Production of Power From the Co-Produced Water of Oil Wells, 3.5 Years of Operation

Joshua Nordquist[1] and Lyle Johnson[2]

[1]Ormat Technologies Inc.
[2]Rocky Mountain Oil Testing Center (Retired)

Keywords

Rocky Mountain Oil Testing Center (RMOTC), United States Department of Energy (US DOE), Ormat Technologies, Ormat, National Renewable Energy Laboratory (NREL), Ormat Energy Converter (OEC), low temperature, Organic Rankine Cycle (ORC), moderate temperature, binary technology, remote operation, oil and gas, oil wells, gas wells, geothermal, geothermal power plants, modular units

ABSTRACT

The co-produced fluids of oil and gas wells are a unique resource for the production of electricity. Inherent in such a resource are challenges that directly impact the economic viability, and hence project viability. US DOE and RMOTC's ongoing project, and the CRADA with Ormat Nevada Inc., have shown the commercial feasibility of generating power from the co-produced fluids of oil and gas wells through 3.5 years of operation. Additionally, the ORMAT OEC has shown there is commercially available and proven technology for this application.

Introduction

In late 2007, Ormat Nevada Inc. and the US Department of Energy (DOE) entered into a Cooperative Research and Development Agreement (CRADA) to demonstrate, on a small scale, Organic Rankine Cycle (ORC) power generation from a producing oil field waste stream at the Rocky Mountain Oil Testing Center (RMOTC) outside of Casper, Wyoming. A small air-cooled Ormat Energy Converter (OEC) was delivered and installed in August 2008, and commissioned in early September. Since then, and for the last three and a half years, Ormat's 250kW OEC has produced over 2,120,000 kWh (enough energy for over 120 homes each year), and utilized over 11,140,000 barrels of water (enough for over 23,400 swimming pools). The Ormat OEC has certainly shown success and continues to operate; and has proven to be the highest capacity, longest running, and most reliable technology for this application (Figure 1). Furthermore, this demonstration project is allowing RMOTC, the DOE, and the National Renewable Energy Laboratory (NREL) to investigate this new application and the potential in providing fuel free energy production from once wasted sources.

Figure 1. The RMOTC OEC, commissioned in September 2008.

History

RMOTC is located at the Teapot Dome oil field, also known as Naval Petroleum Reserve No. 3 (NPR-3). The field is 35 miles north of Casper, Wyoming (Figure 2). 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 (Johnson, Simon, 2009).

The Naval Petroleum reserves originated under federal conservation policies under presidents Roosevelt, Taft, and Wilson. A scandal in the Harding administration involving the illegal lease of the reserves for private development shut down any development of these resources until the late 1970's. In 1977 the jurisdiction of the reserves was transferred from the Navy to the DOE. The

