1(a) Discuss the working principle of LaMont high pressure boiler

This boiler works on basic principle of forced convection. If the water is circulate by a pump inside the tube, the heat transfer rate from gas to the water is increases. It is the basic principle of it.

Construction:

This boiler is the first force circulation boiler. This boiler consist various part which are as follow.

Economizer: Economizer use to preheat the water by using remaining heat of the combustion gases. It increases the boiler efficiency. The feed water first supplied to the economizer before entering to the boiler.

Centrifugal pump: The Lamont boiler is a force convection boiler. So a centrifugal pump is used to circulate water inside the boiler. This pump is driven by a steam turbine. The steam for the turbine is taken by the boiler.

Evaporator tube: The evaporator tube or can say water tubes are situated at furnace wall which increase the heating surface of boiler. This is also at the up side and down side of the furnace and other equipment. The main function of these tubes to evaporate water into steam. This also cools down the furnace wall.

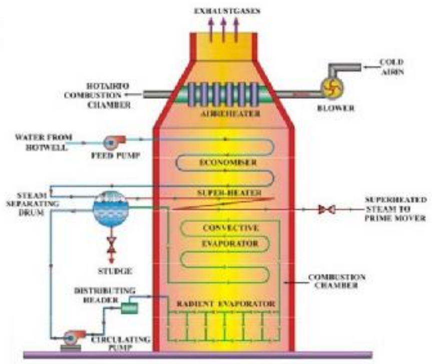
Grate: The space in the furnace where the fuel is burn is called grate. It is bottom side of furnace.

Furnace: In the Lamont boiler vertical furnace is used. The main function of Furnace is to burn the fuel.

Super heater: The steam generated by the evaporator tube is saturated steam. If it directly used in steam turbine can cause the corrosion. So the saturated steam sends to the super heater where it can increase the temperature of steam.

Water steam separator drum: The steam separator is situated outside from the boiler. The mixture of water and steam from the evaporator tube send to the steam separator where it separate the steam and send it to super heater. The remaining water again sends to the economizer.

Air preheater: It’s main function to preheat air before entering into furnace.



Lamont Boiler

Working:

Lamont boiler is a forced circulation, internally fired water tube boiler. The fuel is burn inside the boiler and the water is circulating by a centrifugal pump through evaporator tubes. The working of this boiler is as follow.A feed pump forces the water into the economizer where the temperature of water increases. This water forced into the evaporator tube by using a centrifugal pump driven by steam turbine. Water passes 10 – 15 times into the evaporator tube. The mixture of saturated steam and water is formed inside the tube. This mixture sends to the steam separator drum which is outside the boiler. Steam from the separator sends to the super heater, where the saturated steam converts into superheated steam. The water again sends to the economizer where it again passes by the evaporator tubes. The air from the air preheater enter into the furnace where fuel burn. The flue gases first heat the evaporator tube then passes by the super heater. These gases from the super heater again use to preheat the air into air preheater before exhaust into atmosphere.

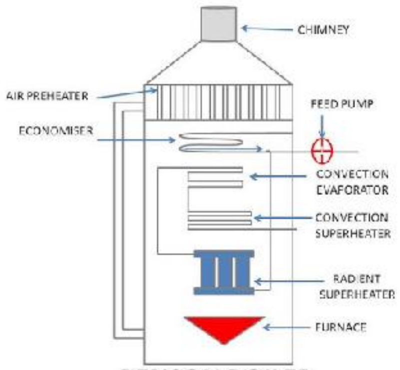
1(b) Discuss the working Principle of Benson Boiler with neat Sketch

Benson boiler is also known as super critical steam generator which is developed by Mark Benson in the year 1922. This boiler can generate high pressure steam, which is further used in production of electricity and other industrial processes. It is a water tube boiler. In the early stage water tube boiler used to generate steam at the pressure up to 10MPa, which is known as sub critical boiler. Two big problem occur in sub-critical boiler.First, in sub critical boiler water form the vapor bubbles at the tube surface, which decrease heat transfer rate, hence decrease efficiency.The second one is, the sub critical boiler used the water steam separator drum to separate steam which make it too complex and heavy. It cannot be easily transfer from one station to another.

To overcome these problems, in 1922, Mark Benson invented a boiler which works above su and generate steam at super critical pressure. This boiler is known as Benson boiler. This boiler works at pressure above critical pressure, at which the water instantly convert into steam. No air bubbles generate in this boiler. This boiler generate a high pressure steam which is used in various industrious processes.

