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GEYSERS PERFORMANCE UPDATE THROUGH 2002

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ABSTRACT

Calpine's major focus at The Geysers is to extend its life and increase its output by improving plant efficiency, developing untapped reserves and extracting additional heat energy through water injection. These efforts have been successful. From 1998 to 2002, the average power plant efficiency has improved by approximately 5%. Seven wells have been brought on-line to provide an additional 450 klbm/hr of steam since 2001. The Southeast Geysers Effluent Pipeline project continues to provide benefits to Calpine by supplying 3600 gpm of secondary treated and lake water for injection since 1997. At year-end 2002, Calpine's seventeen power plants generated approximately 730 mw net from a steam supply of approximately 13,650 klbm/hr from 23 contiguous wellfields through 353 production wells.

Using the production data from 1988 through 2002, the steam decline rate for Sonoma County wellfields supplying steam to Units 5, 6, 7, 8, 9, 10, 11, 12, 14, 17, 18 and 20 (226 steam wells producing from 16 contiguous wellfields) is calculated and compared with earlier forecasts. A new decline rate for Calpine market units (292 wells producing steam from 19 contiguous wellfields) that includes above 12 power plants and Units 13, 16 and Sonoma (former SMUDGEO#1) is calculated using the data from January 1995 through December 2002. The activities related to improvements in the wellfield, water injection and power plants are also discussed.

INTRODUCTION

The Geysers steam field, located in Northern California as shown in Figure 1, began commercial steam production in September 1960 with the start-up of Unit 1, a 12-mw power plant. By mid 1989, the installed capacity rose to a maximum of 2000 mw net (Goyal and Box, 1991). Since then several units have been retired due to aging and/or insufficient steam supply. Presently, Calpine and NCPA (North California Power Agency) operate The Geysers field that has a current installed capacity of 1541 mw net. Calpine owns and operates 17 power plants with an installed capacity of 1302 mw net. The remaining 239-mw capacity comes from two power plants owned and operated by NCPA. Calpine sells electricity to PG&E under Qualifying Facility (QF) contracts from four plants. The remaining 13 plants are referred to as "market units" as the power generated by them is sold to the California Independent System Operator (ISO).

The Geysers field has produced a total of 4,476 billion pounds of steam from 1960 to 2002. This production is equivalent to an electric generation of 235 million mwh at a steam usage factor of 19,000 lbm/mwh. Using a conversion factor of 1.5 bbl of oil per mwh, The Geysers has reduced the need to import 350 million barrels of oil by year-end 2002.

Although various operators have published the information about the Geysers' performance over the years, an industry wide comprehensive report on full performance was published in early 1995 through the Geysers Geothermal Association (GGA, 1995). An update on the performance of the portion of The Geysers field that is operated by Calpine is presented here. After acquiring steam fields from Unocal and Florida Power and Light (FPL) and power plants from PG&E, SMUD and FPL in 1998-99, Calpine invested significant capital to extend the life and increase the output of this valuable renewable asset by improving plant efficiency, developing untapped reserves and extracting additional heat energy through water injection. Additionally, Calpine is managing the field by installing more steam pipelines to interconnect existing wellfields to allow steam shifting and developing a cleanout program for production wells affected by downhole bridging due to scale formation.

STEAM PRODUCTION AND GENERATION

Year-end steam production from the wellfields associated with market plants (19 contiguous wellfields supplying steam to 13 power plants) is presented in Figure 2 from 1994 through 2002 with and without makeup wells and injection benefits. Calpine continues to receive about 3600 gpm of water from the Southeast Geysers Effluent Pipeline (SEGEP) project for injection in the southeast portion of the field. The gains from the seven makeup wells and the SEGEP injection are included in the upper line. The lower line displays the steam production from the original 292 wells without these benefits. By the year-end 2002, Calpine's wells produced 1230 klbm/hr (65 mw) more steam to the market plants because of makeup wells and SEGEP injection benefits as shown in Figure 2.

