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COVER PHOTO:

The DOE-sponsored and NREL-developed Advanced Direct Contact Condenser Packings. This technology has been transferred to industry and the packings were used to retrofit the condenser at PG&E's Geysers unit 11 plant, resulting in a five percent efficiency gain.

INTRODUCTION

The dominant news in the geothermal industry during 1997 was related to the challenges and opportunities arising from the restructuring of the electric power industry in the U.S., the economic crisis in Asia, and promising market activity in Latin America. These stories are reflected in this issue of the Geothermal Progress Monitor.

Although electricity prices in the western U.S. have remained flat due to inexpensive, plentiful supplies of natural gas, opportunities may arise from deregulation of electricity markets. Some electricity providers and marketers in California and other deregulating markets are currently positioning to offer consumers "green power" (power from environmentally preferable sources) for a premium price. Initial surveys indicate that significant numbers of consumers are willing to pay more for electricity that is green. Also, California has created a \$540 million dollar fund to help the renewable energy industry in the transition to a fully competitive market. An additional \$62 million per year will be available in California for renewable energy R&D over the next 4 years. Other states that are in the process of deregulating electricity markets are also considering ways to encourage renewable energy development.

The economic crisis in Asia is adversely affecting electric power markets in the Philippines and Indonesia, two countries that have aggressively

pursued development of their geothermal resources in recent years. It is still premature to accurately gauge the impact of the crisis on geothermal development in the two countries. Indonesia announced that a number of geothermal projects under construction would continue as planned but that others, planned but not yet under construction, would either be delayed or canceled. However, with extensive geothermal resources and policies that favor development of these resources, both countries are likely to continue geothermal development.

Activity in Latin America seems to indicate the area is heating up as a market opportunity. Oxbow Power Services of Reno, NV won a contract to build Miravalles III, the first Build-Operate-Transfer geothermal project in Costa Rica. The project is 27.5 MW, and the state-owned utility, the Instituto Costarricense de Electricidad owns an option to have Oxbow build a second plant of the same size. Also Unocal Corporation signed a geothermal exploration concession agreement with Nicaragua. The 100 square kilometer concession at El Najo-Santa Isabel is in the same volcanic complex as the San Jacinto-Tizate geothermal field. In El Salvador, the Sumitomo Corporation of Japan is installing two 28 MW turbines at the Berlin geothermal field. The first unit is scheduled for completion in October of 1998, and the second for January of 1999.

In response to perceived market opportunities being created by deregulation of electric power markets and the global climate change issue, Enron is expanding into the renewable energy business. The INDUSTRY SCENE section outlines Enron's creation of Enron Renewable Energy Corporation to pursue opportunities in wind and solar. The company will pursue international geothermal opportunities through Enron International and domestic geothermal opportunities through Enron Capital and Trade Resources. This section also covers Pacific Gas and Electric Company's announcement to divest its geothermal power plants at The Geysers geothermal field in northern California. The 12 plants, totalling about 1200 MW, are being divested as part of PG&E's strategic shift from a regulated investor-owned electric utility to a power distribution company.

In the STATE AND LOCAL section, several articles outline California's implementation of two pieces of landmark legislation, Assembly Bill 1890 and Senate Bill 90, creating open competition in the state's electricity markets. The state has created an Independent System Operator to operate the state's transmission system and a Power Exchange to act as a clearinghouse for bulk wholesale electricity transactions. The legislation also creates a \$540 million fund to encourage renewable energy projects in the state and a \$250 million fund for public interest electricity research and development.

The FEDERAL BEAT section describes the U.S. Department of Energy's award of a contract to manage its R&D efforts

in enhanced geothermal systems such as hot dry rock, hot wet rock, marginal hydrothermal systems, margins of hydrothermal systems and fluid-depleted hydrothermal systems. The contract was won by the team of Princeton Economic Research, Inc. of Rockville, MD, and GeothermEx of Richmond, CA. The term of the contract is one year, and DOE has the option to extend it annually for four additional years.

Two exceptionally prolific geothermal wells were completed in Indonesia during the year. As reported in the INTERNATIONAL section, Unocal completed well Silangkitang 1-3 at the Sarulla geothermal field and determined it is capable of supporting approximately 37 MW. Amoseas Indonesia, a joint venture of Chevron and Texaco, completed well DRJ-16 at the Darajat geothermal field and reported it capable of supporting 20 MW. This section also includes an article outlining the new Geothermal Implementing Agreement executed under the International Energy Agency. The U.S. Department of Energy has signed the agreement which consists of collaborative scientific efforts.

Two prominent geothermal organizations received new executive directors during the year. The Geothermal Resources Council named Ted Clutter executive director, and the Geothermal Energy Association named Karl Gawell executive director. Background information about these newcomers to the geothermal industry is found in the PEOPLE section. Also, two long time geothermists retired during the year. Dr. David Lombard retired from DOE's Office of

Geothermal Technologies after more than 20 years of service. Paul Lineau retired as director of the Geo-Heat Center at the Oregon Institute of Technology, a position he held since the Center was established in 1975.

Several of the promising geothermal R&D projects currently underway are outlined in the TECHNOLOGY DEVELOPMENT section.

Development of geothermal drilling and logging technologies continued at Sandia National Laboratory. Reductions of 15% to 20% in the cost of geothermal drilling can be achieved in the next 5 years according to Dave Glowka, Geothermal Program Manager at Sandia. Much of the research there is focused on developing drag bits using synthetic diamond, titanium carbide, and/or boron oxide cutters. Sandia also developed a pressure-temperature-spinner (PTS) memory logging tool and a core tube data logger. The PTS tool can be used in wells at 400 °C and 6,000 psi for up to 10 hours. The tool is now available through Pruett Industries. The core tube data logger currently measures and records temperature and borehole inclination, and a pressure transducer can be easily added to the device. It has been field tested in geothermal exploratory slim holes at the U.S. Army's Fort Bliss in Texas and New Mexico. Both Tonto Drilling Services and Boart Longyear are interested in adopting the tool for commercial use. Also, the Geothermal Drilling Organization initiated three new cost shared drilling projects during the year. Smith International and Puna Geothermal Venture are matching DOE funds to develop a high-temperature/high-pressure valve

changing tool. A second project seeks to develop insulated drill pipe to lower bottom hole temperatures during drilling. Halliburton and CalEnergy are cost-sharing the development of lightweight nitrogen foam cement to ameliorate mud and lost circulation problems common in geothermal drilling.

Three important technology transfer activities are outlined in the TECHNOLOGY TRANSFER section. The Long Island Lighting Company (LILCO) has accepted two technology transfer proposals from Brookhaven National Laboratory (BNL) regarding two DOE-sponsored technologies. Cation-exchange adsorbents and high-performance cements from ash and sludge wastes were selected by LILCO to investigate the possible use of bottom ash and waste water treatment sludge byproducts as starting materials for cements and ion-exchange materials. Pacific Gas & Electric Co. (PG&E) announced that the use of advanced contact condenser (ADCC) technology at its Unit 16 plant at The Geysers resulted in a 5% efficiency gain. PG&E plans to retrofit 5 additional units with the ADCC technology, which was developed under a research partnership between the U.S. DOE, PG&E, and the National Renewable Energy Laboratory. Also, the first biphasic geothermal turbine, developed by Douglas Energy Co with cofunding from the U.S. DOE, was shipped to Mexico for installation in the Cerro Prieto geothermal field.

FEDERAL BEAT

BLM Report on Geothermal Royalties

The U.S. Bureau of Land Management reported that the steam and hot water produced from its 22 leases in California fueled 951 megawatts of installed capacity in 1996. This generation is enough to supply nearly one million people. Revenues from production royalties totaled more than \$17.2 million for the same year.

According to the BLM, two new projects are moving ahead on federal leases on the Klamath and Modoc National Forests at Glass Mountain in Northern California. The Fourmile Hill project was proposed in early FY 1996 with the initiation of an Environmental Impact Statement. The project will consist of a 49.9 megawatt power plant and a 20-mile, 230 kV transmission line. At the end of FY 1996, a second 49.9 megawatt power plant was proposed for Glass Mountain in the Modoc National Forest.

Grant Awards for Reservoir Technology Research

The United States Department of Energy, Idaho Operations Office, provided financial assistance to three entities in FY 1997 for RD&D in geothermal reservoir technology. This

award is in response to the open competition solicitation that the Office had posted in the Federal Register.

