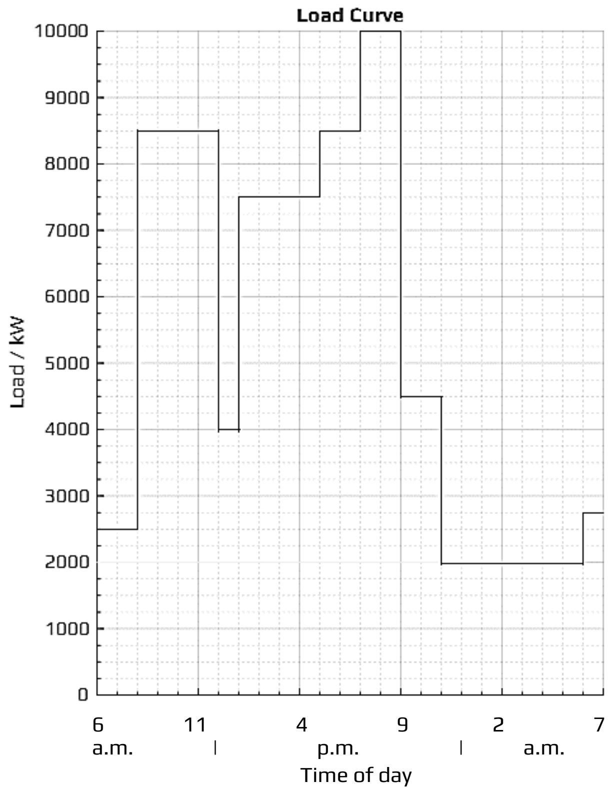
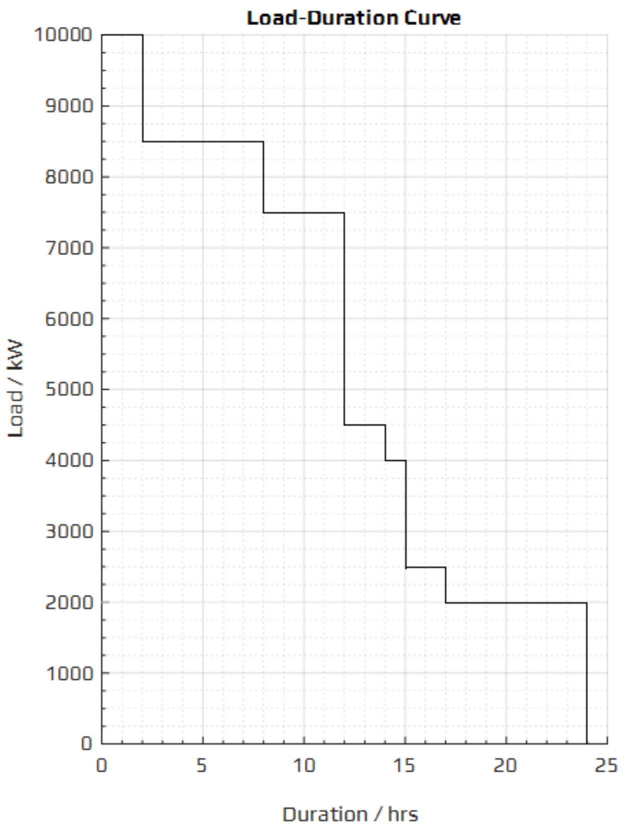
1. (a)


Load Curve
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Load / kW
6
11
4
9
2
7
a.m.
p.m.
a.m.
Time of day


Load-Duration Curve
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Load / kW
0
5
10
15
20
25
Duration / hrs

(b) The base load range is 2,000-2,500 kW, thus **one 2,500 kW** unit is chosen.

The intermediate loads range roughly from 4,000 to 4,500 kW, and loads of 8,500 kW are also common, thus **two** (8,500-2,500) **3,000 kW** (for easier maintenance) units should also be installed.

The peak demand, $\dot{W}_{\text{peak}}$, is 10,000 kW, thus **one** (10,000-8,500) **1,500 kW** unit should be installed as well.

(c) The base unit would operate for 24 hours, meeting the minimum demands of 2,000 to 2,500 kW during 9 hrs.

For the intermediate loads, the 3,000 kW plant would be run for (24-9) 15 hours, with loads up to (2,500+3,000) 5,500 kW being satisfied.

For the second 3,000 kW plant to be in proper use, the loads under or equal to (3,000+5,500) 8,500 kW and above 5,500 kW should exist, which are seen to last for 10 hours from the load duration curve.

Finally for the peak demand of 10,000 kW for 2 hours, the 1,500 kW unit should be run for about 3 hours, as a conservative measure.

