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ELECTRICAL POWER FROM AN OIL PRODUCTION WASTE STREAM

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ABSTRACT

In the production of oil and gas wells, hot water/brine is produced along with the hydrocarbon product. Several of these wells/fields produce fluids at temperatures below 220 °F and have been projected to be capable of generating power for on site consumption. To verify this concept, Ormat Nevada Inc. and the US Department of Energy (DOE) entered into a Cooperative Research and Development Agreement (CRADA) to demonstrate small scale power generation from an oil field waste stream. The project is being conducted by the DOE Rocky Mountain Oilfield Testing Center (RMOTC) at NPR-3 (Teapot Dome Oilfield) near Casper Wyoming. The power system is an air cooled factory integrated, skid mounted standard design Ormat organic Rankine cycle (ORC) power plant with a nominal rating of 250 kW.

The 250 kW ORC power unit was designed to use 40,000 bpd of 170 °F produced water from the field's Tensleep formation to vaporize the working fluid, isopentane. Because of the lack of sufficient cooling water for the condenser, the cooling system was design as an air-cooled unit. The system was installed in August of 2008 and put into full-time service in September 2, 2008. Prior to installation, modifications in the oil production system and the produced water handling system increased the inlet water temperature to 195 °F, increasing the output of the unit. During the initial 4.5 months of operation, the unit produced from 80 to 280 net kW for a total of 485,000 kWhr of power. The unit has been online 90% of the time. The majority down-time (8 of the 10%) was caused by power loss to the main field electric grid. For field safety purposes, the Ormat unit will shut down if the main field power is interrupted.

BACKGROUND

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 1). NPR-3 is operated by the Department of Energy as both a producing oil field and a test site for new and developing oil and gas, and renewable energy related technologies.

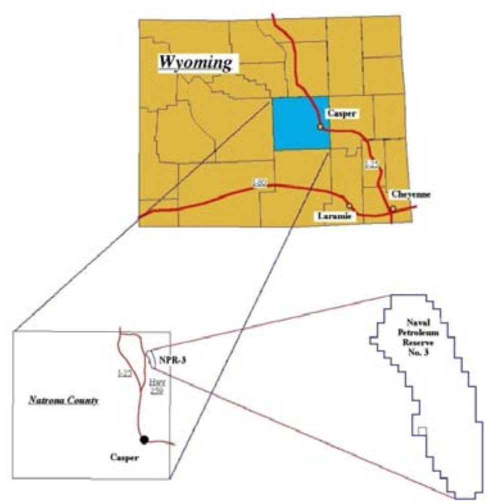

Figure 1: Location Map for Rocky Mountain Oilfield Testing Center

The field is a 9,481-acre operating stripper well oil field offering a full compliment of associated facilities and equipment on-site. There have been 1,319 wells drilled in the field with 589 of them plugged and abandoned. Of the 730 remaining well bores, 300 are producing wells in nine producing reservoirs ranging in depth from 250 to 5,500 feet. The remaining unplugged wellbores are temporarily shut-in or are used for testing.

Two formations at NPR-3, the Tensleep and Madison formations, produce sufficient hot water for the

