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Remote Binary Power Development at Hveravellir, Central Iceland

Ragnar K. Ásmundsson[1] and Gunnar Guðjónsson[2]

1. Heat Research and Development, Akureyri, Iceland 2. Hveravallafélagið, Iceland

rka@heatrd.com, hveravellir@hveravellir.is

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ABSTRACT

Hveravellir at Kjölur is a high temperature geothermal field and a protected natural reserve, located in the center of the Icelandic highlands, containing many warm springs and geysers or fumaroles emitting steam, water and gas and depositing colorful clay material. The location of Hveravellir can be seen on a map of Iceland on Figure 1. Throughout Icelandic history, Hveravellir has served as a temporary camp for travelers crossing the highlands in late summer time and it is possible to spend the night there either in a tent or in one of the small tourist cabins. A diesel generator has been used to power two cabins and a weather station located nearby. A decision has now been made to replace existing diesel facilities with a small geothermal power station. In this way, it will be possible to remove the high operational cost and pollution from the current electricity production and install sustainable 'green power' at this fascinating resort. A shallow research well was drilled and tested before designing a larger well for a binary system operating in island mode (off-grid). First geothermal power generation is predicted in 2016.

Figure 1: The location of Hveravellir is shown with a red circle on a map of Iceland (map was obtained from Landmælingar Íslands).

1. INTRODUCTION

Hveravellir ("Geyserfields") is a remote location in the center of the Icelandic highlands between the two glaciers Langjökull and Hofsjökull, at an altitude of approximately 630 m. The region is not habited and acts as a tourist location but was in early Icelandic history a depot for travelers going from one region to another. Hveravellir can easily be seen from a distance due to steam from several geothermal hot springs and fumaroles that "mark the spot". Remains of centuries old campsites can still be seen and the oldest existing building is from 1922. A hut for travelers was built in 1938 and is still being used along with a newer wooden hut and kitchen, all powered with diesel generators but heated with exchange with effluent geothermal spring water before entering a landmark pool which is a very popular bathing spot for travelers (see Figure 1). A former weather station located in the area (operated from 1963 to 2003) also needs power occasionally and other activities needing electric power are either already in place (e.g. communication masts) or are planned to meet increasing tourism. A 1500 m^2 hotel with 50 rooms, a central kitchen and staff facility, is being built that will need up to 50 kW of electric power. It would be of both economic and environmental benefit to harness the geothermal heat for electric power production to replace expensive and polluting diesel consumption at Hveravellir.

Figure 2: The geothermal pool at Hveravellir. The hut in the background is heated with effluent spring water before entering the pool.

The visible high temperature geothermal activity at surface (geysers, mud pools and fumaroles) is limited to a north-south stretch of 5 km and a width of 0.5 km and much of it is protected as a natural monument, extending 5.341 km^2. Warm springs can however be found outside the main field and the whole geothermal area is considered to stretch some 14 km to the north from the edge of the Kjalhraun lava with a width of 1-2 km. The field is silica rich with many colorful deposits coming from the water-rich geothermal center.

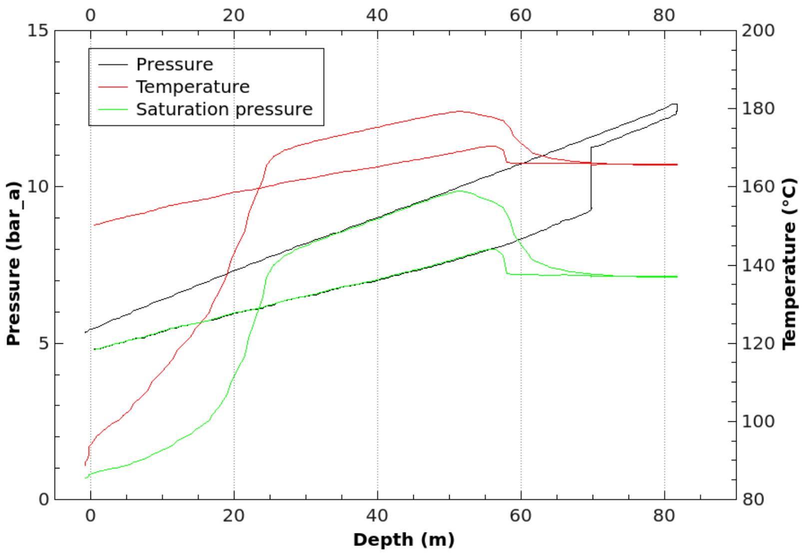

Figure 3: Downhole temperature and pressure profiles in well VE-04 at Hveravellir, measured in September 2010, first with the well shut and then partially opened before pulling the tool up again. The saturation pressure (green profile) is calculated from the temperature curve.

