PRODUCED WATER FROM NPR-3 OIL AND GAS WELLS FOR LOW-TEMPERATURE GEOTHERMAL APPLICATION

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ABSTRACT: There are a large number of oil and gas wells in the USA which produce hot water with the hydrocarbon product. These wells (which in general produce fluids at temperatures below 220 °**F**.) have been estimated as being capable of generating upwards of 5,000 MW. The Teapot Dome oilfield, also known as NPR-3, operated by the U.S. Department of Energy (DOE) is such a field. The present produced water from the Tensleep formation is projected to produce 180 kW of gross power. If the production from the Madison is included with potential increases in Tensleep production, the gross power potential would be be in the 540 to 900 kW range. To verify this concept, Ormat Nevada Inc., has entered into a Cooperative Research and Development Agreement (CRADA) with the DOE operated Rocky Mountain Oilfield Testing Center (RMOTC) to perform a test of an Ormat organic Rankine cycle power system to generate commercial electricity from produced water in a typical oilfield. 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 200kW to over 125 MW in capacity, nearly all of which are still in operation. The project will be conducted at the RMOTC, near Casper, Wyoming. The power system will be a factory integrated, skid mounted standard design air cooled Ormat Energy Converter power plant.

NPR-3 AND ITS GEOTHERMAL POTENTIAL

The Teapot Dome oilfield, also known as the Naval Petroleum Reserve No. 3 (NPR-3) is located thirty-five (35) miles north of Casper, Wyoming (Figure 1). The field is a 9,481-acre operating stripper-well, oilfield offering a full compliment of associated facilities and equipment including drilling and workover rigs. There have been 1,319 wells drilled in the field with 589 of them plugged and abandoned. Of the 730 remaining well bores, 680 are producing wells in nine producing reservoirs ranging in depth from 250 to 5,500 feet. The field is operated as a producing field in conjunction with the Rocky Mountain Oilfield Testing Center (RMOTC) which operates in the field as a test facility for new and developing oil and gas, and renewable energy related technologies.

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 2. The average production temperature for the Tensleep is 190 °F and for the Madison is 200 °F. The present production from the Tensleep formation is in excess of 40,000 BWPD while the Madison has a 26,000 BWPD ability but is only used as a hot water source in the field. 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 projected production for individual wells. There is always the potential to drill additional Tensleep and Madison wells.

The aquifer in both the Tensleep and Madison formations are continuously recharged from the mountains to the west, Figure 3. As shown, the Tensleep and Madison are interconnected by a series of fractures to the underlying formations and the basement rock.

