0.3059	0.2816
-60.5	14.696	-6.75	117.28	110.52	-0.0164	0.2938	0.2774
-60	14.905	-6.59	117.17	110.59	-0.0160	0.2932	0.2772
-50	19.598	-3.30	115.11	111.81	-0.0079	0.2810	0.2731
-40	25.387	0	113.00	113.00	0	0.2692	0.2692
-30	32.436	3.33	110.81	114.14	0.0078	0.2579	0.2657
-20	40.923	6.69	108.55	115.24	0.0155	0.2469	0.2624
-10	51.034	10.08	106.20	116.29	0.0231	0.2362	0.2592
0	62.967	13.52	103.76	117.28	0.0306	0.2257	0.2563
10	76.926	17.00	101.22	118.21	0.0380	0.2155	0.2535
20	93.128	20.52	98.55	119.07	0.0453	0.2055	0.2508
30	111.796	24.11	95.75	119.85	0.0526	0.1955	0.2482
40	133.163	27.75	92.80	120.55	0.0599	0.1857	0.2456
50	157.473	31.47	89.67	121.14	0.0671	0.1759	0.2431
60	184.980	35.27	86.35	121.62	0.0744	0.1662	0.2405
70	215.951	39.17	82.79	121.96	0.0816	0.1563	0.2379
80	250.665	43.17	78.97	122.14	0.0889	0.1463	0.2353
90	289.421	47.30	74.84	122.14	0.0963	0.1361	0.2325
100	332.541	51.58	70.31	121.90	0.1038	0.1256	0.2294
110	380.377	56.06	65.31	121.36	0.1115	0.1146	0.2261
120	433.323	60.78	59.66	120.44	0.1194	0.1029	0.2223
130	491.841	65.85	53.12	118.97	0.1277	0.0901	0.2178
140	556.488	71.49	45.16	116.65	0.1368	0.0753	0.2121
150	627.997	78.30	34.36	112.65	0.1476	0.0564	0.2040
160	707.371	92.87	7.62	100.49	0.1707	0.0123	0.1830
160.4	710.859	97.36	0	97.36	0.1779	0	0.1779

**TABLE F.9.2**  
**Superheated R-410a**

Temp. (F)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)
5 psia (−94.86 F)					10 psia (−73.61 F)			
Sat.	10.5483	96.32	106.08	0.2943	5.5087	98.67	108.87	0.2833
−80	11.0228	98.45	108.65	0.3012	—	—	—	—
−60	11.6486	101.31	112.09	0.3100	5.7350	100.75	111.37	0.2896
−40	12.2654	104.21	115.56	0.3185	6.0583	103.77	114.98	0.2985
−20	12.8764	107.16	119.07	0.3266	6.3746	106.80	118.60	0.3069
0	13.4834	110.17	122.64	0.3346	6.6864	109.87	122.24	0.3150
20	14.0874	113.24	126.27	0.3423	6.9950	112.98	125.93	0.3228
40	14.6893	116.39	129.98	0.3499	7.3014	116.16	129.67	0.3305
60	15.2895	119.61	133.75	0.3573	7.6060	119.41	133.49	0.3379
80	15.8884	122.90	137.60	0.3646	7.9093	122.73	137.37	0.3453
100	16.4863	126.28	141.53	0.3717	8.2115	126.12	141.32	0.3525
120	17.0832	129.73	145.54	0.3787	8.5128	129.59	145.34	0.3595
140	17.6795	133.26	149.62	0.3857	8.8134	133.14	149.44	0.3665
160	18.2752	136.88	153.78	0.3925	9.1135	136.76	153.62	0.3733
180	18.8704	140.57	158.03	0.3992	9.4130	140.46	157.88	0.3801
200	19.4653	144.34	162.35	0.4059	9.7121	144.24	162.21	0.3868
220	20.0597	148.19	166.75	0.4125	10.0109	148.10	166.62	0.3934
15 psia (−59.77 F)					20 psia (−49.24 F)			
Sat.	3.7630	100.17	110.61	0.2771	2.8688	101.28	111.90	0.2728
−40	3.9875	103.31	114.37	0.2862	2.9506	102.81	113.73	0.2772
−20	4.2063	106.43	118.10	0.2949	3.1214	106.04	117.59	0.2862
0	4.4201	109.56	121.83	0.3032	3.2865	109.24	121.41	0.2946
20	4.6305	112.72	125.58	0.3112	3.4479	112.46	125.22	0.3027
40	4.8385	115.94	129.37	0.3189	3.6068	115.71	129.06	0.3106
60	5.0447	119.21	133.22	0.3265	3.7638	119.01	132.94	0.3182
80	5.2495	122.55	137.13	0.3339	3.9194	122.38	136.88	0.3257
100	5.4531	125.97	141.10	0.3411	4.0739	125.81	140.88	0.3329
120	5.6559	129.45	145.15	0.3482	4.2274	129.31	144.95	0.3401
140	5.8580	133.01	149.27	0.3552	4.3803	132.88	149.09	0.3471
160	6.0595	136.64	153.46	0.3621	4.5325	136.52	153.30	0.3540
180	6.2605	140.35	157.73	0.3688	4.6842	140.25	157.58	0.3608
200	6.4611	144.14	162.08	0.3755	4.8355	144.04	161.94	0.3675
220	6.6613	148.01	166.50	0.3821	4.9865	147.91	166.37	0.3741
240	6.8613	151.95	170.99	0.3887	5.1372	151.86	170.88	0.3807
260	7.0609	155.97	175.57	0.3951	5.2876	155.89	175.46	0.3871

