



**UNIVERSITI KUALA LUMPUR**  
**MALAYSIAN INSTITUTE OF MARINE ENGINEERING TECHNOLOGY**

---

**FINAL EXAMINATION**  
**JANUARY 2017 SEMESTER**

---

**COURSE CODE** : LGB21803

**COURSE NAME** : THERMODYNAMICS 2

**PROGRAMME NAME** : BACHELOR OF ENGINEERING TECHNOLOGY (HONS)  
(FOR MPU: PROGRAMME LEVEL) IN MARINE ENGINEERING

**DATE** : 13/07/2017 THU

**TIME** : 9.00 AM - 12.00 PM

**DURATION** : 3 HOURS

---

**INSTRUCTIONS TO CANDIDATES**

---

1. Please read CAREFULLY the instructions given in the question paper.
  2. This question paper has information printed on both sides.
  3. This question paper consists of FIVE (5) questions. Answer FOUR (4) questions only.
  4. Please write yours answers on the answer booklet provided.
  5. Write your answers only in BLACK or BLUE ink.
  6. Answer all questions in English.
- 

**THERE ARE 6 PAGES OF QUESTIONS, INCLUDING THIS PAGE.**

---

## SECTION A (Total: 100 marks)

**INSTRUCTION: Answer only FOUR (4) questions.**

**Please use the answer booklet provided.**

**Question 1**

Figure 1 shows the steam enters a nozzle at  $400\text{ }^{\circ}\text{C}$  and  $800\text{ kPa}$  with a velocity  $10\text{ ms}^{-1}$ , and leaves at  $300\text{ }^{\circ}\text{C}$  and  $200\text{ kPa}$  while losing heat at a rate of  $25\text{ kW}$ . For an inlet area of  $800\text{ cm}^2$ .

- (a) State **THREE (3)** criteria's that required for Conservation of energy in above system. (3 marks)
- (b) Determine mass flow rate of the steam. (5 marks)
- (c) Determine velocity at nozzle exit. (10 marks)
- (d) Determine volume flow rate at nozzle exit. (7 marks)

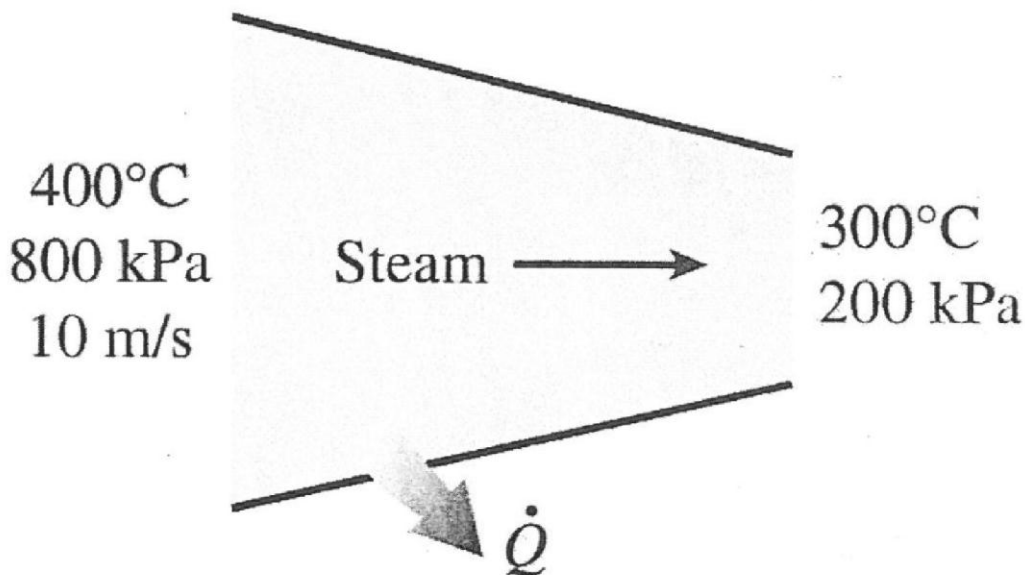


Figure 1

Question 2

A refrigerator uses refrigerant-134a as the working fluid and operates on the ideal vapor-compression refrigerant cycle except for the compression process shown at Figure 2. The refrigerants enter the evaporator at 120 kPa with a quality of 34% and leaves the compressor at 70°C. If the compressor consumes 450 W of power;

- (a) Determine the value of pressure,  $P_3$  by using the interpolation  
(Hint- Refer Table A-11 – A-13) (7 marks)
- (b) Determine the mass flow rate of the refrigerant. (8 marks)
- (c) Determine the condenser pressure. (8 marks)
- (d) Estimate the COP value. (2 marks)

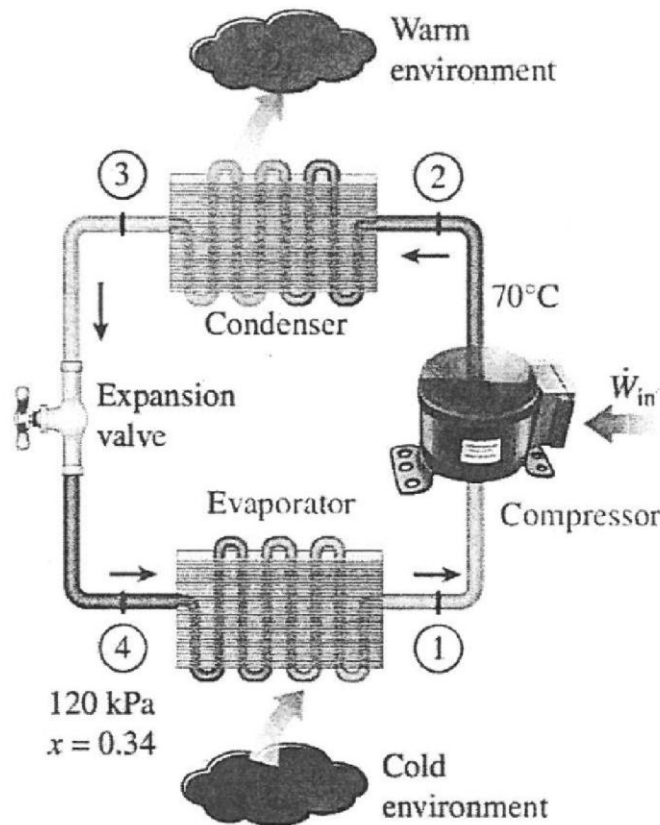


Figure 2

**Question 3**

A two stroke diesel engine was motored when the meter reading was 1.5 kW. Then the test on the engine was carried out for one hour and the following observation were recorded; Brake torque = 120Nm; Speed = 600rpm; Fuel used = 2.5 kg; calorific value of fuel = 40.3 MJ/kg; Cooling water used = 818 kg; Rise in temperature of cooling water = 10°C.