The conclusions of the above discussion are summarised in the table below:

Unit Size / kW	Operating Schedule / hrs
2,500	24
3,000	15
3,000	10
1,500	3

(d) A 3,000 kW plant should be kept as a reserve in cases of failure or maintenance requirements of other power plants, as well as to meet abnormal load demands.

(e) Area under the load/load-demand curves defines the total energy, E, to be generated. Thus,

$$E = 10{,}000 \times 2 + 8{,}500 \times 6 + 7{,}500 \times 4 + 4{,}500 \times 2 + 4{,}000 + 2{,}500 \times 2 + 2{,}500 \times 6$$

$$\Rightarrow 134 \times 10^3 \text{ kWh}$$

The average load, $\dot{W}_{\text{avg}}$, is thus

$$\dot{W}_{\text{avg}} = \frac{134 \text{ MWh}}{24 \text{ h}} = 5{,}583 \text{ kW}$$

The peak load, $\dot{W}_{\text{peak}}$, during 24 hours is 10,000 kW, thus the load factor,

$$m = \frac{E}{\dot{W}_{\text{peak}} \times 24 \text{ h}} = \frac{\dot{W}_{\text{avg}}}{\dot{W}_{\text{peak}}} = \frac{134 \times 10^3 \text{ kWh}}{10{,}000 \text{ kW} \times 24 \text{ h}} = \boxed{0.5583}$$

The cumulative capacity of the running and reserve units, $\dot{W}_{\text{total inst.}}$, is 13,000 kW, thus the plant capacity factor,

$$n = \frac{E}{\dot{W}_{\text{total inst.}} \times 24 \text{ h}} = \frac{\dot{W}_{\text{avg}}}{\dot{W}_{\text{total inst.}}} = \frac{134 \times 10^3 \text{ kWh}}{13{,}000 \text{ kW} \times 24 \text{ h}} = \boxed{0.4295}$$

The plant use factor,

$$u = \frac{\dot{W}_{\text{peak}}}{\dot{W}_{\text{total inst.}}} = \frac{n}{m} = \frac{10{,}000 \text{ kW}}{13{,}000 \text{ kW}} = \boxed{0.7692}$$

2. (a) the average load,

$$\dot{W}_{\text{avg}} = m\dot{W}_{\text{peak}} = 0.45 \times 30 = \boxed{13.5 \text{ MW}}$$

(b) the energy supplied per year,

$$E = \dot{W}_{\text{avg}} \times 8760 \text{ h yr}^{-1} = \boxed{118.26 \text{ GWh yr}^{-1}}$$

(c) the diversity factor,

$$\text{div} = \frac{15 + 8.5 + 10 + 4.5}{30} = \boxed{1.27}$$

(d) the demand factor,

$$\text{dem} = \frac{30}{15 + 8.5 + 10 + 4.5} = \text{div}^{-1} = \boxed{0.79}$$

3. a) The economic loading occurs when

$$\frac{\text{d}F_{\text{A}}}{\text{d}P_{\text{A}}} = \frac{\text{d}F_{\text{B}}}{\text{d}P_{\text{B}}} = 0.06P_{\text{A}} + 11.4 = 0.07P_{\text{B}} + 10 = 0$$

and required that,

$$P_{\text{A}} + P_{\text{B}} = 150$$

So,

$$9 - 0.06P_{\text{B}} + 11.4 = 0.07P_{\text{B}} + 10$$

$$\Rightarrow \boxed{P_{\text{B}} = 80 \text{ MW} \;\&\; P_{\text{A}} = 70 \text{ MW}}$$

b)

$$\int \text{d}F_{\text{A}} = \int 0.06P_{\text{A}} + 11.4 \;\, \text{d}P_{\text{A}}$$

$$\Rightarrow F_{\text{A}} = 0.03P_{\text{A}}^2 + 11.4P_{\text{A}}$$

$$\int \text{d}F_{\text{B}} = \int 0.07P_{\text{B}} + 10 \;\, \text{d}P_{\text{A}}$$

$$\Rightarrow F_{\text{B}} = 0.035P_{\text{B}}^2 + 10P_{\text{B}}$$

[N.B. The arbitrary constants of integration are obviously 0, since fuel costs would be 0 when power generated is 0]

