NOTICE CONCERNING COPYRIGHT RESTRICTIONS

Applying Proven Organic Rankine Cycle Technology for the Generation of Electricity from Geothermal Water Produced by Oil and Gas Wells

Lyle A. Johnson[1] and Daniel N. Schochet[2]

[1]Rocky Mountain Oilfield Testing Center
[2]Ormat Nevada, Inc.

Keywords

Organic Rankine cycle, on site power, hot water from oil and gas wells, low temperature geothermal energy

ABSTRACT

There are a large number of oil and gas wells in the USA which produce hot water as well as their hydrocarbon product. These wells (which in general produce fluids at temperatures below 220 Deg. F.) have been estimated as being capable of generating upwards of 5,000 MW. The use of Ormat's proven geothermal energy conversion technology for on-site power generation, with "off the shelf" designs, is the most mature method of realization of this potential. In the past 25 years Ormat has designed and supplied more than 900 MW of geothermal power plant, from 200 KW to over 125 MW in capacity, nearly all of which are still in operation. To verify this concept, Ormat Nevada Inc., has entered into a Cooperative Research and Development Agreement (CRADA) with the US Department of Energy to perform a shared cost validation of an Ormat organic Rankine cycle (ORC) power system to generate commercial electricity from water which is heated during production at a typical oilfield. The project will be conducted at the DOE Rocky Mountain Oilfield Testing center (RMOTC), near Casper Wyoming. The power system is an air cooled factory integrated, skid mounted standard design air cooled Ormat Energy Converter (OEC) power plant.

On Site Power Production with OEC Units

In the past 25 years Ormat has designed and supplied more than 900 MW of geothermal power plant, nearly all of which are still in operation. Initially focused on low temperature resources only, Ormat's technology has been expanded to a wide range of resource conditions (up to 437°F in Hawaii), with applications that include power units for on site use (as low as 200 kW) and complete central station geothermal power plants (up to 125 MW). Examples of low power OEC units for commercial and on site power from relatively low temperature sources are as follows:

- The first Ormat ORC supplied in 1980 for a geothermal application was a small hermetically sealed unit of about 4 kW, designed for operation with a hot spring at 113°F and cooling water at 39°F.
- The first commercial unit was supplied in 1984 and is still in operation at Wabuska, Nevada. It supplies 700 kW to the grid from a 219°F resource (Figure 1 and Figure 2).
- Other representative small units are: a 300 kW in Fang, Thailand (Figure 3), a 200 kW at the Rogner Hotel in

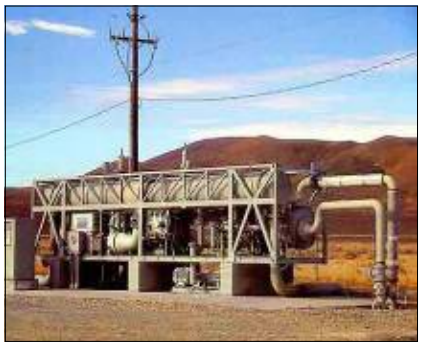

Figure 1.

Figure 2.

Figure 3.

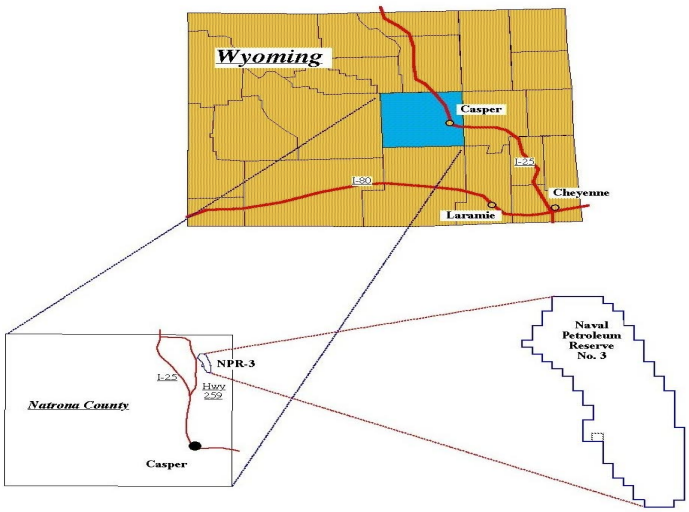

Figure 4. Location Map for Rocky Mountain Oilfield Testing Center.

Bad Blumau, Austria (Figure 4), supplied respectively in 1984 and 2001, still in operation from a resource at about 212°F.

A similar unit was supplied for a solar pond application where it operated from 1986 to 2002 at temperatures as low as 149°F in El Paso, Texas

Description of NPR-3 and its Geothermal Potential

The Rocky Mountain Oilfield Testing Center (RMOTC) is located at the Teapot Dome oil field, also known as the Naval Petroleum Reserve No. 3 (NPR-3). The field is thirty-five (35) miles north of Casper, Wyoming (Figure 4). RMOTC is operated by the Department of Energy as a test site for new and developing oil and gas, and renewable energy related technologies.