TABLE F.9.2 (continued)  
Superheated R-410a

Temp. (F)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)
30 psia (−33.24 F)					40 psia (−21.00 F)			
Sat.	1.9534	102.93	113.77	0.2668	1.4843	104.14	115.13	0.2627
−20	2.0347	105.22	116.52	0.2732	1.4892	104.33	115.35	0.2632
0	2.1518	108.59	120.53	0.2821	1.5833	107.89	119.61	0.2727
20	2.2647	111.91	124.48	0.2905	1.6723	111.34	123.72	0.2814
40	2.3747	115.24	128.43	0.2986	1.7581	114.76	127.78	0.2897
60	2.4827	118.61	132.39	0.3063	1.8418	118.19	131.83	0.2977
80	2.5892	122.02	136.39	0.3139	1.9238	121.66	135.90	0.3053
100	2.6944	125.49	140.45	0.3213	2.0045	125.17	140.00	0.3128
120	2.7988	129.02	144.56	0.3285	2.0844	128.73	144.16	0.3201
140	2.9024	132.62	148.73	0.3356	2.1634	132.36	148.37	0.3273
160	3.0054	136.29	152.97	0.3425	2.2418	136.05	152.64	0.3343
180	3.1079	140.03	157.28	0.3494	2.3197	139.81	156.98	0.3412
200	3.2099	143.84	161.66	0.3561	2.3971	143.64	161.38	0.3479
220	3.3116	147.73	166.11	0.3628	2.4742	147.54	165.86	0.3546
240	3.4130	151.69	170.64	0.3693	2.5510	151.52	170.40	0.3612
260	3.5142	155.73	175.23	0.3758	2.6275	155.56	175.01	0.3677
280	3.6151	159.83	179.90	0.3822	2.7037	159.68	179.69	0.3741
60 psia (−2.34 F)					75 psia (8.71 F)			
Sat.	1.0038	105.91	117.05	0.2570	0.8071	106.89	118.09	0.2538
0	1.0120	106.37	117.60	0.2582	—	—	—	—
20	1.0783	110.13	122.11	0.2678	0.8393	109.15	120.80	0.2595
40	1.1405	113.76	126.42	0.2766	0.8926	112.96	125.35	0.2688
60	1.2001	117.34	130.66	0.2849	0.9429	116.66	129.75	0.2775
80	1.2579	120.91	134.88	0.2929	0.9911	120.33	134.09	0.2857
100	1.3143	124.51	139.10	0.3005	1.0379	124.00	138.40	0.2935
120	1.3696	128.14	143.35	0.3080	1.0835	127.69	142.73	0.3011
140	1.4242	131.83	147.64	0.3153	1.1283	131.42	147.08	0.3085
160	1.4780	135.57	151.98	0.3224	1.1724	135.20	151.47	0.3157
180	1.5313	139.37	156.37	0.3294	1.2159	139.03	155.90	0.3227
200	1.5842	143.23	160.82	0.3362	1.2590	142.92	160.39	0.3296
220	1.6367	147.16	165.34	0.3430	1.3016	146.88	164.94	0.3364
240	1.6888	151.16	169.92	0.3496	1.3439	150.90	169.55	0.3431
260	1.7407	155.23	174.56	0.3561	1.3860	154.99	174.22	0.3497
280	1.7924	159.37	179.27	0.3626	1.4278	159.14	178.96	0.3562
300	1.8438	163.58	184.05	0.3690	1.4694	163.36	183.76	0.3626

