UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2002/2003

Februari / Mac 2003

JNK 502/3 – Sistem Penukaran Tenaga

Masa : 3 jam

ARAHAN KEPADA CALON :

Sila pastikan bahawa kertas soalan ini mengandungi **SEMBILAN (9)** mukasurat dan **TUJUH (7)** soalan yang bercetak serta **SEMBILAN (9)** halaman lampiran sebelum anda memulakan peperiksaan.

Sila jawab **LIMA (5)** soalan sahaja.

Setiap soalan mestilah dimulakan pada mukasurat yang baru.

Lampiran :

1.	Steam Tables	[6 mukasurat]
2.	Mollier Chart	[1 mukasurat]
3.	Solar Constants [For Northern Latitudes]	[1 mukasurat]
4.	Partial List of Isotopes	[1 mukasurat]

Serahkan **KESELURUHAN** soalan dan jawapan kertas peperiksaan ini kepada Ketua Pengawas di akhir sidang peperiksaan. Pelajar yang gagal berbuat demikian akan diambil tindakan disiplin.

KETUA PENGAWAS : Sila pungut :

(a) **KESELURUHAN** kertas soalan ini (tanpa diceraikan mana-mana muka surat) dan mana-mana kertas soalan peperiksaan ini yang berlebihan untuk dikembalikan kepada Bahagian Peperiksaan, Jabatan Pendaftar, USM.

Peringatan :

1. Sila pastikan bahawa anda telah menulis angka giliran dengan betul.

S1. [a] Bandingkan dandang tiub-api dan dandang tiub-air dari segi :

Prinsip kerja
Pembinaan
Kapasiti
Tekanan
Penggunaan

Compare fire-tube boilers with water –tube boilers as regards to:

Principle of working
Construction
Capacity
Pressure
Application

(40 markah)

[b] Perincian berikut merujuk kepada dandang tiga-alur tiub-api dengan pemanas lampau luaran. Bahanapi digunakan ialah minyak diesel.

Perincian dandang :

Tekanan	**1MPa**
Pecahan kekeringan bagi stim yang dihasilkan	**0.94**
Bahanapi digunakan	**30 liter/jam**
Stim dihasilkan	**270 kg/h**
Ketumpatan bahanapi	**840 kg/m^3**
Nilai kalori bahanapi	**42 MJ/kg**
Suhu bagi air suapan	**30°C**

Perincian pemanas lampau

Tekanan	**0.8 MPa**
Suhu	**250 ^{0} C**

Tentukan :
(i) kecekapan dandang.
(ii) sejatan setara.
(iii) kenaikan entalpi bagi stim di dalam pemanas lampau.

The following details refer to a 3-pass Fire-tube boiler with externally fired superheater.The fuel used is diesel oil.

Boiler details:

Pressure	*1 MPa*
Dryness fraction of steam produced	*0.94*
Fuel consumed	$30\ l/h$
Steam produced	$270\ kg/h$
Density of fuel	$840\ kg/m^3$
Calorific value of fuel	$42\ MJ/kg$
Temperature of feed water	$30\ ^0C$

Superheater details:

Pressure	*0.8 MPa*
Temperature	$250\ ^0C$

Determine :

(i) *boiler efficiency*
(ii) *equivalent evaporation*
(iii) *increase in enthalpy of steam in the superheater*

(60 markah)

S2. **[a]** **Dengan lakaran-lakaran yang sesuai, terangkan pembinaan dan fungsi elemen-elemen berikut bagi turbin stim.**

muncung
bilah pegun
bilah bergerak
selinder
rotor

With suitable sketches explain the construction and function of the elements of steam turbine.

Nozzle
Stationary blades
Moving blades
Cylinder
Rotor

(40 markah)

[b] **Sebuah pengisar minyak sawit menghasilkan haba dan kuasa dengan membakar sisa-sisa biojisim (kulit dan fiber) buah kelapa sawit. Pengisar berkenaan mempunyai dandang tiub air yang menjalankan turbin stim tekanan balikan dan digandingkan ke penjana elektrik. Stim ekzos dari turbin digunakan bagi proses. Sprsifikasi bagi loji diberi di bawah :**

Dandang	-	**tekanan stim**	**2 MPa**
	-	**suhu pemanas lampau**	**350° C**
	-	**kapasiti**	**7000 kg/jam**
Turbin	-	**tekanan masukan**	**2 MPa**
	-	**tekanan ekzos**	**0.4 MPa**
	-	**stim meninggalkan turbin dalam bentuk wap tepu kering**	
Bahanapi	-	**nilai kalori**	**18 MJ/kg**
	-	**Penggunaan bahanapi**	**1650 kg/jam**

Kirakan :

(i) **kuasa elektrik**
(ii) **tenaga digunakan di dalam proses**
(iii) **kecekapan keseluruhan bagi gabungan sistem haba dan kuasa**

A palm oil mill produces heat and power from burning biomass residue (shell & fiber) of palm fruit.The mill has a water tube boiler which runs a back pressure steam turbine coupled to an electric generator.The exhaust steam from the turbine is used for the process.The specifications of such a plant is given below:

Boiler	-	*steam pressure*	*2 MPa*
	-	*superheater temperature*	*350 ⁰ C*
	-	*capacity*	*7000 kg / h*
Turbine	-	*Inlet pressure*	*2 MPa*
	-	*Exhaust pressure*	*0.4 MPa*
	-	*Steam leaves the turbine as dry saturated vapour*	
Fuel	-	*Calorific value of fuel*	*18 MJ /kg*
	-	*Fuel consumption*	*1650 kg / h.*

Calculate:

(i) *electric power*
(ii) *energy used in the process*
(iii) *overall efficiency of combined heat and power system*

(60 markah)

S3. [a] Bandingkan stim turbin dan gas turbin dari segi :

Prinsip kerja
Kuasa
Kecekapan
Kegunaan

Bagaimanakah kedua-dua unit dapat digabungkan bagi meningkatkan kecekapan ?

Compare a steam turbine with gas turbine as regards:

working principle
power
efficiency
utility

How these two units can be combined to improve efficiency?

(40 markah)

[b] Sebuah loji STAG mempunyai spesifikasi berikut :

Unit gas turbin

Bilangan unit	**4**
Kadar alir jisim bahanapi di dalam pembakar	**5 kg/s**
Kadar alir jisim udara yang dibekalkan	**150 kg/s**
Kenaikan suhu di dalam pemampat	**240 K**
Kejatuhan suhu di dalam turbin	**560 K**
Nilai kalori bahanapi	**38 MJ/kg**

Unit turbin stim

Tekanan masukan	**10 MPa**
Suhu masukan	**400°C**
Tekanan ekzos	**5 kPa**
Pecahan kekeringan bagi stim ekzos	**1.0**
Kadar alir jisim stim	**125 kg/s**

Tiada pengapian tambahan di dalam HRSG, Andaikan haba tentu bagi gas ekzos pada tekanan malar ialah 1.147 kJ/kg/K dan haba tentu bagi udara pada tekanan malar ialah 1.005 kJ/kg/K

Tentukan

(i) kuasa keluaran bagi gas turbin.
(ii) kuasa keluaran bagi stim turbin.
(iii) kecekapan keseluruhan bagi loji.

