SESSION 9

HEBER GEOTHERMAL BINARY DEMONSTRATION PROJECT

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Project Background and Objectives: The Heber Binary Project had its beginning in studies performed for the Electric Power Research Institute (EPRI), which identified the need for commercial scale (50 Mw or larger) demonstration of the binary cycle technology. In late 1980, SDG&E and the Department of Energy (DOE) signed a Cooperative Agreement calling for DOE to share in 50 percent of the Project costs. Similarly, SDG&E signed Project participation agreements with EPRI, the Imperial Irrigation District, California Department of Water Resources, and Southern California Edison Company, which provided the remaining 50 percent of the required funding. In 1982, the State of California also joined the Project.

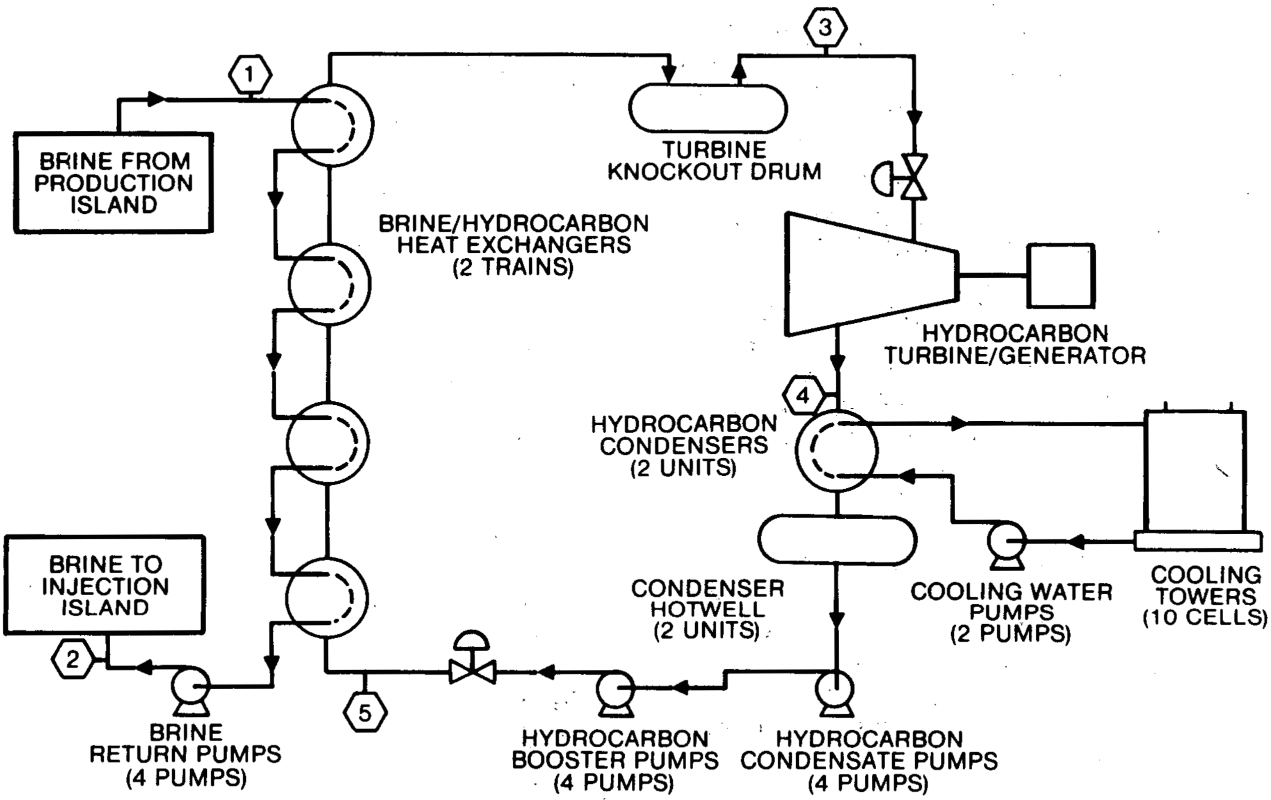
The objectives of the Heber Binary Project are to demonstrate the potential of moderate-temperature (below 410°F) geothermal energy to produce economic electric power with binary cycle conversion technology, and to establish schedule, cost and equipment performance, reservoir performance, and the environmental acceptability of such plants. The plant will be the first large-scale power generating facility in the world utilizing the binary conversion process, and it is expected that information resulting from this Project will be applicable to a wide range of moderate-temperature hydrothermal reservoirs, which represent 80 percent of geothermal resources in the United States.