Exhaust gas temperature = 345°C. Room temperature = 25°C; Air/Fuel ratio = 32 : 1

- (a) Estimate break power of engine. (3 marks)
- (b) Determine the indicated power of engine. (4 marks)
- (c) Estimate mechanical efficiency of engine. (2 marks)
- (d) Determine indicated thermal efficiency. (6 marks)
- (e) Find the heat balance sheet in table form for energy balance (kJ/min) or percentage of energy supplied (%). (10 marks)

**Question 4**

- (a) A vessel contains 0.3m<sup>3</sup> of methane at 60°C and 500 kPa pressure. Calculate the mass of methane. Given Molar mass of methane  $M_m=16$ , gas constant  $R=8.314\text{kJ/Kg.K}$  (5 marks)
- (b) A reciprocating air compressor operates between 1 bar to 8 bar. The clearance is 15 cm<sup>3</sup> and swept volume is 900 cm<sup>3</sup>. The index of compression and expansion is 1.21.
- i. Estimate the ideal volumetric efficiency (6 marks)
  - ii. Execute the free air delivery (6 marks)
  - iii. Solve the indicated power (5 marks)
  - iv. Identify the isothermal efficiency (3 marks)

**Question 5**

- (a) Sketch longitudinal sectional view and describe the pressure variations of a fluid flowing through a steam nozzle by indicating the regions-Subsonic, Sonic and Supersonic region.

(10 marks)

- (b) A hair dryer is basically a duct in which a few layers of electric resistors are placed. A small fan pulls the air in and forces it through the resistors where it is heated. Air enters a 1200 watt hair dryer at 100 kPa and 22°C and leaves at 47°C. The cross sectional area of the hair dryer at the exit is 60cm<sup>2</sup>. The power consumed by the fan is 2 watt and the heat losses through the walls of the hair dryer is 5 watt, determine;

- i. Determine volume flow rate of the air at inlet. (10 marks)
- ii. Find the velocity of the air at exit. (7 marks)

**Question 6**

The following data was obtained during test on a single-cylinder, double acting engine having;

Cylinder diameter	: 20 cm
Stroke diameter	: 25 cm
Mean effective pressure	: 250 KPa
Speed	: 5 r.p.s
Effective radius break wheel	: 38 cm
Net break load	: 1340 N
Fuel consumption	: 3.6 kg/min
Fuel supply pressure at engine stop valve	: 800 kPa
Dryness fraction	: 0.9
Condenser cooling water	: 110 kg/min
Temperature rise of condenser cooling	: 14°C
Condenser pressure	: 0.1 bar (10 kPa)
Hot well temperature	: 40°C
Specific heat of water	: 4.187 kJ/kg.K

- i. Calculate the break power of engine. (3 marks)
- ii. Calculate the indicated power of engine. (2 marks)
- iii. Estimate mechanical efficiency of engine. (5 marks)
- iv. Find the heat balance sheet in table form for energy balance and percentage of energy supplied. (15 marks)

END OF EXAMINATION PAPER

## THERMODYNAMICS FORMULA

<b>First Law of Thermodynamics</b>
<i>Kinetic Energy, <math>KE = \frac{mV^2}{2}</math></i>
<i>Potential Energy, <math>PE = mgz</math></i>
<i>Total energy, <math>E = U + KE + PE</math></i>
<i>Heat transfer, <math>Q = \dot{Q}\Delta t</math></i>
<i><math>W = Fs</math></i>
<i>Force, <math>F = PA</math></i>
<i>Spring Force, <math>F = kx</math></i>
<i>Electrical work, <math>W_e = VI\Delta t</math></i>
<i>Shaft work <math>W_{sh} = 2\pi nt</math></i>
<i>Spring Work, <math>W_{spring} = \frac{1}{2}k(x_2^2 - x_1^2)</math></i>
<i>Enthalpy, <math>H = U + PV</math></i>
<i>Quality, <math>x = \frac{m_g}{m_{total}}</math></i>
<i>Mass total,</i>
<i><math>m_{total} = m_f + m_g</math></i>
<i>Ideal gas equation</i>
<i><math>PV = mRT</math></i>
<i><math>\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}</math></i>
<i>General Energy Balance</i>
<i><math>E_{in} - E_{out} = \Delta E_{system}</math></i>
<i><math>\Delta E_{system} = \Delta U + \Delta KE + \Delta PE</math></i>

*Energy Balance for a closed system*

$$Q - W = \Delta U + \Delta KE + \Delta PE$$

*Energy Balance for a constant pressure process*

$$W_b + \Delta U = \Delta H$$

$$Q - W_{other} = \Delta H + \Delta KE + \Delta PE$$

*Conservation of mass and energy equations for steady-flow process*

$$\sum \dot{m}_{in} = \sum \dot{m}_{out}$$

$$\dot{Q} - \dot{W} = \sum_{out} \dot{m} \left[ h + \frac{V^2}{2} + gz \right] - \sum_{in} \dot{m} \left[ h + \frac{V^2}{2} + gz \right]$$

*Boundary work (P = constant),  $W_b = mP_0(v_2 - v_1)$*

*Boundary work (T = constant),  $W_b = P_1 V_1 \ln \left( \frac{V_2}{V_1} \right)$*

*Mass flow rate*

$$\dot{m} = \rho AV = \rho \dot{V} = \frac{\dot{V}}{v}$$

*Volume flow rate*

$$\dot{V} = VA = \frac{\dot{m}}{\rho}$$

*Thermal efficiency of a Heat Engine*

$$\eta_{th} = \frac{W_{net,out}}{Q_H} = 1 - \frac{Q_L}{Q_H}$$

*Coefficient of performance*

$$COP_R = \frac{Q_L}{W_{net,in}} = \frac{q_L}{w_{net,in}} = \frac{Q_L}{Q_H - Q_L}$$

$$COP_{HP} = \frac{Q_H}{W_{net,in}} = \frac{q_H}{w_{net,in}} = \frac{Q_H}{Q_H - Q_L}$$

*Carnot Heat Engine*

$$\eta_{th,Carnot} = \eta_{th,rev} = 1 - \frac{T_L}{T_H}$$



**Carnot Refrigerators and Heat Pumps**

$$\text{COP}_{R, \text{carnot}} = \frac{1}{\frac{T_H}{T_L} - 1}$$

$$\text{COP}_{HP, \text{carnot}} = \frac{1}{1 - \frac{T_L}{T_H}}$$

**Isentropic Process**

$$s_2 = s_1$$

$$\left(\frac{T_2}{T_1}\right)_{s=\text{const.}} = \left(\frac{v_1}{v_2}\right)^{k-1}$$

$$\left(\frac{T_2}{T_1}\right)_{s=\text{const.}} = \left(\frac{P_2}{P_1}\right)^{(k-1)/k}$$

$$\left(\frac{P_2}{P_1}\right)_{s=\text{const.}} = \left(\frac{v_1}{v_2}\right)^k$$