**TABLE F.9.2** (continued)  
**Superheated R-410a**

Temp. (F)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)
100 psia (23.84 F)					125 psia (36.33 F)			
Sat.	0.6069	108.15	119.38	0.2498	0.4845	109.10	120.31	0.2465
40	0.6433	111.53	123.43	0.2580	0.4918	109.93	121.30	0.2485
60	0.6848	115.48	128.16	0.2673	0.5288	114.21	126.44	0.2586
80	0.7238	119.32	132.72	0.2759	0.5626	118.26	131.28	0.2677
100	0.7611	123.12	137.21	0.2840	0.5945	122.21	135.96	0.2763
120	0.7971	126.92	141.67	0.2919	0.6250	126.11	140.57	0.2844
140	0.8323	130.73	146.13	0.2994	0.6544	130.01	145.15	0.2921
160	0.8666	134.57	150.61	0.3068	0.6830	133.93	149.73	0.2996
180	0.9004	138.46	155.12	0.3140	0.7109	137.88	154.32	0.3069
200	0.9336	142.40	159.68	0.3210	0.7384	141.87	158.95	0.3141
220	0.9665	146.39	164.28	0.3278	0.7654	145.91	163.61	0.3210
240	0.9990	150.45	168.94	0.3346	0.7920	150.00	168.32	0.3278
260	1.0312	154.57	173.65	0.3412	0.8184	154.15	173.08	0.3346
280	1.0632	158.75	178.43	0.3478	0.8445	158.36	177.89	0.3411
300	1.0950	163.00	183.26	0.3542	0.8703	162.63	182.76	0.3476
320	1.1266	167.31	188.16	0.3606	0.8960	166.96	187.69	0.3540
340	1.1580	171.69	193.12	0.3669	0.9215	171.36	192.68	0.3604
150 psia (47.06 F)					175 psia (56.51 F)			
Sat.	0.4016	109.83	120.98	0.2438	0.3417	110.40	121.47	0.2414
60	0.4236	112.82	124.58	0.2508	0.3472	111.27	122.51	0.2434
80	0.4545	117.13	129.74	0.2606	0.3766	115.91	128.11	0.2540
100	0.4830	121.25	134.66	0.2695	0.4029	120.24	133.29	0.2634
120	0.5099	125.28	139.43	0.2779	0.4274	124.41	138.25	0.2721
140	0.5356	129.28	144.14	0.2859	0.4505	128.52	143.11	0.2804
160	0.5604	133.27	148.83	0.2936	0.4727	132.60	147.90	0.2882
180	0.5845	137.28	153.51	0.3010	0.4941	136.68	152.68	0.2958
200	0.6081	141.33	158.20	0.3082	0.5150	140.77	157.45	0.3032
220	0.6312	145.41	162.93	0.3153	0.5353	144.90	162.24	0.3103
240	0.6540	149.54	167.69	0.3222	0.5553	149.07	167.06	0.3173
260	0.6764	153.72	172.50	0.3290	0.5750	153.29	171.91	0.3241
280	0.6986	157.96	177.35	0.3356	0.5944	157.56	176.81	0.3309
300	0.7205	162.26	182.26	0.3422	0.6135	161.88	181.75	0.3375
320	0.7423	166.61	187.22	0.3486	0.6325	166.26	186.74	0.3439
340	0.7639	171.03	192.23	0.3550	0.6513	170.70	191.79	0.3503
360	0.7853	175.51	197.31	0.3612	0.6699	175.19	196.89	0.3566

TABLE F.9.2 (continued)  
Superheated R-410a

Temp. (F)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)
200 psia (65.00 F)					300 psia (92.55 F)			
Sat.	0.2962	110.85	121.81	0.2392	0.1876	111.69	122.10	0.2317
80	0.3174	114.59	126.34	0.2477	—	—	—	—
100	0.3424	119.17	131.84	0.2578	0.1967	113.96	124.88	0.2367
120	0.3652	123.51	137.02	0.2669	0.2176	119.37	131.45	0.2483
140	0.3865	127.73	142.04	0.2754	0.2356	124.26	137.34	0.2582
160	0.4068	131.90	146.96	0.2834	0.2519	128.90	142.89	0.2673
180	0.4262	136.05	151.83	0.2912	0.2671	133.41	148.24	0.2758
200	0.4451	140.21	156.68	0.2987	0.2815	137.84	153.47	0.2839
220	0.4634	144.39	161.54	0.3059	0.2952	142.25	158.63	0.2916
240	0.4813	148.60	166.41	0.3130	0.3084	146.64	163.77	0.2991
260	0.4989	152.85	171.32	0.3199	0.3212	151.05	168.89	0.3063
280	0.5162	157.15	176.26	0.3267	0.3337	155.49	174.01	0.3133
300	0.5333	161.50	181.24	0.3333	0.3460	159.95	179.16	0.3202
320	0.5502	165.90	186.26	0.3398	0.3580	164.45	184.33	0.3269
340	0.5668	170.36	191.34	0.3463	0.3698	169.00	189.53	0.3335
360	0.5834	174.88	196.47	0.3526	0.3814	173.60	194.77	0.3399
380	0.5997	179.45	201.65	0.3588	0.3929	178.24	200.05	0.3463
400 psia (113.82 F)					600 psia (146.21 F)			
Sat.	0.1310	111.37	121.06	0.2247	0.0688	106.83	114.47	0.2075
120	0.1383	113.71	123.95	0.2297	—	—	—	—
140	0.1574	120.01	131.66	0.2428	—	—	—	—
160	0.1729	125.42	138.22	0.2536	0.0871	115.40	125.06	0.2248
180	0.1865	130.44	144.25	0.2632	0.1026	122.94	134.33	0.2396
200	0.1990	135.25	149.98	0.2720	0.1146	129.11	141.83	0.2511
220	0.2106	139.94	155.53	0.2803	0.1249	134.69	148.55	0.2612
240	0.2216	144.57	160.97	0.2882	0.1342	139.96	154.85	0.2703
260	0.2322	149.16	166.35	0.2957	0.1427	145.05	160.89	0.2788
280	0.2424	153.75	171.69	0.3031	0.1508	150.03	166.77	0.2869
300	0.2522	158.34	177.02	0.3102	0.1584	154.95	172.53	0.2946
320	0.2619	162.96	182.34	0.3171	0.1657	159.83	178.23	0.3020
340	0.2713	167.61	187.69	0.3238	0.1728	164.71	183.89	0.3091
360	0.2805	172.29	193.05	0.3305	0.1796	169.58	189.52	0.3161
380	0.2895	177.01	198.44	0.3370	0.1863	174.47	195.15	0.3229
400	0.2985	181.77	203.86	0.3434	0.1928	179.39	200.79	0.3295
420	0.3073	186.58	209.32	0.3496	0.1991	184.33	206.44	0.3360