A STAG plant has the following specifications:

Gas turbine unit

no. of units	*4*
mass flow rate of fuel in combustor	*5 kg / s*
mass flow rate of air supplied	*150 kg / s*
temperature rise in the compressor	*240 K*
temperature drop in the turbine	*560 K*
calorific value of fuel	*38 MJ / kg*

Steam turbine unit

initial pressure	*10 MPa*
initial temperature	$400\,^0 C$
exhaust pressure	*5 kPa*
dryness fraction of exhaust steam	*1.0*
mass flow rate of steam	*125 kg / s*

There is no supplementary firing in HRSG .Assume specific heat of exhaust gases at constant pressure=1.147 kJ/kg/K and specific heat of air at constant pressure = 1.005 kJ/kg/K

Determine:

(i) power output of gas turbine
(ii) power output of steam turbine
(iii) overall efficiency of the plant

(60 markah)

S4. [a] Terangkan secara ringkas dengan bantuan lakaran ringkas prinsip kerja bagi

(i) menara penyejukan hiperbolik
(ii) menara penyejukan drauf teraruh dan paksa

Explain briefly with simple sketches the working principle of

(i) hyperbolic cooling tower
(ii) induced and forced draft cooling towers

(40 markah)

[b] **Sebuah loji kuasa pengapian arang batu terhancur mempunyai unit penjanaan turbin dan menghasilkan kuasa elektrik kasar 1000 MW. Loji berkenaan memerlukan 5% dari kuasa tersebut bagi kegunaan sendiri. Ia menggunakan 9800 tan arang batu sehari. Arang batu berkenaan mempunyai nilai kalori 32 MJ/kg. Kirakan kecekapan bersih loji tersebut.**

Loji berkenaan ditukarkan ke unit pengapian minyak dan tenaga masukan serta keadaan-keadaan lain tidak berubah, tentukan kos bahan api setahun bagi dandang pengapian minyak dengan data-data berikut:

ketumpatan minyak	**890 kg/m^3**
nilai kalori bahan api	**44 mj/kg**
jam bekerja bagi loji	**7000 jam/tahun**
kos bagi bahan api	**RM 0.65/liter**

A pulverised coal- fired power plant has a turbine-generator unit producing gross electric power of 1000 MW.The plant requires 5 % of this power for its own needs.It uses 9800 tonne of coal per day. The coal has a calorific value of 32 MJ / kg.Calculate the net station efficiency.

The plant is switched to oil firing unit.and the energy input to the boiler remains and so also the other conditions,determine cost of fuel per year of oil fired boiler with the following data:

density of oil	*890 kg / m^3*
calorific value value of fuel	*44 MJ / kg*
working hours of plant	*7000 hrs / year*
cost of fuel oil	*RM 0.65 / litre*

(60 markah)

S5. [a] **Dengan bantuan satu gambarajah, terangkan secara ringkas prinsip kerja bagi sebuah kolam garam suria .**

With the aid of a diagram briefly describe the working principle of a solar salt pond.

(40 markah)

[b] **Sebuah bumbung mengarah ke tenggara diselaputi oleh slate dan condong pada sudut 35° dari mengufuk. Ia terletak pada 30° garis lintang Utara dan 57° garis bujur Barat. Kirakan fluks tenaga suria gabungan antara penyerapan langsung dan resapan-berselerak pada jam 10.00 AM waktu penjimatan siang tempatan dan pada 21hb. April.**

Diberi : $\sin \beta_1 = (\cos L)(\cos \delta)(\cos H) + (\sin L)(\sin \delta)$

$\cos \theta = (\sin \beta_1)(\cos \beta_2) - (\cos \beta_1)(\sin \beta_2)\ [\cos(\alpha_1 - \alpha_2)]$

$\sin \alpha_{1,c} = (\cos \delta)(\sin H) / \cos \beta_1$

$F_{ss} = 0.5(1 + \cos \beta_2)$

Dimana: β_1 = sudut diantara sinaran dengan latar melintang (sudut ketinggian)

β_2 = sudut diantara permukaan dan latar melintang (sudut condong permukaan)

α_1= sudut diantara unjuran lintang sinaran dengan garis bujur setempat (sudut azimuth)

$\alpha_{1,c}$= sudut sinar azimuth terkira

α_2 = sudut diantara unjuran lintang permukaan normal dari selatan

L = garis lintang

H = sudut jam [H = (minit selepas 12 tengah malam, AST – 720)/4]

F_{ss} = factor bentuk pancaran bagi pancaran suria tersentuh kelangit

AST = masa suria ternyata

Keberpancaran suria bagi bumbung slate, ε_{su} = 0.90

The south-east roof of a building is covered with slate and is inclined at an angle of 35 °from the horizontal. It is located at 30 ° North latitude and 57 ° West longitude. Evaluate the combined absorbed direct and diffuse-scattered solar energy flux at 10:00 AM local daylight saving time on April 21st.

Given : $\sin \beta_1 = (\cos L)(\cos \delta)(\cos H) + (\sin L)(\sin \delta)$

$\cos \theta = (\sin \beta_1)(\cos \beta_2) - (\cos \beta_1)(\sin \beta_2)\,[\cos(\alpha_1 - \alpha_2)]$

$\sin \alpha_{1,c} = (\cos \delta)(\sin H) / \cos \beta_1$

$F_{ss} = 0.5(1 + \cos \beta_2)$

Where: β_1 *= angle between sun's rays and horizontal surface (altitude angle)*

β_2 *= angle between surface and horizontal plane (surface tilt angle)*

α_1*= angle between horizontal projection of the sun's rays and the local longitude (azimuth angle)*

$\alpha_{1,c}$*= calculated solar azimuth angle*

α_2*= angle between horizontal projection of the normal to the surface due south and is positive in the clockwise direction*

L = latitude

H = hour angle [H = (minutes pass 12 midnight, AST – 720)/4]

F_{ss} = radiation shape factor for radiation that hits the sky

AST = apparent sun time

Solar emissivity for slate roofing, $\varepsilon_{su} = 0.90$

(60 markah)

S6. [a] Terangkan apakah yang dimaksudkan dengan *fusion reaction* dan *fission reaction* yang berkaitan dengan sistem tenaga. Senaraikan kelebihan dan kekurangan bagi kedua-dua sistem tersebut.

Explain what is meant by fusion reaction and fission reaction when related to power systems . List the advantages and disadvantages of each system.

(40 markah)

[b] **Kira tenaga gabungan purata *per nucleon* bagi isotope-isotope berikut:**

(i) ***heavy hydrogen*** $\left({}^{2}_{1}\mathrm{H}\right)$ **dan**

(ii) ***isotope nickel*** $\left({}^{59}_{28}\mathrm{Ni}\right)$

Calculate the average binding energy per nucleon for the following isotopes:

(i) heavy hydrogen $\left({}^{2}_{1}\mathrm{H}\right)$ *and*

(ii) nickel isotope $\left({}^{59}_{28}\mathrm{Ni}\right)$

(30 markah)

[c] **Atom uranium-235 melalui kereputan alpha (helium-4 necleus) dengan pancaran 0.17-MeV sinar gamma. Kira tenaga kinetik necleus dan butir alpha yang terbentuk.**

Uranium-235 atoms undergo alpha (a helium-4 necleus) decay with the emission of a 0.17-MeV gamma ray. Find the kinetic energy of the product necleus and the alpha particle.

(30 markah)

S7. [a] **Senaraikan lima kelebihan dan lima kekurangan bagi sumber-sumber tenaga biojisim**

List five advantages and five disadvantages of biomass energy resources.

(40 markah)

[b] **Peratus komposisi bagi satu sampel kayu mengandungi:**

60.0% C, 5.0% H_2, 30.0% O_2, 2.0% N_2 dan bakinya abu.

(i) **Tentukan nisbah stoikiometri udara-bahanapi berasaskan jisim, dan**

(ii) **Jika 20% udara lebihan dibekalkan, kirakan peratus komposisi bagi gas serombong kering berasaskan jisim**

The percentage composition of a sample of wood was found to be:

60.0% C, 5.0% H_2*, 30.0% O2, 2.0%* N_2*, and remainder ash.*

(i) Determine the stoichiometric air-fuel ratio by mass, and

(ii) If 20% excess air is supplied, find the percentage composition of dry flue gas by mass.