$$\left(\frac{P_2}{P_1}\right)_{s=\text{const.}} = \frac{P_{r2}}{P_{r1}}$$

$$\left(\frac{v_2}{v_1}\right)_{s=\text{const.}} = \frac{v_{r2}}{v_{r1}}$$

**Engine Performance Formula**

$$bp = \frac{2\pi NT}{60}$$

$$IP = \frac{P_{im} LANk}{60}$$

$$\text{Mechanical efficiency} = \frac{bp}{ip}$$

$$P_m = \frac{ip \times 60}{LANk}$$

$$\text{Relative fuel-air ratio, } F_R = \frac{\text{Actual fuel - Air ratio}}{\text{Stoichiometric fuel - Air ratio}}$$

$$\text{Brake specific fuel consumption (bsfc)} = \frac{\text{Actual fuel - Air ratio}}{\text{Stoichiometric fuel - Air ratio}}$$

$$\text{Brake thermal efficiency} = \frac{bp}{m_f \times C_v}$$

$$\eta_{\text{ith}} = \frac{ip}{m_f \times C_v}$$

$$\eta_{\text{vol}} = \frac{\text{Induced Volume}}{\text{Swept Volume}}$$

## Conversion Factors

DIMENSION	METRIC	METRIC/ENGLISH
Acceleration	1 m/s <sup>2</sup> = 100 cm/s <sup>2</sup>	1 m/s <sup>2</sup> = 3.2808 ft/s <sup>2</sup> 1 ft/s <sup>2</sup> = 0.3048* m/s <sup>2</sup>
Area	1 m <sup>2</sup> = 10 <sup>4</sup> cm <sup>2</sup> = 10 <sup>6</sup> mm <sup>2</sup> = 10 <sup>-6</sup> km <sup>2</sup>	1 m <sup>2</sup> = 1550 in <sup>2</sup> = 10.764 ft <sup>2</sup> 1 ft <sup>2</sup> = 144 in <sup>2</sup> = 0.09290304* m <sup>2</sup>
Density	1 g/cm <sup>3</sup> = 1 kg/L = 1000 kg/m <sup>3</sup>	1 g/cm <sup>3</sup> = 62.428 lbm/ft <sup>3</sup> = 0.036127 lbm/in <sup>3</sup> 1 lbm/in <sup>3</sup> = 1728 lbm/ft <sup>3</sup> 1 kg/m <sup>3</sup> = 0.062428 lbm/ft <sup>3</sup>
Energy, heat, work, internal energy, enthalpy	1 kJ = 1000 J = 1000 N · m = 1 kPa · m <sup>3</sup> 1 kJ/kg = 1000 m <sup>2</sup> /s <sup>2</sup> 1 kWh = 3600 kJ 1 cal <sup>†</sup> = 4.184 J 1 IT cal <sup>‡</sup> = 4.1868 J 1 Cal <sup>§</sup> = 4.1868 kJ	1 kJ = 0.94782 Btu 1 Btu = 1.055056 kJ = 5.40395 psia · ft <sup>3</sup> = 778.169 lbf · ft 1 Btu/lbm = 25.037 ft <sup>2</sup> /s <sup>2</sup> = 2.326* kJ/kg 1 kJ/kg = 0.430 Btu/lbm 1 kWh = 3412.14 Btu 1 therm = 10 <sup>5</sup> Btu = 1.055 × 10 <sup>5</sup> kJ (natural gas)
Force	1 N = 1 kg · m/s <sup>2</sup> = 10 <sup>5</sup> dyne 1 kgf = 9.80665 N	1 N = 0.22481 lbf 1 lbf = 32.174 lbm · ft/s <sup>2</sup> = 4.44822 N
Heat flux	1 W/cm <sup>2</sup> = 10 <sup>4</sup> W/m <sup>2</sup>	1 W/m <sup>2</sup> = 0.3171 Btu/h · ft <sup>2</sup>
Heat transfer coefficient	1 W/m <sup>2</sup> · °C = 1 W/m <sup>2</sup> · K	1 W/m <sup>2</sup> · °C = 0.17612 Btu/h · ft <sup>2</sup> · °F
Length	1 m = 100 cm = 1000 mm = 10 <sup>6</sup> μm 1 km = 1000 m	1 m = 39.370 in = 3.2808 ft = 1.0926 yd 1 ft = 12 in = 0.3048* m 1 mile = 5280 ft = 1.6093 km 1 in = 2.54* cm
Mass	1 kg = 1000 g 1 metric ton = 1000 kg	1 kg = 2.2046226 lbm 1 lbm = 0.45359237* kg 1 ounce = 28.3495 g 1 slug = 32.174 lbm = 14.5939 kg 1 short ton = 2000 lbm = 907.1847 kg
Power, heat transfer rate	1 W = 1 J/s 1 kW = 1000 W = 1.341 hp 1 hp <sup>†</sup> = 745.7 W	1 kW = 3412.14 Btu/h = 737.56 lbf · ft/s 1 hp = 550 lbf · ft/s = 0.7068 Btu/s = 42.41 Btu/min = 2544.5 Btu/h = 0.74570 kW 1 boiler hp = 33,475 Btu/h 1 Btu/h = 1.055056 kJ/h 1 ton of refrigeration = 200 Btu/min
Pressure	1 Pa = 1 N/m <sup>2</sup> 1 kPa = 10 <sup>3</sup> Pa = 10 <sup>-3</sup> MPa 1 atm = 101.325 kPa = 1.01325 bars = 760 mm Hg at 0°C = 1.03323 kgf/cm <sup>2</sup> 1 mm Hg = 0.1333 kPa	1 Pa = 1.4504 × 10 <sup>-4</sup> psia = 0.020886 lbf/ft <sup>2</sup> 1 psi = 144 lbf/ft <sup>2</sup> = 6.894757 kPa 1 atm = 14.696 psia = 29.92 in Hg at 30°F 1 in Hg = 3.387 kPa
Specific heat	1 kJ/kg · °C = 1 kJ/kg · K = 1 J/g · °C	1 Btu/lbm · °F = 4.1868 kJ/kg · °C 1 Btu/lbmol · R = 4.1868 kJ/kmol · K 1 kJ/kg · °C = 0.23885 Btu/lbm · °F = 0.23885 Btu/lbm · R

\*Exact conversion factor between metric and English units.

<sup>†</sup>Calorie is originally defined as the amount of heat needed to raise the temperature of 1 g of water by 1°C, but it varies with temperature. The international steam table (IT) calorie (generally preferred by engineers) is exactly 4.1868 J by definition and corresponds to the specific heat of water at 15°C. The thermochemical calorie (generally preferred by physicists) is exactly 4.184 J by definition and corresponds to the specific heat of water at room temperature. The difference between the two is about 0.06 percent, which is negligible. The capitalized Calorie used by nutritionists is actually a kilocalorie (1000 IT calories).

