A: HYBRID MEANING IN GEOTHERMAL TECHNOLOGY

Geothermal Power Plant Types combined to each other/s to increase the efficiencies in different configuration.

B: CONVENTIONAL APPLICATIONS

Flash Type Geothermal Power Plants

The Closed polygon represents the power produced, in all cases

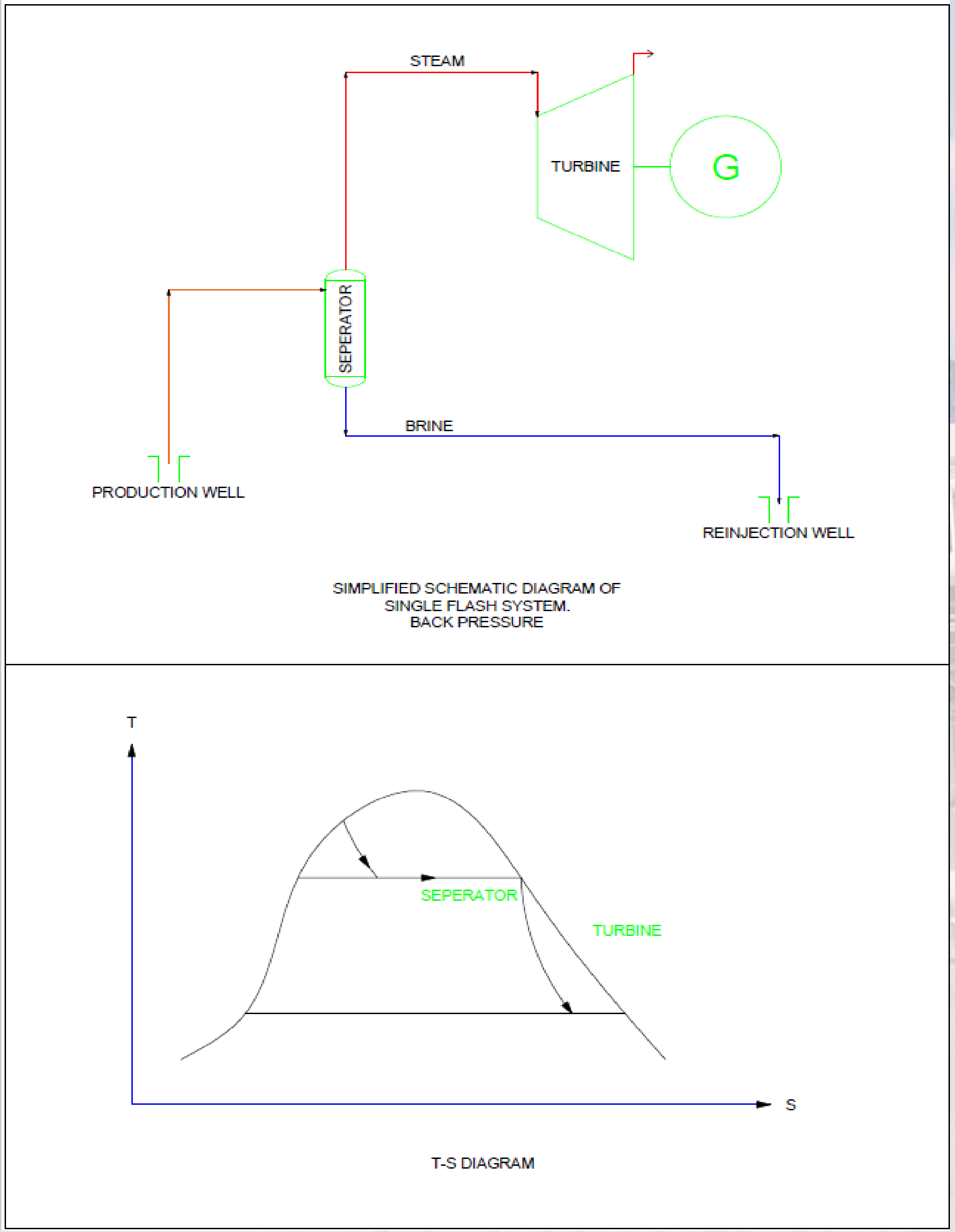
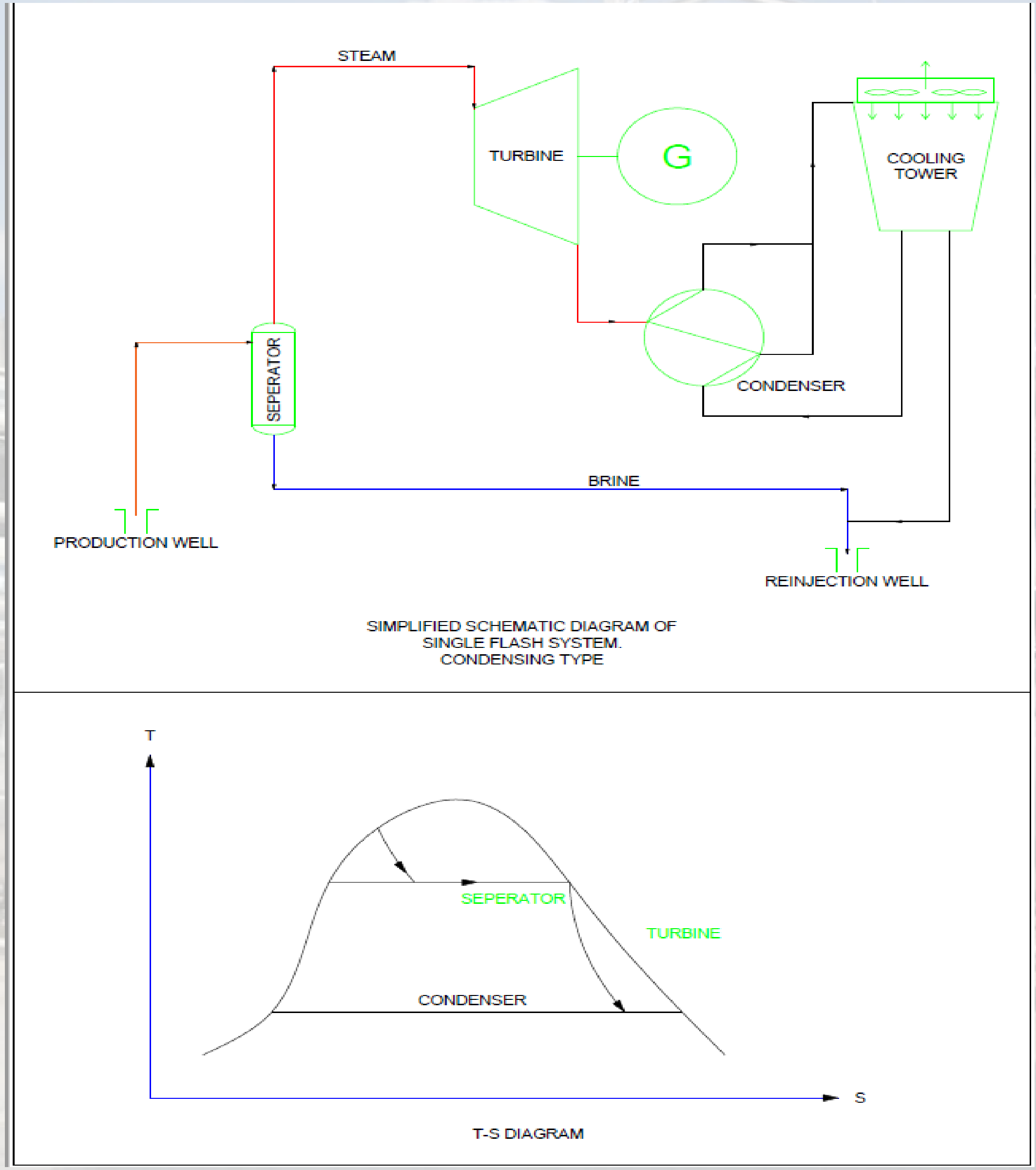


