Pontificia Universidad Católica de Chile Facultad de Física

# Termodinámica para Ingenieros, FIS1523

**Examen Viernes, 3 de Julio 2015, 15:30 – 18:00 hrs.**

**Nombre Completo…….....Sección:.....**

**Importante**

- **Marque con una cruz (X) sólo la alternativa correcta.**
- **Se permite el uso de calculadora básica.**
- **No se permite el uso de celular, ni lápiz mina.**
- **Se descontarán 1/4 punto por respuesta errada**

**Forma –I---2015**

Puntaje (uso del Profesor)

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Considere un motor que funciona por medio de un ciclo ideal Diesel y usa aire como fluido de trabajo. La razón de compresión es 16 y la razón de corte es 2. Al inicio del proceso de compresión, el aire se encuentra a 95 kPa y 27 $^{o}$C. Utilizando la tabla A-17, responda a las siguientes dos preguntas:

**1.-** La temperatura al final del proceso de compresión es:

a. 862.4 K
b. 909.4 K
c. 1724.8 K
d. 1818.8 K

**2.-** El calor por unidad de masa que entra al ciclo es de:

a. 935.3 kJ/kg
b. 913.9 kJ/kg
c. 989.2 kJ/kg
d. 1019.7 kJ/kg

**3.-** El ciclo de Rankine ideal consiste de los siguientes procesos consecutivos:

a. Expansión isentrópica, Adición de calor isobárica, Compresión isentrópica, Pérdida de calor isobárica.
b. Compresión isentrópica, Adición de calor isobárica, Expansión isentrópica, Pérdida de calor isobárica.
c. Expansión isobárica, Adición de calor isotérmica, Compresión isobárica, Pérdida de calor isotérmica.
d. Compresión isobárica, Adición de calor isotérmica, Expansión isobárica, Pérdida de calor isotérmica.

Considere un refrigerador que usa R-134a como líquido refrigerante operando en un ciclo ideal de refrigeración por compresión de vapor entre 0.12 y 0.7 MPa. El flujo másico en el refrigerador es de 0.05 kg/s. Responda las siguientes dos preguntas:

**4.-** La tasa a la que el espacio refrigerado pierde calor:

a. 7.41 kW
b. 7.93 kW
c. 8.24 kW
d. 8.66 kW

**5.-** El coeficiente de desempeño (también conocido como coeficiente de funcionamiento, o COP) del refrigerador:

a. 3.76
b. 4.06
c. 4.75
d. 5.24

**6.-** Considere tres cuerpos sólidos idénticos (mismo material, igual masa y calor específico), que inicialmente se encuentran a temperaturas $T_1 < T_2 < T_3$, respectivamente. Suponga que los cuerpos 1 y 2 se ponen en contacto durante un tiempo arbitrariamente largo, tal que alcanzan equilibrio térmico entre sí. Posteriormente, ambos cuerpos se ponen en contacto simultáneo con el cuerpo 3, hasta que el sistema compuesto por los tres cuerpos alcanza el equilibrio. La temperatura final del sistema es:

a. $T_{eq} = (T_1 + T_2)/2$
b. $T_{eq} = T_3$
c. $T_{eq} = ((T_1 + T_2)/2 + T_3)/2$
d. $T_{eq} = (T_1 + T_2 + T_3)/3$

**7.-** Cuando una sustancia pura experimenta un cambio de fase a presión constante, desde un estado inicial de líquido saturado a temperatura T, hasta un estado final de vapor saturado a la misma temperatura, debe absorber una cierta cantidad de calor por unidad de masa. ¿Cuál de las siguientes expresiones NO corresponde a esta energía?

a. $u_g(T) - u_f(T)$
b. $h_g(T) - h_f(T)$
c. $u_g(T) - u_f(T) + P^{sat}(T)\,[v_g(T) - v_f(T)]$
d. $T\,[s_g(T) - s_f(T)]$

**8.-** Un recipiente de paredes rígidas contiene 5 kg de agua a 95 $^{o}$C. Si 2 kg de agua están en forma de líquido saturado y el resto en forma de vapor saturado, el volumen total del recipiente es:

a. 5 $m^3$
b. 5.94 $m^3$
c. 3.96 $m^3$
d. 1.19 $m^3$

**9.-** Un recipiente cerrado, de paredes rígidas y adiabáticas, contiene 10 kg de agua inicialmente a 95 ºC, de los cuales 5 kg están en forma de líquido saturado y el resto en forma de vapor saturado. Se añade una cierta cantidad de calor al sistema, tal que la temperatura se mantiene en 95 ºC, pero el estado final de la mezcla contiene 1 kg de líquido saturado y el resto en forma de vapor saturado. La cantidad total de calor agregado al recipiente es

a. 907.8 kJ
b. 9078 kJ
c. 2440.7 kJ
d. 1532.9 kJ

Este problema quedó mal planteado. No debiera decir “de paredes rígidas” sino más bien “cilindro-émbolo”, ya que es imposible agregar calor a una mezcla y que tanto la temperatura como el volumen específico permanezcan constantes

**10.-** En el sistema representado en la Figura 1, dos estanques adiabáticos y de paredes rígidas contienen Nitrógeno gaseoso. Los estanques están separados por una válvula cerrada, en las condiciones indicadas en la figura. Considere las propiedades críticas del $N_2$, $P_c = 3.39$ MPa, $T_c = 126.2$ K, y la constante de los gases $R_{N2} = 0.2968$ kJ/(kg K). Usando el factor de compresibilidad generalizado, se tiene que la masa de $N_2$ en el estanque izquierdo y el volumen del estanque derecho son, respectivamente

a. $M_1 = 2.5$ kg y $V_2 = 0.13$ m$^3$
b. $M_1 = 23$ kg y $V_2 = 0.119$ m$^3$
c. $M_1 = 25$ kg y $V_2 = 0.108$ m$^3$
d. $M_1 = 2.3$ kg y $V_2 = 0.13$ m$^3$

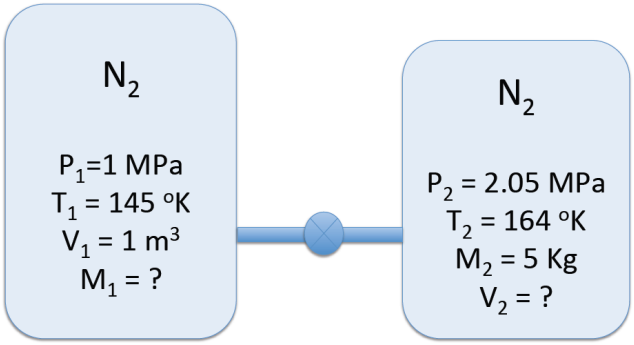



***Figura 1: Problemas 10 y 11***

**11.-** Para el sistema mostrado en la Figura 1, asuma ahora que el Nitrógeno puede ser descrito como un gas ideal con calor específico constante. Bajo esta suposición, si se abre la válvula y se alcanza el equilibrio termodinámico, la presión y la temperatura finales del sistema serán

a. P = 1.5 kPa y T = 154.4 K
b. P = 1.5 MPa y T = 154.4 K
c. P = 1.11 kPa y T = 148.4 K
d. P = 1.11 MPa y T = 148.4 K

**12.-** Determine cuál de las siguientes afirmaciones es falsa:

a. El calor y el trabajo son mecanismos de transferencia de energía.
b. El calor y el trabajo son magnitudes que dependen del camino recorrido durante un proceso.
c. Aunque el calor y el trabajo son propiedades de un sistema, están asociados a un proceso.
d. Si la energía que cruza la pared de un sistema cerrado no es calor, entonces debe ser trabajo.

**13.-** Determine cuál de las siguientes afirmaciones es verdadera para un sistema de flujo estacionario:

a. La cantidad total de masa contenida dentro de un volumen de control puede cambiar con el tiempo.
b. Las propiedades del fluido no pueden cambiar de un punto a otro dentro del volumen de control.
c. La cantidad de energía que entra a un volumen de control en todas las formas (calor, trabajo y masa) debe ser igual a la cantidad de energía que sale.
d. Las propiedades del fluido no pueden variar espacialmente en la sección transversal de una entrada o salida.

**14.-** Se condensa isotérmicamente vapor de agua saturado a 200 °C hasta líquido saturado, en un dispositivo de cilindro-émbolo. La magnitud del trabajo efectuado durante este proceso es aproximadamente:

a. 196 kJ/kg
b. 0 kJ/kg
c. 200000 kJ/kg
d. 1743.7 kJ/kg

**15.-** A una tobera aislada entra vapor de agua a 0.6 MPa y 200 ºC con una velocidad de 50 m/s y sale con una presión de 0.15 MPa y a una velocidad de 600 m/s. El fluido a la salida es:

a. Vapor sobrecalentado
b. Mezcla saturada de líquido-vapor con x = 0.99
c. Mezcla saturada de líquido-vapor con x = 0.96
d. Vapor saturado x=1

**16.-** Se bombea agua a un estanque de 6 m x 9 m de sección transversal, y simultáneamente se descarga el agua del estanque pasando por un orificio de 7 cm de diámetro, a una velocidad promedio constante de 4 m/s. Si el nivel del agua en el estanque sube con una rapidez de 2.5 cm/min, la tasa a la que entra el agua al estanque es aproximadamente:

a. 0.489 $m^3/s$
b. 0.0979 $m^3/s$
c. 0.0225 $m^3/s$
d. 0.0379 $m^3/s$

**17.-** ¿Para cuál de los siguientes procesos la entropía del sistema disminuye?

a. agua es hervida para producir vapor
b. mezcla de dos gases en un contenedor
c. enfriar agua para formar hielo
d. derretir hielo para formar agua

**18.-** ¿Cuál de las siguientes afirmaciones es falsa?

a. La diferencia de entropía entre dos estados de un sistema es independiente del camino recorrido entre ambos estados.
b. La entropía es una medida cuantitativa del desorden.
c. El cambio de entropía total en un ciclo de Carnot es cero.
d. La entropía de un sistema aislado se conserva, es decir, es constante.

**19.-** Un gas ideal en un cilindro con un pistón movible es conectado a un reservorio a cierta temperatura. El gas es lentamente comprimido. (a) ¿Cómo cambia la entropía del gas? (b) ¿Cómo cambia la entropía del reservorio?

a. ambas no cambian
b. (a) disminuye (b) aumenta
c. (a) aumenta (b) disminuye
d. (a) disminuye (b) no cambia

**20.-** Vapor entra a una turbina adiabática en forma estacionaria a 600 ºC y 3 MPa, y sale a 15 kPa. ¿Cuál es el mayor porcentaje de líquido que puede salir de la turbina?

a. 0 %
b. 7 %
c. 16 %
d. 84 %

**21.-** Se pierde calor a través de una pared plana a una tasa de 1000 W. Si las temperaturas interior y exterior de la pared son 30 ºC y 10 ºC, respectivamente, la tasa de generación de entropía en la pared es,

a. 0.23 W/K
b. 66.7 W/K
c. 50.0 W/K
d. 3.4 W/K

**22.-** Agua líquida es comprimida por una bomba con eficiencia isoentrópica de 75% desde 0.3 MPa a 6 MPa a una tasa de 0.30 $m^3$/min. La potencia requerida por la bomba es

a. 4.8 kW
b. 21.4 kW
c. 28.5 kW
d. 38.0 kW

**23.-** Un frasco de vidrio, cuyo volumen es 800 $cm^3$ a 10 ºC, está lleno de mercurio a tal temperatura. Cuando el conjunto se calienta hasta 90 ºC, se derraman 8.8 $cm^3$ de mercurio. Si el coeficiente de dilatación volumétrica de mercurio es 2.0 x $10^{-4}$ $(ºC)^{-1}$, cuál de las siguientes es el coeficiente de dilatación volumétrica de vidrio:

a. 6.25 x $10^{-4}$ $(ºC)^{-1}$
b. 4.25 x $10^{-4}$ $(ºC)^{-1}$
c. 6.25 x $10^{-5}$ $(ºC)^{-1}$
d. 4.25 x $10^{-5}$ $(ºC)^{-1}$

