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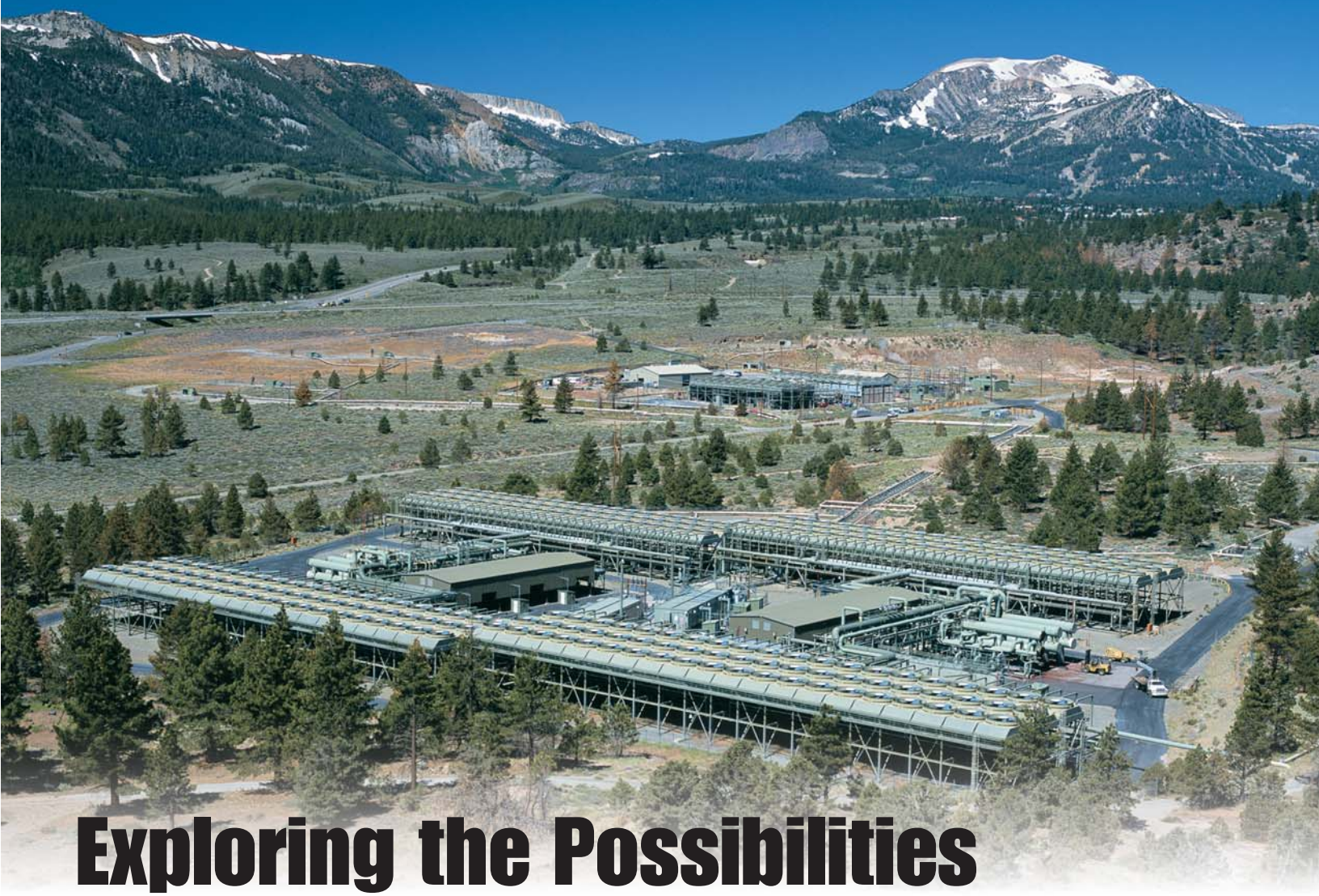

Exploring the Possibilities

Mammoth-Pacific Seeks Cooling Efficiency and More Steam for Geothermal Power Production in California's Sierra Nevada Mountains

In California's newly deregulated market for electricity, geothermal power producers must improve efficiencies and increase power production to compete. According to Mammoth-Pacific L.P. Power Plant Manager Bob Sullivan, "That's the driving force behind our efforts to improve technologies at our facilities, and to find and develop additional, high-quality geothermal resources for the state's power grid and for the environment."

For those familiar with Mammoth-Pacific's record of innovation and its power plants, this should come as no surprise. Located along the eastern front of California's spectacular Sierra Nevada Mountains, the company's power facilities serve as a "showcase" project for geothermal energy development that are "in tune" with the local population and the environment. Indeed, Mammoth-Pacific's power plants are so well designed and concealed from view, they are rarely noticed by the thousands of skiers, hikers and sightseers attracted to the region's splendid high-mountain scenery.

