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Utilizing Low Pressure Waste Steam to Heat Injection Water by Using Direct Contact Steam Condenser: A Case Study

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ABSTRACT

Geothermal reservoir pressures which change due to interferences of wells, drilling of additional production wells, wrong re-injection strategy and reduction of NCGs content in reservoir, etc., drop in time. The decreasing in reservoir pressure results in more steam coming out of wells at less wellhead pressure than initial condition. Because of design parameter ranges of geothermal power plants, most plants could not use the excess low pressure steam which is released to atmosphere at this point as a waste. The feasible ways must be sought after to recover this waste steam. Direct contact steam condenser (DCSC) is a system to recover for the waste steam. The idea behind the DCSC is to condense this waste steam which then can be send to the process to be used. It is different from shell and tube heat exchangers because there is no intermediate metal surface to transfer the heat from hot source to cold source. Hot and cold streams contact directly in the system which result in higher efficiency for the heat transfer then regular heat exchangers. There are several layers of equipment in the vessel to make this direct contact more evenly throughout the vessel. Cold source can be re-injection stream or process stream which is colder than the waste steam. DCSC is not just a pressured vessel but involves pumps, control valves, piping and instruments. This system is designed and implemented for 24 MW Kubilay Geothermal Power Plant of Bestepeler Enerji Üretim Tic. A.S in Aydın/Turkey to use their 139 °C waste steam at 2.7 bar for heating up re-injection fluid. As a result, the temperature of re-injection water with 200 tons/hour flow rate increased from 60 °C to 135 °C by using 25 tons/hour unused waste steam at 139 °C. Then the new fluid at 135 °C with 220 tons/hour is used to generate 1500 kWe net electricity in Kubilay Geothermal Power Plant.

1. INTRODUCTION

During the purchase order of geothermal power plants, when the power plant design data is determined, the thermophysical properties (temperature, flow rate, pressure, etc.) of the geothermal fluid may deviate from the values determined initially after the commissioning of the power plant, since all production wells cannot be opened or long-term interaction tests cannot be performed yet. Sometimes, due to the pressure drop in the reservoir during the operation period, temperature and pressure decrease at wellhead and as a result of this the flow rate of the geothermal brine decreases and the steam rate increases in the total flow rate.

In geothermal wells, steam & NCG and brine are physically separated by separators that are used at the wellheads, then pressurized by brine wellhead pumps and sent to the main brine pipeline, while steam & NCG at the separator outlet flows with natural pressure and is sent to the plant by merging with main steam & NCG pipeline. When wells with low pressure and high pressure are connected to the same steam line, the vapor of the high pressure well overcomes the low pressure well, which can cause the low pressure well to not deliver enough flow or cause the well to die (flow stops).

In order to make maximum use of the brine of the low pressure wells in the fields whose well pressures are different from each other, steam is discharged from the wellhead to the atmosphere after the separation station and only the steam of high pressure wells is sent to the plant for electricity production.

In flash type power plants, low pressure vapors can be used in low pressure steam turbines, whereas in plants with binary cycles, the vapor of wells whose pressure drops at later stages, cannot be included in the cycle. When you observe the Binary Cycle GPP investments in the Aegean Region, which is currently concentrated, it can be seen that the vapor of low pressure wells is thrown from the wellhead to the atmosphere.

The results of the discharge of low pressure steam from the wellhead are given below:

- Geothermal resources from underground cannot be used efficiently.
- Steam with 4 times more energy than geothermal brine at the same temperature and flow is discharged to the atmosphere and cannot be used in electricity generation.
- Since the vapor discharged into the atmosphere cannot be condensed again, it is not re-injected into the reservoir. In this case, less of the total fluid taken from the reservoir is send back into the reservoir.
- Discharging steam creates a negative impact on the environment and causes the reaction of local people.

However, the low pressure also prevents the steam from being sent to the plant.



