NATIONAL EXAMINATIONS

MAY 2017

16-MEC-B3 ENERGY CONVERSION AND POWER GENERATION

Three hours duration

Notes to Candidates

1. This is a **Closed Book** examination.

2. Examination paper consists of two Sections. **Section A is Calculative** with four (4) questions and **Section B is Descriptive** with two (2) questions.

3. **Do three (3) questions (including all parts of each question) from Section A (Calculative) and one (1) question from Section B (Descriptive).**

4. **Four questions constitute a complete paper.** (Total 60 marks).

5. **All questions are of equal value.** (Each 15 marks).

6. If doubt exists as to the interpretation of any question or in the event of missing data, the candidate is urged to submit, with the answer paper, a clear statement of any assumptions made.

7. If any initial parts of a multi-part question cannot be solved the remaining parts may be worked by making appropriate assumptions for the first parts from the technical data given.

8. **Read the entire question before commencing the calculations** and take note of any hints or recommendations given.

9. Candidates may use one of the approved **Casio** or **Sharp** calculators.

10. **Reference data** for particular questions are given on pages 8 to 11. **All pages used are to be returned with the answer booklet showing where data has been obtained.**

11. **Reference formulae and constants** are given on pages 12 to 15.

12. **Steam Tables** from "Thermodynamics and Heat Power" are provided.

SECTION A CALCULATIVE QUESTIONS

Show all steps in the calculations and state the units for all intermediate and final answers.

QUESTION 1 GAS TURBINE MODULAR HELIUM REACTOR

Refer to the Examination Paper Attachments Page 8 **Gas Turbine Modular Helium Reactor**. Refer to General Constants on Page 13 for specific heats.

The diagram shows a schematic of the gas circuit of a high temperature nuclear reactor of the Gas Turbine Modular type. The following terminal conditions apply:

Helium pressure at compressor inlet	2 MPa
Helium pressure at intercooler	4 MPa
Helium pressure at compressor outlet	7 MPa
Helium temperature at compressor inlet	30°C
Helium temperature after intercooler	30°C
Helium temperature at turbine inlet	850°C
Terminal temperature differences in recuperating heat exchanger	20°C
Terminal temperature differences in heat rejection heat exchangers	15°C
Compressor efficiency	90%
Turbine efficiency	85%
Electrical power output	250 MW

The differences in the terminal temperatures are the same at each end of the respective heat exchangers.

Assume negligible pressure loss in the gas circuit and no mechanical nor electrical losses.

(a) Sketch a temperature-entropy diagram for the gas circuit in the space provided on Page 8. Identify key points by number to correspond with the flow diagram. Show terminal temperature differences. (3)

Return this page with the examination answer booklet.

(b) Calculate the temperatures at all key points in the circuit as identified in the diagram on Page 8. (7)

(c) Calculate the thermodynamic cycle efficiency. (2)

(d) Calculate the required flow rate of helium to give the specified power output. (1)

(e) Calculate the required flow rate of cooling water to give the necessary rate of heat rejection. (2)

[15 marks]

QUESTION 2 STEAM PLANT DESIGN

Consider the proposed construction of a new coal fired power plant where an estimate of the required resources (fuel and water) and costs are required. The basic parameters are as follows:

Capacity of power plant	500 MW
Capacity factor of plant*	0.80
Life expectancy of plant	40 years
Heat rate of whole plant**	10 550 kJ/kWh
Efficiency of boiler	90%
Capital cost of plant	2 500 $/kW
Cost of capital repayments	10% of capital cost each year
Cost of administration and maintenance	8% of capital cost each year
Cost of coal	100 $/Mg
Heating value of coal	24 000 kJ/kg
Capacity of one train car	50 Mg
Number of coal cars per train	60

Note: *Capacity factor = actual electrical output / maximum possible electrical output
**Heat rate is inversely proportional to thermal efficiency

Determine the following for a cooling water temperature rise of 10°C:

(a) Annual actual electrical production (kWh) and maximum possible electrical production (kWh). (2)

(b) Annual amount of coal required (Mg) and number of trains required per day. (3)

(c) Annual cost of coal ($) and cost of coal per unit generated (cent/kWh). (1)

(d) Annual capital cost repayment ($) and cost per unit generated (cent/kWh). (2)

(e) Annual administration and maintenance cost ($) and cost per unit generated (cent/kWh). (2)

(f) Total power production cost per unit generated (cent/kWh). (1)

(g) Rate of heat rejection in cooling water from steam cycle at full load (kJ/s). (3)

(h) Quantity of cooling water required at full load (m^3/s). (1)

[15 marks]

QUESTION 3 POWER PLANT EFFICIENCY AND HEAT DISCHARGE

PART I POWER PLANT EFFICIENCY

Refer to the Examination Paper Attachments Page 9 **Heat Balance Diagram** for a Fossil Fired Power Plant.

Using this diagram and steam tables provided, determine the following:

(a) Steam Cycle Efficiency (electrical output / thermal input) (3)

(b) Power Output of High Pressure Turbine (calculated from steam properties) (3)

(c) Power Input to Boiler Feedwater Pump (calculated from steam properties) (3)

(9 marks)

PART II HEAT DISCHARGE

Thermal power plants operating on a Rankine Cycle reject considerable quantities of heat to a cooling system via a condenser. If the cooling medium is water in an open loop with the environment, it can cause significant thermal pollution of a river or lake at the point of discharge. Consider (i) a CANDU Nuclear Plant, and (ii) a Coal Fired Fossil Plant each of 1000 MW electrical output.

(a) Determine the total rate of heat discharge in the cooling water for each. (3)

(b) Find the total rate of heat loss to the atmosphere for each. (3)

Assume that the reactor is water cooled and the electrical equipment air cooled. Use the data given below for efficiencies:

CANDU Nuclear Plant steam cycle efficiency	0.33
Coal Fired Fossil Plant steam cycle efficiency	0.41
CANDU Nuclear Plant reactor thermal efficiency	0.99
Coal Fired Fossil Plant boiler thermal efficiency	0.94
Electrical efficiency for both plants	0.96

Note: Boiler and reactor thermal efficiency is defined as heat output via steam or coolant over heat input from fuel.

(6 marks)

[15 marks]

QUESTION 4 STEAM TURBINE OPERATIONAL CONDITIONS

Refer to the Examination Paper Attachments Page 10 **Mollier Chart**.

Steam is supplied to a turbine with an internal efficiency of 80% at 4 MPa (40 bar) and 400°C and exhausts at 0.005 MPa (0.05 bar). At full load the steam flow is 24 kg/s.

Note that the Mollier Chart is in bar (1 bar = 0.1 MPa). Solve by plotting the processes on the Mollier Diagram on Page 10 but use Steam Tables as provided to obtain improved accuracy in the calculations if necessary.

Clarity of the plotting of the processes as required for solution. (1)

Note that the steam flow under part load conditions is proportional to the inlet turbine pressure. Assume that for parts (a) to (c) the exhaust pressure remains constant.

(a) Calculate the power developed by the turbine at full load. (3)

(b) Calculate the power developed by the turbine when the inlet steam is throttled to 1 MPa. Assume that the internal efficiency is unchanged. (3)

(c) Calculate the power developed by the turbine when the generator output is zero. Under these conditions the turbine power output is dissipated in friction in the bearings and windage in the generator. An inlet steam pressure of 0.1 MPa is required to maintain this condition. Assume that the internal efficiency has decreased to 70%. (3)

Return this page (Mollier chart) with the examination answer booklet.

Refer to the Examination Paper Attachments Page 11 **Condenser Conditions**. The dotted lines show the temperature profiles in the condenser at full load. Assume now that the exhaust steam temperature changes with load and that the inlet cooling water temperature and flow rate remain constant.

(d) Using average temperature differences (not log mean) determine the temperature profiles for steam and water at part load conditions as defined in (b) above and plot these on the diagram. (3)

(e) Determine the condenser pressure under part load conditions at the exhaust temperature as determined in (d) above. (1)

(f) Estimate (without further calculation) the condenser pressure for zero load conditions as defined in (c) above. (1)

Return this page (Condenser conditions) with the examination answer booklet.