Wellfield Update

Calpine brought seven additional wells on-line during 2001 and 2002 adding new steam of approximately 450 klbm/hr (24 mw). The steam field is now fully interconnected through the addition of numerous new pipelines (crossties). New crossties between Units 9/10 and Sonoma, Sonoma and Calistoga, Sonoma and Unit 20, and Unit 13 and Unit 18 were installed after the 1999 acquisition. Units 9 and 10 have been mothballed (in cold standby status) since April 26, 2001 due to their poor efficiency and high O&M costs. The steam from these areas is flowing to nearby plants through crosstie pipelines.

Injection Update

Injection in The Geysers started in 1969 when steam condensate was returned back to the reservoir through injection wells. Since 1980, injection has been supplemented with fresh water from Big Sulphur Creek (BSC) and small streams during the periods of high run off. Three pump stations are used to extract water from Big Sulphur Creek. Pump station BSC#1 started in 1980 and has a pumping capacity of 7000 gpm. BSC#2 started in 1983 and now has a capability to pump 9000 gpm. The third station BSC#3 started pumping water in 1994 and can pump up to 1500 gpm. Both BSC#1 and #2 have been upgraded by 3000 gpm in 2001.

The SEGEP project continues to provide approximately 5400 gpm of secondary treated water and lake water to Calpine and NCPA (Northern California Power Agency) since September 1997. Calpine injects two thirds of this water (3600 gpm) and the rest is utilized by NCPA.

In 2002, Calpine injected approximately 52.5 billion lbm (150 million barrels) of water into the reservoir. This volume of water equated to 44.6% of the steam production. This injected water contained 53.2% steam condensate, 27.3% SEGEP and 19.5% creek water. The benefit from the SEGEP has been estimated to approximately 780 klbm/hr (41 mw) of additional steam by year-end 2002 in the Calpine area. A detailed summary of The Geysers injection experience is available in Goyal (1999).

The Santa Rosa Geysers Recharge Project (SRGRP) is currently providing about 12.1 million gallons per day (MGD) of tertiary treated wastewater from the Santa Rosa regional sewage treatment plant to The Geysers through a 41 mile 30"-48" diameter pipeline since December 3, 2003. It took three years for the City of Santa Rosa (City) to construct the pipeline. The City is contractually obligated to supply an annual average of 11 MGD (4.0 billion gallons) of water per year.

The City is pumping water from a treatment plant to the base of the Mayacamas Mountains using two 1000 hp pumps to overcome an elevation of about 300 feet. The City then uses three pump stations each housing five pumps (3 constant speed and 2 variable speed) of 1000 hp each to provide a total vertical lift of approximately 3000 feet to a storage tank located near The Geysers. Each pump is capable of pumping 4 MGD. Calpine then pumps this water to its storage tank that is 550 feet higher through a pump station that houses five 600 horsepower pumps. Calpine distributes this water to 8-12 injection wells through 18 miles of 8"-30" pipeline network. The SRGRP pipeline is designed to handle approximately 20 MGD (13,500 gpm) of the tertiary treated wastewater to allow for additional water delivered to The Geysers. Only three out of five pumps installed at each station will be used to pump 11 MGD (approximately 7,600 gpm) of treated effluent to The Geysers. Out of the two remaining pumps, one is a standby pump and the other is used during routine service. The benefits from SRGRP include (i) reduced wastewater discharge into the Russian River by approximately two billion gallons per year, (ii) production of renewable green energy of approximately 85 mw at The Geysers, and (iii) water reuse for irrigation purposes that would conserve Russian River water (City, 2003).

Power Plant Update

Due to continuous decline in the reservoir pressure at The Geysers, most power plants are not running at full capacity and thereby are less efficient than when operated at the design capacity. Several power plants have been modified to improve their efficiency at reduced steam flow. For example, single rotor (jack shafted) Units 12 and 17 were each replaced by two tight rotors (with a smaller steam flow area compared to the original design) to accommodate steam from the closure of Units 9 and 10. Unit 20 also received two rotors similar to those in Units 12 and 17. Units 11 and 14 each received new rotors designed for prevailing reservoir pressure and steam flow conditions.

