Geothermal technologies

U.S. Department of Energy

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New Initiatives in the FY 2000 Geothermal Budget Request

Well, the Federal budget season began in earnest this month with the release of the President's budget request for Fiscal Year 2000 (a.k.a. FY00). Within that request, a total of $398 million is budgeted for Solar and Renewable Resources Technologies, an increase of more than 18 percent over this year's appropriation. The increase in the budget for the Geothermal Program is more modest, just $1 million or less than 4%. But the FY00 budget does contain three new initiatives for geothermal technology development, especially in electric power generation.

The first initiative involves the application of the latest reservoir technology to create an Enhanced Geothermal System (EGS) at an existing geothermal field. The initiative's purpose is to demonstrate that the effective lifetimes of fields can be extended, and perhaps sustained indefinitely, by means of EGS techniques. This effort constitutes a major commitment by the federal government to regain momentum lost to other EGS projects around the world with the demise of the Hot Dry Rock Program. Should Congress approve the initiative, we plan to seek partners from industry who have the foresight and resources to make a tangible commitment to this high-risk technology of the future.

The Geothermal Advanced Drilling System (GADS) Program represents a successor to the NADET (National Advanced Drilling and Excavation Technology) Program. Drilling economics remain the bellwether for determining the success of a geothermal project, and our industry has consistently ranked improvement of drilling technology as their highest priority R&D need. As a result, we have proposed the GADS as a directed effort to produce new components of a drilling system specifically designed to drill economically in deep geothermal environments. We expect close cooperation with the drilling community as we develop those components, which in sum, could revolutionize drilling for geothermal resources.

Our third initiative involves the development and testing of a new modular power system for use in remote or off-grid locations. The modular unit would be small (less than 1 MWe) and capable of drawing on the output of less productive wells as might result from slim holes. In addition to modularity, the units should be amenable to mass production for use in geothermal markets everywhere.

I hope you find these new efforts in geothermal technology compelling and worthy of your support. I welcome learning your views about them. Please contact me by mail or send an e-mail message to allan.jelacic@hq.doe.gov.

Allan J. Jelacic, Director
Office of Geothermal Technologies
U.S. Department of Energy

Evaluation of Geothermal Heat Pumps in Schools

A major advantage of GHPs is their individual classroom heating/cooling controls or "zone space conditionaing."

Data accumulated over several years strongly indicate that geothermal heat pumps are an attractive technical and financial option for new and renovated school buildings.

Also known as ground-coupled heat pumps, or GeoExchange systems, geothermal heat pumps (GHPs) work by moving heat to or from the earth, and are very efficient because the temperature of the earth is relatively constant year round. There are currently over 400 schools in the United States with GHP systems. The bar chart below indicates the states with the greatest number.

GHP school installations began slowly in the early 1980s, but major growth has occurred in the 1990s. Commissioning

Mark your calendars now. . .

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Watch your mailbox for more information, or contact Lisa Morgan at Princeton Economic Research, Inc. at (301) 468-8441
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State	Number of GHP schools
Oklahoma	14
Minnesota	16
Nebraska	18
New Jersey	34
Kentucky	39
Missouri	65
Texas	102

Table 1. States with the most GHP schools.

data are incomplete for all 400 schools, but if the available dates are representative, the number of GHP systems placed in school service annually has quadrupled to about 50–60 per year from 1988-91 to 1996-98. Although many of these schools were built new, a strong and growing component of the market has been school renovations. In the past year, Energy Secretary Richardson and Assistant Secretary Reicher launched the Energy $mart Schools Initiative, which featured GHPs in schools at two national teleconferences.

Many Direct Benefits

There are many reasons to use GHPs in schools:

- GHPs offer improved comfort, because teachers can adjust their own classroom temperature; and because there is no seasonal switchover, each room is individually heated or cooled as needed year round.
- School grounds and parking areas provide ample space for burying heat exchangers.
- There is no aboveground outdoor equipment to vandalize.
- It is relatively easy to add or move heat pumps when schools modify their space usage.
- Renovated schools gain usable space since mechanical rooms can be downsized, while in new schools more of the floor space is usable right from the start.
- Roof penetrations and structural reinforcements for rooftop units are not required.
- The simplicity of the overall system concept and controls means that custodial staff can handle operation and maintenance without the need for extensive special training or technical support.

Not only are GHPs well matched to the needs of schools, they can also compete on a monetary basis. Anecdotally, GHPs are starting to come in as the low bid on new schools in areas where school administrators, designers, and contractors are familiar with the technology. Any initial cost premium on renovations can often be justified on the basis of lower energy and maintenance costs over the system's multi-year lifecycle.

