UNIVERSITY OF JOHANNESBURG

PROGRAM	:	NATIONAL DIPLOMA *CHEMICAL ENGINEERING*
SUBJECT	:	**APPLIED THERMODYNAMICS III**
CODE	:	**ACT3111**
DATE	:	SUMMER EXAMINATION 21 NOVEMBER 2017
DURATION	:	(SESSION 1) 08:30 - 11:30
WEIGHT	:	40: 60
TOTAL MARKS	:	100
FULL MARKS	:	100
EXAMINER	:	DR K MOOTHI
MODERATOR	:	PROF GS SIMATE
NUMBER OF PAGES	:	09 PAGES
REQUIREMENTS	:	Use of scientific (non-programmable) calculator is permitted (only one per candidate).

HINTS AND INSTRUCTIONS TO CANDIDATE(S):

- Purpose of assessment is to determine not only if you can write down an answer, but also to assess whether you understand the concepts, principles and expressions involved. Set out solutions in a logical and concise manner with justification for the steps followed.
- **ATTEMPT ALL QUESTIONS**. Please answer each question to the best of your ability.
- Write your details (module name and code, ID number, student number etc.) on script(s).
- Number each question clearly; questions may be answered in any order.
- Make sure that you read each question carefully before attempting to answer the question.
- Show all steps (and units) in calculations; this is a 'closed book' assessment.
- Ensure your responses are legible, clear and include relevant units (where appropriate).

Question One **[Total: 20 Marks]**

1.1 What is the highest possible theoretical efficiency of a heat engine operating with a hot reservoir of furnace gases at 2000°C when the cooling water available is at 10°C? **[3]**

1.2 An air-standard cycle is executed in a closed system and is composed of the following four processes:

(i) 1-2, isentropic compression from 100 kPa and 27°C to 1 MPa
(ii) 2-3, P = constant heat addition in amount of 2800 kJ/kg
(iii) 3-4, V = constant heat rejection to 100 kPa
(iv) 4-1, P = constant heat rejection to initial state

1.2.1 Show the cycle on P-V and T-S diagrams **[6]**
1.2.2 Calculate the maximum temperature in the cycle **[4]**
1.2.3 Determine the thermal efficiency **[7]**

Assume constant specific heats at room temperature (C_p= 1.005 kJ/kg-K; C_v= 0.718 kJ/kg-K)

Question Two **[Total: 20 Marks]**

2.1 For simple ideal Rankine cycles, list three (3) ways one can increase the efficiency? **[5]**

2.2 A feed heater is supplied with condensate at 0.1 bar (Figure 2.1). The bled steam is taken from the turbine at 30 bar and 0.95 dry.

Calculate flow rate of bled steam needed to just produce saturated water at outlet. **[15]**

NB: This is part of the Regenerative Rankine cycle where part of the steam is bled off to heat incoming water.

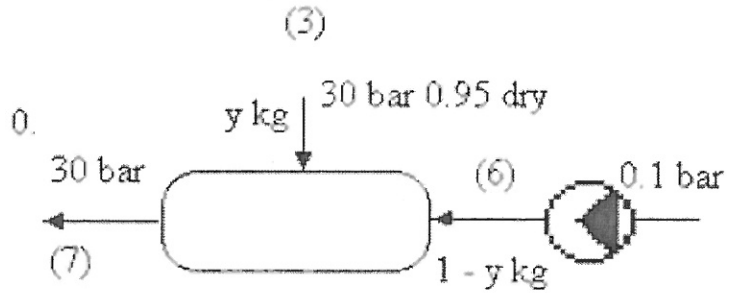

Figure 2.1: Schematic representation of the process whereby, stream 3 (bled off steam), stream 6 (the remainder of steam from the turbine) and stream 7 (the water going back to boiler) are shown

Question Three **[Total: 25 Marks]**

3.1 Somebody claims that at very high pressure ratios, the use of regeneration actually decreases the thermal efficiency of a gas-turbine engine.

Is there any truth in this claim? Explain. **[3]**

3.2 A simple ideal Brayton cycle without regeneration is modified to incorporate multistage compression with inter-cooling and multistage expansion with reheating, without changing the pressure or temperature limits of the cycle. As a result of these two modifications:

3.2.1 Does the network output increase, decrease, or remain the same? **[1]**

3.2.2 Does the thermal efficiency increase, decrease, or remain the same? **[1]**

3.2.3 Does the heat rejected increase, decrease, or remain the same? **[1]**

3.3 A gas turbine uses a pressure ratio of 7.5/1 (Figure 3.1). The inlet temperature and pressure are 10°C and 105 kPa, respectively. The temperature after heating in the combustion chamber is 1300°C. The specific heat capacity, C_p for air is 1.005 kJ/kg K and for the exhaust gas it is 1.15 kJ/kg K. The adiabatic index is 1.4 for air and 1.33 for the gas. The mass flow rate is 1 kg/s.

3.3.1 Calculate the air standard efficiency if no heat exchanger is used **[4]**

3.3.2 Compare it (solution 3.3.1) to the thermal efficiency when an exhaust heat exchanger with a thermal ratio of 0.88 is used. **[15]**

Assume isentropic compression and expansion.

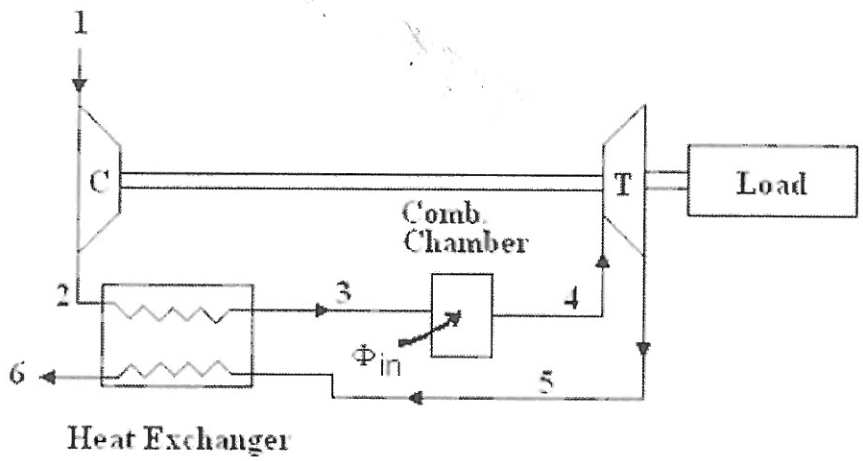

Figure 3.1: A gas turbine using a pressure ratio of 7.5/1

Question Four **[Total: 25 Marks]**

The first stage of a turbine is a two-row velocity compounded wheel (Figure 4.1). Steam at 40 bar and 400 °C is expanded in the nozzle to 15 bar and has a velocity at discharge of 700 m/s. The inlet velocity to the stage is negligible. The relevant exit angles are: nozzle 18°; first row blade 21°; fixed blades 26.5°; second row blades 35°. Take the blade velocity coefficient for all blades as 0.9. The mean diameter of the blading is 750 mm and the turbine shaft speed is 3000 rev/min.