Figure 1: Representative field image for steam ejected from wells (Source: https://steemit.com/geothermal/@tracybkane/geothermal-energy-using-technology-to-harness-free-electricity-from-within-the-earth at 9:00 AM on 29.03.2018)

2. SOLUTION OF WASTE STEAM PROBLEM

2.1 Method

In order to eliminate this problem, GMK Enerji has developed the "Direct Contact Steam Condenser" project. All thermodynamic and mechanical designs of this project have been done with Turkish engineering.

"Direct Contact Steam Condenser" is a heat exchanger on the basis which provides heat transfer by direct contact of two different phase fluids with each other without any steel pipe bundle between them. "Direct Contact Steam Condenser" is 5% more efficient and 60% cheaper than a shell and tube heat exchanger in terms of investment cost.

The advantages of the direct contact steam condenser and tube bundle heat exchanger, which are shown in Figure 2, are presented in Table-1.

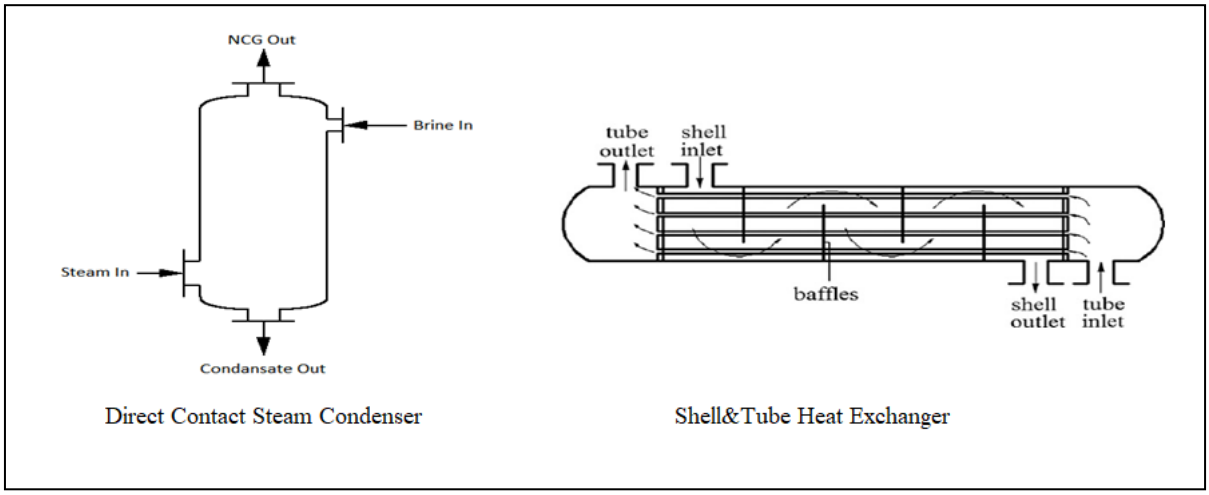


Figure 2: Representation of direct contact steam condenser and tube bundle heat exchanger (utilized from Kakac and Liu, 2002)

Table 1. Differences between direct contact steam condenser and tube bundle heat exchanger

Direct Contact Steam Condenser	**Shell & Tube Heat Exchanger**
Higher Heat Transfer Rate (≈%96).	Lower Heat Transfer Rate (≈%91).
Fluid at Two Different Temperatures, Different or Same Phase can be combined at the same temperature at the outlet.	After the heat transfer, the temperature difference occurs between the two fluids at the heat exchanger outlet.
Fluids must be at the same pressure.	Can work at different pressures.
Easier to separate NCG from steam, lesser waste steam is released.	More waste steam is released.
Installation and Operation is Simple, Investment Cost is Low	Installation and Operation is Difficult and Investment Cost is High.

By using the heat of low pressure steam with the direct contact steam condenser, it is possible to re-heat the cooled re-injection water and send it to the inlet of the plant and thus increase the electricity production in the plant.