(60 markah)

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LAMPIRAN

STEAM TABLES

Water: Liquid-Vapor Saturation, Pressure Table (SI)

		Specific Volume m^3/kg		Internal Energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/kg.K	
Pressure kPa P	Temp. °C T	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}
0.6113	0.01	1000 E-6	206.14	.00	2375.3	2375.3	.01	2501.3	2501.4	.0000	9.1526
1.0	6.98	1000 E-6	129.21	29.3	2355.7	2385.0	29.3	2484.9	2514.2	.1059	8.8697
	13.03	1001 E-6	87.98	54.71	2338.6	2393.3	54.71	2470.6	2525.3	.1957	8.6322
2.0	13.03	1001 E-6	67.00	73.48	2326	2399.5	73.48	2460.0	2533.5	.2607	8.4629
2.5	17.50	1002 E-6	54.25	88.48	2315.9	2404.4	88.49	2451.6	2540.0	.3120	8.3311
3.0	21.08	1003 E-6	45.67	101.04	2307.5	2408.5	101.05	2445.5	2545.5	.3545	8.2231
4.0	28.96	1004 E-6	34.80	121.45	2293.7	2415.2	121.46	2432.9	2554.4	.4226	8.0520
5.0	32.88	1005 E-6	28.19	137.81	2282.7	2420.5	137.82	2423.7	2561.5	.4764	7.9187
7.5	40.29	1008 E-6	19.24	168.78	2261.7	2430.5	168.79	2406.0	2574.8	.5764	7.6750
10	45.81	1010 E-6	14.67	191.82	2246.1	2437.9	191.83	2392.8	2584.7	.6493	7.5009
15	53.97	1014 E-6	10.02	225.92	2222.8	2448.7	225.94	2373.1	2599.1	.7549	7.2536
20	60.06	1017 E-6	7.649	251.38	2205.4	2456.7	251.4	2358.3	2609.7	.8320	7.0766
25	64.97	1020 E-6	6.204	271.90	2191.2	2463.1	271.93	2346.3	2618.2	.8931	6.9383
30	69.1	1022 E-6	5.229	289.20	2179.2	2468.4	289.23	2336.1	2625.3	.9439	6.8247
40	75.87	1027 E-6	3.993	317.53	2159.5	24770	317.58	2319.2	2638.8	1.0259	6.6441
50	81.33	1030 E-6	3.240	340.44	2143.4	2483.9	340.49	2305.4	2645.9	1.0910	6.5029
75	91.78	1037 E-6	2.217	384.31	2112.4	2496.7	384.39	2278.6	2663.0	1.2130	6.2434
MPa											
0.100	99.63	1043 E-6	1.694	417.36	2088.7	2506.1	417.46	2258.0	2675.5	1.3026	6.0568
0.125	105.99	1048 E-6	1.3749	444.19	2069.3	2513.5	444.32	2241.0	2685.4	1.3740	5.9104
0.150	111.37	1053 E-6	1.1593	466.94	2052.7	2519.7	467.11	2226.5	2693.6	1.4336	5.7897
0.175	116.06	1057 E-6	1.0036	486.80	2038.1	2524.9	486.99	2213.6	2700.6	1.4849	5.6868
0.200	120.23	1061 E-6	0.8857	504.49	2025.0	2529.5	504.70	2201.9	2706.7	1.5301	5.597
0.225	124.00	1064 E-6	0.7933	520.47	2013.1	2533.6	520.72	2191.3	2712.1	1.5706	5.5173
0.250	127.44	1067 E-6	0.7187	535.10	2002.1	2537.2	535.37	2181.5	2716.9	1.6072	5.4455
0.275	130.60	1070 E-6	0.6573	548.59	1991.9	2540.5	548.89	2172.4	2721.3	1.6408	5.3801
0.300	133.55	1073 E-6	0.6058	561.15	1982.4	2543.6	561.47	2163.8	2725.3	1.6718	5.3201
0.325	136.30	1076 E-6	0.5620	572.90	1973.5	2546.4	573.25	2155.8	2729.0	1.7006	5.2646
0.350	138.88	1079 E-6	0.5243	583.95	1965.0	2548.9	584.33	2148.1	2732.4	1.7275	5.2130
0.375	141.32	1081 E-6	0.4914	594.40	1956.9	2551.3	594.81	2140.8	2735.6	1.7528	5.1647
0.40	143.63	1084 E-6	0.4625	604.31	1949.3	2553.6	604.74	2133.8	2738.6	1.7766	5.1193
0.45	147.93	1088 E-6	0.4140	622.77	1934.9	2557.6	623.25	2120.7	2743.9	1.8207	5.0359
0.50	151.86	1093 E-6	0.3749	639.68	1921.6	2561.2	640.23	2108.5	2748.7	1.8607	4.9606
0.55	155.48	1097 E-6	0.3427	655.32	1909.6	2564.5	655.93	2097.0	2753.0	1.8973	4.8920
0.60	158.85	1101 E-6	0.3157	669.90	1897.5	2567.4	670.56	2086.3	2756.8	1.9312	4.8288
0.65	162.01	1104 E-6	0.2927	683.56	1886.5	2570.1	684.28	2076.0	2760.3	1.9627	4.7703
0.70	164.97	1108 E-6	0.2729	696.44	1876.1	2572.5	697.22	2066.3	2763.5	1.9922	4.7158
0.75	167.78	1112 E-6	0.2556	708.64	1866.1	2574.7	709.47	2057.0	2766.4	2.0200	4.6647
0.80	170.43	1115 E-6	0.2404	720.22	1856.6	2576.8	721.11	2048.0	2769.1	2.0462	4.6166
0.85	172.96	1118 E-6	0.2270	731.27	1847.4	2578.7	732.22	2039.4	2771.6	2.0710	4.5711
0.90	175.38	1121 E-6	0.2150	741.83	1838.6	2580.5	742.83	2031.1	2773.9	2.0946	4.5280
0.95	177.69	1124 E-6	0.2042	751.95	1830.2	2582.1	753.02	2023.1	2776.1	2.1172	4.4869
1.00	179.91	1127 E-6	0.194 44	761.68	1822.0	2583.6	762.81	2015.3	2778.1	2.1387	4.4478
1.10	184.09	1133 E-6	0.177 53	780.09	1806.3	2586.4	781.34	2000.4	2781.7	2.1792	4.3744
1.20	187.99	1139 E-6	0.163 33	797.29	1791.5	2588.8	798.65	1986.2	2784.8	2.2166	4.3067
1.30	191.64	1144 E-6	0.151 25	813.44	1777.5	2591.0	814.93	1972.7	2787.6	2.2515	4.2438
1.40	195.07	1149 E-6	0.140 84	828.70	1764.1	2592.8	830.30	1959.7	2790	2.2842	4.1850
1.50	198.32	1154 E-6	0.131 77	843.16	1751.3	2594.5	844.89	1947.3	2792.2	2.3150	4.1298

LAMPIRAN

STEAM TABLES

(contd)