Thus

$$C_1 = F_{\text{A}} + F_{\text{B}} = 945 + 1024 = 1{,}969 \text{ Rs h}^{-1}$$

Now if,

$$P_{\text{A}} = P_{\text{B}} = 75 \text{ MW}$$

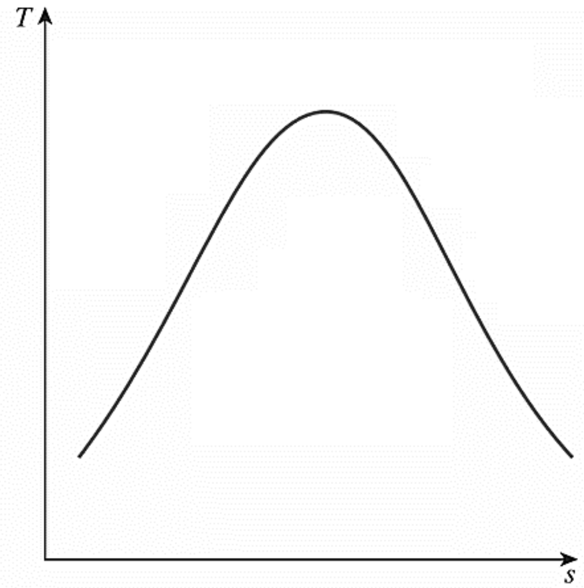
Then,

$$C_2 = F_{\text{A}} + F_{\text{B}} = 1023.75 + 946.875 = 1{,}970.625 \text{ Rs h}^{-1}$$

So

$$\boxed{C_2 - C_1 = 1.625 \text{ Rs h}^{-1}}$$

4.



State # i	State	P_i/kPa	T_i/°C	v_i/ $\mathrm{m^3\ kg^{-1}}$	x_i	h_i/kJ $\mathrm{kg^{-1}}$	s_i/kJ $\mathrm{(kg.K)^{-1}}$
1	Superheated Vapour	9,000	500	0.036793	1	3387.4	6.6603
2s	Superheated Vapour	2,250	289	0.10815	1	2991.8	6.6603
2	Superheated Vapour	2,250	303	0.11141	1	3023.4	6.7157
3	Superheated Vapour	2,250	500	0.15585	1	3465.3	7.3764
4s	Sat. Liquid-Vapour Mixture	7.3851	40	17.282	0.886	2298.2	7.3764
4	Sat. Liquid-Vapour Mixture	7.3851	40	18.229	0.934	2414.9	7.7490
5	Saturated Liquid	7.3851	40	0.001008	0	167.53	0.5724
6s	Subcooled Liquid	9,000	-	0.001008	0	176.59	0.5724

6	Subcooled Liquid	9,000	-	-	0	179.62	0.5821
7	Subcooled Liquid	9,000	220.02	-	0	945.66	-
8	Saturated Liquid	2,250	218.41	0.001187	0	936.21	-
9	Sat. Liquid-Vapour Mixture	7.3851	-	-	-	936.21	-

Assuming the Reheat Pressure to be optimum, i.e., one-fourth of the maximum cycle pressure [*Y.A. Cengel and M.A. Boles, Thermodynamics 8th ed., p.566*], i.e., 22.5 bar.

$$\eta_{\mathrm{T,HP}} = 0.92 = \frac{h_1 - h_2}{h_1 - h_{2s}}; \therefore h_2 = 3023.45\ \mathrm{kJ\ kg^{-1}}$$

$$x_{4\mathrm{s}} = \frac{s_{4\mathrm{s}} - s_f}{s_{fg}} = 0.88556; \therefore h_{4\mathrm{s}} = h_f + x_{4\mathrm{s}} h_{fg} = 2298.2078\ \mathrm{kJ\ kg^{-1}}$$

$$\eta_{\mathrm{T,LP}} = 0.90 = \frac{h_3 - h_4}{h_3 - h_{4\mathrm{s}}}; \therefore h_4 = 2414.91\ \mathrm{kJ\ kg^{-1}}$$

$$h_{6\mathrm{s}} = h_5 + v_5(P_6 - P_5) = 176.5946\ \mathrm{kJ\ kg^{-1}}$$

$$\eta_{\mathrm{P}} = 0.75 = \frac{h_{6\mathrm{s}} - h_5}{h_6 - h_5}; \therefore h_6 = 179.62\ \mathrm{kJ\ kg^{-1}}$$

$$\mathrm{TDD} = T_{\mathrm{sat.}@P_3} - T_7 = -1.6℃; T_7 = 218.42 + 1.6 = 220.02℃$$

Energy Balance across the CFWH Control Volume:

$$y h_2 + h_6 = h_7 + y h_8$$

$$\therefore y = \frac{h_7 - h_6}{h_2 - h_8} = 0.367$$

a)

$$\dot{W}_{\mathrm{net}} = 500\ \mathrm{MW} = \dot{m}\left(w_{\mathrm{T,HP}} + w_{\mathrm{T,LP}} - w_{\mathrm{P}}\right);$$

$$\dot{m} = \frac{\dot{W}_{\mathrm{net}}}{(h_1 - h_2) + [(1-y)(h_3 - h_4)] - (h_6 - h_5)} = \boxed{491.53\ \mathrm{kg\ s^{-1}}}$$