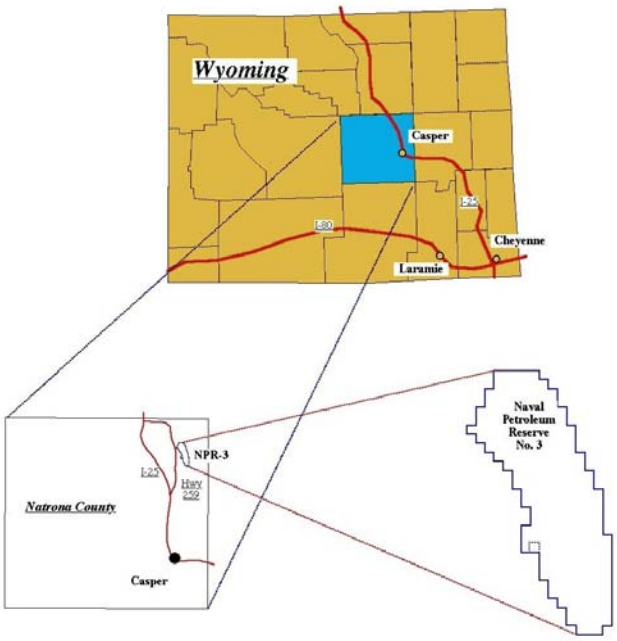

Figure 1. Location Map for Rocky Mountain Oilfield Testing Center

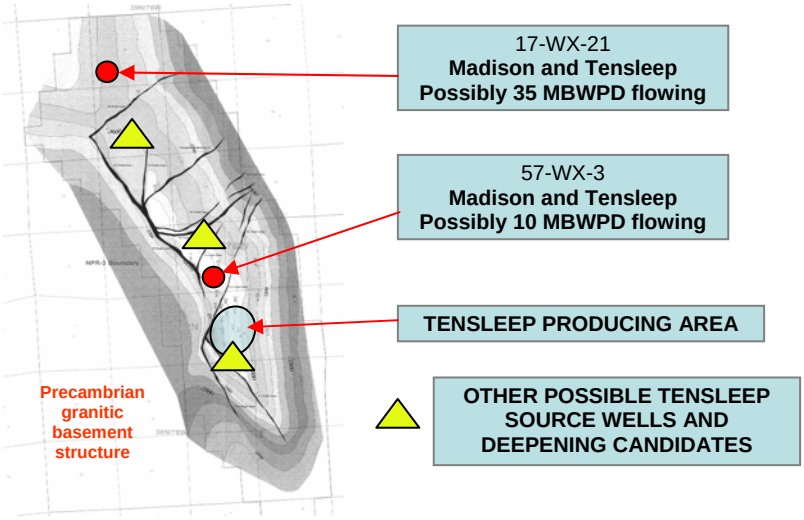

Figure 2. Potential Geothermal Supply Wells at NPR-3

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 deeping
48-X-28	Tensleep	2	6	Flowing
61-2-X-15	Tensleep	2	6	Flowing
61-2-X-15	Madison	6	12	Needs deeping
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

Table 1 NPR-3 Projected Geothermal Potential

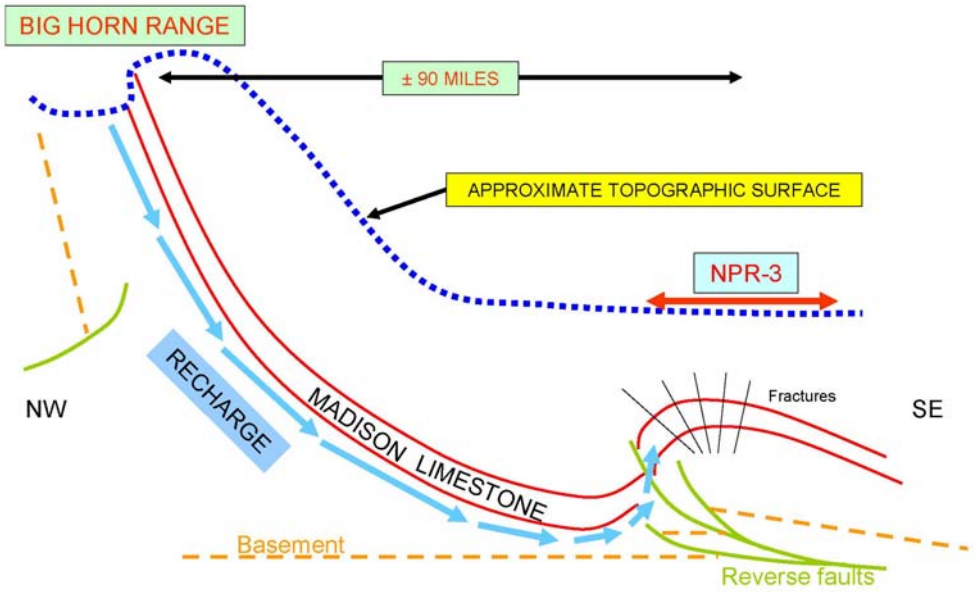

Figure 3. NPR-3 Recharge System

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 200kW) and complete central station geothermal power plants (up to 125 MW). Examples of low power Ormat Energy Converter (OEC) units for commercial and on site power from relatively low temperature sources are as follows:

- The first Ormat organic Rankine cycle **(**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 4).
- Other representative small units are: a 300 kW in Fang, Thailand (Figure 5), a 200 kW at the Rogner Hotel in Bad Blumau, Austria (Figure 6), supplied respectively in 1984 and 2001, still in operation from a resource at about 212 °F.

Figure 4

Figure 5

Figure 6

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.

Figure 7 is a conceptual drawing of the proposed unit. The proposed system is very similar to the standard design OEC installed at the Rogner Hotel in Austria, Figure 6.