Real World Results

Oak Ridge National Laboratory is in the midst of evaluating four GHP-equipped schools placed in service in 1995 in Lincoln, Nebraska. Objectives include documenting the energy and maintenance cost savings and estimating the "best practice" costs and benefits.

These schools were selected because the key data needed were being collected by the local utility. Lincoln Public Schools is sharing their data on the four GHP schools as well as on their 48 other schools, including very detailed performance and operating data taken via the direct digital control systems and school-by-school utility billing, HVAC maintenance, and HVAC capital renewal records.

Our first look at the energy consumption of the four GHP schools versus the other 48 schools gives a strong indication of why school districts might look into using GHPs. Figure 1 compares the average (1996 and 1997) annual source energy use of all K-12 schools in the Lincoln Public School District. Because schools may consume both electricity and natural gas, source energy (sometimes referred to as primary energy) rather than site BTUs were used for the benchmarking comparison. The average efficiency of producing electricity from fossil fuel BTUs and delivering it to the site was assumed to be 33%. Natural gas source and site BTUs were assumed to be the same.

The data indicate that the four GHP schools are exceptionally low-energy users, with Campbell Elementary School as the lowest. Only 12% of the schools in the district use less source energy per square foot than Campbell. Maxey Elementary is the highest energy user among the GHP schools; still, only 30% of the schools in the district use less source energy per square foot.

GHP schools cool 100% of their floor area. These numbers are even more impressive when it is considered that the HVAC systems in the older Lincoln schools cool only a

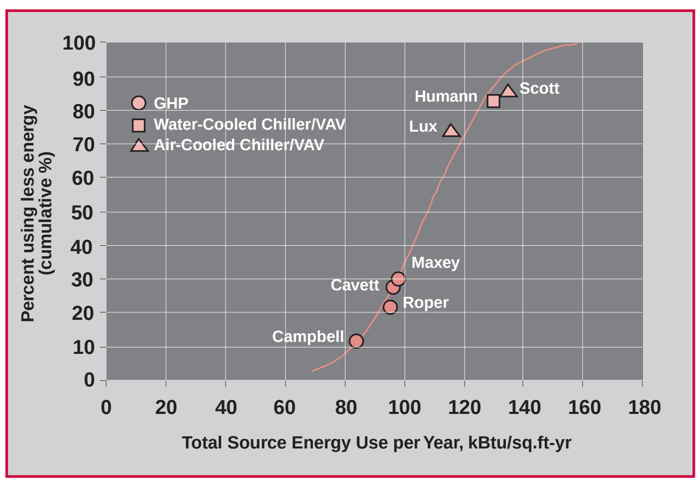


Figure 1. Average (of 1996 and 1997) annual source energy use per square foot for K-12 Schools in the Lincoln Public School District (Lincoln, NE).

fraction of their total floor area. In fact, all of the conventional schools that have lower source energy use than Maxey Elementary cool less that 15% of their floor area (with the exception of two schools that cool 70 and 90% of their floor area, respectively). We are still investigating these two schools, but suspect they deliver considerably less fresh outdoor air than new schools built in the 1990s.

To test this hypothesis, we have identified all of the Lincoln schools built during the 1990s. In addition to the four GHP schools, two air-cooled chiller variable air volume (VAV) schools and one water-cooled chiller VAV school have been put into service. All of these schools presumably deliver quantities of fresh air in accordance with ASHRAE Standard 62-89. Comparing these schools is still not quite comparable because the two air-cooled chiller schools cool only 90% of the floor space and the water-cooled chiller school cools only 78%. Also the GHP schools are elementary schools and the others are middle schools. Nonetheless, the three other new schools average 127 BTUs/ft2/year and the four new GHP schools average 94 BTUs/ft2/year, or 26% less.

Patrick Hughes, P.E., manages the Geothermal Heat Pump Research Program within the Buildings Technology Center at Oak Ridge National Laboratory. He can be reached at (423) 574-9337 or e-mail pj1@ornl.gov.

On September 27, 1998, the European industrial partnership called Socomine convened the Fourth International Hot Dry Rock (HDR) Forum in Strasburg, France, near the Soultz HDR project site. The location was fitting because the Soultz project is by far the most advanced in the race to produce power from an enhanced geothermal system (EGS) reservoir. The forum was an opportunity for the world EGS community to showcase its research and development successes and report on the status of national programs and projects. While much of the meeting focused on current and future R&D at Soultz, the US, Japan, and Australia reported that they are progressing in the development of their EGS programs.

