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DOE/EPRI HYBRID POWER SYSTEM

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ABSTRACT

One of the primary objectives of the DOE Geopressured Geothermal Program is to improve methods for optimum energy extraction from geopressured reservoirs. Hybrid power systems which take advantage of the chemical and thermal energy content of geopressured fluids could improve conversion efficiency by 15 to 20% over the same amount of fuel and geothermal fluid processed separately. In a joint DOE/EPRI effort, equipment from the Direct Contact Heat Exchange test facility at East Mesa is being modified for use in a unique geopressured hybrid power plant located at the Pleasant Bayou wellsite in Brazoria County, TX. Natural gas separated at the wellhead will fuel a gas turbine, and exhaust heat from the engine will be used with the geothermal brine to vaporize isobutane in a binary power cycle. The hybrid power system is designed for 10,000 bbl/day brine flow, with estimated power production of 980 kW (net). In addition to evaluating the enhanced performance resulting from the combined power generation cycles, operation of the hybrid unit will provide a demonstration of fuel flexibility in an individual plant. This approach would allow a resource developer to reduce costs and risks by optimizing production for various economic climates and would improve the mix in a utility's generating system.

INTRODUCTION

A goal of the energy research programs sponsored by the U.S. Department of Energy (DOE) is to develop a balanced domestic energy resource base that will provide a range of competitive options for future energy markets (Lombard, 1985). During the mid-1970's, the National Science Foundation initiated a comprehensive geopressured geothermal research program to investigate the nature and development potential for high-pressured thermal fluids encountered principally in the Gulf Coast Basin. The research program was subsequently transferred to what is now the Department of Energy.

To date, the DOE Geopressured Geothermal Program has demonstrated that geopressured reservoirs can sustain long-term production of brine saturated with methane. The major engineering problems related to production, brine handling and fluid disposal have been solved. Detailed monitoring has shown that subsidence and induced seismicity, once considered major deterrents to the development of geopressured reservoirs, may be much less of a concern.

The current emphasis of DOE's geopressured research efforts is on understanding reservoir production mechanisms and on developing methods for total energy recovery from the produced fluids. Geopressured reservoirs contain brine at moderate to high temperatures and at nearly lithostatic pressure gradients. The brines are frequently saturated with gas which is principally methane. Thus, these resources provide a unique opportunity to recover thermal, chemical and mechanical energies.

Analyses by the Ben Holt Company for the Electric Power Research Institute (EPRI) demonstrated the advantages of converting the thermal and chemical energy of a representative geopressured brine to electricity using a hybrid power system. Their analyses showed that a gas/geothermal hybrid cycle could improve conversion efficiency by at least 15 to 20%. This improvement is relative to the same amount of fuel and geothermal fluid processed separately (Biljetina and Campbell, 1988).

The hybrid concept has been discussed in the technical literature since the early years of the federal government's geothermal research and development program (City of Burbank, 1977; DiPippo, 1979; Khalifa, 1981). However, the concept has not been demonstrated in actual practice. In a joint effort, DOE and EPRI are funding a test of the hybrid power cycle concept to establish its potential benefits. Operating experience and field test data will enable geothermal resource developers to design and build hybrid power systems when the advantages of such a system make it the best option for a particular development.

DISCLAIMER

During the hybrid tests, EPRI will be evaluating the enhanced power output from the hybrid system, as well as assessing several other potential benefits, including:

- Risk Reduction - As a first unit in a new geothermal field, a hybrid power plant offers the plant owner a form of insurance against the risk that the geothermal reservoir will not be capable of producing enough heat for the full capacity of the plant. The insurance would be in the form of back-up capability provided by the gas engine. This concept would also make it possible to build a project in phases that are appropriate for different economic and market conditions (i.e., cost of natural gas).
- Fuel and Resource Flexibility - For utilities, the hybrid concept can be used to increase the resource mix in their generating systems. On an individual plant basis, the concept offers some measure of fuel flexibility, the extent depending on the turndown and turnup capability built into the combustion and geothermal parts of the plant.
- Peaking Capability - When a utility's need for new capacity is a need for peaking or other load following capabilities, the gas engine offers the chance to increase the hybrid plant's output at high-demand periods while keeping the geothermal production at constant level. This would improve project economics, especially when there is a premium price for delivery of on-peak electricity.