Pressure MPa P	Temp. °C T	Specific Volume m³/kg Sat. Liquid v_f	Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Evap. u_{fg}	Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Entropy kJ/kg.K Sat. Liquid s_f	Evap. s_{fg}	Sat. Vapor s_g
1.75	205.76	1166 E-6	0.113 49	876.46	1721.4	2597.8	878.50	1917.9	2796.4	2.3851	4.0044	6.3896
2.00	212.42	1177 E-6	0.099 63	906.44	1693.8	2600.3	908.79	1890.7	2799.5	2.4474	3.8935	6.3409
2.25	218.45	1187 E-6	0.088 75	933.83	1668.2	2602.0	936.49	1865.2	2801.7	2.5035	3.7937	6.2972
2.5	223.99	1197 E-6	0.079 98	959.11	1644.0	2603.1	962.11	1841.0	2803.1	2.5547	3.7028	6.2575
3.0	233.90	1217 E-6	0.066 68	1004.78	1599.3	2604.1	1008.42	1795.7	2804.2	2.6457	3.5412	6.1869
3.5	242.60	1235 E-6	0.057 07	1045.43	1558.3	2603.7	1049.75	1753.7	2803.4	2.7253	3.4000	6.1253
4	250.40	1252 E-6	0.049 78	1082.31	1520.0	2602.3	1087.31	1714.1	2801.4	2.7964	3.2737	6.0701
5	263.99	1286 E-6	0.039 44	1147.81	1449.3	2597.1	1154.23	1640.1	2794.3	2.9202	3.0532	5.9734
6	275.64	1319 E-6	0.032 44	1205.44	1384.3	2589.7	1213.35	1571.0	2784.3	3.0267	2.8625	5.8892
7	285.88	1351 E-6	0.027 37	1257.55	1323.0	2580.5	1267.00	1505.1	2772.1	3.1211	2.6922	5.8133
8	295.06	1384 E-6	0.023 52	1305.57	1264.2	2569.8	1316.64	1441.3	2758.0	3.2068	2.5364	5.7432
9	303.40	1418 E-6	0.020 48	1350.51	1207.3	2557.8	1363.26	1378.9	2742.1	3.2858	2.3915	5.6772
10	311.06	1452 E-6	0.018 026	1393.04	1151.4	2544.4	1407.56	1317.1	2724.7	3.3596	2.2544	5.6141
11	318.15	1489 E-6	0.015 987	1433.7	1096.0	2529.8	1450.1	1255.5	2705.6	3.4295	2.1233	5.5527
12	324.75	1527 E-6	0.014 263	1473.0	1040.7	2513.7	1491.3	1193.6	2684.9	3.4962	1.9962	5.4924
13	330.93	1567 E-6	0.012 780	1511.1	985.0	2496.1	1531.5	1130.7	2662.2	3.5606	1.8718	5.4323
14	336.75	1611 E-6	0.011 485	1548.6	928.2	2476.8	1571.1	1066.5	2637.6	3.6232	1.7485	5.3717
15	342.24	1658 E-6	0.010 337	1585.6	869.8	2455.5	1610.5	1000.0	2610.5	3.6848	1.6249	5.3098
16	347.44	1711 E-6	0.009 306	1622.7	809.0	2431.7	1650.1	930.6	2580.6	3.7461	1.4994	5.2455
17	352.37	1770 E-6	0.008 364	1660.2	744.8	2405.0	1690.3	856.9	2547.2	3.8079	1.3698	5.1777
18	357.06	1840 E-6	0.007 489	1698.9	675.4	2374.3	1732.0	777.1	2509.1	3.8715	1.2329	5.1044
19	361.54	1924 E-6	0.006 657	1739.9	598.1	2338.1	1776.5	688.0	2464.5	3.9388	1.0839	5.0228
20	365.81	2036 E-6	0.005 834	1785.6	507.5	2293.0	1826.3	583.4	2409.7	4.0139	.9130	4.9269
21	369.89	2207 E-6	0.004 952	1842.1	388.5	2230.6	1888.4	446.2	2334.6	4.1075	.6938	4.8013
22	373.80	2742 E-6	0.003 568	1961.9	125.3	2087.1	2022.2	143.4	2165.6	4.3110	.2216	4.5327
22.09	374.14	3155 E-6	0.003 155	2029.6	0	2029.6	2099.3	0	2099.3	4.4298	0	4.4298

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STEAM TABLES

Water: Liquid-Vapor Saturation, Temperature Table SI

Temp. °C T	Pressure K.Pa P	Specific Volume m³/kg Sat. Liquid v_f	Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Evap. u_{fg}	Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Entropy kJ/kg.K Sat. Liquid s_f	Evap. s_{fg}	Sat. Vapor s_g
0.01	0.6113	1000 E-6	206.14	0.00	2375.3	2375.3	0.01	2501.3	2501.4	.0000	9.1562	9.1562
5	0.8721	1000 E-6	147.12	20.97	2361.3	2382.3	20.98	2489.6	2510.6	.0761	8.9496	9.0257
10	1.2276	1000 E-6	106.38	42.00	2347.2	2389.2	42.01	2477.7	2519.8	.1510	8.7498	8.9008
15	1.7051	1001 E-6	77.93	62.99	2333.1	2396.1	62.99	2465.9	2528.9	.2245	8.5569	8.7814
20	2.339	1002 E-6	57.79	83.95	2319.0	2402.9	83.96	2454.1	2538.1	.2966	8.3706	8.6672
25	3.169	1003 E-6	43.36	104.88	2304.9	2409.8	104.89	2442.3	2547.2	.3674	8.1905	8.5580
30	4.246	1004 E-6	32.89	125.78	2290.8	2416.6	125.79	2430.5	2556.3	.4369	8.0164	8.4533
35	5.628	1006 E-6	25.22	146.67	2276.7	2423.4	146.68	2418.6	2565.3	.5053	7.8478	8.3531
40	7.384	1008 E-6	19.52	167.56	2262.6	2430.1	167.57	2406.7	2574.3	.5725	7.6845	8.2570
45	9.593	1010 E-6	15.26	188.44	2248.4	2436.8	188.45	2394.8	2583.2	.6387	7.5261	8.1648
50	12.349	1012 E-6	12.03	209.32	2234.2	2443.5	209.33	2382.7	2592.1	.7038	7.3725	8.0763
55	15.758	1015 E-6	9.568	230.23	2219.9	2450.1	230.23	2370.7	2600.9	.7679	7.2234	7.9913
60	19.94	1017 E-6	7.671	251.13	2205.5	2456.6	251.13	2358.5	2609.6	.8312	7.0784	7.9096
65	25.03	1020 E-6	6.197	272.06	2191.1	2463.1	272.06	2346.2	2618.3	.8935	6.9375	7.831
70	31.19	1023 E-6	5.042	292.98	2176.6	2469.6	292.98	2333.8	2626.8	.9549	6.8004	7.7553
75	38.58	1026 E-6	4.131	313.90	2162.0	2475.9	313.93	2321.4	2635.3	1.0155	6.6669	7.6824
80	47.39	1029 E-6	3.407	334.86	2147.4	2482.2	334.91	2308.8	2643.7	1.0753	6.5369	7.6122
85	57.83	1033 E-6	2.828	355.84	2132.6	2488.4	355.9	2296.0	2651.9	1.1343	6.4102	7.5445
90	70.14	1036 E-6	2.361	376.85	2117.7	2494.5	376.92	2283.2	2660.1	1.1925	6.2866	7.4791
95	84.55	1040 E-6	1.982	397.88	2500.6	2500.6	397.96	2270.2	2668.1	1.2500	6.1659	7.4159
	MPa											
100	0.101	1044 E-6	1.672	418.94	2087.6	2506.5	419.04	2257.0	2676.1	1.3069	6.048	7.3549
105	0.120	1048 E-6	1.419	440.02	2072.3	2512.4	440.15	2243.7	2683.8	1.3630	5.9328	7.2958
110	0.143	1052 E-6	1.210	461.14	2057.0	2518.1	461.30	2230.2	2691.5	1.4185	5.8202	7.2387
115	0.169	1056 E-6	1.036	482.30	2041.4	2523.7	482.48	2216.5	2699.0	1.4734	5.7100	7.8133
120	0.198	1060 E-6	0.891	503.50	2025.8	2529.3	503.71	2202.6	2706.3	1.5276	5.6020	7.1296
125	0.232	1065 E-6	0.770	524.74	2009.9	2534.6	524.99	2188.5	2713.5	1.5813	5.4962	7.0775
130	0.270	1070 E-6	0.668	546.02	1993.9	2539.9	546.31	2174.2	2720.5	1.6344	5.3925	7.0269
135	0.313	1075 E-6	0.582	567.35	1977.7	2545.0	567.69	2159.6	2727.3	1.6870	5.2907	6.9777
140	0.361	1080 E-6	0.508	588.74	1961.3	2550.0	589.13	2144.7	2733.9	1.7391	5.1908	6.9299
145	0.415	1085 E-6	0.446	610.18	1944.7	2554.9	610.63	2129.6	2740.3	1.7907	5.0926	6.8833
150	0.475	1091 E-6	0.392	631.68	1927.9	2559.5	632.20	2114.3	2746.5	1.8418	4.9960	6.8379
155	0.543	1096 E-6	0.346	653.24	1910.8	2564.1	653.84	2098.6	2752.4	1.8925	4.9010	6.7935
160	0.617	1102 E-6	0.307	674.87	1893.5	2568.4	675.55	2082.6	2758.1	1.9427	4.8075	6.7502
165	0.700	1108 E-6	0.272	696.56	1876.0	2572.5	697.34	2066.2	2763.5	1.9925	4.7153	6.7078
170	0.791	1114 E-6	0.242	718.33	1858.1	2576.5	719.21	2049.5	2768.7	2.0419	4.6244	6.6663
175	0.892	1121 E-6	0.216	740.17	1840.0	2580.2	741.17	2032.4	2773.6	2.0909	4.5347	6.6256
180	1.002	1127 E-6	0.194	762.09	1821.6	2583.7	763.22	2015.0	2778.2	2.1396	4.4461	6.5857
185	1.122	1134 E-6	0.174	784.10	1802.9	2587.0	785.37	1997.1	2782.4	2.1879	4.3586	6.5465
190	1.254	1141 E-6	0.156	806.19	1783.8	2590.0	807.62	1978.8	2786.4	2.2359	4.2720	6.5079
195	1.397	1149 E-6	0.141	828.37	1764.4	2592.8	829.98	1960.0	2790.0	2.2835	4.1863	6.4698
200	1.553	1157 E-6	0.127	850.65	1744.7	2595.3	852.45	1940.7	2793.2	2.3309	4.1014	6.4323
205	1.723	1164 E-6	0.115	873.04	1724.5	2597.5	875.04	1921.0	2796.0	2.3780	4.0172	6.3952
210	1.906	1173 E-6	0.104	895.63	1703.9	2599.5	897.76	1900.7	2798.5	2.4248	3.9337	6.3585
215	2.104	1181 E-6	0.094	918.14	1682.9	2601.1	920.62	1879.9	2800.5	2.4714	3.8507	6.3221
220	2.318	1190 E-6	0.086	940.87	1661.5	2602.4	943.62	1858.5	2802.1	2.5178	3.7683	6.2861