**24.-** El calor específico de un sistema durante un proceso es dado por la ecuación

$$C_n = (0.1+0.002\ T)\ kJ/kg\ ºC$$

Si la masa del gas es 10 kg y su temperatura cambia de 20 ºC a 120 ºC, cuál de las siguientes es el calor absorbido por el gas:

a. 240 kJ
b. 100 kJ
c. 1000 kJ
d. 1500 kJ

## TABLA A-4

Agua saturada. Tabla de temperaturas

| | | *Volumen específico, $m^3/kg$* | | *Energía interna, kJ/kg* | | | *Entalpía, kJ/kg* | | | *Entropía, kJ/kg · K* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp., $T$ °C | Pres. sat., $P_{sat}$ kPa | Líq. sat., $v_f$ | Vapor sat., $v_g$ | Líq. sat., $u_f$ | Evap., $u_{fg}$ | Vapor sat., $u_g$ | Líq. sat., $h_f$ | Evap., $h_{fg}$ | Vapor sat., $h_g$ | Líq. sat., $s_f$ | Evap., $s_{fg}$ | Vapor sat., $s_g$ |
| 0.01 | 0.6117 | 0.001000 | 206.00 | 0.000 | 2374.9 | 2374.9 | 0.001 | 2500.9 | 2500.9 | 0.0000 | 9.1556 | 9.1556 |
| 5 | 0.8725 | 0.001000 | 147.03 | 21.019 | 2360.8 | 2381.8 | 21.020 | 2489.1 | 2510.1 | 0.0763 | 8.9487 | 9.0249 |
| 10 | 1.2281 | 0.001000 | 106.32 | 42.020 | 2346.6 | 2388.7 | 42.022 | 2477.2 | 2519.2 | 0.1511 | 8.7488 | 8.8999 |
| 15 | 1.7057 | 0.001001 | 77.885 | 62.980 | 2332.5 | 2395.5 | 62.982 | 2465.4 | 2528.3 | 0.2245 | 8.5559 | 8.7803 |
| 20 | 2.3392 | 0.001002 | 57.762 | 83.913 | 2318.4 | 2402.3 | 83.915 | 2453.5 | 2537.4 | 0.2965 | 8.3696 | 8.6661 |
| 25 | 3.1698 | 0.001003 | 43.340 | 104.83 | 2304.3 | 2409.1 | 104.83 | 2441.7 | 2546.5 | 0.3672 | 8.1895 | 8.5567 |
| 30 | 4.2469 | 0.001004 | 32.879 | 125.73 | 2290.2 | 2415.9 | 125.74 | 2429.8 | 2555.6 | 0.4368 | 8.0152 | 8.4520 |
| 35 | 5.6291 | 0.001006 | 25.205 | 146.63 | 2276.0 | 2422.7 | 146.64 | 2417.9 | 2564.6 | 0.5051 | 7.8466 | 8.3517 |
| 40 | 7.3851 | 0.001008 | 19.515 | 167.53 | 2261.9 | 2429.4 | 167.53 | 2406.0 | 2573.5 | 0.5724 | 7.6832 | 8.2556 |
| 45 | 9.5953 | 0.001010 | 15.251 | 188.43 | 2247.7 | 2436.1 | 188.44 | 2394.0 | 2582.4 | 0.6386 | 7.5247 | 8.1633 |
| 50 | 12.352 | 0.001012 | 12.026 | 209.33 | 2233.4 | 2442.7 | 209.34 | 2382.0 | 2591.3 | 0.7038 | 7.3710 | 8.0748 |
| 55 | 15.763 | 0.001015 | 9.5639 | 230.24 | 2219.1 | 2449.3 | 230.26 | 2369.8 | 2600.1 | 0.7680 | 7.2218 | 7.9898 |
| 60 | 19.947 | 0.001017 | 7.6670 | 251.16 | 2204.7 | 2455.9 | 251.18 | 2357.7 | 2608.8 | 0.8313 | 7.0769 | 7.9082 |
| 65 | 25.043 | 0.001020 | 6.1935 | 272.09 | 2190.3 | 2462.4 | 272.12 | 2345.4 | 2617.5 | 0.8937 | 6.9360 | 7.8296 |
| 70 | 31.202 | 0.001023 | 5.0396 | 293.04 | 2175.8 | 2468.9 | 293.07 | 2333.0 | 2626.1 | 0.9551 | 6.7989 | 7.7540 |
| 75 | 38.597 | 0.001026 | 4.1291 | 313.99 | 2161.3 | 2475.3 | 314.03 | 2320.6 | 2634.6 | 1.0158 | 6.6655 | 7.6812 |
| 80 | 47.416 | 0.001029 | 3.4053 | 334.97 | 2146.6 | 2481.6 | 335.02 | 2308.0 | 2643.0 | 1.0756 | 6.5355 | 7.6111 |
| 85 | 57.868 | 0.001032 | 2.8261 | 355.96 | 2131.9 | 2487.8 | 356.02 | 2295.3 | 2651.4 | 1.1346 | 6.4089 | 7.5435 |
| 90 | 70.183 | 0.001036 | 2.3593 | 376.97 | 2117.0 | 2494.0 | 377.04 | 2282.5 | 2659.6 | 1.1929 | 6.2853 | 7.4782 |
| 95 | 84.609 | 0.001040 | 1.9808 | 398.00 | 2102.0 | 2500.1 | 398.09 | 2269.6 | 2667.6 | 1.2504 | 6.1647 | 7.4151 |
| 100 | 101.42 | 0.001043 | 1.6720 | 419.06 | 2087.0 | 2506.0 | 419.17 | 2256.4 | 2675.6 | 1.3072 | 6.0470 | 7.3542 |
| 105 | 120.90 | 0.001047 | 1.4186 | 440.15 | 2071.8 | 2511.9 | 440.28 | 2243.1 | 2683.4 | 1.3634 | 5.9319 | 7.2952 |
| 110 | 143.38 | 0.001052 | 1.2094 | 461.27 | 2056.4 | 2517.7 | 461.42 | 2229.7 | 2691.1 | 1.4188 | 5.8193 | 7.2382 |
| 115 | 169.18 | 0.001056 | 1.0360 | 482.42 | 2040.9 | 2523.3 | 482.59 | 2216.0 | 2698.6 | 1.4737 | 5.7092 | 7.1829 |
| 120 | 198.67 | 0.001060 | 0.89133 | 503.60 | 2025.3 | 2528.9 | 503.81 | 2202.1 | 2706.0 | 1.5279 | 5.6013 | 7.1292 |
| 125 | 232.23 | 0.001065 | 0.77012 | 524.83 | 2009.5 | 2534.3 | 525.07 | 2188.1 | 2713.1 | 1.5816 | 5.4956 | 7.0771 |
| 130 | 270.28 | 0.001070 | 0.66808 | 546.10 | 1993.4 | 2539.5 | 546.38 | 2173.7 | 2720.1 | 1.6346 | 5.3919 | 7.0265 |
| 135 | 313.22 | 0.001075 | 0.58179 | 567.41 | 1977.3 | 2544.7 | 567.75 | 2159.1 | 2726.9 | 1.6872 | 5.2901 | 6.9773 |
| 140 | 361.53 | 0.001080 | 0.50850 | 588.77 | 1960.9 | 2549.6 | 589.16 | 2144.3 | 2733.5 | 1.7392 | 5.1901 | 6.9294 |
| 145 | 415.68 | 0.001085 | 0.44600 | 610.19 | 1944.2 | 2554.4 | 610.64 | 2129.2 | 2739.8 | 1.7908 | 5.0919 | 6.8827 |
| 150 | 476.16 | 0.001091 | 0.39248 | 631.66 | 1927.4 | 2559.1 | 632.18 | 2113.8 | 2745.9 | 1.8418 | 4.9953 | 6.8371 |
| 155 | 543.49 | 0.001096 | 0.34648 | 653.19 | 1910.3 | 2563.5 | 653.79 | 2098.0 | 2751.8 | 1.8924 | 4.9002 | 6.7927 |
| 160 | 618.23 | 0.001102 | 0.30680 | 674.79 | 1893.0 | 2567.8 | 675.47 | 2082.0 | 2757.5 | 1.9426 | 4.8066 | 6.7492 |
| 165 | 700.93 | 0.001108 | 0.27244 | 696.46 | 1875.4 | 2571.9 | 697.24 | 2065.6 | 2762.8 | 1.9923 | 4.7143 | 6.7067 |
| 170 | 792.18 | 0.001114 | 0.24260 | 718.20 | 1857.5 | 2575.7 | 719.08 | 2048.8 | 2767.9 | 2.0417 | 4.6233 | 6.6650 |
| 175 | 892.60 | 0.001121 | 0.21659 | 740.02 | 1839.4 | 2579.4 | 741.02 | 2031.7 | 2772.7 | 2.0906 | 4.5335 | 6.6242 |
| 180 | 1002.8 | 0.001127 | 0.19384 | 761.92 | 1820.9 | 2582.8 | 763.05 | 2014.2 | 2777.2 | 2.1392 | 4.4448 | 6.5841 |
| 185 | 1123.5 | 0.001134 | 0.17390 | 783.91 | 1802.1 | 2586.0 | 785.19 | 1996.2 | 2781.4 | 2.1875 | 4.3572 | 6.5447 |
| 190 | 1255.2 | 0.001141 | 0.15636 | 806.00 | 1783.0 | 2589.0 | 807.43 | 1977.9 | 2785.3 | 2.2355 | 4.2705 | 6.5059 |
| 195 | 1398.8 | 0.001149 | 0.14089 | 828.18 | 1763.6 | 2591.7 | 829.78 | 1959.0 | 2788.8 | 2.2831 | 4.1847 | 6.4678 |
| 200 | 1554.9 | 0.001157 | 0.12721 | 850.46 | 1743.7 | 2594.2 | 852.26 | 1939.8 | 2792.0 | 2.3305 | 4.0997 | 6.4302 |

## TABLA A-5

Agua saturada. Tabla de presiones

| | | *Volumen específico, $m^3/kg$* | | *Energía interna, kJ/kg* | | | *Entalpía, kJ/kg* | | | *Entropía, kJ/kg · K* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pres., $P$ kPa | Temp. sat., $T_{sat}$ °C | Líq. sat., $v_f$ | Vapor sat., $v_g$ | Líq. sat., $u_f$ | Evap., $u_{fg}$ | Vapor sat., $u_g$ | Líq. sat, $h_f$ | Evap., $h_{fg}$ | Vapor sat., $h_g$ | Líq. sat., $s_f$ | Evap., $s_{fg}$ | Vapor sat., $s_g$ |
| 1.0 | 6.97 | 0.001000 | 129.19 | 29.302 | 2355.2 | 2384.5 | 29.303 | 2484.4 | 2513.7 | 0.1059 | 8.8690 | 8.9749 |
| 1.5 | 13.02 | 0.001001 | 87.964 | 54.686 | 2338.1 | 2392.8 | 54.688 | 2470.1 | 2524.7 | 0.1956 | 8.6314 | 8.8270 |
| 2.0 | 17.50 | 0.001001 | 66.990 | 73.431 | 2325.5 | 2398.9 | 73.433 | 2459.5 | 2532.9 | 0.2606 | 8.4621 | 8.7227 |
| 2.5 | 21.08 | 0.001002 | 54.242 | 88.422 | 2315.4 | 2403.8 | 88.424 | 2451.0 | 2539.4 | 0.3118 | 8.3302 | 8.6421 |
| 3.0 | 24.08 | 0.001003 | 45.654 | 100.98 | 2306.9 | 2407.9 | 100.98 | 2443.9 | 2544.8 | 0.3543 | 8.2222 | 8.5765 |
| 4.0 | 28.96 | 0.001004 | 34.791 | 121.39 | 2293.1 | 2414.5 | 121.39 | 2432.3 | 2553.7 | 0.4224 | 8.0510 | 8.4734 |
| 5.0 | 32.87 | 0.001005 | 28.185 | 137.75 | 2282.1 | 2419.8 | 137.75 | 2423.0 | 2560.7 | 0.4762 | 7.9176 | 8.3938 |
| 7.5 | 40.29 | 0.001008 | 19.233 | 168.74 | 2261.1 | 2429.8 | 168.75 | 2405.3 | 2574.0 | 0.5763 | 7.6738 | 8.2501 |
| 10 | 45.81 | 0.001010 | 14.670 | 191.79 | 2245.4 | 2437.2 | 191.81 | 2392.1 | 2583.9 | 0.6492 | 7.4996 | 8.1488 |
| 15 | 53.97 | 0.001014 | 10.020 | 225.93 | 2222.1 | 2448.0 | 225.94 | 2372.3 | 2598.3 | 0.7549 | 7.2522 | 8.0071 |
| 20 | 60.06 | 0.001017 | 7.6481 | 251.40 | 2204.6 | 2456.0 | 251.42 | 2357.5 | 2608.9 | 0.8320 | 7.0752 | 7.9073 |
| 25 | 64.96 | 0.001020 | 6.2034 | 271.93 | 2190.4 | 2462.4 | 271.96 | 2345.5 | 2617.5 | 0.8932 | 6.9370 | 7.8302 |
| 30 | 69.09 | 0.001022 | 5.2287 | 289.24 | 2178.5 | 2467.7 | 289.27 | 2335.3 | 2624.6 | 0.9441 | 6.8234 | 7.7675 |
| 40 | 75.86 | 0.001026 | 3.9933 | 317.58 | 2158.8 | 2476.3 | 317.62 | 2318.4 | 2636.1 | 1.0261 | 6.6430 | 7.6691 |
| 50 | 81.32 | 0.001030 | 3.2403 | 340.49 | 2142.7 | 2483.2 | 340.54 | 2304.7 | 2645.2 | 1.0912 | 6.5019 | 7.5931 |
| 75 | 91.76 | 0.001037 | 2.2172 | 384.36 | 2111.8 | 2496.1 | 384.44 | 2278.0 | 2662.4 | 1.2132 | 6.2426 | 7.4558 |
| 100 | 99.61 | 0.001043 | 1.6941 | 417.40 | 2088.2 | 2505.6 | 417.51 | 2257.5 | 2675.0 | 1.3028 | 6.0562 | 7.3589 |
| 101.325 | 99.97 | 0.001043 | 1.6734 | 418.95 | 2087.0 | 2506.0 | 419.06 | 2256.5 | 2675.6 | 1.3069 | 6.0476 | 7.3545 |
| 125 | 105.97 | 0.001048 | 1.3750 | 444.23 | 2068.8 | 2513.0 | 444.36 | 2240.6 | 2684.9 | 1.3741 | 5.9100 | 7.2841 |
| 150 | 111.35 | 0.001053 | 1.1594 | 466.97 | 2052.3 | 2519.2 | 467.13 | 2226.0 | 2693.1 | 1.4337 | 5.7894 | 7.2231 |
| 175 | 116.04 | 0.001057 | 1.0037 | 486.82 | 2037.7 | 2524.5 | 487.01 | 2213.1 | 2700.2 | 1.4850 | 5.6865 | 7.1716 |
| 200 | 120.21 | 0.001061 | 0.88578 | 504.50 | 2024.6 | 2529.1 | 504.71 | 2201.6 | 2706.3 | 1.5302 | 5.5968 | 7.1270 |
| 225 | 123.97 | 0.001064 | 0.79329 | 520.47 | 2012.7 | 2533.2 | 520.71 | 2191.0 | 2711.7 | 1.5706 | 5.5171 | 7.0877 |
| 250 | 127.41 | 0.001067 | 0.71873 | 535.08 | 2001.8 | 2536.8 | 535.35 | 2181.2 | 2716.5 | 1.6072 | 5.4453 | 7.0525 |
| 275 | 130.58 | 0.001070 | 0.65732 | 548.57 | 1991.6 | 2540.1 | 548.86 | 2172.0 | 2720.9 | 1.6408 | 5.3800 | 7.0207 |
| 300 | 133.52 | 0.001073 | 0.60582 | 561.11 | 1982.1 | 2543.2 | 561.43 | 2163.5 | 2724.9 | 1.6717 | 5.3200 | 6.9917 |
| 325 | 136.27 | 0.001076 | 0.56199 | 572.84 | 1973.1 | 2545.9 | 573.19 | 2155.4 | 2728.6 | 1.7005 | 5.2645 | 6.9650 |
| 350 | 138.86 | 0.001079 | 0.52422 | 583.89 | 1964.6 | 2548.5 | 584.26 | 2147.7 | 2732.0 | 1.7274 | 5.2128 | 6.9402 |
| 375 | 141.30 | 0.001081 | 0.49133 | 594.32 | 1956.6 | 2550.9 | 594.73 | 2140.4 | 2735.1 | 1.7526 | 5.1645 | 6.9171 |
| 400 | 143.61 | 0.001084 | 0.46242 | 604.22 | 1948.9 | 2553.1 | 604.66 | 2133.4 | 2738.1 | 1.7765 | 5.1191 | 6.8955 |
| 450 | 147.90 | 0.001088 | 0.41392 | 622.65 | 1934.5 | 2557.1 | 623.14 | 2120.3 | 2743.4 | 1.8205 | 5.0356 | 6.8561 |
| 500 | 151.83 | 0.001093 | 0.37483 | 639.54 | 1921.2 | 2560.7 | 640.09 | 2108.0 | 2748.1 | 1.8604 | 4.9603 | 6.8207 |
| 550 | 155.46 | 0.001097 | 0.34261 | 655.16 | 1908.8 | 2563.9 | 655.77 | 2096.6 | 2752.4 | 1.8970 | 4.8916 | 6.7886 |
| 600 | 158.83 | 0.001101 | 0.31560 | 669.72 | 1897.1 | 2566.8 | 670.38 | 2085.8 | 2756.2 | 1.9308 | 4.8285 | 6.7593 |
| 650 | 161.98 | 0.001104 | 0.29260 | 683.37 | 1886.1 | 2569.4 | 684.08 | 2075.5 | 2759.6 | 1.9623 | 4.7699 | 6.7322 |
| 700 | 164.95 | 0.001108 | 0.27278 | 696.23 | 1875.6 | 2571.8 | 697.00 | 2065.8 | 2762.8 | 1.9918 | 4.7153 | 6.7071 |
| 750 | 167.75 | 0.001111 | 0.25552 | 708.40 | 1865.6 | 2574.0 | 709.24 | 2056.4 | 2765.7 | 2.0195 | 4.6642 | 6.6837 |

