Pontificia Universidad Católica de Chile
Facultad de Física
FIS1523 Termodinámica

Nota

27 de Noviembre de 2009

EXAMEN

NOMBRE_____ SECCIÓN____ NOTA_____

PROBLEMA 1 (20%)

Suponga que usted es contratado para evaluar tres proyectos que tratan sobre el diseño e implementación de una máquina térmica para operar entre las temperaturas de 20°C y 220°C. Las cantidades de calor y trabajo involucrados por ciclo de operación y el costo de cada máquina son presentados en la siguiente tabla.

# Proyecto	**Qin (kJ)** Calor que ingresa a la máquina	**Qout (kJ)** Calor que sale de la máquina	**W (kJ)** Trabajo neto realizado por la máquina	**Costo ($)**
A	25	14	11	85.000.000
B	25	17	9	70.000.000
C	25	16	9	80.000.000

¿Cuál de los proyectos usted evaluaría positivamente? (Justifique su respuesta)

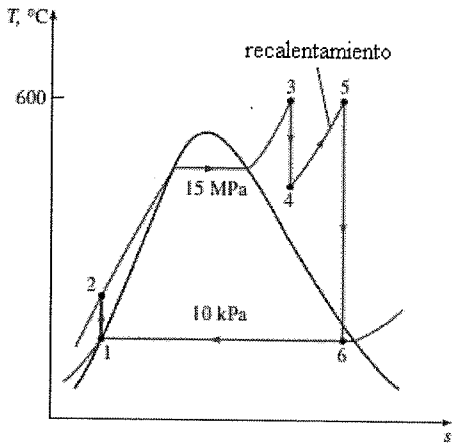
NOMBRE_____ SECCIÓN____ NOTA_____

PROBLEMA 2 (30%)

Considere una planta de potencia a vapor operando en un ciclo ideal de Rankine con recalentamiento, el cual es representado en el diagrama T-s de la figura. El vapor ingresa a la turbina de alta presión a una temperatura de 600°C con una presión de 15MPa, y es condensado en el condensador a una presión de 10 kPa. Si el vapor sale de la turbina de baja presión con una calidad de 0.889, determine:

(a) La presión a la cual el vapor es recalentado.

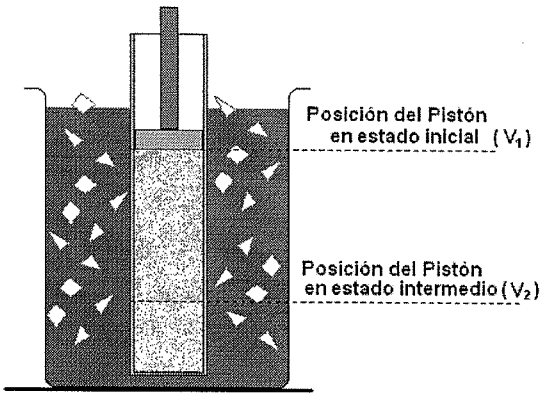
(b) La eficiencia térmica del ciclo. Asuma que el vapor es recalentado hasta la misma temperatura que en la entrada de la turbina de alta presión.



NOMBRE_____ SECCIÓN____ NOTA_____

PROBLEMA 3 (30%)

Un sistema cilindro-pistón que contiene un gas ideal monoatómico, se encuentra en equilibrio termodinámico al estar sumergido en una mezcla de agua con hielo como se muestra en la figura.



En este sistema se realizan las siguientes operaciones:

Proceso 1: El pistón es desplazado rápidamente a la posición inferior.

Proceso 2: El pistón se mantiene en la posición inferior hasta que alcanza el equilibrio térmico con el baño de agua y hielo.

Proceso 3: El pistón se levanta muy lentamente hasta la posición inicial

(a) Dibuje en un diagrama P v/s V los procesos anteriormente descritos (justifique la forma de las curvas del gráfico).

(b) Dibuje el diagrama T v/s S para el ciclo completo (justifique la forma de la curvas del gráfico).

(c) Si se derriten 100g de hielo en el proceso (calor latente de fusión del hielo $L_f = 3{,}33*10^5$ J/kg) ¿Cuál fue el trabajo neto realizado sobre el gas?

NOMBRE_____ SECCIÓN____ NOTA_____

PROBLEMA 4 (20%)

Determine el volumen específico del refrigerante R-134a cuando está sometido a una presión de 1MPa y a una temperatura de 100°C, utilizando:

(a) La ecuación de estado de gas ideal.