Principle:

The Benson boiler is a water tube boiler, works on the basic principle of critical pressure of water. The critical pressure is the pressure at which the liquid and gas phase are at equilibrium. The water enters in the boiler at just above the critical pressure so it suddenly convert into steam without generating air bubbles. No air water separator drum is required. It also takes less fuel to generate steam. This is the basic principle of Benson boiler.



BENSON BOILER

Main parts:

It consist a great large tube. The water enter into the tube from one end and steam exit from other end. No water steam separator drum is used in this boiler. This boiler consist six basic component.

1. Feed pump-Benson boiler is the forced pumped water tube boiler. The water is enter into the boiler at critical pressure A feed pump is used to pump the water into boiler.
2. Air preheated -In this boiler air is preheated from before entering into combustion chamber. It increase the efficiency of boiler.
3. Economizer: Water from the feed pump enter into the tube which first passes from economizer which used the combustion gases to preheat the water which also increase efficiency of boiler.
4. Radiant Evaporator: The water from the economizer further passes to the radiant evaporator, which use radiant heat transfer method to transfer heat from combustion chamber to the water. This section is near the combustion chamber.
5. Convective Evaporator: In the convective chamber, convection is used to transfer heat from the flue gases to the water. The water is completely evaporate in this chamber.
6. Convective Super heater: This is the last chamber of boiler. The steam passes from this chamber, which increase the temperature of steam and this super-heated steam taken out for the industrial work.

Working:

As we discussed this boiler works on the basic principle of critical pressure. The water is pumped at above the critical pressure into boiler tube. This water tube first passes through the economizer, which increase the temperature of water. This hot water further passes from the radiant evaporator where water is evaporate by radiant heat transfer. After that the water and steam passes through the convective evaporate where water is completely convert into steam. The water pressure is critical pressure so the water convert into steam directly without actual boiling. The steam is further heat up and this super-heated high pressure steam is taken out to rotate the turbine.

OR

Q1 (a) Expain the working of Babcock and Wilcox Water tube boiler with neat sketch

This boiler is generally used to produce high pressure steam, and this high pressure steam is used to produce electricity in power generation industries. It is also used in the area where high pressure steam is required. So let’s begin our journey to do detail study about it.

Construction:-

The various main parts of Babcock and Wilcox Boiler are as follows

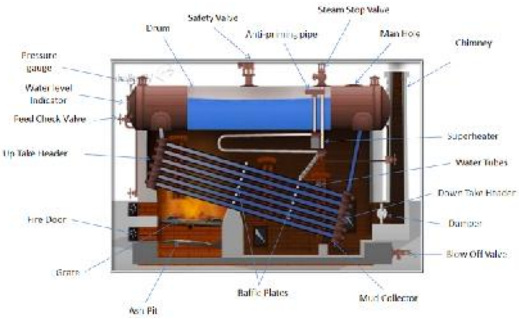
1. Drum: It is horizontal axis drum which contains water and steam.
2. Down Take Header: It is present at rear end of the boiler and connects the water tubes to the rear end of the drum. It receives water from the drum.
3. Up Take Header: it is present at front end of the boiler and connected to the front end of the drum. It transports the steam from the water tubes to the drum.
4. Water Tubes: They are the tubes in which water flows and gets converted into steam. It exchanges the heat from the hot flue gases to the water. It is inclined at angle of 10-15 degree with the horizontal direction. Due to its inclination the water tubes do not completely filled with water and the water and steam separated out easily.
5. Baffle Plates: Baffle plates are present in between water tubes and it allows the zigzag motion of hot flue gases from the furnace.
6. Fire Door: It is used to ignite the solid fuel in the furnace.
7. Grate: It is a base on which the burning of the solid fuel takes place.
8. Mud Collector: It is present at the bottom of down take header and used to collect the mud present in the water.
9. Feed Check Valve: it is used to fill water into the drum.10. Damper: It regulates the flow of air in the boiler.

The various boiler mounting and accessories used in this type of boiler are:

1. Superheater: It increases the temperature of saturated steam to the required temperature before discharging it from steam stop valve.
2. Pressure Gauge: It is used to check the pressure of steam within the boiler drum.
3. Water Level Indicator: It shows the level of water within the drum.
4. Safety Valve: It is a valve which acts when the pressure of steam within the boiler drum increase above the safety level. It opens and releases the extra steam in the environment to maintain the desired pressure within the boiler.