[15 marks]

SECTION B DESCRIPTIVE QUESTIONS

Descriptive questions should be answered in essay form, with sketches if appropriate, and taking approximately one full page for every 5 marks. A full page means approximately 250 words unless diagrams take the place of some words.

QUESTION 5 ENVIRONMENTAL IMPACT

Compare the environmental impact of large scale electric power generation from each of the following (all three) sources of energy:

- ~ Coal (fossil fuel combustion)
- ~ Nuclear (nuclear fission)
- ~ Hydro (renewable energy)

(a) For each explain the physical impact or disruption of the environment to build the plant and to supply the energy required. Suggest ways of alleviating the problems.

(3 marks)

(b) For each explain what detrimental effluents are produced during operation and by what mechanism and to what degree they can be minimised.

(5 marks)

(c) For each explain what solid waste products are produced and how these products may be disposed of in a way that will not be detrimental to the environment.

(5 marks)

(d) Given the evidence presented in your answers to the above, rank the three sources of energy in order of importance (installed MW) currently and their likely order of importance (installed MW) in the future (say 50 years time). Give reasons for the ranking.

(2 marks)

[15 marks]

QUESTION 6 ENERGY GENERATION AND STORAGE

In this question more emphasis may be put on either part and the mark allocation will be adjusted accordingly for a total of 15 marks (approximately 750 words).

PART I NUCLEAR ENERGY

Write a review (300 to 450 words) of the advantages and disadvantages of nuclear power plants over fossil fuel power plants (coal, oil, gas) and renewable energy power plants (hydro, wind, solar). Consider as many aspects as possible (technical, economic, environmental, operational, etc.) in a concise manner.

(6-9 marks)

PART II ENERGY STORAGE

Due to the variability of the operation of certain power plants, particularly those based on wind and solar energy, there is a need to provide large scale energy storage. Write a review (300 to 450 words) of one or more large scale energy storage plants explaining their configuration and method of operation in a concise manner.

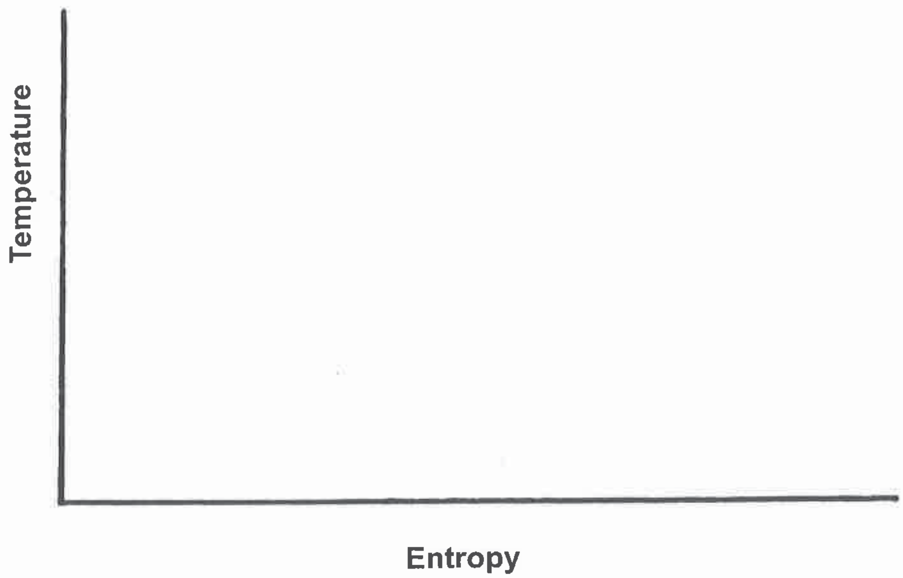
(6-9 marks)

[15 marks]

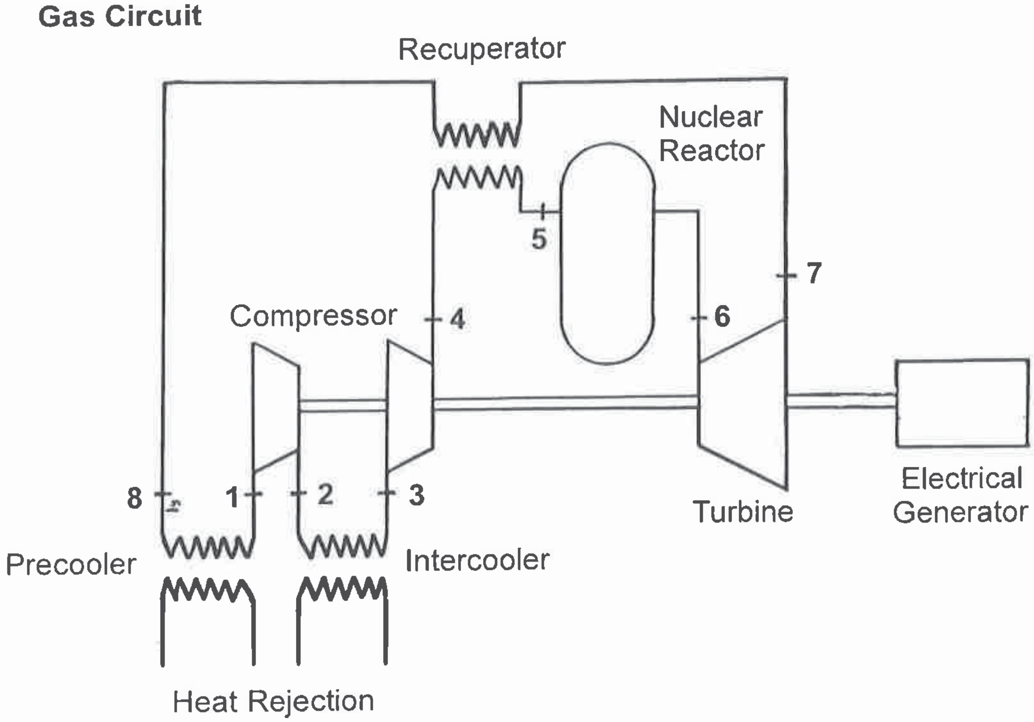
NAME ....

