ELECTRIC POWER GENERATION IN THE ROOSEVELT HOT SPRINGS AREA - THE BLUNDELL GEOTHERMAL POWER PLANT -

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INTRODUCTION

The Blundell Geothermal Power Plant is a single-flash plant with a net capacity of 23 MW_e (26 MW_e gross). The geothermal brine is produced from four wells that tap highly fractured crystalline rock of the Roosevelt Hot Springs geothermal resource. This geothermal resource is a hydrothermal field where groundwater is heated by underlying magma. Production depths generally range from between 1,253 to 7,321 ft (382-2,231 m) at reservoir temperatures of 464°F to 514°F (240-268°C)(Blackett, et al., 2004).

The Blundell Plant, named after a former president of Utah Power, is located in Beaver County, UT, approximately 15 miles northeast of the town of Milford and about 165 miles south of Salt Lake City. The plant itself is currently owned by PacifiCorp (who merged with Scottish Power in 1999), but the geothermal field is owned by Intermountain Geothermal Company, a subsidiary of California Energy Company. The Blundell project was completed in June 1984, at which time the geothermal field was developed by Phillips Petroleum and the power generation plant was built by Utah Power & Light (UP&L). The plant's "claim to fame" was that it was the first commercially-produced geothermal power in the United States outside of California. The project earned the U.S. Department of Energy's innovation award in 1984.

THE GEOTHERMAL RESERVOIR

The Blundell Power Plant is located in the Roosevelt Hot Springs Known Geothermal Area (KGRA) (see Figure 2, page 3), on the eastern margin of the Basin and Range Province near the Colorado Plateau. The area, intensely studied since the early 1970s, has been used as a natural laboratory for the development and testing of geothermal exploration and evaluation methods. Hundreds of geoscience papers and articles appear in the literature regarding the Roosevelt Hot Springs area. Conceptual models of the area are provided by Faulder (1991), Becker and Blackwell (1993), and Moore and Nielson (1994) to name a few.

Geology and Structure

The commercial geothermal reservoir is associated with the Negro Mag and Opal Dome faults. Production from the geothermal system is primarily from highly fractured Tertiary granite and Precambrian metamorphic rocks bounded to the west by the Opal Dome fault, to the north by the Negro Mag fault, and to the east by the Mineral Mountains (Figure 1).

The Mineral Mountains, the first range west of the Wasatch front, are a north-south trending granitic intrusive complex intruded into Precambrian rocks beginning about 25

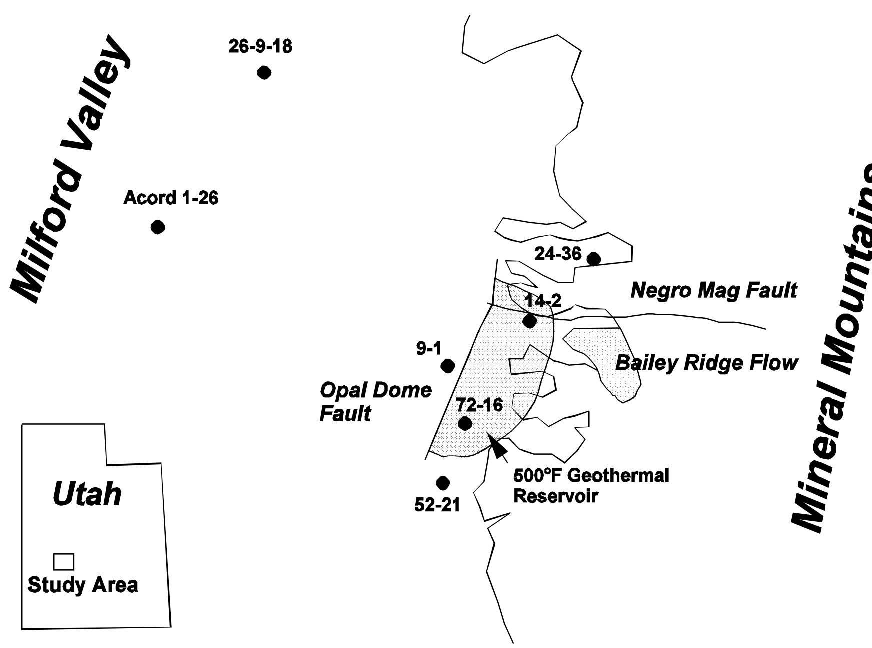

Figure 1. Roosevelt Hot Springs location map.