4.1 Calculate the diagram efficiency. **[25]**

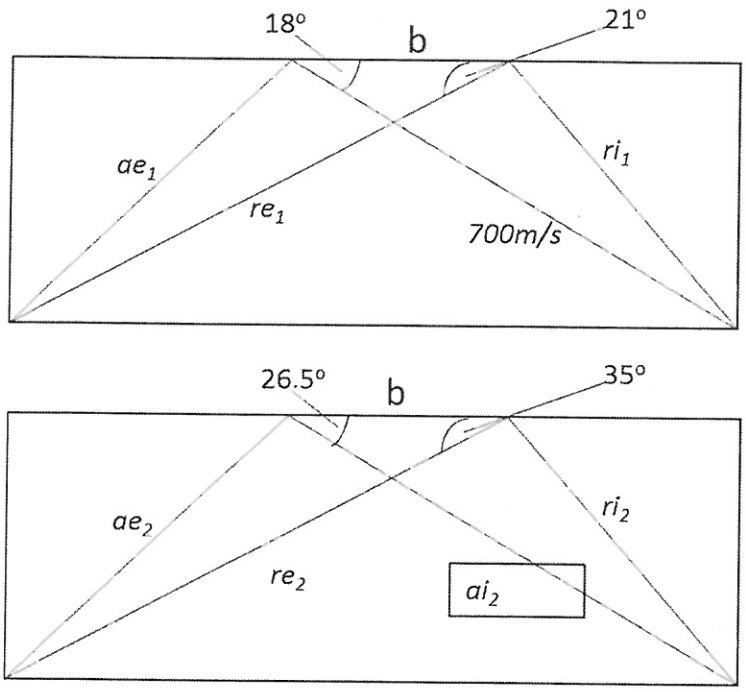

Figure 4.1: Velocity diagram for this wheel

Question Five **[Total: 10 Marks]**

The contents of the freezer in a home refrigerator are maintained at -20°C. The kitchen temperature is 20°C.

5.1 If heat leaks amount to 125 000 kJ per day, and if electricity costs R 1.55/kWh, estimate the yearly cost of running the refrigerator. **[10]**

Assume a coefficient of performance equal to 60% of the Carnot value.

END **[Total: 100 Marks]**

USEFUL EQUATIONS AND FORMULAE

$PV = nRT$; $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$; $v = \frac{V^t}{m}$; $v = \frac{V^t}{n}$; $\dot{m} = uA\rho$; $\dot{n} = \frac{uA}{vM}$; $\rho = v^{-1}$; $\dot{V} = \frac{V}{t}$

t(°C) = T(K) – 273.15; t(°F) = T(R) – 459.67; t(°F) = 1.8t(°C) + 32;

$P_g = \frac{F}{A} = \frac{mg}{A} = \frac{\rho Vg}{A} = \frac{Ah\rho g}{A}$; $P_{abs} = P_g (or \rho gh) + P_{atm}$

Interpolation: $M = \left(\frac{X_2 - X}{X_2 - X_1}\right) M_1 + \left(\frac{X - X_1}{X_2 - X_1}\right) M_2$ OR $M = \frac{M_1(X_2 - X) + M_2(X - X_1)}{X_2 - X_1}$

$\Delta E_{univ} = \Delta E_{syst} + \Delta E_{surr} = 0$; $\eta = \frac{W_{irreversible}}{W_{reversible}}$; $\frac{dm_{cv}}{dt} = \Delta m = \dot{m}_{out} - \dot{m}_{in}$; $\gamma = \frac{C_P}{C_V}$

EB for open systems: $\frac{d(mU)_{cv}}{dt} = -\dot{m}\Delta\left[U + \frac{1}{2}u^2 + gh\right] + \dot{Q} + \dot{W}$

EB for steady-state flow processes: $\Delta\dot{m}\left(H + \frac{1}{2}u^2 + gh\right) = \dot{Q} + \dot{W}_s$

Mechanically reversible closed system processes:

Constant V: $Q = n\Delta U = n\int_{T_1}^{T_2} C_v dT = nC_v\Delta T$

Constant P: $Q = n\Delta H = n\int_{T_1}^{T_2} C_p dT = nC_p\Delta T$; $W = -R(T_2 - T_1)$

Constant T: $Q = -W = RT_1 \ln\frac{V_2}{V_1} = -RT_1 \ln\frac{P_2}{P_1} = P_1V_1 \ln\frac{V_2}{V_1} = -P_1V_1 \ln\frac{P_2}{P_1}$

Adiabatic: $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{R/C_V}$; $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{R/C_P}$; $\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{C_P/C_V}$;

Carnot cycle: $\eta = \frac{W_{net}}{Q_1} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$

Constant-pressure (Joule) cycle: $\eta = 1 - \frac{1}{\left(\frac{P_2}{P_1}\right)^{(\gamma-1)/\gamma}}$

Work ratio: $W = \frac{Net\ work\ output}{Gross\ work\ output} = 1 - \frac{T_1}{T_3}\left(\frac{P_2}{P_1}\right)^{(\gamma-1)/\gamma}$

Compression ratio: $\frac{sweptvolume + clearancevolume}{clearancevolume} = \frac{v_1}{v_2}$

Otto cycle: $\eta = 1 - \frac{1}{\left(\frac{V_1}{V_2}\right)^{\gamma-1}}$

Diesel cycle: $\eta = 1 - \left(\frac{T_4 - T_1}{\gamma(T_3 - T_2)}\right)$ $OR\ \eta = 1 - \left(\frac{1}{V_1/V_2}\right)^{\gamma-1}\left\{\frac{(V_3/V_2)^{\gamma} - 1}{\gamma[(V_3/V_2) - 1]}\right\}$

Dual-combustion cycle: $\eta = 1 - \frac{C_v(T_5 - T_1)}{C_v(T_3 - T_2) + C_p(T_4 - T_3)}$

Mean effective pressure (MEP): $-W_{net} = P_m(V_1 - V_2)$

Stirling and Ericsson cycles: $\eta_{Stirling} = \eta_{Ericsson} = \eta_{Carnot} = 1 - \frac{T_2}{T_1}$

Steam rate: $\dot{m} = \frac{\dot{W}_{net}}{W_{net}} = \frac{\dot{W}_{net}}{W_{turbine} - W_{pump}}$

Rankine cycle (pump work input): $W = v_i(P_{i+1} - P_i)$

Rankine efficiency: $\eta = \frac{Net\ work\ output}{Heat\ supplied\ in\ boiler}$

Efficiency ratio = $\frac{cycle\ efficiency}{Rankine\ efficiency}$; $ssc = \frac{1}{Net\ work\ output}$; $CHL = ssc(\Delta H_{condenser})$

Isentropic efficiency: $\frac{ratio\ of\ work\ input\ required}{actual\ work\ required}$

Gross work output: $work\ output\ of\ HP\ turbine + work\ output\ of\ LP\ turbine$

Work ratio: $W = \frac{Net\ work\ output}{Gross\ work\ output} = 1 - \frac{T_1}{T_3}\left(\frac{P_2}{P_1}\right)^{(\gamma-1)/\gamma}$

Mass flow rate: $\dot{m} = \frac{\dot{W}_{net}}{W_{net}}$; Cycle efficiency: $\eta = \frac{W_{turbine}}{Q_1}$

For steam turbines: $\Delta C_w = C_{wi} + C_{we} = C_{re}\cos\beta_e + C_{ri}\cos\beta_i$

Velocity coefficient: $k = \frac{C_{re}}{C_{ri}}$; Driving force: $F_D = \dot{m}\Delta C_w$

Diagram efficiency: $\eta_d = \frac{2C_b\Delta C_w}{C_{ai}^2}$; $Energy\ supplied\ per\ unit\ mass\ of\ steam = \frac{1}{2}\dot{m}C_{ai}^2$

Power output: $\dot{W}_{output} = \dot{m}C_b\Delta C_w$

End (Axial) thrust: $\dot{m}\Delta C_f$; Where: $\Delta C_f = C_{fi} - C_{fe} = C_{ri}\sin\beta_i - C_{re}\sin\beta_e$

For Nozzles (EB): $H_1 + \frac{C_1^2}{2} = H_2 + \frac{C_2^2}{2}$

Critical pressure: $\frac{P_c}{P_1} = \left(\frac{2}{\gamma+1}\right)^{\gamma/(\gamma-1)}$ Critical temperature: $\frac{T_c}{T_1} = \left(\frac{P_c}{P_1}\right)^{(\gamma-1)/\gamma}$