The University of Idaho was awarded \$199,770 to study "The Behavior of Rare Earth Elements (REE) in Selected Geothermal Fluids." The study will establish information on REE contents in geothermal fluids; determine any distinctions in REE content between producing, potentially producing, and non-economic geothermal fields; determine seasonal changes in REE geochemistry; ascertain whether REE geochemistry changes systematically over the production history of a geothermal field; and assess the utility of REE geochemistry a tool for the industry.

Southern Methodist University (SMU) was awarded \$274,789 to conduct "Geothermal Resource/Reservoir Investigations Based on Gradient/Heat Flow Data for the United States. SMU will maintain and upgrade existing thermal databases; initiate a WWW home page with the present eastern US geothermal data sets and total heat flow database; develop geothermal gradient/heat flow potential high temperature site-specific database for the western US; and create a model of a typical geothermal system in the Basin and Range region based on site-specific thermal gradient/heat flow data.

William Lettis and Associates of Reno, Nevada, was awarded \$237,860 for "Application of Advanced Seismic Imaging Techniques to Mapping Permeable Zones in a Geothermal System." The project will test the ability of recently developed seismic reflection analysis methods to locate and characterize faults, fractures, and other permeable features within the Dixie Valley geothermal field in northern Nevada. William Lettis & Associates will use existing hybrid-source, multifold reflection data owned by Oxbow geothermal to test and demonstrate new seismic reflection data processing technology that will map the true-depth location of lithologic contacts, faults, fractures, and other permeable features within the Dixie Valley geothermal field.

DOE's HDR R&D Program To be Refocussed by Private Sector Team

Effective October 1, 1997, the U.S. Department of Energy (DOE) has contracted the operational management of its R&D program in Hot Dry Rock (HDR) geothermal energy to a team of two private sector firms. The team is led by Princeton Economic Research, Inc. (PERI), a professional services firm that specializes in analysis and development of renewable energy technologies, including geothermal, wind, and solar. The second firm, GeothermEx, Inc. of Richmond, CA is a leading provider of international geothermal exploration and field development services. The term of the contract is one year, with options for four additional years.

The Princeton/GeothermEx team (P/GX) won the contract in an open competition conducted by the DOE's Idaho Operations Office (DOE/ID) for DOE's Office of Geothermal Technologies (OGT). The team also includes Dr. John E. (Ted) Mock, the former director of the Federal geothermal R&D program, and Mr. Cliff Carwille, former manager of the HDR program.

The refocussed research program will differ significantly from the former one, the exact extent of which will be determined by stakeholders as well as funding levels. The most significant difference is that it is not being approached as an "HDR research" program. The term HDR will temporarily describe the program until stakeholders adopt a better term to describe the broad wet-to-dry geothermal resource continuum that will require new technology if it is to be fully exploited. This continuum ranges from highly permeable, low-fluid or fluid-depleted hydrothermal reservoirs, through less permeable marginal hydrothermal reservoirs, to very tight, impermeable, mostly dry, hot rock.

The U.S. Geological Survey has determined that U.S. geothermal resources are significant. However, technology currently limits the economic development of geothermal energy to hydrothermal reservoirs, which constitute only a fraction (probably less than 10%) of the entire geothermal resource base. Demonstration projects in the U.S., U.K., Japan, and Europe have proven the technical feasibility of extracting heat from hot impermeable or semi-permeable rock. The future of the

geothermal industry will depend on its ability to economically develop low permeability resources as the limited inventory of high potential resources becomes fully developed. If technology can be improved to enable economic energy extraction from abundant low permeability resources,

geothermal resources can become a major contributor to the nation's objectives of mitigating global warming and developing clean, indigenous sources of energy. Further, new technology developed in the U.S. will give our industry a competitive advantage in international markets.

INDUSTRY SCENE

Enron Expands Renewable Businesses

According to Kenneth L. Lay, Chairman and CEO of Enron "A growing concern over global climate change is providing the momentum for an increasing share of the world energy market to turn to renewable energy over the next decade. Based on an assessment of these global needs, Enron is expanding its renewable activities across several lines of business."

Enron Renewable Energy Corp. (EREC) was established in January 1997 to strengthen Enron's position as a world leader in the renewable energy market. EREC will pursue solar and wind energy development opportunities worldwide through Amoco/Enron Solar, a joint venture partnership, and Enron Wind Corp., respectively.

Enron International will pursue international business opportunities to capitalize on the significant potential of hydroelectric and geothermal power from a world market standpoint. Enron Capital & Trade Resources will oversee hydroelectric and geothermal opportunities in North America.

Enron Corp. is one of the world's largest integrated natural gas and electricity companies with approximately \$21 billion in assets.

NCPA Receives Geothermal Award

The Northern California Power Agency (NCPA) was selected as the 1997 recipient of the Resource Conservation Award for the Southeast Geysers Effluent Pipeline Project. This prestigious award is conferred by the Municipal Utility Companies Association. The award cited NCPA's leadership in demonstrating geothermal injection technology.

The Southeast Geysers Effluent Pipeline and Injection Project is designed to deliver 8 million gallons of treated municipal wastewater per day for injection into The Geysers reservoir. The project provides an environmentally superior and affordable municipal wastewater disposal system.

The injected wastewater serves to mitigate fluid and pressure depletion in the SE portion of The Geysers. The increase in steam production will be enough to support an additional 70 megawatts of electricity, providing 625,000 megawatt-hours annually to more than one million consumers in northern California. The life span of the SE portion of The Geysers geothermal steamfield will be extended by more than ten years. Furthermore, this wastewater-to-electricity system will displace 68,000 tons of CO₂ emissions per year that could have resulted from electricity generation by fossil fuels.

The project represents a unique public/private partnership of 11 state, federal, and corporate sponsors cooperating to develop and construct the world's first wastewater-to-electricity production system. This diverse group includes the Department of Energy, Environmental Protection Agency, Bureau of Land Management, Lake County Sanitation District, Unocal Corp., Calpine Corp., the California Energy Commission as well as NCPA. The partnership has become a national model of environmental management.

PG&E to Divest Geysers Geothermal Holdings

Pacific Gas & Electric Co. has announced plans to divest its geothermal power plants at The Geysers in 1998, following regulatory approval. The company's Geysers operations consist of 12 turbine-generator sets totalling 1,224 megawatts of installed geothermal capacity.

The planned divestiture is part of PG&E's strategic shift from a regulated investor-owned utility to a power distribution company. The shift is driven by passage of legislation to deregulate California's electricity market to encourage competition.

California's electricity restructuring law, Assembly Bill 1890, endorses a competitive generation industry separate from power transmission and distribution operations. The California Public Utilities Commission (CPUC) has issued a directive asking that the

state's utilities voluntarily divest at least 50 percent of fossil-fueled power plants within their service territories.

PG&E estimates the book value for its Geysers operations at \$381 million. Unocal and Calpine Corp. have indicated interest in the acquisition and are evaluating the commercial potential of the power plants. AB 1890 requires buyers to retain PG&E to run and maintain the facilities for two years after the sale.

GRC Annual Meeting Features Utility Restructuring

The Geothermal Resources Council's annual meeting, held in San Francisco on October 13th through 15th, 1997, was a big success with almost 500 participants from 31 countries. This continued the trend of increased participation of the international geothermal community in the GRC annual meeting.

The theme of the meeting, "Meeting the Challenge of Increasing Competition," was echoed in the speeches and a panel discussion during the opening session. Maureen Palmer, Enron Corporation's California Director of Government Affairs, delivered the keynote address entitled, "Marketing the Green." Ms. Palmer emphasized Enron's commitment to play a major role in California's energy market, as well as nationwide, and that green marketing will be a significant component of the company's marketing strategy, especially in California. She pointed out that no one is sure exactly

how many California consumers will pay a premium for green power, or even how many are willing to exercise choice of an energy service provider other than their utility. These are questions that Enron is seeking to answer in order to design an effective marketing strategy for the state.

Ms. Palmer stated that California's \$540 million in renewable transition funding under Assembly Bill 1890 will play an important role in shaping California's green power market. It will help finance project development and fund existing projects as well as provide rebates to customers of 1.5 cents per kilowatt hour for power they purchase that is more than 50% derived from renewable energy sources. Enron believes the renewables market will develop slowly in California and that there is sufficient renewable supply for the short term. However, the company believes that differentiation of renewables in the market will create opportunities to develop new renewable resources.