ENERGY CONVERSION SYSTEM DESIGN

The DOE/EPRI hybrid power system will be tested at the Pleasant Bayou geopressured wellsite in Brazoria County, Texas. Much of the equipment for the binary system was obtained from the DOE Direct Contact Heat Exchange (DCHX) test facility and refurbished for this project. New equipment provided for the Pleasant Bayou installation includes heat exchangers, an evaporative cooler, firewater pump, gas-freeing condenser and electrical switchgear. The operating conditions will approximate those of the DCHX system to minimize design and equipment modifications (Biljetina and Campbell, 1988).

Brine production from the Pleasant Bayou well will be controlled at 20,000 bbl/day (290,000 lb/hr), which is the capacity of the two separators in the brine handling system (Figure 1). Nominal flowing wellhead conditions are expected to be 295 F and 3000 to 4000 psi. At the primary choke, pressure will be reduced to 1500 psi. The brine flow will then be run through two flow-splitting chokes where the pressure will be further reduced to 800 psig. At that point, the brine will enter one of two gas/brine separators which will be operated in parallel.

The operating pressure for the gas/brine separators is determined by the gas sales pressure, which is nominally 600 psig. The gas produced from the Pleasant Bayou well consists of approximately 83% methane, 11% carbon dioxide and 6% ethane and higher components. After separation, cooling and dehydration, the gas can be either sold or run to the gas engine included in the energy conversion system. The gas engine will produce 650 kW under normal operating conditions. The exhaust from the gas engine will be used to vaporize a portion of the isobutane in the binary cycle.

Brine from the gas/brine separators will be split into two nominal 10,000 bbl/day (150,000 lb/hr) flow streams. One brine stream will be filtered and injected. The other brine stream will be run through a binary heat exchanger and then through an isobutane preheater prior to disposal. Condensed isobutane will be pumped through the preheater, where the temperature will be raised from 96 F to 210 F. Approximately 86% of the isobutane will then be vaporized in the primary heat exchanger. The remaining 14% of the isobutane will be vaporized in a secondary evaporator using heat from the 1130 F gas engine exhaust. The combined isobutane vapor streams will then be run through an isobutane turbine-generator with 540 kW design output. Parasitic power loads are estimated to total 210 kW, for a net power production for the combined cycles of 980 kW.

Some design changes have been made in the brine system based on operating experience at the Gladys McCall wellsite. At Gladys McCall, erosion and corrosion of pipe was high in areas of high brine velocity and where tortuous piping paths or gas entrapment existed. The highest piping failure rates at Gladys McCall were located just downstream of the chokes and the separator level control valves. At Pleasant Bayou, most of the brine piping remains carbon steel. Piping immediately downstream of the chokes and control valves has been upgraded to 316 stainless steel. In addition, pipe velocities will be maintained below 10 fps under normal operating conditions. Tighter specifications for material and welding have also been instituted (Biljetina and Campbell, 1988).

TEST PLAN

The primary objective of operating the energy conversion system is to demonstrate for the first time the generation of electricity from a geothermal hybrid power cycle. The system will be operated over a range of conditions to obtain data for system optimization and as a base for future commercial installations. Following initial startup and shakedown, the facility will be operated under a variety of operating conditions. Following this will be a period of operation at maximum power output under conditions as close as possible to that of a commercial facility. Performance data will be used to evaluate the reliability of the hybrid cycle and to develop and document those design, operation and maintenance features that are important for achieving high reliability. The duration of the test program will range from 12 to 24 months, depending on the operating experience and on funding availability.

During the test period, data will be collected on system performance under the adverse conditions of saline geothermal brine (total dissolved solids content of about 130,000 mg/l) and methane containing contaminants. Of particular interest will be heat exchanger fouling, scale formation, corrosion, erosion and long-term reliability of the geopressured fluid supply. Also important will be changes in the rotating equipment efficiency over time, which would indicate potential problems such as wear of the rotor or impeller, changes in clearance, vibration or mechanical failure.

To ensure that an operational data set is provided that can be verified and reanalyzed, an extensive instrumentation and data acquisition system will be installed. Instrument readings for key parameters will be recorded using a data logging computer and chart recorders. Many of the critical process streams will have backup instrumentation which will be read and recorded manually to confirm the automatically-recorded values. Data for calculation of equipment performance will be gathered at regular intervals, with the frequency of gathering depending on the test being run.

Key calculations for the hybrid system are rotating equipment efficiency and heat exchanger performance. While most of the required calculations are straightforward, the turbine efficiency calculations will require an estimate of the thermodynamic properties of isobutane. An equation of state, such as the Benedict-Webb-Rubin equation will be used to estimate these properties. Even at the turbine inlet, the isobutane will be substantially below the critical point in a region where the properties are known and the equations are considered accurate.