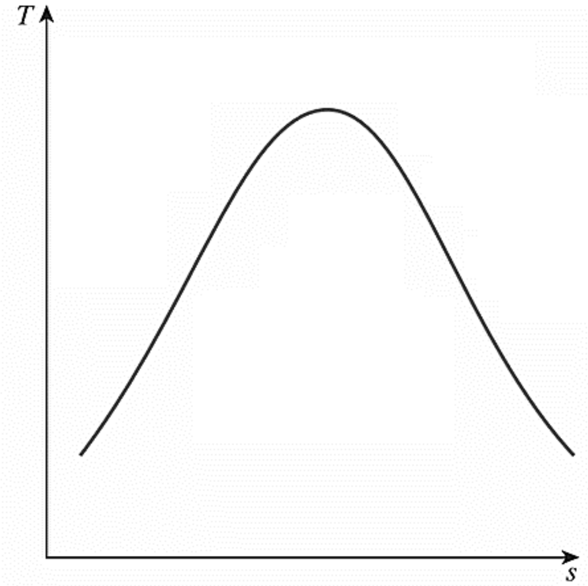
b)

$$\eta_{\mathrm{cycle}} = \frac{\dot{W}_{\mathrm{net}}}{\dot{Q}_{\mathrm{in}}} = \frac{\dot{W}_{\mathrm{net}}}{\dot{m}[(h_1 - h_7) + (1-y)(h_3 - h_2)]} \times 100\% = \boxed{37.4\%}$$

c) Cycle Work Ratio:

$$\frac{\dot{W}_{\mathrm{net}}}{\dot{m}\left(w_{\mathrm{T,HP}} + w_{\mathrm{T,LP}}\right)} = \frac{\dot{W}_{\mathrm{net}}}{\dot{m}[(h_1 - h_2) + (1-y)(h_3 - h_4)]} = \boxed{0.9887}$$

5.



State # i	State	P_i/kPa	T_i/°C	x_i	h_i/kJ kg^{-1}	s_i/kJ (kg. K)$^{-1}$
1	Superheated Vapour	5,000	350	1	3069.3	6.4516
2s	Sat. Liquid-Vapour Mixture	150	111.35	0.867	2396.5	6.4516
2	Superheated Vapour	150	111.35	0.915	2504.2	6.7315
3	Superheated Vapour	150	250	1	2972.9	7.8451
4s	Sat. Liquid-Vapour Mixture	5	32.87	0.931	2392.8	7.8451
4	Sat. Liquid-Vapour Mixture	5	32.87	0.976	2503.0	8.2052
5	Saturated Liquid	5	32.87	0	137.75	0.4762

$$x_{2s} = \frac{s_{2s} - s_f}{s_{fg}} = 0.86674; \therefore h_{2s} = h_f + x_{2s} h_{fg} = 2396.4915 \text{ kJ kg}^{-1}$$

$$\eta_{\text{T,HP}} = 0.84 = \frac{h_1 - h_2}{h_1 - h_{2s}}; \therefore h_2 = 2504.15 \text{ kJ kg}^{-1}$$

$$x_{4s} = \frac{s_{4s} - s_f}{s_{fg}} = 0.93070; \therefore h_{4s} = h_f + x_{4s} h_{fg} = 2392.8329 \text{ kJ kg}^{-1}$$

$$\eta_{\text{T,LP}} = 0.81 = \frac{h_3 - h_4}{h_3 - h_{4s}}; \therefore h_4 = 2503.02 \text{ kJ kg}^{-1}$$

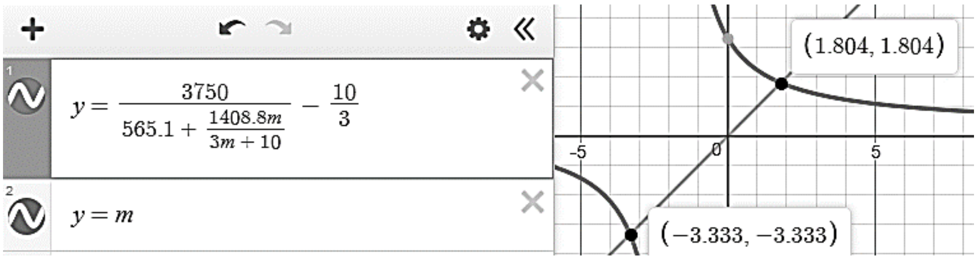
$$\dot{m}_{\text{total}} = \dot{m}_{\text{bleed}} + \dot{m}_{\text{retained}}; \dot{m}_{\text{bleed}} = 12{,}000 \text{ kg h}^{-1} = \frac{10}{3} \text{ kg s}^{-1}$$