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STEAM TABLES

(contd)

Temp. °C T	Pressure MPa P	Specific Volume m³/kg Sat. Liquid v_f	Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Evap. u_{fg}	Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Entropy kJ/kg.K Sat. Liquid s_f	Evap. s_{fg}	Sat. Vapor s_g
225	2.548	1199 E-6	0.078	963.73	1639.6	2603.3	966.78	1836.5	2803.3	2.5639	3.6863	6.2503
230	2.795	1209 E-6	0.071	986.74	1617.2	2603.9	990.12	1813.8	2804.0	2.6099	3.6047	6.2146
235	3.060	1219 E-6	0.065	1009.89	1594.2	2604.1	1013.62	1790.5	2804.2	2.6558	3.5233	6.1791
240	3.344	1229 E-6	0.059	1033.21	1570.8	2604.0	1037.32	1766.5	2803.8	2.7015	3.4422	6.1437
245	3.648	1240 E-6	0.054	1056.71	1546.7	2603.4	1061.23	1741.7	2803.0	2.7472	3.3612	6.1083
250	3.973	1251 E-6	0.050	1080.39	1522.0	2602.4	1085.36	1716.2	2801.5	2.7927	3.2802	6.0730
255	4.319	1263 E-6	0.045	1104.28	1496.7	2600.9	1109.73	1689.8	2799.5	2.8383	3.1992	6.0375
260	4.688	1276 E-6	0.042	1128.39	1470.6	2599.0	1134.37	1662.5	2796.9	2.8838	3.1181	6.0015
265	5.081	1289 E-6	0.038	1152.74	1443.9	2596.6	1159.28	1634.4	2793.6	2.9294	3.0368	5.9662
270	5.499	1302 E-6	0.035	1177.36	1416.3	2593.7	1184.51	1605.2	2789.7	2.9751	2.9551	5.9301
275	5.942	1317 E-6	0.032	1202.25	1387.9	2590.2	1210.07	1574.9	2785.0	3.0208	2.8730	5.8938
280	6.412	1332 E-6	0.030	1227.46	1358.7	2586.1	1235.99	1543.6	2779.6	3.0668	2.7903	5.8571
285	6.909	1348 E-6	0.027	1253.00	1328..4	2581.4	1262.31	1511.0	2773.3	3.1130	2.7070	5.8199
290	7.436	1366 E-6	0.025	1278.92	1297.1	2576.0	1289.07	1477.1	2766.2	3.1594	2.6227	5.7821
295	7.993	1384 E-6	0.023	1305.20	1264.7	2569.9	1316.30	1441.8	2758.1	3.2062	2.5375	5.7437
300	8.581	1404 E-6	0.216	1332.0	1231.0	2563.0	1344.0	1404.9	2749.0	3.2534	2.4511	5.7045
305	9.202	1425 E-6	0.019	1359.3	1195.9	2555.2	1372.4	1366.4	2738.7	3.3010	2.3633	5.6643
310	9.856	1447 E-6	0.018	1387.0	1159.4	2546.4	1401.3	1326	2727.3	3.3493	2.2737	5.6230
315	10.547	1472 E-6	0.016	1415.5	1121.1	2536.6	1431.0	1283.5	2714.5	3.3982	2.1821	5.5804
320	11.274	1499 E-6	0.015	1446.6	1080.9	2525.5	1461.5	1238.6	2700.1	3.4480	2.0882	5.5362
330	12.845	1561 E-6	0.012	1505.3	993.7	2498.9	1525.3	1140.6	2665.9	3.5507	1.8909	5.4417
340	14.586	1638 E-6	0.010	1570.3	894.3	2464.6	1594.2	1027.9	2622.0	3.6594	1.6763	5.3357
350	16.513	1740 E-6	0.008	1641.9	776.6	2418.4	1670.6	893.4	2563.9	3.7777	1.4335	5.2112
360	18.651	1893 E-6	0.006	1725.2	625.3	2351.5	1760.5	720.5	2481.0	3.9147	1.1379	5.0526
370	21.03	2213 E-6	0.004	1844.0	384.5	2228.5	1890.5	4416.6	2332.1	4.1106	.6865	4.7971
374.1	22.09	3155 E-6	0.003	2029.6	0	2029.6	2099.3	0	2099.3	4.4298	0	4.4298

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STEAM TABLES

Superheated Steam Table

Superheated Steam (Saturation temperature in °C shown in parentheses following each pressure)(SI)