2.2 Working Principle

The direct contact steam condenser is on basis a pressure vessel of which width, height and interior are specially designed. The design is precise and difficult, as the heat transfer is achieved by contacting the liquid and gas phases with each other. Within the direct contact steam condenser, steam & NCG proceed from the bottom upward, while the geothermal brine falls from the top downward. An example system design for the direct contact steam condenser is shown in Figure-3.

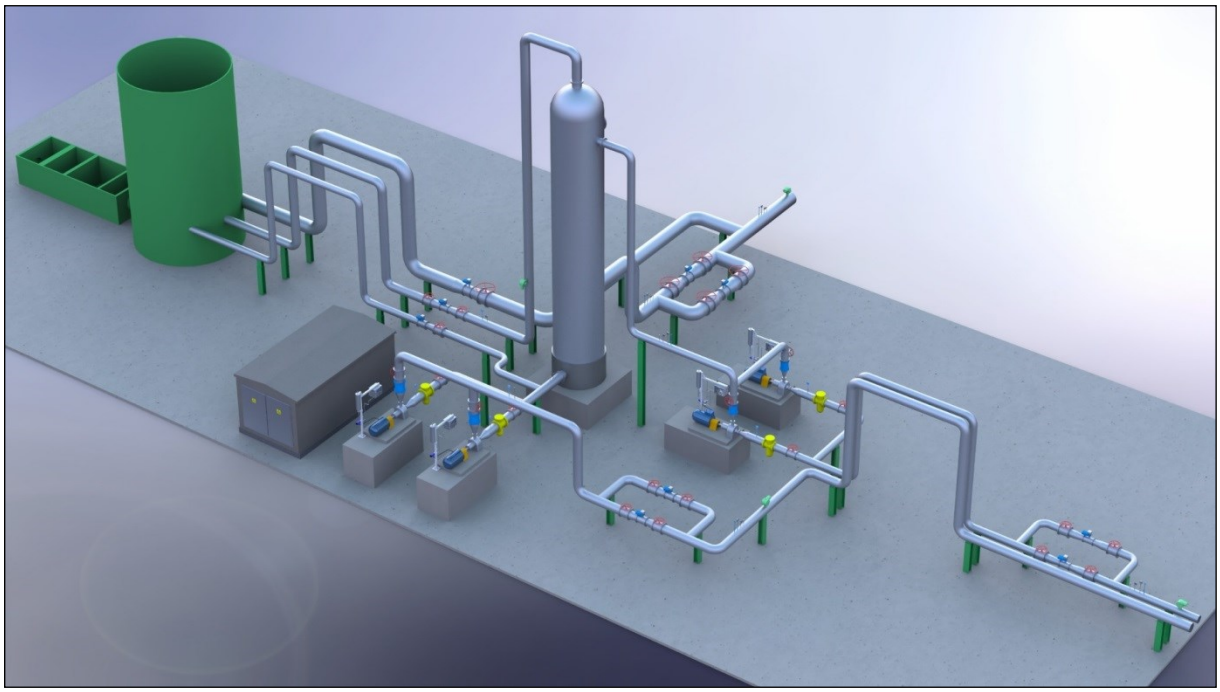
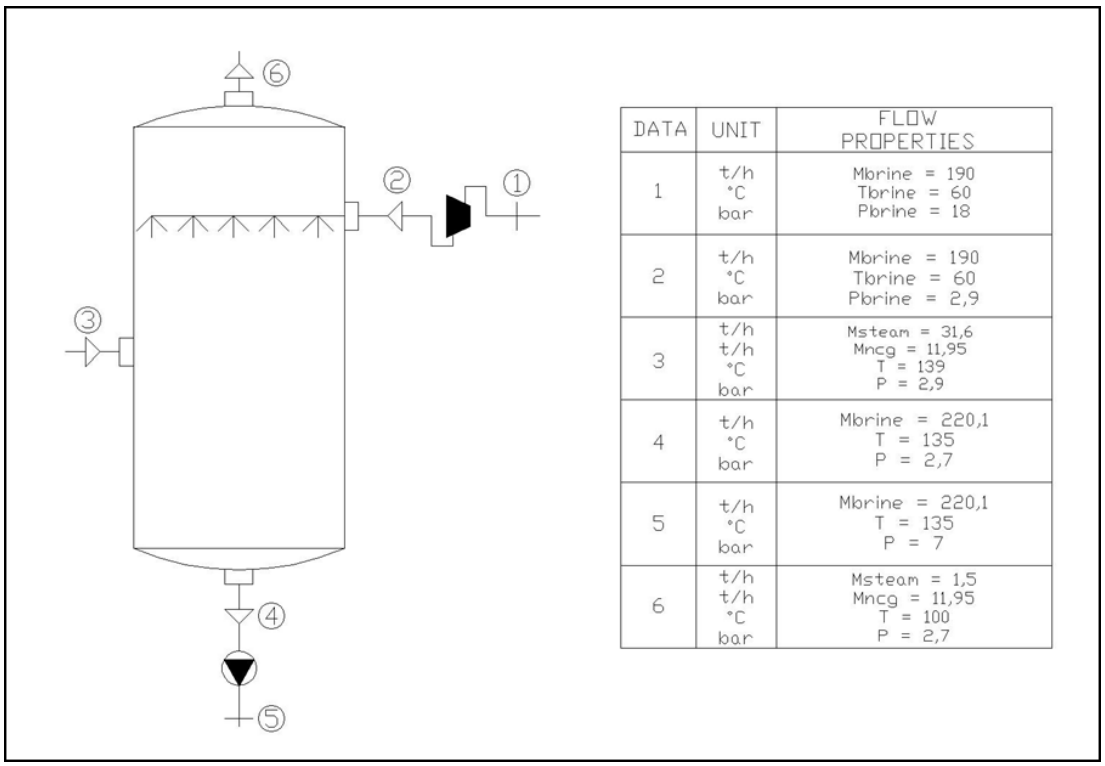