million years ago. Subsequent rhyolitic volcanism occurred beginning about eight million years ago and ended about 500,000 years ago, resulting in the formation of rhyolite domes in the central Mineral Mountains.

Geochemistry

Chemical analyses of waters from wells intersecting the geothermal reservoir are shown in Table 1 from Capuano and Cole (1982) and Moore and Nielson (1994). The waters are described as a dilute sodium brine, and analyses of the samples from wells and springs suggest that they are from a common reservoir source. The isotopic composition indicates they are of meteoric origin.

Table 1. Chemical Analyses of Waters from the Roosevelt Hot Springs Geothermal System

Parameter	Units	Well 14-2	Well 72-16
Total Depth	m	1,862	382
	ft	6,109	1,253
Na	ppm	2,150	2,000
K	ppm	390	400
Ca	ppm	9.2	12.2
Mg	ppm	0.6	0.29
Si	ppm	229	244
Sr	ppm	-	1.2
As	ppm	3.0	-
Li	ppm	-	16
B	ppm	29	27.2
F	ppm	5.2	5.3
Cl	ppm	3,650	3,860
HCO_3	ppm	-	181
SO_4	ppm	78	32
TDS	ppm	>6,614	6,444
pH		5.9	7.5
Temp.(bottom hole)	°C	268	243
	°F	514	469

Reservoir Model

Faulder (1991) describes a conceptual model that summarizes the hydrothermal system (Figure 2). The model describes fluid recharge, fluid circulation paths, a heat source, and an outflow plume.

The primary geothermal reservoir dimensions were estimated by Faulder (1991) at 10,000 by 23,000 ft (3,050-7,010 m) with a depth of about 10,000 ft (3,050 m). Initial well test information reported by Butz (1980) on well 14-2 showed total well flow rates of 500,000 lb_m/hr (226,800 kg/hr), and under flowing conditions, the maximum temperature recorded was 503°F (262°C) at a maximum pressure of 954 psi (6.57 MPa). Kerna and Allen (1984) reported that subsequent well tests showed that each production well was capable of producing 1 million lb_m/hr (454,000 kg/hr) of geothermal fluid at wellhead conditions approaching pressures and temperatures of 380 psi and 440°F (227°C).

Groundwater recharge to the geothermal reservoir is mainly from runoff and snow-melt (meteoric water) from the west flank of the Mineral Mountains. Some groundwater contribution from inter-basin transfer from Beaver Valley (to the east) to Milford Valley through the Negro Mag graben structure is also possible. Downward circulation of water occurs through the system of extensive joints and fractures associated with the Negro Mag graben. Microseismicity suggests that the presence of open fractures may exist at depths of 10,000 to 26,000 ft (3,050 to 7,925 m)(Faulder, 1991). Groundwater then heats up and flows until it encounters the deep-seated Opal Dome and Negro Mag Faults. Up-flow occurs through these faults into the intensely fractured intersection of the Opal Dome and Negro Mag grabens and other low-angle faults, providing a geothermal reservoir for the fluids. Circulation in the reservoir occurs in the complex, well-developed, three-dimensional permeability structure.

The favored theory explaining the heat source is the presence of a magma chamber under the western central Mineral Mountains. This magma plume is believed to extend from a depth of 16,000 ft (4,875 m) to the upper mantle.