Figure 1: Single Flash System with back pressure

Single Flash System with condensing type

Figure 2: Single Flash System with condensing type

The difference is essentially to reduce the condensing pressure to increase the power production. The condensing pressure consequently reduces the condensing temperature.

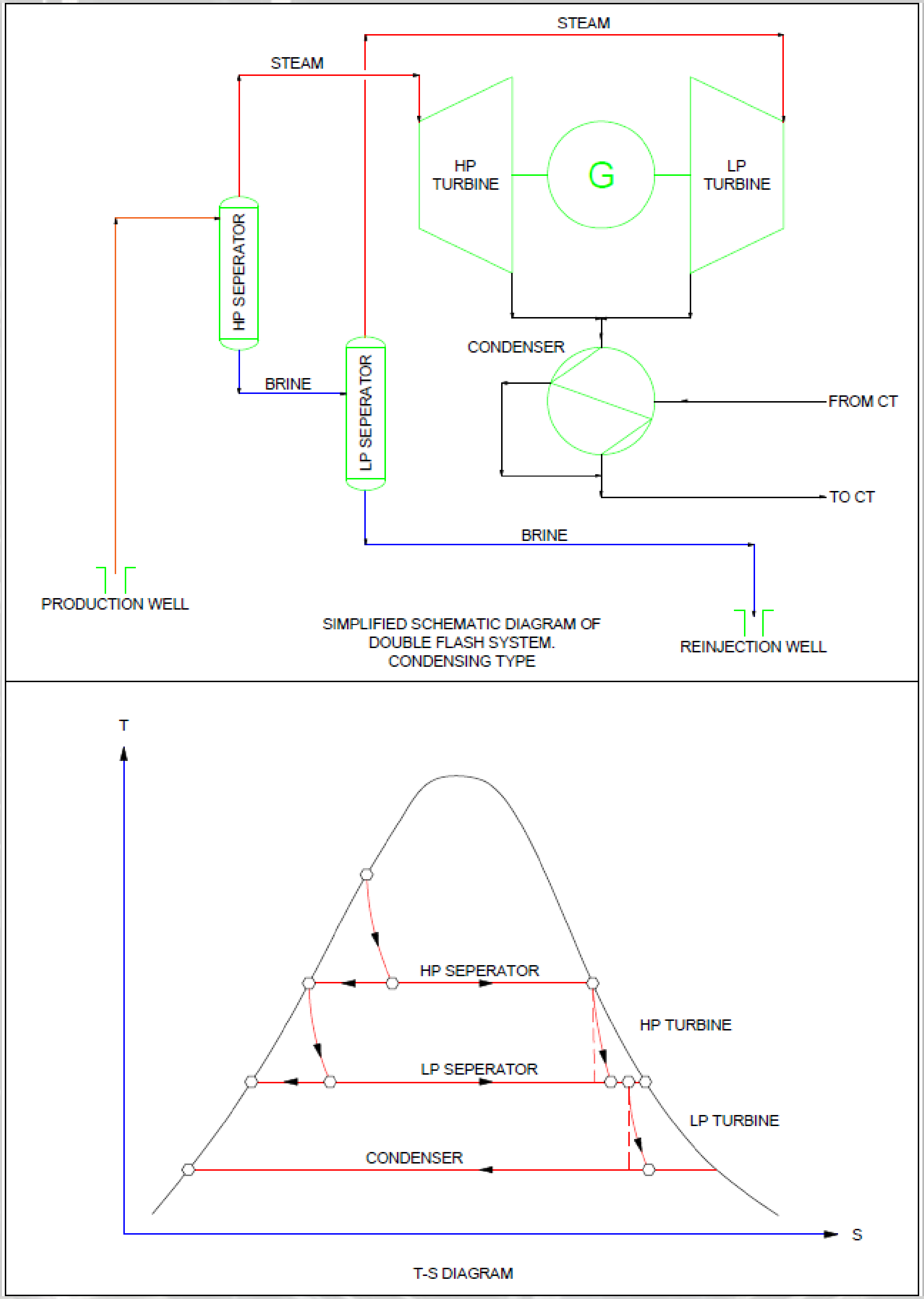


Double Flash System with condensing type

Figure 3: Double Flash System with condensing type

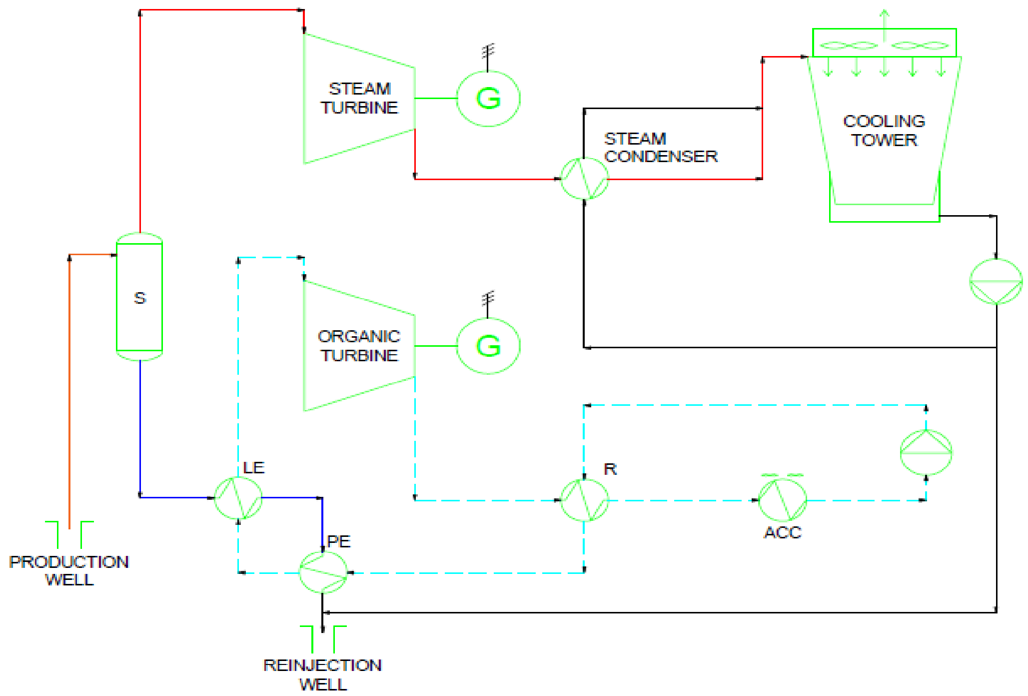
The Brine from the Single Flash System is evaporated in the LP Separator to obtain LP steam and given to the LP steam turbine.