**TABLE F.10**  
**Thermodynamic Properties of R-134a**

**TABLE F.10.1**  
**Saturated R-134a**

Temp. (F)	Press. (psia)	Specific Volume, ft <sup>3</sup> /lbm			Internal Energy, Btu/lbm		
		Sat. Liquid $v_f$	Evap. $v_{fg}$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Evap. $u_{fg}$	Sat. Vapor $u_g$
−100	0.951	0.01077	39.5032	39.5139	50.47	94.15	144.62
−90	1.410	0.01083	27.3236	27.3345	52.03	93.89	145.92
−80	2.047	0.01091	19.2731	19.2840	53.96	93.27	147.24
−70	2.913	0.01101	13.8538	13.8648	56.19	92.38	148.57
−60	4.067	0.01111	10.1389	10.1501	58.64	91.26	149.91
−50	5.575	0.01122	7.5468	7.5580	61.27	89.99	151.26
−40	7.511	0.01134	5.7066	5.7179	64.04	88.58	152.62
−30	9.959	0.01146	4.3785	4.3900	66.90	87.09	153.99
−20	13.009	0.01159	3.4049	3.4165	69.83	85.53	155.36
−15.3	14.696	0.01166	3.0350	3.0466	71.25	84.76	156.02
−10	16.760	0.01173	2.6805	2.6922	72.83	83.91	156.74
0	21.315	0.01187	2.1340	2.1458	75.88	82.24	158.12
10	26.787	0.01202	1.7162	1.7282	78.96	80.53	159.50
20	33.294	0.01218	1.3928	1.4050	82.09	78.78	160.87
30	40.962	0.01235	1.1398	1.1521	85.25	76.99	162.24
40	49.922	0.01253	0.9395	0.9520	88.45	75.16	163.60
50	60.311	0.01271	0.7794	0.7921	91.68	73.27	164.95
60	72.271	0.01291	0.6503	0.6632	94.95	71.32	166.28
70	85.954	0.01313	0.5451	0.5582	98.27	69.31	167.58
80	101.515	0.01335	0.4588	0.4721	101.63	67.22	168.85
90	119.115	0.01360	0.3873	0.4009	105.04	65.04	170.09
100	138.926	0.01387	0.3278	0.3416	108.51	62.77	171.28
110	161.122	0.01416	0.2777	0.2919	112.03	60.38	172.41
120	185.890	0.01448	0.2354	0.2499	115.62	57.85	173.48
130	213.425	0.01483	0.1993	0.2142	119.29	55.17	174.46
140	243.932	0.01523	0.1684	0.1836	123.04	52.30	175.34
150	277.630	0.01568	0.1415	0.1572	126.89	49.21	176.11
160	314.758	0.01620	0.1181	0.1343	130.86	45.85	176.71
170	355.578	0.01683	0.0974	0.1142	134.99	42.12	177.11
180	400.392	0.01760	0.0787	0.0963	139.32	37.91	177.23
190	449.572	0.01862	0.0614	0.0801	143.97	32.94	176.90
200	503.624	0.02013	0.0444	0.0645	149.19	26.59	175.79
210	563.438	0.02334	0.0238	0.0471	156.18	16.17	172.34
214.1	589.953	0.03153	0	0.0315	164.65	0	164.65