EXAMINATION PAPER ATTACHMENTS

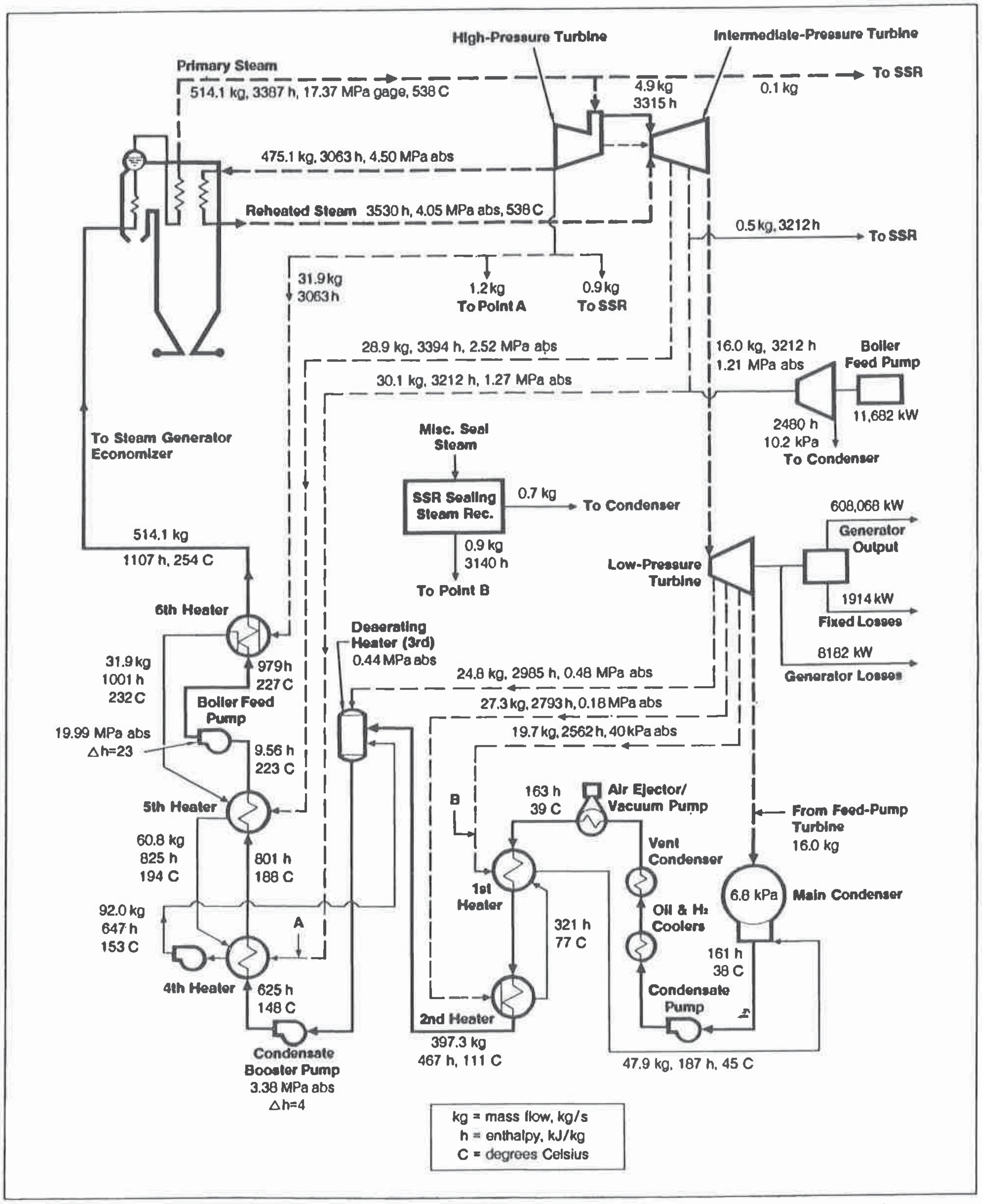
QUESTION 1 GAS TURBINE MODULAR HELIUM REACTOR



Gas Circuit



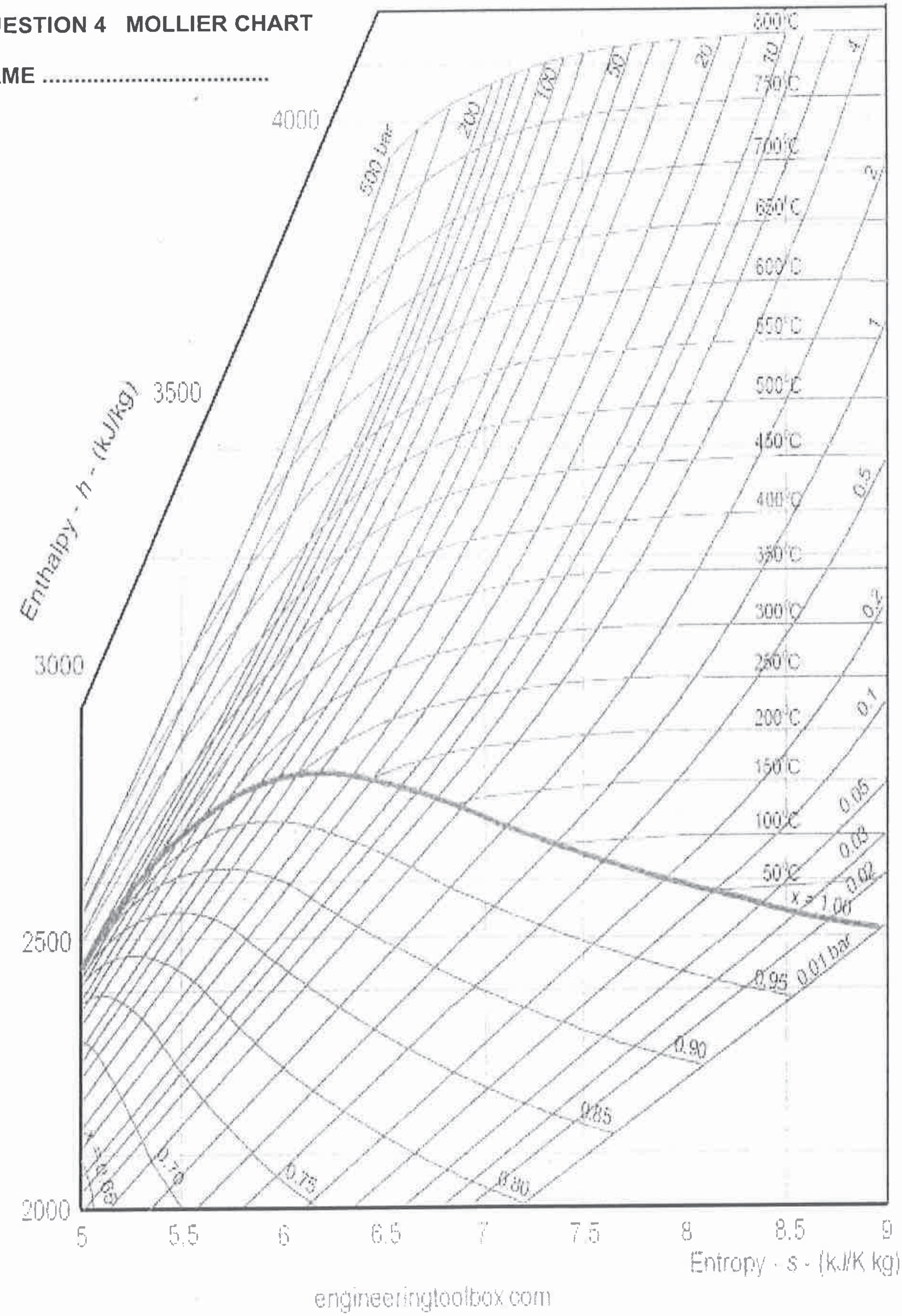
QUESTION 3 HEAT BALANCE DIAGRAM



Reheat regenerative cycle, 600-MW subcritical-pressure fossil power plant (SI-metric units)