$$\dot{W}_{\text{out}} = 3750 \text{ kW} = \dot{m}_{\text{total}}\left(w_{\text{T,HP}} + w_{\text{T,LP}}\right);$$

$$\dot{m}_{\text{bleed}} + \dot{m}_{\text{retained}} = \frac{\dot{W}_{\text{out}}}{(h_1 - h_2) + \left[\left(\frac{\dot{m}_{\text{total}} - \dot{m}_{\text{bleed}}}{\dot{m}_{\text{total}}}\right)(h_3 - h_4)\right]}$$

$$\Rightarrow \dot{m}_{\text{retained}} = \frac{\dot{W}_{\text{out}}}{(h_1 - h_2) + \left[\left(\frac{3\dot{m}_{\text{retained}}}{3\dot{m}_{\text{retained}} + 10}\right)(h_3 - h_4)\right]} - \frac{10}{3}$$

Since this is a non-linear equation in one unknown, graphs are plotted for both sides of the equation and their positive intercept is noted as the solution:



$$\therefore \dot{m}_{\text{retained}} = 1.804 \text{ kg s}^{-1} = 6494.4 \text{ kg h}^{-1}$$

Thus the boiler should be sized to

$$\dot{m}_{\text{total}} = \dot{m}_{\text{bleed}} + \dot{m}_{\text{retained}} = \boxed{18{,}494 \text{ kg h}^{-1}}$$

6.

$$\dot{Q}_{\text{in}} = \frac{m_{\text{coal}} h_{\text{value}}}{t} = \frac{10 \times 10^6 \text{ kg} \times 26 \text{ MJ kg}^{-1}}{24 \text{ h}} = \frac{260 \times 10^6 \text{ MJ}}{24 \text{ h}} = 3{,}009.25 \text{ MW}$$

$$\dot{W}_{\text{gross gen. out}} = 1000 \text{ MW}$$

$$\text{Heat Rate}_{\text{gross station}} = \frac{\dot{Q}_{\text{in}}}{\dot{W}_{\text{gross gen. out}}} = \frac{260 \times 10^6 \text{ MJ}}{1{,}000{,}000 \text{ kW} \times 24 \text{ h}} = \boxed{10{,}833 \text{ kJ/kWh}}$$

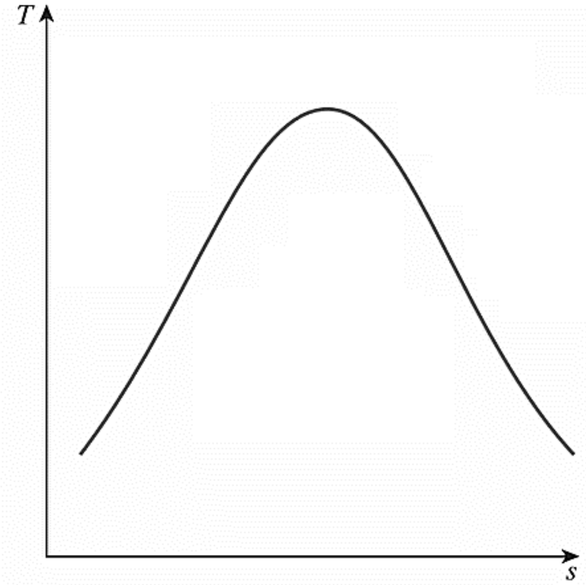
$$\dot{W}_{\text{net station out}} = (1 - 0.07)\dot{W}_{\text{gross gen. out}} = 930 \text{ MW}$$

$$\text{Heat Rate}_{\text{net station}} = \frac{\dot{Q}_{\text{in}}}{\dot{W}_{\text{net station out}}} = \frac{\text{Heat Rate}_{\text{gross station}}}{0.93} = \boxed{11{,}648 \text{ kJ/kWh}}$$

$$\eta_{\text{gross}} = \frac{\dot{W}_{\text{gross gen. out}}}{\dot{Q}_{\text{in}}} \times 100\ \% = \frac{1000}{3{,}009.25} \times 100\ \% = \boxed{33.2\ \%}$$

$$\eta_{\text{net}} = \frac{\dot{W}_{\text{net station out}}}{\dot{Q}_{\text{in}}} \times 100\ \% = \frac{930}{3{,}009.25} \times 100\ \% = \boxed{30.9\%}$$

7.