2. POTENTIAL FOR POWER PRODUCTION

Hveravellir is a fluid rich high temperature geothermal field with a good potential for electric power production. Fluid can be extracted on the outskirts of the reserved monument area, without risking drawdown in any of the natural springs or geysers. In August 2010, a shallow exploration well was drilled on a sand bank called Breiðimelur slightly to the north of the reserved area. The well location was suggested by Árni Hjartarson at Iceland GeoSurvey, based on previous surface temperature measurements and geological features (Ásmundsson et al. 2010). Drilling was performed by Árni Kópsson and prepared for flow and production measurements conducted by Ragnar Ásmundsson and Elías Þorsteinsson at Heat Research and Development. The well was cased to 30 m with a 6″ casing and drilled at a diameter of 5.5″ to a depth of 88 m. The well struck an inflow fracture at 56 m depth, identified with a downhole pressure and temperature survey conducted by Iceland GeoSurvey, see Figure 3. When the well was partially opened with the downhole tool at bottom in the previously shut well, water was removed from the well and replaced with saturated steam. Highest temperature in the shut well was 179 °C but was 169 °C during flow. At the latter temperature, enthalpy is 715 kJ/kg. Steam fraction at the measured 4.8 bar at wellhead is 3,85%. Further opening of the well led to pulsing behavior, indicating insufficient inflow.

In order to evaluate the thermal power of the well, a flow discharge measurement was conducted in July 2013, using a 3700 L plastic tank that could be easily transported to the site, over rough terrain (the tank was borrowed from Kaupfélag Skagfirðinga). Wellhead pressure and temperature was recorded along with water level in the tank (see Figure 4). It turned out that stable flow was only reached at 0.2 L/s (a standard 10 L bucket is sufficient to estimate that flow rate). If left alone and open, the well will erupt like a geyser with relatively regular intervals, creating intermittent flow rates larger than 2 L/s, or at least 10 times greater than the stable flow.

Figure 4: Wellhead setup during the flow test. A 6" tube was directed into the tank, which has a water level indicator.

It can be estimated that increased thermal power can be achieved at Breiðimelur with a more advanced and deeper well, allowing higher wellhead pressure and more flow from a deeper and hotter region. The well depth needs not exceed 300 m and if directed eastwards, it has a high chance of entering into the main high temperature zone. The enthalpy and therefore steam ratio may however not be sufficient to operate a 50 kW or more steam turbine and a binary setup has been determined to be the most appropriate arrangement (Ásmundsson and Þorsteinsson, 2013). Binary turbines have their own pre-selected cycle fluid through the expander (e.g. turbine or screw) and only touch the geothermal fluid on the evaporator side, where heat exchangers and/or a heat exchange loop can be selected to defend against potential deposition and corrosion properties (silica deposition is expected at Hveravellir, see Figure 5). In addition, binary turbines can operate at lower temperature, making fluids usable that have been extracted from less costly shallow wells. Finally, certain manufacturers offer the ability to operate power production in remote areas, where no grid power lines are available which would otherwise allow the expander rotation to be regulated to suit the required generator frequency.

Figure 5: Silica deposits at Hveravellir. Hot springs and outflow can be seen. A hut built in 1922 can be spotted in company with some sheep.

The binary power generating unit selected for Hveravellir is an ElectraTherm "Green Machine 4400" which has been successfully tested for geothermal applications. The waste heat from the plant can be used for additional space heating at the new hotel facilities at Hveravellir. Cooling water is available from a nearby well (VE-03), which was also drilled by Árni Kópsson in 2010 according to Iceland GeoSurvey specifications. The cooling water is required to reject heat from the binary working fluid in the condenser.

3. CONCLUSION

A binary geothermal power plant can be expected to be installed in Hveravellir in 2016, replacing existing diesel generators and provide electric power and options for heating at a new hotel facility.

Figure 6: Well VE-04 at Breiðimelur showing off. Steam from the main Hveravellir field can be seen in the distance.

The authors would like to thank ÍSOR for providing the sensor setup and recalibration of pressure and temperature recordings and Kaupfélag Skagfirðinga for lending a tank for flow measurements and adding one connection for water level recordings. The staff at Hveravellir is also thanked for providing local assistance, great food and accommodation.

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