Long-term production from the Pleasant Bayou well is scheduled to begin in May, 1988. Final construction of the energy conversion system is expected to begin in late 1988, with operation of the system to begin in early 1989.

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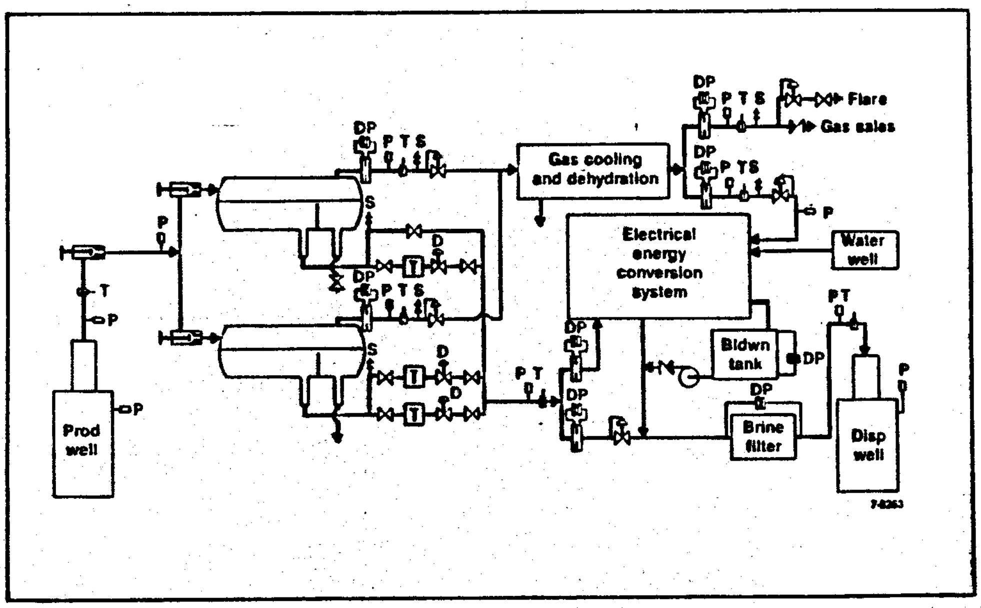

FIGURE 1. Pleasant Bayou Process Flow Diagram.

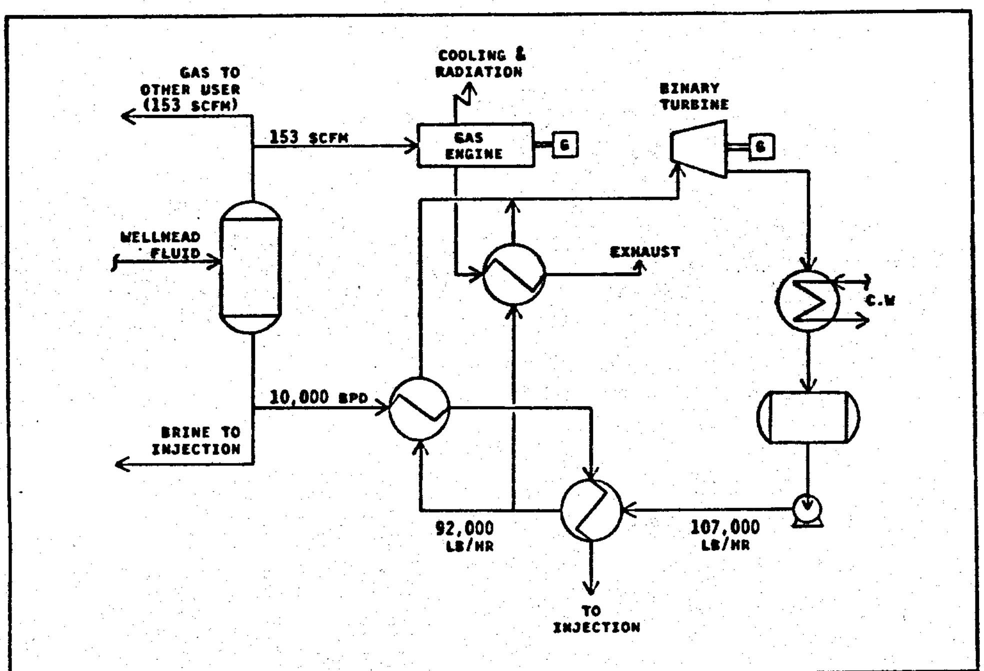

FIGURE 2. Process flow diagram for hybrid energy conversion system at Pleasant Bayou.