State # i	State	P_i/kPa	T_i/°C	v_i/ $\mathrm{m^3\ kg^{-1}}$	x_i	h_i/kJ kg^{-1}	s_i/kJ (kg. K)$^{-1}$
1	Superheated Vapour	10,000	550	0.035655	1	3502.0	6.7585
2s	Superheated Vapour	3632.24	381.8	0.078624	1	3178.0	6.7585
2	Superheated Vapour	3632.24	391.4	0.080054	1	3200.7	6.7929
3s	Superheated Vapour	966.38	208.8	0.218672	1	2851.2	6.7585
3	Superheated Vapour	966.38	228.6	0.229639	1	2896.8	6.8511

4s	Sat. Liquid-Vapour Mixture	153.83	112.1	1.04299	0.921	2518.6	6.7585
4	Sat. Liquid-Vapour Mixture	153.83	112.1	1.07801	0.952	2587.4	6.9372
5s	Sat. Liquid-Vapour Mixture	10	45.8	11.9509	0.814	2140.4	6.7585
5	Sat. Liquid-Vapour Mixture	10	45.8	12.5354	0.854	2235.7	7.0573
6	Saturated Liquid	10	45.8	0.00101026	0	191.8	0.649218
7s	Subcooled Liquid	966.38	45.8	0.00100985	0	192.8	0.649218
7	Subcooled Liquid	966.38	45.9	0.00100987	0	192.9	0.649834
8	Subcooled Liquid	966.38	107.1	0.00104873	0	449.7	1.38595
9	Saturated Liquid	966.38	178.4	0.00112524	0	756.2	2.12407
10s	Subcooled Liquid	10,000	179.6	0.0011195	0	766.3	2.12407
10	Subcooled Liquid	10,000	180.1	0.00112006	0	768.1	2.12817
11	Subcooled Liquid	10,000	244.7	0.00122929	0	1060.5	2.73062
12	Saturated Liquid	153.83	112.1	0.00105337	0	470.3	1.44187
13s	Subcooled Liquid	966.38	112.2	0.00105299	0	471.2	1.44187
13	Subcooled Liquid	966.38	112.2	0.00105303	0	471.3	1.44237
14	Saturated Liquid	3632.24	244.7	0.00123969	0	1060.06	2.74497
15	Sat. Liquid-Vapour Mixture	966.38	178.4	0.0311704	0.15	1060.06	2.7971

Since the 3 feed-water heaters are optimally placed, the optimum temperature rise, ΔT_{opt} per heater should be equally divided between the boiler and condenser temperatures[*M.M.Wakil, Powerplant Technology, p.68*], i.e.,

$$\Delta T_{\text{opt}} = \frac{T_{\text{sat@100bar}} - T_{\text{sat@0.1bar}}}{4} = \frac{311 - 45.81}{4} = 66.2975\text{°C}$$

The pressures at which steam is bled in each FWH is then the saturation pressure at the optimum temperature;

$$\therefore T_{\text{sat@}P_{2s}} = T_{\text{sat@100bar}} - \Delta T_{\text{opt}} = 244.7025\text{°C}; \therefore P_2 = 3632.24\ \text{kPa}$$

$$\eta_{\mathrm{T,HP}} = 0.93 = \frac{h_1 - h_2}{h_1 - h_{2\mathrm{s}}}; \therefore h_2 = 3200.6893 \text{ kJ kg}^{-1}$$

$$T_{\mathrm{sat}@P_{3\mathrm{s}}} = T_{\mathrm{sat}@P_{2\mathrm{s}}} - \Delta T_{\mathrm{opt}} = 178.405°\mathrm{C}; \therefore P_3 = 966.382 \text{ kPa}$$

$$\eta_{\mathrm{T,IP}} = 0.93 = \frac{h_1 - h_3}{h_1 - h_{3\mathrm{s}}}; \therefore h_3 = 2896.7653 \text{ kJ kg}^{-1}$$

$$T_{\mathrm{sat}@P_{4\mathrm{s}}} = T_{\mathrm{sat}@P_{3\mathrm{s}}} - \Delta T_{\mathrm{opt}} = 112.1075°\mathrm{C}; \therefore P_4 = 153.825 \text{ kPa}$$

$$x_{4\mathrm{s}} = \frac{s_{4\mathrm{s}} - s_f}{s_{fg}} = 0.921; \therefore h_{4\mathrm{s}} = h_f + x_{4\mathrm{s}} h_{fg} = 2518.57 \text{ kJ kg}^{-1}$$

$$\eta_{\mathrm{T,LP}} = 0.93 = \frac{h_1 - h_4}{h_1 - h_{4\mathrm{s}}}; \therefore h_3 = 2587.4101 \text{ kJ kg}^{-1}$$