HISTORY OF POWER GENERATION

The Early Days

Utah Power and Light (UP&L) reported that the hot springs in the area was used around the early 1900s by settlers, miners, and cattlemen for bathing, laundry and swimming. Figure 3 is a photograph showing remnants of one building. The springs are reported to have been dry since 1966, but steam still seeps from the ground near a swimming pool once filled with geothermal water (Figure 4).

Phillips Petroleum obtained a lease at Roosevelt Hot Springs in 1974. Through exploratory drilling in 1975, the 500°F (260°C) liquid-dominated reservoir was discovered and in April 1976, the Roosevelt Hot Springs Unit (RHSU) was formed and was the first geothermal unit approved by the U.S. Department of the Interior. The RHSU is eight miles long and six miles wide. Extensive resource and reservoir evaluation then took place and Phillips Petroleum and UP&L signed a contract in 1980, with Phillips agreeing to develop the geothermal resource and UP&L agreeing to provide the generating plant and steam transportation facilities.

Biphase Turbine Testing

UP&L first generated commercial electricity in 1981 using a 1.6-MW_e-biphase turbine research unit installed on one of the wells. The unit was designed by Biphase Energy Systems of Santa Monica, CA (now Douglas Energy Company,) with additional funding and effort from Electric Power Research Institute (EPRI) and UP&L.

At that time, biphase turbines were considered somewhat pioneering technology. Also referred to as "total flow" turbines, biphase turbines are wellhead units that accept brine and steam and improve energy conversion. One field test by Cerini and Hughes (1981) reported a 25% greater power output with a biphase unit as compared to a single-flash operation.

In principle, the biphase stage does the same job as a single-flash stage, but extracts extra power from the fluid stream by converting kinetic energy in the brine to shaft power