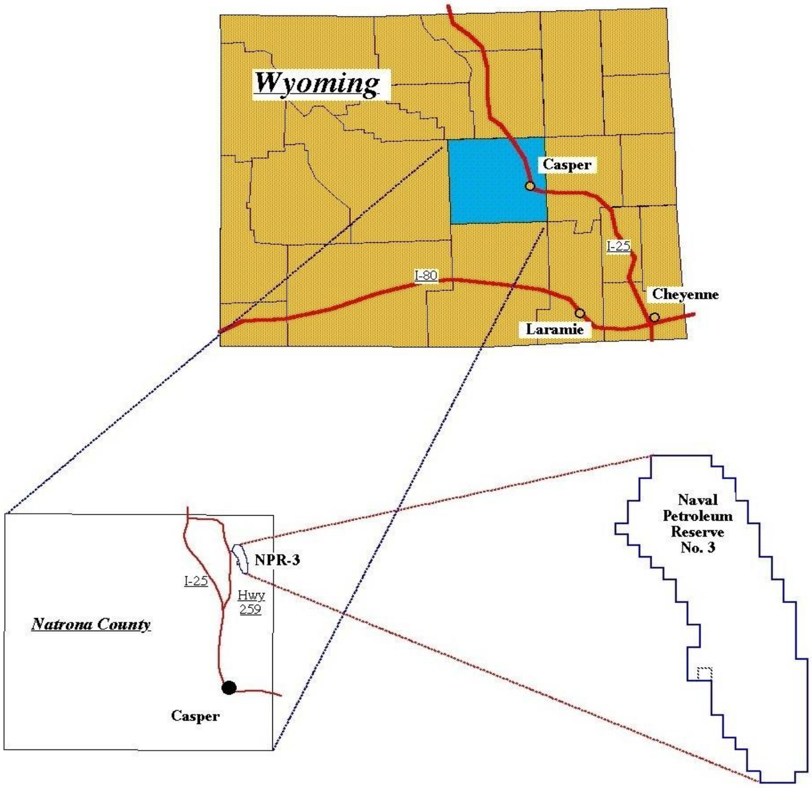

Figure 2. RMOTC and NPR-3 are located north of Casper, Wyoming.

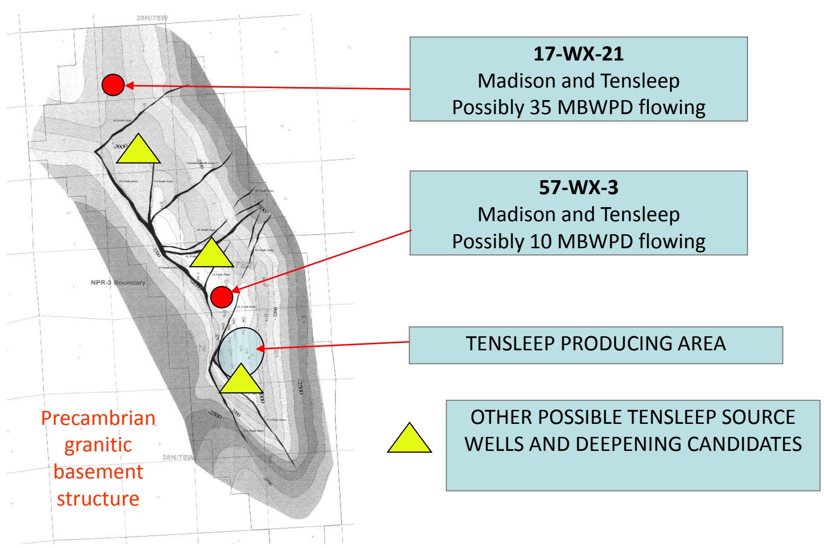

Figure 3. RMOTC has two main formations; Tensleep and Madison.

soon following energy crisis of the mid 1980's caused oil companies to move overseas and cut Research & Development (R&D) budgets. The DOE realized the continuous need for oil (and gas) research, and opened RMOTC in 1993. Since then, research & development activities at RMOTC have grown substantially and have branched in to new industries, such as renewable energy, to develop and test new technologies (www.rmotc.doe.gov).

The oil field is contained in approximately 9,500 acres of land. There have been 1,319 wells drilled in the field with 629 of them plugged and abandoned today. Of the 690 remaining wells, 120 are producing currently. Two main formations (the Tensleep and Madison) produce approximately 45 Million barrels of water per day (MBWPD), which is about 1,312,000 gallons per minute (Johnson, 2009)(Figure 3). This water is produced at about 195º-210ºF. For comparison, the temperature of boiling water at this elevation is 202ºF (Johnson,Simon, 2009).