Covanta Energy Corp. (Fairfield, NJ) operates the Mammoth-Pacific projects three binary geothermal power plants, and owns 50 percent of the project, which lies about three miles east from the bustling alpine village of Mammoth Lakes, CA. The company also manages and operates two additional geothermal projects in southern California—the Heber 52-MW and 48-MW SIGC geothermal power plants in the Imperial Valley.

The Mammoth-Pacific power plants use geothermally heated water produced by 12 production wells averaging 400 feet in depth and producing fluids at 350°F from the Casa Diablo Geothermal Field. Six injection wells return spent fluid to the geothermal reservoir, ensuring a sustainable system. The power plants boast a total elec-

trical production capacity of 40 megawatts (MW), sold to Southern California Edison. Mammoth-Pacific Unit MP-1 was commissioned in 1984 at 10 MW, and MP-2 and PLES-1 were both commissioned in 1990 at 15 MW each.

A binary geothermal power facility passes geothermal water though heat exchangers, where its heat is transferred to a secondary (binary) liquid, such as the isobutane used at the Mammoth-Pacific power plants. Isobutane "flashes" to vapor at a much lower temperature than water, efficiently expanding across the power plants' turbines to generate power. The isobutane vapor then condenses back to liquid form and is directed back through the system to repeat its work. "In this 'closed-loop' cycle," explains Sullivan, "there are no polluting emissions and no fuel is required."

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Mammoth-Pacific's fin fan condensing system relies on air cooling, but performance—and power output—suffer during the hot summer months.

Geothermal experts and researchers from around the world regularly visit the Casa Diablo Geothermal Field and Mammoth-Pacific power plants. The geothermal facilities routinely participate in research projects with agencies such as the U. S. Department of Energy (DOE), the National Renewable Energy Laboratory (NREL - Golden, CO), and the California Energy Commission (CEC).

"We continually seek projects for improving our operations and efficiency," Sullivan explains, "ensuring that Mammoth-Pacific stays on the cutting edge of geothermal and power technologies." Sullivan was a recipient of the Geothermal Resources Council's prestigious *Special Achievement Award* in 2000 for his "...outstanding contribution to the development of geothermal resources."

DOE and CEC have provided significant funding to help maximize electricity production at the Mammoth-Pacific geothermal power plants. DOE has granted nearly $100,000 to develop improved geothermal downhole pump systems (matching funds from Mammoth-Pacific totaled $25,000). Through its Public Interest Energy Research Program, CEC provided $1 million to help the company test ideas for an evaporative cooling process utilizing reclaimed wastewater (matching funds from Mammoth-Pacific totaled $3 million). And from its Geothermal Research Development Account, CEC granted $793,122 to assist exploration for new resources and assess the possibility of an additional 50-MW power plant (matching funds from Mammoth-Pacific totaled $1.5 million).

Cooling Enhancement Project

Conventional steam power plants dissipate excess heat after electricity generation through cooling towers or shell-and-tube heat exchangers, where it is transferred to the outside (ambient) air through evaporation or direct contact. Like other binary systems, Mammoth-Pacific's uses air-cooled "fin fans" to dissipate excess heat directly to the ambient air. In doing so, the closed-loop system continuously converts isobutane gas that has done its work spinning turbines back to its fluid state for yet another pass through the power plants' turbines.

This gas-to-liquid conversion depends on the efficiency of the fin fan cooling system to dissipate heat, which is seriously compromised when ambient temperatures rise. To help maintain power output during hot summer days, Mammoth-Pacific conducted an experiment last year to boost their fin fan system efficiency with evaporative cooling.

Sullivan decided on two different evaporative cooling technologies supplied by Munters Corp. (Fort Myers, FL). With both, corrugated media pads were installed around the bottom of three air-cooled condensing units chosen for the test. The idea was to trickle water through the media pads extensive surface area, where it would efficiently make contact with the ambient air. As the water evaporates it absorbs heat, lowering the temperature of the isobutane within the condensing units.

One of the technologies tried at the Mammoth-Pacific facilities used a misting system that sprayed small droplets of water onto Munters MI-T-Fog® media pads. The second system used a more conventional evaporative cooling method that draws air through Munters GLASdek® media pads as water is flushed over them. GLASdek® meets National Fire Protection Association codes, an important factor when dealing with flammable liquids like isobutane. DOE's National Renewable Energy Laboratory (NREL - Golden, CO) provided technical support for the experiment.

To bring the experiment to fruition, a huge volume of water was needed. For this all-important cooling source in the arid region surrounding the Mammoth-Pacific power plants, Sullivan turned to the Mammoth Community Water District. In a unique partnership, the agency agreed to provide over a million gallons of tertiary recycled wastewater per day to the project through a 2.5-mile pipeline built by Mammoth-Pacific.