Additionally, the gas ejector capacity of several power plants was also optimized to handle more non-condensable gases (NCG's), as well as, to remove NCG's efficiently by increasing the number of stages. The efficient removal of NCG's reduces backpressure in the condenser that, in turn, increases power generation. All these changes reduced the steam usage from 19.7 klbm/mwh in 1998 to 18.8 klbm/mwh in 2002. At year-end 2002, Calpine's seventeen power plants generated approximately 730 mw net from a steam supply of approximately 13,650 klbm/hr from 23 contiguous wellfields through 353 production wells. At a usage factor of 19.7 klbm/mwh, this steam production would have generated approximately 695 mw net. Thus the efficiency improvement provided a net gain of approximately 35 mw.

DECLINE RATE OF CALPINE WELLFIELDS (MARKET UNITS)

The steam flow rate data associated with the Calpine market plants from the lower curve in Figure 2 (292 wells producing steam from 19 contiguous wellfields and supplying it to 13 power plants) is presented in Figure 3. The data points in this figure reflect steam production from The Geysers under base (normal operating) conditions but without any sources of water outside the Geysers. These data include internal field gain from the injection of creek water and steam condensate. The loss of steam due to conversion from production to injection wells are also included. Figure 3 suggests a harmonic decline rate of 6% starting in January 1995. The data points above the trend line in 1999-2001 may reflect puff production associated with curtailments from 1995-1998. PG&E, the previous owner of the power plants, curtailed the output of The Geysers seasonally during 1995-96 reflecting economic and contractual conditions. The field was heavily curtailed during these years. The field was also curtailed in 1997-98 but less due to improved economics. After the acquisition in 1999, Calpine produced the field with small or no curtailments.

DECLINE RATE OF SIXTEEN SONOMA WELLFIELDS FROM 1988 THROUGH 2002

The steam production from unit area 1 through 12, 14, 17, 18 and 20 (former Unocal areas) of The Geysers from year-end 1987 to year-end 2002 is presented in Figure 4. These areas are mostly located in the Sonoma County. This figure represents the behavior of 226 steam wells producing from 16 contiguous wellfields. Figure 4 compares the actual decline rate of The Geysers field with that predicted in the past. Barker et. al. (1991) used the production data from 1987 to 1989 and forecasted a 10.5% harmonic decline rate starting in January 1987. GeothermEx (1992), predicted a long term decline rate of 9% harmonic starting in January 1988 based on their three dimensional model of the entire Geysers field. The data from 1994 to 2002 is similar to that in Figure 3 minus the production from the wellfields Sonoma (former SMUD wellfield), Unit 13 and Unit 16. Data points reflect steam production under normal operating conditions but without any improvements such as makeup wells and additional sources of water outside The Geysers. The data points for year-end 1987 and 1988 are obtained from Figure 13 of Barker et al., (1991). The data in Figure 4 spanning 15 years suggest a harmonic decline rate of 9% starting in January 1988. This is consistent with both earlier predictions.

CONCLUSIONS

Calpine's efforts at The Geysers have focused on extending the life of the field and increasing the field output by improving plant efficiency, developing untapped reserves and extracting additional heat energy through water injection. From May 1999 to December 2002, these improvements have resulted in a total increase of 100 mw in the field capacity. In other words, plant efficiency improvements, developing additional reserves and SEGEP injection provided a gain of 35 mw, 24 mw and 41 mw respectively. Using the data from 1988 through 2002, base decline rate (without improvements) for the Sonoma County wellfields since January 1988 is estimated at 9% harmonic, which is consistent with both earlier predictions. For all Calpine market units, the base decline rate is estimated at 6% harmonic starting from January 1995. This translates into a decline rate of approximately 4% in 2002.