In reporting on the U.S. program, the U.S. Department of Energy's Paul Grabowski, the U.S. representative to the Forum, stated that the program is building on all the knowledge gained over several years at its Fenton Hill HDR site, and is partnering with US industry to drive an EGS program. This industry-based program will utilize an industry coordinating committee to guide and support R&D, and to conduct field experiments that will lead to a power producing EGS project by 2010. While this announcement was well received, the U.S. program and funding are, in fact, well behind European commitments to the Soultz project.

The first order of business was a meeting of the partners in the International Energy Agency's Geothermal Implementing Agreement (GIA), Annex III—Hot Dry Rock, to which the U.S. DOE is a signatory. Dr. Michio Kuriyagawa of Japan led the meeting. The United States provided a status report on the Economic Modeling subtask on which it has the lead. The U.S. contribution to this subtask consists of updating the MIT Energy Laboratory's EGS economic model to include actual case studies and a more useful, Windows-based user interface. A technical team consisting of two U.S. organizations (Princeton Economic Research and GeothermEx Inc.) is reviewing Fenton Hill data and preparing to index and archive it on a database that was developed by the Swiss. A potential new subtask is for the United States and Italy to lead an effort in documenting, and possibly funding, hydrofracturing and stimulation schemes in geothermal fields. While this subtask has not yet been created, the potential for the useful exchange of information is great, especially because this technology is developing into one of the major pieces in the evolving U.S. EGS program.

By far the most exciting news at the Forum was the report on developments at the Soultz project. Research at the European HDR project has been in existence for about 10 years. This has lead to the creation of the "Soultz concept" that utilizes three wells as a basic module and consists of one injector and two producers with a down-hole pump in each producer. In 1997, a 4-month circulation test was completed that resulted in a production temperature above 140°C with negligible losses, a minimal energy input for pumping, and acceptable flow rates. As a result of this success, and as requested by their industrial partners, the Socomine team has since begun drilling the GPK2 production well to a depth of 5000 m. The objective is to obtain flow rates equal to the 4-month circulation test and water temperatures of at least 200°C. They feel that a cost-competitive power plant can be constructed if these objectives can be achieved.

The United States has been a limited partner in the Soultz project, funding scientists and engineers for technical work, and participating in general scientific interchange. One particular project that was very well received by the Europeans and provided useful data to U.S. scientists and engineers was the work of Pete Rose from the Energy and Geosciences Institute at the University of Utah. Pete performed fluorescent tracer experiments at the site.

The Socomine partners have developed a sound plan for producing power at Soultz. Their perseverance and determination, their financial and technical capabilities, and the steadfast support of the European Community constitute a powerful triumvirate that should succeed in its goals. The U.S. EGS program has a similar opportunity to accomplish its long-term goal of producing power from an EGS reservoir. All that is needed is the same level of determination and perseverance from the U.S. partners and stakeholders.

For more information, contact P. Grabowski, U.S. DOE, (202) 586-0478 or e-mail: paul.grabowski@hq.doe.gov, or L. McLarty, PERI, (301) 468-8442.

"We do it with electron beams," is the motto of a group of researchers at the Science Research Laboratory (SRL) of Somerville, Massachusetts, who have developed a new technology useful for brazing drill bits and bonding of plastic cars. Under sponsorship from a Small Business Innovative Research grant from the U. S. Department of Energy Office of Geothermal Technologies, the company has developed drilling processes and equipment that are also finding commercial applications in automotive and aircraft manufacture.

The research is designed to produce a new type of drill bit, or "cutter," that will be more resistant to the higher impact forces and higher cutting temperatures encountered when drilling for oil or geothermal resources in hard rock formations. The new cutter utilizes thermally stable polycrystalline diamond (TSPCD), which cannot be brazed to supports using conventional methods.

High-energy electron beams allow TSPCD to be brazed to tungsten carbide/cobalt substrates. Electron beams penetrate through the diamond to melt a thin braze alloy interlayer. Using this advanced bonding technique minimizes diamond degradation, eliminates residual stresses caused by the coefficient of thermal expansion mismatch, and creates a strong bond between the diamond material and the substrate.