$$x_{5\mathrm{s}} = \frac{s_{5\mathrm{s}} - s_f}{s_{fg}} = 0.814606; \therefore h_{5\mathrm{s}} = h_f + x_{5\mathrm{s}} h_{fg} = 2140.41 \text{ kJ kg}^{-1}$$

$$\eta_{\mathrm{T,EXIT}} = 0.93 = \frac{h_1 - h_5}{h_1 - h_{5\mathrm{s}}}; \therefore h_5 = 2235.7213 \text{ kJ kg}^{-1}$$

$$h_{7\mathrm{s}} = h_6 + v_6(P_7 - P_6) = 192.8 \text{ kJ kg}^{-1}$$

$$\eta_{\mathrm{P,3}} = 0.85 = \frac{h_{7\mathrm{s}} - h_6}{h_7 - h_6}; \therefore h_7 = 192.92847 \text{ kJ kg}^{-1}$$

For the HP and LP CFWH, assuming a TTD of 0°C and 5°C, [from the typical range of TTD stated by *M.M.Wakil* in *Powerplant Technology, pp.53*-4] respectively. Thus,

$$\because \mathrm{TTD} = T_{\text{bleed sat}} - T_{\text{exit water}}$$

Thus for the HP CFWH

$$T_{\text{exit water}} = T_{11} = T_{\text{bleed sat}} = T_{14} = 244.7025°\mathrm{C}$$

$$\therefore h_{11} = 1060.49 \text{ kJ kg}^{-1} \& \, h_{14} = 1060.06 \text{ kJ kg}^{-1}$$

And for the LP CFWH

$$T_{\text{exit water}} = T_8 = T_{\text{bleed sat}} - 5 = 107.1075°\mathrm{C}$$

$$\therefore h_8 = 449.738 \text{ kJ kg}^{-1} \& h_{12} = 470.29 \text{ kJ kg}^{-1}$$

Further,

$$h_{13\mathrm{s}} = h_{12} + v_{12}(P_{13} - P_{12}) = 471.16 \text{ kJ kg}^{-1}$$

$$\eta_{\mathrm{P,2}} = 0.85 = \frac{h_{13\mathrm{s}} - h_{12}}{h_{13} - h_{12}}; \therefore h_{13} = 471.31 \text{ kJ kg}^{-1}$$

$$h_{10\mathrm{s}} = h_9 + v_9(P_{10} - P_9) = 766.28 \text{ kJ kg}^{-1}$$

$$\eta_{\mathrm{P,1}} = 0.85 = \frac{h_{10\mathrm{s}} - h_9}{h_{10} - h_9}; \therefore h_{10} = 768.068 \text{ kJ kg}^{-1}$$

$$w + x + y + z = 1 \tag{1}$$

Energy Balance across the HP CFWH Control Volume:

$$x h_2 + h_{10} = x h_{14} + h_{11} \tag{2}$$

$$\therefore x = \frac{h_{11} - h_{10}}{h_2 - h_{14}} = 0.1366$$

Energy Balance across the IP OFWH Control Volume:

$$yh_3 + xh_{15} + zh_{13} + wh_8 = h_9 \tag{3}$$

Energy Balance across the LP CFWH Control Volume:

$$zh_4 + wh_7 = wh_8 + zh_{12} \tag{4}$$

$$\therefore w = z\frac{h_4 - h_{12}}{h_8 - h_7} \tag{5}$$

Substituting the value of x and equation 5 into equation 1:

$$y = 0.8634 - z\left(\frac{h_4 - h_{12}}{h_8 - h_7} + 1\right) \tag{6}$$

Substituting the value of x and equations 5 & 6 into equation 3:

$$\left[0.8634 - z\left(\frac{h_4 - h_{12}}{h_8 - h_7} + 1\right)\right] h_3 + 0.1366h_{15} + zh_{13} + z\frac{h_4 - h_{12}}{h_8 - h_7} h_8 = h_9$$

Solving for z

$$z = 0.0836; \therefore w = 0.6893 \;\&\; y = 0.0904$$

a)

$$\dot{W}_{\text{net}} = 1320 \text{ MW} = \dot{m}\left(w_{\text{T}} - \sum w_{\text{P}}\right)$$

$$\Rightarrow \dot{m}\{[x(h_1 - h_2) + y(h_1 - h_3) + z(h_1 - h_4) + w(h_1 - h_5)] - [(h_{10} - h_9) + z(h_{13} - h_{12}) + w(h_7 - h_6)]\}$$

$$\therefore \dot{m} = \frac{\dot{W}_{\text{net}}}{(w_{\text{T}} - \sum w_{\text{P}})} = 1278.516 \text{ kg s}^{-1} = \boxed{4{,}602{,}658 \text{ kg h}^{-1}}$$