DIMENSION	METRIC	METRIC/ENGLISH
Specific volume	$1 \text{ m}^3/\text{kg} = 1000 \text{ L}/\text{kg} = 1000 \text{ cm}^3/\text{g}$	$1 \text{ m}^3/\text{kg} = 16.02 \text{ ft}^3/\text{lbm}$ $1 \text{ ft}^3/\text{lbm} = 0.062428 \text{ m}^3/\text{kg}$
Temperature	$T(\text{K}) = T(^{\circ}\text{C}) + 273.15$ $\Delta T(\text{K}) = \Delta T(^{\circ}\text{C})$	$T(\text{R}) = T(^{\circ}\text{F}) + 459.67 = 1.8 T(\text{K})$ $T(^{\circ}\text{F}) = 1.8 T(^{\circ}\text{C}) + 32$ $\Delta T(^{\circ}\text{F}) = \Delta T(\text{R}) = 1.8 \Delta T(\text{K})$
Thermal conductivity	$1 \text{ W}/\text{m} \cdot ^{\circ}\text{C} = 1 \text{ W}/\text{m} \cdot \text{K}$	$1 \text{ W}/\text{m} \cdot ^{\circ}\text{C} = 0.57782 \text{ Btu}/\text{h} \cdot \text{ft} \cdot ^{\circ}\text{F}$
Velocity	$1 \text{ m}/\text{s} = 3.60 \text{ km}/\text{h}$	$1 \text{ m}/\text{s} = 3.2808 \text{ ft}/\text{s} = 2.237 \text{ mi}/\text{h}$ $1 \text{ mi}/\text{h} = 1.46667 \text{ ft}/\text{s}$ $1 \text{ mi}/\text{h} = 1.6093 \text{ km}/\text{h}$
Volume	$1 \text{ m}^3 = 1000 \text{ L} = 10^6 \text{ cm}^3 (\text{cc})$	$1 \text{ m}^3 = 6.1024 \times 10^4 \text{ in}^3 = 35.315 \text{ ft}^3$ $= 264.17 \text{ gal (U.S.)}$ $1 \text{ U.S. gallon} = 231 \text{ in}^3 = 3.7854 \text{ L}$ $1 \text{ fl ounce} = 29.5735 \text{ cm}^3 = 0.0295735 \text{ L}$ $1 \text{ U.S. gallon} = 128 \text{ fl ounces}$
Volume flow rate	$1 \text{ m}^3/\text{s} = 60,000 \text{ L}/\text{min} = 10^6 \text{ cm}^3/\text{s}$	$1 \text{ m}^3/\text{s} = 15,850 \text{ gal}/\text{min (gpm)} = 35.315 \text{ ft}^3/\text{s}$ $= 2118.9 \text{ ft}^3/\text{min (cfm)}$

<sup>1</sup>Mechanical horsepower. The electrical horsepower is taken to be exactly 746 W.

### Some Physical Constants

Universal gas constant	$R_u = 8.31447 \text{ kJ}/\text{kmol} \cdot \text{K}$ $= 8.31447 \text{ kPa} \cdot \text{m}^3/\text{kmol} \cdot \text{K}$ $= 0.0831447 \text{ bar} \cdot \text{m}^3/\text{kmol} \cdot \text{K}$ $= 82.05 \text{ L} \cdot \text{atm}/\text{kmol} \cdot \text{K}$ $= 1.9858 \text{ Btu}/\text{lbmol} \cdot \text{R}$ $= 1545.37 \text{ ft} \cdot \text{lb}^2/\text{lbmol} \cdot \text{R}$ $= 10.73 \text{ psia} \cdot \text{ft}^3/\text{lbmol} \cdot \text{R}$
Standard acceleration of gravity	$g = 9.80665 \text{ m}/\text{s}^2$ $= 32.174 \text{ ft}/\text{s}^2$
Standard atmospheric pressure	$1 \text{ atm} = 101.325 \text{ kPa}$ $= 1.01325 \text{ bar}$ $= 14.696 \text{ psia}$ $= 760 \text{ mm Hg } (0^{\circ}\text{C})$ $= 29.9213 \text{ in Hg } (32^{\circ}\text{F})$ $= 10.3323 \text{ m H}_2\text{O } (4^{\circ}\text{C})$
Stefan-Boltzmann constant	$\sigma = 5.6704 \times 10^{-8} \text{ W}/\text{m}^2 \cdot \text{K}^4$ $= 0.1714 \times 10^{-8} \text{ Btu}/\text{h} \cdot \text{ft}^2 \cdot \text{R}^4$
Boltzmann's constant	$k = 1.380650 \times 10^{-23} \text{ J}/\text{K}$
Speed of light in vacuum	$c_0 = 2.9979 \times 10^8 \text{ m}/\text{s}$ $= 9.836 \times 10^8 \text{ ft}/\text{s}$
Speed of sound in dry air at $0^{\circ}\text{C}$ and 1 atm	$c = 331.36 \text{ m}/\text{s}$ $= 1089 \text{ ft}/\text{s}$
Heat of fusion of water at 1 atm	$h_f = 333.7 \text{ kJ}/\text{kg}$ $= 143.5 \text{ Btu}/\text{lbm}$
Enthalpy of vaporization of water at 1 atm	$h_{fg} = 2256.5 \text{ kJ}/\text{kg}$ $= 970.12 \text{ Btu}/\text{lbm}$