TABLE F.10.1 (continued)  
Saturated R-134a

Temp. (F)	Press. (psia)	Enthalpy, Btu/lbm			Entropy, Btu/lbm R		
		Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$
−100	0.951	50.47	101.10	151.57	0.1563	0.2811	0.4373
−90	1.410	52.04	101.02	153.05	0.1605	0.2733	0.4338
−80	2.047	53.97	100.58	154.54	0.1657	0.2649	0.4306
−70	2.913	56.19	99.85	156.04	0.1715	0.2562	0.4277
−60	4.067	58.65	98.90	157.55	0.1777	0.2474	0.4251
−50	5.575	61.29	97.77	159.06	0.1842	0.2387	0.4229
−40	7.511	64.05	96.52	160.57	0.1909	0.2300	0.4208
−30	9.959	66.92	95.16	162.08	0.1976	0.2215	0.4191
−20	13.009	69.86	93.72	163.59	0.2044	0.2132	0.4175
−15.3	14.696	71.28	93.02	164.30	0.2076	0.2093	0.4169
−10	16.760	72.87	92.22	165.09	0.2111	0.2051	0.4162
0	21.315	75.92	90.66	166.58	0.2178	0.1972	0.4150
10	26.787	79.02	89.04	168.06	0.2244	0.1896	0.4140
20	33.294	82.16	87.36	169.53	0.2310	0.1821	0.4132
30	40.962	85.34	85.63	170.98	0.2375	0.1749	0.4124
40	49.922	88.56	83.83	172.40	0.2440	0.1678	0.4118
50	60.311	91.82	81.97	173.79	0.2504	0.1608	0.4112
60	72.271	95.13	80.02	175.14	0.2568	0.1540	0.4108
70	85.954	98.48	77.98	176.46	0.2631	0.1472	0.4103
80	101.515	101.88	75.84	177.72	0.2694	0.1405	0.4099
90	119.115	105.34	73.58	178.92	0.2757	0.1339	0.4095
100	138.926	108.86	71.19	180.06	0.2819	0.1272	0.4091
110	161.122	112.46	68.66	181.11	0.2882	0.1205	0.4087
120	185.890	116.12	65.95	182.07	0.2945	0.1138	0.4082
130	213.425	119.88	63.04	182.92	0.3008	0.1069	0.4077
140	243.932	123.73	59.90	183.63	0.3071	0.0999	0.4070
150	277.630	127.70	56.49	184.18	0.3135	0.0926	0.4061
160	314.758	131.81	52.73	184.53	0.3200	0.0851	0.4051
170	355.578	136.09	48.53	184.63	0.3267	0.0771	0.4037
180	400.392	140.62	43.74	184.36	0.3336	0.0684	0.4020
190	449.572	145.52	38.05	183.56	0.3409	0.0586	0.3995
200	503.624	151.07	30.73	181.80	0.3491	0.0466	0.3957
210	563.438	158.61	18.65	177.26	0.3601	0.0278	0.3879
214.1	589.953	168.09	0	168.09	0.3740	0	0.3740



TABLE F.10.2

*Superheated R-134a*

Temp. (F)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)
5 psia (−53.51 F)					15 psia (−14.44 F)			
Sat.	8.3676	150.78	158.53	0.4236	2.9885	156.13	164.42	0.4168
−20	9.1149	156.03	164.47	0.4377	—	—	—	—
0	9.5533	159.27	168.11	0.4458	3.1033	158.58	167.19	0.4229
20	9.9881	162.58	171.83	0.4537	3.2586	162.01	171.06	0.4311
40	10.4202	165.99	175.63	0.4615	3.4109	165.51	174.97	0.4391
60	10.8502	169.48	179.52	0.4691	3.5610	169.07	178.95	0.4469
80	11.2786	173.06	183.50	0.4766	3.7093	172.70	183.00	0.4545
100	11.7059	176.73	187.56	0.4840	3.8563	176.41	187.12	0.4620
120	12.1322	180.49	191.71	0.4913	4.0024	180.20	191.31	0.4694
140	12.5578	184.33	195.95	0.4985	4.1476	184.08	195.59	0.4767
160	12.9828	188.27	200.28	0.5056	4.2922	188.03	199.95	0.4838
180	13.4073	192.29	204.69	0.5126	4.4364	192.07	204.39	0.4909
200	13.8314	196.39	209.19	0.5195	4.5801	196.19	208.91	0.4978
220	14.2551	200.58	213.77	0.5263	4.7234	200.40	213.51	0.5047
240	14.6786	204.86	218.44	0.5331	4.8665	204.68	218.19	0.5115
260	15.1019	209.21	223.19	0.5398	5.0093	209.05	222.96	0.5182
280	15.5250	213.65	228.02	0.5464	5.1519	213.50	227.80	0.5248
300	15.9478	218.17	232.93	0.5530	5.2943	218.03	232.72	0.5314
320	16.3706	222.78	237.92	0.5595	5.4365	222.64	237.73	0.5379
30 psia (15.15 F)					40 psia (28.83 F)			
Sat.	1.5517	160.21	168.82	0.4136	1.1787	162.08	170.81	0.4125
20	1.5725	161.09	169.82	0.4157	—	—	—	—
40	1.6559	164.73	173.93	0.4240	1.2157	164.18	173.18	0.4173
60	1.7367	168.41	178.05	0.4321	1.2796	167.95	177.42	0.4256
80	1.8155	172.14	182.21	0.4400	1.3413	171.74	181.67	0.4336
100	1.8929	175.92	186.43	0.4477	1.4015	175.57	185.95	0.4414
120	1.9691	179.77	190.70	0.4552	1.4604	179.46	190.27	0.4490
140	2.0445	183.68	195.03	0.4625	1.5184	183.41	194.65	0.4565
160	2.1192	187.68	199.44	0.4697	1.5757	187.43	199.09	0.4637
180	2.1933	191.74	203.92	0.4769	1.6324	191.52	203.60	0.4709
200	2.2670	195.89	208.48	0.4839	1.6886	195.69	208.18	0.4780
220	2.3403	200.12	213.11	0.4908	1.7444	199.93	212.84	0.4849
240	2.4133	204.42	217.82	0.4976	1.7999	204.24	217.57	0.4918
260	2.4860	208.80	222.61	0.5044	1.8552	208.64	222.37	0.4985
280	2.5585	213.27	227.47	0.5110	1.9102	213.11	227.25	0.5052
300	2.6309	217.81	232.41	0.5176	1.9650	217.66	232.20	0.5118
320	2.7030	222.42	237.43	0.5241	2.0196	222.28	237.23	0.5184
340	2.7750	227.12	242.53	0.5306	2.0741	226.99	242.34	0.5248
360	2.8469	231.89	247.70	0.5370	2.1285	231.76	247.52	0.5312