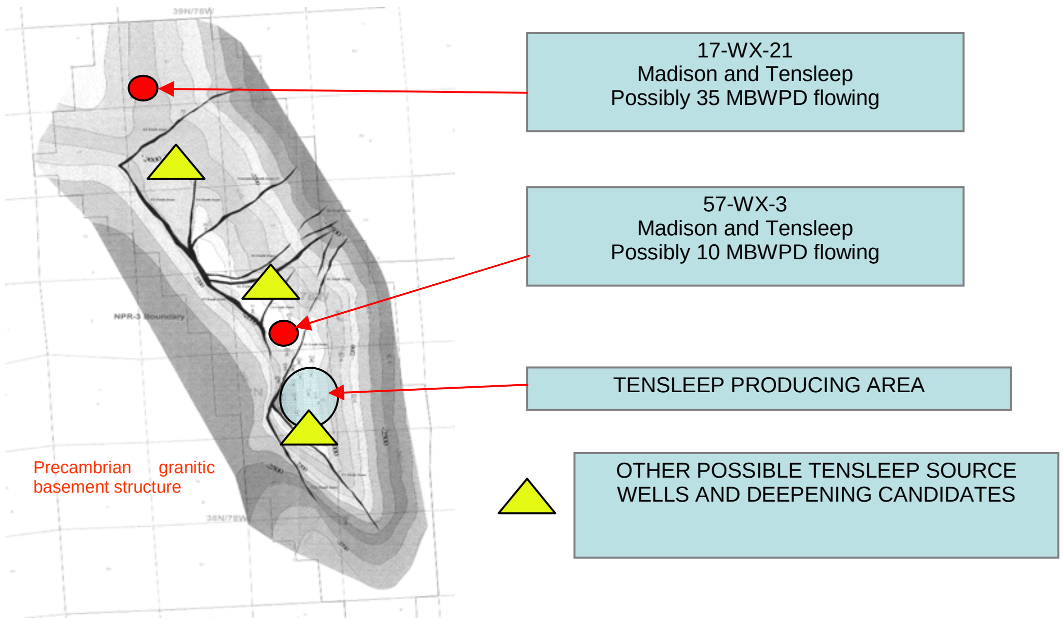

Figure 2: Potential Geothermal Supply Wells at NPR-3

generation of low-temperature geothermal energy. The current flowing water resource from these formations is 45 MBWPD. The present and potential Tensleep and Madison production sites are shown in Figure 2. The average production temperature for the Tensleep is 195-200 °F and for the Madison is 200-210 °F. It is projected that with minor work on existing wells, the rate for the combined Tensleep and Madison produced water would be between 126 and 210 MBWPD. There is also the potential to drill additional Tensleep and Madison wells. The water resource in both the Tensleep and Madison formations are continuously recharged from mountains to the west. 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.

In January, 2007 Reno-based Ormat Nevada Inc., which develops and operates geothermal power plants in Nevada, California and Hawaii, entered into a Cooperative Research and Development Agreement (CRADA) with the US Department of Energy at RMOTC to perform a 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 is to validate the premise that a binary geothermal power generation system that uses the hot water produced by an oilfield can reliably generate commercial electricity. For the demonstration, Ormat supplied the ORC power unit while the DOE installed and is operating the facility for a 12 month period.

THE POWER PRODUCTION UNIT

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). The power system supplied for the RMOTC demonstration is a factory integrated, skid mounted standard design air cooled Ormat ORC power plant similar to the standard design Ormat Energy Converter (OEC) installed at the Rogner Hotel in Austria.

The 250 kW unit arrived in the field as three skids with parts. The three main components were an 8 ft by 40 ft vaporizer skid which also contained the turbine, generator and instrumentation cabinet, and two 8 ft by 40 ft finned-tube condensers. The assembly was completed in about one month using an oilfield roustabout crew and contract welders (Figure 3). The unit was wired directly into a 480 V leg of the field power distribution system. The power from the unit is metered and monitored for reliability and quality. For field safety purposes, the Ormat unit was installed such that the unit will shut down if the main field power is interrupted.

Figure 3: 250 kW ORC Low-Temperature Geothermal System at NPR-3

RESULTS AND DISCUSSION

The power generation system was installed in August 2008. The design of the unit was based on a relatively low produced water temperature of 170 °F and an average ambient temperature of 50 °F, Table 1. At design conditions, the nominal 250 kW unit would produce a gross power of 180 kW (net 132 kW). However, between initial design and installation, two major changes were made. On the equipment design, the pump for the working fluid, isopentane, was incorporated into the turbine-generator package. By incorporating this feature, the parasitic electrical load of the unit was decreased. On the field side, the Tensleep production facility was upgraded and an insulated, produced water storage tank installed. This change kept the produced water temperature in the 195 to 198 °F range.

The higher inlet water temperature permits the system to operate nearer the maximum net power output of 225 kW. Since the system was put into full-time service on September 2, 2008, the net power output has ranged from 80 to 280 kW, Table 1. The output power fluctuates with the average daily ambient temperature when a constant hot water inlet volume is used, Figure 4. The power fluctuation is evident through the normal daily temperature cycle, Figure 5. Through January 20, 2009, the unit has produced over 485 megawatt hours of power from 2.6 million barrels of hot water.

Table 1. Design and Operational Data

	Design	Operational Results
Flow Rate, bpd	40,000	12,000 to 40,000
Total Hot Water Used, bbl		2,593,192
Inlet Water Temperature, °F	170	195 to 198
Outlet Water Temperature, °F	152	80 to 170
Average Ambient Temp, °F	50	-7 to 85
Generator Gross Power, kW	180	305 to 105
Net Power Output, kW	132	280 to 80
Total Power Produced, kWhr		485,455

To date, the generation system has been online 90% of the time. If the downtime caused by shutdown of the system as a result of field power loss is removed, then the online percentage for the system is 98%. The system related downtime are the results of the operators learning curve.

FUTURE PLANS

The plans are to operate the demonstration until September 2009. During this period, evaluation of changes to the system for better control of the inlet hot water to reduce fluctuating output power and the ability to generate power above 250 kW will be made. Also to be evaluated will be the future for this unit, will it remain in place or will it move to a new home.

