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Higher Power Generation Efficiencies Are Possible and Will Increase EGS Viability

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Concerning the EGS power generation, the current industry focus is mainly on minimization of risk and maximization of flow rate. Power generation is seen as mature technology where only marginal improvements are possible. We challenge this view.

This is an important topic because the proven performance of the mature technology may not be sufficient to ensure EGS project viability, unless very high flow rates are achieved in the order of 100 kg/s from a single well. The question that needs to be asked is if this is the only direction towards commercial viability or if it is more prudent to spread the risk.

Achievement of sufficiently high flow rates is certainly of critical importance to the success of an EGS project. But what is "sufficiently high"? In our view, a flow rate is sufficiently high when it allows the project to deliver electricity at an acceptable cost.

For example, it is accepted as common wisdom that high temperatures may compensate for lower flow rates because a higher temperature means higher power conversion efficiency, more power generation, and lower unit cost. Similarly, if 100 kg/s is needed for a viable project at a power conversion efficiency of 15%, then 75 kg/s would be "sufficiently high" if the power conversion efficiency is increased to 22%, if this can be achieved without substantial additional investment.

In this paper we will argue that there is room for substantial improvements in geothermal power conversion efficiency. We will also argue that such improvements will require development of equipment designed for the requirements of the geothermal sector, which is different from the rest of the thermal power generation applications.

First, we need to identify the space for improvement. Figure 1 compares geothermal against nuclear, coal and gas in terms of how close each technology is to its theoretical limit. The geothermal efficiencies are for binary plants calculated from data provided in Tester (2006) and the other plant data are from Willson (2007). The important message from Figure 1 is that less than 40% of the theoretical limit is realised in actual geothermal practice and the ratio is as low as 30% for low reservoir or high ambient temperatures. In contrast, any other modern power technology is able to enjoy around 70% of its ideal efficiency limit. Clearly, the geothermal energy practice has room to improve.

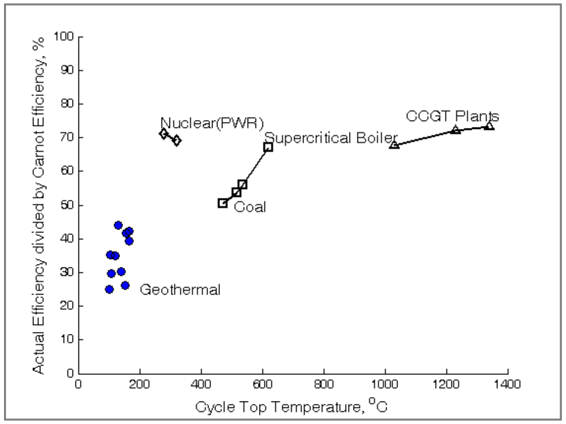

Figure 1. Fraction of the theoretical limit realised by different power generation technologies

Secondly, we need to identify opportunities to realize these improvements. A significance source for efficiency loss in geothermal power plants is the irreversibility in the heat exchangers. This can be minimised if not totally removed by continuously matching the power cycle working fluid temperature against the temperature of the geothermal fluid during the heat exchange process. This is the promise of the Kalina cycle but a similar result can be obtained using a supercritical or a transcritical cycle using a simpler plant lay-out not dissimilar to a standard binary plant configuration (Figure 2).

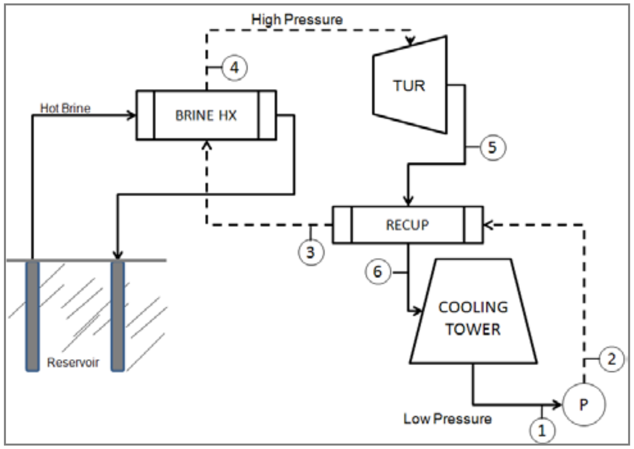

Figure 2. Binary geothermal plant components based on a transcritical cycle

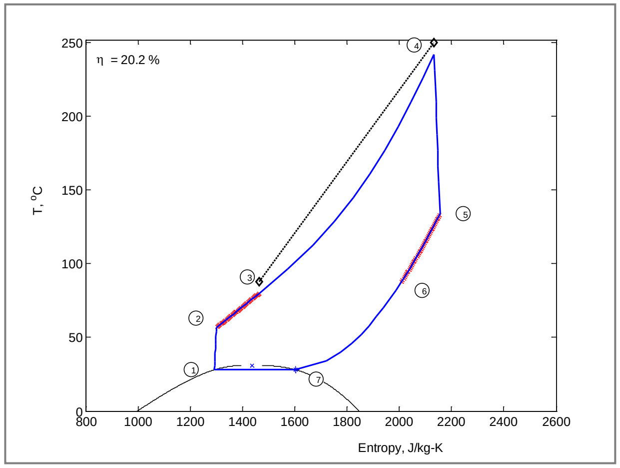

Figure 3. The design-point performance of a transcritical cycle for the geothermal case study

A supercritical cycle is a type of Brayton cycle in which the cycle fluid stays above the critical point through the entire cycle. A transcritical cycle is a condensing cycle where condensation occurs but the condensed liquid is then pumped to a supercritical pressure and the heat addition and expansion take place in the supercritical region with no phase change. There is a range of fluids available for supercritical cycles and we continue to search for a fluid or mixture best for the resource temperatures facing the Australian industry. For example, a transcritical CO_2 cycle (as shown in Figure 3) show promise especially at geothermal resource temperatures of 200-250^{o}C, producing 50% more power from the same geothermal stream compared to a steam cycle running under the same conditions.

QGECE and a US manufacturing company has established a partnership to develop supercritical turbines and supercritical cycle equipment for geothermal, solar thermal and waste heat power generation applications and new cycle fluids and fluid mixtures suitable for supercritical cycles. We are expecting a small (<5 kW) laboratory prototype in 2011 and a relatively larger (100 kWe) unit in 2013 and aiming a field demonstration at 1-MWe scale after that.

The aim of the supercritical turbine project is to increase the power output from a given capital investment in a geothermal reservoir by 50%. An increase in the power conversion efficiency while maintaining similar capital investment levels leads to a proportional and direct increase in the reward from a given subsurface investment. This is equivalent to achieving a higher electricity sales price and, obviously, would have a significant effect on whether a geothermal project proposal is seen as viable.

Tester, J.: The Future of Geothermal Energy, *MIT Press*, (2006)

Willson, P.: The Nu gas Concept – Combining Nuclear and Gas Power Generation, PB Power, ://www.imeche.org/industries/power/nugas-june-2007. (2007).