Working:- First the water starts to come in the water tubes from drum through down take header.

The water present in the inclined water tubes gets heated up by the hot flue gases. The coal burning on the grate produces hot flue gases and it is forced to move in zigzag way with the help of baffle plates. As the hot flue gases come in contact with water tubes, it exchanges the heat with water and converts it into steam. The steam generated is moved upward and through up take header it gets collected at upper side in the boiler drum. An anti-priming pipe is provided in the drum. This anti-priming pipe filters the water content from the steam and allows only dry steam to enter into superheater. The superheater receives the water free steam from the anti-priming pipe. It increases the temperature of steam to desired level and transfers it to the steam stop valve. The superheated steam from the steam stop valve is either collected in a steam drum or made to strike on the steam turbine for electricity generation.



OR

Q1(b) Explain the working of Stirling bent water tube boiler

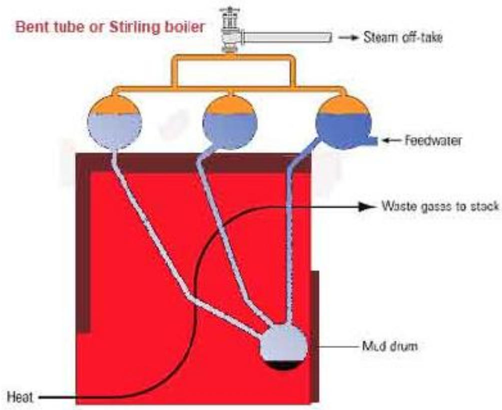
Bend Tube Boiler or Sterling Boiler is the developed version of water tube boiler. The working principle of bend tube boiler is more or less same as other water tube boilers, but it utilizes four drums.

Construction of Bend Tube Boiler

Three drums are placed on the heat source as shown on the figure. Fourth drum is placed inside the heat chamber and this fourth drum is connected to upper three steam drums with help of bend water tube. Upper three drums are connected with equalizer tubes as shown in the figure. Steam is taken from equalizer tubes.

Working Principle of Bent Tube or Stirling Boiler

The feed water first enters into right most upper drum. Due to more density this water comes down in the lower water drum. The water within that water drum and the connecting pipes to the other two upper drums, are heated up and consequently steam bubbles are produced. This is the most basic working principle of bent tube boiler .



Q2(a) Explain the working of regenerative with open feedwater heating cycle with neat sketch, also draw t-s diagram.

Regenerative Cycles - Open Feedwater Heaters

In a simple Rankine cycle, heat is added to the cycle during process 2-2'-3 (see the T-s diagram on the left). During this first stage (process 2-2'), the temperature of the water is low. That reduces the average temperature during heat addition (process 2-2'-3). To remedy this shortcoming, increasing the temperature of the feedwater (water leaving the pump and entering the boiler) can be considered. This is accomplished by extracting stream from the turbine to heat the feedwater. This process is called regeneration and the heat exchanger where heat is transferred from steam to feedwater is called a regenerator, or a feedwater heater. There are actually two main types of feedwater heaters. If the steam mixes with the compressed water from the pump, it is an open feedwater heater. If the steam does not mix with the compressed water from the pump, it is a closed feedwater heater.

An open feedwater heater is basically a mixing chamber, where the steam extracted from the turbine mixes with the water exiting the pump. In an ideal condition, the water leaves the heater as a saturated liquid at the heater pressure. The schematic of a steam power plant with one open feedwater heater is shown on fig. In an ideal regenerative Rankine cycle with an open feedwater heater, steam from the boiler (state 5) expands in the turbine to an intermediate pressure (state 6). At this state, some of the steam is extracted and sent to the feedwater heater, while the remaining steam in the turbine continues to expand to the condenser pressure (state 7). Saturated water from the condenser (state 1) is pumped to the feedwater pressure and send to the feedwater heater (state 2). At the feedwater heater, the compressed water is mixed with the steam extracted from the turbine (state 6) and exits the feedwater heater as saturated water at the heater pressure (state 3). Then the saturated water is pumped to the boiler pressure by a second pump (state 4). The water is heated to a higher temperature in the boiler (state 5) and the cycle repeats again. The T-s diagram of this cycle is shown on fig. Note that the mass flow rate at each component is different. If 1 kg steam enters the turbine, y kg is extracted to the feedwater heater and (1-y) kg continues to expand to the condenser pressure. So if the mass flow rate at the boiler is $\dot{m}$, then the mass flow rate from other components are:

Condenser: $\dot{m}(1\text{-}y)$

Pump I: $\dot{m}(1\text{-}y)$

Feedwater Heater: $\dot{m}y + \dot{m}(1\text{-}y) = \dot{m}$

Pump II: $\dot{m}$

For convenience, heat and work interactions for regenerative Rankine cycle is expressed per unit mass of steam flowing through the boiler. They are:

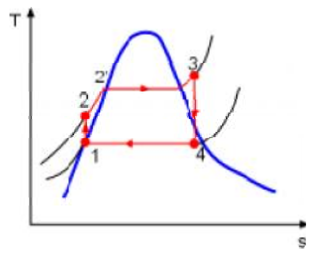
Heat Input: $q_{in} = h_5 - h_4$

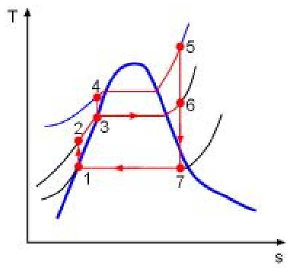
Heat Output: $q_{out} = (1 - y)(h_1 - h_7)$

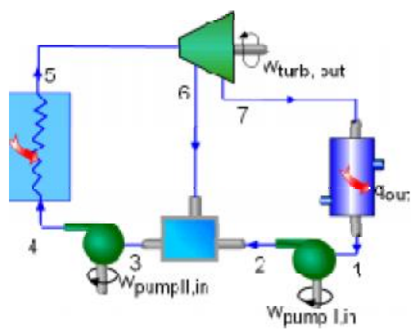
Work Output: $W_{turb,out} = (h_5 - h_6) + (1 - y)(h_6 - h_7)$

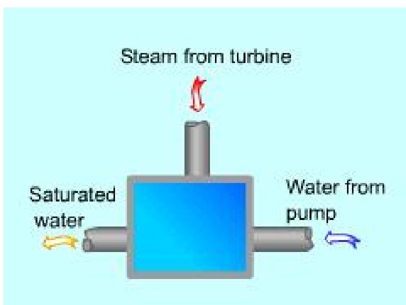
Work input: $W_{pump,in} = (1 - y)(h_2 - h_1) + (h_4 - h_3)$

Open feedwater heaters are simple and inexpensive, and can also bring the feedwater to saturated state. However, each feedwater needs a separate pump which adds to the cost.





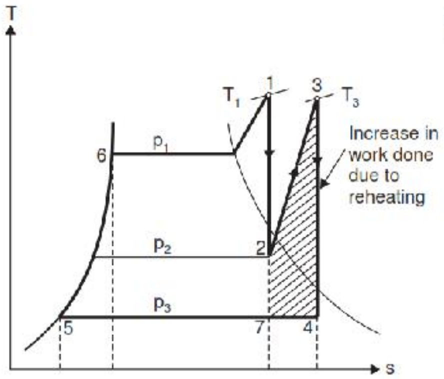


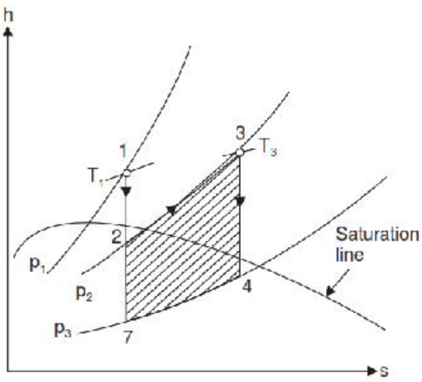


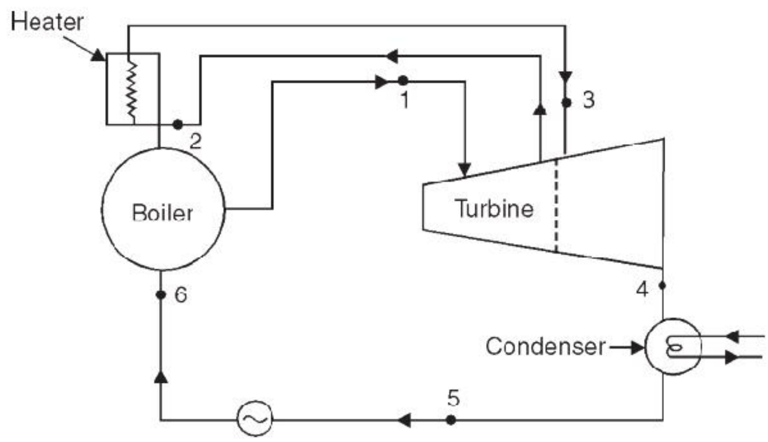
Q.2(b) Explain the working of reheat cycle with neat sketch and also plot t-s and h-s diagram.