P= 0.1MPa

T	v	u	h	s	v	u	h	s	v	u	h	s
	P = 0.010 MPa (45.81)				P = 0.050 MPa (81.33)				P = 0.010 MPa (99.63)			
Sat.	14.674	2437.9	2584.7	8.1502	3.24	2483.9	2645.9	7.5939	1.6940	2506.1	2676	7.3594
50	14.869	2443.9	2592.6	8.1749								
100	17.196	2515.5	2687.5	8.4479	3.418	2511.6	2682.5	7.6947	1.6958	2506.7	2676	7.3614
150	19.512	2587.9	2783.0	8.6882	3.889	2585.6	2780.1	7.9401	1.9364	2582.8	2776	7.6134
200	21.825	2661.3	2879.5	8.9038	4.356	2659.9	2877.7	8.1580	2.1720	2658.1	2875	7.8343
250	24.136	2736.0	2977.3	9.1002	4.820	2735.0	2976.0	8.3556	2.4060	2.406	2974	8.0333
	P = 0.20 MPa (120.23)				P = 0.30 MPa (133.55)				P = 0.40 MPa (143.63)			
Sat.	0.8857	2529.5	2706.7	7.1272	.6058	2543.6	2725.3	6.9919	.4625	2553.6	2739	6.8959
150	0.9596	2576.9	2768.8	7.2795	.6339	2570.8	2761.0	7.0778	.4708	2564.5	2753	6.9299
200	1.0803	2654.4	2870.5	7.5066	.7163	2650.7	2865.6	7.3115	.5342	2646.8	2861	7.1706
250	1.1988	2731.2	2971.0	7.7086	.7964	2728.7	2967.6	7.5166	.5951	2726.1	2964	7.3789
300	1.3162	2808.6	3071.8	7.8926	.8753	2806.7	3069.3	7.7022	.6548	2804.8	3067	7.5662
400	1.5493	2966.7	3276.6	8.2218	1.0315	2965.6	3275.0	8.033	.7726	2964.4	3273	7.8985
	P = 0.50 MPa (151.86)				P = 0.60 MPa (158.85)				P = 0.80 MPa (170.43)			
Sat.	.3749	2561.2	2748.7	6.8213	.3157	2567.4	2756.8	6.760	.2404	2576.8	2769	6.6628
200	.4249	2642.9	2855.4	7.0592	.3520	2638.9	2850.1	6.9665	.2608	2630.6	2839	6.8158
250	.4744	2723.5	2960.7	7.2709	.3938	2720.9	2957.2	7.1816	.2931	2715.5	2950	7.0384
300	.5226	2802.9	3064.2	7.4599	.4344	2801.0	3061.6	7.3724	.3241	2797.2	3057	7.2328
350	.5701	2882.6	3167.7	7.6329	.4742	2881.2	3165.7	7.5464	.3544	2878.2	3132	7.4089
400	.6173	2963.2	3271.9	7.7938	.5137	2962.1	3270.3	7.7079	.3843	2959.7	3267	7.5716
	P = 1.00 MPa (179.91)				P = 1.20 MPa (187.99)				P = 1.40 MPa (195.07)			
Sat.	.194 44	2583.6	2778.1	6.5865	.163 33	2588.8	2784.8	6.5233	.140 84	2592.8	2790	6.4693
200	.2060	2621.9	2827.9	6.6940	.169 30	2612.3	2815.9	6.5898	.143 02	2603.1	2803	6.4975
250	.2327	2709.9	2942.6	6.9247	.192 34	2704.2	2935.0	6.8294	.163 50	2698.3	2927	6.7467
300	.2579	2793.2	3051.2	7.1229	0.2138	2789.2	3045.8	7.0317	.182 28	2785.2	3040	6.9534
350	.2825	2875.2	3157.7	7.3011	0.2345	2872.2	3153.6	7.2121	.2003	2869.2	3150	7.1360
400	.3066	2957.3	3263.9	7.4651	0.2548	2954.9	3260.7	7.3774	.2178	2952.5	3258	7.3026
500	.3541	3124.4	3478.5	7.7622	0.2946	3122.8	3476.3	7.6759	.2521	3121.1	3474	7.6027
600	.4011	3296.8	3697.9	8.0290	0.3339	3295.6	3696.3	7.9435	.2860	3294.4	3695	7.8710
	P = 1.60 MPa (201.41)				P = 1.80 MPa (207.15)				P = 2.00 MPa (212.42)			
Sat.	.123 80	2596.0	2794.0	6.4218	.110 42	2598.4	2797.1	6.3794	.099 63	2600.3	2799.5	6.3409
225	.132 87	2644.7	2857.3	6.5518	.116 73	2636.6	2846.7	6.4808	.103 77	2628.3	2835.8	6.4147
250	.141 84	2692.3	2919.2	6.6732	.124 97	2686.0	2911.0	6.6066	.111 44	2679.6	2902.5	6.5453
300	.158 62	2781.1	3034.8	6.8844	.140 21	2776.9	3029.2	6.8226	.125 47	2772.6	3023.5	6.7664
350	.174 56	2866.1	3145.4	7.0694	.154 57	2863.0	3141.2	7.0100	.138 57	2859.8	3137.0	6.9563
400	.190 05	2950.1	3254.2	7.2374	.168 47	2947.7	3250.9	7.1794	.151 20	2945.2	3247.6	7.1271
500	.2203	3119.5	3472.0	7.5390	.195 50	3117.9	3469.8	7.4825	.175 68	3116.2	3467.6	7.4317
600	.2500	3293.3	3693.2	7.8080	.2220	3292.1	3691.7	7.7523	.199 60	3290.9	3690.1	7.7024
	P = 2.50 MPa (223.99)				P = 3.00 MPa (233.90)				P = 3.50 MPa (242.60)			
Sat.	.079 98	2603.1	2803.1	6.2575	.066 68	2604.1	2804.2	6.1869	.057 07	2603.7	2803	6.1253
225	.080 27	2605.6	2806.3	6.2639								
250	.087 00	2662.6	2880.1	6.4085	.070 58	2644	2855.8	6.2872	.058 72	2829.2	2829	6.1749
300	.098 90	2761.6	3008.8	6.6438	.081 14	2750.1	2993.5	6.539	.068 42	2977.5	2978	6.4461
350	.109 76	2851.9	3126.3	6.8403	.090 53	2843.7	3115.3	6.7428	.076 78	3104.0	3104.0	6.6579
400	.120 10	2939.1	3239.3	7.0148	.099 36	2932.8	3230.9	6.9212	.084 53	3222.3	3222	6.8405
450	.130 14	3025.5	3350.8	7.1746	.107 87	3020.4	3344.0	7.0834	.091 96	3337.2	3337	7.0052
500	.130 14	3112.1	3462.1	7.3234	.116 19	3108.0	3456.5	7.2338	.099 18	3450.9	3451	7.1572
600	.139 98	3288	3686.3	7.596	.132 43	3285.0	3682.3	7.5085	.113 24	3678.4	3678	7.4339
	P = 4.0 MPa (250.40)				P = 4.5 MPa (257.49)				P = 5.0 MPa (263.99)			
Sat.	.049 78	2602.3	2801.4	6.0701	.044 06	2600.1	2798.3	6.0198	.039 44	2597.1	2794	5.9734
275	.054 57	2667.9	2886.2	6.2285	.047 30	2650.3	2863.2	6.1401	.041 41	2631.3	2838	6.0544
300	.058 84	2725.3	2960.7	6.3615	.051 35	2712.0	2943.1	6.2828	.045 32	2698.0	2925	6.2084
350	.066 45	2826.7	3213.6	6.5821	.058 40	2817.8	3080.6	6.5131	.051 94	2808.7	3068	6.4493
400	.073 41	2919.9	3330.3	6.769	.064 75	2913.3	3204.7	6.7047	.057 81	2906.6	3196	6.6459
450	.080 02	3010.2	3445.3	6.9363	.070 74	3005.0	3323.3	6.8746	.063 30	2999.7	3316	6.8186
500	.086 43	3099.5	3674.4	7.0901	.076 51	3095.3	3439.6	7.0301	.068 57	3091.0	3434	6.9759
600	.098 85	3279.1	3905.9	7.3688	.087 65	3276.0	3670.5	7.3110	.078 69	3273.0	3667	7.2589
700	.110 95	3462.1	4141.5	7.6198	.098 47	3459.9	3903.0	7.5631	.088 49	3457.6	3900	7.5122
800	.122 87	3650.0	4382.3	7.8502	.109 11	3648.3	4139.3	7.7942	.098 11	3646.6	4137	7.7744