It is well know that water is produced with most oil or gas production. Estimates say that the co-produced water makes up 98% of the waste of oil and gas production. On average, 7 barrels of water (294 gallons) is produced for every 1 barrel of oil (42 gallons). This water is a byproduct and is not used in the transportation or processing of oil or gas. For any producing operation, the water must either be re-injected or treated and/or disposed of. Furthermore, as an oil well ages (oil production reduces), it produces more water. Re-injection seems to be nice solution by returning the water to its origin, but is counterproductive to producing oil, and so is usually re-injected in an alternate location. Treatment and disposal of water can be an expensive solution as treatment facilities and processes are required along with transportation. Given the actual amount of water produced, it is easy to see how the costs of dealing with the co-produced water can be staggering.

A white paper by the Argonne National Laboratory in 2009 estimated co-produced water production of 15 and 20 billion barrels per year. This is equivalent to 1.7 to 2.3 billion gallons per day (Argonne, 2009). Disposal costs for this water range from cents to dollars per barrel, but either way is a considerable cost.

Lastly, as the oil (or gas) and water are coming from hundreds to thousands of feet below the surface, it is naturally hot. Hot water can be re-injected (though may require cooling), but treatment and disposal almost always require that the water be cooled. Cooling such amounts of water comes at a high cost and either a large space and time or energy consumption.

A Solution

The presence of hot water and the intention to produce power from such a resource turned heads towards the already existing geothermal industry, which was doing just that. At that time, Ormat Technologies (Reno, NV), had been producing technologies for the conversion of low temperature heat to power for over 25 years, and had over 900 MW of installed capacity.

Ormat commercialized the use of the Organic Rankine Cycle (ORC) for the conversion of low to moderate temperature heat sources to power. Ormat had success generating power from low temperature geothermal resources as low as 120ºF and current installed experience, operating commercially since 1984, with resources as low as 231ºF (Nordquist, 2009). The Ormat Energy

Converter (OEC) was the perfect commercially proven and reliable solution for RMOTC.

In January of 2007, Reno (NV) based Ormat Nevada Inc. entered into a CRADA with the US DOE at RMOTC to develop an OEC to generate power from RMOTC's waste water stream. Under the CRADA, Ormat would deliver an OEC to RMOTC, and the US DOE would install the OEC and operate for 12 months.

All major components of the OEC (heat exchangers, turbines, condensers) are designed and manufactured by Ormat, allowing for an optimized power plant design to maximize output, and key control on the manufacturing and supply chain to minimize production and installation time.

Figure 4. The OEC was installed and commissioned in approximately 4 weeks.

The OEC arrived at RMOTC in August 2008 as three skids and parts. The unit was installed and commissioned in four weeks using local oilfield crews and welders (Figure 4). Operations began immediately and continued until February of 2009, when the unit was stopped for maintenance. During this time the unit produced 586,574 kWh, utilized over three million barrels of water, and was available 97% of the time (Johnson, 2009).

The oil field at RMOTC constantly requires attention and frequently is shut down for maintenance work. When the field is shut down, the OEC must also be shut down as water supply to the power unit stops. Luckily, the OEC can easily be restarted with little effort when the oil field is operating again.

The environment at RMOTC introduces another challenge. While the spring and summer seasons are relatively mild, the winter season can be extremely cold. Ambient temperatures can easily -30F levels with high winds.

For this reason, and the lack of available clean water, RMOTC chose an air cooled OEC. While a water cooled OEC could have been provided, it would have required a water cooling tower. During winter months, these towers can ice up if not maintained properly which greatly reduces its performance. Additionally, such towers require constant attention and usually chemical inhibitors to maintain the water chemistry and tower's performance. Ormat's air cooling design requires minimal maintenance and simplifies the power unit design while minimizing the required attention, and therefore allows remote operation.

3.5 Years of Operations

As of today, the RMOTC OEC has been operating for over 3.5 years with consistent and reliable power production. The OEC has clearly shown commercial power production from this low temperature resource, and hence the viability of utilizing such a resource for power production. To extend the research from this project, the DOE has also purchased other ORC technologies in order to evaluate alternative technologies than that which was installed. While indications show that other technologies have been delivered to RMOTC as early as January 2011, installing and commissioning such equipment is still in process.