There are now two closed polygons which have totally more area, showing the increase of power production.

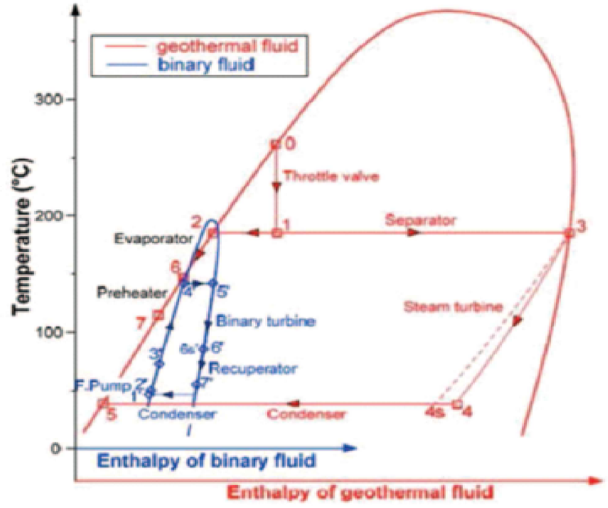


C. HYBRID TYPE GEOTHERMAL POWER PLANTS

Brine Bottoming Binary System
Figure 4: Brine Bottoming Binary (BBB) coupled to Flash System of condensing Type



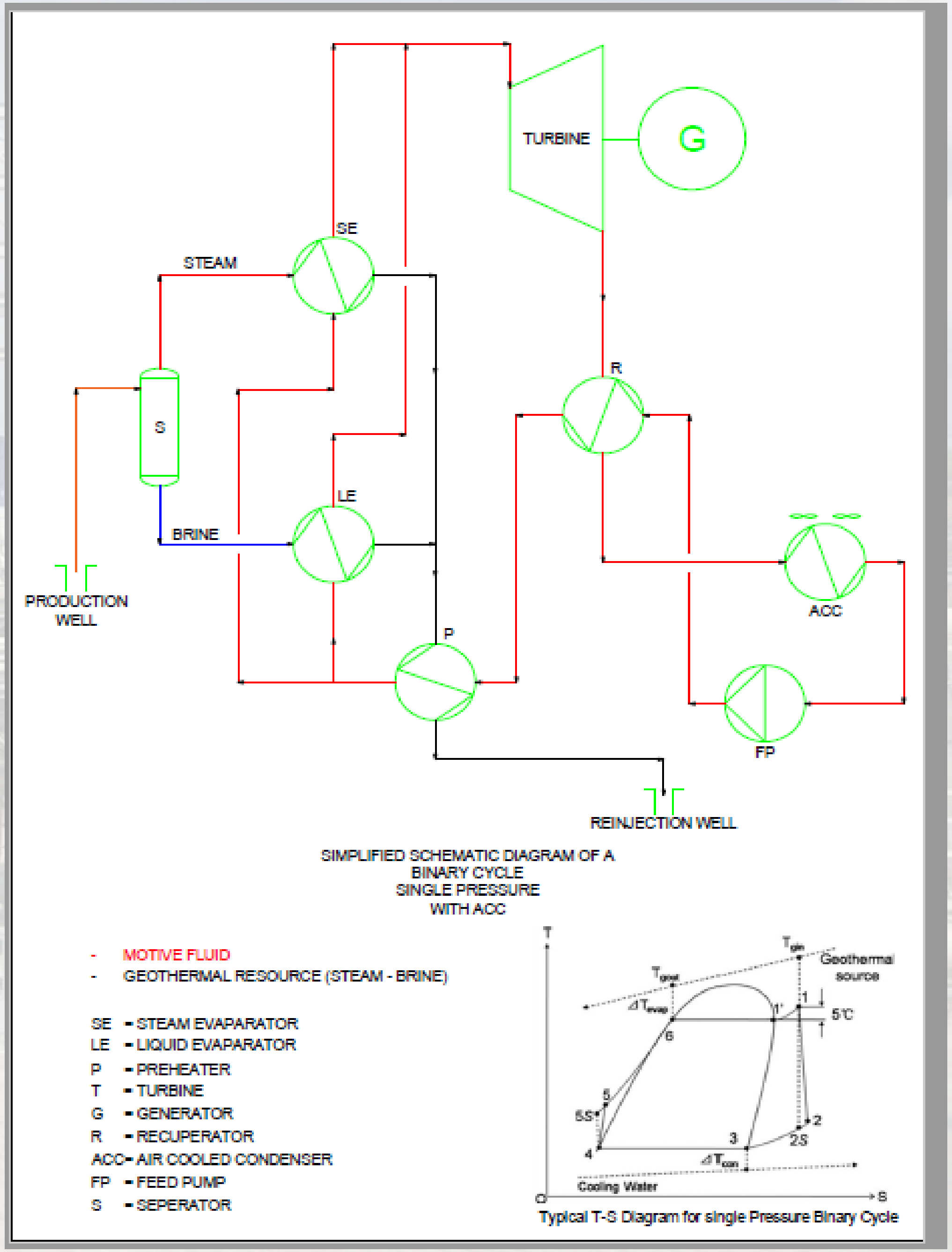
Simplified schematic diagram of a BBB system



Temperature-enthalpy diagram of a BBB system with n-pentane as the ORC fluid

Typical Binary Cycle ORC System of ACC Cooling
Figure 5: Typical Binary Cycle System with ACC cooling

The binary ORC Plants are most commonly used in our country as the resource temperatures are in the range of 130 – 165 ^{o}C.