SRL has demonstrated high-strength, low-stress joining of TSPCD to carbide substrates. Computer simulations showed that by optimizing parameters, the SRL process may nearly eliminate residual braze stresses for these materials. SRL also recently completed building and is now testing a low-cost electron beam unit that is small

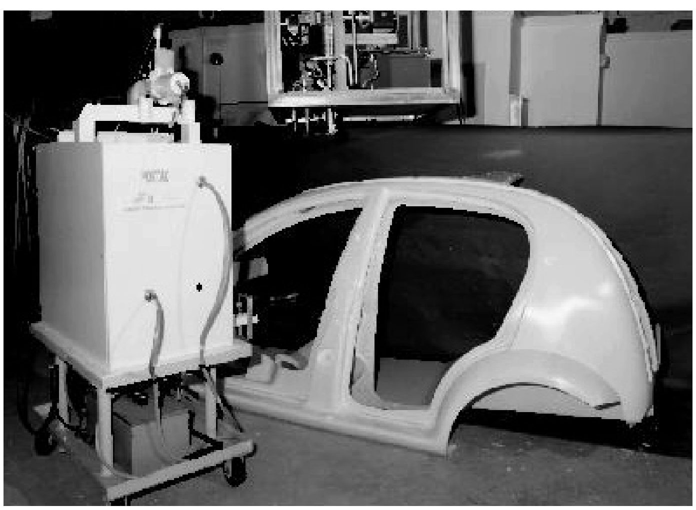


Figure 1. Portac (left) and EB10 electron beam guns available from Science Research Laboratory/Electron Solutions Inc. of Somerville, Massachusetts. These systems are useful for brazing and for curing of adhesives or composites.

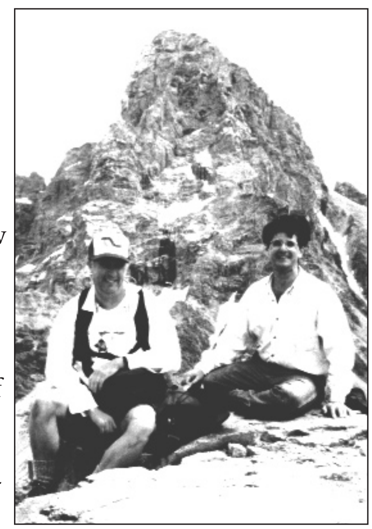
(~ 3 foot cube) and suited to commercial brazing. During 1999, SRL plans to optimize brazing parameters and develop a better way to hold parts during brazing.

This same electron beam technology can also be used in manufacturing of cars and airplanes. SRL has been working with Daimler-Chrysler to bond their Composite Concept Vehicle (CCV) using electron beam-curable adhesives. Conventional heat-curable adhesives take at least 15 minutes to cure. Expansion differences between plastic and metal can cause cracking. Chrysler would like to use adhesives to bond an entire plastic car body together within two minutes, and electron beam curing may be the answer.

Figure 1 shows pictures of two electron accelerators available through SRL's Electron Solutions Inc. (ESI) subsidiary, and shows Chrysler's plastic CCV car body.

For more information, visit the ESI Web site at http://users.aol.com/ElecSoln, or call Daniel Goodman at (617) 547-1122.programs.

After completing graduate work at the University of Minnesota on the Precambrian Duluth Complex, Joel moved to the U.S. Geological Survey (USGS) at Menlo Park, California, and jumped a few years forward geologically to work on Pleistocene saline deposits in the Basin and Range. With the passage of the Geothermal Steam Act of 1970, he began working on geothermal energy and has spent most of his professional career in hot water. He is one of the charter members of the Geothermal Resources Council. He was a member of the USGS team that defined the first group of "Known Geothermal Resource Areas" (also known as KGRAs)—one of the areas that he defined was Mount St. Helens. He also worked with Don White on the first nationwide assessment of geothermal resources, published as USGS Circular 726.



Joel Renner and Ray LaSala, DOE Energy Conversion Program Manager, Office of Geothermal Technologies, on Table Mountain (in the Teton Range) at 3,385m.

After a brief career change to become a USGS coal geologist, Joel joined the Gruy Companies and worked under contract with the U.S. Department of Energy's Office of Geothermal Technologies performing assessments of the low-temperature geothermal potential of the Eastern United States. Although the Eastern United States is usually not thought of as a geothermal region, early colonists developed many of the springs for therapeutic uses and bathing. Some of these sites are still used today and include resorts such as Warm Springs, Georgia.

While with the Gruy Companies, Joel and Marshall Reed (the current DOE Reservoir Technology and Exploration Program Manager) worked together on the USGS assessment of low-temperature geothermal resources of the United States (USGS Circular 892).

Joel has worked at the Idaho National Engineering and Environmental Laboratory (INEEL) since 1985, primarily working with geothermal energy. INEEL's program is primarily focused on energy conversion and reservoir engineering. Current work includes efficiency improvements in binary power plants, study of microbially induced corrosion, real-time monitoring of emissions from geothermal power plants, development of improved reservoir simulation methods, and continued development of the DOE Geothermal Technical Information Web site (http://geothermal.id.doe.gov).