(b) La carta generalizada de la compresibilidad.

Compare los valores obtenidos con el valor real de 0.02755 m^3/kg y determine el error en cada caso, esto es: error = |Vcal –Vreal| / Vreal.

NOMBRE_____ SECCIÓN____

Algunas fórmulas:

$P = P_0 + \rho g h$; $T_C = T_K - 273{,}15$; $T_F = \frac{9}{5}T_C + 32$; $\Delta L = \alpha \cdot L \cdot \Delta T$; $1cal \equiv 4{,}186J$; $Q = C \cdot \Delta T$;

$Q = m \cdot c \cdot \Delta T$; $c = \frac{C}{m}$; $Q = m \cdot L$;;; $H = hA\left(T_s - T_f\right)$;; $\boldsymbol{R}$ = 8,314 J/mol·K = 1,986 cal/mol·K;

$N_A = 6{,}022 \times 10^{23}$; $n = \frac{m}{M}$; $PV = nRT$; $k_B \equiv \frac{R}{N_A}$; $PV = Nk_BT$;; $\Delta p_{xi} = 2mv_{xi}$; $P_x = \frac{Nm\overline{v^2}}{3V}$;

$\overline{v^2} = \frac{\sum_{i=1}^{N} v_i^2}{N}$; $\overline{v_x^2} = \frac{\overline{v^2}}{3}$; $P = \frac{Nm\overline{v^2}}{3V}$; $T = \frac{2}{3k_B}\frac{m\overline{v^2}}{2}$; $U = \frac{3}{2}Nk_BT$; $W = \int_{V_i}^{V_f} PdV$; $W = Nk_BT\ln\left(\frac{V_f}{V_i}\right)$;

$\Delta U = Q - W$; $dU = dQ - dW$; $Q = nc_v\Delta T$; $Q = nc_p\Delta T$; $R = c_p - c_v$; 1atm=1,01x10^{5}Pa, $\gamma \equiv \frac{c_p}{c_v}$;

G.L aporta con $\frac{1}{2}k_BT$; $PV^\gamma = cte$ 1mol de aire tiene: $n_{N_2} = 0{,}78$ $n_{O_2} = 0{,}21$ $n_{Ar} = 0{,}01$;

$\frac{P_1}{P_2} = \frac{n_1}{n_2}$; $P_j = \frac{n_j}{\sum_{i=1}^{N} n_i}P$; $H = U + PV$; $Z = \frac{PV}{nRT}$; $P_R = \frac{P}{P_{cr}}$; $T_R = \frac{T}{T_{cr}}$; $S_2 - S_1 = \int_1^2 \frac{dQ}{T}$; $\oint \frac{dQ}{T} = 0$

$\eta = 1 - \frac{|Q_2|}{|Q_1|} = 1 - \frac{T_2}{T_1}$ $\eta = \frac{W}{|Q_1|} = \frac{|Q_1| - |Q_2|}{|Q_1|} = 1 - \frac{|Q_2|}{|Q_1|}$ $CDF_R \equiv \frac{|Q_f|}{W_{in}}$ $CDF_R = \frac{1-\eta}{\eta}$

$S_2 - S_1 \geq \int_1^2 \frac{\delta Q}{T}$; $\Delta S = S_2 - S_1 = \int_1^2 \frac{\delta Q}{T} + S_{gen}$; $S_{gen} = \Delta S_{total} = \Delta S_{sistema} + \Delta S_{entorno} \geq 0$; $x = \frac{m_g}{m_g + m_f}$;

$s_{fg} = s_g - s_f$; $s = s_f + x \cdot s_{fg}$; $dS = \frac{\delta Q}{T}$; $Q = \int_1^2 TdS$; $\dot{m}_{in} - \dot{m}_{out} = \frac{dm_{sist}}{dt}$; $\dot{m} = \rho VA$

$\theta = h + \text{ke} + \text{pe} = h + \frac{V^2}{2} + gz$; $\Delta ke = \frac{V_2^2 - V_1^2}{2}$; $\Delta pe = g(z_2 - z_1)$;

$\dot{Q} + \dot{m}_{in}\left(h_{in} + \frac{V_{in}^2}{2} + gz_{in}\right) = \dot{W} + \dot{m}_{out}\left(h_{out} + \frac{V_{out}^2}{2} + gz_{out}\right)$; $w_{out} = -\left[(h_2 - h_1) + \left(\frac{V_2^2}{2} - \frac{V_1^2}{2}\right) + (gz_2 - gz_1)\right]$;