TABLE F.10.2 (continued)  
Superheated R-134a

Temp. (F)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)
60 psia (49.72 F)					80 psia (65.81 F)			
Sat.	0.7961	164.91	173.75	0.4113	0.5996	167.04	175.91	0.4105
60	0.8204	166.95	176.06	0.4157	—	—	—	—
80	0.8657	170.89	180.51	0.4241	0.6262	169.97	179.24	0.4168
100	0.9091	174.85	184.94	0.4322	0.6617	174.06	183.86	0.4252
120	0.9510	178.82	189.38	0.4400	0.6954	178.15	188.44	0.4332
140	0.9918	182.85	193.86	0.4476	0.7279	182.25	193.03	0.4410
160	1.0318	186.92	198.38	0.4550	0.7595	186.39	197.64	0.4485
180	1.0712	191.06	202.95	0.4623	0.7903	190.58	202.28	0.4559
200	1.1100	195.26	207.59	0.4694	0.8205	194.83	206.98	0.4632
220	1.1484	199.54	212.29	0.4764	0.8503	199.14	211.72	0.4702
240	1.1865	203.88	217.05	0.4833	0.8796	203.51	216.53	0.4772
260	1.2243	208.30	221.89	0.4902	0.9087	207.95	221.41	0.4841
280	1.2618	212.79	226.80	0.4969	0.9375	212.47	226.34	0.4909
300	1.2991	217.36	231.78	0.5035	0.9661	217.05	231.35	0.4975
320	1.3362	222.00	236.83	0.5101	0.9945	221.71	236.43	0.5041
340	1.3732	226.71	241.96	0.5166	1.0227	226.44	241.58	0.5107
360	1.4100	231.51	247.16	0.5230	1.0508	231.24	246.80	0.5171
380	1.4468	236.37	252.43	0.5294	1.0788	236.12	252.09	0.5235
400	1.4834	241.31	257.78	0.5357	1.1066	241.07	257.46	0.5298
100 psia (79.08 F)					125 psia (93.09 F)			
Sat.	0.4794	168.74	177.61	0.4100	0.3814	170.46	179.28	0.4094
80	0.4809	168.93	177.83	0.4104	—	—	—	—
100	0.5122	173.20	182.68	0.4192	0.3910	172.01	181.06	0.4126
120	0.5414	177.42	187.44	0.4276	0.4171	176.43	186.08	0.4214
140	0.5691	181.62	192.15	0.4356	0.4413	180.77	190.98	0.4297
160	0.5957	185.84	196.86	0.4433	0.4642	185.10	195.84	0.4377
180	0.6215	190.08	201.58	0.4508	0.4861	189.43	200.68	0.4454
200	0.6466	194.38	206.34	0.4581	0.5073	193.79	205.52	0.4529
220	0.6712	198.72	211.15	0.4653	0.5278	198.19	210.40	0.4601
240	0.6954	203.13	216.00	0.4723	0.5480	202.64	215.32	0.4673
260	0.7193	207.60	220.91	0.4792	0.5677	207.15	220.28	0.4743
280	0.7429	212.14	225.88	0.4861	0.5872	211.72	225.30	0.4811
300	0.7663	216.74	230.92	0.4928	0.6064	216.35	230.38	0.4879
320	0.7895	221.42	236.03	0.4994	0.6254	221.05	235.51	0.4946
340	0.8125	226.16	241.20	0.5060	0.6442	225.81	240.71	0.5012
360	0.8353	230.98	246.44	0.5124	0.6629	230.65	245.98	0.5077
380	0.8580	235.87	251.75	0.5188	0.6814	235.56	251.32	0.5141
400	0.8806	240.83	257.13	0.5252	0.6998	240.53	256.72	0.5205