Figure 3: 3D application of direct contact steam condenser (Source: GMK Energy).

2.3 Example Field Application at Bestepeler Enerji

Direct Contact Steam Condenser project designed by GMK Energy to eliminate the waste steam problem in the 24 MW capacity Kubilay GPP plant owned by Bestepeler Enerji Üretim Tic AŞ, which has low pressure waste vapor at high flow rate. It was commissioned on 22 February 2018.

With this project, temperature of the re-injection water with 60°C and 190 tons/hour flow rate increased to 135°C and with addition of condensed steam 220.1 tons / hour additional geothermal fluid was sent to the power plant.



DATA	UNIT	FLOW PROPERTIES
1	t/h °C bar	Mbrine = 190 Tbrine = 60 Pbrine = 18
2	t/h °C bar	Mbrine = 190 Tbrine = 60 Pbrine = 2,9
3	t/h t/h °C bar	Msteam = 31,6 Mncg = 11,95 T = 139 P = 2,9
4	t/h °C bar	Mbrine = 220,1 T = 135 P = 2,7
5	t/h °C bar	Mbrine = 220,1 T = 135 P = 7
6	t/h t/h °C bar	Msteam = 1,5 Mncg = 11,95 T = 100 P = 2,7

Figure 4: Heat&Mass balance values of the direct contact steam condenser applied in Bestepeler Enerji (Source: GMK Energy)

In addition, a special pressure reducing turbine was used to equalize the pressure of the water taken from the re-injection to the steam pressure and it was planned to generate an additional energy of 60 kW with this turbine.

GMK Energy's special design Direct Contact Steam Condenser enables Kubilay JES to generate 1500 kW of net electricity without additional wells.

In addition, the project has been beneficial to the environment with the use of waste steam, which had to be thrown into the atmosphere in the past.

As a result, the application of “Direct Contact Steam Condenser” will play a major role in recovery of the waste steam into energy production in low well pressure fields.



Figure 5: Start-up day photo of DCSC.

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