$\dot{m} = \frac{\dot{W}_{out}}{w_{out}}$; $\frac{dS_{v.c.}}{dt} = \sum \dot{m}_{in}s_{in} - \sum \dot{m}_{out}s_{out} + \sum \frac{\dot{Q}_{v.c.}}{T} + \dot{S}_{gen}$; $\sum \frac{\dot{Q}_{v.c.}}{T} = \int \frac{d\dot{Q}}{T} = \int_{\text{superficie}} \frac{\left(\dot{Q}/A\right)}{T} dA$;

$s_{out} = s_{in} + \sum \frac{q}{T} + s_{gen}$; $\eta_t = \frac{w_{out}}{(w_{out})_s} \approx \frac{(h_1 - h_2)}{(h_1 - h_{2s})}$; $w_{out} \approx \eta_t(h_1 - h_{2s})$; $\eta_c = \frac{(w_{in})_s}{w_{in}} \approx \frac{(h_{2s} - h_1)}{(h_2 - h_1)}$;

$w_{turb,out} = \frac{\dot{W}_{turb,out}}{\dot{m}} \approx h_1 - h_2$, $w_{pump,in} \approx h_4 - h_3$; $q_{in} \approx h_1 - h_4$; $q_{out} \approx h_2 - h_3$; $\eta = \frac{w_{turb,out} - w_{pump,in}}{q_{in}}$;

$rw = \frac{w_{pump,in}}{w_{turb,out}}$; $\left(\frac{\dot{W}}{\dot{m}}\right)_{rev} = \int_{in}^{out} Tds + (h_{in} - h_{out}) + \left(\frac{V_{in}^2 - V_{out}^2}{2}\right) + g\left(z_{in} - z_{out}\right)$; $Tds = du + Pdv$;

$Tds = dh - vdP$; $\left(\frac{\dot{W}}{\dot{m}}\right)_{rev} = -\int_{in}^{out} vdP$; $w_{pump} \approx -v(P_{out} - P_{in})$