LAMPIRAN

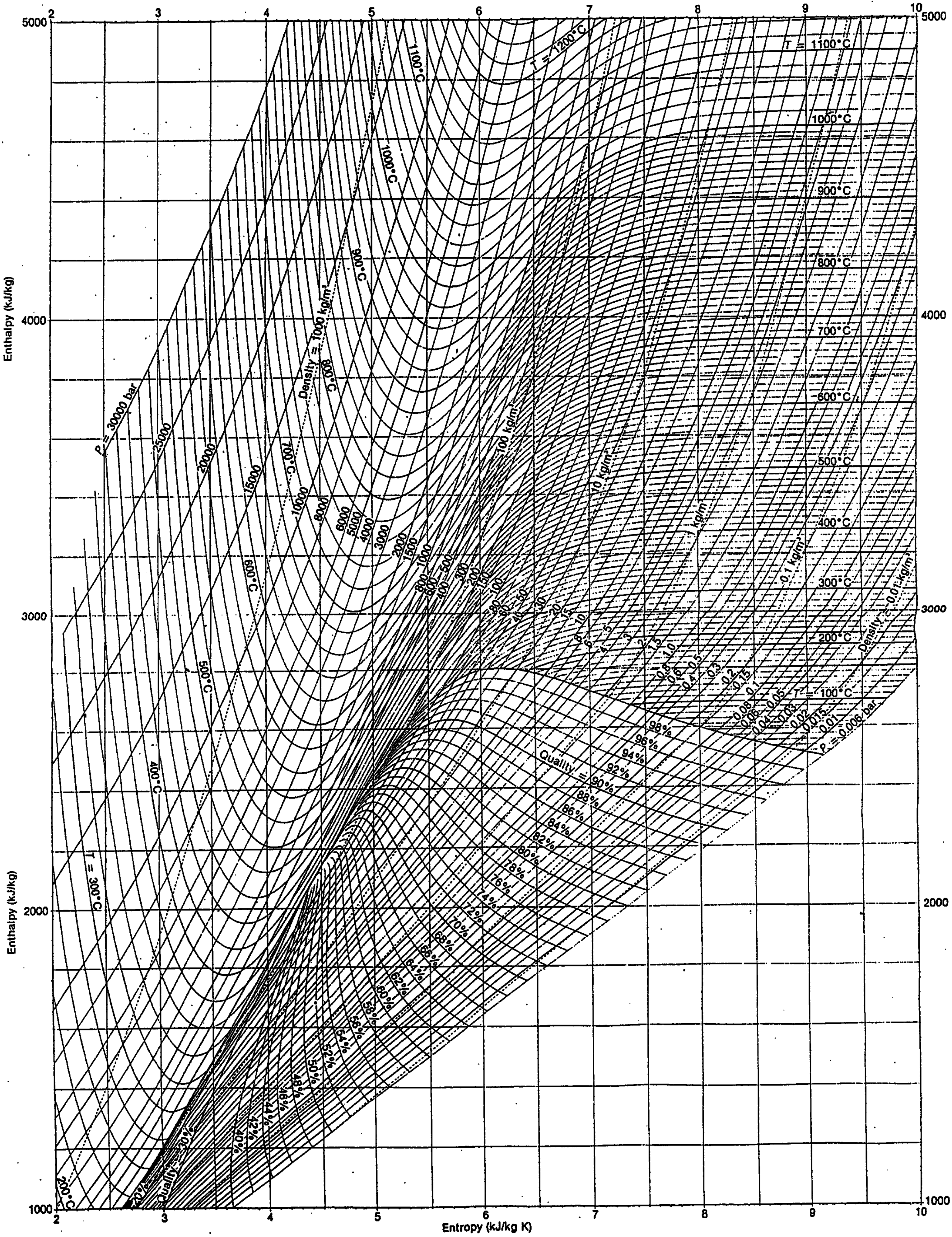
STEAM TABLES

(contd)

T	v	u	h	s	v	u	h	s	v	u	h	s
	P = 6.0 MPa (275.64)				P = 7.0 MPa (285.88)				P = 8.0 MPa (295.06)			
Sat.	.032 44	2589.7	2784.3	5.8892	.027 37	2580.5	2772.1	5.8133	.023 52	2569.8	2758	5.7432
300	.036 16	2667.2	2884.2	6.0674	.029 47	2632.2	2838.4	5.9305	.024 26	2590.9	2785	5.7906
350	.042 23	2789.6	3043	6.3335	.035 24	2769.4	3016.0	6.2283	.029 95	2747.7	2987	6.1301
400	.047 39	2892.9	3177.2	6.5408	.039 93	2878.6	3158.1	6.4478	.034 32	2863.8	3138	6.3634
450	.052 14	2988.9	3301.8	6.7193	.044 16	2978.0	3287.1	6.6327	.038 17	2966.7	3272	6.5551
500	.056 65	3082.2	3422.2	6.8803	.048 14	3073.4	3410.3	6.7975	.041 75	3064.3	3398	6.7240
550	.061 01	3174.6	3540.6	7.0288	.051 95	3167.2	3530.9	6.9486	.045 16	3159.8	3521	6.8778
600	.065 25	3266.9	3658.4	7.1677	.055 65	3260.7	3650.3	7.0894	.048 45	3254.4	3642.0	7.0206
700	.073 52	3453.1	3894.2	7.4234	.062 83	3448.5	3888.3	7.3476	.054 86	3443.9	3882	7.2812
800	.081 60	3643.1	4132.7	7.6566	.069 81	3639.5	4128.2	7.5822	.060 97	3636.0	4124	7.5173
	P = 9.0 MPa (303.40)				P = 10.0 MPa (311.06)				P = 12.5 MPa (327.89)			
Sat.	.020 48	2557.8	2742.1	5.6772	.018 026	2544.4	2724.7	5.6141	.013 495	2505.1	2674	5.4624
225	.023 27	2646.6	2856.0	5.8712	.019 861	2610.4	2809.1	5.7568				
350	.025 80	2724.4	2956.6	6.0361	.022 42	2699.2	2923.4	5.9443	.016 126	2624.6	2826	5.7118
400	.029 93	2848.4	3117.8	6.2854	.026 41	2832.4	3096.5	6.212	.020 00	2789.3	3039	6.0417
450	.033 50	2955.2	3256.6	6.4844	.029 75	2943.4	3240.9	6.419	.022 99	2912.5	3200	6.2719
500	.036 77	3055.2	3386.1	6.6576	.032 79	3045.8	3373.7	6.5966	.025 60	3021.7	3342	6.4618
550	.039 87	3152.2	3511.0	6.8142	.035 64	3144.6	3500.9	6.7561	.028 01	3125.0	3475	6.629
600	.042 85	3248.1	3633.7	6.9589	.038 37	3241.7	3625.3	6.9029	.030 29	3225.4	3604.0	6.781
650	.045 74	3343.6	3755.3	7.0943	.041 01	3338.2	3748.2	7.0398	.032 48	3324.4	3730	6.9218
700	.048 57	3439.3	3876.5	7.2221	.043 58	3870.5	3870.5	7.1687	.034 60	3422.9	3855	7.0536
800	.054 09	3632.5	4119.3	7.4596	.048 59	3628.9	4114.8	7.4077	0.38 69	3620.0	4104	7.2965
	P = 15.0 MPa (342.24)				P = 17.5 MPa (354.75)				P = 20.0 MPa (365.81)			
Sat.	.010 337	2455.5	2610.5	5.3098	.007 920	2390.2	2528.8	5.1419	.005 834	2293.0	2410	4.9269
350	.011 470	2520.4	2692.4	5.4421								
400	.015 649	2740.7	2975.5	5.8811	.012 447	2685.0	2902.9	5.7213	.009 942	2619.3	2818	5.554
450	.018 649	2879.5	3156.2	6.1404	.015 174	2844.2	3109.7	6.0184	.012 695	2806.2	3060	5.9017
500	.018 445	2879.5	3308.6	6.3443	.017 358	2970.3	3274.1	6.2383	.014 768	2942.9	3238	6.1401
550	.020 445	2996.6	3448.6	6.5199	.019 288	3083.9	3421.4	6.4230	.016 555	3062.4	3394	6.3348
600	.022 93	3104.7	3582.3	6.6779	.021 06	3191.5	3560.1	6.5866	.018 178	3174.0	3538	6.5048
650	.026 80	3208.6	3712.3	6.8224	.022 74	3296.0	3693.9	6.7357	.019 693	3281.4	3675	6.6582
700	.028 61	3310.3	3840.1	6.9572	.024 34	3398.7	3824.6	6.8736	.021 13	3386.4	3809.0	6.7993
800	.032 10	3410.9	4092.4	7.2040	.027 38	3601.8	4081.1	7.1244	.023 85	3592.7	4070	7.0544
	P = 25.0 MPa				P = 30.0 MPa				P = 35.0 MPa			
375	001 973	1798.7	1848	4.032	.001 789	1737.8	1791.5	3.9305	.001 700	1702.9	1762	3.8722
400	.006 004	2430.1	2580.2	5.1418	.002 790	2067.4	2151.1	4.4728	.002 100	1914.1	1988	4.2126
425	.007 881	2609.2	2806.3	5.4723	.005 303	24551	2614.2	5.1504	.003 428	2253.4	2373	4.7747
450	.009 162	2720.7	2949.7	5.6744	.006 735	2619.3	2821.4	5.4424	.004 961	2498.7	2672	5.1962
500	.011 123	2884.3	3162.4	5.9592	.008 678	2820.7	3081.1	5.7905	.006 927	2751.9	2994	5.6282
550	.012 724	3017.5	3335.6	6.1765	.010 168	2970.3	3275.4	6.0342	.008 345	2921.0	3213.0	5.9026
600	.014 137	3137.9	3491.4	6.3602	.011 446	3100.5	3443.9	6.2331	.009 527	3062.0	3396	6.1179
650	.015 433	3251.6	3637.4	6.5229	.012 596	3221.0	3598.9	6.4058	.010 575	3189.8	3560	6.3010
700	.016 646	3361.3	3777.5	6.6707	.013 661	3335.8	3745.6	6.5606	.011 533	3309.8	3714	6.4631
800	.018 912	3574.3	4047.1	6.9345	.015 623	3555.5	4042.2	6.8332	.013 278	3536.7	4002	6.7450
900	.021 045	3783	4309.1	7.168	.017 448	3768.5	4291.9	7.0718	.014 883	3754.0	4275	6.9886
1000	.023 10	3990.9	4568.5	7.3802	.019 196	3978.8	4554.7	7.2867	.016 410	3966.7	4541	7.2064
	P = 40.0 MPa				P = 50.0 MPa				P = 60.0 MPa			
375	.001 640	1677.1	1742.8	3.829	.001 559	1638.6	1716.6	3.7639	.001 502	1609.4	1700	3.7141
400	.001 907	1854.6	1930.9	4.1135	.001 730	1788.1	1874.6	4.0031	.001 633	1745.4	1843	3.9318
425	.002 532	2096.9	2198.1	4.5029	.002 007	1959.7	2060.0	4.2734	.001 816	1892.7	2002	4.1626
450	.003 693	2365.1	2512.8	4.9459	.002 486	2159.6	2284.0	4.5884	.002 085	2053.9	2179	4.4121
500	.005 622	2678.1	2903.3	5.4700	.003 892	2525.5	2720.1	5.1726	.002 956	2390.6	2568	4.9321
550	.006 984	2869.7	3149.1	5.7785	.005 118	2763.6	3019.5	5.5485	.003 956	2658.8	2896	5.3441
600	.008 094	3022.6	3346.4	6.0114	.006 112	2942	3247.6	5.8178	.004 834	2861.1	3151	5.6452
650	.009 063	3158.0	3520.6	6.2054	.006 966	3093.5	3441.8	6.0342	.005 595	3028.1	3365	5.8829
700	.009 941	3283.6	3681.2	6.3750	.007 727	3230.5	3616.8	6.2189	.006 272	3177.2	3554	6.0824
800	.011 523	3517.8	3978.7	6.6662	.009 076	3479.8	3933.6	6.529	.007 459	3441.5	3889	6.4109
900	.012 962	3739.4	4257.9	6.9150	.010 283	3710.3	4224.4	6.7882	.008 508	3681.0	4192	6.6805