Gregory Conlan, president of the California Public Utilities Commission, presented a speech titled "Today is the Day." Mr. Conlan described the utility restructuring process currently being implemented in California. The process, designed to begin open competition in electricity markets on January 1, 1998, creates an Independent System Operator to control and administer the transmission system and a Power Exchange through which all electricity will be sold by competitive bid. Mr. Conlan also stated his belief that national efforts to abate global climate change will result in an emissions cap and tradeable credits.

Such national policy, he pointed out, when implemented with the state's restructuring policy (which gives preference to green power), will create a truly bright future for geothermal and other forms of green energy.

William Keese, Chairman of the California Energy Commission (CEC), also addressed the opening session, describing his agency's role for renewables during electric utility restructuring. Chairman Keese outlined three competitive themes that will affect the geothermal industry. First, the renewables market will be restructured for full competition on January 1, 2002, and \$540 million will be available to help renewables successfully compete. Geothermal projects will share \$38 million of the \$540 million with landfill gas projects. Second, the state of California will invest approximately \$62 million in renewable energy R&D annually to fund programs the utilities once funded. Third, green marketing will play an important role in the growth of renewables, and the CEC will provide \$75 million for a program of rebates to electricity consumers who buy electricity from renewable sources, including geothermal. Chairman Keese pointed out that if the cost of electricity is 10 cents per kilowatthour and only one fourth of that is attributable to generation (the rest covers transmission, distribution and administration), a one cent premium for green power would represent a 40% increase in revenue for the generator and only a 10% increase in the consumers' electricity rate.

The panel discussion during the Opening Session focused on meeting

the challenges of competition. The discussion was moderated by Tom Hinrichs of Pacific Energy Consultants, Escondido, CA. The panel members included Jan Smutney-Jones, interim chair of the Independent System Operator and chair of the Power Exchange; Ken Abreu, director of supplier contract management for Pacific Gas & Electric; Roger Fontes, assistant general manager for the Northern California Power Agency; and Peter Cartwright, founder of Calpine Corporation.

The discussion centered around the state's restructuring process and how it will affect geothermal operators and electric utilities. In that process, the transmission system will remain a regulated monopoly, operated by the Independent System Operator which will function as an "air traffic controller" for electrons. The generation and distribution of electricity will be market based with open competition. A significant ramification for geothermal developers is that electric utilities will no longer be their customers. Rather the developers will become the customers of the utilities, buying transmission and distribution services to deliver their electrons to the market.

GRC Awards Presentations

Several persons received awards during the 1997 GRC annual meeting. Subir Sanyal, president of GeothermEx, Richardson, CA, received the prestigious Aidlin Award, recognizing his "outstanding contributions to the Geothermal Resources Council and the development of geothermal energy." Paul Lienau and John Lund received the Pioneer Award for "outstanding achievement in the development of geothermal resources." The GRC recognized Baldur Lindal with its first Special Citation Award for his "significant contributions to the geothermal industry through his life's work." Lindal, who died last year in Reykjavik, Iceland, was a pioneer in direct utilization of geothermal energy.

Distinguished Service Awards were bestowed on Dave Anderson, the former executive director of the GRC and the 15 former presidents of the GRC. The GRC staff received Certificates of Appreciation.

INTERNATIONAL

GEA Participates at World Sustainable Energy Trade Fair

The Geothermal Energy Association (GEA) participated at the World Sustainable Energy Trade Fair and Congress held May 27-29 in Amsterdam, The Netherlands. Organized and coordinated by European Marketing Ltd. (London, UK) and hosted by NOVEM, the Netherlands agency for energy and the environment, the trade fair attracted nearly 5,100 people from around the world. More than 175 exhibits featuring renewable energy, waste-to-energy, and sustainable transport technologies were on display and about 600 delegates attended the sessions. The GEA was an official sponsor of the event, and Mike Wright, President of the GRC, served on the Renewable Energy Committee for the Congress.

GEA's exhibit consisted of more than 30 photo posters with captions depicting various aspects of a geothermal project, U.S. geothermal technology development, the diversity of geothermal energy applications, and the many regions throughout the world where geothermal projects are being developed, under construction or in operation. Photos were obtained from industry and government-sponsored organizations. Gary Schulman of Geothermal Power Company also

attended the trade fair and provided some assistance at the GEA booth. As part of the exhibit, a wide variety of printed materials on geothermal energy was available and distributed, including a paper authored by Mike Wright and Perle Dorr specifically written for the trade fair. (Note: This paper is being published in three parts in the *Sustainable Energy Industries Journal*, a quarterly publication prepared and issued by European Media Marketing Ltd.). GEA estimated that more than 1,000 persons, or roughly 20% of the total trade fair attendance, visited the GEA booth to learn about geothermal energy.

In addition to the exhibit, the GEA hosted a half-day seminar, "Understanding Geothermal Project Risks and their Mitigation," for bankers, representatives of multilateral institutions, policy makers and others interested in geothermal energy development. The program focused on the worldwide potential of geothermal resources and the risks associated with investment in geothermal energy development. Mike Wright, Subir Sanyal, George Knapp, Thomas Boehlert, and Jonathan Weisgall made presentations. Feedback received from the seminar attendees was extremely positive.

The Asia-Pacific Initiative for Renewable Energy and Energy Efficiency

A conference of the Asia-Pacific Initiative for Renewable Energy & Energy Efficiency, jointly organized by the U.S. Export Council for Renewable Energy (ECRE) and Alternative Development Asia Ltd., was held in Jakarta, Indonesia, October 13-16, 1997. President Suharto of Indonesia inaugurated the conference during an official ceremony held at the presidential palace. The event received extensive local media coverage.

In his inaugural statement President Suharto indicated that during the 21st century, Indonesia's need for electricity will reach 28,000 megawatts based on an annual demand rate of 13.8 percent. He mentioned the importance of discovering new energy resources and the need to conserve, diversify, and use energy efficiently. In regards to geothermal's contribution to the energy needs of Indonesia, President Suharto had the following to say: "Geothermal is one of the primary power generators in Indonesia. Today, there are more than 300 megawatts installed geothermal electric power in Indonesia. This installed capacity is still very small compared with our geothermal reserves of around 19,000 megawatts."

The conference was organized in cooperation with the U.S. Department of Commerce, U.S. Agency for International Development, U.S. Department of Energy, U.S. Environmental Protection Agency, and

support by a number of associations. Close to 400 representatives of renewable energy and energy efficiency businesses, non-governmental organizations, and government agencies attended.

Unocal Begins Operation of First Private Geothermal Plant in Indonesia

On October 21, 1997, Unocal announced the commissioning of Unit #4 at Gunung Salak, the first of three new 55-megawatt plants. The plant will be operated by Dayabumi Salak Pratama Ltd., jointly owned by Unocal Geothermal of Indonesia, Ltd. (UGI) and PT Nusamba Geothermal. The other two 55 MW plants, Units 5 and 6, were also commissioned a few weeks later.

With the three Dayabumi power plants on-line, the geothermal generating capacity of the Gunung Salak field totals 330 megawatts, making it the largest geothermal project in Indonesia. The first three 55-megawatt units are operated by PLN, the Indonesian state electricity utility, with Unocal as the supplier of geothermal steam.

With completion of development at Gunung Salak, the combined results of steam production and sale of electricity will add an estimated \$24 million to Unocal's net earnings and \$44 million to operating cash flow on an annualized basis.

Ijen -- CalEnergy's New Geothermal Prospect

One of CalEnergy's newly formed Indonesian subsidiaries and its local Indonesian partner have been awarded the exclusive right to negotiate contracts to build, own and operate a geothermal power project at the Ijen geothermal area in Java, Indonesia. Exploration of the Ijen resource (estimated to support 100 to 400 net MW) is expected to commence in early 1998, following the negotiation and signing of a Joint Operation Contract with the state oil company, Pertamina, and an Energy Sales Contract with the state utility, PLN.

Unocal Signs Geothermal Exploration Concession Agreement in Nicaragua

In late August 1997, a subsidiary of Unocal Corporation, Unocal Geothermica Nicaragua, signed an agreement for a new geothermal exploration concession in Nicaragua. This marks Unocal's first geothermal energy venture in Latin America.

The 100-square-kilometer concession area at El Najo-Santa Isabel, is located east of Leon, a major regional city. It is in the same volcanic complex as the San Jacinto-Tizate field, a proven geothermal resource.