I therefore wish to open a new era for different configurations of hybrid type binary plants as to increase the efficiency and ideas to develop the applications in various combinations.

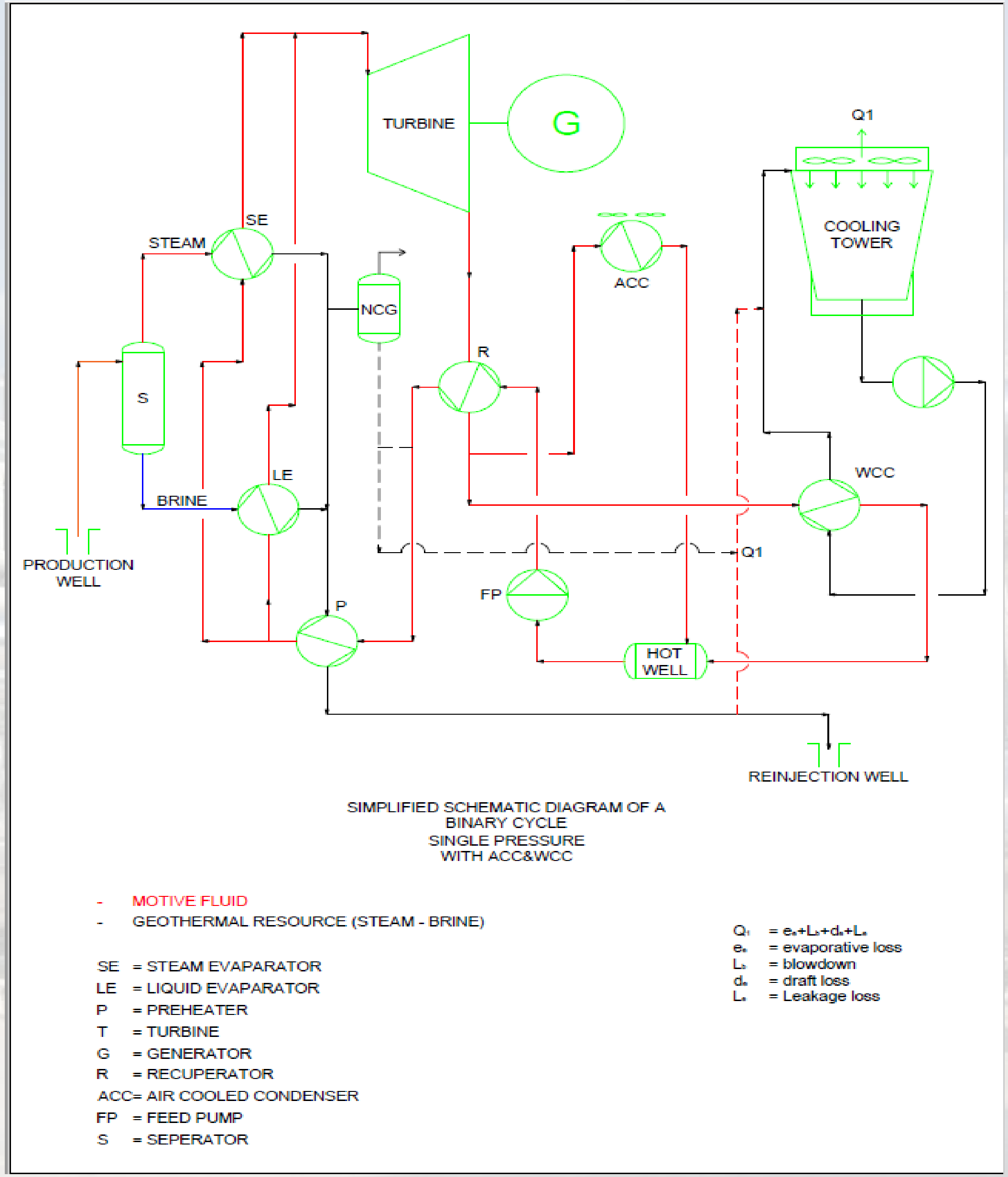
- The main problem of the Binary Plants of Air Cooled Condenser type is the production loss during summer time.
- Let us think to combine ACC with a Water Cooled condenser (WCC) with a Cooling Tower.
- The immediate question is where the additional make up water can be found.
- The answer is from the steam condensation and/or from the reinjection water.
- Now another question is how the increase of pond water temperature can be prevented due to high condensate and/or high reinjection water temperature.
- The answer is the cooling tower. Please think that in case the circulation of cooling water 2500 cum/h, the makeup water is only 55 – 60 cum/h. When it is passed thru the cooling tower, the pond water temperature is kept above 3 ^{o}C above the wet bulb temperature which can be estimated as 26 ^{o}C at about 34 ^{o}C ambient temperature. (wet bulb temperature is about 21 - 22 ^{o}C)

Meteorological wet bulb temp for AYDIN

Şehir	Yaz Kuru Termometre °C	Yaz Yaş Termometre °C
Aydın	39	24

Binary Cycle ORC System ACC & WCC Cooling

Figure 6: Hybrid Cooling with combined ACC & WCC



THE SOLUTION FOR BELOW COMBINED ACC & WCC APPLICATION

Binary plant of 7 mw binary Plant

Ambient Temperature is 20 ºC

Wells are equipped with ESP

Brine Flow rate is 546 t/h

Brine temperature to ORC is 150 ºC

Brine Pressure to ORC 8 bara

Reinjection temperature is 75 º

WCC Circulating water rate is 2555 cum/h

Case	ACC Air_In	ACC Duty	ACC Butane Out T	Expander Out Pressure	Expander Out T	**Butane Flow Percentage to WCC (%)**	Gross Power	ORC Thermal Efficiency	Power Difference vs design	Gain Percentage vs design
1	20	43820	31.16	4.439	50.02	**0**	7012	13.87		
2	26	42770	37.06	5.186	54.48	**0**	6314	12.94	698	
3	26	28320	32.72	4.627	51.36	**35**	6792	13.38	220	68.48
4	30	42170	40.99	5.736	57.92	**0**	5748	12.07	1264	
5	30	21680	34.78	4.889	53.62	**50**	6400	12.94	612	51.58
6	34	41650	44.93	6.328	61.66	**0**	5116	11.01	1896	
7	34	19320	38.15	5.334	57.07	**55**	5776	11.46	1236	34.81
8	38	41180	48.86	6.965	65.68	**0**	4420	9.758	2592	
9	38	17050	41.51	5.811	60.96	**60**	5068	10.09	1944	25.00