LAMPIRAN

MOLLIER CHART



LAMPIRAN

SOLAR CONSTANTS
[FOR NORTHERN LATITUDES]

Date	Angle of declination δ	Equation of time, min	A_S,† kW/m²‡	B_S,† am§	C_S†	Day of year
January						
1	−23.0	−3.6	1231	0.142	0.057	1
11	−21.7	−8.0	1230	0.142	0.058	11
21	−19.6	−11.4	1229	0.142	0.058	21
31	−17.3	−13.5	1224	0.142	0.058	31
February						
1	−17.0	−13.6	1223	0.143	0.059	32
11	−13.9	−14.4	1218	0.143	0.059	42
21	−10.4	−13.8	1213	0.144	0.060	52
28	−7.6	−12.6	1206	0.147	0.063	59
March						
1	−7.4	−12.5	1205	0.148	0.063	60
11	−3.5	−10.2	1195	0.152	0.067	70
21	0.0	−7.4	1185	0.156	0.071	80
31	4.3	−4.3	1169	0.164	0.079	90
April						
1	4.7	−4.0	1167	0.165	0.080	91
11	8.5	−1.1	1151	0.172	0.088	101
21	12.0	1.2	1135	0.180	0.096	111
30	14.9	2.8	1126	0.185	0.104	120
July						
1	23.1	−3.4	1086	0.206	0.135	182
11	22.1	−5.6	1085	0.206	0.135	192
21	20.6	−6.2	1084	0.207	0.136	202
31	18.1	−6.2	1091	0.205	0.132	212
August						
1	17.9	−6.2	1092	0.205	0.132	213
11	15.2	−5.1	1099	0.203	0.126	223
21	12.0	−3.1	1106	0.201	0.122	233
31	8.7	−1.5	1120	0.193	0.113	243
September						
1	8.2	0.0	1122	0.192	0.112	244
11	4.4	3.3	1136	0.185	0.097	254
21	0.0	6.8	1150	0.177	0.092	264
30	−2.9	9.9	1162	0.172	0.086	273
October						
1	−3.3	10.2	1164	0.171	0.086	274
11	−7.2	13.1	1177	0.166	0.079	284
21	−10.8	15.3	1191	0.160	0.073	294
31	−14.3	16.2	1200	0.157	0.070	304
November						
1	−14.6	16.3	1201	0.156	0.069	305
11	−17.5	15.9	1211	0.153	0.066	315
21	−20.0	15.1	1220	0.149	0.063	325
30	−21.7	11.3	1224	0.147	0.061	334
December						
1	−21.9	11.0	1224	0.147	0.061	335
11	−23.0	6.8	1228	0.144	0.059	345
21	−23.45	2.0	1232	0.142	0.057	355
31	−23.1	−3.1	1231	0.142	0.057	365

LAMPIRAN

PARTIAL LIST OF ISOTOPES

Element Chemical symbol Atomic weight	Atomic number Z	Atomic mass number A	Isotopic mass, amu	Natural abundance, %	Half-life†	Type of decay†
Electron	−1	0	0.000549			
Neutron	0	1	1.008665		11.7 m	β^-
Hydrogen	1	1	1.007825	99.985		
H	1	2	2.01410	0.015		
1.00797	1	3	3.01605		12.26 y	β^-
Helium	2	3	3.01603	0.00013		
He	2	4	4.00260	99.99987		
4.0026	2	5	5.01230		2×10^{-21} s	α
	2	6	6.01888		0.8 s	β^-
	2	8	8.03750		0.122 s	β^-
Nickel	28	57	56.9394		36.1 h	K
Ni	28	58	57.9353	68.30		
58.710	28	59	58.9342		8.0×10^4 y	K
	28	60	59.9308	26.13		
	28	61	60.9310	1.09		
	28	62	61.9283	3.56		
	28	63	62.9286		100.0 y	β^-
	28	64	63.9280	0.92		
	28	65	64.9291		2.56 h	β^-
Copper	29	58	57.9456		3.30 s	β^+
Cu	29	60	59.9375		24.0 m	β^+
63.546	29	61	60.9327		3.30 h	β^+
	29	62	61.9316		9.80 m	β^+
	29	63	62.9298	69.20		
	29	64	63.9288		12.9 h	β^+/K/β^-
	29	65	64.9278	30.80		
	29	66	65.9288		5.10 m	β^-
	29	67	66.9278		61.0 h	β^-
Zinc	30	62	61.9339		9.30 h	β^+
Zn	30	63	62.9330		38.8 m	β^+
65.370	30	64	63.9291	48.60		
	30	65	64.9283		243.6 d	K/β^+
Thorium	90	227	227.0277		18.7 d	α
Th	90	228	228.0287		1.91 y	α
232.038	90	229	229.0316		7340 y	α
	90	230	230.0331		80,000 y	α
	90	231	231.0347		25.5 h	β^-
	90	232	232.0382	100.00	1.41×10^{10} y	α
	90	233	233.0387		22.2 m	β^-
	90	234			24.2 d	β^-
Uranium	92	227	227.0309		1.30 m	α
U	92	228	228.0313		9.30 m	α/K
238.03	92	229	229.0335		58.0 m	K/α
	92	230	230.0339		20.8 d	α
	92	231	231.0363		4.30 d	K
	92	232	232.0372		73.6 y	α
	92	233	233.0395		1.65×10^5 y	α
	92	234	234.0409	0.006	2.4×10^5 y	α
	92	235	235.0439	0.720	7.1×10^8 y	α
	92	236	236.0457		2.39×10^7 y	α
	92	237	237.0469		6.75 d	β^-
	92	238	238.0508	99.274	4.51×10^9	α
	92	239	239.0526		23.5 m	β^-
	92	240	240.0546		14.1 h	β^-