TABLE F.10.2 (continued)  
*Superheated R-134a*

Temp. (F)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)
150 psia (105.13 F)					200 psia (125.25 F)			
Sat.	0.3150	171.87	180.61	0.4089	0.2304	174.00	182.53	0.4080
120	0.3332	175.33	184.57	0.4159	—	—	—	—
140	0.3554	179.85	189.72	0.4246	0.2459	177.72	186.82	0.4152
160	0.3761	184.31	194.75	0.4328	0.2645	182.54	192.33	0.4242
180	0.3955	188.74	199.72	0.4407	0.2814	187.23	197.64	0.4327
200	0.4141	193.18	204.67	0.4484	0.2971	191.86	202.85	0.4407
220	0.4321	197.64	209.63	0.4558	0.3120	196.46	208.01	0.4484
240	0.4496	202.14	214.62	0.4630	0.3262	201.08	213.15	0.4559
260	0.4666	206.69	219.64	0.4701	0.3400	205.72	218.31	0.4631
280	0.4833	211.29	224.70	0.4770	0.3534	210.40	223.48	0.4702
300	0.4998	215.95	229.82	0.4838	0.3664	215.13	228.69	0.4772
320	0.5160	220.67	235.00	0.4906	0.3792	219.91	233.94	0.4840
340	0.5320	225.46	240.23	0.4972	0.3918	224.74	239.24	0.4907
360	0.5479	230.32	245.52	0.5037	0.4042	229.64	244.60	0.4973
380	0.5636	235.24	250.88	0.5102	0.4165	234.60	250.01	0.5038
400	0.5792	240.23	256.31	0.5166	0.4286	239.62	255.48	0.5103
250 psia (141.87 F)					300 psia (156.14 F)			
Sat.	0.1783	175.50	183.75	0.4068	0.1428	176.50	184.43	0.4055
160	0.1955	180.42	189.46	0.4162	0.1467	177.70	185.84	0.4078
180	0.2117	185.49	195.28	0.4255	0.1637	183.44	192.53	0.4184
200	0.2261	190.38	200.84	0.4340	0.1779	188.71	198.59	0.4278
220	0.2394	195.18	206.26	0.4421	0.1905	193.77	204.35	0.4364
240	0.2519	199.94	211.60	0.4498	0.2020	198.72	209.93	0.4445
260	0.2638	204.70	216.90	0.4573	0.2128	203.62	215.43	0.4522
280	0.2752	209.47	222.21	0.4646	0.2230	208.50	220.88	0.4597
300	0.2863	214.27	227.52	0.4717	0.2328	213.39	226.31	0.4669
320	0.2971	219.12	232.86	0.4786	0.2423	218.30	231.75	0.4740
340	0.3076	224.01	238.24	0.4854	0.2515	223.25	237.21	0.4809
360	0.3180	228.95	243.66	0.4921	0.2605	228.24	242.70	0.4877
380	0.3282	233.95	249.13	0.4987	0.2693	233.29	248.24	0.4944
400	0.3382	239.01	254.65	0.5052	0.2779	238.38	253.81	0.5009

TABLE F.10.2 (continued)