## TABLA A-6

Vapor de agua sobrecalentado

| $T$ °C | $v$ m³/kg | $u$ kJ/kg | $h$ kJ/kg | $s$ kJ/kg · K | $v$ m³/kg | $u$ kJ/kg | $h$ kJ/kg | $s$ kJ/kg · K | $v$ m³/kg | $u$ kJ/kg | $h$ kJ/kg | $s$ kJ/kg · K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $P$ = 0.01 MPa (45.81°C)* | | | | $P$ = 0.05 MPa (81.32°C) | | | | $P$ = 0.10 MPa (99.61°C) | | | |
| Sat.† | 14.670 | 2437.2 | 2583.9 | 8.1488 | 3.2403 | 2483.2 | 2645.2 | 7.5931 | 1.6941 | 2505.6 | 2675.0 | 7.3589 |
| 50 | 14.867 | 2443.3 | 2592.0 | 8.1741 | | | | | | | | |
| 100 | 17.196 | 2515.5 | 2687.5 | 8.4489 | 3.4187 | 2511.5 | 2682.4 | 7.6953 | 1.6959 | 2506.2 | 2675.8 | 7.3611 |
| 150 | 19.513 | 2587.9 | 2783.0 | 8.6893 | 3.8897 | 2585.7 | 2780.2 | 7.9413 | 1.9367 | 2582.9 | 2776.6 | 7.6148 |
| 200 | 21.826 | 2661.4 | 2879.6 | 8.9049 | 4.3562 | 2660.0 | 2877.8 | 8.1592 | 2.1724 | 2658.2 | 2875.5 | 7.8356 |
| 250 | 24.136 | 2736.1 | 2977.5 | 9.1015 | 4.8206 | 2735.1 | 2976.2 | 8.3568 | 2.4062 | 2733.9 | 2974.5 | 8.0346 |
| 300 | 26.446 | 2812.3 | 3076.7 | 9.2827 | 5.2841 | 2811.6 | 3075.8 | 8.5387 | 2.6389 | 2810.7 | 3074.5 | 8.2172 |
| 400 | 31.063 | 2969.3 | 3280.0 | 9.6094 | 6.2094 | 2968.9 | 3279.3 | 8.8659 | 3.1027 | 2968.3 | 3278.6 | 8.5452 |
| 500 | 35.680 | 3132.9 | 3489.7 | 9.8998 | 7.1338 | 3132.6 | 3489.3 | 9.1566 | 3.5655 | 3132.2 | 3488.7 | 8.8362 |
| 600 | 40.296 | 3303.3 | 3706.3 | 10.1631 | 8.0577 | 3303.1 | 3706.0 | 9.4201 | 4.0279 | 3302.8 | 3705.6 | 9.0999 |
| 700 | 44.911 | 3480.8 | 3929.9 | 10.4056 | 8.9813 | 3480.6 | 3929.7 | 9.6626 | 4.4900 | 3480.4 | 3929.4 | 9.3424 |
| 800 | 49.527 | 3665.4 | 4160.6 | 10.6312 | 9.9047 | 3665.2 | 4160.4 | 9.8883 | 4.9519 | 3665.0 | 4160.2 | 9.5682 |
| 900 | 54.143 | 3856.9 | 4398.3 | 10.8429 | 10.8280 | 3856.8 | 4398.2 | 10.1000 | 5.4137 | 3856.7 | 4398.0 | 9.7800 |
| 1000 | 58.758 | 4055.3 | 4642.8 | 11.0429 | 11.7513 | 4055.2 | 4642.7 | 10.3000 | 5.8755 | 4055.0 | 4642.6 | 9.9800 |
| 1100 | 63.373 | 4260.0 | 4893.8 | 11.2326 | 12.6745 | 4259.9 | 4893.7 | 10.4897 | 6.3372 | 4259.8 | 4893.6 | 10.1698 |
| 1200 | 67.989 | 4470.9 | 5150.8 | 11.4132 | 13.5977 | 4470.8 | 5150.7 | 10.6704 | 6.7988 | 4470.7 | 5150.6 | 10.3504 |
| 1300 | 72.604 | 4687.4 | 5413.4 | 11.5857 | 14.5209 | 4687.3 | 5413.3 | 10.8429 | 7.2605 | 4687.2 | 5413.3 | 10.5229 |
| | $P$ = 0.20 MPa (120.21°C) | | | | $P$ = 0.30 MPa (133.52°C) | | | | $P$ = 0.40 MPa (143.61°C) | | | |
| Sat. | 0.88578 | 2529.1 | 2706.3 | 7.1270 | 0.60582 | 2543.2 | 2724.9 | 6.9917 | 0.46242 | 2553.1 | 2738.1 | 6.8955 |
| 150 | 0.95986 | 2577.1 | 2769.1 | 7.2810 | 0.63402 | 2571.0 | 2761.2 | 7.0792 | 0.47088 | 2564.4 | 2752.8 | 6.9306 |
| 200 | 1.08049 | 2654.6 | 2870.7 | 7.5081 | 0.71643 | 2651.0 | 2865.9 | 7.3132 | 0.53434 | 2647.2 | 2860.9 | 7.1723 |
| 250 | 1.19890 | 2731.4 | 2971.2 | 7.7100 | 0.79645 | 2728.9 | 2967.9 | 7.5180 | 0.59520 | 2726.4 | 2964.5 | 7.3804 |
| 300 | 1.31623 | 2808.8 | 3072.1 | 7.8941 | 0.87535 | 2807.0 | 3069.6 | 7.7037 | 0.65489 | 2805.1 | 3067.1 | 7.5677 |
| 400 | 1.54934 | 2967.2 | 3277.0 | 8.2236 | 1.03155 | 2966.0 | 3275.5 | 8.0347 | 0.77265 | 2964.9 | 3273.9 | 7.9003 |
| 500 | 1.78142 | 3131.4 | 3487.7 | 8.5153 | 1.18672 | 3130.6 | 3486.6 | 8.3271 | 0.88936 | 3129.8 | 3485.5 | 8.1933 |
| 600 | 2.01302 | 3302.2 | 3704.8 | 8.7793 | 1.34139 | 3301.6 | 3704.0 | 8.5915 | 1.00558 | 3301.0 | 3703.3 | 8.4580 |
| 700 | 2.24434 | 3479.9 | 3928.8 | 9.0221 | 1.49580 | 3479.5 | 3928.2 | 8.8345 | 1.12152 | 3479.0 | 3927.6 | 8.7012 |
| 800 | 2.47550 | 3664.7 | 4159.8 | 9.2479 | 1.65004 | 3664.3 | 4159.3 | 9.0605 | 1.23730 | 3663.9 | 4158.9 | 8.9274 |
| 900 | 2.70656 | 3856.3 | 4397.7 | 9.4598 | 1.80417 | 3856.0 | 4397.3 | 9.2725 | 1.35298 | 3855.7 | 4396.9 | 9.1394 |
| 1000 | 2.93755 | 4054.8 | 4642.3 | 9.6599 | 1.95824 | 4054.5 | 4642.0 | 9.4726 | 1.46859 | 4054.3 | 4641.7 | 9.3396 |
| 1100 | 3.16848 | 4259.6 | 4893.3 | 9.8497 | 2.11226 | 4259.4 | 4893.1 | 9.6624 | 1.58414 | 4259.2 | 4892.9 | 9.5295 |
| 1200 | 3.39938 | 4470.5 | 5150.4 | 10.0304 | 2.26624 | 4470.3 | 5150.2 | 9.8431 | 1.69966 | 4470.2 | 5150.0 | 9.7102 |
| 1300 | 3.63026 | 4687.1 | 5413.1 | 10.2029 | 2.42019 | 4686.9 | 5413.0 | 10.0157 | 1.81516 | 4686.7 | 5412.8 | 9.8828 |
| | $P$ = 0.50 MPa (151.83°C) | | | | $P$ = 0.60 MPa (158.83°C) | | | | $P$ = 0.80 MPa (170.41°C) | | | |
| Sat. | 0.37483 | 2560.7 | 2748.1 | 6.8207 | 0.31560 | 2566.8 | 2756.2 | 6.7593 | 0.24035 | 2576.0 | 2768.3 | 6.6616 |
| 200 | 0.42503 | 2643.3 | 2855.8 | 7.0610 | 0.35212 | 2639.4 | 2850.6 | 6.9683 | 0.26088 | 2631.1 | 2839.8 | 6.8177 |
| 250 | 0.47443 | 2723.8 | 2961.0 | 7.2725 | 0.39390 | 2721.2 | 2957.6 | 7.1833 | 0.29321 | 2715.9 | 2950.4 | 7.0402 |
| 300 | 0.52261 | 2803.3 | 3064.6 | 7.4614 | 0.43442 | 2801.4 | 3062.0 | 7.3740 | 0.32416 | 2797.5 | 3056.9 | 7.2345 |
| 350 | 0.57015 | 2883.0 | 3168.1 | 7.6346 | 0.47428 | 2881.6 | 3166.1 | 7.5481 | 0.35442 | 2878.6 | 3162.2 | 7.4107 |
| 400 | 0.61731 | 2963.7 | 3272.4 | 7.7956 | 0.51374 | 2962.5 | 3270.8 | 7.7097 | 0.38429 | 2960.2 | 3267.7 | 7.5735 |
| 500 | 0.71095 | 3129.0 | 3484.5 | 8.0893 | 0.59200 | 3128.2 | 3483.4 | 8.0041 | 0.44332 | 3126.6 | 3481.3 | 7.8692 |
| 600 | 0.80409 | 3300.4 | 3702.5 | 8.3544 | 0.66976 | 3299.8 | 3701.7 | 8.2695 | 0.50186 | 3298.7 | 3700.1 | 8.1354 |
| 700 | 0.89696 | 3478.6 | 3927.0 | 8.5978 | 0.74725 | 3478.1 | 3926.4 | 8.5132 | 0.56011 | 3477.2 | 3925.3 | 8.3794 |
| 800 | 0.98966 | 3663.6 | 4158.4 | 8.8240 | 0.82457 | 3663.2 | 4157.9 | 8.7395 | 0.61820 | 3662.5 | 4157.0 | 8.6061 |
| 900 | 1.08227 | 3855.4 | 4396.6 | 9.0362 | 0.90179 | 3855.1 | 4396.2 | 8.9518 | 0.67619 | 3854.5 | 4395.5 | 8.8185 |
| 1000 | 1.17480 | 4054.0 | 4641.4 | 9.2364 | 0.97893 | 4053.8 | 4641.1 | 9.1521 | 0.73411 | 4053.3 | 4640.5 | 9.0189 |
| 1100 | 1.26728 | 4259.0 | 4892.6 | 9.4263 | 1.05603 | 4258.8 | 4892.4 | 9.3420 | 0.79197 | 4258.3 | 4891.9 | 9.2090 |
| 1200 | 1.35972 | 4470.0 | 5149.8 | 9.6071 | 1.13309 | 4469.8 | 5149.6 | 9.5229 | 0.84980 | 4469.4 | 5149.3 | 9.3898 |
| 1300 | 1.45214 | 4686.6 | 5412.6 | 9.7797 | 1.21012 | 4686.4 | 5412.5 | 9.6955 | 0.90761 | 4686.1 | 5412.2 | 9.5625 |

*La temperatura entre paréntesis es la temperatura de saturación a la presión especificada.

† Propiedades del vapor saturado a la presión especificada.