QUESTION 4 MOLLIER CHART

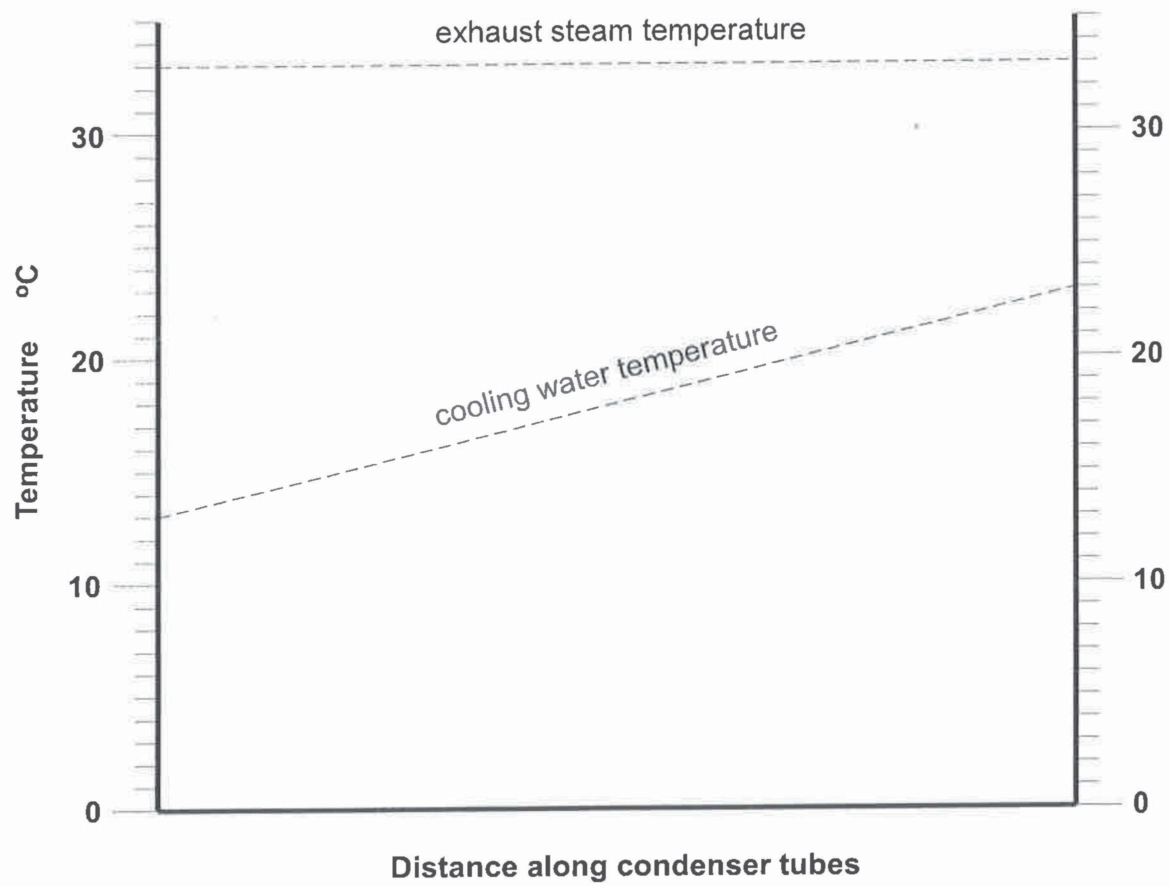
NAME ....



NAME ....

QUESTION 4 CONDENSER CONDITIONS

(e) Show temperature profiles (exhaust steam and cooling water) for part load conditions (when throttled to 4 MPa. Assume that the cooling water inlet temperature remains constant



(f) Determine the condenser pressure at part load conditions (4 MPa steam inlet)

(g) Estimate the exhaust steam temperature and condenser pressure at zero load conditions (0.1 MPa steam inlet)

EXAMINATION REFERENCE MATERIAL

NOMENCLATURE FOR REFERENCE EQUATIONS (SI UNITS)

a	Acceleration	m/s^2
A	Flow area, Surface area	m^2
c_p	Specific heat at constant pressure	J/kg°C
c_v	Specific heat at constant volume	J/kg°C
D	Diameter	m
E	Energy	J
E_f	Energy release per fission of one atom	
h	Specific enthalpy	J/kg
H	Enthalpy	J
F	Force	N
g	Gravitational acceleration	m/s^2
k	Ratio of specific heats	
L	Length	m
m	Mass	kg
m	Fractional mass flow rate	
M	Mass flow rate	kg/s
M	Molecular weight	
N	Number of nuclei	number/g
N_A	Avogadro's Number	
N_f	Number of fissile nuclei	number/cm^3
n	Gas expansion index	
p	Pressure	Pa
P	Power	W
q	Heat transferred	J/kg
q*	Heat release rate	J/cm^3
Q	Heat	J
Q	Volume flow rate	m^3/s
R	Specific gas constant	J/kgEK
R_0	Universal gas constant	J/kg-moleEK
s	Specific entropy	J/kgEK
S	Entropy	J/EK
t	Time	s
t	Temperature	EC
T	Absolute temperature	°K
u	Specific internal energy	J/kg
U	Internal energy	J
v	Specific volume	m^3/kg
V	Volume	m^3
V	Velocity	m/s
w	Specific work	J/kg
W	Work	J

x	Length	m
z	Elevation	m
γ	Fuel enrichment	
η	Efficiency	
ϕ	Neutron flux	neutrons/cm^{2}s
σ_f	Cross section	barn
μ	Dynamic viscosity	Ns/m^2
<	Kinematic viscosity	m^2/s
ρ	Density	kg/m^3
T	Thrust	N
T	Torque	Nm
Ω	Heat transfer rate	J/s

CONSTANTS

For consistency in calculations the following constants should be used:

Gravitational Acceleration	g =	9.81 m/s
Atmospheric Pressure	p =	100 kPa
Universal Gas Constant	R_o =	8.314 kJ/kg moleEK
Density of Water	ρ =	1000 kg/m^3
Specific Heat of Water	c_p =	4.19 kJ/kg°C
Specific Heat of Air	c_p =	1.005 kJ/kgEC
Specific Heat of Air	c_v =	0.718 kJ/kgEC
Specific Heat of Helium	c_p =	5.193 kJ/kgEC
Specific Heat of Helium	c_v =	3.116 kJ/kgEC
Specific Gas Constant for Air	R =	0.287 kJ/kgEK
Avogadro's Number	N_A =	0.602 x 10^{24} atoms/mole
Nuclear Cross Section	1 barn = 10^{-24} cm^2	

GENERAL REFERENCE EQUATIONS

Ideal Gas Relationships

Gas Law:	$pv = RT$
Gas Law:	$pV = mRT$
Specific Heat at Constant Pressure:	$c_p = \Delta h/\Delta T$
Specific Heat at Constant Volume:	$c_v = \Delta u/\Delta T$
Gas Constant:	$R = c_p - c_v$

Specific Heat Ratio:	$k = c_p/c_v$
Constant Volume:	$T_1/T_2 = p_1/p_2$
Constant Pressure:	$T_1/T_2 = v_1/v_2$
Constant Temperature:	$p_1v_1 = p_2v_2$
Constant Entropy:	$p_1v_1^k = p_2v_2^k$
Isentropic Relations:	$p_1/p_2 = (v_2/v_1)^k = (T_1/T_2)^{k/(k-1)}$
	$T_1/T_2 = (v_2/v_1)^{k-1} = (p_1/p_2)^{(k-1)/k}$

Work in Non-Flow Processes

Constant Pressure:	$w = p\,(v_2 - v_1)$
Constant Temperature:	$w = p_1v_1 \ln(v_2/v_1)$
Constant Entropy:	$w = (p_2v_2 - p_1v_1) / (1 - k)$
	$w = (T_2 - T_1)\,R / (1 - k)$

Work in Flow Processes

Constant Temperature:	$w = p_1v_1 \ln(v_2v_1)$
Constant Volume:	$w = (p_2 - p_1)\,v$
Constant Entropy:	$w = (p_1v_1 - p_2v_2)\,k / (k - 1)$

Thermodynamics

First Law:	$dE = \delta Q - \delta W$
Enthalpy:	$h = u + pv$
Enthalpy Change	$\Delta h = \Delta u + \Delta(pv)$
Continuity:	$\rho VA = \text{constant}$
Flow Work:	$w = \Delta(pv)$
Energy Equation:	$zg + V^2/2 + u + pv + \Delta w + \Delta q = \text{constant}$
Entropy:	$\Delta s = q/T$ (reversible conditions)

Fluid Mechanics

Continuity Equation:	$\rho_1V_1A_1 = \rho_2V_2A_2 = M$
Energy Equation:	$z_1g + V_1^2/2 + u_1 + p_1v_1 + w_{in} + q_{in}$
	$= z_2g + V_2^2/2 + u_2 + p_2\,v_2 + w_{out} + q_{out}$
Bernoulli's Equation:	$p_1/\rho g + z_1 + V_1^2/2g = p_2/\rho g + z_2 + V_2^2/2g$
Momentum Equation:	$F = p_1A_1 - p_2A_2 - \rho VA(V_2 - V_1)$
	(one dimensional)

Internal Combustion Engines

Power Output	$P = 2\pi N\tau / 60$
Engine Capacity	$V_{total} = 1000\,(\pi D^2/4)\,LN_{cylinders}$
Mean Effective Pressure	$MEP = Work / (V_1 - V_2)$

Steam Turbines

Nozzle Equation:	$h_1 - h_2 = (V_2^2 - V_1^2) / 2$
Work:	$w = [(V_1^2{}_{absolute} - V_2^2{}_{absolute}) + (V_2^2{}_{relative} - V_1^2{}_{relative})] / 2$