Critical specific volume: $v_c = \frac{(R/M)T_c}{P_c}$ Critical velocity: $C_c = \sqrt{\frac{\gamma RT_c}{M}} = \sqrt{2(H_1 - H_c)} = \sqrt{2C_p(T_1 - T_c)}$

Exit specific volume: $v_2 = \frac{(R/M)T_{2s}}{P_2}$ Exit velocity: $C_2 = \sqrt{2(H_1 - H_2)}$

Mass flowrate per unit area: $\frac{\dot{m}}{A_2} = \frac{C_2}{v_2}$ Nozzle efficiency: $\frac{H_1 - H_2}{H_1 - H_{2s}} = \frac{C_p(T_1 - T_2)}{C_p(T_1 - T_{2s})} = \frac{T_1 - T_2}{T_1 - T_{2s}}$

Velocity coefficient: $\frac{C_2}{C_{2s}}$ Coefficient of discharge: $\frac{\dot{m}}{\dot{m}_s}$

For dry saturated steam, $\gamma = 1.135$ For superheated steam, $\gamma = 1.3$

Refrigeration (Engine efficiency): $\eta_{carnot} = \frac{W_{netcarnotengine}}{Q_1} = 1 - \frac{T_2}{T_1}$

Coefficient of Performance: $COP_{carnot} = \frac{Q_1\ refrigerator}{W_{refrigeratorinput}} = \frac{T_2}{T_1 - T_2}$

Table A.1: Conversion Factors

Quantity	Conversion
Length	1 m = 100 cm = 3.28084(ft) = 39.3701(in)
Mass	1 kg = 10^3 g = 2.20462(lb_m)
Force	1 N = 1 kg m s^{-2} = 10^5(dyne) = 0.224809(lb_f)
Pressure	1 bar = 10^5 kg m^{-1} s^{-2} = 10^5 N m^{-2} = 10^5 Pa = 10^2 kPa = 10^6(dyne) cm^{-2} = 0.986923(atm) = 14.5038(psia) = 750.061(torr)
Volume	1 m^3 = 10^6 cm^3 = 10^3 liters = 35.3147$(ft)^3$ = 264.172(gal)
Density	1 g cm^{-3} = 10^3 kg m^{-3} = 62.4278$(lb_m)(ft)^{-3}$
Energy	1 J = 1 kg m^2 s^{-2} = 1 N m = 1 m^3 Pa = 10^{-5} m^3 bar = 10 cm^3 bar = 9.86923 cm^3(atm) = 10^7(dyne) cm = 10^7(erg) = 0.239006(cal) = 5.12197 × $10^{-3}$$(ft)^3$(psia) = 0.737562(ft)($lb_f$) = 9.47831 × 10^{-4}(Btu) = 2.77778 × 10^{-7} kWhr
Power	1 kW = 10^3 W = 10^3 kg m^2 s^{-3} = 10^3 J s^{-1} = 239.006(cal) s^{-1} = 737.562(ft)(lb_f) s^{-1} = 0.947831(Btu) s^{-1} = 1.34102(hp)

Table A.2: Values of the Universal Gas Constant

R = 8.314 J mol^{-1} K^{-1} = 8.314 m^3 Pa mol^{-1} K^{-1}
= 83.14 cm^3 bar mol^{-1} K^{-1} = 8.314 cm^3 kPa mol^{-1} K^{-1}
= 82.06 cm^3(atm) mol^{-1} K^{-1} = 62.356 cm^3(torr) mol^{-1} K^{-1}
= 1.987(cal) mol^{-1} K^{-1} = 1.986(Btu)(lb mole)$^{-1}$(R)$^{-1}$
= 0.7302$(ft)^3$(atm)(lb mol)$^{-1}$(R)$^{-1}$ = 10.75$(ft)^3$(psia)(lb mol)$^{-1}$(R)$^{-1}$
= 1.545(ft)(lb_f)(lb mol)$^{-1}$(R)$^{-1}$

Table F.1 Saturated Steam, SI Units

V = SPECIFIC VOLUME $cm^3\ g^{-1}$
U = SPECIFIC INTERNAL ENERGY kJ kg
H = SPECIFIC ENTHALPY kJ kg
S = SPECIFIC ENTROPY $kJ\ kg^{-1}\ K^{-1}$

	T	P	SPECIFIC VOLUME V			INTERNAL ENERGY U			ENTHALPY H			ENTROPY S		
	K	kPa	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.
0	273.15	0.611	1.000	206300.	206300.	−0.04	2375.7	2375.6	−0.04	2501.7	2501.6	0.0000	9.1578	9.1578
0.01	**273.16**	**0.611**	**1.000**	**206200.**	**206200.**	**0.00**	**2375.6**	**2375.6**	**0.00**	**2501.6**	**2501.6**	**0.0000**	**9.1575**	**9.1575**
1	274.15	0.657	1.000	192600.	192600.	4.17	2372.7	2376.9	4.17	2499.2	2503.4	0.0153	9.1158	9.1311
2	275.15	0.705	1.000	179900.	179900.	8.39	2369.9	2378.3	8.39	2496.8	2505.2	0.0306	9.0741	9.1047
3	276.15	0.757	1.000	168200.	168200.	12.60	2367.1	2379.7	12.60	2494.5	2507.1	0.0459	9.0326	9.0785
4	277.15	0.813	1.000	157300.	157300.	16.80	2364.3	2381.1	16.80	2492.1	2508.9	0.0611	8.9915	9.0526
5	278.15	0.872	1.000	147200.	147200.	21.01	2361.4	2382.4	21.01	2489.7	2510.7	0.0762	8.9507	9.0269
6	279.15	0.935	1.000	137800.	137800.	25.21	2358.6	2383.8	25.21	2487.4	2512.6	0.0913	8.9102	9.0014
7	280.15	1.001	1.000	129100.	129100.	29.41	2355.8	2385.2	29.41	2485.0	2514.4	0.1063	8.8699	8.9762
8	281.15	1.072	1.000	121000.	121000.	33.60	2353.0	2386.6	33.60	2482.6	2516.2	0.1213	8.8300	8.9513
9	282.15	1.147	1.000	113400.	113400.	37.80	2350.1	2387.9	37.80	2480.3	2518.1	0.1362	8.7903	8.9265
10	283.15	1.227	1.000	106400.	106400.	41.99	2347.3	2389.3	41.99	2477.9	2519.9	0.1510	8.7510	8.9020
11	284.15	1.312	1.000	99910.	99910.	46.18	2344.5	2390.7	46.19	2475.5	2521.7	0.1658	8.7119	8.8776
12	285.15	1.401	1.000	93830.	93840.	50.38	2341.7	2392.1	50.38	2473.2	2523.6	0.1805	8.6731	8.8536
13	286.15	1.497	1.001	88180.	88180.	54.56	2338.9	2393.4	54.57	2470.8	2525.4	0.1952	8.6345	8.8297
14	287.15	1.597	1.001	82900.	82900.	58.75	2336.1	2394.8	58.75	2468.5	2527.2	0.2098	8.5963	8.8060
15	288.15	1.704	1.001	77980.	77980.	62.94	2333.2	2396.2	62.94	2466.1	2529.1	0.2243	8.5582	8.7826
16	289.15	1.817	1.001	73380.	73380.	67.12	2330.4	2397.6	67.13	2463.8	2530.9	0.2388	8.5205	8.7593
17	290.15	1.936	1.001	69090.	69090.	71.31	2327.6	2398.9	71.31	2461.4	2532.7	0.2533	8.4830	8.7363
18	291.15	2.062	1.001	65090.	65090.	75.49	2324.8	2400.3	75.50	2459.0	2534.5	0.2677	8.4458	8.7135
19	292.15	2.196	1.002	61340.	61340.	79.68	2322.0	2401.7	79.68	2456.7	2536.4	0.2820	8.4088	8.6908
20	293.15	2.337	1.002	57840.	57840.	83.86	2319.2	2403.0	83.86	2454.3	2538.2	0.2963	8.3721	8.6684
21	294.15	2.485	1.002	54560.	54560.	88.04	2316.4	2404.4	88.04	2452.0	2540.0	0.3105	8.3356	8.6462
22	295.15	2.642	1.002	51490.	51490.	92.22	2313.6	2405.8	92.23	2449.6	2541.8	0.3247	8.2994	8.6241
23	296.15	2.808	1.002	48620.	48620.	96.40	2310.7	2407.1	96.41	2447.2	2543.6	0.3389	8.2634	8.6023
24	297.15	2.982	1.003	45920.	45930.	100.6	2307.9	2408.5	100.6	2444.9	2545.5	0.3530	8.2277	8.5806
25	298.15	3.166	1.003	43400.	43400.	104.8	2305.1	2409.9	104.8	2442.5	2547.3	0.3670	8.1922	8.5592
26	299.15	3.360	1.003	41030.	41030.	108.9	2302.3	2411.2	108.9	2440.2	2549.1	0.3810	8.1569	8.5379
27	300.15	3.564	1.003	38810.	38810.	113.1	2299.5	2412.6	113.1	2437.8	2550.9	0.3949	8.1218	8.5168
28	301.15	3.778	1.004	36730.	36730.	117.3	2296.7	2414.0	117.3	2435.4	2552.7	0.4088	8.0870	8.4959
29	302.15	4.004	1.004	34770.	34770.	121.5	2293.8	2415.3	121.5	2433.1	2554.5	0.4227	8.0524	8.4751

