Seasonal Storage of Air Cooled Water for Arid Zone Geothermal Power Plants

Robert Collins
Enreco Pty Ltd P.O. Box 690 Alice Springs NT 0871
Email: enreco.geothermal@gmail.com

This paper presents a new option for heat rejection from geothermal plants. Our 20 years experience with small geothermal plants at Mulka Station and Birdsville has convinced us that heat rejection is a major issue in Australian conditions. In arid zones air cooling has been the option of choice due to lack of water and the availability of industrial air condensers. This option has proved expensive, with costs in the U.S. of 20 - 30% of the total capital costs, including wells for 5 major geothermal plants

As noted previously by several authors this option also comes with severe performance penalties due to the extreme summer daytime temperatures. When the demand for electricity is greatest the geothermal electric output will drop by up to 40%. The geothermal industry needs to begin development and testing of new heat rejection options to solve this problem.

Just as the desert presents problems with high daytime temperatures, it offers opportunities with very low night time temperatures, large areas of land available and in most regions, shallow, saline aquifers suitable for water storage. A simple heat rejection system taking advantage of these characteristics is illustrated in Figure 1. A water cooled condenser using saline water from a shallow aquifer provides the heat rejection sink for the geothermal plant. The area of the aquifer used is sized to provide approximately 6 months of cooling water. The water that is returned to the aquifer is intermittently cooled by air coolers when the air temperature is below a set value. As long as the heat rejected to the air during cooler periods matches the heat going into the water form the condenser over the year, a constant water temperature will be maintained.

While the conditions necessary for this concept to work occur in most desert regions, the focus of this paper is on the geothermal areas of interest in the North East of South Australia above the Cooper Basin. Details of this concept, along with advantages and issues, and a design for an illustrative 2 MW geothermal plant cooling system are provided below. Also the matching of this concept with CO_2 as the geothermal fluid as well as plant working fluid is considered

SYSTEM CONCEPT

The system has 3 separate energy loops. The first is the circulation of the saline groundwater from production bores through the geothermal plant condenser and into the reinjection bores. The second energy loop is the intermittent air cooling of the groundwater after it leaves the condenser. This loop rejects to the atmosphere during cooler periods of the year, the heat from the condenser. The third energy loop is also an intermittent air cooling of the groundwater. This loop takes groundwater part of the way between the production and re injection bores and also cools it intermittently during cooler periods. The purpose of this third loop is to provide the extra cooling capacity to compensate for the intermittent operation.

The massive energy storage capacity of the shallow aquifer means that the heat rejected by the condenser can be balanced out over the year by the heat rejected to the atmosphere from the aquifer. The temperature of the water reinjected into the aquifer will vary from 40 °C on a summer day to due to no air cooling to 15 °C on a winter night with air cooling. These temperature variations will be smoothed over the year as the water slowly migrates in the aquifer from the reinjection to production bores.

The air coolers used for aquifer water cooling will be air to water coolers rather than air condensers. This will allow more efficient counter flow heat exchange compared to constant temperature condensing. However, they will have to transfer the same amount of heat only operating intermittently for 1/2 of the year. A major benefit of the intermittent operation is that they can be operated when desired during periods of minimal demand. This will remove the heavy parasitic power load during peak periods, increasing the net power output of the geothermal plant by 10-15% above its rated capacity.

Using saline ground water for cooling should not be a problem as seawater fed condensers operate around the world. Scaling problems should be minimal if the water temperature is kept below 40 °C. The 2 potential scaling problems with this groundwater are silica and calcium compounds. Both can be serious if there is any evaporation which brings them closer to saturation in the solution. Calcium can be a problem if there is heating beyond 40 °C as its saturation limit rapidly declines above this. Neither condition exists for this concept.

The cost of this complete condensing system will be greater than a standard air cooled condenser. The air to water coolers will have to have double the heat rejection capacity of an standard continuously operating air condenser, since they will only be operating ½ the time. There will also be additional components such as the water cooled condenser, the saline aquifer bores, and submersible pumps. We estimate the cost for the complete system will add approximately 10% to the cost of a geothermal plant. The benefits far outweigh this cost. Instead of a 2 MW plant producing 1.2 MW on a hot day due to higher condensing temperatures, it would produce its rated 2 MW plus an extra 0.3 MW of reduced parasitic power loss not required for air cooling fans. Thus the useful output is nearly doubled when it is most needed and high value.

SALINE AQUIFERS

Shallow saline aquifers are nearly ubiquitous in the areas of interest above the Cooper Basin.

This is not surprising as Cooper Creek is part of the Lake Eyre Basin, which is the largest internal drainage basin in the world. Cooper Creek spreads out into a vast meandering area of ephemeral channels that are normally dry.

Saline groundwater is normally found at depths of 10 - 100 metres and even closer to the surface near salt pans. Aquifers can be 10s - 100s of metres thick. This water is of no economic value because it usually has too high a salt content for stock watering or cropping. Salt content is quite variable.