Gas Turbines

Isentropic Equation:	$(T_2/T_1) = (p_2/p_1)^{(k-1)/k}$
Enthalpy Change:	$h_1 - h_2 = c_p(T_1 - T_2)$ (ideal gas)
Nozzle Equation:	$h_1 - h_2 = (V_2^2 - V_1^2) / 2$

Jet Propulsion

Thrust:	$\tau = M(V_{jet} - V_{aircraft})$
Thrust Power:	$\tau V_{aircraft} = M(V_{jet} - V_{aircraft})V_{aircraft}$
Jet Power:	$P = M(V_{jet}^2 - V_{aircraft}^2) / 2$
Propulsion Efficiency:	$\eta_p = 2V_{aircraft}/(V_{jet} + V_{aircraft})$

Wind Turbines

Maximum Ideal Power:	$P_{max} = 8\, \rho\, AV_1^3 / 27$

Nuclear Energy

Number of nuclei per gram of material:	$N = N_A / M$
Number of fissile nuclei per cm^3 of material:	$N_f = \gamma\, (N_A / M)\, \rho$
Heat release rate in nuclear fuel:	$q^* = \phi\, N_f\, \sigma_f\, E_f$

Cycle Efficiencies

$$\eta_{cycle} = w_{out} / q_{in} = W_{out} / Q_{in} = P_{out} / \Omega_{in}$$

$$\eta_{Carnot} = (T_{hot} - T_{cold}) / T_{hot}$$

$$\eta_{Rankine} = (\Delta h_{turbine} - \Delta h_{pump}) / \Delta h_{boiler}$$

$$\eta_{Brayton} = (\Delta T_{turbine} - \Delta T_{Compressor}) / \Delta T_{combustion}$$

Component Efficiencies

$$\eta_{boiler} = \Omega_{out} / \Omega_{in}$$

$$\eta_{boiler} = (\Omega_{in} / \Omega_{lost}) / \Omega_{in}$$

$$\eta_{turbine} = \Delta h_{actual} / \Delta h_{isentropic}$$

$$\eta_{nozzle} = \Delta h_{actual} / \Delta h_{isentropic}$$

$$\eta_{gas\ turbine} = \Delta T_{actual} / \Delta T_{isentropic}$$

$$\eta_{pump} = \Delta h_{isentropic} / \Delta h_{actual}$$

$$\eta_{compressor} = \Delta T_{isentropic} / \Delta T_{actual}$$

Thermodynamics and Heat Power

SIXTH EDITION

Irving Granet, P.E.

late, Queensborough Community College of City University of New York

Maurice Bluestein, Ph.D.

Indiana University–Purdue University, Indianapolis

PRENTICE HALL

Upper Saddle River, New Jersey   Columbus, Ohio

TABLE A.1 (SI) (cont'd.)

Temp. °C T	Press. kPa 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
	MPa											
100	0.101 35	0.001 044	1.6729	418.94	2087.6	2506.5	419.04	2257.0	2676.1	1.3069	6.0480	7.3549
105	0.120 82	0.001 048	1.4194	440.02	2072.3	2512.4	440.15	2243.7	2683.8	1.3630	5.9328	7.2958
110	0.143 27	0.001 052	1.2102	461.14	2057.0	2518.1	461.30	2230.2	2691.5	1.4185	5.8202	7.2387
115	0.169 06	0.001 056	1.0366	482.30	2041.4	2523.7	482.48	2216.5	2699.0	1.4734	5.7100	7.1833
120	0.198 53	0.001 060	0.8919	503.50	2025.8	2529.3	503.71	2202.6	2706.3	1.5276	5.6020	7.1296
125	0.2321	0.001 065	0.7706	524.74	2009.9	2534.6	524.99	2188.5	2713.5	1.5813	5.4962	7.0775
130	0.2701	0.001 070	0.6685	546.02	1993.9	2539.9	546.31	2174.2	2720.5	1.6344	5.3925	7.0269
135	0.3130	0.001 075	0.5822	567.35	1977.7	2545.0	567.69	2159.6	2727.3	1.6870	5.2907	6.9777
140	0.3613	0.001 080	0.5089	588.74	1961.3	2550.0	589.13	2144.7	2733.9	1.7391	5.1908	6.9299
145	0.4154	0.001 085	0.4463	610.18	1944.7	2554.9	610.63	2129.6	2740.3	1.7907	5.0926	6.8833
150	0.4758	0.001 091	0.3928	631.68	1927.9	2559.5	632.20	2114.3	2746.5	1.8418	4.9960	6.8379
155	0.5431	0.001 096	0.3468	653.24	1910.8	2564.1	653.84	2098.6	2752.4	1.8925	4.9010	6.7935
160	0.6178	0.001 102	0.3071	674.87	1893.5	2568.4	675.55	2082.6	2758.1	1.9427	4.8075	6.7502
165	0.7005	0.001 108	0.2727	696.56	1876.0	2572.5	697.34	2066.2	2763.5	1.9925	4.7153	6.7078
170	0.7917	0.001 114	0.2428	718.33	1858.1	2576.5	719.21	2049.5	2768.7	2.0419	4.6244	6.6663
175	0.8920	0.001 121	0.2168	740.17	1840.0	2580.2	741.17	2032.4	2773.6	2.0909	4.5347	6.6256
180	1.0021	0.001 127	0.194 05	762.09	1821.6	2583.7	763.22	2015.0	2778.2	2.1396	4.4461	6.5857
185	1.1227	0.001 134	0.174 09	784.10	1802.9	2587.0	785.37	1997.1	2782.4	2.1879	4.3586	6.5465
190	1.2544	0.001 141	0.156 54	806.19	1783.8	2590.0	807.62	1978.8	2786.4	2.2359	4.2720	6.5079
195	1.3978	0.001 149	0.141 05	828.37	1764.4	2592.8	829.98	1960.0	2790.0	2.2835	4.1863	6.4698
200	1.5538	0.001 157	0.127 36	850.65	1744.7	2595.3	852.45	1940.7	2793.2	2.3309	4.1014	6.4323
205	1.7230	0.001 164	0.115 21	873.04	1724.5	2597.5	875.04	1921.0	2796.0	2.3780	4.0172	6.3952
210	1.9062	0.001 173	0.104 41	895.53	1703.9	2599.5	897.76	1900.7	2798.5	2.4248	3.9337	6.3585
215	2.104	0.001 181	0.094 79	918.14	1682.9	2601.1	920.62	1879.9	2800.5	2.4714	3.8507	6.3221
220	2.318	0.001 190	0.086 19	940.87	1661.5	2602.4	943.62	1858.5	2802.1	2.5178	3.7683	6.2861
225	2.548	0.001 199	0.078 49	963.73	1639.6	2603.3	966.78	1836.5	2803.3	2.5639	3.6863	6.2503
230	2.795	0.001 209	0.071 58	986.74	1617.2	2603.9	990.12	1813.8	2804.0	2.6099	3.6047	6.2146
235	3.060	0.001 219	0.065 37	1009.89	1594.2	2604.1	1013.62	1790.5	2804.2	2.6558	3.5233	6.1791
240	3.344	0.001 229	0.059 76	1033.21	1570.8	2604.0	1037.32	1766.5	2803.8	2.7015	3.4422	6.1437
245	3.648	0.001 240	0.054 71	1056.71	1546.7	2603.4	1061.23	1741.7	2803.0	2.7472	3.3612	6.1083

TABLE A.2 (SI)

Saturation Pressures (Steam)