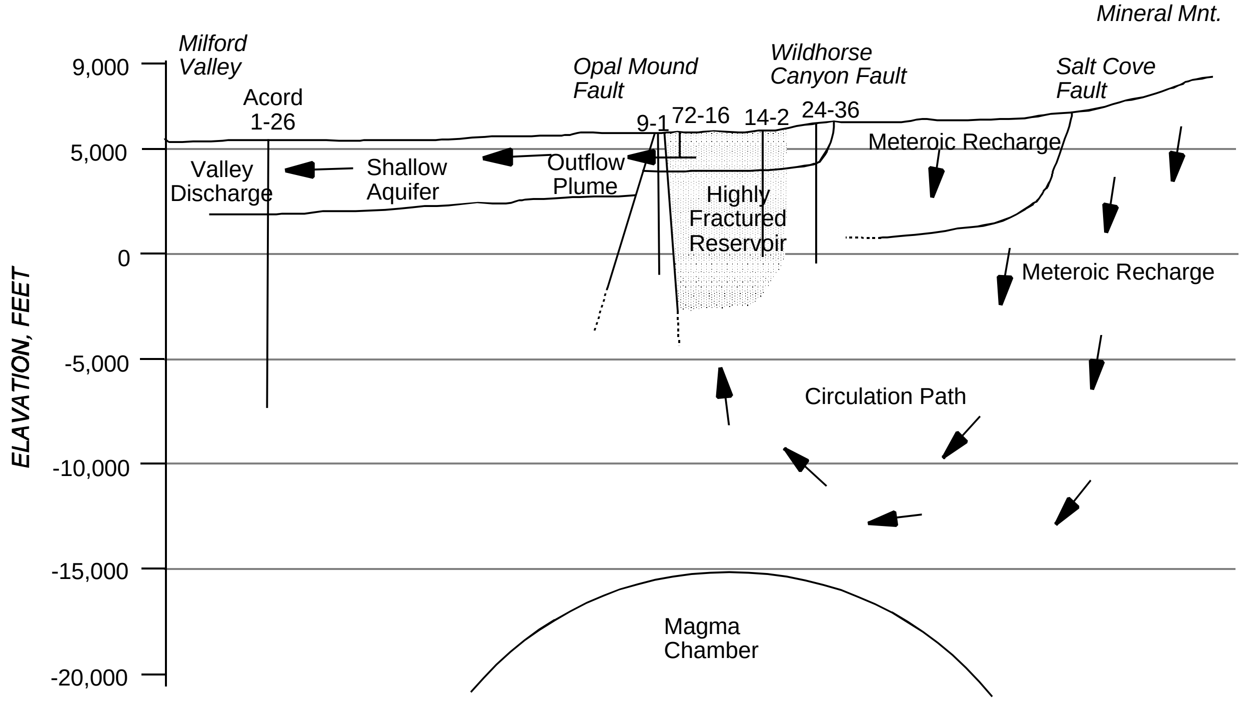

Figure 2. *Conceptual geologic model of the Roosevelt Hot Springs hydrothermal system after Faulder (1991).*

Figure 3. ***Building remnants from old hot springs days.***

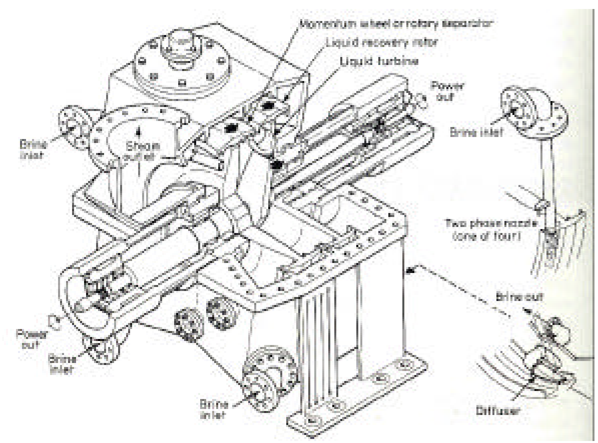

Figure 5. ***The biphase turbine. (By courtsey of Biphase Energy Systems of Santa Monica, CA).***

Figure 4. ***Steam seeps at Roosevelt Hot Springs.***

(Figure 5). First, the pressurized water/steam mixture flows through a nozzle where it impinges tangentially on the inside rim of a rotary separator. Frictional drag forces causes the rotary separator to spin. Flashing occurs as the fluid passes through the impingement nozzle, and the faster moving steam further accelerates the rotor. The clean steam, separated by centrifugal force, then passes along the radial axis of the rotor to a conventional steam turbine which can be installed at the wellhead or in a central plant. The brine layer on the inner wall of the rotary separator passes through holes to an outer liquid turbine whose shaft is connected to a generator. The used brine is then repressurized for reinjection.

A photo of the skid-mounted unit installed at the Blundell location is shown in Figure 6. This 1600-kWe unit

Figure 6. ***Skid-mounted biphase turbine system operated at Roosevelt Hot Springs (photo from www.douglasenergy.com).***

generated power to the UP&L grid for approximately 4,000 hours beginning in October 1981. Inspection after the service time revealed no corrosion or scale deposits on the high velocity surfaces. Options were weighed regarding use of conventional flash technology vs. biphase technology, and for various reasons, conventional flash technology was chosen (Hays, 2004).

The Present and Future

UP&L began construction on the present plant in 1982 and commercial power generation began in 1984. The plant uses a single-flash process. According to Kerna and Allen (1984), electricity was produced from 2.25 million lb_m/hr (1.00 million kg/hr) of geothermal fluids from four production wells. Wellhead separators at each well produces clean steam that is piped to the power plant's turbine to turn the generator. The generator uses about 400,000 lb_m/hr (180,000 kg/hr) of steam. Unused wellhead brine, as well as steam condensate from the turbine, are fed to a surge tank and then returned to the reservoir through three gravity-fed injection wells. The piping network consists of about 4.5 miles (7.2 km) of brine piping and one mile of steam piping as shown in Figure 7. Photographs of the plant are shown in Figure 8.