## TABLE A–6

Superheated water (*Continued*)

| *T* °C | *v* m³/kg | *u* kJ/kg | *h* kJ/kg | *s* kJ/kg · K | *v* m³/kg | *u* kJ/kg | *h* kJ/kg | *s* kJ/kg · K | *v* m³/kg | *u* kJ/kg | *h* kJ/kg | *s* kJ/kg · K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *P* = 1.00 MPa (179.88°C) | | | | *P* = 1.20 MPa (187.96°C) | | | | *P* = 1.40 MPa (195.04°C) | | | |
| Sat. | 0.19437 | 2582.8 | 2777.1 | 6.5850 | 0.16326 | 2587.8 | 2783.8 | 6.5217 | 0.14078 | 2591.8 | 2788.9 | 6.4675 |
| 200 | 0.20602 | 2622.3 | 2828.3 | 6.6956 | 0.16934 | 2612.9 | 2816.1 | 6.5909 | 0.14303 | 2602.7 | 2803.0 | 6.4975 |
| 250 | 0.23275 | 2710.4 | 2943.1 | 6.9265 | 0.19241 | 2704.7 | 2935.6 | 6.8313 | 0.16356 | 2698.9 | 2927.9 | 6.7488 |
| 300 | 0.25799 | 2793.7 | 3051.6 | 7.1246 | 0.21386 | 2789.7 | 3046.3 | 7.0335 | 0.18233 | 2785.7 | 3040.9 | 6.9553 |
| 350 | 0.28250 | 2875.7 | 3158.2 | 7.3029 | 0.23455 | 2872.7 | 3154.2 | 7.2139 | 0.20029 | 2869.7 | 3150.1 | 7.1379 |
| 400 | 0.30661 | 2957.9 | 3264.5 | 7.4670 | 0.25482 | 2955.5 | 3261.3 | 7.3793 | 0.21782 | 2953.1 | 3258.1 | 7.3046 |
| 500 | 0.35411 | 3125.0 | 3479.1 | 7.7642 | 0.29464 | 3123.4 | 3477.0 | 7.6779 | 0.25216 | 3121.8 | 3474.8 | 7.6047 |
| 600 | 0.40111 | 3297.5 | 3698.6 | 8.0311 | 0.33395 | 3296.3 | 3697.0 | 7.9456 | 0.28597 | 3295.1 | 3695.5 | 7.8730 |
| 700 | 0.44783 | 3476.3 | 3924.1 | 8.2755 | 0.37297 | 3475.3 | 3922.9 | 8.1904 | 0.31951 | 3474.4 | 3921.7 | 8.1183 |
| 800 | 0.49438 | 3661.7 | 4156.1 | 8.5024 | 0.41184 | 3661.0 | 4155.2 | 8.4176 | 0.35288 | 3660.3 | 4154.3 | 8.3458 |
| 900 | 0.54083 | 3853.9 | 4394.8 | 8.7150 | 0.45059 | 3853.3 | 4394.0 | 8.6303 | 0.38614 | 3852.7 | 4393.3 | 8.5587 |
| 1000 | 0.58721 | 4052.7 | 4640.0 | 8.9155 | 0.48928 | 4052.2 | 4639.4 | 8.8310 | 0.41933 | 4051.7 | 4638.8 | 8.7595 |
| 1100 | 0.63354 | 4257.9 | 4891.4 | 9.1057 | 0.52792 | 4257.5 | 4891.0 | 9.0212 | 0.45247 | 4257.0 | 4890.5 | 8.9497 |
| 1200 | 0.67983 | 4469.0 | 5148.9 | 9.2866 | 0.56652 | 4468.7 | 5148.5 | 9.2022 | 0.48558 | 4468.3 | 5148.1 | 9.1308 |
| 1300 | 0.72610 | 4685.8 | 5411.9 | 9.4593 | 0.60509 | 4685.5 | 5411.6 | 9.3750 | 0.51866 | 4685.1 | 5411.3 | 9.3036 |
| | *P* = 1.60 MPa (201.37°C) | | | | *P* = 1.80 MPa (207.11°C) | | | | *P* = 2.00 MPa (212.38°C) | | | |
| Sat. | 0.12374 | 2594.8 | 2792.8 | 6.4200 | 0.11037 | 2597.3 | 2795.9 | 6.3775 | 0.09959 | 2599.1 | 2798.3 | 6.3390 |
| 225 | 0.13293 | 2645.1 | 2857.8 | 6.5537 | 0.11678 | 2637.0 | 2847.2 | 6.4825 | 0.10381 | 2628.5 | 2836.1 | 6.4160 |
| 250 | 0.14190 | 2692.9 | 2919.9 | 6.6753 | 0.12502 | 2686.7 | 2911.7 | 6.6088 | 0.11150 | 2680.3 | 2903.3 | 6.5475 |
| 300 | 0.15866 | 2781.6 | 3035.4 | 6.8864 | 0.14025 | 2777.4 | 3029.9 | 6.8246 | 0.12551 | 2773.2 | 3024.2 | 6.7684 |
| 350 | 0.17459 | 2866.6 | 3146.0 | 7.0713 | 0.15460 | 2863.6 | 3141.9 | 7.0120 | 0.13860 | 2860.5 | 3137.7 | 6.9583 |
| 400 | 0.19007 | 2950.8 | 3254.9 | 7.2394 | 0.16849 | 2948.3 | 3251.6 | 7.1814 | 0.15122 | 2945.9 | 3248.4 | 7.1292 |
| 500 | 0.22029 | 3120.1 | 3472.6 | 7.5410 | 0.19551 | 3118.5 | 3470.4 | 7.4845 | 0.17568 | 3116.9 | 3468.3 | 7.4337 |
| 600 | 0.24999 | 3293.9 | 3693.9 | 7.8101 | 0.22200 | 3292.7 | 3692.3 | 7.7543 | 0.19962 | 3291.5 | 3690.7 | 7.7043 |
| 700 | 0.27941 | 3473.5 | 3920.5 | 8.0558 | 0.24822 | 3472.6 | 3919.4 | 8.0005 | 0.22326 | 3471.7 | 3918.2 | 7.9509 |
| 800 | 0.30865 | 3659.5 | 4153.4 | 8.2834 | 0.27426 | 3658.8 | 4152.4 | 8.2284 | 0.24674 | 3658.0 | 4151.5 | 8.1791 |
| 900 | 0.33780 | 3852.1 | 4392.6 | 8.4965 | 0.30020 | 3851.5 | 4391.9 | 8.4417 | 0.27012 | 3850.9 | 4391.1 | 8.3925 |
| 1000 | 0.36687 | 4051.2 | 4638.2 | 8.6974 | 0.32606 | 4050.7 | 4637.6 | 8.6427 | 0.29342 | 4050.2 | 4637.1 | 8.5936 |
| 1100 | 0.39589 | 4256.6 | 4890.0 | 8.8878 | 0.35188 | 4256.2 | 4889.6 | 8.8331 | 0.31667 | 4255.7 | 4889.1 | 8.7842 |
| 1200 | 0.42488 | 4467.9 | 5147.7 | 9.0689 | 0.37766 | 4467.6 | 5147.3 | 9.0143 | 0.33989 | 4467.2 | 5147.0 | 8.9654 |
| 1300 | 0.45383 | 4684.8 | 5410.9 | 9.2418 | 0.40341 | 4684.5 | 5410.6 | 9.1872 | 0.36308 | 4684.2 | 5410.3 | 9.1384 |
| | *P* = 2.50 MPa (223.95°C) | | | | *P* = 3.00 MPa (233.85°C) | | | | *P* = 3.50 MPa (242.56°C) | | | |
| Sat. | 0.07995 | 2602.1 | 2801.9 | 6.2558 | 0.06667 | 2603.2 | 2803.2 | 6.1856 | 0.05706 | 2603.0 | 2802.7 | 6.1244 |
| 225 | 0.08026 | 2604.8 | 2805.5 | 6.2629 | | | | | | | | |
| 250 | 0.08705 | 2663.3 | 2880.9 | 6.4107 | 0.07063 | 2644.7 | 2856.5 | 6.2893 | 0.05876 | 2624.0 | 2829.7 | 6.1764 |
| 300 | 0.09894 | 2762.2 | 3009.6 | 6.6459 | 0.08118 | 2750.8 | 2994.3 | 6.5412 | 0.06845 | 2738.8 | 2978.4 | 6.4484 |
| 350 | 0.10979 | 2852.5 | 3127.0 | 6.8424 | 0.09056 | 2844.4 | 3116.1 | 6.7450 | 0.07680 | 2836.0 | 3104.9 | 6.6601 |
| 400 | 0.12012 | 2939.8 | 3240.1 | 7.0170 | 0.09938 | 2933.6 | 3231.7 | 6.9235 | 0.08456 | 2927.2 | 3223.2 | 6.8428 |
| 450 | 0.13015 | 3026.2 | 3351.6 | 7.1768 | 0.10789 | 3021.2 | 3344.9 | 7.0856 | 0.09198 | 3016.1 | 3338.1 | 7.0074 |
| 500 | 0.13999 | 3112.8 | 3462.8 | 7.3254 | 0.11620 | 3108.6 | 3457.2 | 7.2359 | 0.09919 | 3104.5 | 3451.7 | 7.1593 |
| 600 | 0.15931 | 3288.5 | 3686.8 | 7.5979 | 0.13245 | 3285.5 | 3682.8 | 7.5103 | 0.11325 | 3282.5 | 3678.9 | 7.4357 |
| 700 | 0.17835 | 3469.3 | 3915.2 | 7.8455 | 0.14841 | 3467.0 | 3912.2 | 7.7590 | 0.12702 | 3464.7 | 3909.3 | 7.6855 |
| 800 | 0.19722 | 3656.2 | 4149.2 | 8.0744 | 0.16420 | 3654.3 | 4146.9 | 7.9885 | 0.14061 | 3652.5 | 4144.6 | 7.9156 |
| 900 | 0.21597 | 3849.4 | 4389.3 | 8.2882 | 0.17988 | 3847.9 | 4387.5 | 8.2028 | 0.15410 | 3846.4 | 4385.7 | 8.1304 |
| 1000 | 0.23466 | 4049.0 | 4635.6 | 8.4897 | 0.19549 | 4047.7 | 4634.2 | 8.4045 | 0.16751 | 4046.4 | 4632.7 | 8.3324 |
| 1100 | 0.25330 | 4254.7 | 4887.9 | 8.6804 | 0.21105 | 4253.6 | 4886.7 | 8.5955 | 0.18087 | 4252.5 | 4885.6 | 8.5236 |
| 1200 | 0.27190 | 4466.3 | 5146.0 | 8.8618 | 0.22658 | 4465.3 | 5145.1 | 8.7771 | 0.19420 | 4464.4 | 5144.1 | 8.7053 |
| 1300 | 0.29048 | 4683.4 | 5409.5 | 9.0349 | 0.24207 | 4682.6 | 5408.8 | 8.9502 | 0.20750 | 4681.8 | 5408.0 | 8.8786 |

