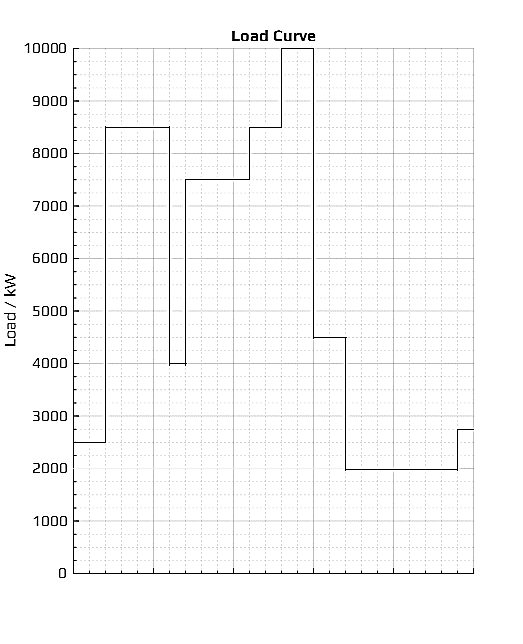
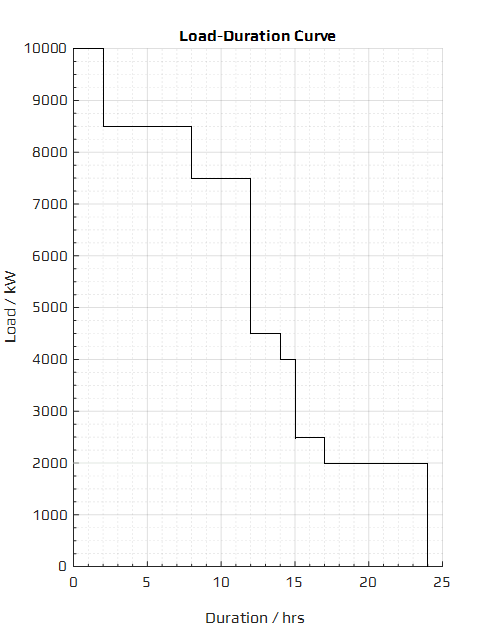
1. (a)



a.m. | p.m. | a.m.

6 11 4 9 2 7

Time of day



(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, , 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, , to be generated. Thus,

The average load, , is thus

The peak load, , during 24 hours is 10,000 kW, thus the load factor,

The cumulative capacity of the running and reserve units, , is 13,000 kW, thus the plant capacity factor,

The plant use factor,

2. (a) the average load,

(b) the energy supplied per year,

(c) the diversity factor,

(d) the demand factor,

3. a) The economic loading occurs when

and required that,

So,

b)

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

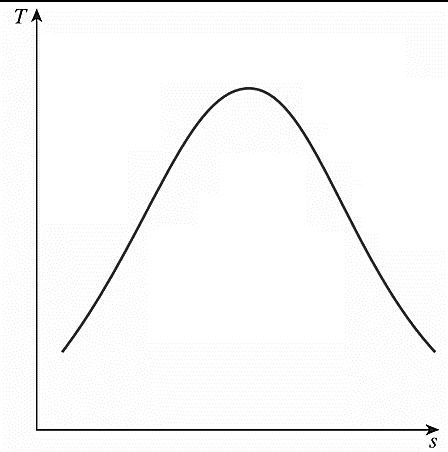
Thus

Now if,

Then,

So

4.



|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| State # | State |  |  |  |  |  |  |
|  | Superheated Vapour | 9,000 |  | 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 |
|  | 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.