He worked with the industry to develop the Geothermal Technology Organization, modeled after the Sandia-initiated Geothermal Drilling Organization, to streamline the inception of DOE-industry cost-shared research projects.

Now that we've profiled the professional side, an additional item must be mentioned about Joel—he loves to travel! Joel has added to his international experience in mining with a worldview of geothermal energy. While he has been the Geothermal Research Coordinator at INEEL, Joel has participated in trips with the U.S. geothermal industry to Indonesia, New Zealand, Italy, the Lesser Antilles, Uganda, Ethiopia, and Eritrea. In many of these countries, Joel was able to gather important information on the geothermal resources. Thanks, Joel, for your many valued contributions.

Spire Corporation, a Massachusetts high-tech firm, is having success in developing technology that holds great promise for the geothermal drilling industry, and may even make the crossover to other industries.

In the spring of 1997, Spire won a two year, $750,000 Small Business Innovative Research (SBIR) grant from the U. S. Department of Energy's Office of Geothermal Technologies to develop an ultra-hard ceramic coating for application in drill-bit components. Thus far, Spire's success has attracted a potential drilling-industry partner who would be a customer of Spire's, to either purchase the technology or have Spire coat components for them. In addition to their functionally graded ceramic coating, Spire has recently begun to develop a functionally graded coating that has diamond material as its outermost layer.

Spire Corporation (better known for their involvement in photovoltaic manufacturing technology) is developing an ultra-hard, functionally graded ceramic coating process that will be used to protect drill-bit bearings and other parts from wear. Spire has utilized the SBIR funds to develop the process, and has leveraged its funding to partner with the Hughes-Christensen Company in an effort to test its coating on drill-bit parts for the oil-service giant. While Spire has successfully coated various test samples of high carbon steel, and other materials, it is now trying to fine tune the process for bearings and bearing races that are vital components in the drill bits used in oil and geothermal drilling. The company is also in contact with Dynaflow, Inc., and Sandia National Laboratories regarding coating injector nozzles for jet assisted bits to protect against wear. Although other solutions have been presented for the nozzle wear problem, Spire's coating may prove to be an attractive option.

The coatings are nanocrystalline layers of Spire's ceramic material that are "stitched" to the metal substrate with an ion beam deposition (IBAD) process. One of the key attributes of the technique is that the coating is functionally graded. This allows an almost pure, ultra-hard ceramic surface to be graded down to a bottom metallic surface that bonds much more securely to the metal substrate (e.g., tungsten carbide or high carbon steel). This produces the ultra-hard surface with a "backing" that creates a super strong bond to the steel being coated. The advantages of this are many, because diamond is a much harder, and much lower friction material than the successfully proven ceramic.

Recent tests have shown excellent results with the ceramic coatings, and a good potential for future success, once the IBAD process is perfected. The ultra-hard coatings dramatically extend the wear life of any material they are applied to. Another interesting finding is that any material that contacts the coated piece (and normally causes the wear) also wears at a far lower rate. For example, if a bearing race alone were coated, it would last longer, and the associated bearing would also wear less. The applications for extending the life of drill bits, engine parts, knee implants, or anything that wears from abrasion or adhesion appear unlimited, and the market for such technology is vast.

Spire's technology is an exciting development with broad and lucrative potential in the drilling industry and beyond. While Hughes-Christensen has been a good partner in testing the coatings, they have not yet provided full cost sharing for development, testing, and commercialization. The next step for Spire is to fine-tune its coating process, and then obtain a funding-partner from private industry. This may allow it to win additional SBIR funding to help commercialize this advanced technology.

For more information, contact F. Namavar at (781) 275-6000, x286 or e-mail at fnamavar@spirecorp.com.

Two of the U. S. Department of Energy's premier national laboratories are developing advanced technologies that promise to significantly reduce operating costs at The Geysers —and at other geothermal steam fields where hydrogen sulfide abatement is a costly problem. Scientists at the Lawrence Livermore National Laboratory (LLNL) and the Idaho National Engineering and Environmental Laboratory (INEEL) are exploring continuous monitoring devices that use two newly developed infrared optical techniques—an active laser-based technique and a new type of infrared spectrometer.