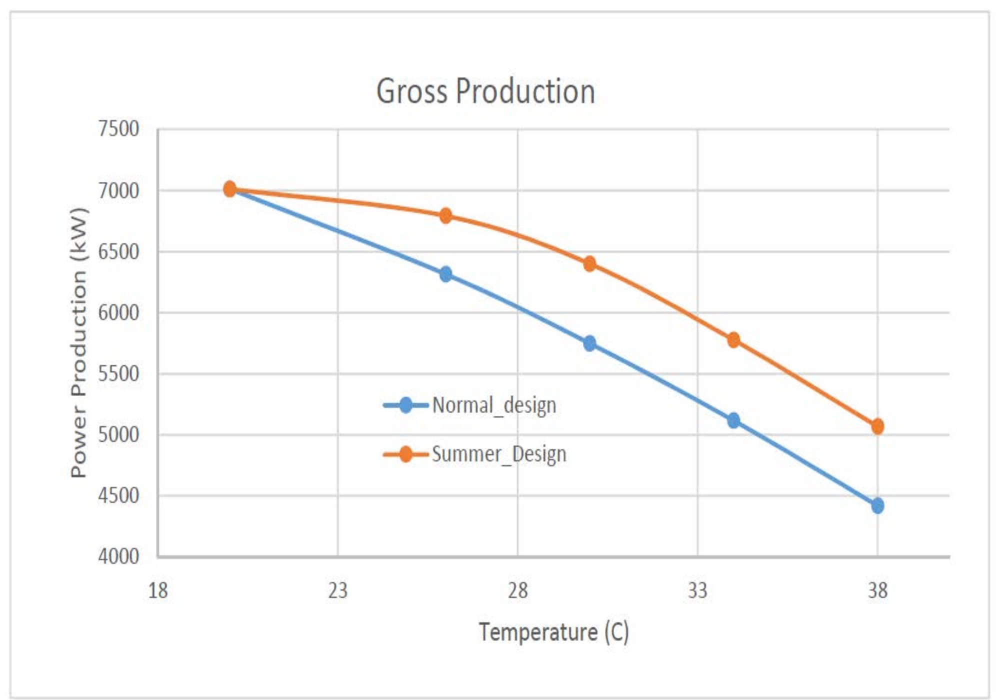
Table 1: Power Production increase

Where;

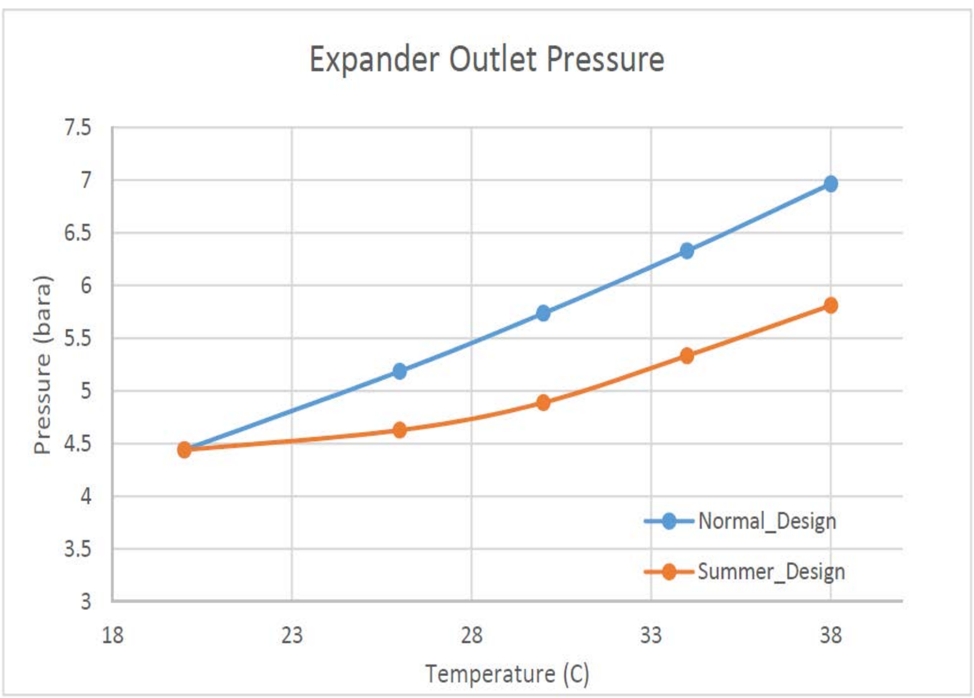
- Design case
- The conditions with ACC only
- The conditions with ACC & WCC combination

ACC air in	Ambient temperature
ACC Butane Out T	ACC outlet temperature
Butane Flow Percentage to WCC to (%) cooling water circulation	Percentage of Butane flow to WCC with fixed amount of
Gross Power	Gross Power without WCC and with WCC
Power Difference vs design	Power Los with the change of ambient temperature both for ACC only and ACC+WCC combination
Gain percentage vs design	ie @26 ºC, the production loss would be 698 kw for the power plant of 7 mw with ambient temp design 20 ºC.

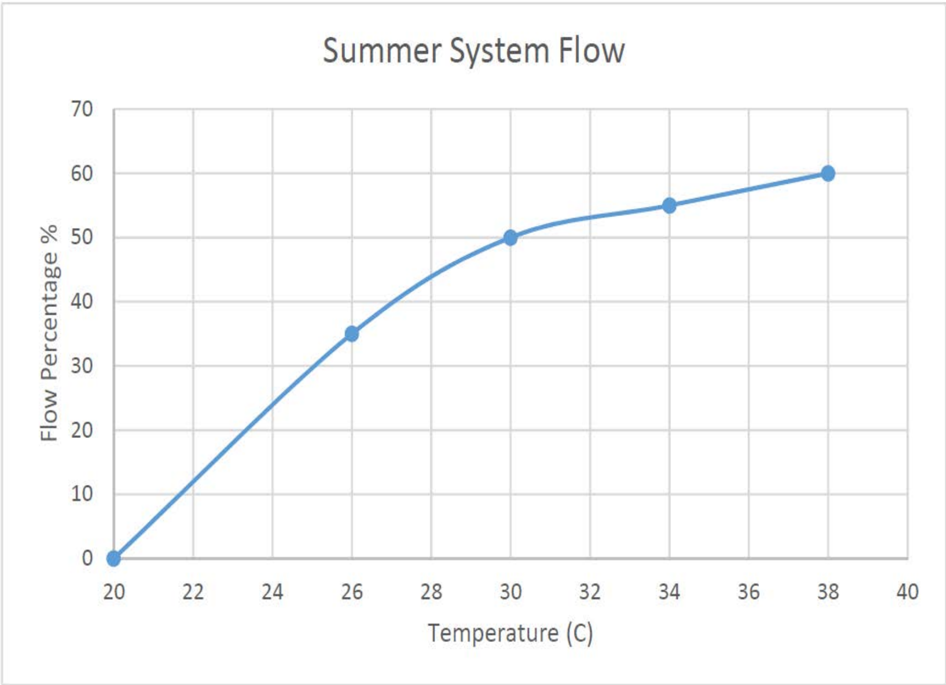
But when combined with WCC of constant circulating water (2550 cum/h) and butane thru WCC is 35 % of total butane circulation, the loss is only 220 kw. The gain is (698-220)/698=68,48%