b) The mass flow rate to the condenser is

$$\dot{m}w = \boxed{3{,}172{,}612 \text{ kg h}^{-1}}$$

The energy balance across the condenser is, assuming the cooling water is at 1 atm at 25°C

$$\dot{m}w(h_{14} - h_{15}) = \dot{m}_{\text{cooling water}} c_p \Delta T_{\text{cooling water}}$$

$$\therefore \dot{m}_{\text{cooling water}} = \frac{\dot{m}w(h_5 - h_6)}{c_p \Delta T_{\text{cooling water}}} = \frac{3{,}172{,}612 \times 2043.9}{4.18 \times 25} = \boxed{62{,}052{,}648 \text{ kg h}^{-1}}$$

c)

$$\eta_{\text{cycle}} = \frac{\dot{W}_{\text{net}}}{\dot{Q}_{\text{in}}} = \frac{\dot{W}_{\text{net}}}{\dot{m}(h_1 - h_{11})} \times 100\% = \boxed{42.3\%}$$

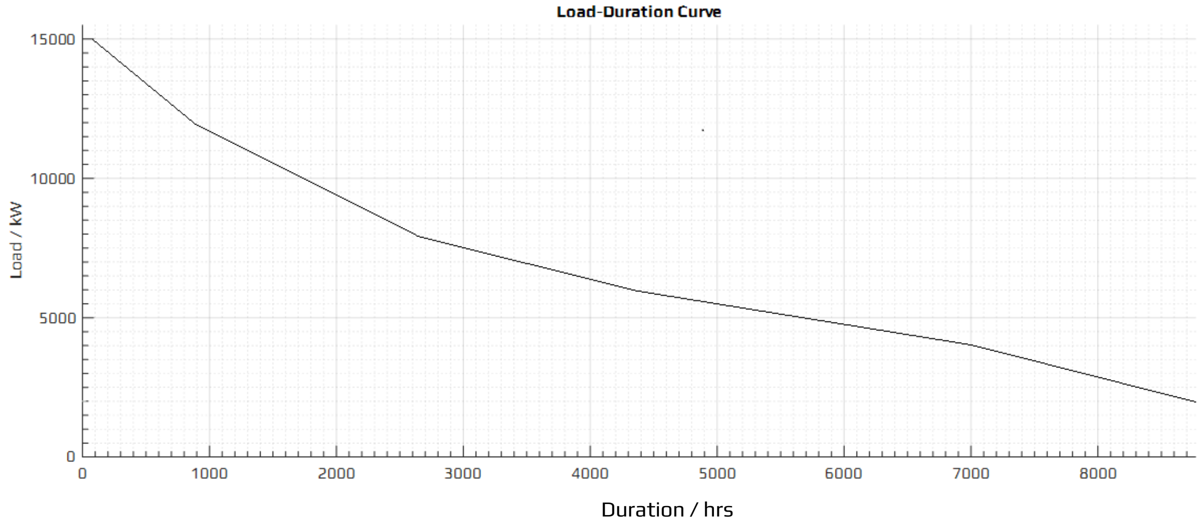
d)

$$\text{Heat Rate}_{\text{cycle}} = \frac{\dot{Q}_{\text{in}}}{\dot{W}_{\text{net}}} = \frac{11237389507 \ldots \text{kJ h}^{-1}}{1{,}320{,}000 \text{ kW}} = \boxed{8513.17 \text{ kJ/kWh}}$$

8. For a given time-frame of a load curve, say a day (24 hours), the load duration curve would be plotted for the same time-frame by starting from the peak load. The duration during which each load value lasts would be plotted for that span of time in order of decreasing magnitude of load. Each loads' hours would cumulate with the previous load's value.

From the given data:

Load / kW	Duration (h)
2,000-4,000	1,760
4,000-6,000	2,620
6,000-8,000	1,752
8,000-10,000	876
10,000-12,000	876
12,000-15,000	789
15,000	87



Area under the load/load-demand curves defines the total energy, E, generated. Thus, each small box represents 50 MWh of energy. The load-duration curve plotted bounds about 1200 such boxes, thus

$$E = 50 \text{ MWh box}^{-1} \times 1200 \text{ boxes} = 60 \times 10^6 \text{ kWh}$$

The average load, $\dot{W}_{\text{avg}}$, is thus

$$\dot{W}_{\text{avg}} = \frac{60{,}000{,}000}{8760} = 6{,}849 \text{ kW}$$

and the load factor

$$m = \frac{\dot{W}_{\text{avg}}}{\dot{W}_{\text{peak}}} = \boxed{0.457}$$