TABLE A-11

Saturated refrigerant-134a—Temperature table

Temp., $T$ , °C	Specific volume, $m^3/kg$			Internal energy, $kJ/kg$			Enthalpy, $kJ/kg$			Entropy, $kJ/kg\cdot K$		
	Sat. press., $P_{sat}$ , kPa	Sat. liquid, $v_f$	Sat. vapor, $v_g$	Sat. liquid, $u_f$	Evap., $u_{fg}$	Sat. vapor, $u_g$	Sat. liquid, $h_f$	Evap., $h_{fg}$	Sat. vapor, $h_g$	Sat. liquid, $s_f$	Evap., $s_{fg}$	Sat. vapor, $s_g$
-40	51.25	0.0007053	0.36064	-0.036	207.42	207.38	0.00	225.86	225.86	0.00000	0.96869	0.96869
-38	56.86	0.0007082	0.32718	2.472	206.06	208.53	2.512	224.62	227.13	0.01071	0.95516	0.96588
-36	62.95	0.0007111	0.29740	4.987	204.69	209.68	5.032	223.37	228.40	0.02137	0.94182	0.96319
-34	69.56	0.0007141	0.27082	7.509	203.32	210.83	7.559	222.10	229.66	0.03196	0.92867	0.96063
-32	76.71	0.0007171	0.24706	10.04	201.94	211.97	10.09	220.83	230.93	0.04249	0.91569	0.95819
-30	84.43	0.0007201	0.22577	12.58	200.55	213.12	12.64	219.55	232.19	0.05297	0.90289	0.95586
-28	92.76	0.0007232	0.20666	15.12	199.15	214.27	15.19	218.25	233.44	0.06339	0.89024	0.95364
-26	101.73	0.0007264	0.18947	17.67	197.75	215.42	17.75	216.95	234.70	0.07376	0.87776	0.95152
-24	111.37	0.0007296	0.17398	20.23	196.34	216.57	20.31	215.63	235.94	0.08408	0.86542	0.94950
-22	121.72	0.0007328	0.15999	22.80	194.92	217.71	22.89	214.30	237.19	0.09435	0.85323	0.94758
-20	132.82	0.0007361	0.14735	25.37	193.49	218.86	25.47	212.96	238.43	0.10456	0.84119	0.94575
-18	144.69	0.0007394	0.13589	27.96	192.05	220.00	28.07	211.60	239.67	0.11473	0.82927	0.94401
-16	157.38	0.0007428	0.12550	30.55	190.60	221.15	30.67	210.23	240.90	0.12486	0.81749	0.94234
-14	170.93	0.0007463	0.11605	33.15	189.14	222.29	33.28	208.84	242.12	0.13493	0.80583	0.94076
-12	185.37	0.0007498	0.10744	35.76	187.66	223.42	35.90	207.44	243.34	0.14497	0.79429	0.93925
-10	200.74	0.0007533	0.099600	38.38	186.18	224.56	38.53	206.02	244.55	0.15496	0.78286	0.93782
-8	217.08	0.0007570	0.092438	41.01	184.69	225.69	41.17	204.59	245.76	0.16491	0.77154	0.93645
-6	234.44	0.0007607	0.085888	43.64	183.18	226.82	43.82	203.14	246.95	0.17482	0.76033	0.93514
-4	252.85	0.0007644	0.079889	46.29	181.66	227.94	46.48	201.66	248.14	0.18469	0.74921	0.93390
-2	272.36	0.0007683	0.074388	48.94	180.12	229.07	49.15	200.17	249.33	0.19452	0.73819	0.93271
0	293.01	0.0007722	0.069335	51.61	178.58	230.18	51.83	198.67	250.50	0.20432	0.72726	0.93158
2	314.84	0.0007761	0.064690	54.28	177.01	231.30	54.53	197.14	251.66	0.21408	0.71641	0.93050
4	337.90	0.0007802	0.060412	56.97	175.44	232.40	57.23	195.58	252.82	0.22381	0.70565	0.92946
6	362.23	0.0007843	0.056469	59.66	173.84	233.51	59.95	194.01	253.96	0.23351	0.69496	0.92847
8	387.88	0.0007886	0.052829	62.37	172.23	234.60	62.68	192.42	255.09	0.24318	0.68435	0.92752
10	414.89	0.0007929	0.049466	65.09	170.61	235.69	65.42	190.80	256.22	0.25282	0.67380	0.92661
12	443.31	0.0007973	0.046354	67.82	168.96	236.78	68.17	189.16	257.33	0.26243	0.66331	0.92574
14	473.19	0.0008018	0.043471	70.56	167.30	237.86	70.94	187.49	258.43	0.27201	0.65289	0.92490
16	504.58	0.0008064	0.040798	73.31	165.62	238.93	73.72	185.80	259.51	0.28157	0.64252	0.92409
18	537.52	0.0008112	0.038317	76.07	163.92	239.99	76.51	184.08	260.59	0.29111	0.63219	0.92330
20	572.07	0.0008160	0.036012	78.85	162.19	241.04	79.32	182.33	261.64	0.30062	0.62192	0.92254
22	608.27	0.0008209	0.033867	81.64	160.45	242.09	82.14	180.55	262.69	0.31012	0.61168	0.92180
24	646.18	0.0008260	0.031869	84.44	158.68	243.13	84.98	178.74	263.72	0.31959	0.60148	0.92107
26	685.84	0.0008312	0.030008	87.26	156.89	244.15	87.83	176.90	264.73	0.32905	0.59131	0.92036
28	727.31	0.0008366	0.028271	90.09	155.08	245.17	90.70	175.03	265.73	0.33849	0.58117	0.91967
30	770.64	0.0008421	0.026648	92.93	153.24	246.17	93.58	173.13	266.71	0.34792	0.57105	0.91897
32	815.89	0.0008477	0.025131	95.79	151.37	247.17	96.49	171.19	267.67	0.35734	0.56095	0.91829
34	863.11	0.0008535	0.023712	98.67	149.48	248.15	99.41	169.21	268.61	0.36675	0.55086	0.91760
36	912.35	0.0008595	0.022383	101.56	147.55	249.11	102.34	167.19	269.53	0.37615	0.54077	0.91692
38	963.68	0.0008657	0.021137	104.47	145.60	250.07	105.30	165.13	270.44	0.38554	0.53068	0.91622
40	1017.1	0.0008720	0.019968	107.39	143.61	251.00	108.28	163.03	271.31	0.39493	0.52059	0.91552
42	1072.8	0.0008786	0.018870	110.34	141.59	251.92	111.28	160.89	272.17	0.40432	0.51048	0.91480
44	1130.7	0.0008854	0.017837	113.30	139.53	252.83	114.30	158.70	273.00	0.41371	0.50036	0.91407

TABLE A-11

Saturated refrigerant-134a—Temperature table (Concluded)

Temp., $T$ , °C	Sat. press., $P_{sat}$ , kPa	Specific volume, $m^3/kg$		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg·K		
		Sat. liquid, $v_f$	Sat. vapor, $v_g$	Sat. liquid, $u_f$	Evap., $u_{fg}$	Sat. vapor, $u_g$	Sat. liquid, $h_f$	Evap., $h_{fg}$	Sat. vapor, $h_g$	Sat. liquid, $s_f$	Evap., $s_{fg}$	Sat. vapor, $s_g$
46	1191.0	0.0008924	0.016866	116.28	137.43	253.71	117.34	156.46	273.80	0.42311	0.49020	0.91331
48	1253.6	0.0008997	0.015951	119.28	135.30	254.58	120.41	154.17	274.57	0.43251	0.48001	0.91252
52	1386.2	0.0009151	0.014276	125.35	130.89	256.24	126.52	149.41	276.03	0.45136	0.45948	0.91084
56	1529.1	0.0009317	0.012782	131.52	126.29	257.81	132.94	144.41	277.35	0.47028	0.43870	0.90898
60	1682.8	0.0009498	0.011434	137.79	121.45	259.23	139.38	139.09	278.47	0.48930	0.41746	0.90676
65	1891.0	0.0009751	0.009959	145.80	115.06	260.86	147.64	132.05	279.69	0.51330	0.39048	0.90379
70	2118.2	0.0010037	0.008650	154.03	108.17	262.20	156.15	124.37	280.52	0.53763	0.36239	0.90002
75	2365.8	0.0010373	0.007486	162.55	100.62	263.17	165.01	115.87	280.88	0.56252	0.33279	0.89531
80	2635.3	0.0010774	0.006439	171.43	92.22	263.66	174.27	106.35	280.63	0.58812	0.30113	0.88925
85	2928.2	0.0011273	0.005484	180.81	82.64	263.45	184.11	95.39	279.51	0.61487	0.26632	0.88120
90	3246.9	0.0011938	0.004591	190.94	71.19	262.13	194.82	82.22	277.04	0.64354	0.22638	0.86991
95	3594.1	0.0012945	0.003713	202.49	56.25	258.73	207.14	64.94	272.08	0.67605	0.17638	0.85243
100	3975.1	0.0015269	0.002657	218.73	29.72	248.46	224.80	34.22	259.02	0.72224	0.09169	0.81393

Source of Data: Tables A-11 through A-13 are generated using the Engineering Equation Solver (EES) software developed by S. A. Klein and F. L. Alvarado. The routine used in calculations is the R134a, which is based on the fundamental equation of state developed by R. Tillner-Roth and H.D. Baehr, "An International Standard Formulation for the Thermodynamic Properties of 1,1,1,2-Tetrafluoroethane (HFC-134a) for temperatures from 170 K to 455 K and pressures up to 70 MPa," *J. Phys. Chem. Ref. Data*, Vol. 23, No. 5, 1994. The enthalpy and entropy values of saturated liquid are set to zero at  $-40^\circ\text{C}$  (and  $-40^\circ\text{F}$ ).