"Nicaragua is a key part of our long-term growth strategy for geothermal development in Central America," said Randy L. Howard, Unocal vice president

for worldwide geothermal operations. "There is not only significant geothermal potential in the region, but Nicaragua has opened the door for private power generation and the export of electricity to neighboring countries," he elaborated.

Nicaraguan president Dr. Arnoldo Aleman presided over the signing ceremony which was also attended by U.S. Ambassador Lino Gutierrez.

Oxbow to Develop First Costa Rican BOT Geothermal Project

Oxbow Power Corp. (West Palm Beach, FL) announced on April 8 that an international consortium led by the firm has been selected to develop Costa Rica's first Build-Operate-Transfer (BOT) power project, the 27.5 MW Miravalles III geothermal power station in Guanacaste Province.

The Instituto Costarricense de Electricidad (ICE), Costa Rica's national utility, selected the Oxbow consortium over two other groups. The winning consortium includes Marubeni Corp. of Japan and Oxbow Power Services of Reno, Nevada. A second 27.5 MW unit is included in the bid, and can be awarded at the discretion of ICE.

Miravalles III is the third major international geothermal project for Oxbow. In March 1997, the Oxbow/Marubeni consortium executed a contract for the 48 MW Mindanao II power plant in the Philippines, after winning an international tender. During the same month, the 52 MW Mindano

I plant, built by the same consortium, entered commercial operation.

Unocal Drills Super Geothermal Well in North Sumatra

A subsidiary of Unocal Corporation in Indonesia, Unocal North Sumatra Geothermal, Ltd (UNSG) has announced completion of one of the world's largest geothermal wells at the Sarulla contract area. Sarulla is located on the island of Sumatra, about 200 miles south of Medan, the island's most populous city.

Well Silangkitang 1-3 is one of five wells drilled in the area and will supply geothermal steam to the Sarulla Unit 1 plant, scheduled to begin operation in 2000. The well was completed to a depth of 7,085 feet and registered a total mass flow rate of 1.9 million pounds per hour through a 7-inch liner at a restricted flow setting of 650 psi wellhead pressure. This represents the equivalent of 37 megawatts (MW) of electricity generation capacity. Under normal geothermal power plant operating conditions of 200 psi wellhead pressure, the well is estimated to have a production capacity equivalent to more than 50 MW.

UNSG has a contract to supply up to 1000 megawatts of electricity from the Sarulla contract area and Unit 1 would become the first privately developed Indonesian generating facility outside of Java. The power from Sarulla will be delivered to PT PLN, Indonesia's state-owned electric company, for distribution to the Medan grid.

Amoseas Completes Prolific Well in Java

Amoseas Indonesia, Inc., a joint-venture of Chevron and Texaco, announced in June that it had successfully drilled one of the world's largest geothermal wells at the Darajat geothermal resource, located near Garut, West Java, Indonesia.

Well DRJ-16 was drilled to a total depth of 5,988 feet (1,942 meters) and produced 0.44 million pounds per hour of dry steam during testing at 196 psi wellhead pressure. The well is capable of supplying enough steam for 20 megawatts of capacity, nearly one-third of the required steam for the 70 megawatt plant being built at the site.

According to James W. Cox, general manager of Amoseas, DRJ-16 represents the latest in a series of significant drilling successes at Darajat. Four of the five recently completed wells are within 85 percent of this record, demonstrating the exceptional productivity of the resource.

New Capacity Under Construction at Berlin Field, El Salvador

New capacity is under construction at the Berlin field in El Salvador. The Berlin First Condensation Development Project is about 30% finished now, and consists of five main components: (1) installation of two Fuji 28 MW modular condensation units, to be supplied and

installed by Sumitomo Corporation of Japan. (2) Drilling of 16 new deep geothermal wells (2500 km depth) for production and injection to be done by the Forasal-Foraky Group (El Salvador-Belgium). (3) Construction of a new 6 km long 115 kV transmission line to connect to the national grid to be done by Ingenieria Asociada (El Salvador). (4) Construction of the steam and brine gathering system to be done by MONELCA (El Salvador). (5) Construction of a permanent camp for the plant operators to be done by OMNI (El Salvador). Total cost is budgeted at \$113 million, and financing is from the Interamerican Development Bank.

The extension of the Berlin field is about 14 square kilometers, and the potential capacity is estimated at a maximum of 150 MW. Currently, there are two 5 MW backpressure wellhead generating units operating with steam from two production wells (TR-2 and TR-9). Produced brine is reinjected into two wells (TR-8 and TR-14). Annual generation from the two units is about 60 GWh. The units were installed in 1992 by ACEC (a Belgian company since bought by ABB).

Each MW of geothermal saves CEL (the national electric company) about \$1100 per day, depending on fuel cost. Therefore, the Berlin project will produce a savings in fuel of \$56,000 per day. These estimates consider operating and financial costs.

The first 28 MW unit of the Berlin First Condensation Development Project is scheduled for completion in October, 1998, and the second unit by January 1999. Drilling and other activities will continue after the second unit is installed.

New Geothermal Implementing Agreement Executed under IEA

Prior to the International Geothermal Symposium in Japan on March 11-13, 1997, the Department of Energy joined a new International Energy Agency (IEA) Agreement on geothermal energy. The Agreement runs for four years and will consist of collaborative scientific efforts on state-of-the-art geothermal developments worldwide, improved technologies for geothermal utilization, and improved understanding of the environmental benefits of geothermal energy.

The umbrella agreement includes several annexes ranging from environmental impacts of geothermal development to deep geothermal resources. DOE initially is participating in Annex III on Hot Dry Rock (HDR) which covers the evaluation of issues associated with commercial development of hot dry rock resources. DOE participation in the HDR annex is timely since the Department recently decided to restructure its HDR program to place a greater emphasis on industry driven projects.

A Look at Asian Geothermal Markets

Faced with significant power shortages that curtail economic growth, many developing Asian nations recognize reform of the power sector as an indispensable first step to meet capacity needs and improve overall efficiencies of state-owned utilities.

Some Asian countries have approved legislation permitting private sector participation in power project development, sales, and ownership of generation facilities. This environment is providing U.S. power companies an opportunity to diversify internationally.

With state-of-the-art geothermal technology and innovative financial instruments, U.S. developers have been quite successful in Asian markets. Since 1993, new contracts worth \$3 billion for installing close to 2700 MW, mostly in the Philippines and Indonesia, have been negotiated and signed. A breakdown of approximate project sizes and capital costs is shown in Table 1.

Recently, both the Philippines and Indonesia have been hard hit by the Asian economic crisis. The effect of the crisis on geothermal development in these countries remains uncertain. According to a Presidential Decree issued in Jakarta, Indonesia, on September 20, 1997, the start-up dates for a number of private power projects would be: (i) continued according to their initial schedule (because construction is underway), (ii) postponed as to their start-up dates (because they are not yet in progress) until economic conditions improve, or (iii) reviewed with a view to being continued, postponed or rescheduled, depending on their status.

Accordingly, the Indonesian Minister of Mines and Energy postponed geothermal power projects at Cibuni, Dieng (unit 4), Patuha (units 2,3,&4), and Bali (units 3&4) and Sibiyak, whereas projects at Kamojang and the remaining units at Bali are under review to decide whether to continue,

postpone, or reschedule them. The projects at Cibuni, Sibiyak, and Kamojang are sponsored by local investors and as such do not affect American geothermal firms. However, these actions delay installing nearly 870 MW valued at approximately \$1.13 billion.

An earlier press release by CalEnergy on September 24 had indicated that "unlike certain other power contracts, the Company's contracts and government undertakings for the Dieng, Pathua, and Bali projects do not by their terms permit any delays by the government and the government has confirmed that it intends to fully honor all existing obligations."

Primary energy and electricity consumption are closely correlated with a nation's gross domestic product (GDP) as well as with its population's life expectancy, literacy rates, and living standards. Therefore, capital investments in geothermal power generation facilities that help provide clean and cost-competitive electricity should by no means be compared to the debt-fueled speculative investments in vacant office towers, extravagant golf courses, and superfluous shopping malls. According to some Asian market analysts, the glut in the latter types of non-productive and speculative investments are some of the primary causes for the recent financial crisis.