30	303.15	4.241	1.004	32930.	32930.	125.7	2291.0	2416.7	125.7	2430.7	2556.4	0.4365	8.0180	8.4546
31	304.15	4.491	1.005	31200.	31200.	129.8	2288.2	2418.0	129.8	2428.3	2558.2	0.4503	7.9839	8.4342
32	305.15	4.753	1.005	29570.	29570.	134.0	2285.4	2419.4	134.0	2425.9	2560.0	0.4640	7.9500	8.4140
33	306.15	5.029	1.005	28040.	28040.	138.2	2282.6	2420.8	138.2	2423.6	2561.8	0.4777	7.9163	8.3939
34	307.15	5.318	1.006	26600.	26600.	142.4	2279.7	2422.1	142.4	2421.2	2563.6	0.4913	7.8828	8.3740
35	308.15	5.622	1.006	25240.	25240.	146.6	2276.9	2423.5	146.6	2418.8	2565.4	0.5049	7.8495	8.3543
36	309.15	5.940	1.006	23970.	23970.	150.7	2274.1	2424.8	150.7	2416.4	2567.2	0.5184	7.8164	8.3348
37	310.15	6.274	1.007	22760.	22760.	154.9	2271.3	2426.2	154.9	2414.1	2569.0	0.5319	7.7835	8.3154
38	311.15	6.624	1.007	21630.	21630.	159.1	2268.4	2427.5	159.1	2411.7	2570.8	0.5453	7.7509	8.2962
39	312.15	6.991	1.007	20560.	20560.	163.3	2265.6	2428.9	163.3	2409.3	2572.6	0.5588	7.7184	8.2772
40	313.15	7.375	1.008	19550.	19550.	167.4	2262.8	2430.2	167.5	2406.9	2574.4	0.5721	7.6861	8.2583
41	314.15	7.777	1.008	18590.	18590.	171.6	2259.9	2431.6	171.6	2404.5	2576.2	0.5854	7.6541	8.2395
42	315.15	8.198	1.009	17690.	17690.	175.8	2257.1	2432.9	175.8	2402.1	2577.9	0.5987	7.6222	8.2209
43	316.15	8.639	1.009	16840.	16840.	180.0	2254.3	2434.2	180.0	2399.7	2579.7	0.6120	7.5905	8.2025
44	317.15	9.100	1.009	16040.	16040.	184.2	2251.4	2435.6	184.2	2397.3	2581.5	0.6252	7.5590	8.1842
45	318.15	9.582	1.010	15280.	15280.	188.3	2248.6	2436.9	188.4	2394.9	2583.3	0.6383	7.5277	8.1661
46	319.15	10.09	1.010	14560.	14560.	192.5	2245.7	2438.3	192.5	2392.5	2585.1	0.6514	7.4966	8.1481
47	320.15	10.61	1.011	13880.	13880.	196.7	2242.9	2439.6	196.7	2390.1	2586.9	0.6645	7.4657	8.1302
48	321.15	11.16	1.011	13230.	13230.	200.9	2240.0	2440.9	200.9	2387.7	2588.6	0.6776	7.4350	8.1125
49	322.15	11.74	1.012	12620.	12620.	205.1	2237.2	2442.3	205.1	2385.3	2590.4	0.6906	7.4044	8.0950
50	323.15	12.34	1.012	12040.	12050.	209.2	2234.3	2443.6	209.3	2382.9	2592.2	0.7035	7.3741	8.0776
51	324.15	12.96	1.013	11500.	11500.	213.4	2231.5	2444.9	213.4	2380.5	2593.9	0.7164	7.3439	8.0603
52	325.15	13.61	1.013	10980.	10980.	217.6	2228.6	2446.2	217.6	2378.1	2595.7	0.7293	7.3138	8.0432
53	326.15	14.29	1.014	10490.	10490.	221.8	2225.8	2447.6	221.8	2375.7	2597.5	0.7422	7.2840	8.0262
54	327.15	15.00	1.014	10020.	10020.	226.0	2222.9	2448.9	226.0	2373.2	2599.2	0.7550	7.2543	8.0093
55	328.15	15.74	1.015	9577.9	9578.9	230.2	2220.0	2450.2	230.2	2370.8	2601.0	0.7677	7.2248	7.9925
56	329.15	16.51	1.015	9157.7	9158.7	234.3	2217.2	2451.5	234.4	2368.4	2602.7	0.7804	7.1955	7.9759
57	330.15	17.31	1.016	8758.7	8759.8	238.5	2214.3	2452.8	238.5	2365.9	2604.5	0.7931	7.1663	7.9595
58	331.15	18.15	1.016	8379.8	8380.8	242.7	2211.4	2454.1	242.7	2363.5	2606.2	0.8058	7.1373	7.9431
59	332.15	19.02	1.017	8019.7	8020.8	246.9	2208.6	2455.4	246.9	2361.1	2608.0	0.8184	7.1085	7.9269
60	333.15	19.92	1.017	7677.5	7678.5	251.1	2205.7	2456.8	251.1	2358.6	2609.7	0.8310	7.0798	7.9108
61	334.15	20.86	1.018	7352.1	7353.2	255.3	2202.8	2458.1	255.3	2356.2	2611.4	0.8435	7.0513	7.8948
62	335.15	21.84	1.018	7042.7	7043.7	259.4	2199.9	2459.4	259.5	2353.7	2613.2	0.8560	7.0230	7.8790
63	336.15	22.86	1.019	6748.2	6749.3	263.6	2197.0	2460.7	263.6	2351.3	2614.9	0.8685	6.9948	7.8633
64	337.15	23.91	1.019	6468.0	6469.0	267.8	2194.1	2462.0	267.8	2348.8	2616.6	0.8809	6.9667	7.8477
65	338.15	25.01	1.020	6201.3	6202.3	272.0	2191.2	2463.2	272.0	2346.3	2618.4	0.8933	6.9388	7.8322
66	339.15	26.15	1.020	5947.2	5948.2	276.2	2188.3	2464.5	276.2	2343.9	2620.1	0.9057	6.9111	7.8168
67	340.15	27.33	1.021	5705.2	5706.2	280.4	2185.4	2465.8	280.4	2341.4	2621.8	0.9180	6.8835	7.8015
68	341.15	28.56	1.022	5474.6	5475.6	284.6	2182.5	2467.1	284.6	2338.9	2623.5	0.9303	6.8561	7.7864
69	342.15	29.84	1.022	5254.8	5255.8	288.8	2179.6	2468.4	288.8	2336.4	2625.2	0.9426	6.8288	7.7714
70	343.15	31.16	1.023	5045.2	5046.3	292.9	2176.7	2469.7	293.0	2334.0	2626.9	0.9548	6.8017	7.7565
71	344.15	32.53	1.023	4845.4	4846.4	297.1	2173.8	2470.9	297.2	2331.5	2628.6	0.9670	6.7747	7.7417
72	345.15	33.96	1.024	4654.7	4655.7	301.3	2170.9	2472.2	301.4	2329.0	2630.3	0.9792	6.7478	7.7270
73	346.15	35.43	1.025	4472.7	4473.7	305.5	2168.0	2473.5	305.5	2326.5	2632.0	0.9913	6.7211	7.7124
74	347.15	36.96	1.025	4299.0	4300.0	309.7	2165.1	2474.8	309.7	2324.0	2633.7	1.0034	6.6945	7.6979