The field is a 9,481-acre operating stripper well oil field offering a full compliment of associated facilities and equipment

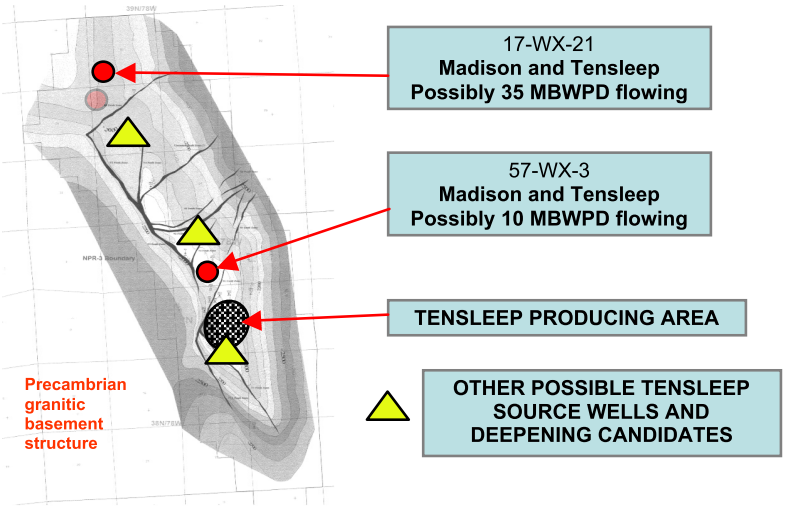

Figure 5. Potential Geothermal Supply Wells at NPR-3.

Table 1. NPR-3 Projected Geothermal Potential.

Well	Zone	Rate, MBWPD		Comments
		Low	High	
17-WX-21	Madison	20	25	Flowing
17-WX-21	Tensleep	4	10	Needs perforating
41-2-X-3	Tensleep	1	3	Flowing
41-2-X-3	Madison	6	12	Needs deepening
48-X-28	Tensleep	2	6	Flowing
61-2-X-15	Tensleep	2	6	Flowing
61-2-X-15	Madison	6	12	Needs deepening
57-WX-3	Madison	2	6	Flowing
Total all other Tensleep Production		40	60	Pumping
Total Flowing Production		43	80	Projected
Total Pumping Production		86	160	Projected
All Potential Production		126	210	All on pump

on-site. There have been 1,319 wells drilled in the field with 589 of them plugged and abandoned. Of the 730 remaining non-plugged and abandoned well bores, 680 are producing wells in nine producing reservoirs ranging in depth from 250 to 5,500 feet.

Two formations at NPR-3 produce sufficient hot water for the generation of low-temperature geothermal energy. The present and potential of the Tensleep and Madison production sites are shown in Figure 5. The average production temperature for the Tensleep is 190°F and for the Madison is 200°F. It is projected that with minor work on present wells, the rate for the combined Tensleep and Madison produced water would be between 126 and 210 MBWPD. Table 1 gives the breakdown of the present projected production for individual wells. There is also the potential to drill additional Tensleep and Madison wells.

Description of the CRADA

Reno-based Ormat Nevada Inc., which develops and operates geothermal power plants in Nevada, California and Hawaii, In December 2006 signed the Cooperative Research and Development Agreement (CRADA) with the US department of Energy to perform a shared cost validation of an Ormat organic Rankine cycle (ORC) power system to generate commercial electricity from hot water produced at a typical oilfield.

The purpose of the project which will be conducted at RMOTC, is to validate the premise that binary geothermal power generation system that uses the hot water produced by an oilfield can reliably generate commercial electricity. The power system to be tested is an air cooled factory integrated, skid mounted standard design air cooled Ormat organic Rankine cycle power plant similar to the standard design OEC installed at the Rogner Hotel in Austria.

Currently the hot water in the oilfield is a waste stream and is treated through a series of treatment ponds and then discharged into an adjacent stream. The produced electricity from the Tensleep wells described above will be used to power field production equipment. The ORC power unit will be interconnected into the field electrical system and the produced energy will be metered for sale and monitored for reliability quality**.** Ormat is supplying the ORC power unit at its own expense while the DOE will install and operate facility for a 12 month period.

Summary

The Ormat supplied power unit is currently scheduled for delivery in 2008. Based on the latest information from the field the performance expected is as follows:

The resource is expected to be flowing at the inlet to the power unit at the relatively low temperature of 170 Deg. F. At the design ambient temperature of 50 Deg. F. the anticipated performance is as follows:

Table 2. OEC Projected Performance at Design Temperature.

Flow Rate:	584,000 pounds per hour
Inlet Temperature:	170 Deg. F
Outlet Temperature:	152 Deg. F
Ambient Temperature:	50 Deg. F
Generator Gross Power:	178 KW
Net Power Output:	128 KW

If in the future the resource temperature can be increased to 190 Deg. F the net output may be increased from 180 KW to approximately 230 KW. This analysis and the future measured performance data are expected to demonstrate the viability of the premise of the CRADA.