Recovery from the financial crisis is a top priority for all the governments involved. Building and maintaining a strong and stable economy is the next pursuit. Most importantly, for both the Philippines and Indonesia, geothermal energy is an indigenous and abundant source for power that will have an increasingly important role in meeting growth expectations. Some knowledgeable observers expect the suspension of geothermal projects to be of short duration.

Country	Site	Developer	# of Units	Total Capacity (MW)	Est. Cost (\$ M)	Status
Indonesia	Salak	Unocal	7	400	519	On-line
	Dieng	CalEnergy	4	400	520	Unit I on-line
	Patuha	CalEnergy	4	400	520	Postponed
	Karaha	Caithness	3	220	286	Uncertain
	Bali	CalEnergy	4	400	520	Postponed
	Darajat	Amoseas	5	330	429	Unit I on-line
	Sarulla	Unocal	1	55	71	Halted
Philippines	Upper Mahiao	CalEnergy	1	125	100	On-line
	Maltibog	CalEnergy	2	216	172	On-line
	Mahanagdong	CalEnergy	1	180	144	On-line
	Alto Peak	CalEnergy	1	77	62	On-line
	Leyte	Ormat	4	50	70	On-line
	Mindanao	Oxbow	2	87	69	Unit I on-line
TOTAL			36	2940	3484	

Table 1. Geothermal Power Project in the Philippines and Indonesia.

PEOPLE

DOE Honors Dave Anderson

David N. Anderson, former Executive Director of the Geothermal Resources Council (GRC), received a Certificate of Appreciation and the Office of Geothermal Technologies' new "Ring of Fire" award for his exceptional service to the U.S. geothermal community. Dr. Allan Hoffman, Acting Deputy Assistant Secretary for Utility Technologies, and Dr. Allan Jelacic, Director of the Office of Geothermal Technologies presented the awards to Mr. Anderson during a ceremony conducted at the 1997 Geothermal Program Review in San Francisco.

Dave, who has served the GRC since 1972, is moving on to direct the Geothermal Heat Pump Training Center. The Center is operated by the Geothermal Energy Association at the GRC facility in Davis, California.

Paul Lineau Retires

On June 30, Paul J. Lineau retired as Director of the Geo-Heat Center at the Oregon Institute of Technology (OIT); a position he held since the center was established in 1975.

Lineau was editor of the quarterly Geo-Heat Center Bulletin and active in many

DOE-funded research projects. Recently he coordinated a low-temperature resource assessment of 10 western states. He contributed two chapters to the Geothermal Direct Use Engineering and Design Handbook and authored many other important technical articles during his tenure.

Paul Lineau was presented with the Office of Geothermal Technologies' new "Ring of Fire" award for his exceptional service to the U.S. geothermal community.

Dave Lombard Retires

Dr. David Lombard, of the DOE Office of Geothermal Technologies, retired after more than 20 years of dedicated service to the geothermal community.

Lombard participated in establishing the Geothermal Research and Development Program at the Energy Research and Development Administration (ERDA), the precursor agency to DOE. Lombard was Chief of the Advanced Energy Systems Branch in DOE's Geothermal Energy Division that oversaw the Geopressured and Hot Dry Rock programs.

Since the establishment of DOE in 1977, Lombard continued in the management of Federal research programs. He briefly served as branch chief of the Biomass program in 1981,

and in 1984 was assistant director of the office overseeing biomass and geothermal programs. Since 1989, he led the Energy Conversion Team in the Office of Geothermal Technologies.

Baldur Lindal Passes Away

Baldur Lindal, one of the world pioneers of direct utilization of geothermal energy, died in Reykjavik, Iceland, on June 17, 1997. Mr. Lindal, an MIT engineering graduate, spearheaded the planning and design of the Kislidjan diatomite factory in northern Iceland. The plant produces 24,000 tons of diatomaceous earth annually and is a major user of geothermal heat for drying purposes. He was also the key person behind the development of the Reykjanes sea chemical plant, which produces up to 18,000 tons of salt annually and generates power from a single geothermal well.

Mr. Lindal produced the "Lindal Diagram" depicting temperature ranges of geothermal water and steam suitable for various direct-use applications. He also published numerous papers on geothermal direct-use applications and participated in geothermal projects in various parts of the world.

Karl Gawell Named New GEA Executive Director

In February, the Board of Directors of the Geothermal Energy Association (GEA) named Karl Gawell as the first

head of the east coast office in Washington, D.C.

Prior to taking his current position, Gawell was director of government affairs for the American Wind Energy Association, director of the Wilderness Society's National Parks Program, director of government relations for Zero Population Growth, legislative representative for public lands and energy issues for the National Wildlife Federation, and a senior planner and project director for the Solar Energy Research Institute.

Karl, a graduate of Georgetown University's Foreign Service Program, also served on the staff of the U.S. House of Representatives Committee on Appropriations (Interior Subcommittee) and the House Committee on Science & Technology. In addition, he has held positions as legislative director and assistant to various elected officials.

Ted Clutter Named New GRC Executive Director

Ted Clutter has succeeded Dave Anderson as the Executive Director of the Geothermal Resources Council (GRC), Davis, California.

For seven years prior to joining the GRC, Ted was Director of Communications for the Pennsylvania Coal Association, where he gained in-depth knowledge of energy issues. From 1985 to 1990, he was at Virginia Tech's Center for Coal and Energy Research covering technology and

development issues. He brings with him a wealth of practical public relations experience and association management skills.

Ted earned two degrees from the University of Idaho College of Mines. He is also an experienced writer and photographer.

STATE & LOCAL

CALIFORNIA ELECTRICITY MARKET OPEN TO UTILITY CUSTOMERS IN 1998

On May 6, 1997, the California Public Utilities Commission (CPUC) released its decision allowing all investor-owned utility customers -- regardless of customer class (residential, commercial, agricultural, industrial) or amount of electricity used -- to choose their supplier when the electric services market turns competitive in 1998.

Beginning January 1, 1998, all competitors can offer electric service to customers of Pacific Gas & Electric, Southern California Edison, San Diego Gas & Electric, Kirkwood Gas & Electric, PacifiCorp., Sierra Pacific Power Company, and Southern California Water Company. Customers of these utilities can also choose either of these direct access options to purchase power:

- through competing nonutility retail electric service providers such as brokers, marketers, aggregators or other retailers, or
- through direct negotiated contracts with electric generators.

Direct access is a choice for consumers. Consumers who do not want direct access, nor change how

they currently receive electric service, do not have to do anything. Their current utility will continue to serve them. A customer who chooses direct access, but later wishes to return to utility service can do so after giving the utility adequate notice. *Customers who request direct access and have at least half of their electrical load supplied by a renewable resource provider will have their requests processed first.*

To be able to have direct access, customers with a maximum demand of 20 kW or more must have hourly metering. Residential, commercial, agricultural and other customers who use less than 20 kW can participate either by installing an hourly meter or through load profiling. By way of comparison, an average family residence with every appliance and light turned on would have a maximum demand of about 1 kW. An hourly interval meter records usage in hourly increments and can be read on a daily or monthly basis.

SENATE BILL 90: CALIFORNIA'S COMMITMENT TO RENEWABLE, CLEAN, AND COST-EFFECTIVE ELECTRICITY

Governor Pete Wilson signed legislation on October 12, 1997, that will help solidify a role for renewable energy and public interest research,

development and demonstration projects in the new electricity market in California. Senate Bill 90 implements \$540 million in renewable energy projects and \$250 million in public interest electricity research and development. The overall goal is to build a market-driven renewable power industry in California.

The bill, which complements the 1996 landmark electricity restructuring legislation AB1890, authorizes the California Energy Commission to implement renewable energy and public interest research and development programs. Both programs were developed at the Energy Commission with broad public input from utilities, environmental and consumer groups, and participants from the renewable power and research industries.

The \$540 million earmarked will be provided to consumers and producers of renewable energy, such as wind, solar, geothermal, biomass, landfill gas, and small hydroelectric power. The program includes provisions for credits on consumer's bills if they purchase eligible renewable electricity and provides market-based support for upgrading and extending California's renewable power industry.

The Energy Commission will allocate \$62 million a year from 1998 to 2001 to research projects that best meet public-interest goals. Selected research projects may include some technologies already in the developmental stage, as well as new concepts with strong potential to increase the reliability, cost-effectiveness, and environmental cleanliness of California's electricity industry.