The bores for production and reinjection would be approximately 40 metres deep and cased with slotted PVC pipe. For a 2 MW geothermal plant approximately 20 of each would be required. These shallow bores should be relatively cheap to drill at 50 metre spacings. There are many suitable patterns for the bores, but probably the simplest is 2 parallel lines of bores separated by a suitable distance for the required 6 months storage requirements. For the other air cooling loop an additional 20 production and re injection bores would also be required

If we assume an aquifer thickness of 30 metres, soil porosity of 30%, then there is 10 thousand mega litres of water available per km^2. Thicker aquifers are better as they provide greater storage in the same area and also have higher flow rates/bore, requiring less bores. Typical shallow aquifer water temperatures in the Cooper basin are 23 °C. This is a substantial cold water storage system that is freely available.

Pumping from the aquifer would be via submersible pumps in the production bores. Since it is a closed circulation system, the head required would be primarily friction losses in piping, the condenser and air cooler. Total pumping head for the cooling system is estimated at 20 metres.

2 MW GEOTHERMAL PLANT OPERATION

A 2 MW geothermal plant has been chosen to illustrate the cooling concept. Assumed design parameters are 15% thermal efficiency and a working fluid condensing temperature of 40 °C. The heat rejection rate required is 11.3 MW. For water entering at 23 °C and exiting at 40 °C the required flow rate to capture this heat is 159 litres/sec. To provide 6 months storage requires 2514 mega litres.

Assuming the saline aquifer parameters described in the preceding section, we require an aquifer area .25 km^2 or a square 500 metres on a side. This could be satisfied by our parallel lines of production and reinjection bores spaced 600 metres apart. The geothermal plant would be in the middle between these 2 lines. A single large diameter pipe would connect the 2 lines of bores to the geothermal plant, so that a top view looked like the letter H. The bores would be spaced 50 metres apart on 1 kilometre lines forming the sides of the H.

To make up for the intermittent cooling, a second identical set of bores would be placed inside the H, forming a smaller H. These would operate at the same time to double the air cooling capacity. The production bores and re injection bores would be 200 metres apart and the 2 lines of these would be 200 metres inside the lines of the first set of bores.

These bores would operate counter flow to the first set of bores. They would provide additional cooling to aquifer water that had been reinjected several months before. This would make up for the intermittent operation of the cooling system. The relatively huge capacity of the aquifer and soil would smooth out the daily and seasonal temperature variations of reinjected water.

The power requirement to pump 159 litre/sec flow rate against a 20 metre head would be 50 kW or 2.5% of the plant capacity. This would be full time. The air cooler fans (300 kW) would operate intermittently when air temperatures were below 25C and when power demands allowed. Use of variable speed drives on the fans would allow even greater flexibility to cool the water at the optimum times.

The total fan power and pump power for both sets of bores and air coolers would be approximately 700 kW or 35% of the plant capacity to provide double the normal heat rejection to the atmosphere. Based on climate data from Moomba South Australia the fans would run approximately 1/2 of the year, during cooler, lower demand periods.

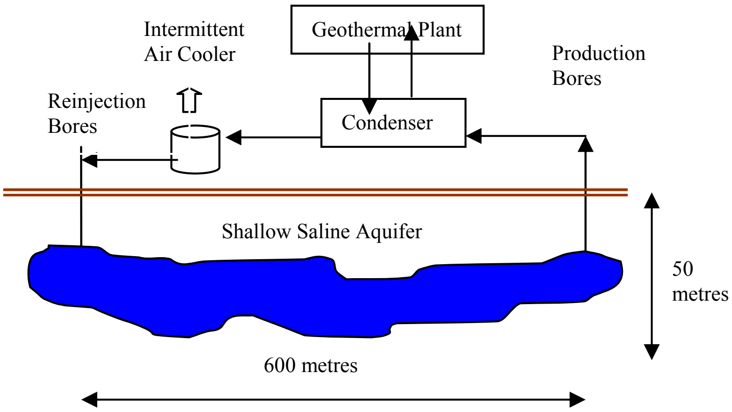

Figure 1. 2 MW geothermal plant cooling system using air cooled water with a shallow saline aquifer

CO_2 GEOTHERMAL SYSTEMS

CO_2 geothermal systems, where CO_2 is used as both the geothermal fluid for heat extraction, and as the working cycle fluid, offer significant advantages. There is a very big issue on the cooling side as the supercritical temperature for CO_2 is 31 °C. Above this temperature there is a huge performance penalty on the plant of up to 40%. Conventional air cooling systems could not meet this requirement most of year in the Cooper basin. The proposed cooling system in this paper could provide the necessary cooling to condense the CO_2 below its critical temperature. This would be critical during the summer periods of peak electricity demand.

CONCLUSIONS

The seasonal storage of water with air cooling offers a possible solution to the significant problem of summer heat rejection from geothermal power plants in arid regions. The presence of shallow saline aquifers in the Cooper Basin appears to offer a straight forward implementation of this concept in this region.

The additional costs are more than compensated for by the much greater plant output in peak periods and the flexibility to schedule parasitic cooling loads. The same benefits accrue to CO_2 geothermal systems.

Heat rejection is a major issue for geothermal plants in terms of capital cost, performance, and maintenance costs in Australian conditions. New concepts beyond just simple air condensers need to be developed and tested.