Table F.1 Saturated Steam, SI Units (Continued)

			SPECIFIC VOLUME V			INTERNAL ENERGY U			ENTHALPY H			ENTROPY S		
t °C	T K	P kPa	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.	sat liq	evap	sat vap	sat. liq.	evap.	sat. vap
75	348.15	38.55	1.026	4133.1	4134.1	313.9	2162.1	2 476.0	313.9	2 021,5	2 6354	1.0154	6.6681	7.6835
76	349.15	40.19	1.027	3974.6	3975.7	318.1	2159.2	2 477.3	316.1	2 318,0	2 637.1	1.0275	6.6418	7.6693
77	350.15	41.89	1.027	3823.3	3824.3	322.3	2156.3	2 478.5	322.3	2 316,4	2 638,7	1.0395	6.6156	7.6551
78	351.15	43.65	1.028	3678.6	3679.6	326.5	2153.3	2 479.8	326.5	2 313,9	2 640,4	1.0514	6.5895	7.6410
79	352.15	45.47	1.029	3540.3	3541.3	330.7	2150.4	2 481.1	330.7	2 311,4	2 642,1	1.0634	6.5637	7.6271
80	353.15	47.36	1.029	3408.1	3409.1	334.9	2147.4	2 482.3	334.9	2 308,8	2 643,8	1.0753	6.5380	7.6132
81	354.15	49.31	1.030	3281.6	3282.6	339.1	2144.5	2 483.5	339.1	2 306,3	2 645,4	1.0871	6.5123	7.5995
82	355.15	51.33	1.031	3160.6	3161.6	343.3	2141.5	2 484.8	343.3	2 303,8	2 647,1	1.0990	6.4868	7.5858
83	356.15	53.42	1.031	3044.8	3045.8	347.5	2138.6	2 486.0	347.5	2 301,2	2 648,7	1.1108	6.4615	7.5722
84	357.15	55.57	1.032	2933.9	2935.0	351.7	2135.6	2 487.3	351.7	2 298,6	2 650,4	1.1225	6.4362	7.5587
85	358.15	57.80	1.033	2827.8	2828.8	355.9	2132.6	2 488.5	355.9	2 296,1	2 652,0	1.1343	6.4111	7.5454
86	359.15	60.11	1.033	2726.1	2727.2	360.1	2129.7	2 489.7	360.1	2 293,5	2 653,6	1.1460	6.3861	7.5321
87	360.15	62.49	1.034	2628.8	2629.8	364.3	2126.7	2 490.9	364.3	2 290,9	2 655,3	1.1577	6.3612	7.5189
88	361.15	64.95	1.035	2535.4	2536.5	368.5	2123.7	2 492.2	368.5	2 288,4	2 656,9	1.1693	6.3365	7.5058
89	362.15	67.49	1.035	2446.0	2447.0	372.7	2120.7	2 493.4	372.7	2 285,8	2 658,5	1.1809	6.3119	7.4928
90	363.15	70.11	1.036	2360.3	2361.3	376.9	2117.7	2 494.6	376.9	2 283,2	2 660,1	1.1925	6.2873	7.4799
91	364.15	72.81	1.037	2278.0	2279.1	381.1	2114.7	2 495.8	381.1	2 280,6	2 661,7	1.2041	6.2629	7.4670
92	365.15	75.61	1.038	2199.2	2200.2	385.3	2111.7	2 497.0	385.4	2 278,0	2 663,4	1.2156	6.2387	7.4543
93	366.15	78.49	1.038	2123.5	2124.5	389.5	2108.7	2 498.2	389.6	2 275,4	2 665,0	1.2271	6.2145	7.4416
94	367.15	81.46	1.039	2050.9	2051.9	393.7	2105.7	2 499.4	393.8	2 272,8	2 666,6	1.2386	6.1905	7.4291
95	368.15	84.53	1.040	1981.2	1982.2	397.9	2102.7	2 500.6	398.0	2 270,2	2 668,1	1.2501	6.1665	7.4166
96	369.15	87.69	1.041	1914.3	1915.3	402.1	2099.7	2 501.8	402.2	2 267,5	2 669,7	1.2615	6.1427	7.4042
97	370.15	90.94	1.041	1850.0	1851.0	406.3	2096.6	2 503.0	406.4	2 264,9	2 671,3	1.2729	6.1190	7.3919
98	371.15	94.30	1.042	1788.3	1789.3	410.5	2093.6	2 504.1	410.6	2 262,2	2 672,9	1.2842	6.0954	7.3796
99	372.15	97.76	1.043	1729.0	1730.0	414.7	2090.6	2 505.3	414.8	2 259,6	2 674,4	1.2956	6.0719	7.3675
100	373.15	101.33	1.044	1672.0	1673.0	419.0	2087.5	2 506.5	419.1	2 256,9	2 676,0	1.3069	6.0485	7.3554
102	375.15	108.78	1.046	1564.5	1565.5	427.4	2081.4	2 508.8	427.5	2 251,6	2 679,1	1.3294	6.0021	7.3315
104	377.15	116.68	1.047	1465.1	1466.2	435.8	2075.3	2 511.1	435.9	2 246,3	2 682,2	1.3518	5.9560	7.3078
106	379.15	125.04	1.049	1373.1	1374.2	444.3	2069.2	2 513.4	444.4	2 240,9	2 685,3	1.3742	5.9104	7.2845
108	381.15	133.90	1.050	1287.9	1288.9	452.7	2063.0	2 515.7	452.9	2 235,4	2 688,3	1.3964	5.8651	7.2615
110	383.15	143.27	1.052	1208.9	1209.9	461.2	2056.8	2 518.0	461.3	2 230,0	2 691,3	1.4185	5.8203	7.2388
112	385.15	153.16	1.054	1135.6	1136.6	469.6	2050.6	2 520.2	469.8	2 224,5	2 694,3	1.4405	5.7758	7.2164
114	387.15	163.62	1.055	1067.5	1068.5	478.1	2044.3	2 522.4	478.3	2 219,0	2 697,2	1.4624	5.7318	7.1942
116	389.15	174.65	1.057	1004.2	1005.2	486.6	2038.1	2 524.6	486.7	2 213,4	2 700,2	1.4842	5.6881	7.1723
118	391.15	186.28	1.059	945.3	946.3	495.0	2031.8	2 526.8	495.2	2 207,9	2 703,1	1.5060	5.6447	7.1507
120	393.15	198.54	1.061	890.5	891.5	503.5	2025.4	2 529.0	503.7	2 202,2	2 706,0	1.5276	5.6017	7.1293
122	395.15	211.45	1.062	839.4	840.5	512.0	2019.1	2 531.1	512.2	2 196,6	2 708,8	1.5491	5.5590	7.1082
124	397.15	225.04	1.064	791.8	792.8	520.5	2012.7	2 533.2	520.7	2 190,9	2 711,6	1.5706	5.5167	7.0873
126	399.15	239.33	1.066	747.3	748.4	529.0	2006.3	2 535.3	529.2	2 185,2	2 714,4	1.5919	5.4747	7.0666
128	401.15	254.35	1.068	705.8	706.9	537.5	1999.9	2 537.4	537.8	1 179,4	1 717,2	1.6132	5.4330	7.0462