Carta generalizada de compresibilidad

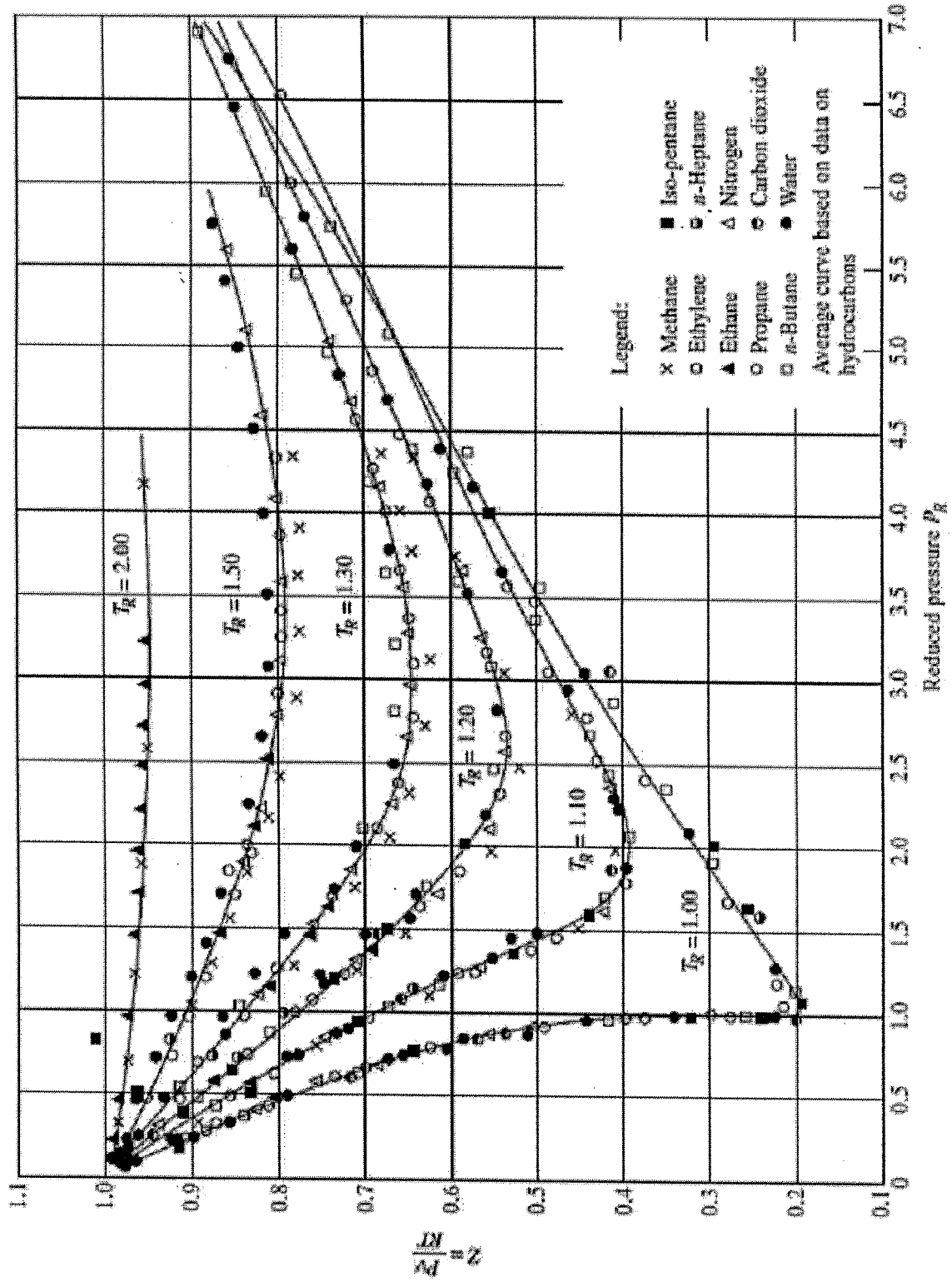


TABLA A-1* Masas atómicas o moleculares y propiedades críticas de elementos y compuestos comunes.

Sustancia	Fórmula química	M	T_c, K	p_c, bar	$z_c = \frac{p_c v_c}{RT_c}$
Acetileno	C_2H_2	26.04	309	62.8	0.274
Agua	H_2O	18.02	647.3	220.9	0.233
Aire	-	28.97	133	37.7	0.284
Amoníaco	NH_3	17.04	406	112.8	0.242
Argón	Ar	39.94	151	48.6	0.290
Benceno	C_6H_6	78.11	563	49.3	0.274
Butano	C_4H_{10}	58.12	425	38.0	0.274
Carbono	C	12.01	-	-	-
Cobre	Cu	63.54	-	-	-
Dióxido de azufre	SO_2	64.06	431	78.7	0.268
Dióxido de carbono	CO_2	44.01	304	73.9	0.276
Etano	C_2H_6	30.07	305	48.8	0.285
Etanol	C_2H_5OH	46.07	516	63.8	0.249
Etileno	C_2H_4	28.05	283	51.2	0.270
Helio	He	4.003	5.2	2.3	0.300
Hidrógeno	H_2	2.018	33.2	13.0	0.304
Metano	CH_4	16.04	191	46.4	0.290
Metanol	CH_3OH	32.05	513	79.5	0.220
Monóxido de carbono	CO	28.01	133	35.0	0.294
Nitrógeno	N_2	28.01	126	33.9	0.291
Octano	C_8H_{18}	114.22	569	24.9	0.258
Oxígeno	O_2	32.00	154	50.5	0.290
Propano	C_3H_8	44.09	370	42.7	0.276
Propileno	C_3H_6	42.08	365	46.2	0.276
Refrigerante 12	CCl_2F_2	120.92	385	41.2	0.278
Refrigerante 134a	CF_3CH_2F	102.03	374	40.7	0.260

Fuentes: Adaptado de *International Critical Tables* y L. C. Nelson y E.F. Obert, Generalized Compressibility Charts, *Chem. Eng., 61*: 203 (1954).

* Nota: Adviértase que el punto (.) separa la parte entera de la decimal.