Press. kPa 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
0.6113	0.01	0.001 000	206.14	.00	2375.3	2375.3	.01	2501.3	2501.4	.0000	9.1562	9.1562
1.0	6.98	0.001 000	129.21	29.30	2355.7	2385.0	29.30	2484.9	2514.2	.1059	8.8697	8.9756
1.5	13.03	0.001 001	87.98	54.71	2338.6	2393.3	54.71	2470.6	2525.3	.1957	8.6322	8.8279
2.0	17.50	0.001 001	67.00	73.48	2326.0	2399.5	73.48	2460.0	2533.5	.2607	8.4629	8.7237
2.5	21.08	0.001 002	54.25	88.48	2315.9	2404.4	88.49	2451.6	2540.0	.3120	8.3311	8.6432
3.0	24.08	0.001 003	45.67	101.04	2307.5	2408.5	101.05	2444.5	2545.5	.3545	8.2231	8.5776
4.0	28.96	0.001 004	34.80	121.45	2293.7	2415.2	121.46	2432.9	2554.4	.4226	8.0520	8.4746
5.0	32.88	0.001 005	28.19	137.81	2282.7	2420.5	137.82	2423.7	2561.5	.4764	7.9187	8.3951
7.5	40.29	0.001 008	19.24	168.78	2261.7	2430.5	168.79	2406.0	2574.8	.5764	7.6750	8.2515
10	45.81	0.001 010	14.67	191.82	2246.1	2437.9	191.83	2392.8	2584.7	.6493	7.5009	8.1502
15	53.97	0.001 014	10.02	225.92	2222.8	2448.7	225.94	2373.1	2599.1	.7549	7.2536	8.0085
20	60.06	0.001 017	7.649	251.38	2205.4	2456.7	251.40	2358.3	2609.7	.8320	7.0766	7.9085
25	64.97	0.001 020	6.204	271.90	2191.2	2463.1	271.93	2346.3	2618.2	.8931	6.9383	7.8314
30	69.10	0.001 022	5.229	289.20	2179.2	2468.4	289.23	2336.1	2625.3	.9439	6.8247	7.7686
40	75.87	0.001 027	3.993	317.53	2159.5	2477.0	317.58	2319.2	2636.8	1.0259	6.6441	7.6700
50	81.33	0.001 030	3.240	340.44	2143.4	2483.9	340.49	2305.4	2645.9	1.0910	6.5029	7.5939
75	91.78	0.001 037	2.217	384.31	2112.4	2496.7	384.39	2278.6	2663.0	1.2130	6.2434	7.4564
MPa												
0.100	99.63	0.001 043	1.6940	417.36	2088.7	2506.1	417.46	2258.0	2675.5	1.3026	6.0568	7.3594
0.125	105.99	0.001 048	1.3749	444.19	2069.3	2513.5	444.32	2241.0	2685.4	1.3740	5.9104	7.2844
0.150	111.37	0.001 053	1.1593	466.94	2052.7	2519.7	467.11	2226.5	2693.6	1.4336	5.7897	7.2233
0.175	116.06	0.001 057	1.0036	486.80	2038.1	2524.9	486.99	2213.6	2700.6	1.4849	5.6868	7.1717
0.200	120.23	0.001 061	0.8857	504.49	2025.0	2529.5	504.70	2201.9	2706.7	1.5301	5.5970	7.1271
0.225	124.00	0.001 064	0.7933	520.47	2013.1	2533.6	520.72	2191.3	2712.1	1.5706	5.5173	7.0878

TABLE A.2 (SI) (cont'd.)

Press. 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
1.50	198.32	0.001 154	0.131 77	843.16	1751.3	2594.5	844.89	1947.3	2792.2	2.3150	4.1298	6.4448
1.75	205.76	0.001 166	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	0.001 177	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	0.001 187	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	0.001 197	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	0.001 217	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	0.001 235	0.057 07	1045.43	1558.3	2603.7	1049.75	1753.7	2803.4	2.7253	3.4000	6.1253
4	250.40	0.001 252	0.049 78	1082.31	1520.0	2602.3	1087.31	1714.1	2801.4	2.7964	3.2737	6.0701
5	263.99	0.001 286	0.039 44	1147.81	1449.3	2597.1	1154.23	1640.1	2794.3	2.9202	3.0532	5.9734
6	275.64	0.001 319	0.032 44	1205.44	1384.3	2589.7	1213.35	1571.0	2784.3	3.0267	2.8625	5.8892
7	285.88	0.001 351	0.027 37	1257.55	1323.0	2580.5	1267.00	1505.1	2772.1	3.1211	2.6922	5.8133
8	295.06	0.001 384	0.023 52	1305.57	1264.2	2569.8	1316.64	1441.3	2758.0	3.2068	2.5364	5.7432
9	303.40	0.001 418	0.020 48	1350.51	1207.3	2557.8	1363.26	1378.9	2742.1	3.2858	2.3915	5.6772
10	311.06	0.001 452	0.018 026	1393.04	1151.4	2544.4	1407.56	1317.1	2724.7	3.3596	2.2544	5.6141
11	318.15	0.001 489	0.015 987	1433.7	1096.0	2529.8	1450.1	1255.5	2705.6	3.4295	2.1233	5.5527
12	324.75	0.001 527	0.014 263	1473.0	1040.7	2513.7	1491.3	1193.6	2684.9	3.4962	1.9962	5.4924
13	330.93	0.001 567	0.012 780	1511.1	985.0	2496.1	1531.5	1130.7	2662.2	3.5606	1.8718	5.4323
14	336.75	0.001 611	0.011 485	1548.6	928.2	2476.8	1571.1	1066.5	2637.6	3.6232	1.7485	5.3717
15	342.24	0.001 658	0.010 337	1585.6	869.8	2455.5	1610.5	1000.0	2610.5	3.6848	1.6249	5.3098
16	347.44	0.001 711	0.009 306	1622.7	809.0	2431.7	1650.1	930.6	2580.6	3,7461	1.4994	5.2455
17	352.37	0.001 770	0.008 364	1660.2	744.8	2405.0	1690.3	856.9	2547.2	3.8079	1.3698	5.1777
18	357.06	0.001 840	0.007 489	1698.9	675.4	2374.3	1732.0	777.1	2509.1	3.8715	1.2329	5.1044
19	361.54	0.001 924	0.006 657	1739.9	598.1	2338.1	1776.5	688.0	2464.5	3.9388	1.0839	5.0228
20	365.81	0.002 036	0.005 834	1785.6	507.5	2293.0	1826.3	583.4	2409.7	4.0139	.9130	4.9269
21	369.89	0.002 207	0.004 952	1842.1	388.5	2230.6	1888.4	446.2	2334.6	4.1075	.6938	4.8013
22	373.80	0.002 742	0.003 568	1961.9	125.2	2087.1	2022.2	143.4	2165.6	4.3110	.2216	4.5327
22.09	374.14	0.003 155	0.003 155	2029.6	0	2029.6	2099.3	0	2099.3	4.4298	0	4.4298

TABLE A.3 (SI) (cont'd.)