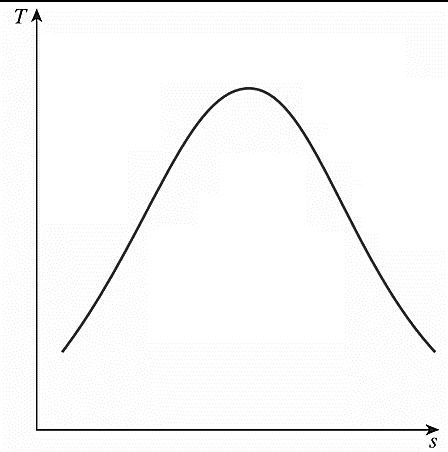
Energy Balance across the CFWH Control Volume:

a)

b)

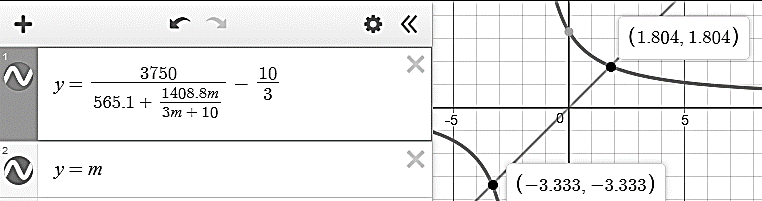
c) Cycle Work Ratio:

5.



|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| State # | State |  |  |  |  |  |
|  | 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 |
|  | 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 |

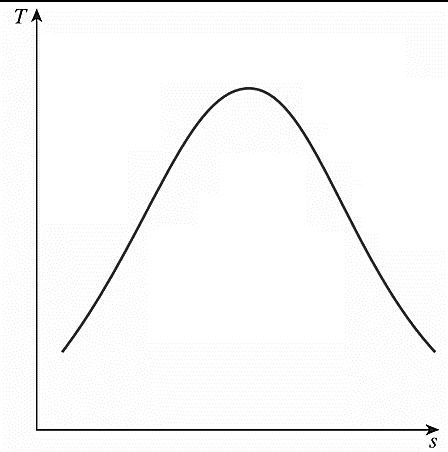
Since this is a non-linear equation in one unknown, graphs are plotted for both sides of the equation and their positive intercept is noted as the solution:



Thus the boiler should be sized to

6.

7.



|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| State # | State |  |  |  |  |  |  |
| 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, per heater should be equally divided between the boiler and condenser temperatures[*M.M.Wakil, Powerplant Technology, p.68*], i.e.,

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

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

Thus for the HP CFWH

And for the LP CFWH

Further,

Energy Balance across the HP CFWH Control Volume:

Energy Balance across the IP OFWH Control Volume:

Energy Balance across the LP CFWH Control Volume:

Substituting the value of and equation 5 into equation 1:

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

Solving for

a)

b) The mass flow rate to the condenser is

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

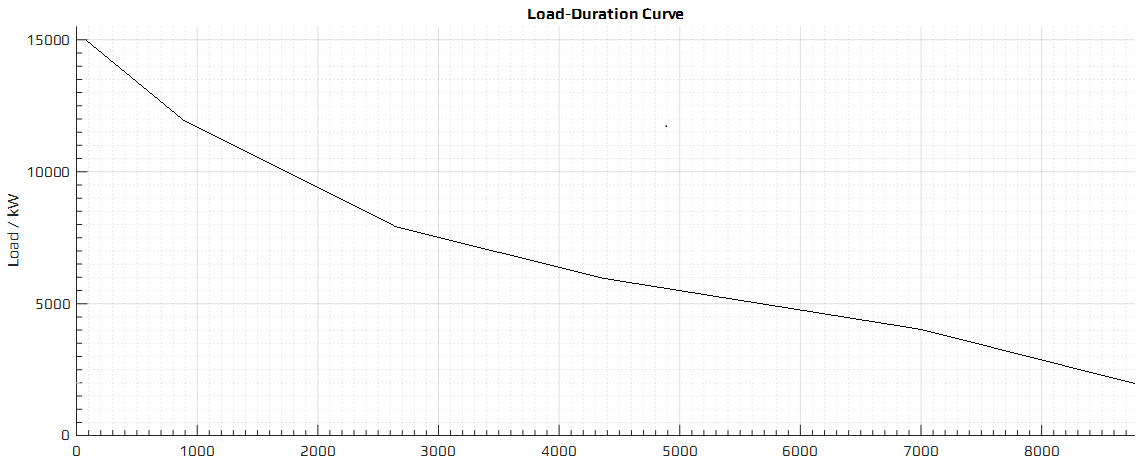
c)

d)

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 |



Duration / hrs

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

The average load, , is thus

and the load factor