**TABLE A-12**

Saturated refrigerant-134a—Pressure table

Press., <i>P</i> kPa	Sat. temp., <i>T</i> <sub>sat</sub> °C	Specific volume, m <sup>3</sup> /kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg·K		
		Sat. liquid, <i>v</i> <sub>f</sub>	Sat. vapor, <i>v</i> <sub>g</sub>	Sat. liquid, <i>u</i> <sub>f</sub>	Evap., <i>u</i> <sub>fg</sub>	Sat. vapor, <i>u</i> <sub>g</sub>	Sat. liquid, <i>h</i> <sub>f</sub>	Evap., <i>h</i> <sub>fg</sub>	Sat. vapor, <i>h</i> <sub>g</sub>	Sat. liquid, <i>s</i> <sub>f</sub>	Evap., <i>s</i> <sub>fg</sub>	Sat. vapor, <i>s</i> <sub>g</sub>
60	-36.95	0.0007097	0.31108	3.795	205.34	209.13	3.837	223.96	227.80	0.01633	0.94812	0.96445
70	-33.87	0.0007143	0.26921	7.672	203.23	210.90	7.722	222.02	229.74	0.03264	0.92783	0.96047
80	-31.13	0.0007184	0.23749	11.14	201.33	212.48	11.20	220.27	231.47	0.04707	0.91009	0.95716
90	-28.65	0.0007222	0.21261	14.30	199.60	213.90	14.36	218.67	233.04	0.06003	0.89431	0.95434
100	-26.37	0.0007258	0.19255	17.19	198.01	215.21	17.27	217.19	234.46	0.07182	0.88008	0.95191
120	-22.32	0.0007323	0.16216	22.38	195.15	217.53	22.47	214.52	236.99	0.09269	0.85520	0.94789
140	-18.77	0.0007381	0.14020	26.96	192.60	219.56	27.06	212.13	239.19	0.11080	0.83387	0.94467
160	-15.60	0.0007435	0.12355	31.06	190.31	221.37	31.18	209.96	241.14	0.12686	0.81517	0.94202
180	-12.73	0.0007485	0.11049	34.81	188.20	223.01	34.94	207.95	242.90	0.14131	0.79848	0.93979
200	-10.09	0.0007532	0.099951	38.26	186.25	224.51	38.41	206.09	244.50	0.15449	0.78339	0.93788
240	-5.38	0.0007618	0.083983	44.46	182.71	227.17	44.64	202.68	247.32	0.17786	0.75689	0.93475
280	-1.25	0.0007697	0.072434	49.95	179.54	229.49	50.16	199.61	249.77	0.19822	0.73406	0.93228
320	2.46	0.0007771	0.063681	54.90	176.65	231.55	55.14	196.78	251.93	0.21631	0.71395	0.93026
360	5.82	0.0007840	0.056809	59.42	173.99	233.41	59.70	194.15	253.86	0.23265	0.69591	0.92856
400	8.91	0.0007905	0.051266	63.61	171.49	235.10	63.92	191.68	255.61	0.24757	0.67954	0.92711
450	12.46	0.0007983	0.045677	68.44	168.58	237.03	68.80	188.78	257.58	0.26462	0.66093	0.92555
500	15.71	0.0008058	0.041168	72.92	165.86	238.77	73.32	186.04	259.36	0.28021	0.64399	0.92420
550	18.73	0.0008129	0.037452	77.09	163.29	240.38	77.54	183.44	260.98	0.29460	0.62842	0.92302
600	21.55	0.0008198	0.034335	81.01	160.84	241.86	81.50	180.95	262.46	0.30799	0.61398	0.92196
650	24.20	0.0008265	0.031680	84.72	158.51	243.23	85.26	178.56	263.82	0.32052	0.60048	0.92100
700	26.69	0.0008331	0.029392	88.24	156.27	244.51	88.82	176.26	265.08	0.33232	0.58780	0.92012
750	29.06	0.0008395	0.027398	91.59	154.11	245.70	92.22	174.03	266.25	0.34348	0.57582	0.91930
800	31.31	0.0008457	0.025645	94.80	152.02	246.82	95.48	171.86	267.34	0.35408	0.56445	0.91853
850	33.45	0.0008519	0.024091	97.88	150.00	247.88	98.61	169.75	268.36	0.36417	0.55362	0.91779
900	35.51	0.0008580	0.022703	100.84	148.03	248.88	101.62	167.69	269.31	0.37383	0.54326	0.91709
950	37.48	0.0008640	0.021456	103.70	146.11	249.82	104.52	165.68	270.20	0.38307	0.53333	0.91641
1000	39.37	0.0008700	0.020329	106.47	144.24	250.71	107.34	163.70	271.04	0.39196	0.52378	0.91574
1200	46.29	0.0008935	0.016728	116.72	137.12	253.84	117.79	156.12	273.92	0.42449	0.48870	0.91320
1400	52.40	0.0009167	0.014119	125.96	130.44	256.40	127.25	148.92	276.17	0.45325	0.45742	0.91067
1600	57.88	0.0009400	0.012134	134.45	124.05	258.50	135.96	141.96	277.92	0.47921	0.42881	0.90802
1800	62.87	0.0009639	0.010568	142.36	117.85	260.21	144.09	135.14	279.23	0.50304	0.40213	0.90517
2000	67.45	0.0009887	0.009297	149.81	111.75	261.56	151.78	128.36	280.15	0.52519	0.37684	0.90204
2500	77.54	0.0010567	0.006941	167.02	96.47	263.49	169.66	111.18	280.84	0.57542	0.31701	0.89243
3000	86.16	0.0011410	0.005272	183.09	80.17	263.26	186.51	92.57	279.08	0.62133	0.25759	0.87893

