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Raft River 5MW Geothermal Pilot Plant

J. F. Whitbeck, et al

Idaho National Engineering Laboratory
Idaho Falls, Idaho

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RAFT RIVER 5MW GEOTHERMAL PILOT PLANT

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J. F. Whitbeck and R. R. Piscitella
Idaho National Engineering Laboratory
Idaho Falls, Idaho 83401

Introduction The Idaho National Engineering Laboratory geothermal programs have been geared to the utilization of moderate temperature hydrothermal resources (say 280°F to 350°F). An outgrowth of this work has been the design of a 5MW(e) binary cycle pilot plant to be built in the Raft River valley in Idaho. This plant will utilize state-of-the-art components but will employ a dual boiling power cycle using isobutane as a working fluid. It will be designed to take maximum advantage of the low average seasonal temperatures and will contain sufficient instrumentation and data aquisition equipment to obtain accurate performance data. In addition, some of the large heat exchangers contain special instrumentation to obtain details of their performance.

Design was completed on this facility in January 1978. Construction is scheduled to start August 1978. Plant startup and operation are scheduled for July 1980. The following sections of this paper provide a detailed description of the 5 MW(e) facility.

Power Cycle Selection and Description A variety of working fluids and cycles were initially studied for moderate temperature power applications. It was found that the dual boiling cycle had significantly better performance than either the single boiler cycle or a supercritical cycle when resource temperatures were about 300°F or below.

Figure 1 is a diagram of the dual boiling cycle. The state points are those resulting from optimization using a 290°F resource [1]* which is the design geofluid temperature selected for the Raft River 5MW pilot plant.

In this cycle, isobutane condensate is heated by the low pressure preheater to the approximate temperature of the low pressure boiler (180°F). Upon leaving the low pressure preheater, the isobutane flow is split; about two thirds of the flow going to the high pressure preheater where it is heated to the high pressure boiler temperature of 240°F while the remaining one third goes to the low pressure boiler where it is vaporized. No attempt is made to recover the energy lost by throttling the flow to the low pressure boiler.

*Numbers in brackets refer to References at the end of the paper.

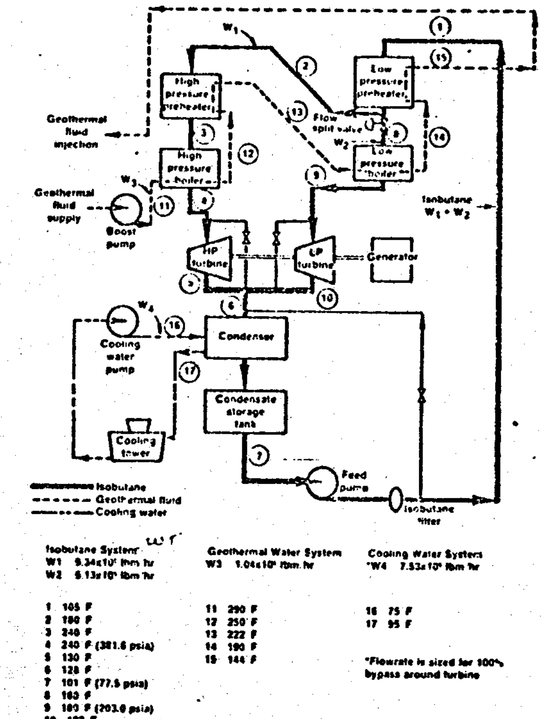

Figure 1 - Dual Boiling Cycle

Performance studies have shown that in the moderate temperature range the dual boiling cycle results in better geofluid utilization than either the supercritical or the single boiler cycles. The improvement is about 23% for a 290°F resource. The improvement provided by the dual boiling cycle increases as resource temperature decreases and decreases with higher resource temperatures so that by 340°F there is no merit in the use of dual boiling cycles.

The system has been designed to take maximum advantage of the seasonal variations in ambient temperature. Condensing conditions for a 65°F wet bulb temperature, which corresponds to a 95% condition, is 105°F (78 psia). At minimum tower conditions, a condensing temperature of ~66°F (42 psia) is obtained. The resulting increase in average power production over a year is estimated [2] at 20-25% compared with the constant power.

Heat and Power Balance The system is designed to operate over a wide range of ambient conditions. The nominal design point is 5MW(e) gross at an ambient wet bulb of 65°F. Up to 7.4MW(e) gross can be generated at lower ambient temperatures. A breakdown of the heat loads and power requirements based upon the nominal 5MW(e) case is given in Table I.

Table I - Heat and Power Balance

	MW
Heat Addition	
L.P. Preheater	14.0
L.P. Boiler	10.0
H.P. Preheater	8.5
H.P. Boiler	12.5
Total	45.0
Heat Rejection	
Condenser	40
Turbine Work	5
Turbine Gross Power	5
Feed Pump	0.71
Cooling Tower	0.59
Geothermal Booster Pump	0.14
Total Losses	1.44
Net Power Nominal Condition	3.56

Physical and Design Description The location of the facility in Idaho and the general arrangement is shown in Figure 2.