For the future, the US DOE (through the Geothermal Technologies Program), RMOTC, and NREL will use these facilities for R&D on other geothermal technologies and geothermal systems, and to implement further geothermal initiatives. The overall goal is to provide the geothermal industry with means to develop and deploy economically viable and innovative technologies that can capture a considerable portion of such a low temperature resource (Reinhart, 2011).

The below graph represents operational data experienced by RMOTC since the OEC was commissioned in 2008. As can be clearly seen by the graph there were many times the OEC was operating at above or below its design output. Fluctuations, changes, and required maintenance on the oil field constitute the major cause of this varying output. The availability of power production when considering all necessary field maintenance ranged between 70-91%. The RMOTC OEC achieved an availability of 94-98% not considering the oil field maintenance. Clearly the driving factor for commercial consideration is the availability of the oil field.

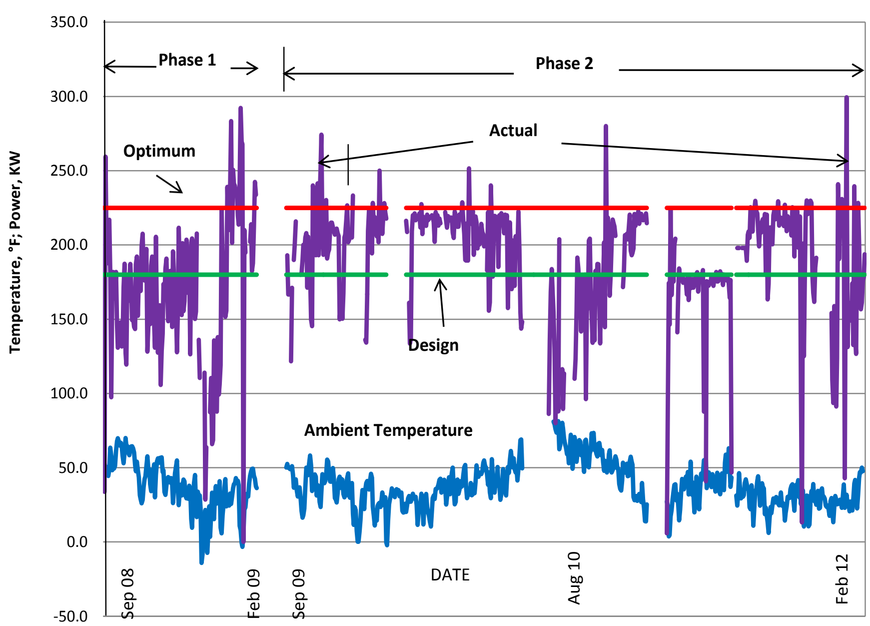

Figure 5. The RMOTC OEC has been operating for over 3.5 years.

Co-Produced Fluids as a Resource for Power Production

US DOE's and RMOTC's project has clearly proven the feasibility of commercial power production from co-produced water in an oil field. Considering the location, the quick completion time, and the three and a half years of experience already achieved, the project at RMOTC is clearly a success.

However, RMOTC's project also brings to light some of the challenges of using a resource such as co-produced water and how they would affect the viability and economics of the same project employed in other locations.

One unique benefit of the RMOTC test site is the large number of producing oil wells which are piped to a central facility for separation. This characteristic allows for a central source of the co-produced water and a maximum amount of fluid availability. Therefore, for the RMOTC and US DOE project, building new pipelines to deliver co-produced water to the OEC was not necessary, the infrastructure was already present.

Many producing oil fields today do not incorporate a central separation facility. The fields that do tend to have a generally low number of wells per separation facility which limits the amount of available flow for such a power unit. This configuration will increase the cost of power production and operation either through the addition of infrastructure (pipelines, etc..) and a higher cost for lower capacity ORC equipment, and so will negatively impact the economics of the project.