Tablas de vapor super-calentado:

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 = 4.0 MPa (250.35°C)				P = 4.5 MPa (257.44°C)				P = 5.0 MPa (263.94°C)			
Sat.	0.04978	2601.7	2800.8	6.0696	0.04406	2599.7	2798.0	6.0198	0.03945	2597.0	2794.2	5.9737
275	0.05461	2668.9	2887.3	6.2312	0.04733	2651.4	2864.4	6.1429	0.04144	2632.3	2839.5	6.0571
300	0.05887	2726.2	2961.7	6.3639	0.05138	2713.0	2944.2	6.2854	0.04535	2699.0	2925.7	6.2111
350	0.06647	2827.4	3093.3	6.5843	0.05842	2818.6	3081.5	6.5153	0.05197	2809.6	3069.3	6.4516
400	0.07343	2920.8	3214.5	6.7714	0.06477	2914.2	3205.7	6.7071	0.05784	2907.5	3196.7	6.6483
450	0.08004	3011.0	3331.2	6.9386	0.07076	3005.8	3324.2	6.8770	0.06332	3000.6	3317.2	6.8210
500	0.08644	3100.3	3446.0	7.0922	0.07652	3096.0	3440.4	7.0323	0.06858	3091.8	3434.7	6.9781
600	0.09886	3279.4	3674.9	7.3706	0.08766	3276.4	3670.9	7.3127	0.07870	3273.3	3666.9	7.2605
700	0.11098	3462.4	3906.3	7.6214	0.09850	3460.0	3903.3	7.5647	0.08852	3457.7	3900.3	7.5136
800	0.12292	3650.6	4142.3	7.8523	0.10916	3648.8	4140.0	7.7962	0.09816	3646.9	4137.7	7.7458
900	0.13476	3844.8	4383.9	8.0675	0.11972	3843.3	4382.1	8.0118	0.10769	3841.8	4380.2	7.9619
1000	0.14653	4045.1	4631.2	8.2698	0.13020	4043.9	4629.8	8.2144	0.11715	4042.6	4628.3	8.1648
1100	0.15824	4251.4	4884.4	8.4612	0.14064	4250.4	4883.2	8.4060	0.12655	4249.3	4882.1	8.3566
1200	0.16992	4463.5	5143.2	8.6430	0.15103	4462.6	5142.2	8.5880	0.13592	4461.6	5141.3	8.5388
1300	0.18157	4680.9	5407.2	8.8164	0.16140	4680.1	5406.5	8.7616	0.14527	4679.3	5405.7	8.7124
	P = 6.0 MPa (275.59°C)				P = 7.0 MPa (285.83°C)				P = 8.0 MPa (295.01°C)			
Sat.	0.03245	2589.9	2784.6	5.8902	0.027378	2581.0	2772.6	5.8148	0.023525	2570.5	2758.7	5.7450
300	0.03619	2668.4	2885.6	6.0703	0.029492	2633.5	2839.9	5.9337	0.024279	2592.3	2786.5	5.7937
350	0.04225	2790.4	3043.9	6.3357	0.035262	2770.1	3016.9	6.2305	0.029975	2748.3	2988.1	6.1321
400	0.04742	2893.7	3178.3	6.5432	0.039958	2879.5	3159.2	6.4502	0.034344	2864.6	3139.4	6.3658
450	0.05217	2989.9	3302.9	6.7219	0.044187	2979.0	3288.3	6.6353	0.038194	2967.8	3273.3	6.5579
500	0.05667	3083.1	3423.1	6.8826	0.048157	3074.3	3411.4	6.8000	0.041767	3065.4	3399.5	6.7266
550	0.06102	3175.2	3541.3	7.0308	0.051966	3167.9	3531.6	6.9507	0.045172	3160.5	3521.8	6.8800