**TABLE A-13**

Superheated refrigerant-134a

<i>T</i> °C	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K	<i>v</i> m <sup>3</sup> /kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/kg·K
<i>P</i> = 0.06 MPa ( <i>T</i> <sub>sat</sub> = -36.95°C)				<i>P</i> = 0.10 MPa ( <i>T</i> <sub>sat</sub> = -26.37°C)				<i>P</i> = 0.14 MPa ( <i>T</i> <sub>sat</sub> = -18.77°C)				
Sat.	0.31108	209.13	227.80	0.9645	0.19255	215.21	234.46	0.9519	0.14020	219.56	239.19	0.9447
-20	0.33608	220.62	240.78	1.0175	0.19841	219.68	239.52	0.9721				
-10	0.35048	227.57	248.60	1.0478	0.20743	226.77	247.51	1.0031	0.14605	225.93	246.37	0.9724
0	0.36476	234.67	256.56	1.0775	0.21630	233.97	255.60	1.0333	0.15263	233.25	254.61	1.0032
10	0.37893	241.94	264.68	1.1067	0.22506	241.32	263.82	1.0628	0.15908	240.68	262.95	1.0331
20	0.39302	249.37	272.95	1.1354	0.23373	248.81	272.18	1.0919	0.16544	248.24	271.40	1.0625
30	0.40705	256.97	281.39	1.1637	0.24233	256.46	280.69	1.1204	0.17172	255.95	279.99	1.0913
40	0.42102	264.73	289.99	1.1916	0.25088	264.27	289.36	1.1485	0.17794	263.80	288.72	1.1196
50	0.43495	272.66	298.75	1.2192	0.25937	272.24	298.17	1.1762	0.18412	271.81	297.59	1.1475
60	0.44883	280.75	307.68	1.2464	0.26783	280.36	307.15	1.2036	0.19025	279.97	306.61	1.1750
70	0.46269	289.01	316.77	1.2732	0.27626	288.65	316.28	1.2306	0.19635	288.29	315.78	1.2021
80	0.47651	297.43	326.02	1.2998	0.28465	297.10	325.57	1.2573	0.20242	296.77	325.11	1.2289
90	0.49032	306.02	335.43	1.3261	0.29303	305.71	335.01	1.2836	0.20847	305.40	334.59	1.2554
100	0.50410	314.76	345.01	1.3521	0.30138	314.48	344.61	1.3097	0.21449	314.19	344.22	1.2815
<i>P</i> = 0.18 MPa ( <i>T</i> <sub>sat</sub> = -12.73°C)				<i>P</i> = 0.20 MPa ( <i>T</i> <sub>sat</sub> = -10.09°C)				<i>P</i> = 0.24 MPa ( <i>T</i> <sub>sat</sub> = -5.38°C)				
Sat.	0.11049	223.01	242.90	0.9398	0.09995	224.51	244.50	0.9379	0.08398	227.17	247.32	0.9348
-10	0.11189	225.04	245.18	0.9485	0.09991	224.57	244.56	0.9381				
0	0.11722	232.49	253.59	0.9799	0.10481	232.11	253.07	0.9699	0.08617	231.30	251.98	0.9520
10	0.12240	240.02	262.05	1.0103	0.10955	239.69	261.60	1.0005	0.09026	239.00	260.66	0.9832
20	0.12748	247.66	270.60	1.0400	0.11418	247.36	270.20	1.0304	0.09423	246.76	269.38	1.0134
30	0.13248	255.43	279.27	1.0691	0.11874	255.16	278.91	1.0596	0.09812	254.63	278.17	1.0429
40	0.13741	263.33	288.07	1.0976	0.12322	263.09	287.74	1.0882	0.10193	262.61	287.07	1.0718
50	0.14230	271.38	297.00	1.1257	0.12766	271.16	296.70	1.1164	0.10570	270.73	296.09	1.1002
60	0.14715	279.58	306.07	1.1533	0.13206	279.38	305.79	1.1441	0.10942	278.98	305.24	1.1281
70	0.15196	287.93	315.28	1.1806	0.13641	287.75	315.03	1.1714	0.11310	287.38	314.53	1.1555
80	0.15673	296.43	324.65	1.2075	0.14074	296.27	324.41	1.1984	0.11675	295.93	323.95	1.1826
90	0.16149	305.09	334.16	1.2340	0.14504	304.93	333.94	1.2250	0.12038	304.62	333.51	1.2093
100	0.16622	313.90	343.82	1.2603	0.14933	313.75	343.62	1.2513	0.12398	313.46	343.22	1.2356
<i>P</i> = 0.28 MPa ( <i>T</i> <sub>sat</sub> = -1.25°C)				<i>P</i> = 0.32 MPa ( <i>T</i> <sub>sat</sub> = 2.46°C)				<i>P</i> = 0.40 MPa ( <i>T</i> <sub>sat</sub> = 8.91°C)				
Sat.	0.07243	229.49	249.77	0.9323	0.06368	231.55	251.93	0.9303	0.051266	235.10	255.61	0.9271
0	0.07282	230.46	250.85	0.9362								
10	0.07646	238.29	259.70	0.9681	0.06609	237.56	258.70	0.9545	0.051506	235.99	256.59	0.9306
20	0.07997	246.15	268.54	0.9987	0.06925	245.51	267.67	0.9856	0.054213	244.19	265.88	0.9628
30	0.08338	254.08	277.42	1.0285	0.07231	253.52	276.66	1.0158	0.056796	252.37	275.09	0.9937
40	0.08672	262.12	286.40	1.0577	0.07530	261.62	285.72	1.0452	0.059292	260.60	284.32	1.0237
50	0.09000	270.28	295.48	1.0862	0.07823	269.83	294.87	1.0739	0.061724	268.92	293.61	1.0529
60	0.09324	278.58	304.69	1.1143	0.08111	278.17	304.12	1.1022	0.064104	277.34	302.98	1.0814
70	0.09644	287.01	314.01	1.1419	0.08395	286.64	313.50	1.1299	0.066443	285.88	312.45	1.1095
80	0.09961	295.59	323.48	1.1690	0.08675	295.24	323.00	1.1572	0.068747	294.54	322.04	1.1370
90	0.10275	304.30	333.07	1.1958	0.08953	303.99	332.64	1.1841	0.071023	303.34	331.75	1.1641
100	0.10587	313.17	342.81	1.2223	0.09229	312.87	342.41	1.2106	0.073274	312.28	341.59	1.1908
110	0.10897	322.18	352.69	1.2484	0.09503	321.91	352.31	1.2368	0.075504	321.35	351.55	1.2172
120	0.11205	331.34	362.72	1.2742	0.09775	331.08	362.36	1.2627	0.077717	330.56	361.65	1.2432
130	0.11512	340.65	372.88	1.2998	0.10045	340.41	372.55	1.2883	0.079913	339.92	371.89	1.2689
140	0.11818	350.11	383.20	1.3251	0.10314	349.88	382.89	1.3136	0.082096	349.42	382.26	1.2943



TABLE A-13

Superheated refrigerant-134a (Concluded)