130	403.15	270.13	1.070	667.1	668.1	546.0	1993.4	2 539.4	546.3	2 173.6	2 719.9	1.6344	5.3917	7.0261
132	405.15	286.70	1.072	630.8	631.9	554.5	1986.9	2 541.4	554.8	2 167.8	2 722.6	1.6555	5.3507	7.0061
134	407.15	304.07	1.074	596.9	598.0	563.1	1980.4	2 543.4	563.4	2 161.9	2 725.3	1.6765	5.3099	6.9864
136	409.15	322.29	1.076	565.1	566.2	571.6	1973.8	2 545.4	572.0	2 155.9	2 727.9	1.6974	5.2695	6.9669
138	411.15	341.38	1.078	535.3	536.4	580.2	1967.2	2 547.4	580.5	2 150.0	2 730.5	1.7182	5.2293	6.9475
140	413.15	361.38	1.080	507.4	508.5	588.7	1960.6	2 549.3	589.1	2 144.0	2 733.1	1.7390	5.1894	6.9284
142	415.15	382.31	1.082	481.2	482.3	597.3	1953.9	2 551.2	597.7	2 137.9	2 735.6	1.7597	5.1499	6.9095
144	417.15	404.20	1.084	456.6	457.7	605.9	1947.2	2 553.1	606.3	2 131.8	2 738.1	1.7803	5.1106	6.8908
146	419.15	427.09	1.086	433.5	434.6	614.4	1940.5	2 554.9	614.9	2 125.7	2 740.6	1.8008	5.0715	6.8723
148	421.15	451.01	1.089	411.8	412.9	623.0	1933.7	2 556.8	623.5	2 119.5	2 743.0	1.8213	5.0327	6.8539
150	423.15	476.00	1.091	391.4	392.4	631.6	1926.8	2 558.6	632.1	2 113.2	2 745.4	1.8416	4.9941	6.8358
152	425.15	502.08	1.093	372.1	373.2	640.2	1920.1	2 560.3	640.8	2 106.9	2 747.7	1.8619	4.9558	6.8178
154	427.15	529.29	1.095	354.0	355.1	648.9	1913.2	2 562.1	649.4	2 100.6	2 750.0	1.8822	4.9178	6.8000
156	429.15	557.67	1.098	336.9	338.0	657.5	1906.3	2 563.8	658.1	2 094.2	2 752.3	1.9023	4.8800	6.7823
158	431.15	587.25	1.100	320.8	321.9	666.1	1899.3	2 565.5	666.8	2 087.7	2 754.5	1.9224	4.8424	6.7648
160	433.15	618.06	1.102	305.7	306.8	674.8	1892.3	2 567.1	675.5	2 081.3	2 756.7	1.9425	4.8050	6.7475
162	435.15	650.16	1.105	291.3	292.4	683.5	1885.3	2 568.8	684.2	2 074.7	2 758.9	1.9624	4.7679	6.7303
164	437.15	683.56	1.107	277.8	278.9	692.1	1878.2	2 570.4	692.9	2 068.1	2 761.0	1.9823	4.7309	6.7133
166	439.15	718.31	1.109	265.0	266.1	700.8	1871.1	2 571.9	701.6	2 061.4	2 763.1	2.0022	4.6942	6.6964
168	441.15	754.45	1.112	252.9	254.0	709.5	1863.9	2 573.4	710.4	2 054.7	2 765.1	2.0219	4.6577	6.6796
170	443.15	792.02	1.114	241.4	242.6	718.2	1856.7	2 574.9	719.1	2 047.9	2 767.1	2.0416	4.6214	6.6630
172	445.15	831.06	1.117	230.6	231.7	727.0	1849.5	2 576.4	727.9	2 041.1	2 769.0	2.0613	4.5853	6.6465
174	447.15	871.60	1.120	220.3	221.5	735.7	1842.2	2 577.8	736.7	2 034.2	2 770.9	2.0809	4.5493	6.6302
176	449.15	913.68	1.122	210.6	211.7	744.4	1834.8	2 579.3	745.5	2 027.3	2 772.7	2.1004	4.5136	6.6140
178	451.15	957.36	1.125	201.4	202.5	753.2	1827.4	2 580.6	754.3	2 020.2	2 774.5	2.1199	4.4780	6.5979
180	453.15	1002.7	1.128	192.7	193.8	762.0	1820.0	2 581.9	763.1	2 013.1	2 776.3	2.1393	4.4426	6.5819
182	455.15	1049.6	1.130	184.4	185.5	770.8	1812.5	2 583.2	772.0	2 006.0	2 778.0	2.1587	4.4074	6.5660
184	457.15	1098.3	1.133	176.5	177.6	779.6	1804.9	2 584.5	780.8	1 998.8	2 779.6	2.1780	4.3723	6.5503
186	459.15	1148.8	1.136	169.0	170.2	788.4	1797.3	2 585.7	789.7	1 991.5	2 781.2	2.1972	4.3374	6.5346
188	461.15	1201.0	1.139	161.9	163.1	797.2	1789.7	2 586.9	798.6	1 984.2	2 782.8	2.2164	4.3026	6.5191
190	463.15	1255.1	1.142	155.2	156.3	806.1	1782.0	2 588.1	807.5	1 976.7	2 784.3	2.2356	4.2680	6.5036
192	465.15	1311.1	1.144	148.8	149.9	814.9	1774.2	2 589.2	816.5	1 969.3	2 785.7	2.2547	4.2336	6.4883
194	467.15	1369.0	1.147	142.6	143.8	823.8	1766.4	2 590.2	825.4	1 961.7	2 787.1	2.2738	4.1993	6.4730
196	469.15	1428.9	1.150	136.8	138.0	832.7	1758.6	2 591.3	834.4	1 954.1	2 788.4	2.2928	4.1651	6.4578
198	471.15	1490.9	1.153	131.3	132.4	841.6	1750.6	2 592.3	843.4	1 946.4	2 789.7	2.3117	4.1310	6.4428
200	473.15	1554.9	1.156	126.0	127.2	850.6	1742.6	2 593.2	852.4	1 938.6	2 790.9	2.3307	4.0971	6.4278
202	475.15	1621.0	1.160	121.0	122.1	859.5	1734.6	2 594.1	861.4	1 930.7	2 792.1	2.3495	4.0633	6.4128
204	477.15	1689.3	1.163	116.2	117.3	868.5	1726.5	2 595.0	870.5	1 922.8	2 793.2	2.3684	4.0296	6.3980
206	479.15	1759.8	1.166	111.6	112.8	877.5	1718.3	2 595.8	879.5	1 914.7	2 794.3	2.3872	3.9961	6.3832
208	481.15	1832.6	1.169	107.2	108.4	886.5	1710.1	2 596.6	888.6	1 906.6	2 795.3	2.4059	3.9626	6.3686
210	483.15	1907.7	1.173	103.1	104.2	895.5	1701.8	2 597.3	897.7	1 898.5	2 796.2	2.4247	3.9293	6.3539
212	485.15	1985.2	1.176	99.09	100.26	904.5	1693.5	2 598.0	906.9	1 890.2	2 797.1	2.4434	3.8960	6.3394
214	487.15	2065.1	1.179	95.28	96.46	913.6	1685.1	2 598.7	916.0	1 881.8	2 797.9	2.4620	3.8629	6.3249
216	489.15	2147.5	1.183	91.65	92.83	922.7	1676.6	2 599.3	925.2	1 873.4	2 798.6	2.4806	3.8298	6.3104
218	491.15	2232.4	1.186	88.17	89.36	931.8	1668.0	2 599.8	934.4	1 864.9	2 799.3	2.4992	3.7968	6.2960