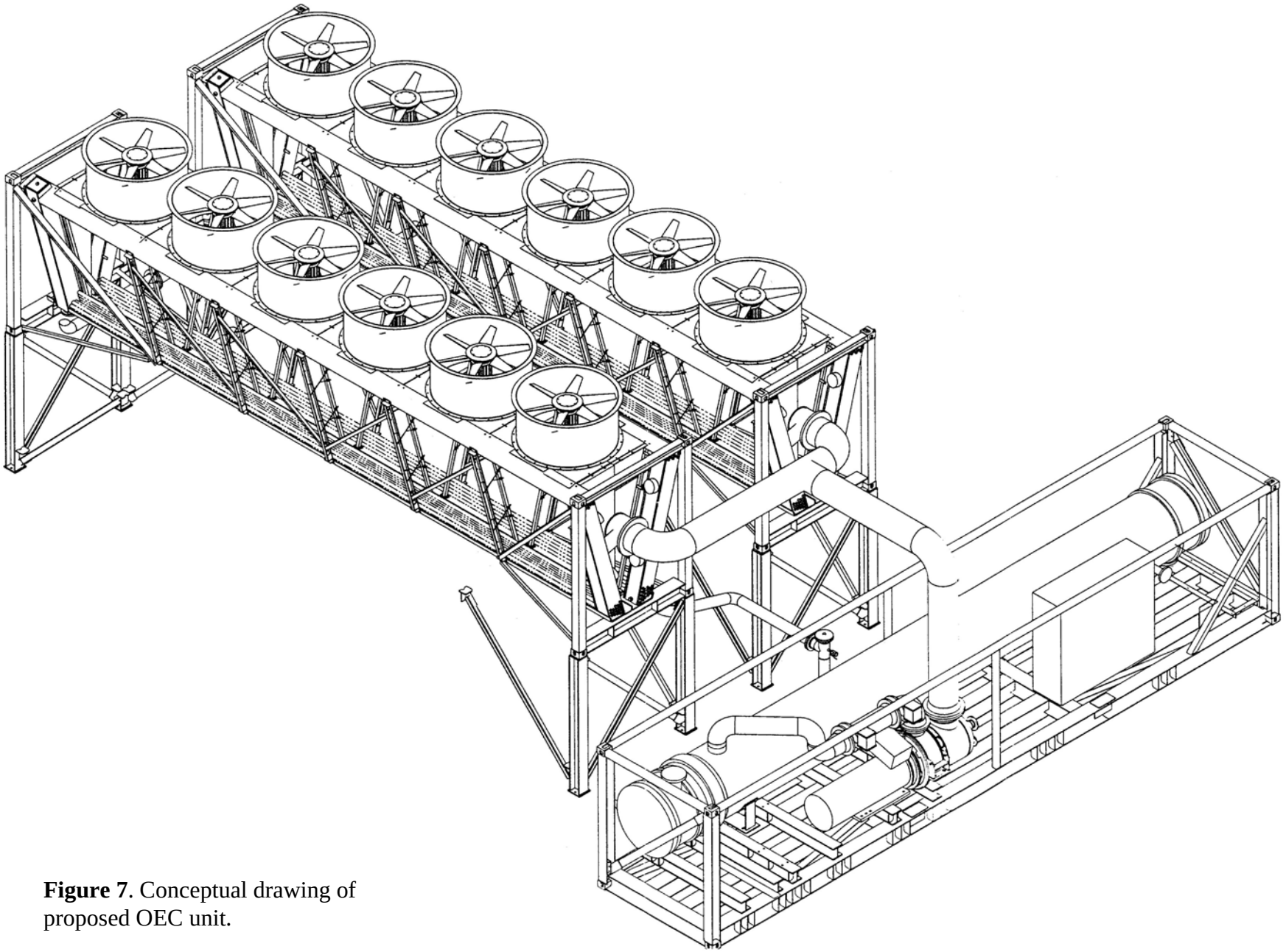

Figure 7. Conceptual drawing of proposed OEC unit.

DESCRIPTION OF THE CRADA

Reno-based Ormat Nevada Inc. has developed and operates geothermal power plants in Nevada, California and Hawaii. In December, 2006 Ormat signed a Cooperative Research and Development Agreement (CRADA) with the U.S. Department of Energy to perform a validation of an ORC power system to generate commercial electricity from hot water produced at a typical oilfield.

The project to be conducted at RMOTC will validate the premise that a binary geothermal power generation system using hot water produced by an oilfield can reliably generate commercial electricity. The power system to be tested is a factory integrated, skid mounted standard design, air cooled ORC 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 for use and the produced energy will be metered and monitored for reliability quality**.** Ormat is supplying the ORC power unit while RMOTC will install and operate facility for a 12 month period.

CONCLUSIONS

The Ormat supplied power unit is currently scheduled for delivery in January 2008. Based on the field information, 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 °F. At the design ambient temperature of 50 °F, the anticipated performance is shown in Table 2.

Table 2 OEC Projected Performance at Design Temperature

Flow Rate:	584,000 pounds per hour
Inlet Temperature:	170 °F
Outlet Temperature:	152 °F
Ambient Temperature:	50 °F
Generator Gross Power:	180 kW
Net Power Output:	132 kW

If in the future the resource temperature can be increased to 190 °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 the concept for the CRADA.