## TABLE A–12

Saturated refrigerant-134a—Pressure table

| | | *Specific volume,* $m^3/kg$ | | *Internal energy,* kJ/kg | | | *Enthalpy,* kJ/kg | | | *Entropy,* kJ/kg · K | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Press., $P$ kPa | Sat. temp., $T_{sat}$ °C | 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, $s_g$ |
| 60 | −36.95 | 0.0007098 | 0.31121 | 3.798 | 205.32 | 209.12 | 3.841 | 223.95 | 227.79 | 0.01634 | 0.94807 | 0.96441 |
| 70 | −33.87 | 0.0007144 | 0.26929 | 7.680 | 203.20 | 210.88 | 7.730 | 222.00 | 229.73 | 0.03267 | 0.92775 | 0.96042 |
| 80 | −31.13 | 0.0007185 | 0.23753 | 11.15 | 201.30 | 212.46 | 11.21 | 220.25 | 231.46 | 0.04711 | 0.90999 | 0.95710 |
| 90 | −28.65 | 0.0007223 | 0.21263 | 14.31 | 199.57 | 213.88 | 14.37 | 218.65 | 233.02 | 0.06008 | 0.89419 | 0.95427 |
| 100 | −26.37 | 0.0007259 | 0.19254 | 17.21 | 197.98 | 215.19 | 17.28 | 217.16 | 234.44 | 0.07188 | 0.87995 | 0.95183 |
| 120 | −22.32 | 0.0007324 | 0.16212 | 22.40 | 195.11 | 217.51 | 22.49 | 214.48 | 236.97 | 0.09275 | 0.85503 | 0.94779 |
| 140 | −18.77 | 0.0007383 | 0.14014 | 26.98 | 192.57 | 219.54 | 27.08 | 212.08 | 239.16 | 0.11087 | 0.83368 | 0.94456 |
| 160 | −15.60 | 0.0007437 | 0.12348 | 31.09 | 190.27 | 221.35 | 31.21 | 209.90 | 241.11 | 0.12693 | 0.81496 | 0.94190 |
| 180 | −12.73 | 0.0007487 | 0.11041 | 34.83 | 188.16 | 222.99 | 34.97 | 207.90 | 242.86 | 0.14139 | 0.79826 | 0.93965 |
| 200 | −10.09 | 0.0007533 | 0.099867 | 38.28 | 186.21 | 224.48 | 38.43 | 206.03 | 244.46 | 0.15457 | 0.78316 | 0.93773 |
| 240 | −5.38 | 0.0007620 | 0.083897 | 44.48 | 182.67 | 227.14 | 44.66 | 202.62 | 247.28 | 0.17794 | 0.75664 | 0.93458 |
| 280 | −1.25 | 0.0007699 | 0.072352 | 49.97 | 179.50 | 229.46 | 50.18 | 199.54 | 249.72 | 0.19829 | 0.73381 | 0.93210 |
| 320 | 2.46 | 0.0007772 | 0.063604 | 54.92 | 176.61 | 231.52 | 55.16 | 196.71 | 251.88 | 0.21637 | 0.71369 | 0.93006 |
| 360 | 5.82 | 0.0007841 | 0.056738 | 59.44 | 173.94 | 233.38 | 59.72 | 194.08 | 253.81 | 0.23270 | 0.69566 | 0.92836 |
| 400 | 8.91 | 0.0007907 | 0.051201 | 63.62 | 171.45 | 235.07 | 63.94 | 191.62 | 255.55 | 0.24761 | 0.67929 | 0.92691 |
| 450 | 12.46 | 0.0007985 | 0.045619 | 68.45 | 168.54 | 237.00 | 68.81 | 188.71 | 257.53 | 0.26465 | 0.66069 | 0.92535 |
| 500 | 15.71 | 0.0008059 | 0.041118 | 72.93 | 165.82 | 238.75 | 73.33 | 185.98 | 259.30 | 0.28023 | 0.64377 | 0.92400 |
| 550 | 18.73 | 0.0008130 | 0.037408 | 77.10 | 163.25 | 240.35 | 77.54 | 183.38 | 260.92 | 0.29461 | 0.62821 | 0.92282 |
| 600 | 21.55 | 0.0008199 | 0.034295 | 81.02 | 160.81 | 241.83 | 81.51 | 180.90 | 262.40 | 0.30799 | 0.61378 | 0.92177 |
| 650 | 24.20 | 0.0008266 | 0.031646 | 84.72 | 158.48 | 243.20 | 85.26 | 178.51 | 263.77 | 0.32051 | 0.60030 | 0.92081 |
| 700 | 26.69 | 0.0008331 | 0.029361 | 88.24 | 156.24 | 244.48 | 88.82 | 176.21 | 265.03 | 0.33230 | 0.58763 | 0.91994 |
| 750 | 29.06 | 0.0008395 | 0.027371 | 91.59 | 154.08 | 245.67 | 92.22 | 173.98 | 266.20 | 0.34345 | 0.57567 | 0.91912 |
| 800 | 31.31 | 0.0008458 | 0.025621 | 94.79 | 152.00 | 246.79 | 95.47 | 171.82 | 267.29 | 0.35404 | 0.56431 | 0.91835 |
| 850 | 33.45 | 0.0008520 | 0.024069 | 97.87 | 149.98 | 247.85 | 98.60 | 169.71 | 268.31 | 0.36413 | 0.55349 | 0.91762 |
| 900 | 35.51 | 0.0008580 | 0.022683 | 100.83 | 148.01 | 248.85 | 101.61 | 167.66 | 269.26 | 0.37377 | 0.54315 | 0.91692 |
| 950 | 37.48 | 0.0008641 | 0.021438 | 103.69 | 146.10 | 249.79 | 104.51 | 165.64 | 270.15 | 0.38301 | 0.53323 | 0.91624 |
| 1000 | 39.37 | 0.0008700 | 0.020313 | 106.45 | 144.23 | 250.68 | 107.32 | 163.67 | 270.99 | 0.39189 | 0.52368 | 0.91558 |
| 1200 | 46.29 | 0.0008934 | 0.016715 | 116.70 | 137.11 | 253.81 | 117.77 | 156.10 | 273.87 | 0.42441 | 0.48863 | 0.91303 |
| 1400 | 52.40 | 0.0009166 | 0.014107 | 125.94 | 130.43 | 256.37 | 127.22 | 148.90 | 276.12 | 0.45315 | 0.45734 | 0.91050 |
| 1600 | 57.88 | 0.0009400 | 0.012123 | 134.43 | 124.04 | 258.47 | 135.93 | 141.93 | 277.86 | 0.47911 | 0.42873 | 0.90784 |
| 1800 | 62.87 | 0.0009639 | 0.010559 | 142.33 | 117.83 | 260.17 | 144.07 | 135.11 | 279.17 | 0.50294 | 0.40204 | 0.90498 |
| 2000 | 67.45 | 0.0009886 | 0.009288 | 149.78 | 111.73 | 261.51 | 151.76 | 128.33 | 280.09 | 0.52509 | 0.37675 | 0.90184 |
| 2500 | 77.54 | 0.0010566 | 0.006936 | 166.99 | 96.47 | 263.45 | 169.63 | 111.16 | 280.79 | 0.57531 | 0.31695 | 0.89226 |
| 3000 | 86.16 | 0.0011406 | 0.005275 | 183.04 | 80.22 | 263.26 | 186.46 | 92.63 | 279.09 | 0.62118 | 0.25776 | 0.87894 |

## TABLE A–13

Superheated refrigerant-134a

| $T$ °C | $v$ m³/kg | $u$ kJ/kg | $h$ kJ/kg | $s$ kJ/kg · K | $v$ m³/kg | $u$ kJ/kg | $h$ kJ/kg | $s$ kJ/kg · K | $v$ m³/kg | $u$ kJ/kg | $h$ kJ/kg | $s$ kJ/kg · K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $P$ = 0.06 MPa ($T_{sat}$ = −36.95°C) | | | | $P$ = 0.10 MPa ($T_{sat}$ = −26.37°C) | | | | $P$ = 0.14 MPa ($T_{sat}$ = −18.77°C) | | | |
| Sat. | 0.31121 | 209.12 | 227.79 | 0.9644 | 0.19254 | 215.19 | 234.44 | 0.9518 | 0.14014 | 219.54 | 239.16 | 0.9446 |
| −20 | 0.33608 | 220.60 | 240.76 | 1.0174 | 0.19841 | 219.66 | 239.50 | 0.9721 | | | | |
| −10 | 0.35048 | 227.55 | 248.58 | 1.0477 | 0.20743 | 226.75 | 247.49 | 1.0030 | 0.14605 | 225.91 | 246.36 | 0.9724 |
| 0 | 0.36476 | 234.66 | 256.54 | 1.0774 | 0.21630 | 233.95 | 255.58 | 1.0332 | 0.15263 | 233.23 | 254.60 | 1.0031 |
| 10 | 0.37893 | 241.92 | 264.66 | 1.1066 | 0.22506 | 241.30 | 263.81 | 1.0628 | 0.15908 | 240.66 | 262.93 | 1.0331 |
| 20 | 0.39302 | 249.35 | 272.94 | 1.1353 | 0.23373 | 248.79 | 272.17 | 1.0918 | 0.16544 | 248.22 | 271.38 | 1.0624 |
| 30 | 0.40705 | 256.95 | 281.37 | 1.1636 | 0.24233 | 256.44 | 280.68 | 1.1203 | 0.17172 | 255.93 | 279.97 | 1.0912 |
| 40 | 0.42102 | 264.71 | 289.97 | 1.1915 | 0.25088 | 264.25 | 289.34 | 1.1484 | 0.17794 | 263.79 | 288.70 | 1.1195 |
| 50 | 0.43495 | 272.64 | 298.74 | 1.2191 | 0.25937 | 272.22 | 298.16 | 1.1762 | 0.18412 | 271.79 | 297.57 | 1.1474 |
| 60 | 0.44883 | 280.73 | 307.66 | 1.2463 | 0.26783 | 280.35 | 307.13 | 1.2035 | 0.19025 | 279.96 | 306.59 | 1.1749 |
| 70 | 0.46269 | 288.99 | 316.75 | 1.2732 | 0.27626 | 288.64 | 316.26 | 1.2305 | 0.19635 | 288.28 | 315.77 | 1.2020 |
| 80 | 0.47651 | 297.41 | 326.00 | 1.2997 | 0.28465 | 297.08 | 325.55 | 1.2572 | 0.20242 | 296.75 | 325.09 | 1.2288 |
| 90 | 0.49032 | 306.00 | 335.42 | 1.3260 | 0.29303 | 305.69 | 334.99 | 1.2836 | 0.20847 | 305.38 | 334.57 | 1.2553 |
| 100 | 0.50410 | 314.74 | 344.99 | 1.3520 | 0.30138 | 314.46 | 344.60 | 1.3096 | 0.21449 | 314.17 | 344.20 | 1.2814 |
| | $P$ = 0.18 MPa ($T_{sat}$ = −12.73°C) | | | | $P$ = 0.20 MPa ($T_{sat}$ = −10.09°C) | | | | $P$ = 0.24 MPa ($T_{sat}$ = −5.38°C) | | | |
| Sat. | 0.11041 | 222.99 | 242.86 | 0.9397 | 0.09987 | 224.48 | 244.46 | 0.9377 | 0.08390 | 227.14 | 247.28 | 0.9346 |
| −10 | 0.11189 | 225.02 | 245.16 | 0.9484 | 0.09991 | 224.55 | 244.54 | 0.9380 | | | | |
| 0 | 0.11722 | 232.48 | 253.58 | 0.9798 | 0.10481 | 232.09 | 253.05 | 0.9698 | 0.08617 | 231.29 | 251.97 | 0.9519 |
| 10 | 0.12240 | 240.00 | 262.04 | 1.0102 | 0.10955 | 239.67 | 261.58 | 1.0004 | 0.09026 | 238.98 | 260.65 | 0.9831 |
| 20 | 0.12748 | 247.64 | 270.59 | 1.0399 | 0.11418 | 247.35 | 270.18 | 1.0303 | 0.09423 | 246.74 | 269.36 | 1.0134 |
| 30 | 0.13248 | 255.41 | 279.25 | 1.0690 | 0.11874 | 255.14 | 278.89 | 1.0595 | 0.09812 | 254.61 | 278.16 | 1.0429 |
| 40 | 0.13741 | 263.31 | 288.05 | 1.0975 | 0.12322 | 263.08 | 287.72 | 1.0882 | 0.10193 | 262.59 | 287.06 | 1.0718 |
| 50 | 0.14230 | 271.36 | 296.98 | 1.1256 | 0.12766 | 271.15 | 296.68 | 1.1163 | 0.10570 | 270.71 | 296.08 | 1.1001 |
| 60 | 0.14715 | 279.56 | 306.05 | 1.1532 | 0.13206 | 279.37 | 305.78 | 1.1441 | 0.10942 | 278.97 | 305.23 | 1.1280 |
| 70 | 0.15196 | 287.91 | 315.27 | 1.1805 | 0.13641 | 287.73 | 315.01 | 1.1714 | 0.11310 | 287.36 | 314.51 | 1.1554 |
| 80 | 0.15673 | 296.42 | 324.63 | 1.2074 | 0.14074 | 296.25 | 324.40 | 1.1983 | 0.11675 | 295.91 | 323.93 | 1.1825 |
| 90 | 0.16149 | 305.07 | 334.14 | 1.2339 | 0.14504 | 304.92 | 333.93 | 1.2249 | 0.12038 | 304.60 | 333.49 | 1.2092 |
| 100 | 0.16622 | 313.88 | 343.80 | 1.2602 | 0.14933 | 313.74 | 343.60 | 1.2512 | 0.12398 | 313.44 | 343.20 | 1.2356 |
| | $P$ = 0.28 MPa ($T_{sat}$ = −1.25°C) | | | | $P$ = 0.32 MPa ($T_{sat}$ = 2.46°C) | | | | $P$ = 0.40 MPa ($T_{sat}$ = 8.91°C) | | | |
| Sat. | 0.07235 | 229.46 | 249.72 | 0.9321 | 0.06360 | 231.52 | 251.88 | 0.9301 | 0.051201 | 235.07 | 255.55 | 0.9269 |
| 0 | 0.07282 | 230.44 | 250.83 | 0.9362 | | | | | | | | |
| 10 | 0.07646 | 238.27 | 259.68 | 0.9680 | 0.06609 | 237.54 | 258.69 | 0.9544 | 0.051506 | 235.97 | 256.58 | 0.9305 |
| 20 | 0.07997 | 246.13 | 268.52 | 0.9987 | 0.06925 | 245.50 | 267.66 | 0.9856 | 0.054213 | 244.18 | 265.86 | 0.9628 |
| 30 | 0.08338 | 254.06 | 277.41 | 1.0285 | 0.07231 | 253.50 | 276.65 | 1.0157 | 0.056796 | 252.36 | 275.07 | 0.9937 |
| 40 | 0.08672 | 262.10 | 286.38 | 1.0576 | 0.07530 | 261.60 | 285.70 | 1.0451 | 0.059292 | 260.58 | 284.30 | 1.0236 |
| 50 | 0.09000 | 270.27 | 295.47 | 1.0862 | 0.07823 | 269.82 | 294.85 | 1.0739 | 0.061724 | 268.90 | 293.59 | 1.0528 |
| 60 | 0.09324 | 278.56 | 304.67 | 1.1142 | 0.08111 | 278.15 | 304.11 | 1.1021 | 0.064104 | 277.32 | 302.96 | 1.0814 |
| 70 | 0.09644 | 286.99 | 314.00 | 1.1418 | 0.08395 | 286.62 | 313.48 | 1.1298 | 0.066443 | 285.86 | 312.44 | 1.1094 |
| 80 | 0.09961 | 295.57 | 323.46 | 1.1690 | 0.08675 | 295.22 | 322.98 | 1.1571 | 0.068747 | 294.53 | 322.02 | 1.1369 |
| 90 | 0.10275 | 304.29 | 333.06 | 1.1958 | 0.08953 | 303.97 | 332.62 | 1.1840 | 0.071023 | 303.32 | 331.73 | 1.1640 |
| 100 | 0.10587 | 313.15 | 342.80 | 1.2222 | 0.09229 | 312.86 | 342.39 | 1.2105 | 0.073274 | 312.26 | 341.57 | 1.1907 |
| 110 | 0.10897 | 322.16 | 352.68 | 1.2483 | 0.09503 | 321.89 | 352.30 | 1.2367 | 0.075504 | 321.33 | 351.53 | 1.2171 |
| 120 | 0.11205 | 331.32 | 362.70 | 1.2742 | 0.09775 | 331.07 | 362.35 | 1.2626 | 0.077717 | 330.55 | 361.63 | 1.2431 |
| 130 | 0.11512 | 340.63 | 372.87 | 1.2997 | 0.10045 | 340.39 | 372.54 | 1.2882 | 0.079913 | 339.90 | 371.87 | 1.2688 |
| 140 | 0.11818 | 350.09 | 383.18 | 1.3250 | 0.10314 | 349.86 | 382.87 | 1.3135 | 0.082096 | 349.41 | 382.24 | 1.2942 |