600	0.06527	3267.2	3658.8	7.1693	0.055665	3261.0	3650.6	7.0910	0.048463	3254.7	3642.4	7.0221
700	0.07355	3453.0	3894.3	7.4247	0.062850	3448.3	3888.3	7.3487	0.054829	3443.6	3882.2	7.2822
800	0.08165	3643.2	4133.1	7.6582	0.069856	3639.5	4128.5	7.5836	0.061011	3635.7	4123.8	7.5185
900	0.08964	3838.8	4376.6	7.8751	0.076750	3835.7	4373.0	7.8014	0.067082	3832.7	4369.3	7.7372
1000	0.09756	4040.1	4625.4	8.0786	0.083571	4037.5	4622.5	8.0055	0.073079	4035.0	4619.6	7.9419
1100	0.10543	4247.1	4879.7	8.2709	0.090341	4245.0	4877.4	8.1982	0.079025	4242.8	4875.0	8.1350
1200	0.11326	4459.8	5139.4	8.4534	0.097075	4457.9	5137.4	8.3810	0.084934	4456.1	5135.5	8.3181
1300	0.12107	4677.7	5404.1	8.6273	0.103781	4676.1	5402.6	8.5551	0.090817	4674.5	5401.0	8.4925
	P = 9.0 MPa (303.35°C)				P = 10.0 MPa (311.00°C)				P = 12.5 MPa (327.81°C)			
Sat.	0.020489	2558.5	2742.9	5.6791	0.018028	2545.2	2725.5	5.6159	0.013496	2505.6	2674.3	5.4638
325	0.023284	2647.6	2857.1	5.8738	0.019877	2611.6	2810.3	5.7596				
350	0.025816	2725.0	2957.3	6.0380	0.022440	2699.6	2924.0	5.9460	0.016138	2624.9	2825.6	5.7130
400	0.029960	2849.2	3118.8	6.2876	0.026436	2833.1	3097.5	6.2141	0.020030	2789.6	3040.0	6.0433
450	0.033524	2956.3	3258.0	6.4872	0.029782	2944.5	3242.4	6.4219	0.023019	2913.7	3201.5	6.2749
500	0.036793	3056.3	3387.4	6.6603	0.032811	3047.0	3375.1	6.5995	0.025630	3023.2	3343.6	6.4651
550	0.039885	3153.0	3512.0	6.8164	0.035655	3145.4	3502.0	6.7585	0.028033	3126.1	3476.5	6.6317
600	0.042861	3248.4	3634.1	6.9605	0.038378	3242.0	3625.8	6.9045	0.030306	3225.8	3604.6	6.7828
650	0.045755	3343.4	3755.2	7.0954	0.041018	3338.0	3748.1	7.0408	0.032491	3324.1	3730.2	6.9227
700	0.048589	3438.8	3876.1	7.2229	0.043597	3434.0	3870.0	7.1693	0.034612	3422.0	3854.6	7.0540
800	0.054132	3632.0	4119.2	7.4606	0.048629	3628.2	4114.5	7.4085	0.038724	3618.8	4102.8	7.2967
900	0.059562	3829.6	4365.7	7.6802	0.053547	3826.5	4362.0	7.6290	0.042720	3818.9	4352.9	7.5195
1000	0.064919	4032.4	4616.7	7.8855	0.058391	4029.9	4613.8	7.8349	0.046641	4023.5	4606.5	7.7269
1100	0.070224	4240.7	4872.7	8.0791	0.063183	4238.5	4870.3	8.0289	0.050510	4233.1	4864.5	7.9220
1200	0.075492	4454.2	5133.6	8.2625	0.067938	4452.4	5131.7	8.2126	0.054342	4447.7	5127.0	8.1065
1300	0.080733	4672.9	5399.5	8.4371	0.072667	4671.3	5398.0	8.3874	0.058147	4667.3	5394.1	8.2819