Installation of the experimental evaporative cooling system units was completed in July 2001, and tested throughout the summer. "We improved our power output by as much as 20 percent," says Sullivan, "and averaged 10 to 15 percent more electricity production." Based on the successful pilot program, Mammoth-Pacific is now considering adding evaporative media pads to their power plants' remaining fin fan cooling units.

Sullivan believes the pilot demonstration will have long-term, positive results—not just for geothermal energy developers, but for the entire power generation indus-

try. "It could lead to a new, more efficient use of water at power plants," he says, "increasing output of existing facilities and at more efficient electric generation facilities planned for the future."

In addition to Mammoth-Pacific's work with evaporative cooling techniques, the company is also involved in a DOE-sponsored effort with NREL, Brookhaven National Laboratory (Upton, NY), and other industry partners to field test various formulations of low-cost, highly conductive polymer coatings applied to inexpensive shell-and-tube heat exchangers. Initial studies indicate that such coatings may allow capital-cost reductions of up to 67 percent, while providing improved corrosion protection, wear resistance, thermal conductivity and ease of scale removal. Field tests at Mammoth-Pacific began in August 2000 using geothermal sidestream fluid.

Exploration Drilling Program

In addition to leases from the U.S. Bureau of Land Management (BLM) for its production wellfield and power plants, Mammoth-Pacific maintains additional leases on nearby federal lands. Half the company's royalty payments on those leases are paid back to the State of California, and half of that is paid by the state to Mono County. Mammoth-Pacific's leases were issued in 1981 and 1985.

Federal law and regulations demand that geothermal lease holders diligently explore undeveloped holdings for potential commercial geothermal energy production. In an effort that may expand their operations, Mammoth-Pacific drilled one exploration slim hole to the west of their power operations last spring, and plans additional drilling this fall as part of its Basalt Canyon Exploration Project.

BLM approved the project last March (with U.S. Forest Service concurrence) after completing an environmental analysis with public input. Environmental mitigation measures include strict control of roads and drill pad construction, restriction of drill site occupancy during spring deer migration, avoidance of cultural resources, and revegetation standards with attention to noxious weed control. Mammoth-Pacific will use best management practices and implement various mitigation measures to minimize or eliminate other potential environmental impacts, including footprint, noise and visibility.

BLM is currently reviewing an additional Mammoth-Pacific exploration project in the nearby Upper Basalt Canyon area, which is currently undergoing the same environmental review process. With approval of both projects, the company will drill several observation slim holes on up to 15 sites to total depths of approximately 1,500 feet (into the geothermal zone). After completion of each slim hole, a temperature profile will be measured, water chemistry samples taken, and reservoir pressure monitored. If successful, several production wells may be drilled at these sites. Slim hole and production well locations are based upon surface geology, geophysical data, land status, topography and proximity to existing roads.

Sullivan anticipates that additional exploration drilling will commence this fall, or as soon as required permits are obtained.

Mammoth-Pacific

Mammoth-Pacific installed experimental evaporative cooling systems last year, boosting power production as much as 20 percent.

Around-the-clock drilling of each observation slim hole is expected to take approximately 12 days, while drilling each exploration well will take approximately 20 days.

In the future, Mammoth-Pacific may submit additional geothermal exploration proposals that target their federal leases to the north of Mammoth Lakes, CA. If commercially viable geothermal resources are discovered, commercial production—either for power generation or non-power uses, such as community heating—may be proposed. In any case, complete environmental review for such projects will be of paramount importance to the federal government, the community and the company.

With the new technologies and steam properties it seeks, the Mammoth-Lakes geothermal power plants promise to be a sustainable, non-polluting source of energy for decades to come. "We want to make our facilities as efficient and environmentally sound as we can," concludes Sullivan, "to provide power for the California grid while protecting the beauty and unique natural resources of the Eastern Sierra."

That goal is punctuated by an annual payroll of over $1.4 million in this rural area, where Mammoth-Pacific plays a significant role as an employer and one of the largest taxpayers in Mono County. Add to that the company's record of environmental protection and community service, and the result is a quintessential "good neighbor." Indeed, the company has pledged a significant contribution to the local school district for equipment purchases over the next three years.

Elected and agency officials agree. The Governor's Environmental and Economic Leadership Program awarded the Mammoth-Pacific evaporative cooling project a *Certificate of Recognition*, for "...meritorious contributions to environmental protection and resource conservation in the State of California." And in 2000, the California Department of Conservation Division of Oil, Gas & Geothermal Resources honored the Mammoth facility with its *Outstanding Lease Maintenance Award*—the first time a geothermal operator has received the distinction two years in a row. (TJC/GRC) ■