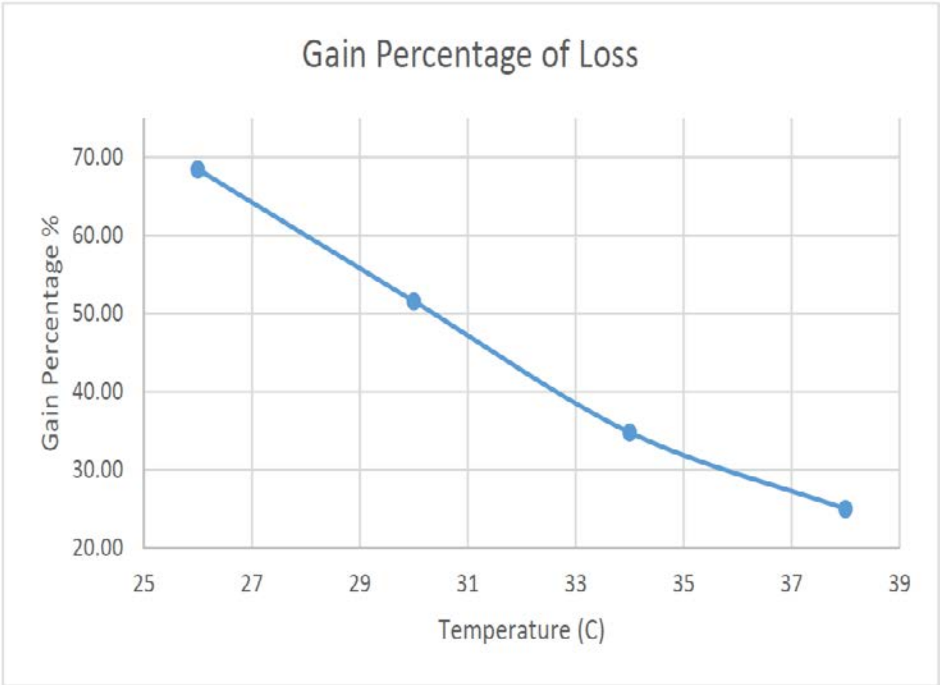
Graph 1: The red line shows the gross production of combined WCC + ACC
The Blue lie shows the gross production of ACC only



Graph 2: The red line shows the expander outlet pressure of combined WCC + ACC
The Blue lie shows the expander outlet pressure of ACC only



Graph 3: Butane percentage flow to WCC vs ambient temperature



Graph 4: Power gain percentage with WCC vs ambient temperature

ENHANCED COOLING with CHILLED WATER

Using the properties of ADSORPTION or ABSORPTION CHILLER, Chilled Water can be prepared by hot water which can be reinjection water.

The main advantage of these type of chillers are to function without compressors. Therefore no power consumption for chillers.

ADSORPTION Chillers do not need maintenance as no chemicals contain which causes high corrosion.

Chiller requirements are:

For Q1 cum/h amount of chilled water:

•2,75*Q1 cum/h cooling water circulation

•1,5*Q1 cum/h reinjection water

It can be thought that this type of enhanced cooling can be made for 4 hours a day from 11 to 15 O'clock