## TABLE A–13

Superheated refrigerant-134a (*Continued*)

| $T$ °C | $v$ m³/kg | $u$ kJ/kg | $h$ kJ/kg | $s$ kJ/kg · K | $v$ m³/kg | $u$ kJ/kg | $h$ kJ/kg | $s$ kJ/kg · K | $v$ m³/kg | $u$ kJ/kg | $h$ kJ/kg | $s$ kJ/kg · K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $P$ = 0.50 MPa ($T_{sat}$ = 15.71°C) | | | | $P$ = 0.60 MPa ($T_{sat}$ = 21.55°C) | | | | $P$ = 0.70 MPa ($T_{sat}$ = 26.69°C) | | | |
| Sat. | 0.041118 | 238.75 | 259.30 | 0.9240 | 0.034295 | 241.83 | 262.40 | 0.9218 | 0.029361 | 244.48 | 265.03 | 0.9199 |
| 20 | 0.042115 | 242.40 | 263.46 | 0.9383 | | | | | | | | |
| 30 | 0.044338 | 250.84 | 273.01 | 0.9703 | 0.035984 | 249.22 | 270.81 | 0.9499 | 0.029966 | 247.48 | 268.45 | 0.9313 |
| 40 | 0.046456 | 259.26 | 282.48 | 1.0011 | 0.037865 | 257.86 | 280.58 | 0.9816 | 0.031696 | 256.39 | 278.57 | 0.9641 |
| 50 | 0.048499 | 267.72 | 291.96 | 1.0309 | 0.039659 | 266.48 | 290.28 | 1.0121 | 0.033322 | 265.20 | 288.53 | 0.9954 |
| 60 | 0.050485 | 276.25 | 301.50 | 1.0599 | 0.041389 | 275.15 | 299.98 | 1.0417 | 0.034875 | 274.01 | 298.42 | 1.0256 |
| 70 | 0.052427 | 284.89 | 311.10 | 1.0883 | 0.043069 | 283.89 | 309.73 | 1.0705 | 0.036373 | 282.87 | 308.33 | 1.0549 |
| 80 | 0.054331 | 293.64 | 320.80 | 1.1162 | 0.044710 | 292.73 | 319.55 | 1.0987 | 0.037829 | 291.80 | 318.28 | 1.0835 |
| 90 | 0.056205 | 302.51 | 330.61 | 1.1436 | 0.046318 | 301.67 | 329.46 | 1.1264 | 0.039250 | 300.82 | 328.29 | 1.1114 |
| 100 | 0.058053 | 311.50 | 340.53 | 1.1705 | 0.047900 | 310.73 | 339.47 | 1.1536 | 0.040642 | 309.95 | 338.40 | 1.1389 |
| 110 | 0.059880 | 320.63 | 350.57 | 1.1971 | 0.049458 | 319.91 | 349.59 | 1.1803 | 0.042010 | 319.19 | 348.60 | 1.1658 |
| 120 | 0.061687 | 329.89 | 360.73 | 1.2233 | 0.050997 | 329.23 | 359.82 | 1.2067 | 0.043358 | 328.55 | 358.90 | 1.1924 |
| 130 | 0.063479 | 339.29 | 371.03 | 1.2491 | 0.052519 | 338.67 | 370.18 | 1.2327 | 0.044688 | 338.04 | 369.32 | 1.2186 |
| 140 | 0.065256 | 348.83 | 381.46 | 1.2747 | 0.054027 | 348.25 | 380.66 | 1.2584 | 0.046004 | 347.66 | 379.86 | 1.2444 |
| 150 | 0.067021 | 358.51 | 392.02 | 1.2999 | 0.055522 | 357.96 | 391.27 | 1.2838 | 0.047306 | 357.41 | 390.52 | 1.2699 |
| 160 | 0.068775 | 368.33 | 402.72 | 1.3249 | 0.057006 | 367.81 | 402.01 | 1.3088 | 0.048597 | 367.29 | 401.31 | 1.2951 |
| | $P$ = 0.80 MPa ($T_{sat}$ = 31.31°C) | | | | $P$ = 0.90 MPa ($T_{sat}$ = 35.51°C) | | | | $P$ = 1.00 MPa ($T_{sat}$ = 39.37°C) | | | |
| Sat. | 0.025621 | 246.79 | 267.29 | 0.9183 | 0.022683 | 248.85 | 269.26 | 0.9169 | 0.020313 | 250.68 | 270.99 | 0.9156 |
| 40 | 0.027035 | 254.82 | 276.45 | 0.9480 | 0.023375 | 253.13 | 274.17 | 0.9327 | 0.020406 | 251.30 | 271.71 | 0.9179 |
| 50 | 0.028547 | 263.86 | 286.69 | 0.9802 | 0.024809 | 262.44 | 284.77 | 0.9660 | 0.021796 | 260.94 | 282.74 | 0.9525 |
| 60 | 0.029973 | 272.83 | 296.81 | 1.0110 | 0.026146 | 271.60 | 295.13 | 0.9976 | 0.023068 | 270.32 | 293.38 | 0.9850 |
| 70 | 0.031340 | 281.81 | 306.88 | 1.0408 | 0.027413 | 280.72 | 305.39 | 1.0280 | 0.024261 | 279.59 | 303.85 | 1.0160 |
| 80 | 0.032659 | 290.84 | 316.97 | 1.0698 | 0.028630 | 289.86 | 315.63 | 1.0574 | 0.025398 | 288.86 | 314.25 | 1.0458 |
| 90 | 0.033941 | 299.95 | 327.10 | 1.0981 | 0.029806 | 299.06 | 325.89 | 1.0860 | 0.026492 | 298.15 | 324.64 | 1.0748 |
| 100 | 0.035193 | 309.15 | 337.30 | 1.1258 | 0.030951 | 308.34 | 336.19 | 1.1140 | 0.027552 | 307.51 | 335.06 | 1.1031 |
| 110 | 0.036420 | 318.45 | 347.59 | 1.1530 | 0.032068 | 317.70 | 346.56 | 1.1414 | 0.028584 | 316.94 | 345.53 | 1.1308 |
| 120 | 0.037625 | 327.87 | 357.97 | 1.1798 | 0.033164 | 327.18 | 357.02 | 1.1684 | 0.029592 | 326.47 | 356.06 | 1.1580 |
| 130 | 0.038813 | 337.40 | 368.45 | 1.2061 | 0.034241 | 336.76 | 367.58 | 1.1949 | 0.030581 | 336.11 | 366.69 | 1.1846 |
| 140 | 0.039985 | 347.06 | 379.05 | 1.2321 | 0.035302 | 346.46 | 378.23 | 1.2210 | 0.031554 | 345.85 | 377.40 | 1.2109 |
| 150 | 0.041143 | 356.85 | 389.76 | 1.2577 | 0.036349 | 356.28 | 389.00 | 1.2467 | 0.032512 | 355.71 | 388.22 | 1.2368 |
| 160 | 0.042290 | 366.76 | 400.59 | 1.2830 | 0.037384 | 366.23 | 399.88 | 1.2721 | 0.033457 | 365.70 | 399.15 | 1.2623 |
| 170 | 0.043427 | 376.81 | 411.55 | 1.3080 | 0.038408 | 376.31 | 410.88 | 1.2972 | 0.034392 | 375.81 | 410.20 | 1.2875 |
| 180 | 0.044554 | 386.99 | 422.64 | 1.3327 | 0.039423 | 386.52 | 422.00 | 1.3221 | 0.035317 | 386.04 | 421.36 | 1.3124 |
| | $P$ = 1.20 MPa ($T_{sat}$ = 46.29°C) | | | | $P$ = 1.40 MPa ($T_{sat}$ = 52.40°C) | | | | $P$ = 1.60 MPa ($T_{sat}$ = 57.88°C) | | | |
| Sat. | 0.016715 | 253.81 | 273.87 | 0.9130 | 0.014107 | 256.37 | 276.12 | 0.9105 | 0.012123 | 258.47 | 277.86 | 0.9078 |
| 50 | 0.017201 | 257.63 | 278.27 | 0.9267 | | | | | | | | |
| 60 | 0.018404 | 267.56 | 289.64 | 0.9614 | 0.015005 | 264.46 | 285.47 | 0.9389 | 0.012372 | 260.89 | 280.69 | 0.9163 |
| 70 | 0.019502 | 277.21 | 300.61 | 0.9938 | 0.016060 | 274.62 | 297.10 | 0.9733 | 0.013430 | 271.76 | 293.25 | 0.9535 |
| 80 | 0.020529 | 286.75 | 311.39 | 1.0248 | 0.017023 | 284.51 | 308.34 | 1.0056 | 0.014362 | 282.09 | 305.07 | 0.9875 |
| 90 | 0.021506 | 296.26 | 322.07 | 1.0546 | 0.017923 | 294.28 | 319.37 | 1.0364 | 0.015215 | 292.17 | 316.52 | 1.0194 |
| 100 | 0.022442 | 305.80 | 332.73 | 1.0836 | 0.018778 | 304.01 | 330.30 | 1.0661 | 0.016014 | 302.14 | 327.76 | 1.0500 |
| 110 | 0.023348 | 315.38 | 343.40 | 1.1118 | 0.019597 | 313.76 | 341.19 | 1.0949 | 0.016773 | 312.07 | 338.91 | 1.0795 |
| 120 | 0.024228 | 325.03 | 354.11 | 1.1394 | 0.020388 | 323.55 | 352.09 | 1.1230 | 0.017500 | 322.02 | 350.02 | 1.1081 |
| 130 | 0.025086 | 334.77 | 364.88 | 1.1664 | 0.021155 | 333.41 | 363.02 | 1.1504 | 0.018201 | 332.00 | 361.12 | 1.1360 |
| 140 | 0.025927 | 344.61 | 375.72 | 1.1930 | 0.021904 | 343.34 | 374.01 | 1.1773 | 0.018882 | 342.05 | 372.26 | 1.1632 |
| 150 | 0.026753 | 354.56 | 386.66 | 1.2192 | 0.022636 | 353.37 | 385.07 | 1.2038 | 0.019545 | 352.17 | 383.44 | 1.1900 |
| 160 | 0.027566 | 364.61 | 397.69 | 1.2449 | 0.023355 | 363.51 | 396.20 | 1.2298 | 0.020194 | 362.38 | 394.69 | 1.2163 |
| 170 | 0.028367 | 374.78 | 408.82 | 1.2703 | 0.024061 | 373.75 | 407.43 | 1.2554 | 0.020830 | 372.69 | 406.02 | 1.2421 |
| 180 | 0.029158 | 385.08 | 420.07 | 1.2954 | 0.024757 | 384.10 | 418.76 | 1.2807 | 0.021456 | 383.11 | 417.44 | 1.2676 |