The generation of power at The Geysers Geothermal Field utilizes primary and secondary abatement to control atmospheric emissions of H_2S. The primary abatement uses conventional oxidation methods, including the Stretford, LO-CAT, sulferox, and incineration, to reduce the H_2S levels in the non-condensable stream vented from the condenser. The secondary abatement uses an iron chelate concentration in the cooling water to oxidize the H_2S partitioned into the steam condensate used for cooling water makeup. Presently, there is no satisfactory way of continuously and accurately monitoring the H_2S content in the various streams.

These abatement processes increase the operating and maintenance costs for the plants. The amount of expensive iron chelate added to the steam condensate is based upon the amount of H_2S released from the cooling tower stack. These emissions are periodically measured using portable analyzers at multiple sample points in a cooling tower. Chemical usage is then conservatively targeted to achieve 75% of allowable emissions to assure regulatory limits are never exceeded. Continuous monitoring could allow chemical usage to be adjusted in response to the fluctuations in H_2S, reducing this conservatism and associated cost. Currently, field operators are spending between $1 million and $1.5 million annually for iron chelate, a cost that could be reduced to between $300,000 and $400,000 if the actual need for H_2S abatement could be more accurately and continuously determined.

The infrared spectrometer being developed at LLNL is based upon the principle of cross-dispersion, which provides a two-dimensional spectrum that is focused onto a detector array. This provides spectral snapshots of an entire infrared spectral region with no moving parts. The instrument, referred to as an Echelle Grating Spectrometer (EGS), yields high spectral resolution in a small package. This instrument is intrinsically robust and, coupled with modern infrared detector arrays, can be more than 100 times more sensitive than existing infrared instruments. Experiments conducted at The Geysers (Figure 1) measured the H_2S content in steam entering the turbine. The weak H_2S absorption in the vapor was detected after establishing measurement precision

Figure 1. On-site collection and analysis of H_2S data with the Echelle Grating Spectrometer.

levels approaching 0.002%. These experiments demonstrated our ability to detect H_2S down to 60-PPM (v) level under these field conditions. Improvements in the technology are presently underway and the measurement of H_2S directly at the steam cooling towers appears possible.

The instrument under investigation at the INEEL is based upon the use of a compact, near-infrared diode laser technology. Fortuitously, a standard communication diode frequency (1.55 microns) can be easily temperature-shifted to access an H_2S combination absorption band at 1.578 microns. The spectral resolution of the diode laser is extremely narrow, reducing the signal contributions from interferents (i.e., such as water vapor or carbon dioxide) that can limit the sensitivity and accuracy of the measurement. The output from these lasers can be propagated over standard optical fibers, allowing sensitive components to be located in controlled environments. The system also allows multiplexing of signals so that a single device can make a number of remote measurements.

This instrument has been tested in a Geysers plant. In this test, a side stream of the vent gas entering the Stretford system was passed through a 10-cm sample cell (Figure 2). The instrument operated continuously for as long as 24 hours

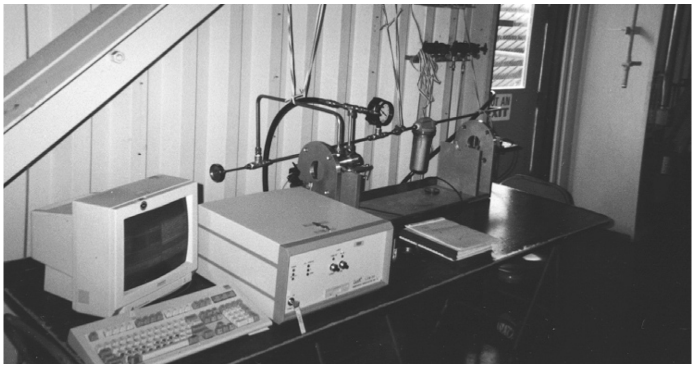


Figure 2. Near-Infrared Spectroscopy System on-line at a Geysers plant.

with a precision of ± 25 PPM (v)/meter. Measured H_2S levels were periodically benchmarked against independent measurements using a Tutwiler method.

Additional testing with the INEEL instrument is planned for the first quarter of 1999 in one of Northern California Power Authority's facilities at The Geysers. Several weeks of testing will be conducted in parallel to a lead-acetate device currently used to detect H_2S levels in the gas stream leaving the Stretford process. If measurements are comparable and the postulated improved reliability and minimal operational support are confirmed, this instrument could potentially replace the lead-acetate devices. The LLNL approach will be extended into the long-wave infrared where stronger H_2S radiance will provide for more sensitive detection. The system will be tested in the last quarter of 1999 at The Geysers and as a direct monitor of H_2S emissions from the cooling towers.

For more information, contact: Dr. Charles G. Stevens, LLNL, (925) 422-6208 or Dr. Judy K. Partin, INEEL, (208) 526-2822.