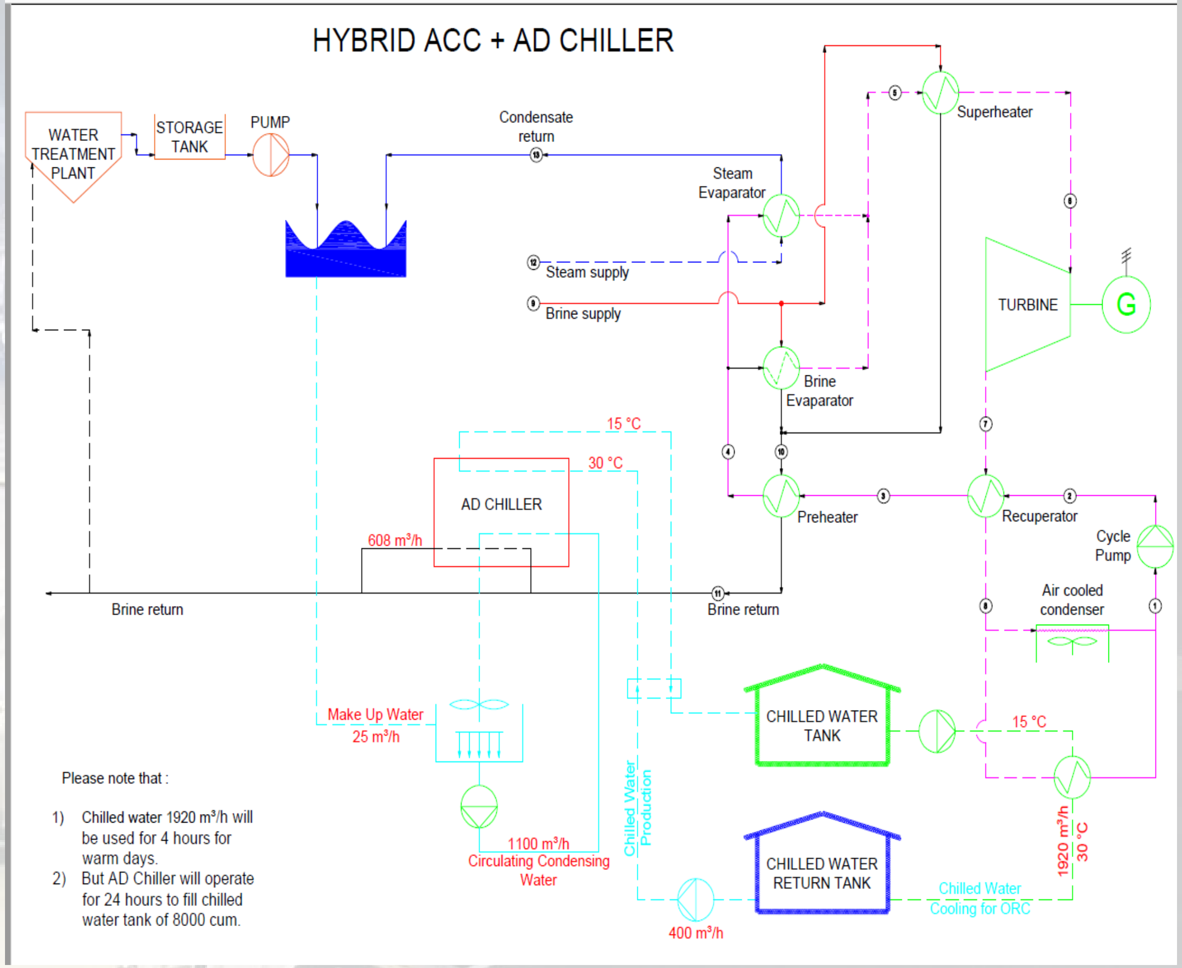
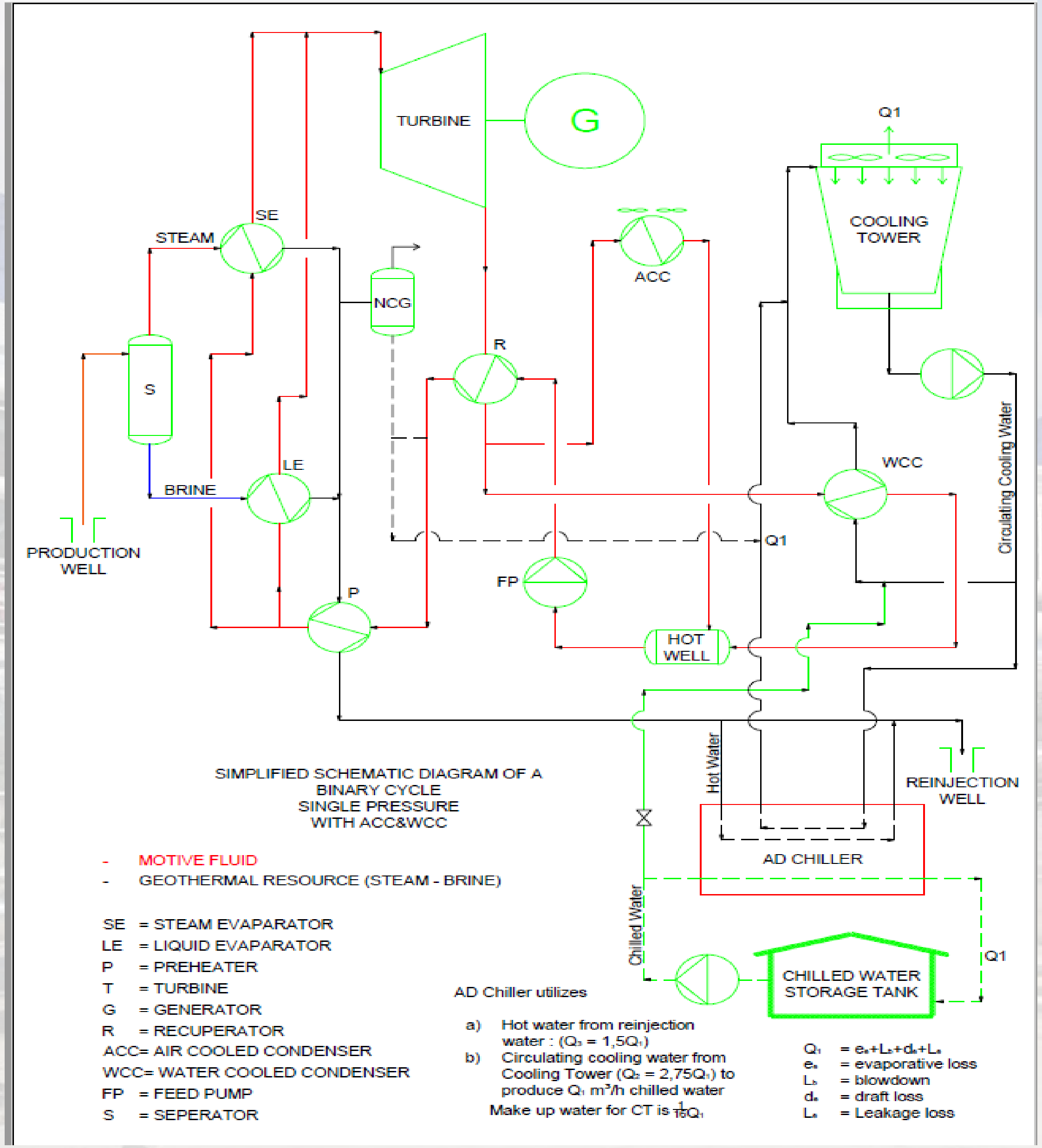


Figure 7: Hybrid ACC & AD Chiller



ENHANCED COOLING WITH 3 COMBINATION; ACC+WCC+CHILLED WATER

Figure 8: Cooling with ACC & WCC & AD Chiller

HYBRID ORC PLANT WITH SOLAR ENERGY

DESIGN CONCEPT WITH HYBRID SOLAR ENERGY APPLICATION TO ORC BINARY PLANT

Application for a 5 MW Electricity Production Power Plant:

Thermal Resource Media is Synthetic Oil (Therminol 75) heated by solar Energy

ORC Cycle efficiency is about 20 %.

Thermal Energy Requirement for ORC Cycle is then 25 MW.

Thermal Energy Requirement from Solar plant is then about 45 MW

The electrical production is planned for 8.00 am to 10.00 pm, that is 14 hour production.

The availability of solar energy 10 hours from 8.00 am to 6.00 pm. That is 10 hours.

The energy requirement from 6.00 pm to 10.00 pm must be provided by stored thermal energy.