## TABLE A–17

Ideal-gas properties of air

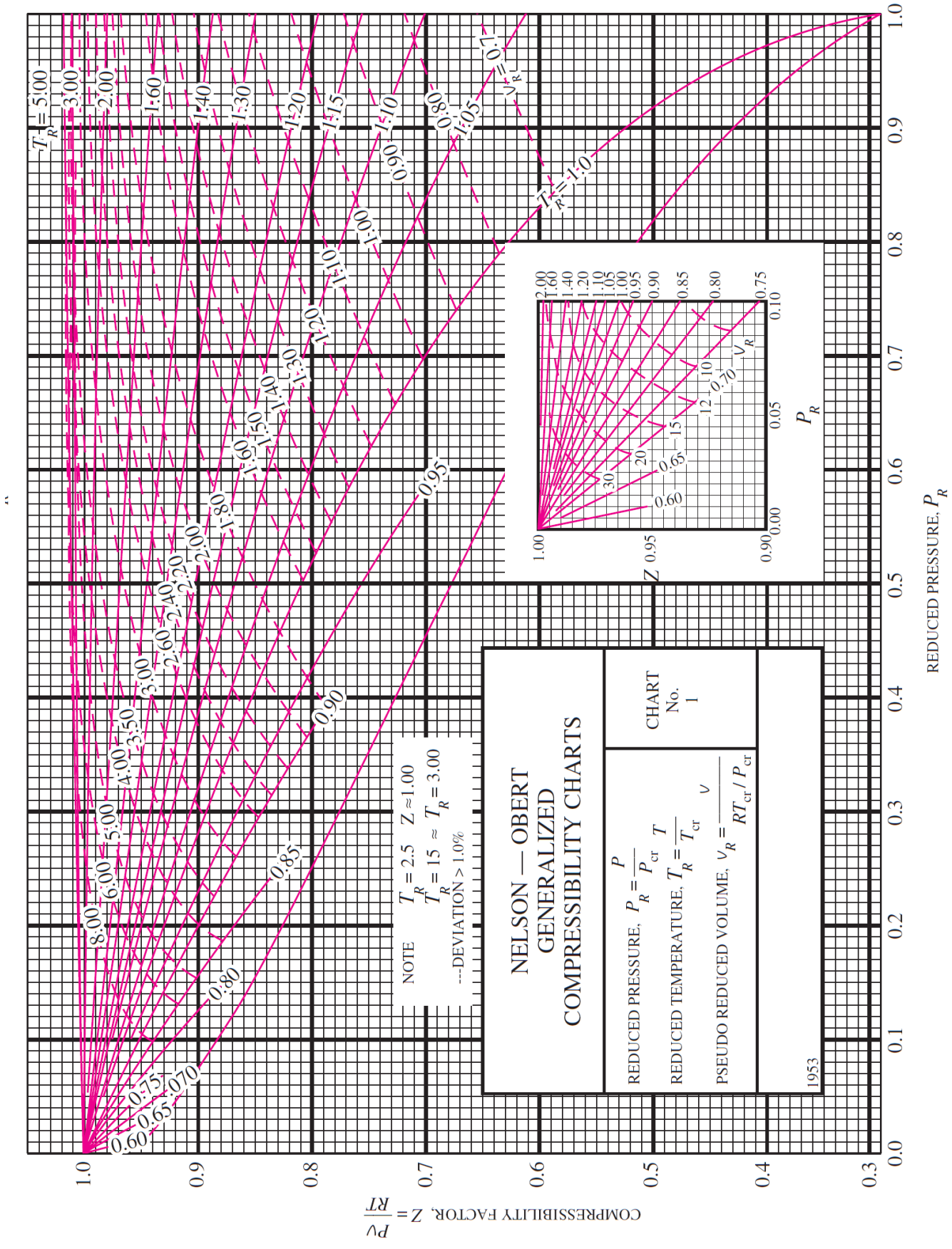
| $T$ K | $h$ kJ/kg | $P_r$ | $u$ kJ/kg | $v_r$ | $s^\circ$ kJ/kg · K | $T$ K | $h$ kJ/kg | $P_r$ | $u$ kJ/kg | $v_r$ | $s^\circ$ kJ/kg · K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 200 | 199.97 | 0.3363 | 142.56 | 1707.0 | 1.29559 | 580 | 586.04 | 14.38 | 419.55 | 115.7 | 2.37348 |
| 210 | 209.97 | 0.3987 | 149.69 | 1512.0 | 1.34444 | 590 | 596.52 | 15.31 | 427.15 | 110.6 | 2.39140 |
| 220 | 219.97 | 0.4690 | 156.82 | 1346.0 | 1.39105 | 600 | 607.02 | 16.28 | 434.78 | 105.8 | 2.40902 |
| 230 | 230.02 | 0.5477 | 164.00 | 1205.0 | 1.43557 | 610 | 617.53 | 17.30 | 442.42 | 101.2 | 2.42644 |
| 240 | 240.02 | 0.6355 | 171.13 | 1084.0 | 1.47824 | 620 | 628.07 | 18.36 | 450.09 | 96.92 | 2.44356 |
| 250 | 250.05 | 0.7329 | 178.28 | 979.0 | 1.51917 | 630 | 638.63 | 19.84 | 457.78 | 92.84 | 2.46048 |
| 260 | 260.09 | 0.8405 | 185.45 | 887.8 | 1.55848 | 640 | 649.22 | 20.64 | 465.50 | 88.99 | 2.47716 |
| 270 | 270.11 | 0.9590 | 192.60 | 808.0 | 1.59634 | 650 | 659.84 | 21.86 | 473.25 | 85.34 | 2.49364 |
| 280 | 280.13 | 1.0889 | 199.75 | 738.0 | 1.63279 | 660 | 670.47 | 23.13 | 481.01 | 81.89 | 2.50985 |
| 285 | 285.14 | 1.1584 | 203.33 | 706.1 | 1.65055 | 670 | 681.14 | 24.46 | 488.81 | 78.61 | 2.52589 |
| 290 | 290.16 | 1.2311 | 206.91 | 676.1 | 1.66802 | 680 | 691.82 | 25.85 | 496.62 | 75.50 | 2.54175 |
| 295 | 295.17 | 1.3068 | 210.49 | 647.9 | 1.68515 | 690 | 702.52 | 27.29 | 504.45 | 72.56 | 2.55731 |
| 298 | 298.18 | 1.3543 | 212.64 | 631.9 | 1.69528 | 700 | 713.27 | 28.80 | 512.33 | 69.76 | 2.57277 |
| 300 | 300.19 | 1.3860 | 214.07 | 621.2 | 1.70203 | 710 | 724.04 | 30.38 | 520.23 | 67.07 | 2.58810 |
| 305 | 305.22 | 1.4686 | 217.67 | 596.0 | 1.71865 | 720 | 734.82 | 32.02 | 528.14 | 64.53 | 2.60319 |
| 310 | 310.24 | 1.5546 | 221.25 | 572.3 | 1.73498 | 730 | 745.62 | 33.72 | 536.07 | 62.13 | 2.61803 |
| 315 | 315.27 | 1.6442 | 224.85 | 549.8 | 1.75106 | 740 | 756.44 | 35.50 | 544.02 | 59.82 | 2.63280 |
| 320 | 320.29 | 1.7375 | 228.42 | 528.6 | 1.76690 | 750 | 767.29 | 37.35 | 551.99 | 57.63 | 2.64737 |
| 325 | 325.31 | 1.8345 | 232.02 | 508.4 | 1.78249 | 760 | 778.18 | 39.27 | 560.01 | 55.54 | 2.66176 |
| 330 | 330.34 | 1.9352 | 235.61 | 489.4 | 1.79783 | 780 | 800.03 | 43.35 | 576.12 | 51.64 | 2.69013 |
| 340 | 340.42 | 2.149 | 242.82 | 454.1 | 1.82790 | 800 | 821.95 | 47.75 | 592.30 | 48.08 | 2.71787 |
| 350 | 350.49 | 2.379 | 250.02 | 422.2 | 1.85708 | 820 | 843.98 | 52.59 | 608.59 | 44.84 | 2.74504 |
| 360 | 360.58 | 2.626 | 257.24 | 393.4 | 1.88543 | 840 | 866.08 | 57.60 | 624.95 | 41.85 | 2.77170 |
| 370 | 370.67 | 2.892 | 264.46 | 367.2 | 1.91313 | 860 | 888.27 | 63.09 | 641.40 | 39.12 | 2.79783 |
| 380 | 380.77 | 3.176 | 271.69 | 343.4 | 1.94001 | 880 | 910.56 | 68.98 | 657.95 | 36.61 | 2.82344 |
| 390 | 390.88 | 3.481 | 278.93 | 321.5 | 1.96633 | 900 | 932.93 | 75.29 | 674.58 | 34.31 | 2.84856 |
| 400 | 400.98 | 3.806 | 286.16 | 301.6 | 1.99194 | 920 | 955.38 | 82.05 | 691.28 | 32.18 | 2.87324 |
| 410 | 411.12 | 4.153 | 293.43 | 283.3 | 2.01699 | 940 | 977.92 | 89.28 | 708.08 | 30.22 | 2.89748 |
| 420 | 421.26 | 4.522 | 300.69 | 266.6 | 2.04142 | 960 | 1000.55 | 97.00 | 725.02 | 28.40 | 2.92128 |
| 430 | 431.43 | 4.915 | 307.99 | 251.1 | 2.06533 | 980 | 1023.25 | 105.2 | 741.98 | 26.73 | 2.94468 |
| 440 | 441.61 | 5.332 | 315.30 | 236.8 | 2.08870 | 1000 | 1046.04 | 114.0 | 758.94 | 25.17 | 2.96770 |
| 450 | 451.80 | 5.775 | 322.62 | 223.6 | 2.11161 | 1020 | 1068.89 | 123.4 | 776.10 | 23.72 | 2.99034 |
| 460 | 462.02 | 6.245 | 329.97 | 211.4 | 2.13407 | 1040 | 1091.85 | 133.3 | 793.36 | 23.29 | 3.01260 |
| 470 | 472.24 | 6.742 | 337.32 | 200.1 | 2.15604 | 1060 | 1114.86 | 143.9 | 810.62 | 21.14 | 3.03449 |
| 480 | 482.49 | 7.268 | 344.70 | 189.5 | 2.17760 | 1080 | 1137.89 | 155.2 | 827.88 | 19.98 | 3.05608 |
| 490 | 492.74 | 7.824 | 352.08 | 179.7 | 2.19876 | 1100 | 1161.07 | 167.1 | 845.33 | 18.896 | 3.07732 |
| 500 | 503.02 | 8.411 | 359.49 | 170.6 | 2.21952 | 1120 | 1184.28 | 179.7 | 862.79 | 17.886 | 3.09825 |
| 510 | 513.32 | 9.031 | 366.92 | 162.1 | 2.23993 | 1140 | 1207.57 | 193.1 | 880.35 | 16.946 | 3.11883 |
| 520 | 523.63 | 9.684 | 374.36 | 154.1 | 2.25997 | 1160 | 1230.92 | 207.2 | 897.91 | 16.064 | 3.13916 |
| 530 | 533.98 | 10.37 | 381.84 | 146.7 | 2.27967 | 1180 | 1254.34 | 222.2 | 915.57 | 15.241 | 3.15916 |
| 540 | 544.35 | 11.10 | 389.34 | 139.7 | 2.29906 | 1200 | 1277.79 | 238.0 | 933.33 | 14.470 | 3.17888 |
| 550 | 555.74 | 11.86 | 396.86 | 133.1 | 2.31809 | 1220 | 1301.31 | 254.7 | 951.09 | 13.747 | 3.19834 |
| 560 | 565.17 | 12.66 | 404.42 | 127.0 | 2.33685 | 1240 | 1324.93 | 272.3 | 968.95 | 13.069 | 3.21751 |
| 570 | 575.59 | 13.50 | 411.97 | 121.2 | 2.35531 | | | | | | |

## TABLE A–17

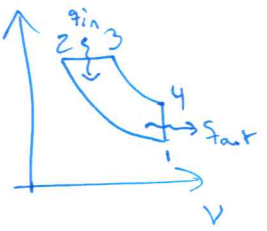
Ideal-gas properties of air (*Concluded*)

| $T$ K | $h$ kJ/kg | $P_r$ | $u$ kJ/kg | $v_r$ | $s^\circ$ kJ/kg · K | $T$ K | $h$ kJ/kg | $P_r$ | $u$ kJ/kg | $v_r$ | $s^\circ$ kJ/kg · K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1260 | 1348.55 | 290.8 | 986.90 | 12.435 | 3.23638 | 1600 | 1757.57 | 791.2 | 1298.30 | 5.804 | 3.52364 |
| 1280 | 1372.24 | 310.4 | 1004.76 | 11.835 | 3.25510 | 1620 | 1782.00 | 834.1 | 1316.96 | 5.574 | 3.53879 |
| 1300 | 1395.97 | 330.9 | 1022.82 | 11.275 | 3.27345 | 1640 | 1806.46 | 878.9 | 1335.72 | 5.355 | 3.55381 |
| 1320 | 1419.76 | 352.5 | 1040.88 | 10.747 | 3.29160 | 1660 | 1830.96 | 925.6 | 1354.48 | 5.147 | 3.56867 |
| 1340 | 1443.60 | 375.3 | 1058.94 | 10.247 | 3.30959 | 1680 | 1855.50 | 974.2 | 1373.24 | 4.949 | 3.58335 |
| 1360 | 1467.49 | 399.1 | 1077.10 | 9.780 | 3.32724 | 1700 | 1880.1 | 1025 | 1392.7 | 4.761 | 3.5979 |
| 1380 | 1491.44 | 424.2 | 1095.26 | 9.337 | 3.34474 | 1750 | 1941.6 | 1161 | 1439.8 | 4.328 | 3.6336 |
| 1400 | 1515.42 | 450.5 | 1113.52 | 8.919 | 3.36200 | 1800 | 2003.3 | 1310 | 1487.2 | 3.994 | 3.6684 |
| 1420 | 1539.44 | 478.0 | 1131.77 | 8.526 | 3.37901 | 1850 | 2065.3 | 1475 | 1534.9 | 3.601 | 3.7023 |
| 1440 | 1563.51 | 506.9 | 1150.13 | 8.153 | 3.39586 | 1900 | 2127.4 | 1655 | 1582.6 | 3.295 | 3.7354 |
| 1460 | 1587.63 | 537.1 | 1168.49 | 7.801 | 3.41247 | 1950 | 2189.7 | 1852 | 1630.6 | 3.022 | 3.7677 |
| 1480 | 1611.79 | 568.8 | 1186.95 | 7.468 | 3.42892 | 2000 | 2252.1 | 2068 | 1678.7 | 2.776 | 3.7994 |
| 1500 | 1635.97 | 601.9 | 1205.41 | 7.152 | 3.44516 | 2050 | 2314.6 | 2303 | 1726.8 | 2.555 | 3.8303 |
| 1520 | 1660.23 | 636.5 | 1223.87 | 6.854 | 3.46120 | 2100 | 2377.7 | 2559 | 1775.3 | 2.356 | 3.8605 |
| 1540 | 1684.51 | 672.8 | 1242.43 | 6.569 | 3.47712 | 2150 | 2440.3 | 2837 | 1823.8 | 2.175 | 3.8901 |
| 1560 | 1708.82 | 710.5 | 1260.99 | 6.301 | 3.49276 | 2200 | 2503.2 | 3138 | 1872.4 | 2.012 | 3.9191 |
| 1580 | 1733.17 | 750.0 | 1279.65 | 6.046 | 3.50829 | 2250 | 2566.4 | 3464 | 1921.3 | 1.864 | 3.9474 |

*Note:* The properties $P_r$ (relative pressure) and $v_r$ (relative specific volume) are dimensionless quantities used in the analysis of isentropic processes, and should not be confused with the properties pressure and specific volume.


NELSON — OBERT
GENERALIZED
COMPRESSIBILITY CHARTS
REDUCED PRESSURE, $P_R = \frac{P}{P_{cr}}$
REDUCED TEMPERATURE, $T_R = \frac{T}{T_{cr}}$
PSEUDO REDUCED VOLUME, $V_R = \frac{V}{RT_{cr}/P_{cr}}$
CHART No. 1
1953
NOTE
$T_R = 2.5$ $Z \approx 1.00$
$T_R = 15 \approx T_R = 3.00$
---DEVIATION > 1.0%
COMPRESSIBILITY FACTOR, $Z = \frac{PV}{RT}$
REDUCED PRESSURE, $P_R$
$T_R = 5.00$
$T_R = 3.00$
$T_R = 2.00$
$T_R = 1.60$
$T_R = 1.40$
$T_R = 1.30$
$T_R = 1.20$
$T_R = 1.15$
$T_R = 1.10$
$T_R = 1.05$
$T_R = 1.0$
$V_R = 0.7$
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
8.00
6.00
5.00
4.00
3.50
3.00
2.60
2.40
2.20
2.00
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.75
0.70
0.65
0.60
Z
$P_R$

# Panta, Examen
# Probs 1 - 5

1) 


El proceso de compresión es isentrópico. Por ende:

$$\left(\frac{v_2}{v_1}\right)_{isentrópico} = \left(\frac{v_{r_2}}{v_{r_1}}\right)$$

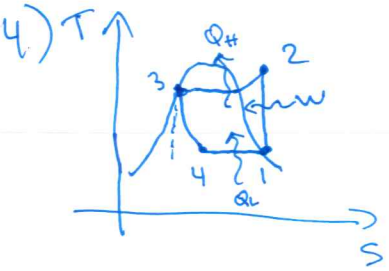
En la tabla A-17 vemos que $T_1 = 300\,K$, $v_{r_1} = 621.2$ y $\frac{v_1}{v_2} = 16$, por lo que $v_{r_2} = \frac{v_2}{v_1} v_{r_1} = 38.825$. En la tabla, haciendo interpolación, vemos que ese $v_{r_2}$ corresponde a $T_2 = 862.4\,K$ ($y\ h_2 = 890.9\ kJ/kg$)

2) Para $q_{in}$ necesitamos $h_3 - h_2$ ($q_{in} = h_3 - h_2$). El proceso 2-3 es isobárico y podemos aplicar la ley de los gases ideales: $pv = RT \Rightarrow \frac{pv}{T} = cte$

$$\frac{P_2 v_2}{T_2} = \frac{P_3 v_3}{T_3} \Rightarrow T_3 = \frac{v_3}{v_2} T_2 = 2\,(862.4) = 1724.8\,K$$

Interpolando en la tabla vemos $h_3 = 1910.6\ kJ/kg.k \Rightarrow q_{in} = 1019.7\ kJ/kg$.