Tabla de agua saturada:

Saturated water—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
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 de agua líquida comprimida:

TABLE A–7

Compressed liquid water

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 = 5 MPa (263.94°C)				P = 10 MPa (311.00°C)				P = 15 MPa (342.16°C)			
Sat.	0.0012862	1148.1	1154.5	2.9207	0.0014522	1393.3	1407.9	3.3603	0.0016572	1585.5	1610.3	3.6848
0	0.0009977	0.04	5.03	0.0001	0.0009952	0.12	10.07	0.0003	0.0009928	0.18	15.07	0.0004
20	0.0009996	83.61	88.61	0.2954	0.0009973	83.31	93.28	0.2943	0.0009951	83.01	97.93	0.2932
40	0.0010057	166.92	171.95	0.5705	0.0010036	166.33	176.37	0.5685	0.0010013	165.75	180.77	0.5666
60	0.0010149	250.29	255.36	0.8287	0.0010127	249.43	259.55	0.8260	0.0010105	248.58	263.74	0.8234
80	0.0010267	333.82	338.96	1.0723	0.0010244	332.69	342.94	1.0691	0.0010221	331.59	346.92	1.0659
100	0.0010410	417.65	422.85	1.3034	0.0010385	416.23	426.62	1.2996	0.0010361	414.85	430.39	1.2958
120	0.0010576	501.91	507.19	1.5236	0.0010549	500.18	510.73	1.5191	0.0010522	498.50	514.28	1.5148
140	0.0010769	586.80	592.18	1.7344	0.0010738	584.72	595.45	1.7293	0.0010708	582.69	598.75	1.7243
160	0.0010988	672.55	678.04	1.9374	0.0010954	670.06	681.01	1.9316	0.0010920	667.63	684.01	1.9259
180	0.0011240	759.47	765.09	2.1338	0.0011200	756.48	767.68	2.1271	0.0011160	753.58	770.32	2.1206
200	0.0011531	847.92	853.68	2.3251	0.0011482	844.32	855.80	2.3174	0.0011435	840.84	858.00	2.3100
220	0.0011868	938.39	944.32	2.5127	0.0011809	934.01	945.82	2.5037	0.0011752	929.81	947.43	2.4951
240	0.0012268	1031.6	1037.7	2.6983	0.0012192	1026.2	1038.3	2.6876	0.0012121	1021.0	1039.2	2.6774
260	0.0012755	1128.5	1134.9	2.8841	0.0012653	1121.6	1134.3	2.8710	0.0012560	1115.1	1134.0	2.8586
280					0.0013226	1221.8	1235.0	3.0565	0.0013096	1213.4	1233.0	3.0410
300					0.0013980	1329.4	1343.3	3.2488	0.0013783	1317.6	1338.3	3.2279
320									0.0014733	1431.9	1454.0	3.4263
340									0.0016311	1567.9	1592.4	3.6555
	P = 20 MPa (365.75°C)				P = 30 MPa				P = 50 MPa			
Sat.	0.0020378	1785.8	1826.6	4.0146								
0	0.0009904	0.23	20.03	0.0005	0.0009857	0.29	29.86	0.0003	0.0009767	0.29	49.13	−0.0010
20	0.0009929	82.71	102.57	0.2921	0.0009886	82.11	111.77	0.2897	0.0009805	80.93	129.95	0.2845
40	0.0009992	165.17	185.16	0.5646	0.0009951	164.05	193.90	0.5607	0.0009872	161.90	211.25	0.5528
60	0.0010084	247.75	267.92	0.8208	0.0010042	246.14	276.26	0.8156	0.0009962	243.08	292.88	0.8055
80	0.0010199	330.50	350.90	1.0627	0.0010155	328.40	358.86	1.0564	0.0010072	324.42	374.78	1.0442
100	0.0010337	413.50	434.17	1.2920	0.0010290	410.87	441.74	1.2847	0.0010201	405.94	456.94	1.2705
120	0.0010496	496.85	517.84	1.5105	0.0010445	493.66	525.00	1.5020	0.0010349	487.69	539.43	1.4859
140	0.0010679	580.71	602.07	1.7194	0.0010623	576.90	608.76	1.7098	0.0010517	569.77	622.36	1.6916
160	0.0010886	665.28	687.05	1.9203	0.0010823	660.74	693.21	1.9094	0.0010704	652.33	705.85	1.8889
180	0.0011122	750.78	773.02	2.1143	0.0011049	745.40	778.55	2.1020	0.0010914	735.49	790.06	2.0790
200	0.0011390	837.49	860.27	2.3027	0.0011304	831.11	865.02	2.2888	0.0011149	819.45	875.19	2.2628
220	0.0011697	925.77	949.16	2.4867	0.0011595	918.15	952.93	2.4707	0.0011412	904.39	961.45	2.4414
240	0.0012053	1016.1	1040.2	2.6676	0.0011927	1006.9	1042.7	2.6491	0.0011708	990.55	1049.1	2.6156
260	0.0012472	1109.0	1134.0	2.8469	0.0012314	1097.8	1134.7	2.8250	0.0012044	1078.2	1138.4	2.7864
280	0.0012978	1205.6	1231.5	3.0265	0.0012770	1191.5	1229.8	3.0001	0.0012430	1167.7	1229.9	2.9547
300	0.0013611	1307.2	1334.4	3.2091	0.0013322	1288.9	1328.9	3.1761	0.0012879	1259.6	1324.0	3.1218
320	0.0014450	1416.6	1445.5	3.3996	0.0014014	1391.7	1433.7	3.3558	0.0013409	1354.3	1421.4	3.2888
340	0.0015693	1540.2	1571.6	3.6086	0.0014932	1502.4	1547.1	3.5438	0.0014049	1452.9	1523.1	3.4575
360	0.0018248	1703.6	1740.1	3.8787	0.0016276	1626.8	1675.6	3.7499	0.0014848	1556.5	1630.7	3.6301
380					0.0018729	1782.0	1838.2	4.0026	0.0015884	1667.1	1746.5	3.8102