For attaining greater thermal efficiencies when the initial pressure of steam was raised beyond 42 bar it was found that resulting condition of steam after, expansion was increasingly wetter and exceeded in the safe limit of 12 per cent condensation. It, therefore, became necessary to reheat the steam after part of expansion was over so that the resulting condition after complete expansion fell within the region of permissible wetness. The reheating or resuperheating of steam is now universally used when high pressure and temperature steam conditions such as 100 to 250 bar and 500°C to 600°C are employed for throttle. For plants of still higher pressures and temperatures, a double reheating may be used. In actual practice reheat improves the cycle efficiency by about 5% for a 85/15 bar cycle. A second reheat will give a much less gain while the initial cost involved would be so high as to prohibit use of two stage reheat except in case of very high initial throttle onditions. The cost of reheat equipment consisting of boiler, piping and controls may be 5% to 10% more than that of the conventional boilers and this additional expenditure is justified only if gain in thermal efficiency is sufficient to promise a return of this investment. Usually a plant with a base load capacity of 50000 kW and initial steam pressure of 42 bar would economically justify the extra cost of reheating. The improvement in thermal efficiency due to reheat is greatly dependent upon the reheat pressure with respect to the original pressure of steam. The steam as at state point 1 (*i.e.*, pressure p_1 and temperature T) enters the turbine and expands isentropically to a certain pressure p_2 and temperature T_{21}. From this state point 2 the whole of steam is drawn out of the turbine and is reheated in a reheater to a temperature T. (Although there is an *optimum pressure* at which the steam should be removed for reheating, if the highest return is to be obtained, yet, for simplicity, the whole steam is removed from the high pressure exhaust, where the pressure is about *one-fifth* of boiler pressure, and after undergoing a 10% pressure drop, in circulating through the heater, it is returned to intermediate pressure or low pressure turbine). This reheated steam is then readmitted to the turbine where it is expanded to condenser pressure isentropically.

The primary object of superheating steam and supplying it to the primemovers is to avoid too much wetness at the end of expansion. Use of inadequate degree of superheat in steam engines would cause greater condensation in the engine cylinder ; while in case of turbines the moisture content of steam would result in undue blade erosion. The maximum wetness in the final condition of steam that may be tolerated without any appreciable harm to the turbine blades is about 12 per cent. Broadly each 1 per cent of moisture in steam reduces the efficiency of that part of the turbine in which wet steam passes by 1 per cent to 1.5 per cent and in engines about 2 per cent.







OR

Q2 A steam turbine power plant equipped with a single regenerative feed heater operates under the given conditions. Initial pressure=16.5 bar, Initial superheat=93^o C, Extraction pressure= 2 bar and Exhaust pressure=0.05 bar. Compare the regenerative and non regenerative cycle with respect to the following (a) Thermal Efficiency(b) Steam Consumption in Kg per KWh and (c) condenser duty. It may be assumed that expansion is isentropic; that the feed water is heated to steam saturation temperature in the heater.

Q2 (OR)

Soln:-

From steam table, the initial temperature of steam

$= 202.85 + 93 = 295.85°C$

From chart, $h_0 = 3022$ kJ/kg [at 16.5 bar and 195.85°C]

$h_1 = 2598$ kJ/kg (at 2 bar),

$h_2 = 2115$ kJ/kg [Corresponding to 0.05 bar]

From steam table, $h_{f_1} = 505$ kJ/kg (at to 2 bar)

& $h_{f_2} = 138$ kJ/kg (at 0.05 bar)

Using heat balance equation at heater:-

$$m_1 h_1 + (1 - m_1) h_{f_2} = h_{f_1}$$

$$\therefore \quad m_1 = \frac{h_{f_1} - h_{f_2}}{h_1 - h_{f_2}} = \frac{505 - 138}{2598 - 138} = 0.1491 \text{ kg/kg (of entering steam)}$$