Production availability of the oil field is also an important factor when considering this resource. As seen at RMOTC, availability of the well field could range between 70-91%. Obviously, this availability has a direct impact on the production of power, and therefore has a direct impact on the economics of the project. Most successful power projects today experience availability in the range of 90-99%. A low availability mixed with generally more expensive costs for power and inherently lower efficiency present very clear challenges for an economical project.

RMOTC was able to use the power produced from the OEC for its own internal use, by reducing their dependency on the local electricity grid, and directly offsetting their utility power rates. This is a key benefit compared to directly selling the power to a utility. In order to sell power to a utility you must negotiate a purchase agreement. Depending on the location and the utility, this agreement could be simple (such as a utility distributed generation program) or complicated (such as a long term PPA). In either case, you are selling power to the utility which then must sell the power to the end user, and make a profit. Therefore, the rate you will get from the utility will be less than the rate you pay as an end user, and hence affecting the economics of the project.

There are other scenarios that would be beneficial to have on-site local power generation from available co-produced fluids. Some oil fields are remote, and use fossil fuel sources (some use their own production streams) for power generation to run the oil or gas field (such as diesel engines, gas engines, gas turbines, etc…). The cost of such generation is dependent on fuel costs, which are volatile and not within the control of the field operator. Or, if they choose to use their own production streams they will reduce potential revenues from these resources. Additionally, this fuel requires transportation, and sometimes processing, and hence labor in order for it to be used, which adds another level of costs to the generation of power. The cost per kW of generation for this scenario is almost always higher than grid available power, and therefore can provide a higher economic feasibility for producing power from co-produced fluids.

BUT, if a field is remote, it is likely that remote generation was chosen because the cost to integrate a local grid connection was not economical. Furthermore, in order to use any local power generation from a centralized source (such as co-produced fluids) you will need an electrical distribution system (transmission lines, transformers, switchgears, etc..) which must be considered within the project economics.

However, remote fossil fuel generation tends to be of small capacity. When considering the applicability of an ORC technology for small capacity generation, equipment and installation costs must be carefully considered.

Conclusion

US DOE and RMOTC's ongoing project, and the CRADA with Ormat Nevada Inc., have shown the commercial feasibility of generating power from the co-produced fluids of oil and gas wells. Additionally, the ORMAT OEC has shown there is commercially available and proven technology for this application. The continual operation of the US DOE and RMOTC project will show the long term reliability of the technology. Continual research and development for the application will help to test the true commercial viability of such a project and its applicability to oil fields and other low temperature resources.

The co-produced fluids of oil and gas wells are a unique resource. Inherent in such a resource are challenges that directly impact the economic viability, and hence project viability. Challenges such as central infrastructure, grid connectivity, remote locations, low temperature, low capacity and capital costs are only a few when considering the commercial viability of a utilizing such a resource. As with any project, these challenges require a thorough and completed analysis early in the development process and continual attention until the project is completed.

References

Johnson L, Simon D, 2009. Electrical Power from an Oil Production Waste Stream. Proceedings, Thirty-Fourth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, February 9-11, 2009.

Rocky Mountain Oil Testing Center, 2012. History, www.rmotc.doe.gov.

Clark C.E., Veil J.A., 2009. Produced Water Volumes and Management Practices in the United States. Argonne National Laboratory, www.evs.anl.gov/pub.

Nordquist J, 2009. Use of Small, Sub 1 MW Organic Rankine Cycle Power Systems and Low Temperature Resources, GRC Transactions, Vol. 33.

Johnson L, Walker E, 2010. Oil Production Waste Stream, A Source of Electrical Power. Proceeding, Thirty-fifth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, February 1-3, 2010.

Reinhart T, Johnson L, Popovich N, 2011. Systems for Electrical Power from Coproduced and Low Temperature Geothermal Resources. Proceedings, Thirty-Sixth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, January 31-February 2, 2011.