In 1991, PacifiCorp, which operates as Utah Power in Utah and Idaho, began a 30-year steam purchase contract. Since that time, the plant's average annual power generation has been about 167,000 MWh (Figure 9). PacifiCorp merged with Scottish Power in 1999. A new turbine rotor was installed in May 2001 to increase plant efficiency.

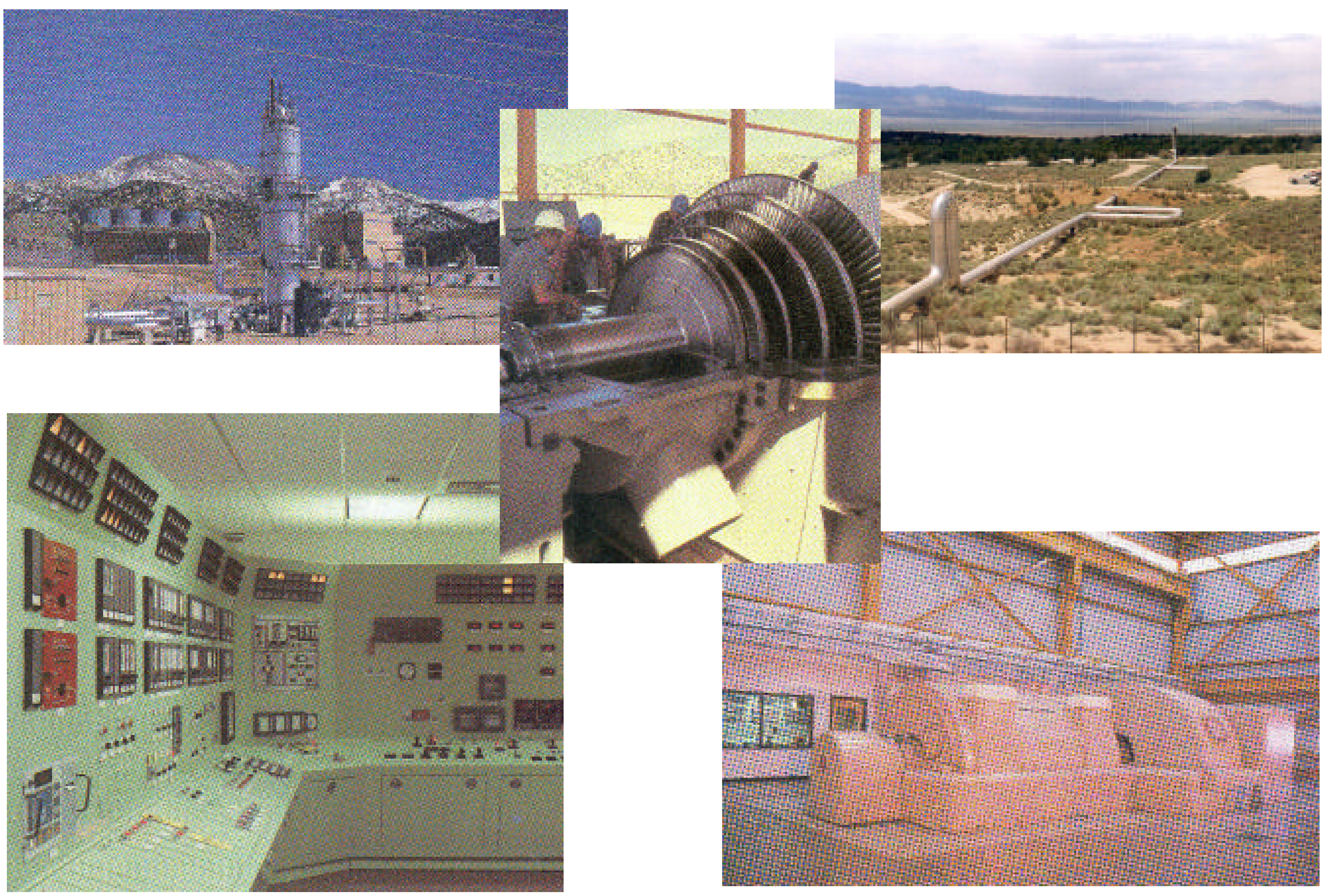

Figure 8. ***Photographs of the Blundell Geothermal Power Plant (clockwise from upper left: seperator, cooling tower and plant building; turbine exposed; transfer piping showing expansion in loops; turbine and generator; control room).***