Table F.I Saturated Steam, SI Units (Continued)

			SPECIFIC VOLUME V			INTERNAL ENERGY U			ENTHALPY H			ENTROPY S		
t °C	T K	P kPa	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap	sat. liq.	evap.	sat. vap
220	493.15	2319.8	1.190	84.85	86.04	940.9	1659.4	2600.3	943.7	1856.2	2799.9	2.5178	3.7639	6.2817
222	495.15	2409.9	1.194	81.67	82.86	950.1	1650.7	2600.8	952.9	1847.5	2800.5	2.5363	3.7311	6.2674
224	497.15	2502.7	1.197	78.62	79.82	959.2	1642.0	2601.2	962.2	1838.7	2800.9	2.5548	3.6984	6.2532
226	499.15	2598.2	1.201	75.71	76.91	968.4	1633.1	2601.5	971.5	1829.8	2801.4	2.5733	3.6657	6.2390
228	501.15	2696.5	1.205	72.92	74.12	977.6	1624.2	2601.8	980.9	1820.8	2801.7	2.5917	3.6331	6.2249
230	503.15	2797.6	1.209	70.24	71.45	986.9	1615.2	2602.1	990.3	1811.7	2802.0	2.6102	3.6006	6.2107
232	505.15	2901.6	1.213	67.68	68.89	996.2	1606.1	2602.3	999.7	1802.5	2802.2	2.6286	3.5681	6.1967
234	507.15	3008.6	1.217	65.22	66.43	1005.4	1597.0	2602.4	1009.1	1793.2	2802.3	2.6470	3.5356	6.1826
236	509.15	3118.6	1.221	62.86	64.08	1014.8	1587.7	2602.5	1018.6	1783.8	2802.3	2.6653	3.5033	6.1686
238	511.15	3231.7	1.225	60.60	61.82	1024.1	1578.4	2602.5	1028.1	1774.2	2802.3	2.6837	3.4709	6.1546
240	513.15	3347.8	1.229	58.43	59.65	1033.5	1569.0	2602.5	1037.6	1764.6	2802.2	2.7020	3.4386	6.1406
242	515.15	3467.2	1.233	56.34	57.57	1042.9	1559.5	2602.4	1047.2	1754.9	2802.0	2.7203	3.4063	6.1266
244	517.15	3589.8	1.238	54.34	55.58	1052.3	1549.9	2602.2	1056.8	1745.0	2801.8	2.7386	3.3740	6.1127
246	519.15	3715.7	1.242	52.41	53.66	1061.8	1540.2	2602.0	1066.4	1735.0	2801.4	2.7569	3.3418	6.0987
248	521.15	3844.9	1.247	50.56	51.81	1071.3	1530.5	2601.8	1076.1	1724.9	2801.0	2.7752	3.3096	6.0848
250	523.15	3977.6	1.251	48.79	50.04	1080.8	1520.6	2601.4	1085.8	1714.7	2800.4	2.7935	3.2773	6.0708
252	525.15	4113.7	1.256	47.08	48.33	1090.4	1510.6	2601.0	1095.5	1704.3	2799.8	2.8118	3.2451	6.0569
254	527.15	4253.4	1.261	45.43	46.69	1100.0	1500.5	2600.5	1105.3	1693.8	2799.1	2.8300	3.2129	6.0429
256	529.15	4396.7	1.266	43.85	45.11	1109.6	1490.4	2600.0	1115.2	1683.2	2798.3	2.8483	3.1807	6.0290
258	531.15	4543.7	1.271	42.33	43.60	1119.3	1480.1	2599.3	1125.0	1672.4	2797.4	2.8666	3.1484	6.0150
260	533.15	4694.3	1.276	40.86	42.13	1129.0	1469.7	2598.6	1134.9	1661.5	2796.4	2.8848	3.1161	6.0010
262	535.15	4848.8	1.281	39.44	40.73	1138.7	1459.2	2597.8	1144.9	1650.4	2795.3	2.9031	3.0838	5.9869
264	537.15	5007.1	1.286	38.06	39.37	1148.5	1448.6	2597.0	1154.9	1639.2	2794.1	2.9214	3.0515	5.9729
266	539.15	5169.3	1.291	36.77	38.06	1158.3	1437.8	2596.1	1165.0	1627.8	2792.8	2.9397	3.0191	5.9588
268	541.15	5335.5	1.297	35.51	36.80	1168.2	1426.9	2595.0	1175.1	1616.3	2791.4	2.9580	2.9866	5.9446
270	543.15	5505.8	1.303	34.29	35.59	1178.1	1415.9	2593.9	1185.2	1604.6	2789.9	2.9763	2.9541	5.9304
272	545.15	5680.2	1.308	33.11	34.42	1188.0	1404.7	2592.7	1195.4	1592.8	2788.2	2.9947	2.9215	5.9162
274	547.15	5858.7	1.314	31.97	33.29	1198.0	1393.4	2591.4	1205.7	1580.8	2786.5	3.0131	2.8889	5.9019
276	549.15	6041.5	1.320	30.88	32.20	1208.0	1382.0	2590.1	1216.0	1568.5	2784.6	3.0314	2.8561	5.8876
278	551.15	6228.7	1.326	29.82	31.14	1218.1	1370.4	2588.6	1226.4	1556.2	2782.6	3.0499	2.8233	5.8731
280	553.15	6420.2	1.332	28.79	30.13	1228.3	1358.7	2587.0	1236.8	1543.6	2780.4	3.0683	2.7903	5.8586
282	555.15	6616.1	1.339	27.81	29.14	1238.5	1346.8	2585.3	1247.3	1530.8	2778.1	3.0868	2.7573	5.8440
284	557.15	6816.6	1.345	26.85	28.20	1248.7	1334.8	2583.5	1257.9	1517.8	2775.7	3.1053	2.7241	5.8294
286	559.15	7021.8	1.352	25.93	27.28	1259.0	1322.6	2581.6	1268.5	1504.6	2773.2	3.1239	2.6908	5.8146
288	561.15	7231.5	1.359	25.03	26.39	1269.4	1310.2	2579.6	1279.2	1491.2	2770.5	3.1424	2.6573	5.7997
290	563.15	7446.1	1.366	24.17	25.54	1279.8	1297.7	2577.5	1290.0	1477.6	2767.6	3.1611	2.6237	5.7848
292	565.15	7665.4	1.373	23.33	24.71	1290.3	1284.9	2575.3	1300.9	1463.8	2764.6	3.1798	2.5899	5.7697
294	567.15	7889.7	1.381	22.52	23.90	1300.9	1272.0	2572.9	1311.8	1449.7	2761.5	3.1986	2.5560	5.7545
296	569.15	8118.9	1.388	21.74	23.13	1311.5	1258.9	2570.4	1322.8	1435.4	2758.2	3.2173	2.5218	5.7392
298	571.15	8353.2	1.396	20.98	22.38	1322.2	1245.6	2567.8	1333.9	1420.8	2754.7	3.2362	2.4875	5.7237