The fund will be collected from the three investor-owned electric utilities over the next four years to replace their programs undertaken with ratepayer funding. This significant financial commitment will continue California's leading role in advancing renewable energy and help the renewables industry make the move to a competitive market.

GHP Project Saves 26 Million KWh per Year in Louisiana

Installation of geothermal heat pumps (GHPs) in over 4000 homes at Fort Polk, Louisiana, was completed in the summer of 1996 under the Nation's largest shared energy savings contract. DOE's statistically valid pre- and post-retrofit data shows annual savings exceeding 26 million kWh, over 30 percent summer peak demand load reduction of 6.8 MW, and improved load factor from .55 to .62.

TECHNOLOGY DEVELOPMENT

Advances in Bit Technology

Within the next five years, ongoing geothermal drilling research at Sandia National Laboratories (SNL) will make major R&D advances. According to Dave Glowka, Geothermal Program Manager at SNL, (a) If current penetration rates are doubled and bit life maintained the same, a 15% reduction in drilling costs is achievable, or (b) If both current penetration rates and bit life can be doubled, a 20% cost reduction is achievable.

The above improvements in drilling performance involve developing drag bits for hard-rock and high-temperature environments using synthetic diamond, titanium carbide, and/or boron oxide. These materials have been found to have better thermal characteristics, improved fracturing, and wear resistance than existing PDC bits. There are currently numerous ongoing projects funded by DOE in pursuit of the 15 to 20% cost reduction. Some of the key research focusses on:

- Modifying cutter geometry
- Extending diamond wrapping around bottom of cutter
- Reducing impact and vibration on cutters
- Improving placement of cutter on bit
- Developing thermally-stable polycrystalline (TSP) cutters

- Testing explosion compaction of boron sub-oxide -- B_6O and B_4O - which produce the same hardness characteristics as PDC bits and fracturing abilities as tungsten carbide with no thermal mismatch.
- Adding water jets to the bit and improving cutter-rock interface

Drilling performance can also be improved through use of measurement-while-drilling (MWD) techniques. However, MWD is needed for target-precision drilling that requires continuous feedback on the bit's direction. High temperature is also a key limitation for MWD geothermal applications. Therefore, MWD is not highly useful for geothermal drilling. As an alternative to MWD techniques, the data rate coming from the bit can be increased by installing accelerometers. The Gas Research Institute has recently issued a RFP for development of MWD techniques at temperatures up to 200°C in deep gas wells. This work would likely benefit geothermal drilling.

The advent of high-temperature (up to 300°C) unshielded technology (using silicon-on-insulator) from defense-related R&D should benefit the downhole instrumentation needs of the geothermal industry. Honeywell, Inc. is adopting this technology for applications to 250°C, and SNL is testing applications to 300°C. Results have been very promising and may bring a major breakthrough.

GDO's Three New Cost Shared Drilling Projects

The May 1997 issue of *Geothermal Technologies*, a quarterly update of the DOE's Office of Geothermal Technologies, reported that the Geothermal Drilling Organization approved three new research and development (R&D) projects to help industry reduce the overall cost of drilling wells.

The GDO is a government/industry partnership established by the Office of Geothermal Technologies and managed by Sandia National Laboratories (SNL). The organization coordinates research between DOE and U.S. industry and provides expertise from SNL for R&D. The GDO has funded several R&D projects that have resulted in products used by industry to reduce the cost of drilling. New products currently under development include a high-temperature/high-pressure valve changing tool, insulated drill pipe, and nitrogen foam cement.

High-Temperature/High-Pressure Valve Changing Tool

This new tool temporarily blocks the flow inside a geothermal well to allow for quick and safe replacement or repair of the surface shut-off valve(s). The new tool will operate at 335 °C (635 °F) and 2000 psig. Smith International, the tool developer, and Puna Geothermal Venture will match DOE's development funding of \$150K. The project is scheduled for completion by the end of 1997.

Insulated Drill Pipe

The drill pipe commonly used in geothermal well drilling allows substantial heat to transfer from the formation to the drilling fluid. An insulated drill pipe will allow lower fluid and bottom hole temperatures during drilling. A reduction in temperature lessens degradation of fluid properties and drill bit wear while improving the performance of downhole electronics. The ease with which measurement-while-drilling and measurement-while-logging systems are employed will also be improved. This ability to better characterize downhole conditions without the costly practice of tripping out the drill string will help lower drilling costs.

Nitrogen Foam Cement

The Department of Energy, Halliburton, and CalEnergy are cost-sharing the development of lightweight nitrogen foam cement to ameliorate mud and lost circulation problems common in geothermal drilling. Portland cement foamed with nitrogen has been employed in the oil and gas industry but has only had limited success in geothermal operations.

The cost-sharing partners will evaluate the use of the cement for geothermal applications. Sandia will provide rig instrumentation, analysis of surface and downhole logging data, and possibly testing facilities to evaluate the cement's ability to plug loss zones.

Halliburton and CalEnergy will match \$200K of DOE funds. Project completion is expected by May 1999.

New Logging Tools Approaching Commercialization

Sandia National Laboratories has developed a pressure/temperature and spinner (PTS) memory logging tool and a core-tube data logger for DOE's geothermal R&D program.

The PTS memory tool is a dewatered, heat-shielded device that can be deployed on a non-conducting wireline. The tool measures and records pressure, temperature, and relative flow velocity in wells at 400°C and 6000 psi for up to 10 hours. When retrieved, the data can be downloaded from the tool's memory to a notebook computer. The time-series data recovered can then be merged with depth data, recorded with a depth encoder, to produce downhole information.

The pressure-temperature portion of the tool has been extensively field tested, with more than 40 logging runs performed without a single failure or loss of data. This reliable performance, combined with the tool's exceptional precision and accuracy, prompted Pruett Industries to express an interest in commercializing the tool. Pruett proposed adding its existing spinner transducer to the SNL tool to increase the commercial viability of the combined tool. Pruett has provided SNL with one of its spinner transducers, and SNL has integrated it into the memory tool. The versatility of the combined memory tool was demonstrated by the relative ease with which the tool's on-board computer was reprogrammed to accept and

interpret data from the spinner transducer.

The combined PTS tool was field tested in the spring of 1997. It is now available through Pruett as a made-to-order tool or as part of Pruett's logging services. This fulfills the goal of the project, which has been to make PTS surveys much more affordable than conventional surveys requiring a logging truck and conducting wireline.

The core tube data logger is a tool that attaches to the tube that receives rock core during wireline coring operations. The tube and its rock contents are retrieved to the surface every 5-10 feet of drilling using a non-conducting wireline deployed down the center of the drill string. The tool contains an on-board computer, memory, and transducers for measuring and recording downhole data during the drilling process. The data are downloaded to a notebook computer when the tool is brought to the surface with the core tube.

To date, a temperature probe and a two-axis inclinometer have been incorporated into the tube and field tested. This configuration provides downhole temperatures during drilling as well as borehole inclination. A pressure transducer can be easily added to provide additional data such as borehole fluid level. The feasibility of determining in situ core orientation is also being investigated.

Both unshielded and dewatered versions of the tool have been successfully tested so far. The tool has already provided valuable downhole data in a slimhole geothermal exploration project

at the U.S. Army's Fort Bliss, in Texas and at a site in New Mexico. Both Tonto Drilling Services and Boart Longyear have expressed an interest in using the tool in their commercial operations.

Brookhaven Lab Develops High-Performance Cement

Brookhaven National Laboratory has developed a new CO₂-resistant cement for use in geothermal wells where conventional cements deteriorate rapidly through a chemical process called carbonation. The new cement creates a zeolite mineral and a calcium phosphate mineral that block this destructive chemical reaction. It contains fly ash, calcium aluminate, sodium polyphosphate and water in compositions that vary with the depth at which the cement will be used. Since these materials are abundant and inexpensive, and no technical training is required to make the cement, it is economical compared to conventional cements. It is environmentally friendly because it is made mostly of recycled fly ash - the byproduct of steel production - and no harsh chemicals are used in manufacturing it.

The high-performance cement is not only resistant to the deterioration produced by carbon dioxide, but also adheres well to steel and soil, protects steel from corrosion, has high mechanical strength, low permeability, and withstands temperature extremes. Besides geothermal environments, it can also be used in walkways, roads, and buildings - anywhere ordinary cement is used. In laboratory tests, when the cement had been exposed for six months to steam as hot as 572°F and with a concentration of four percent carbon dioxide, the high-performance cement became only one percent carbonated while conventional cement was ready to crumble with 50 percent carbonation. In July 1997, large-scale field testing of high-performance cement began at a geothermal well in Sumatra, Indonesia, operated by Unocal corporation. Halliburton Energy Services is supplying the cement for these tests.