$T$ °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	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/kg·K
P = 0.50 MPa ( $T_{sat} = 15.71^\circ\text{C}$ )				P = 0.60 MPa ( $T_{sat} = 21.55^\circ\text{C}$ )				P = 0.70 MPa ( $T_{sat} = 26.69^\circ\text{C}$ )				
Sat.	0.041168	238.77	259.36	0.9242	0.034335	241.86	262.46	0.9220	0.029392	244.51	265.08	0.9201
20	0.042115	242.42	263.48	0.9384								
30	0.044338	250.86	273.03	0.9704	0.035984	249.24	270.83	0.9500	0.029966	247.49	268.47	0.9314
40	0.046456	259.27	282.50	1.0011	0.037865	257.88	280.60	0.9817	0.031696	256.41	278.59	0.9642
50	0.048499	267.73	291.98	1.0309	0.039659	266.50	290.30	1.0122	0.033322	265.22	288.54	0.9955
60	0.050485	276.27	301.51	1.0600	0.041389	275.17	300.00	1.0417	0.034875	274.03	298.44	1.0257
70	0.052427	284.91	311.12	1.0884	0.043069	283.91	309.75	1.0706	0.036373	282.88	308.34	1.0550
80	0.054331	293.65	320.82	1.1163	0.044710	292.74	319.57	1.0988	0.037829	291.81	318.29	1.0835
90	0.056205	302.52	330.63	1.1436	0.046318	301.69	329.48	1.1265	0.039250	300.84	328.31	1.1115
100	0.058053	311.52	340.55	1.1706	0.047900	310.75	339.49	1.1536	0.040642	309.96	338.41	1.1389
110	0.059880	320.65	350.59	1.1971	0.049458	319.93	349.61	1.1804	0.042010	319.21	348.61	1.1659
120	0.061687	329.91	360.75	1.2233	0.050997	329.24	359.84	1.2068	0.043358	328.57	358.92	1.1925
130	0.063479	339.31	371.05	1.2492	0.052519	338.69	370.20	1.2328	0.044688	338.06	369.34	1.2186
140	0.065256	348.85	381.47	1.2747	0.054027	348.26	380.68	1.2585	0.046004	347.67	379.88	1.2445
150	0.067021	358.52	392.04	1.3000	0.055522	357.98	391.29	1.2838	0.047306	357.42	390.54	1.2700
160	0.068775	368.34	402.73	1.3250	0.057006	367.83	402.03	1.3089	0.048597	367.31	401.32	1.2952
P = 0.80 MPa ( $T_{sat} = 31.31^\circ\text{C}$ )				P = 0.90 MPa ( $T_{sat} = 35.51^\circ\text{C}$ )				P = 1.00 MPa ( $T_{sat} = 39.37^\circ\text{C}$ )				
Sat.	0.025645	246.82	267.34	0.9185	0.022686	248.82	269.25	0.9169	0.020319	250.71	271.04	0.9157
40	0.027035	254.84	276.46	0.9481	0.023375	253.15	274.19	0.9328	0.020406	251.32	271.73	0.9180
50	0.028547	263.87	286.71	0.9803	0.024809	262.46	284.79	0.9661	0.021796	260.96	282.76	0.9526
60	0.029973	272.85	296.82	1.0111	0.026146	271.62	295.15	0.9977	0.023068	270.33	293.40	0.9851
70	0.031340	281.83	306.90	1.0409	0.027413	280.74	305.41	1.0280	0.024261	279.61	303.87	1.0160
80	0.032659	290.86	316.99	1.0699	0.028630	289.88	315.65	1.0574	0.025398	288.87	314.27	1.0459
90	0.033941	299.97	327.12	1.0982	0.029806	299.08	325.90	1.0861	0.026492	298.17	324.66	1.0749
100	0.035193	309.17	337.32	1.1259	0.030951	308.35	336.21	1.1141	0.027552	307.52	335.08	1.1032
110	0.036420	318.47	347.61	1.1531	0.032068	317.72	346.58	1.1415	0.028584	316.96	345.54	1.1309
120	0.037625	327.89	357.99	1.1798	0.033164	327.19	357.04	1.1684	0.029592	326.49	356.08	1.1580
130	0.038813	337.42	368.47	1.2062	0.034241	336.78	367.59	1.1949	0.030581	336.12	366.70	1.1847
140	0.039985	347.08	379.07	1.2321	0.035302	346.48	378.25	1.2211	0.031554	345.87	377.42	1.2110
150	0.041143	356.86	389.78	1.2577	0.036349	356.30	389.01	1.2468	0.032512	355.73	388.24	1.2369
160	0.042290	366.78	400.61	1.2830	0.037384	366.25	399.89	1.2722	0.033457	365.71	399.17	1.2624
170	0.043427	376.83	411.57	1.3081	0.038408	376.33	410.89	1.2973	0.034392	375.82	410.22	1.2876
180	0.044554	387.01	422.65	1.3328	0.039423	386.54	422.02	1.3221	0.035317	386.06	421.38	1.3125
P = 1.20 MPa ( $T_{sat} = 46.29^\circ\text{C}$ )				P = 1.40 MPa ( $T_{sat} = 52.40^\circ\text{C}$ )				P = 1.60 MPa ( $T_{sat} = 57.88^\circ\text{C}$ )				
Sat.	0.016728	253.84	273.92	0.9132	0.014119	256.40	276.17	0.9107	0.012134	258.50	277.92	0.9080
50	0.017201	257.64	278.28	0.9268								
60	0.018404	267.57	289.66	0.9615	0.015005	264.46	285.47	0.9389	0.012372	260.91	280.71	0.9164
70	0.019502	277.23	300.63	0.9939	0.016060	274.62	297.10	0.9733	0.013430	271.78	293.27	0.9536
80	0.020529	286.77	311.40	1.0249	0.017023	284.51	308.34	1.0056	0.014362	282.11	305.09	0.9875
90	0.021506	296.28	322.09	1.0547	0.017923	294.28	319.37	1.0364	0.015215	292.19	316.53	1.0195
100	0.022442	305.81	332.74	1.0836	0.018778	304.01	330.30	1.0661	0.016014	302.16	327.78	1.0501
110	0.023348	315.40	343.41	1.1119	0.019597	313.76	341.19	1.0949	0.016773	312.09	338.93	1.0795
120	0.024228	325.05	354.12	1.1395	0.020388	323.55	352.09	1.1230	0.017500	322.03	350.03	1.1081
130	0.025086	334.79	364.90	1.1665	0.021155	333.41	363.02	1.1504	0.018201	332.02	361.14	1.1360
140	0.025927	344.63	375.74	1.1931	0.021904	343.34	374.01	1.1773	0.018882	342.06	372.27	1.1633
150	0.026753	354.57	386.68	1.2192	0.022636	353.37	385.07	1.2038	0.019545	352.19	383.46	1.1901
160	0.027566	364.63	397.71	1.2450	0.023355	363.51	396.20	1.2298	0.020194	362.40	394.71	1.2164
170	0.028367	374.80	408.84	1.2704	0.024061	373.75	407.43	1.2554	0.020830	372.71	406.04	1.2422
180	0.029158	385.10	420.09	1.2955	0.024757	384.12	418.78	1.2808	0.021456	383.13	417.46	1.2677