300	573.15	8592.7	1.404	20.24	21.65	1333.0	1232.0	2565.0	1345.1	1406.0	2751.0	3.2552	2.4529	5.7081
302	575.15	8837.4	1.412	19.53	20.94	1343.8	1218.3	2562.1	1356.3	1390.9	2747.2	3.2742	2.4182	5.6924
304	577.15	9087.3	1.421	18.84	20.26	1354.8	1204.3	2559.1	1367.7	1375.5	2743.2	3.2933	2.3832	5.6765
306	579.15	9342.7	1.430	18.17	19.60	1365.8	1190.1	2555.9	1379.1	1359.8	2739.0	3.3125	2.3479	5.6604
308	581.15	9603.6	1.439	17.52	18.96	1376.9	1175.6	2552.5	1390.7	1343.9	2734.6	3.3318	2.3124	5.6442
310	583.15	9870.0	1.448	16.89	18.33	1388.1	1161.0	2549.1	1402.4	1327.6	2730.0	3.3512	2.2766	5.6278
312	585.15	10142.1	1.458	16.27	17.73	1399.4	1146.0	2545.4	1414.2	1311.0	2725.2	3.3707	2.2404	5.6111
314	587.15	10420.0	1.468	15.68	17.14	1410.8	1130.8	2541.6	1426.1	1294.1	2720.2	3.3903	2.2040	5.5943
316	589.15	10703.	1.478	15.09	16.57	1422.3	1115.2	2537.5	1438.1	1276.8	2714.9	3.4101	2.1672	5.5772
318	591.15	10993.4	1.488	14.53	16.02	1433.9	1099.4	2533.3	1450.3	1259.1	2709.4	3.4300	2.1300	5.5599
320	593.15	11289.1	1.500	13.98	15.48	1445.7	1083.2	2528.9	1462.6	1241.1	2703.7	3.4500	2.0923	5.5423
322	595.15	11591.0	1.511	13.44	14.96	1457.5	1066.7	2524.3	1475.1	1222.6	2697.6	3.4702	2.0542	5.5244
324	597.15	11899.2	1.523	12.92	14.45	1469.5	1049.9	2519.4	1487.7	1203.6	2691.3	3.4906	2.0156	5.5062
326	599.15	12213.7	1.535	12.41	13.95	1481.7	1032.8	2514.3	1500.4	1184.2	2684.6	3.5111	1.9764	5.4876
328	601.15	12534.8	1.548	11.91	13.46	1494.0	1014.8	2508.8	1513.4	1164.2	2677.6	3.5319	1.9367	5.4685
330	603.15	12862.5	1.561	11.43	12.99	1506.4	996.7	2503.1	1526.5	1143.6	2670.2	3.5528	1.8962	5.4490
332	605.15	13197.0	1.575	10.95	12.53	1519.1	978.0	2497.0	1539.9	1122.5	2662.3	3.5740	1.8550	5.4290
334	607.15	13538.3	1.590	10.49	12.08	1531.9	958.7	2490.6	1553.4	1100.7	2654.1	3.5955	1.8129	5.4084
336	609.15	13886.7	1.606	10.03	11.63	1544.9	938.9	2483.7	1567.2	1078.1	2645.3	3.6172	1.7700	5.3872
338	611.15	14242.3	1.622	9.58	11.20	1558.1	918.4	2476.4	1581.2	1054.8	2636.0	3.6392	1.7261	5.3653
340	613.15	14605.2	1.639	9.14	10.78	1571.5	897.2	2468.7	1595.5	1030.7	2626.2	3.6616	1.6811	5.3427
342	615.15	14975.5	1.657	8.71	10.37	1585.2	875.2	2460.5	1610.0	1005.7	2615.7	3.6844	1.6350	5.3194
344	617.15	15353.5	1.676	8.286	9.962	1599.2	852.5	2451.7	1624.9	979.7	2604.7	3.7075	1.5877	5.2952
346	619.15	15739.3	1.698	7.870	9.566	1613.5	828.9	2442.4	1640.2	952.8	2593.0	3.7311	1.5391	5.2702
348	621.15	16133.1	1.718	7.461	9.178	1628.1	804.5	2432.6	1655.8	924.8	2580.7	3.7553	1.4891	5.2444
350	623.15	16535.1	1.741	7.058	8.799	1643.0	779.2	2422.2	1671.8	895.9	2567.7	3.7801	1.4375	5.2177
352	625.15	16945.5	1.766	6.654	8.420	1659.4	751.5	2410.8	1689.3	864.2	2553.5	3.8071	1.3822	5.1893
354	627.15	17364.4	1.794	6.252	8.045	1676.3	722.4	2398.7	1707.5	830.9	2538.4	3.8349	1.3247	5.1596
356	629.15	17792.2	1.824	5.850	7.674	1693.4	692.2	2385.6	1725.9	796.2	2522.1	3.8629	1.2654	5.1283
358	631.15	18229.0	1.858	5.448	7.306	1710.8	660.5	2371.4	1744.7	759.9	2504.6	3.8915	1.2037	5.0953
360	633.15	18675.1	1.896	5.044	6.940	1728.8	627.1	2355.8	1764.2	721.3	2485.4	3.9210	1.1390	5.0600
361	634.15	18901.7	1.917	4.840	6.757	1738.0	609.5	2347.5	1774.2	701.0	2475.2	3.9362	1.1052	5.0414
362	635.15	19130.7	1.939	4.634	6.573	1747.5	591.2	2338.7	1784.6	679.8	2464.4	3.9518	1.0702	5.0220
363	636.15	19362.1	1.963	4.425	6.388	1757.3	572.1	2329.3	1795.3	657.8	2453.0	3.9679	1.0338	5.0017
364	637.15	19596.1	1.988	4.213	6.201	1767.4	552.0	2319.4	1806.4	634.6	2440.9	3.9846	0.9958	4.9804
365	638.15	19832.6	2.016	3.996	6.012	1778.0	530.8	2308.8	1818.0	610.0	2428.0	4.0021	0.9558	4.9579
366	639.15	20071.6	2.046	3.772	5.819	1789.1	508.2	2297.3	1830.2	583.9	2414.1	4.0205	0.9134	4.9339
367	640.15	20313.2	2.080	3.540	5.621	1801.0	483.8	2284.8	1843.2	555.7	2399.0	4.0401	0.8680	4.9081
368	641.15	20557.5	2.118	3.298	5.416	1813.8	457.3	2271.1	1857.3	525.1	2382.4	4.0613	0.8189	4.8801
369	642.15	20804.4	2.162	3.039	5.201	1827.8	427.9	2255.7	1872.8	491.1	2363.9	4.0846	0.7647	4.8492
370	643.15	21054.0	2.214	2.759	4.973	1843.6	394.5	2238.1	1890.2	452.6	2342.8	4.1108	0.7036	4.8144
371	644.15	21306.4	2.278	2.446	4.723	1862.0	355.3	2217.3	1910.5	407.4	2317.9	4.1414	0.6324	4.7738
372	645.15	21561.6	2.364	2.075	4.439	1884.6	306.6	2191.2	1935.6	351.4	2287.0	4.1794	0.5446	4.7240
373	646.15	21819.7	2.496	1.588	4.084	1916.0	238.9	2154.9	1970.5	273.5	2244.0	4.2325	0.4233	4.6559
374	647.15	22080.5	2.843	0.623	3.466	1983.9	95.7	2079.7	2046.7	109.5	2156.2	4.3493	0.1692	4.5185