T	v	u	h	s	v	u	h	s	v	u	h	s
	$P = .20$ MPa (120.23)				$P = .30$ MPa (133.55)				$P = .40$ MPa (143.63)			
500	1.7814	3130.8	3487.1	8.5133	1.1867	3130.0	3486.0	8.3251	.8893	3129.2	3484.9	8.1913
600	2.013	3301.4	3704.0	8.7770	1.3414	3300.8	3703.2	8.5892	1.0055	3300.2	3702.4	8.4558
700	2.244	3478.8	3927.6	9.0194	1.4957	3478.4	3927.1	8.8319	1.1215	3477.9	3926.5	8.6987
800	2.475	3663.1	4158.2	9.2449	1.6499	3662.9	4157.8	9.0576	1.2372	3662.4	4157.3	8.9244
900	2.706	3854.5	4395.8	9.4566	1.8041	3854.2	4395.4	9.2692	1.3529	3853.9	4395.1	9.1362
1000	2.937	4052.5	4640.0	9.6563	1.9581	4052.3	4639.7	9.4690	1.4685	4052.0	4639.4	9.3360
1100	3.168	4257.0	4890.7	9.8458	2.1121	4256.8	4890.4	9.6585	1.5840	4256.5	4890.2	9.5256
1200	3.399	4467.5	5147.3	10.0262	2.2661	4467.2	5147.1	9.8389	1.6996	4467.0	5146.8	9.7060
1300	3.630	4683.2	5409.3	10.1982	2.4201	4683.0	5409.0	10.0110	1.8151	4682.8	5408.8	9.8780
	$P = .50$ MPa (151.86)				$P = .60$ MPa (158.85)				$P = .80$ MPa (170.43)			
Sat.	.3749	2561.2	2748.7	6.8213	.3157	2567.4	2756.8	6.7600	.2404	2576.8	2769.1	6.6628
200	.4249	2642.9	2855.4	7.0592	.3520	2638.9	2850.1	6.9665	.2608	2630.6	2839.3	6.8158
250	.4744	2723.5	2960.7	7.2709	.3938	2720.9	2957.2	7.1816	.2931	2715.5	2950.0	7.0384
300	.5226	2802.9	3064.2	7.4599	.4344	2801.0	3061.6	7.3724	.3241	2797.2	3056.5	7.2328
350	.5701	2882.6	3167.7	7.6329	.4742	2881.2	3165.7	7.5464	.3544	2878.2	3161.7	7.4089
400	.6173	2963.2	3271.9	7.7938	.5137	2962.1	3270.3	7.7079	.3843	2959.7	3267.1	7.5716
500	.7109	3128.4	3483.9	8.0873	.5920	3127.6	3482.8	8.0021	.4433	3126.0	3480.6	7.8673
600	.8041	3299.6	3701.7	7.3522	.6697	3299.1	3700.9	8.2674	.5018	3297.9	3699.4	8.1333
700	.8969	3477.5	3925.9	8.5952	.7472	3477.0	3925.3	8.5107	.5601	3476.2	3924.2	8.3770
800	.9896	3662.1	4156.9	8.8211	.8245	3661.8	4156.5	8.7367	.6181	3661.1	4155.6	8.6033
900	1.0822	3853.6	4394.7	9.0329	.9017	3853.4	4394.4	8.9486	.6761	3852.8	4393.7	8.8153
1000	1.1747	4051.8	4639.1	9.2328	.9788	4051.5	4638.8	9.1485	.7340	4051.0	4638.2	9.0153
1100	1.2672	4256.3	4889.9	9.4224	1.0559	4256.1	4889.6	9.3381	.7919	4255.6	4889.1	9.2050
1200	1.3596	4466.8	5146.6	9.6029	1.1330	4466.5	5146.3	9.5185	.8497	4466.1	5145.9	9.3855
1300	1.4521	4682.5	5408.6	9.7749	1.2101	4682.3	5408.3	9.6906	.9076	4681.8	5407.9	9.5575

TABLE A.3 (SI) (cont'd.)

T	v	u	h	s	v	u	h	s	v	u	h	s
	$P = 1.60$ MPa (201.41)				$P = 1.80$ MPa (207.15)				$P = 2.00$ MPa (212.42)			
800	.3086	3658.3	4152.1	8.2808	.2742	3657.6	4151.2	8.2258	.2467	3657.0	4150.3	8.1765
900	.3377	3850.5	4390.8	8.4935	.3001	3849.9	4390.1	8.4386	.2700	3849.3	4389.4	8.3895
1000	.3668	4049.0	4635.8	8.6938	.3260	4048.5	4635.2	8.6391	.2933	4048.0	4634.6	8.5901
1100	.3958	4253.7	4887.0	8.8837	.3518	4253.2	4886.4	8.8290	.3166	4252.7	4885.9	8.7800
1200	.4248	4464.2	5143.9	9.0643	.3776	4463.7	5143.4	9.0096	.3398	4463.3	5142.9	8.9607
1300	.4538	4679.9	5406.0	9.2364	.4034	4679.5	5405.6	9.1818	.3631	4679.0	5405.1	9.1329
	$P = 2.50$ 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	2803.4	6.1253
225	.080 27	2605.6	2806.3	6.2639								
250	.087 00	2662.6	2880.1	6.4085	.070 58	2644.0	2855.8	6.2872	.058 72	2623.7	2829.2	6.1749
300	.098 90	2761.6	3008.8	6.6438	.081 14	2750.1	2993.5	6.5390	.068 42	2738.0	2977.5	6.4461
350	.109 76	2851.9	3126.3	6.8403	.090 53	2843.7	3115.3	6.7428	.076 78	2835.3	3104.0	6.6579
400	.120 10	2939.1	3239.3	7.0148	.099 36	2932.8	3230.9	6.9212	.084 53	2926.4	3222.3	6.8405
450	.130 14	3025.5	3350.8	7.1746	.107 87	3020.4	3344.0	7.0834	.091 96	3015.3	3337.2	7.0052
500	.139 98	3112.1	3462.1	7.3234	.116 19	3108.0	3456.5	7.2338	.099 18	3103.0	3450.9	7.1572
600	.159 30	3288.0	3686.3	7.5960	.132 43	3285.0	3682.3	7.5085	.113 24	3282.1	3678.4	7.4339
700	.178 32	3468.7	3914.5	7.8435	.148 38	3466.5	3911.7	7.7571	.126 99	3464.3	3908.8	7.6837
800	.197 16	3655.3	4148.2	8.0720	.164 14	3653.5	4145.9	7.9862	.140 56	3651.8	4143.7	7.9134
900	.215 90	3847.9	4387.6	8.2853	.179 80	3846.5	4385.9	8.1999	.154 02	3845.0	4384.1	8.1276
1000	.2346	4046.7	4633.1	8.4861	.195 41	4045.4	4631.6	8.4009	.167 43	4044.1	4630.1	8.3288
1100	.2532	4251.5	4884.6	8.6762	.210 98	4250.3	4883.3	8.5912	.180 80	4249.2	4881.9	8.5192
1200	.2718	4462.1	5141.7	8.8569	.226 52	4460.9	5140.5	8.7720	.194 15	4459.8	5139.3	8.7000
1300	.2905	4677.8	5404.0	9.0291	.242 06	4676.6	5402.8	8.9442	.207 49	4675.5	5401.7	8.8723

TABLE A.3 (SI) (cont'd.)

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)			
700	.073 52	3453.1	3894.2	7.4234	.062 83	3448.5	3888.3	7.3476	.054 81	3443.9	3882.4	7.2812
800	.081 60	3643.1	4132.7	7.6566	.069 81	3639.5	4128.2	7.5822	.060 97	3636.0	4123.8	7.5173
900	.089 58	3837.8	4375.3	7.8727	.076 69	3835.0	4371.8	7.7991	.067 02	3832.1	4368.3	7.7351
1000	.097 49	4037.8	4622.7	8.0751	.083 50	4035.3	4619.8	8.0020	.073 01	4032.8	4616.9	7.9384
1100	.105 36	4243.3	4875.4	8.2661	.090 27	4240.9	4872.8	8.1933	.078 96	4238.6	4870.3	8.1300
1200	.113 21	4454.0	5133.3	8.4474	.097 03	4451.7	5130.9	8.3747	.084 89	4449.5	5128.5	8.3115
1300	.121 06	4669.6	5396.0	8.6199	.103 77	4667.3	5393.7	8.5473	.090 80	4665.0	5391.5	8.4842
	$P = 9.0$ 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	2673.8	5.4624
325	.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	2826.2	5.7118
400	.029 93	2848.4	3117.8	6.2854	.026 41	2832.4	3096.5	6.2120	.020 00	2789.3	3039.3	6.0417
450	.033 50	2955.2	3256.6	6.4844	.029 75	2943.4	3240.9	6.4190	.022 99	2912.5	3199.8	6.2719
500	.036 77	3055.2	3386.1	6.6576	.032 79	3045.8	3373.7	6.5966	.025 60	3021.7	3341.8	6.4618
550	.039 87	3152.2	3511.0	6.8142	.035 64	3144.6	3500.9	6.7561	.028 01	3125.0	3475.2	6.6290
600	.042 85	3248.1	3633.7	6.9589	.038 37	3241.7	3625.3	6.9029	.030 29	3225.4	3604.0	6.7810
650	.045 74	3343.6	3755.3	7.0943	.041 01	3338.2	3748.2	7.0398	.032 48	3324.4	3730.4	6.9218
700	.048 57	3439.3	3876.5	7.2221	.043 58	3434.7	3870.5	7.1687	.034 60	3422.9	3855.3	7.0536
800	.054 09	3632.5	4119.3	7.4596	.048 59	3628.9	4114.8	7.4077	.038 69	3620.0	4103.6	7.2965
900	.059 50	3829.2	4364.8	7.6783	.053 49	3826.3	4361.2	7.6272	.042 67	3819.1	4352.5	7.5182
1000	.064 85	4030.3	4614.0	7.8821	.058 32	4027.8	4611.0	7.8315	.046 58	4021.6	4603.8	7.7237
1100	.070 16	4236.3	4867.7	8.0740	.063 12	4234.0	4865.1	8.0237	.050 45	4228.2	4858.8	7.9165
1200	.075 44	4447.2	5126.2	8.2556	.067 89	4444.9	5123.8	8.2055	.054 30	4439.3	5118.0	8.0987
1300	.080 72	4662.7	5389.2	8.4284	.072 65	4460.5	5387.0	8.3783	.058 13	4654.8	5381.4	8.2717