THE APPROACH TO THE SOLUTION AS AN EXAMPLE

- Choose the Synthetic Oil to be heated by Solar Energy,
- Decide the temperature of oil from the Solar Plant to ORC Plant
- Decide the temperature of Oil from the ORC Plant back to the Solar Plant
- Calculate the required Oil flow rate to ORC Plant during sunny hours
- Calculate the amount of oil to be stored for ORC Plant to run for 4 hours from 6.00 pm to 10.00 pm in the dysfunctional state of solar plant after sun set
- Set up the Hybrid Plant configuration and its operational scenario as below:
    - Solar Plant capacity must be sufficient to run ORC plant + Oil to be stored, in sunny hours that is 10 hours from 8.00 am to 6.00 pm.
    - The required land area for the Solar Plant must be decided: (about 300 decare)
    - Two Storage Tanks have to be planned to function as:

during sunny hours (8.00 am – 6.00 pm)
Oil Flow Rate from Solar Plant: m1 = 225 kg/s in line A
Oil Flow Rate to ORC Plant: m2 = 135 kg/s in line B
Oil Flow Rate to Storage Tank I: m3 = 90 kg/s in line C
Oil Flow Rate from ORC Plant: m4 = 135 kg/s in line E
Oil Flow Rate from Storage Tank II: m6 =90 kg/s in line H
Oil Flow Rate to Solar Plant: m7 = 225 kg/s in line F

Please note that;
m1 = m2 + m3
m7 = m5 + m6

Therefore, Mass Flow for Solar Plant is balanced
The required quantity of Oil for 4 hours is 1920 ton.
This amount is thought to be filled in 6 hours.

As a result: m3 = m6 = 90 kg/s

during no sun hours (6.00 pm – 10.00 pm)
Oil Flow Rate from Solar Plant: m1 = 0,0 kg/s in line A
Oil Flow Rate to ORC Plant: m2 = 135 kg/s in line B

Oil Flow Rate from Storage Tank I: m4 = 135 kg/s in line D
Oil Flow Rate to Storage Tank II: m5 = 135 kg/s in line G
Oil Flow Rate from Storage Tank II: m6 = 0,0 kg/s in line H

Please note that;
m2 = m4 This means that ORC is running as in sunny hours

m4 = m5 This means that the Oil Flow from ORC is taken to Storage Tank II

m6 = 0,0 This means that no flow from storage tank II and is filled

EXTENSION OF THE APPLICATION BY COMBINED BIOMASS AND HVAC

- A Cattle Farm can be established in the neighbored area to couple the biomass energy plant to solar energy plant thru the recovery boiler especially for cloudy days and no sun hours.

- In case water is utilized for the cooling of the motive fluid, the heat gained by the water can be used for:
  - Heating of residents or industrial zone by heating the feed water of boiler in winter time and
  - Air conditioning of residents or industrial zone in summer time by adsorption chiller in summer time.

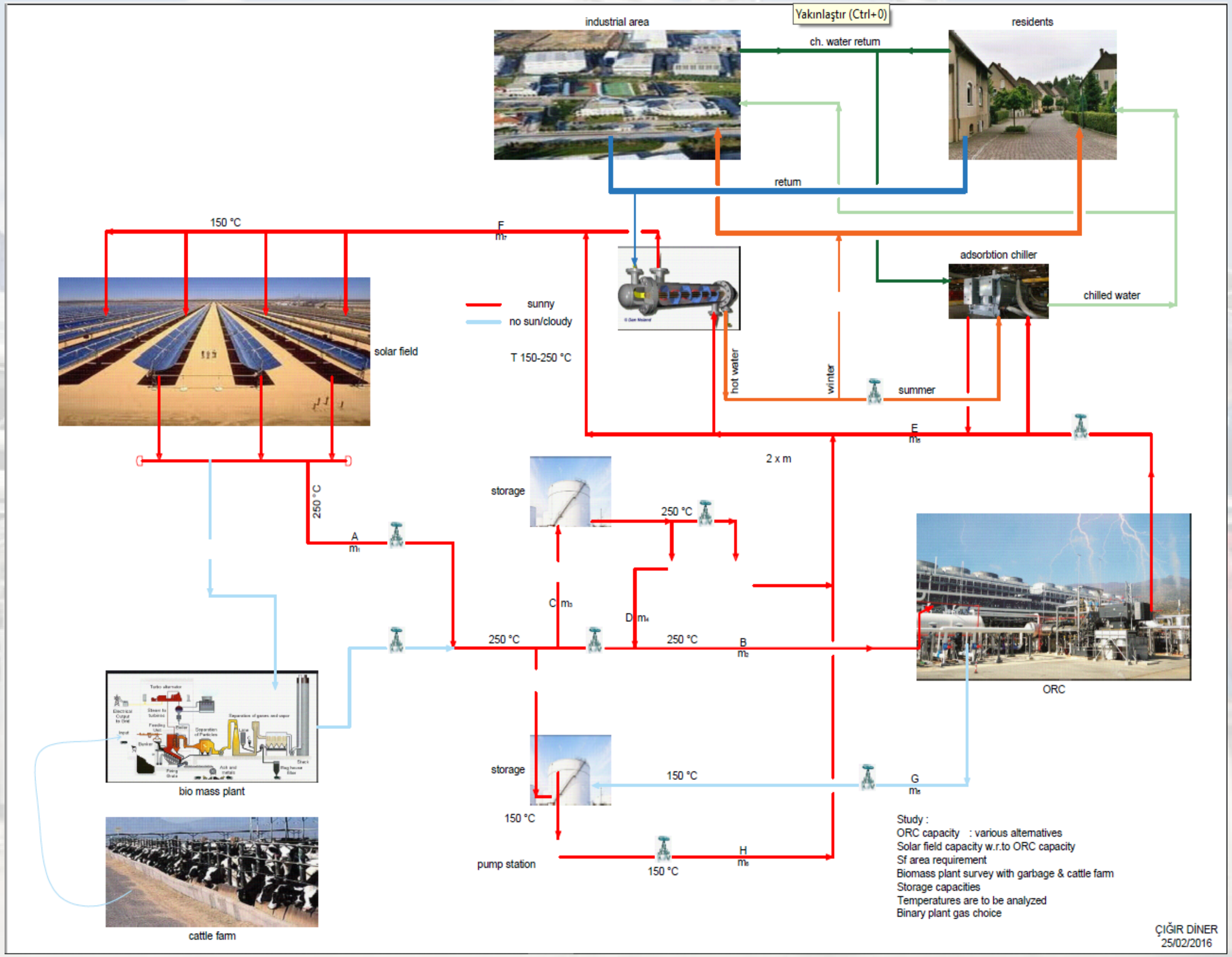


Figure 9: ORC Plant with Solar Energy and combination with Cattle farm & HVAC System

Thank You For Your Attention

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