3) Ciclo ideal Rankine: compresión isentrópica, $q_{in}$ isobárica, expansión isentrópica, $q_{out}$ isobárica

4) 


Queremos $\dot{Q}_L = \dot{m}(h_1 - h_4)$. En la tabla A-13 vemos que, para el estado 1 ($P_1 = 120\,kPa$):

$$\begin{cases} T_1 = -22.32 \\ h_1 = h_{g@120kPa} = 236.97\ kJ/kg \\ s_1 = s_{g@120kPa} = 0.94775\ kJ/kg.K \end{cases}$$

Para el estado 2 sabemos $P_2 = 0.7\,MPa$, y $s_2 = s_1$. Como $s_{g@0.7MPa} < s_2$, tenemos vapor sobrecalentado (ya lo sabíamos, por el diagrama).

En la tabla A-13 haciendo la interpolación vemos que $\begin{cases} h_2 = 273.50\ kJ/kg \\ T_2 = 34.95\,^\circ C \end{cases}$.

Sabemos que $P_3 = 0.7\,MPa = P_2$, y líquido saturado, por lo que $\begin{cases} P_3 = 0.7\,MPa \\ h_3 = h_{f@0.7MPa} = 88.82\ kJ/kg \end{cases}$

Por ende $h_4 = h_3$ (proceso isentálpico), y

$$\dot{Q}_L = 0.05\,kg/s\,(236.97 - 88.82) = 7.41\,kW$$

5) $\dot{W} = \dot{m}(h_2 - h_1) = 0.05\,kg/s\ (273.50 - 236.97) = 1.83\,kW$

Por lo que $COP_R = \frac{\dot{Q}_L}{\dot{W}} = 4.06$

# Pauta corrección.

**Pregunta 6**: Respuesta simple: el equilibrio térmico es una relación simétrica y transitiva, por lo que no importa el orden en que se pongan los cuerpos en contacto.

$$\underbrace{3MCT}_{\text{en equilibrio}} = \underbrace{MC(T_1 + T_2 + T_3)}_{\text{antes}}$$

$$\boxed{T = \frac{T_1 + T_2 + T_3}{3}}$$

**Pregunta 7**:

$$\lambda_{f\to g}(T) = h_g(T) - h_f(T)$$

$$= \left(u_g(T) + \overset{\text{sat}}{P}(T)\cdot v_g(T)\right) - \left(u_f(T) + \overset{\text{sat}}{P}(T)\cdot v_f(T)\right)$$

$$= u_g(T) - u_f(T) + \overset{\text{sat}}{P}(T)\cdot(v_g - v_f)$$

$\neq u_g - u_f$ : la respuesta incorrecta es (a).

Pregunta 8: $M = 5\ kg$

$v_f(95) = 0.001040\ m^3/kg$

$v_g(95) = 1.9808\ m^3/kg$.

$$X = \frac{m_g}{m_{tot}} = \frac{3}{5}$$

$$v_{AVG} = X \cdot v_g + (1-X) \cdot v_f = \frac{3}{5} \cdot 1.9808 + \frac{2}{5} \cdot 0.001040$$

$$= 1.1889\ m^3/kg.$$

$$V = M \cdot v_{AVG} = 5\,(kg) \cdot 1.1889\ \frac{m^3}{kg} = 5.94\ m^3.$$

Pregunta 9: $M = 10\ kg$.

$h_f(95) = 398.09\ kJ/kg$

$h_g(95) = 2667.6\ kJ/kg$.

$X_0 = \frac{5}{10}$

$X_1 = \frac{9}{10}$

Antes

$$h_0 = X_0 \cdot h_g + (1-X_0) \cdot h_f = \frac{5}{10} \cdot 2667.6 + \frac{5}{10} \cdot 398.09$$

$$h_0 = 1532.9\ kJ/kg.$$

Después

$$h_1 = X_1 h_g + (1-X_1) h_f = \frac{9}{10} \cdot 2667.6 + \frac{1}{10} \cdot 398.09$$

$$h_1 = 2440.7\ kJ/kg.$$

$$Q = M \cdot (h_1 - h_0) = 10\ kg \cdot (2440.7 - 1532.9)\ \frac{kJ}{kg}$$

$$\boxed{Q = 9078\ kJ}$$

Problema 10:

$$P_{R_1} = \frac{P_1}{P_c} = \frac{1}{3.39} = 0.295$$

$$T_{R_1} = \frac{T_1}{T_c} = \frac{145}{126.2} = 1.15$$

$\Rightarrow Z_1 = 0.93$

$$\Rightarrow M_1 = \frac{P_1 V_1}{R_{N_2} T_1 Z_1} = \frac{1000\ kPa \cdot 1\ m^3}{0.2968\left(\frac{kJ}{kg \cdot K}\right) \cdot 145(K) \cdot 0.93} = 25\ kg$$

$$P_{R_2} = \frac{P_2}{P_c} = \frac{2.05}{3.39} = 0.605$$

$$T_{R_2} = \frac{T_2}{T_c} = \frac{164.0}{126.2} = 1.3$$

$\Rightarrow Z_2 = 0.91$

$$\Rightarrow V_2 = \frac{M_2 Z_2 R_{N_2} T_2}{P_2} = \frac{0.91 \cdot 0.2968 \cdot 164.5}{2050}$$

$$\boxed{V_2 = 0.108\ m^3}$$

Problema 11: Usando gas ideal.

$$M_1 = \frac{P_1 V_1}{R_{N_2} T_1} = 23.24 \text{ kg}; \qquad V_2 = \frac{M_2 R_{N_2} T_2}{P_2} = 0.119 \text{ m}^3$$

- Se abre la válvula: $M_1 \to M_1'$, $M_2 \to M_2'$ : $\begin{cases} M_1': \text{ masa final en rec. 1} \\ M_2': \text{ " en rec. 2} \end{cases}$

- Cons. de materia: $\boxed{M_1 + M_2 = M_1' + M_2'}$ (1)

- En equilibrio: $\left.\begin{aligned} T_1' &= T_2' = T \\ P_1' &= P_2' = P \end{aligned}\right\}$

$$\frac{P}{R_{N_2} T} = \frac{M_1'}{V_1} = \frac{M_2'}{V_2} \Rightarrow \boxed{\frac{M_1'}{M_2'} = \frac{V_1}{V_2}} \quad (2)$$

- Combinando (2) en (1):

$$\begin{cases} M_1' = \dfrac{M_1 + M_2}{1 + \dfrac{M_2'}{M_1'}} = \dfrac{M_1 + M_2}{1 + \dfrac{V_2}{V_1}} = \dfrac{23.24 + 5}{1 + \dfrac{0.119}{1}} = 25.24 \text{ kg} \\ M_2' = \dfrac{V_2}{V_1} M_1' = 3 \text{ kg}. \end{cases}$$

- 1ª ley: Cons. energía ($T_1' = T_2' = T$):

$$M_1' C_v T + M_2' C_v T = M_1 C_v T_1 + M_2 C_v T_2$$

$$T = \frac{M_1 T_1 + M_2 T_2}{M_1' + M_2'} = \frac{23.24 \cdot 145 + 5 \cdot 164}{28.24}$$

$$\boxed{T = 148.4 \text{ °K}}$$

- Pression finale :

$$\boxed{P = \frac{R_{N_2} T \cdot M_2'}{V_2} = \frac{R_{N_2} \cdot T \cdot M_1'}{V_1} = 1.11 \text{ MPa}}$$

Pregunta 12: c)

Pregunta 13: c)

Pregunta 14: a)

Proceso isotérmico $\quad w = P\Delta v$

$T = 200°C \Rightarrow P_{sat@200°C} = 1554.9\ kPa$ (TABLA A-4)

$v_1 = v_{g@200°C} = 0.12721\ m^3/kg$

$v_2 = v_{g@200°C} = 0.001157\ m^3/kg$

} TABLA A-4

$w = 1554.9\ kPa\ (0.12721 - 0.001157)\ \frac{m^3}{kg} = 196\ \frac{kJ}{kg}$

Pregunta 15: b)

| | | | |
|---|---|---|---|
| 0.6 MPa | | 0.15 MPa | $\dot{Q}_{vc} \approx 0$ |
| 200°C | ⟶ | | $\dot{W}_{vc} \approx 0$ |
| 50 m/s | | 600 m/s | $\Delta E_p \approx 0$ |

$$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2} \Rightarrow h_2 = h_1 + \frac{V_1^2}{2} - \frac{V_2^2}{2}$$

Estado inicial → Vapor sobrecalentado: $h_1 = 2850.6\ \frac{kJ}{kg}$ (TABLA A-6)

$h_2 = 2671.85 \Rightarrow$ Mezcla saturada

TABLA A-5:

$h_f = 467.13 \text{ KJ/Kg}$

$h_{fg} = 2226 \text{ KJ/Kg}$

$h_2 = h_f + x\, h_{fg}$

$x = 0.99$

Pregunta 16: d)

$A_{estanque} = 6\,m \times 9\,m$

$\frac{d\,m_{estanque}}{dt} = \dot{m}_{entrada} - \dot{m}_{salida}$ Considerando la densidad del agua constante

$\frac{d\,V_{estanque}}{dt} = \dot{V}_{entrada} - \dot{V}_{salida} \Rightarrow \dot{V}_{entrada} = \frac{d\,V_{estanque}}{dt} + \dot{V}_{salida}$

$\dot{V}_{salida} = \frac{1}{4}\pi\phi^2 v_{salida} = \frac{1}{4}\pi (0.07\,m)^2 \cdot 4\,m/s = 0.01539\,\frac{m^3}{s}$

$\frac{d\,V_{estanque}}{dt} = A_{estanque} \cdot v_{nivel} = (6 \cdot 9)\,m \left(0.025\,\frac{m}{min}\right) = 1.35\,\frac{m^3}{min}$

$\dot{V}_{entrada} = 1.35\,\frac{m^3}{min} \cdot \frac{1\,min}{60\,s} + 0.01539\,\frac{m^3}{s} = 0.0379\,\frac{m^3}{s}$

Pauta preguntas 17, 18, 19, 20, 21, 22

17) C

18) D

19) B

20) El mayor porcentaje de líquido que puede salir de la turbina está determinado por el proceso de expansión isoentrópica en la turbina




① $600°C, 3MPa \rightarrow s_1 = 7.5103 \frac{kJ}{kg \cdot K}$

② $15 kPa$ $s_f @ 15 kPa = 0.7549 \ kJ/kg \cdot K$

$s_g @ 15 kPa = 8.0071 \ kJ/kg \cdot K$

Como $s_2 = s_1$ y $s_f < s_1 < s_g$, la salida de la turbina se encuentra en mezcla líquido-vapor saturado. La calidad es,

$$x_2 = \frac{s_2 - s_f}{s_g - s_f} = 0.9315$$

Por lo tanto, el mayor porcentaje de líquido es

$$1 - x_2 = 6.85\% = 7\%$$

Opción B //

21) Utilizando balance de entropía para un proceso estacionario se tiene que,

$$\cancel{\dot{S}}^{\,0} = \dot{S}_{in} - \dot{S}_{out} + \dot{S}_{gen}$$

Luego $$\dot{S}_{gen} = -\frac{\dot{Q}}{T_i} + \frac{\dot{Q}}{T_e} = -\frac{1000\,W}{(273+30)K} + \frac{1000\,W}{(273+10)K}$$

$$= 0.23\,\frac{W}{K}\,//$$ Opción A

22) El trabajo realizado por la bomba es, $W = W_{rev}/\eta$

con $W_{rev} = V(P_2 - P_1)$

Luego, la potencia es $\dot{W} = \dfrac{\dot{V}(P_2 - P_1)}{\eta}$

$$\dot{W} = \frac{0.3\,m^3}{60\,s} \times \frac{(6-0.3)\,MPa}{0.75}$$

$$= 0.038\,MW = 38.0\,kW\,//$$

Opción D

P 23 :

$$\Delta V_{Hg} = \beta_{Hg} V_0 \Delta T = 2{,}0 \times 10^{-4} \times 800 \times (90-10)\ cm^3$$

$$= 12{,}8\ cm^3$$

$$\Delta V_{frasco} = \Delta V_{Hg} - V_{derramado} = 12{,}8 - 8{,}8 = 4\ cm^3$$

$$\Delta V_{frasco} = \beta_V V_0 \Delta T \Rightarrow \beta_V = \frac{\Delta V_{frasco}}{V_0 \Delta T} = \frac{4}{800 \times (90-10)}$$

$$\beta_V = 6{,}25 \times 10^{-5}\ /^{\circ}C$$

P 24:

$$Q = \int m c_n dT = 10 \int_{20}^{120} (0{,}1 + 0{,}002T)\, dT$$

$$\Rightarrow Q = 10 \left[ 0{,}1 (120-20) + \frac{0{,}002}{2} (120^2 - 20^2) \right]$$

$$\Rightarrow Q = 10 . [10 + 0.001 \cdot 14000]$$

$$\Rightarrow Q = 240\ kJ$$