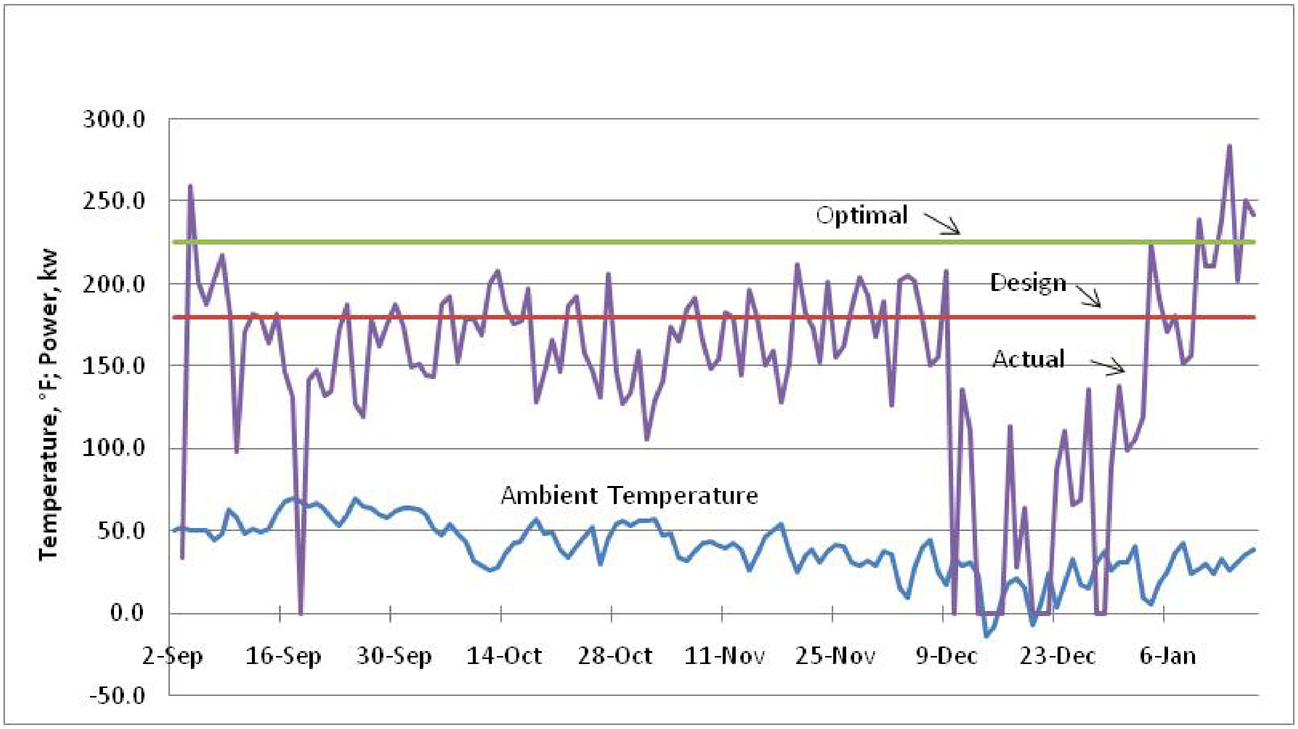

Figure 4: Daily Power Output and Ambient Temperature

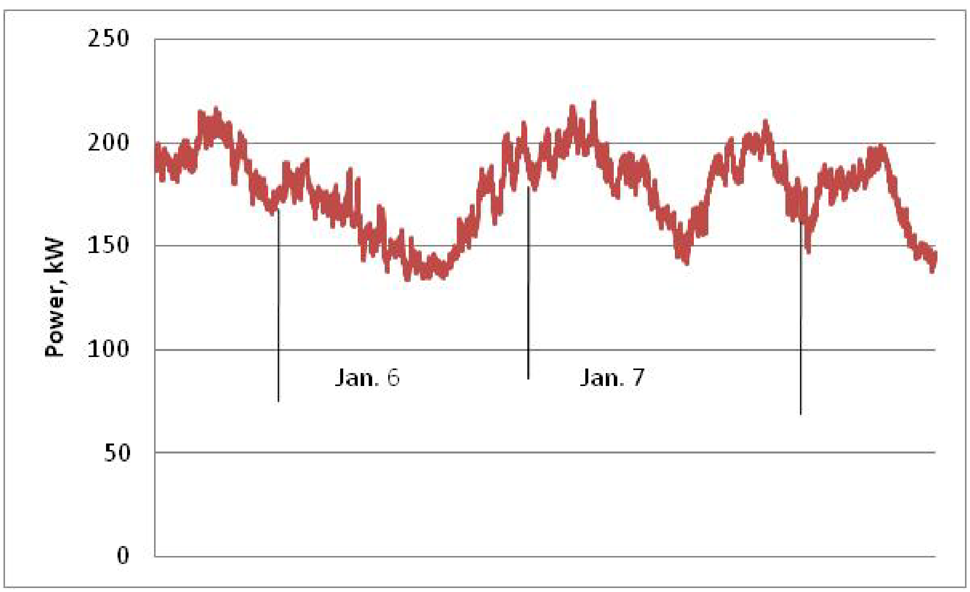

Figure 5: Daily Power Fluctuation