Long recognized as a superior heating and cooling technology in homes, geothermal heat pumps (GHPs) are increasing market penetration in commercial and institutional buildings. This is because of a variety of reasons: recent reductions in up-front costs (indeed, sometimes GHP systems actually have a lower first cost than competing systems), clear life-cycle cost advantages due to lower energy and maintenance bills, superior comfort and reliability, and reduced space requirements.

However, one of the most significant barriers to wider use of geothermal heat pumps (sometimes called ground source heat pumps or GeoExchange systems) is lack of design experience among architects and engineers. Often, when a customer inquires about GHPs as an option, the customer's architects and engineers are reluctant to consider them seriously because they lack design and installation experience with the systems. In many cases, even when the architects or engineers are willing to design a GHP system, neither they nor the client are willing to pay for the design.

To address this barrier, the Geothermal Heat Pump Consortium (GHPC) has initiated the Design Assistance Program. In this program, GHPC provides small grants (usually under $10,000 per project) to pay GHP design experts to consult with the customer's architects and/or engineers on geothermal heat pump feasibility and design. Applying their extensive knowledge of GHP technology, these experts identify the optimal design parameters for the project. They work with the architects and engineers to be sure they understand how geothermal systems work, how they compare with other options, and why they provide superior service and reliability.

GHPC makes it easy to apply for this expert consultation. The prospective client submits a two-page application for design assistance, noting the building's location, size, type, and so forth. The applicant also makes a commitment to specify GHPs when he puts the project out for bids, if the consultation identifies them to be practical and cost-effective. If the application for assistance is accepted, GHPC usually contracts directly with the selected design expert to provide the consultation. At the conclusion of work, the client and GHPC both receive a report from the expert determining the feasibility and cost-effectiveness of geothermal heat pumps, as well as design details.

GHPC's Design Assistance Program has achieved very strong results. So far, 25 projects, or about three-quarters of the recipients of design assistance who have selected an HVAC system, have said "yes" to GHPs. This is a striking result, because the decision to invest in a relatively new HVAC technology is a big step for many architectural and engineering design firms, which are generally very risk-averse when it comes to selecting HVAC systems. One of the first school systems to use design assistance, Pulaski School System in Kentucky, has now committed to install GHPs in all new schools. And some architects and engineers, once introduced to the practical application of geothermal heat pumps in actual projects, have themselves become firm believers in the technology.

Michael L'Ecuyer, Senior Project Director at the Geothermal Heat Pump Consortium, can be reached at (202) 508-5513.

alley—

One of 1998's more surprising and significant discoveries was the presence of small amounts of oil in western Nevada's high-temperature (250°C) Dixie Valley geothermal system. This is surprising because oil is traditionally considered unstable at these elevated temperatures, and significant because the oil, as a complex mixture of delicate organic compounds, may be a sensitive recorder of natural and production-induced reservoir behavior.

The Dixie Valley geothermal system, owned and operated by Oxbow Power Services, is one of the largest in the Great Basin, producing roughly 65 MW of electrical power from ten

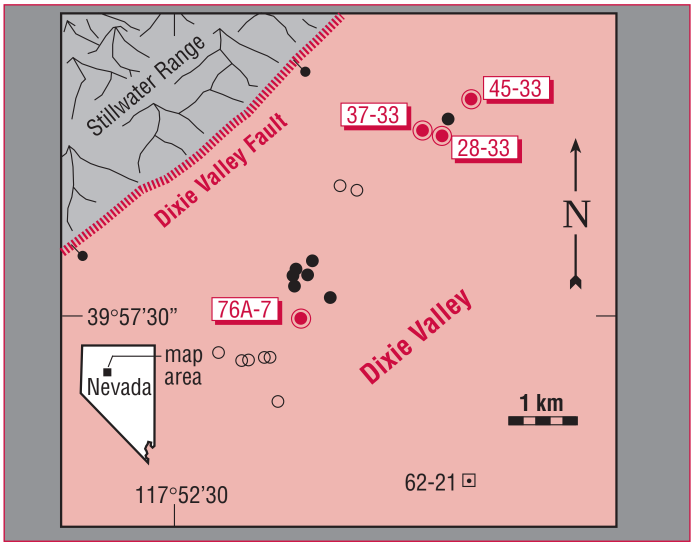


Figure 1. Map of the Dixie Valley geothermal field, Nevada, showing locations of production wells with "oil shows" (symbolozed by ringed, red filled circles), other production wells (black filled circles), injection wells (open circles), and a non-productive well (square). Dixie Valley fault zone, the principal source, at depth, of the field's high-temperature (nominally 250°C) geothermal waters.

deep wells penetrating a great fault zone at the eastern edge of the lofty Stillwater mountain range (see Figure 1). Oxbow geologist Stu Johnson first noticed traces of oil here in a carefully controlled production-wellhead "bleed" (see Figure 2). Geologists at the Energy and Geoscience Institute (EGI) at the University of Utah, later found oil in "scales" of calcium carbonate and clay deposited in the upper portions of three other wells.