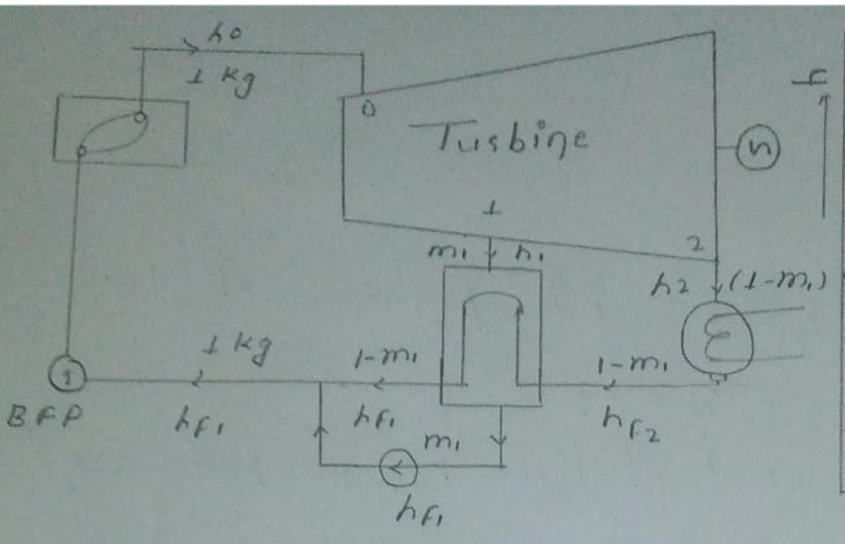
Neglecting pump Work = Work done in the cycle with regenerative feed heating.

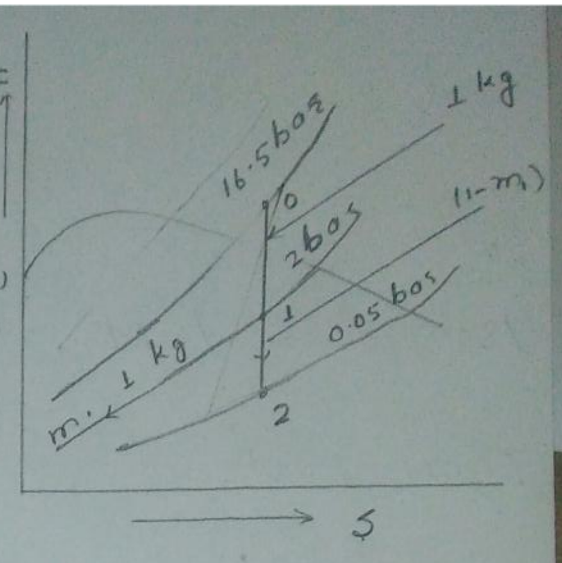
$= $ Work done by turbine

$= (h_0 - h_1) + (1 - m_1)(h_1 - h_2)$

$= (3022 - 2598) + (1 - 0.1491)(2598 - 2115)$

$= 834.984$ kJ/kg.





Heat supply = $h_0 - h_{f_1}$ = 3022 − 505 = 2517 kJ/kg

Hence the thermal efficiency with regenerative feed heating

$$(\eta_{th})_{Reg} = \frac{834.984}{2517} = 33.17\%$$

Workdone without feed heating = $h_0 - h_2$

= 3022 − 2115 = 907 kJ/kg

Heat supplied without feed heating = $h_0 - h_{f_2}$

= 3022 − 138 = 2884 kJ/kg

∴ Thermal efficiency without Regenerative feed heating (ie Rankine cycle)

$$(\eta_{th})_{Rank} = \frac{907}{2884} = 31.449\%$$

∴ Specific steam consumption/kwh without regeneration

$$= \frac{3600}{\text{workdone/kg}} = \frac{3600}{834.984} = 4.31 \text{ kg/kwh}$$

Specific steam consumption/kwh without reg. = $\frac{3600}{907}$ = 3.969 kg/kwh

Steam condensed in the condenser with regeneration is $(1-m_1)$ kg of entering steam.

Hence, condenser duty with regeneration is = (1 − 0.1491) × 4.31

= 3.667 kg/kwh

condenser duty without regeneration = 1 × 3.969 = 3.969 kg/kwh.