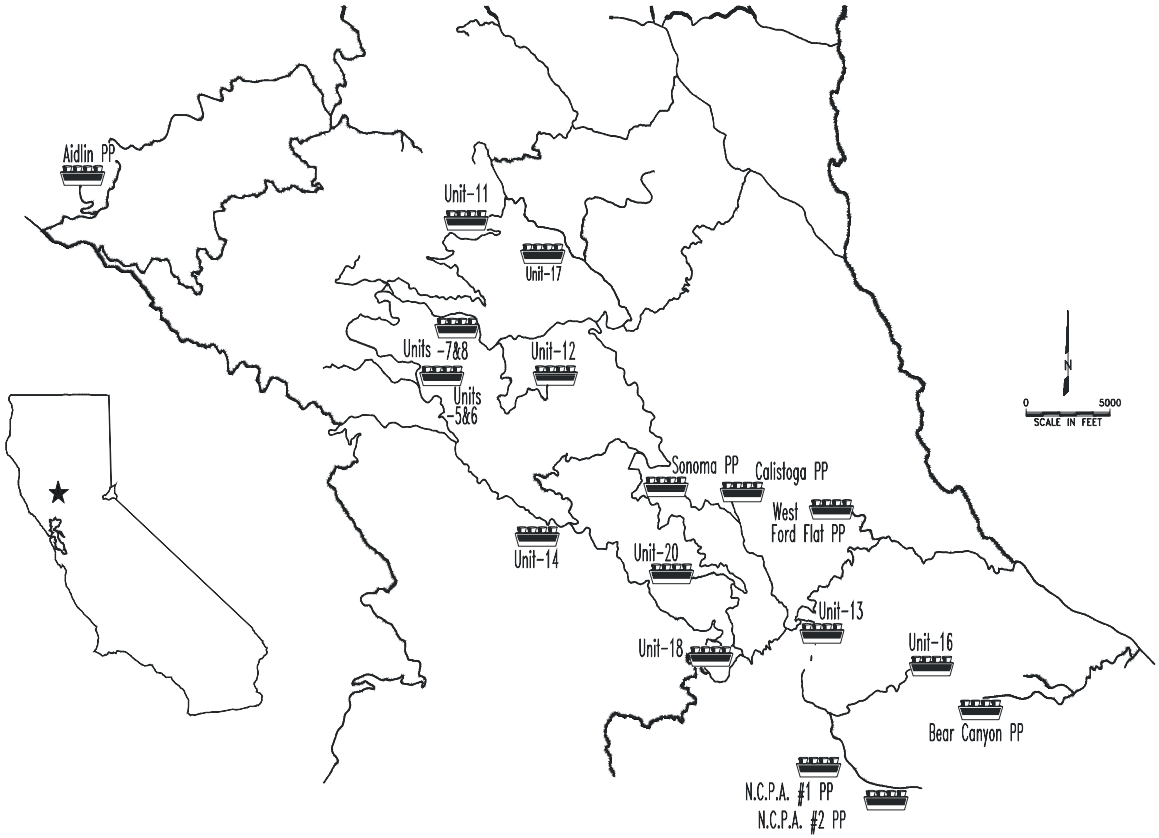

Figure 1: Power Plant Locations in the Geysers Geothermal Field, California

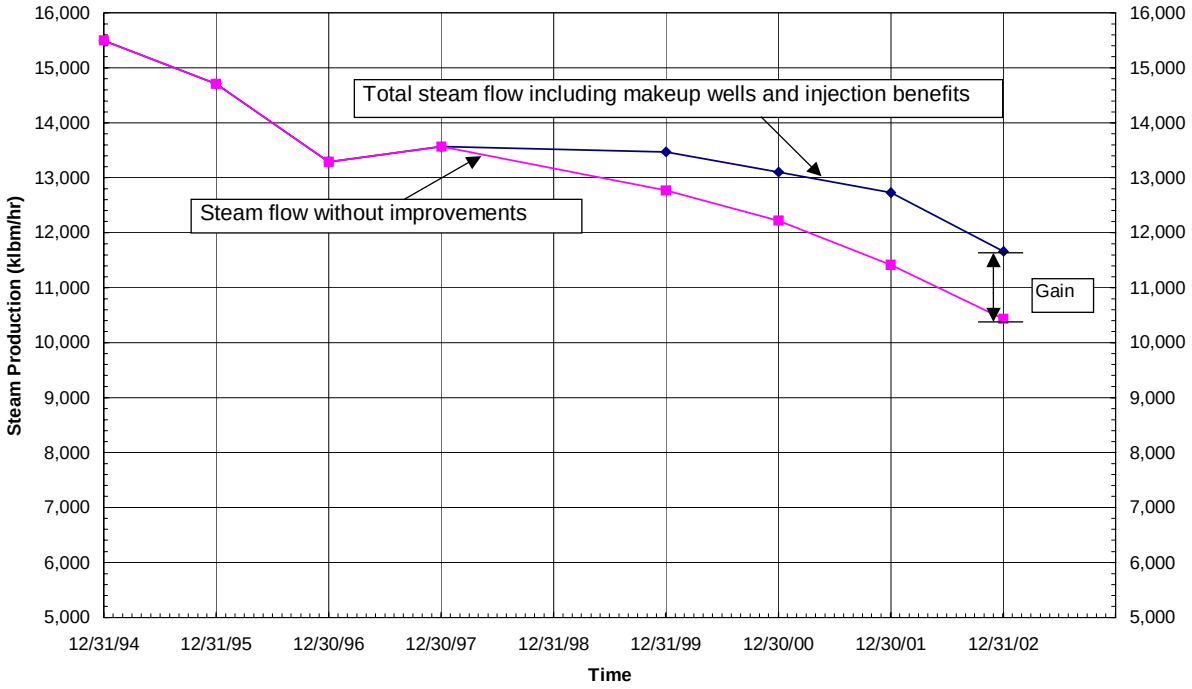

Figure 2: Steam Production from Calpine Market Units

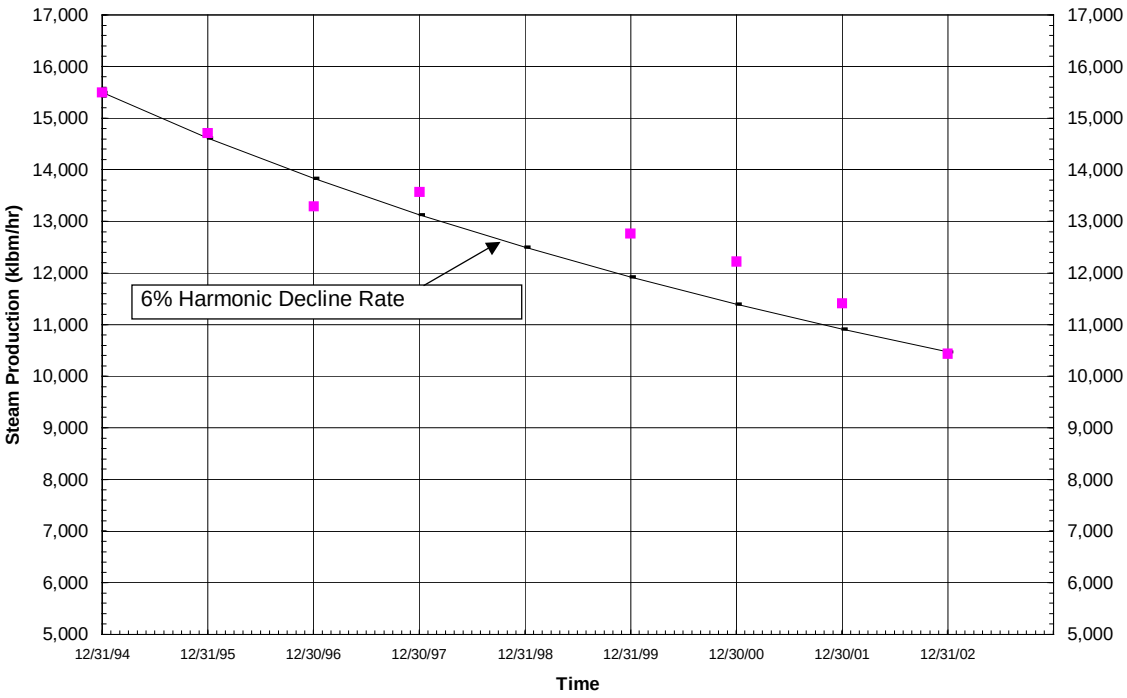

Figure 3: Steam Production Decline Trend In Calpine Market Units

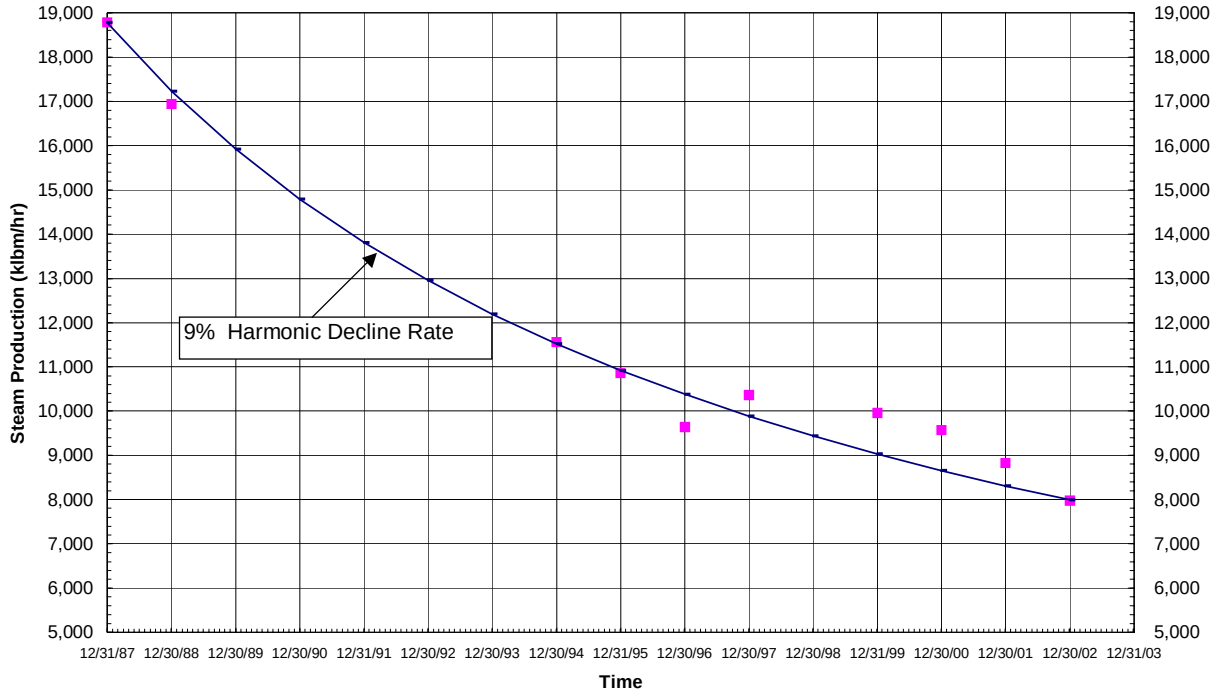

Figure 4: Steam Production from the Sonoma County Areas of The Geysers

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REFERENCES

Barker, B. J., Gulati, M.S., Bryan, M. A., and Riedel, K. L. (1991), Geysers Reservoir Performance, Geothermal Resources Council, Monograph on The Geysers Geothermal Field, Special Report No. 17, pp: 167-177.

City of Santa Rosa (2003), Connections-Santa Rosa Utilities Update, Vol. 1, Issue 1, October 2003, 2 pages.

GeothermEx, Inc. (1992), Fieldwide Reservoir Modeling of The Geysers Geothermal Field, California, for Lake and Sonoma Counties via Criterion, Portland Oregon. August 1992.

Geysers Geothermal Association (1995), An Update on The Geysers, November 1994, GRC Bulletin, vol. 24, Number 1, January 1995, pp 9-21.

Goyal, K. P. and Box, W. T. Jr. (1991), Reservoir Response to Production: Castle Rock Springs Area, East Geysers, California. SPE 21790, Western Regional Meeting held in Long Beach, California, March 20-22.

Goyal, K. P. (1999), Injection Experience in The Geysers, California – A Summary, GRC, vol. 23, pp 541-547.