*Superheated R-134a*

Temp. (F)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)	$v$ (ft <sup>3</sup> /lbm)	$u$ (Btu/lbm)	$h$ (Btu/lbm)	$s$ (Btu/lbm R)
400 psia (179.92 F)					500 psia (199.36 F)			
Sat.	0.0965	177.23	184.37	0.4020	0.0655	175.90	181.96	0.3960
180	0.0966	177.26	184.41	0.4020	—	—	—	—
200	0.1146	184.44	192.92	0.4152	0.0666	176.38	182.54	0.3969
220	0.1277	190.41	199.86	0.4255	0.0867	185.78	193.80	0.4137
240	0.1386	195.92	206.19	0.4347	0.0990	192.46	201.62	0.4251
260	0.1484	201.21	212.20	0.4432	0.1089	198.40	208.47	0.4347
280	0.1573	206.38	218.03	0.4512	0.1174	204.00	214.86	0.4435
300	0.1657	211.49	223.76	0.4588	0.1252	209.41	220.99	0.4517
320	0.1737	216.58	229.44	0.4662	0.1323	214.74	226.98	0.4594
340	0.1813	221.68	235.09	0.4733	0.1390	220.01	232.87	0.4669
360	0.1886	226.79	240.75	0.4803	0.1454	225.27	238.73	0.4741
380	0.1957	231.93	246.42	0.4872	0.1516	230.53	244.56	0.4812
400	0.2027	237.12	252.12	0.4939	0.1575	235.82	250.39	0.4880
750 psia					1000 psia			
180	0.01640	136.22	138.49	0.3285	0.01593	134.77	137.71	0.3262
200	0.01786	144.85	147.32	0.3421	0.01700	142.70	145.84	0.3387
220	0.02069	155.27	158.14	0.3583	0.01851	151.26	154.69	0.3519
240	0.03426	173.83	178.58	0.3879	0.02102	160.95	164.84	0.3666
260	0.05166	187.78	194.95	0.4110	0.02603	172.59	177.40	0.3843
280	0.06206	196.16	204.77	0.4244	0.0341	184.70	191.01	0.4029
300	0.06997	203.08	212.79	0.4351	0.04208	194.58	202.37	0.4181
320	0.07662	209.37	220.00	0.4445	0.04875	202.67	211.69	0.4302
340	0.08250	215.33	226.78	0.4531	0.05441	209.79	219.86	0.4406
360	0.08786	221.11	233.30	0.4611	0.05938	216.36	227.35	0.4498
380	0.09284	226.78	239.66	0.4688	0.06385	222.61	234.43	0.4583
400	0.09753	232.39	245.92	0.4762	0.06797	228.67	241.25	0.4664

TABLE F.11

*Enthalpy of Formation and Absolute Entropy of Various Substances at 77 F, 1 atm Pressure*

Substance	Formula	M lbm/lbmol	State	$\bar{h}_f^0$ Btu/lbmol	$\bar{s}_f^0$ Btu/lbmol R
Acetylene	C <sub>2</sub> H <sub>2</sub>	26.038	gas	+97 477	47.972
Ammonia	NH <sub>3</sub>	17.031	gas	−19 656	45.969
Benzene	C <sub>6</sub> H <sub>6</sub>	78.114	gas	+35 675	64.358
Carbon dioxide	CO <sub>2</sub>	44.010	gas	−169 184	51.038
Carbon (graphite)	C	12.011	solid	0	1.371
Carbon monoxide	CO	28.011	gas	−47 518	47.182
Ethanol	C <sub>2</sub> H <sub>5</sub> OH	46.069	gas	−101 032	67.434
Ethanol	C <sub>2</sub> H <sub>5</sub> OH	46.069	liq	−119 252	38.321
Ethane	C <sub>2</sub> H <sub>6</sub>	30.070	gas	−36 432	54.812
Ethene	C <sub>2</sub> H <sub>4</sub>	28.054	gas	+22 557	52.360
Heptane	C <sub>7</sub> H <sub>16</sub>	100.205	gas	−80 782	102.153
Hexane	C <sub>6</sub> H <sub>14</sub>	86.178	gas	−71 926	92.641
Hydrogen peroxide	H <sub>2</sub> O <sub>2</sub>	34.015	gas	−58 515	55.623
Methane	CH <sub>4</sub>	16.043	gas	−32 190	44.459
Methanol	CH <sub>3</sub> OH	32.042	gas	−86 543	57.227
Methanol	CH <sub>3</sub> OH	32.042	liq	−102 846	30.261
<i>n</i> -Butane	C <sub>4</sub> H <sub>10</sub>	58.124	gas	−54 256	73.215
Nitrogen oxide	N <sub>2</sub> O	44.013	gas	+35 275	52.510
Nitromethane	CH <sub>3</sub> NO <sub>2</sub>	61.04	liq	−48 624	41.034
<i>n</i> -Octane	C <sub>8</sub> H <sub>18</sub>	114.232	gas	−89 682	111.399
<i>n</i> -Octane	C <sub>8</sub> H <sub>18</sub>	114.232	liq	−107 526	86.122
Ozone	O <sub>3</sub>	47.998	gas	+61 339	57.042
Pentane	C <sub>5</sub> H <sub>12</sub>	72.151	gas	−62 984	83.318
Propane	C <sub>3</sub> H <sub>8</sub>	44.094	gas	−44 669	64.442
Propene	C <sub>3</sub> H <sub>6</sub>	42.081	gas	+8 783	63.761
Sulfur	S	32.06	solid	0	7.656
Sulfur dioxide	SO <sub>2</sub>	64.059	gas	−127 619	59.258
Sulfur trioxide	SO <sub>3</sub>	80.058	gas	−170 148	61.302
T-T-Diesel	C <sub>14.4</sub> H <sub>24.9</sub>	198.06	liq	−74 807	125.609
Water	H <sub>2</sub> O	18.015	gas	−103 966	45.076
Water	H <sub>2</sub> O	18.015	liq	−122 885	16.707