TECHNOLOGY TRANSFER

NREL/PG&E System Increases Geothermal Power Plant Efficiency

Pacific Gas & Electric Co. (PG&E) announced May 16 that tests conducted at its Geysers Unit 11 plant confirmed that the advanced direct-contact condenser (ADCC) technology, with which the plant was retrofitted, resulted in a five percent efficiency gain. The ADCC technology was developed under a research partnership between the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) and Pacific Gas and Electric (PG&E).

PG&E and NREL engineers used computer modeling to design optimal geometric frameworks that enhance steam condensation. Renovation of Unit 11's condensation system reduced vapor pressure in the condenser, helping "pull" steam through the turbines. The result is more efficient power production. PG&E plans to retrofit five more units at The Geysers with advanced direct-contact condenser technology.

NREL plans to license the ADCC technology to manufacturers interested in building condensers for new plants or retrofits, and to service companies interested in renovating existing condensers.

Technical information about advanced direct-contact condensers is available from Desikan Bharathan at:

(303) 384-7418 or

e-mail: Desikan_Bharathan@nrel.gov

Biphase Turbine Export to Mexico

The first Biphase geothermal turbine unit was shipped from California to Mexico in March, 1997. The turbine, patented by Douglas Energy, was built with the support of the U.S. Department of Energy and the California Energy Commission (CEC). It is the first export product under the CEC's Geothermal Loan Grant Program.

The turbine, a wellhead unit, to be installed at the Cerro Prieto geothermal field will deliver an additional 4 MW through the recovery of existing waste heat. The turbine produces power from the mixed flow of steam and brine and also delivers pure steam for use at the central station.

According to Don Douglas, Chairman of Douglas Energy, the addition of the Biphase turbine will make the Cerro Prieto plant, which already has an availability of over 90 percent, the most efficient geothermal power plant in the world.

Geothermal Cement Selected for Technology Transfer

The Long Island Lighting Company (LILCO) has announced the award of 15 contracts, valued at \$2.5 million, that meet LILCO's strategic goals in the areas of natural gas, electric energy, and generation and environment. One of the two technology transfer proposals from Brookhaven National Laboratory (BNL) that were accepted was based upon DOE-sponsored work on chemically-bonded geothermal well cements. This proposal titled "Cation-Exchange Adsorbents and High-Performance Cements from Ash and Sludge Wastes" will investigate the possible use of bottom ash and waste water treatment sludge byproducts from their oil-fired electric power plants as the starting materials for cements

and ion-exchange materials. The former may find applications in precast concrete components while the latter can be used to remove toxic metals from groundwater and to stabilize contaminated soils. LILCO annually produces many hundreds of tons of these wastes, and since they are classified as toxic materials, disposal costs are very high. Analyses have indicated that the major constituents of these waste streams are compounds similar to those present in the BNL-developed chemically-bonded geothermal well cements. Preliminary research at BNL in collaboration with Unocal and Halliburton has already demonstrated the technical feasibility of using these wastes in geothermal well cements for hot, CO₂ -rich environments.

OTHER SOURCES OF GEOTHERMAL INFORMATION

Some additional sources of information are listed here.

- Geothermal Resources Council Bulletin, Monthly publication of the GRC, P.O. Box 1350, Davis, California 95617-1350.
- Geothermal Resources Council Transactions, Proceedings of the GRC Annual Meetings. Same address as above.
- Stanford University Annual Workshop on Geothermal Reservoir Engineering, Stanford Geothermal Program, Department of Petroleum Engineering, Stanford University, Stanford, California 94305.
- Proceedings of the Annual Geothermal Program Review, Office of Geothermal Technologies, U.S. Department of Energy. Available from the National Technical and Information Service, U.S. Department of Commerce, Springfield, VA 22161.
- Federal Geothermal Research Program Update, Office of Geothermal Technologies, U.S. Department of Energy. Available for Fiscal Years 1994, 1995, 1996.
- Geo-Heat Center Quarterly Bulletin, Oregon Institute of Technology, Klamath Falls, Oregon 97601-8801.

GEOHERMAL POWER PLANT TABLES

The following tables present data on U.S. geothermal power generation facilities. The facilities listed are operational, except where footnoted otherwise, or where the year on line indicates the facility is planned. The information was assembled from published sources and direct contact with industry spokespersons. It is believed to be accurate as of the end of 1996.

The key to the abbreviations used in the following power plant tables is as follows:

Companies

GDA Geothermal Development Associates
HL Honey Lake Power Company
OESI OESI Power Corporation

Plant Cycle Type

DS Dry Steam
DF Dual Flash
SF Single Flash
B Binary

Utilities

BPA Bonneville Power Administration
CDWR California Department of Water Resources
HELCO Hawaii Electric Light Co.
IID Imperial Irrigation District
LADWP Los Angeles Department of Water and Power
NCPA Northern California Power Agency
PG&E Pacific Gas and Electric Co.
PP&L Pacific Power and Light Co.
PSPETL Puget Sound Power Et Light Co.
SCE Southern California Edison
SDG&E San Diego Gas and Electric Co.
SPP Sierra Pacific Power Co.
SMUD Sacramento Municipal Utility District
UPD Utah Power Division of Pacific Corp.

U.S. GEOTHERMAL ELECTRIC POWER PLANTS: DRY STEAM PLANTS AT THE GEYSERS

PLANT NAME	FIELD DEVELOPER	PLANT OWNER	UTILITY	RATED CAPACITY (MW)	YEAR ON LINE
PG&E Unit 1 ^a	UNOCAL	PG&E	PG&E	11	1960
PG&E Unit 2 ^a	"	"	"	13	1963
PG&E Unit 3 ^a	"	"	"	27	1967
PG&E Unit 4 ^a	"	"	"	27	1968
PG&E Unit 5	"	"	"	53	1971
PG&E Unit 6	"	"	"	53	1971
PG&E Unit 7	"	"	"	53	1972
PG&E Unit 8	"	"	"	53	1972
PG&E Unit 9	"	"	"	53	1973
PG&E Unit 10	"	"	"	53	1973
PG&E Unit 11	"	"	"	106	1975
PG&E Unit 12	"	"	"	106	1979
PG&E Unit 15 ^a	Geothermal Resources Int'l.	"	"	59	1979
PG&E Unit 13	Santa Rosa Geothermal Co. ^b	"	"	133	1980
PG&E Unit 14	UNOCAL	"	"	109	1980
PG&E Unit 17	UNOCAL	PG&E	PG&E	110	1982

^a Retired

^b Formed by Calpine Corp. and Freeport-McMoran as new owner of leases and steam supply operations; originally Aminoil properties

U.S. GEOTHERMAL ELECTRIC POWER PLANTS: DRY STEAM PLANTS AT THE GEYSERS

PLANT NAME	FIELD DEVELOPER	PLANT OWNER	UTILITY	RATED CAPACITY (MW)	YEAR ON LINE
PG&E Unit 18	UNOCAL	PG&E	PG&E	110	1983
SMUDGEON No. 1	Santa Rosa Geothermal Co. ^b	SMUD	SMUD	72	1983
NCPA No. 1 ^c	NCPA	NCPA	NCPA	110	1983
Santa Fe Geothermal I	Santa Fe Geothermal	Santa Fe Geothermal	PG&E	80	1984
Bottle Rock ^d		CDWR	CDWR	55	1984
NCPA No. 2 ^c	NCPA	NCPA	NCPA	110	1985
PG&E Unit 16	Santa Rosa Geothermal Co. ^b	PG&E	PG&E	110	1985
PG&E Unit 20	UNOCAL	PG&E	PG&E	110	1985
Cold Water Creek ^d	Cold Water Creek Operating Co.	CCPA ^e	CCPA ^e	124	1988
Bear Canyon Creek	Santa Rosa Geothermal Co. ^f	Santa Rosa ^f	PG&E	22	1988
West Ford Flat	Santa Rosa Geothermal Co. ^f	Santa Rosa	PG&E	29	1988
Joseph W. Aidlin Power Plant	Geothermal Energy Partners ^g	Geothermal Energy Partners/Cloverdale Geothermal Partners ^h	PG&E	20	1989

^c Originally NCPA Nos. 2 and 3

^d Closed

^e Plant ownership divided among Sacramento Municipal Utility District (SMUD), Modesto Irrigation District (MID), and the City of Santa Clara

^f The new partnership of Calpine Corp. and Freeport-McMoRan owns both field and power plant operations; originally Geysers Geothermal properties

^g A subsidiary of Mission Power is general partner

^h Calpine Corp. and Metlife Capital Corp. (affiliate of Metropolitan Life Ins. Co.)