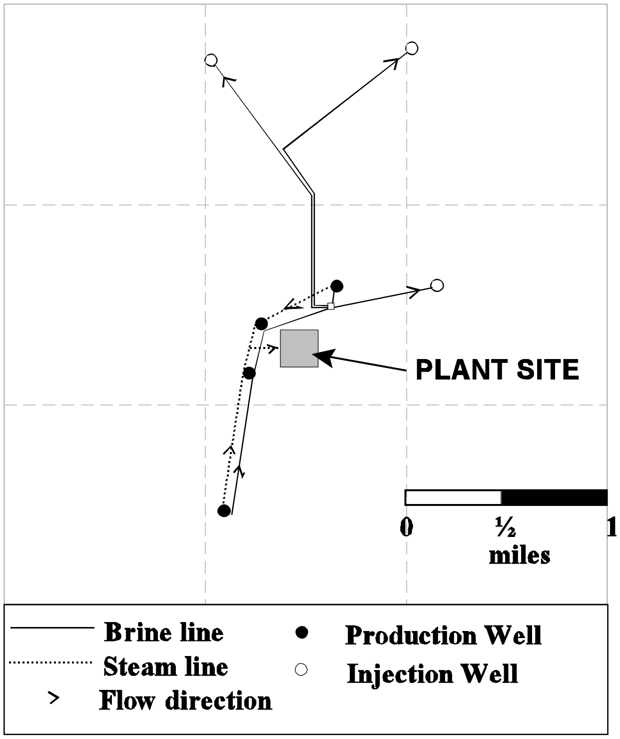

Figure 7. ***Piping layout at the Blundell Geothermal Power Plant.***

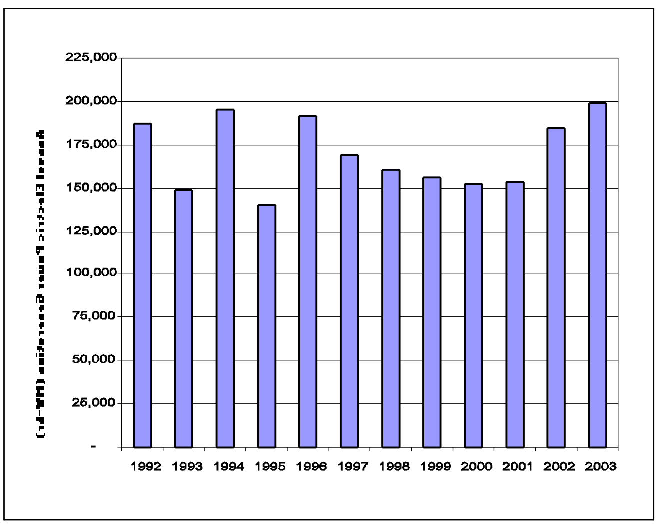

Figure 9. ***Electric power generation from Blundell Geothermal Power Plant, 1992-2003 (Blackett, et al., 2004).***

According to PacifiCorp's 2003 Integrated Resource Plan (IRP) (www.PacifiCorp.com), a 10-12 MW_e expansion is being evaluated and will be implemented if deemed "appropriate and cost effective." The expansion is reportedly from a "bottoming cycle" using binary power technology (Blackett, et al., 2004). Based on PacifiCorp's steam-purchase contract, the plant is scheduled for retirement in 2021.

ACKNOWLEDGMENTS

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