EGI is funded by the U.S. Department of Energy's Office of Geothermal Technologies to characterize hydrothermal systems and to evaluate the role of natural and augmented fluid recharge in the quality and maintenance of reservoir production. In pursuit of these goals, EGI researchers began investigating the Dixie Valley oil with the following initial questions in mind: Where did it come from? How long had it been in the system, and how fast might it have traveled? Was it already in place, or was it drawn into the system in response to reservoir production? Preliminary answers to these questions were presented by EGI and Oxbow at the 24th Stanford University Geothermal Reservoir Engineering Workshop on January 26, 1999.

Oil is conventionally considered to form from raw organic matter in the approximate temperature range 90—150°C. When subjected to higher temperatures, the oil breaks down into natural gas and a carbonaceous residue. The Dixie Valley oil has clearly experienced the reservoir temperature of 250°C, yet it is still a liquid, and its molecular configuration indicates heating to barely 120°C. This contradiction can be explained by the heating duration—it takes time for the oil to begin "cracking" and to re-equilibrate geochemically at the higher temperature. Even so, the hotter it gets, the more quickly it transforms. The geochemistry and numerically modeled thermal history of the Dixie Valley oil suggest that it has existed in the hot-water reservoir for only a fraction of the geothermal system's probable age of tens to hundreds of thousands of years.

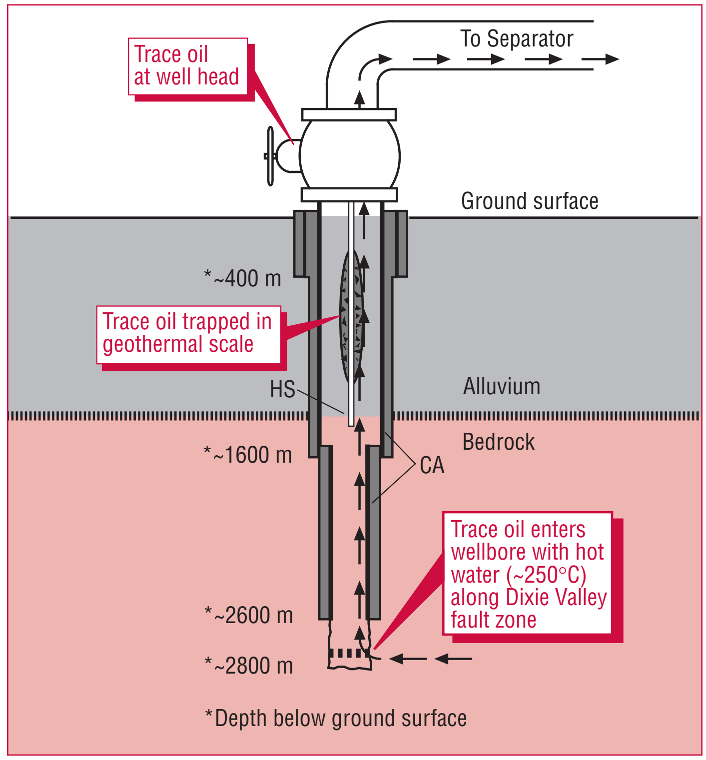


Figure 2. Schematic diagram of producing geothermal wells with "oil shows" in the Dixie Valley geothermal field. Wellbore is lined with casing (CA) to about 2600 m depth, limiting oil access to the open-hole interval between there and total depth (about 2800 m). Above the "flash point," the produced hot water boils, and geothermal scale is precipitated on hangdown strings (HS) installed to inhibit the process. A small amount of oil continues to accumulate at the wellhead (37-33 only).

The currently preferred explanation is that the oil was drawn into the system recently, at a rate of several kilometers per year, from an external source in response to a production-induced "pressure sink". If so, the oil can be used as a qualitative natural tracer for the Dixie Valley reservoir fluids, augmenting sophisticated manufactured tracers to establish fluid flowrates, pathways, and mechanisms. Because the Great Basin is rich in petroleum source rocks, the use of natural oil in this regard might well have application in high-temperature geothermal systems throughout the region.

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