U.S. GEOTHERMAL ELECTRIC POWER PLANTS: HOT WATER PLANTS							
LOCATION (State and Site)	PLANT NAME	TYPE	FIELD DEVELOPER	PLANT OWNER	UTILITY	RATED CAPACITY (MW)	YEAR ON LINE
CALIFORNIA							
Coso Hot Springs ^a	Navy 1, Units 1, 2, & 3	DF	CalEnergy	CalEnergy	SCE	80	1987- 1988
	BLM East (Units 1 & 2)	DF	CalEnergy	CalEnergy	SCE	48	1988
	BLM West	DF	CalEnergy	CalEnergy	SCE	28	1989
	Navy 2, Units 4, 5, & 6	DF	CalEnergy	CalEnergy	SCE	80	1989
East Mesa	GEM I (formerly B.C. McCabe)	B	GEO Operator/ Mission ^{b,c}	GEO/Mission ^c	SCE	12.5 ^d	1980
	Ormesa I	B	OESI	OESI	SCE	24	1986
	Ormesa II	B	OESI/Harbert Int'l	OESI/Harbert	SCE	17	1988
	Ormesa IE	B	OESI	OESI	SCE	8	1988
	Ormesa IH	B	OESI	OESI/Harbert	SCE	6	1989
	GEM 2	DF	GEO/Mission ^c	GEO/Mission ^c	SCE	37	1989

^a Various venture partners are involved in all CalEnergy Coso plants

^b Magma Power original owner

^c Mission Energy, a subsidiary of SCE

^d Enlarged from 10 MWe

U.S. GEOTHERMAL ELECTRIC POWER PLANTS: HOT WATER PLANTS

LOCATION (State and Site)	PLANT NAME	TYPE	FIELD DEVELOPER	PLANT OWNER	UTILITY	RATED CAPACITY (MW)	YEAR ON LINE
Glass Mountain	BPA Pilot II*	DF	Calpine	Trans-Pacific	BPA	30	2000 (est.)
Heber	Heber Dual Flash Power Plant	DF	Heber Geothermal Co.	ERC Int'l ^f	SCE	47	1985
	Heber Binary Project*	B	Chevron	SDG&E	SDG&E	45	1985
	Second Imperial	B	Ogden Corporation	Ogden Corporation	SCE	37	1993
Mono-Long Valley	Mammoth Pacific (MP) Unit I	B	Pacific Energy ^h	Ogden Corporation	SCE	7	1984
	MP Unit II	B	Pacific Energy	Ogden Corporation	SCE	10	1990
	MP Unit III	B	Pacific Energy	Ogden Corporation	SCE	10	1998 (est.)
	PLES Unit I	B	Pacific Energy	Ogden Corporation	SCE	10	1990
Salton Sea	Salton Sea Unit 1 ⁱ	SF	CalEnergy	CalEnergy	SCE	10	1982
	Salton Sea Unit 2 ⁱ	SF	CalEnergy	CalEnergy	SCE	18	1990
	Vulcan	DF	CalEnergy/Mission ^e	CalEnergy/Mission ^e	SCE	30	1985

* Bonneville Power Administration Geothermal Pilot Project

^f Partnership of Dravo Corp. and Centennial Energy original owner

^e Demonstration plant supported by the U.S. Department of Energy; retired

^h Subsidiary of Pacific Enterprises

ⁱ Formerly developed by Unocal

U.S. GEOTHERMAL ELECTRIC POWER PLANTS: HOT WATER PLANTS

LOCATION (State and Site)	PLANT NAME	TYPE	FIELD DEVELOPER	PLANT OWNER	UTILITY	RATED CAPACITY (MW)	YEAR ON LINE
Salton Sea (Cont'd)	Del Ranch	DF	CalEnergy/Mission ^o	CalEnergy/Mission ^o	SCE	34	1988
	Elmore I	DF	CalEnergy/Mission ^o	CalEnergy/Mission ^o	SCE	34	1988
	Leathers I	DF	CalEnergy/Mission ^o	CalEnergy/Mission ^o	SCE	34	1989
	Salton Sea Unit 3	DF	CalEnergy	CalEnergy	SCE	48	1989
	Salton Sea Unit 4 ^j	DF	CalEnergy	CalEnergy	SCE	40	1996
Wendel-Amedee	Wineagle Project	B	Wineagle Developers	Wineagle Developers	PG&E	.7	1985
	Amedee Geothermal	B	Trans-Pacific Geothermal Inc. (TPG)/U.S. Energy Corp.	TPG/U.S.	PG&E	2	1988
	Honey Lake ^k	B	GeoProducts Corp.	HL Power Co.	PG&E	30	1988
<u>HAWAII</u>							
Puna	Puna I	SF/B	Puna Geo Venture ^l	Puna Geo Venture	HELCO	30	1993
	Puna II ^m	SF/B	Constellation	Constellation	HELCO	20	1999 (est.)
<u>NEVADA</u>							
Beowawe	Beowawe	DF	CalEnergy	CalEnergy	SCE	15	1985

^j A renegotiated power purchase agreement combined the Salton Sea I expansion and Fish Lake projects.

^k A hybrid plant using wood waste and geothermal heat; geothermal fluid used only to preheat boiler feedwater

^l Partnership between OESI and Constellation

^m Constellation is negotiating with HELCO for additional power purchase agreement

U.S. GEOTHERMAL ELECTRIC POWER PLANTS: HOT WATER PLANTS

LOCATION (State and Site)	PLANT NAME	TYPE	FIELD DEVELOPER	PLANT OWNER	UTILITY	RATED CAPACITY (MW)	YEAR ON LINE
Brady-Hazen	Desert Peak	DF	CalEnergy	CalEnergy	SPP	9	1985
	Brady Hot Springs I	DF	Brady Power Partners	Brady Power Partners	SPP	20	1992
Dixie Valley	Oxbow	DF	Oxbow Geothermal	Oxbow	SCE	50	1988
San Emidio Desert	Empire Geothermal	B	OESI	Empire Geothermal	SPP	3	1987
Steamboat Springs	Steamboat Geothermal I	B	Geothermal Development Assoc.	Far West Electric Energy Fund, Ltd.	SPP	6.8	1986
	Steamboat Geo IA	B	OESI/GDA	Far West	SPP	1.2	1989
	Yankee/Caithness	SF	Caithness/Sequa	Caithness/Sequa	SPP	12	1988
	Steamboat 2	B	Steamboat Development	Steamboat Development	SPP	12	1992
	Steamboat 3	B	Steamboat Development	Steamboat Development	SPP	12	1993
Stillwater/Soda Lake	Soda Lake I	B	Chevron	Institutional Investors	SPP	2.7	1987
	Stillwater Geothermal I Project	B	OESI	OESI/Constellation Development/Chrysler Capital	SPP	13	1989
	Soda Lake II	B	Amor	OESI	SPP	13	1990
Wabuska	Wabuska	B	Tad's Enterprises	Tad's Enterprises	SPP	1.5	1984

U.S. GEOTHERMAL ELECTRIC POWER PLANTS: HOT WATER PLANTS							
LOCATION (State and Site)	PLANT NAME	TYPE	FIELD DEVELOPER	PLANT OWNER	UTILITY	RATED CAPACITY (MW)	YEAR ON LINE
UTAH							
Roosevelt Hot Springs	Blundell I	SF	CalEnergy Co. (originally Phillips; subsequently Chevron)	Utah Power Div. (UPD) of PacifiCorp	UPD	20	1984
Cove Fort-Sulphurdale	Cove Fort Geothermal No. 1	B	Mother Earth	City of Provo	Utah Municipal Power Agency	2	1985
	Cove Fort Steam Plant	DS	Mother Earth	City of Provo	Provo Power Co.	2	1988
	Cove Fort Steam No. 2	DS	Mother Earth	City of Provo	Provo Power Co.	7	1989

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