TABLE A.3 (SI) (cont'd.)

T	v	u	h	s	v	u	h	s	v	u	h	s
	$P = 25.0$ MPa				$P = 30.0$ MPa				$P = 35.0$ MPa			
700	.016 646	3361.3	3777.5	6.6707	.013 661	3335.8	3745.6	6.5606	.011 533	3309.8	3713.5	6.4631
800	.018 912	3574.3	4047.1	6.9345	.015 623	3555.5	4024.2	6.8332	.013 278	3536.7	4001.5	6.7450
900	.021 045	3783.0	4309.1	7.1680	.017 448	3768.5	4291.9	7.0718	.014 883	3754.0	4274.9	6.9886
1000	.023 10	3990.9	4568.5	7.3802	.019 196	3978.8	4554.7	7.2867	.016 410	3966.7	4541.1	7.2064
1100	.025 12	4200.2	4828.2	7.5765	.020 903	4189.2	4816.3	7.4845	.017 895	4178.3	4804.6	7.4057
1200	.027 11	4412.0	5089.9	7.7605	.022 589	4401.3	5079.0	7.6692	.019 360	4390.7	5068.3	7.5910
1300	.029 10	4626.9	5354.4	7.9342	.024 266	4616.0	5344.0	7.8432	.020 815	4605.1	5333.6	7.7653
	$P = 40.0$ MPa				$P = 50.0$ MPa				$P = 60.0$ MPa			
375	.001 640 7	1677.1	1742.8	3.8290	.001 559 4	1638.6	1716.6	3.7639	.001 502 8	1609.4	1699.5	3.7141
400	.001 907 7	1854.6	1930.9	4.1135	.001 730 9	1788.1	1874.6	4.0031	.001 633 5	1745.4	1843.4	3.9318
425	.002 532	2096.9	2198.1	4.5029	.002 007	1959.7	2060.0	4.2734	.001 816 5	1892.7	2001.7	4.1626
450	.003 693	2365.1	2512.8	4.9459	.002 486	2159.6	2284.0	4.5884	.002 085	2053.9	2179.0	4.4121
500	.005 622	2678.4	2903.3	5.4700	.003 892	2525.5	2720.1	5.1726	.002 956	2390.6	2567.9	4.9321
550	.006 984	2869.7	3149.1	5.7785	.005 118	2763.6	3019.5	5.5485	.003 956	2658.8	2896.2	5.3441
600	.008 094	3022.6	3346.4	6.0114	.006 112	2942.0	3247.6	5.8178	.004 834	2861.1	3151.2	5.6452
650	.009 063	3158.0	3520.6	6.2054	.006 966	3093.5	3441.8	6.0342	.005 595	3028.8	3364.5	5.8829
700	.009 941	3283.6	3681.2	6.3750	.007 727	3230.5	3616.8	6.2189	.006 272	3177.2	3553.5	6.0824
800	.011 523	3517.8	3978.7	6.6662	.009 076	3479.8	3933.6	6.5290	.007 459	3441.5	3889.1	6.4109
900	.012 962	3739.4	4257.9	6.9150	.010 283	3710.3	4224.4	6.7882	.008 508	3681.0	4191.5	6.6805
1000	.014 324	3954.6	4527.6	7.1356	.011 411	3930.5	4501.1	7.0146	.009 480	3906.4	4475.2	6.9127
1100	.015 642	4167.4	4793.1	7.3364	.012 496	4145.7	4770.5	7.2184	.010 409	4124.1	4748.6	7.1195
1200	.016 940	4380.1	5057.7	7.5224	.013 561	4359.1	5037.2	7.4058	.011 317	4338.2	5017.2	7.3083
1300	.018 229	4594.3	5323.5	7.6969	.014 616	4572.8	5303.6	7.5808	.012 215	4551.4	5284.3	7.4837

TABLE A.4 (SI)
Properties of Compressed Liquid (Steam)

	P = 5 MPa (263.99)				P = 10 MPa (311.06)				P = 15 MPa (342.24)			
T	v	u	h	s	v	u	h	s	v	u	h	s
Sat.	.001 285 9	1147.8	1154.2	2.9202	.001 452 4	1393.0	1407.6	3.3596	.001 658 1	1585.6	1610.5	3.6848
0	.000 997 7	.04	5.04	.0001	.000 995 2	.09	10.04	.0002	.000 992 8	.15	15.05	.0004
20	.000 999 5	83.65	88.65	.2956	.000 997 2	83.36	93.33	.2945	.000 995 0	83.06	97.99	.2934
40	.001 005 6	166.95	171.97	.5705	.001 003 4	166.35	176.38	.5686	.001 001 3	165.76	180.78	.5666
60	.001 014 9	250.23	255.30	.8285	.001 012 7	249.36	259.49	.8258	.001 010 5	248.51	263.67	.8232
80	.001 026 8	333.72	338.85	1.0720	.001 024 5	332.59	342.83	1.0688	.001 022 2	331.48	346.81	1.0656
100	.001 041 0	417.52	422.72	1.3030	.001 038 5	416.12	426.50	1.2992	.001 036 1	414.74	430.28	1.2955
120	.001 057 6	501.80	507.09	1.5233	.001 054 9	500.08	510.64	1.5189	.001 052 2	498.40	514.19	1.5145
140	.001 076 8	586.76	592.15	1.7343	.001 073 7	584.68	595.42	1.7292	.001 070 7	582.66	598.72	1.7242
160	.001 098 8	672.62	678.12	1.9375	.001 095 3	670.13	681.08	1.9317	.001 091 8	667.71	684.09	1.9260
180	.001 124 0	759.63	765.25	2.1341	.001 119 9	756.65	767.84	2.1275	.001 115 9	753.76	770.50	2.1210
200	.001 153 0	848.1	853.9	2.3255	.001 148 0	844.5	856.0	2.3178	.001 143 3	841.0	858.2	2.3104
220	.001 186 6	938.4	944.4	2.5128	.001 180 5	934.1	945.9	2.5039	.001 174 8	929.9	947.5	2.4953
240	.001 226 4	1031.4	1037.5	2.6979	.001 218 7	1026.0	1038.1	2.6872	.001 211 4	1020.8	1039.0	2.6771
260	.001 274 9	1127.9	1134.3	2.8830	.001 264 5	1121.1	1133.7	2.8699	.001 255 0	1114.6	1133.4	2.8576
280					.001 321 6	1220.9	1234.1	3.0548	.001 308 4	1212.5	1232.1	3.0393
300					.001 397 2	1328.4	1342.3	3.2469	.001 377 0	1316.6	1337.3	3.2260
320									.001 472 4	1431.1	1453.2	3.4247
340									.001 631 1	1567.5	1591.9	3.6546