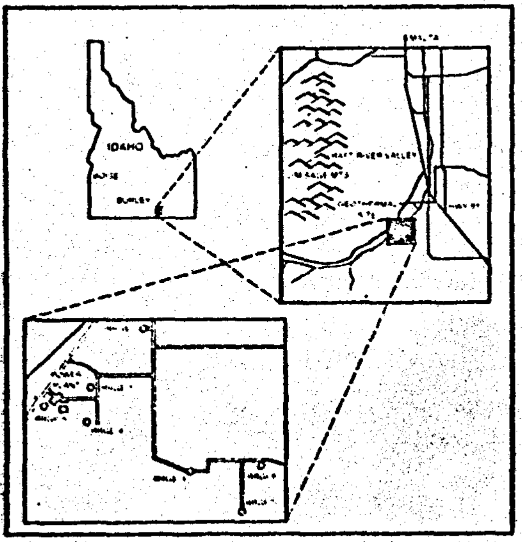

Figure 2 - Raft River Geothermal Site

The power plant area is divided into a process area that contains the heat exchangers, turbine generator and feed pump. Adjacent to this area are buried storage tanks for the isobutane and propane.

Because of the flammable working fluid, the system is designed using the National Fire Protection Association (NFPA) Standards as the governing code. Power Plants are not specifically included in the facilities covered by the code. NFPA No. 59, "Standards for the Storage and Handling of Liquified Petroleum Gases at Utility Gas Plants" was selected as the governing specification supplemented by the ASME Boiler and Pressure Vessel Code (Section VIII), the Power Piping Code (ANSI 31.1) and the Refinery Piping Code (ANSI B31.3).

The geothermal systems have a design pressure and temperature of 250 psig and 320°F. The isobutane system, except for the condenser, design conditions are 650 psig and 320°F. The condenser is designed to the lower conditions of 230 psig and 280°F.

The design pressures were selected to permit the use of propane as a working fluid. From a thermodynamic point of view, the Raft River resource temperature is at the point where the preferred working fluid changes from isobutane to propane [3].

Component Descriptions Feed Pumps - The feed pumping is provided by two parallel vertical turbine pumps rated at 1514 ft and 1747 gpm each. Each pump has six stages and a 500 hp motor. The pump efficiency at rated conditions is 78 percent. The pumps are sized for the minimum condenser pressure of 42 psia.

Geothermal Boost Pumps - The geothermal boost pump provides the head required to pump the geothermal fluid through the heat exchangers and through the transmission lines to the injection pumps. Two parallel, vertical-split-case centrifugal pumps (each with a head of 272 ft at a flow of 1115 gpm, an efficiency at this operating point of 80.5 and driven by a 125 hp electric motor) provide this capability.

Heat Exchangers - The heat exchanger characteristics are defined in the following tabulations:

Heat Exchanger	Surface Area-ft^2	L. ft	Dia. in.	Wt. Tons
L.P. Preheater	30,039*	49	50	43
L.P. Boiler	5,938	42	33/68	20
H.P. Preheater	15,059*	50	35	22
H.P. Boiler	5,938	42	33/68	20
Condenser	56,996	50	88	140

*Extended Surface

The tube material on all geothermal fluid heat exchangers is Admiralty brass. The tube sheets are Aluminum Bronze clad carbon steel. A geothermal side fouling factor of .0015 hr-ft^2-°F/Btu and an isobutane side factor of .0005 hr-ft^2-°F/Btu were used for the design of the geofluid heat exchangers.

The condenser is made of carbon steel throughout, including the tubes.

Cooling Tower - The cooling tower is a crossflow, two cell, mechanical draft, wet cooling tower. The tower is constructed of treated douglas fir and redwood. Pumps circulate 15,373 gpm of coolant. Treated geothermal water is used for coolant makeup.

Turbine-Generator - The turbine will be a radical inflow design. Specifications permit either single or double casing units to accommodate the high and low pressure streams. A single generator is required.

Production and Injection System Description
The relative arrangement of the wells and the planned routing of the supply and injection lines are shown in Figure 2. All lines are made of cement-asbestos pipe with transition to steel pipe at the wells and the plant. The cement-asbestos pipe is buried to a depth of about 2-1/2 ft. The supply lines are insulated with urethane foam to limit the temperature drop to less than 1.5°F/mile.

Pumps will be installed in each of the supply wells. Raft River resource temperatures permit the use of submersible pumps and our test experience with these pumps have been very good. They are about half the cost of shaft driven pumps and require virtually none of the operational restrictions (warmup) that are required by shaft driven pumps.

The pilot plant requires about 2250 gpm of geofluid 290°F for full power operation. In addition, approximately 200 gpm will be required for regulation and another 400 gpm for experiments which are under way at Raft River. This gives a total flow requirement of 2850 gpm. To provide this flow and its injection, four production wells and three injection wells will be drilled, including a standby for each. A summary of the well status is given in Table II.

Table II - Production and Injection Well Data

Production Wells

Designation	Well Depth ft	Cased Depth ft	Remarks
RRGE-1	4989	3623	1-leg
RRGE-2	6543	4227	1-leg
RRGP-4	~5500	~3500	3-leg (when complete)
RRGP-5	5500	Now Drilling	3-leg (standby)

Injection Wells

Designation	Well Depth ft	Cased Depth ft	Remarks
RRGE-3	5917-C 5532-B 5853-A	4237	3-leg
RRGI-6	3972	~1700	1-leg
RRGI-7	3500	2000	1-leg (Now Drilling)

References

1. Madsen, W. W. and I. J. Ingvarsson, "Determination of the 5MW Gross Nominal Design Case Binary Cycle for Power Generation at Raft River, Idaho," INEL Report TREE 1039, December 1976.

2. Shaffer, C. J., "Floating Power Optimization Studies for the Cooling System of a Geothermal Power Plant," INEL Report TREE-1164, August 1977.

3. Ingvarsson, I. J. and Turner, S. E., "Working Fluid and Cycle Selection Criteria for Binary Geothermal Power Plants with Resource Temperatures in the Range of 220°F to 400°F," INEL Report TREE-1108, April 1977.