To accomplish the plant engineering, design, and equipment procurement, SDG&E has hired Fluor Engineers, Inc., Power Division, of Irvine, California. In early 1982, SDG&E contracted for construction management services with Dravo Constructors, Inc. (DCI) of New York. DCI is responsible for casting the Fluor design into construction packages, letting the construction contracts, and overseeing the construction in the field.

Power Cycle Description: The major elements of the power cycle consist of a geothermal brine loop, a hydrocarbon binary loop, and a cooling water loop. Figure 1 shows the three major loops, along with process conditions at full load.

The geothermal brine is delivered to the power plant from an adjacent production facility as a liquid from pumped wells at a temperature of approximately 360°F and a pressure of 250 psia. The brine loop contains a bank of eight shell and tube heat exchangers arranged in two parallel trains of four heat exchangers each. The thermally spent brine is returned for injection back into the geothermal reservoir at a temperature of about 162°F. The injection facility will be located about 1½ miles northwest of the plant site.

FIGURE 1: Process Flow Diagram; 70 MWe At 55°F Wet Bulb Temperature



	1	2	3	4	5
PRESSURE - PSIA	250	320-595	578	73	630
TEMPERATURE - °F	360	162	306	150	101
FLOW - 10^6 LB/HR	7.7	7.7	8.4	8.4	8.4

The binary loop contains the hydrocarbon working fluid and provides the medium for the transfer of geothermal energy from the brine to the hydrocarbon turbine. The liquid hydrocarbon is pressurized and heated under supercritical conditions to a vapor before entering the turbine throttle at 578 psia and 306°F. The hydrocarbon exhaust from the turbine is then condensed back into a liquid in two cross flow shell and tube heat exchangers. The make-up of the working fluid is a mixture of 90 percent isobutane and 10 percent isopentane.

The power cycle will operate under the floating cooling concept. The turbine back pressure, as controlled by the cooling water temperature, will be allowed to fluctuate with the wet bulb temperature in order to generate the maximum amount of power for a given ambient condition. By incorporating floating cooling, the plant average efficiency is improved, and brine requirements are reduced while maintaining an average net power output of 45 Mw.

Design Progress: The design of the Heber binary cycle power plant has evolved extensively from the initial work performed for EPRI. Operability of the plant, plant safety, and equipment economics were key factors behind the development of the design. A design was considered economic if the cumulative present worth of the energy and O&M savings showed a five-year payback when compared to the present worth of the revenue requirement for the incremental investment.

The major development effort for the brine system has centered on the brine return pumps, which supply the pressure necessary for reinjection, and must accommodate both plugged and unplugged wells. In addition, these pumps control brine flow through plant, and in that sense they are somewhat analogous to a fuel throttle valve, since changes in brine flow directly change the amount of heat added to the process. To accomplish these varying flow and pressure requirements, variable speed pumps, means of pump drive utilizing hydraulic couplings was selected as the most economical means of pump drive. While economic analyses also showed some cost advantages in using three 33-1/3% capacity pumps, significant operating advantages could be achieved with a four 25% capacity pump design. The most notable advantage is that since the designs are based on end-of-run brine flow rates, at start-of-run conditions only three pumps would be required, leaving one for a spare. To meet the hydraulic coupling cooling requirements of the four brine pumps, a small, dedicated cooling tower will be used rather than routing piping from the main cooling tower.

An additional development on the brine system was the enlargement of the capacity of the brine heat exchanger by-pass to handle 100% of brine flow. The opening of the by-pass valve on a turbine trip will allow dumping of the heat input to the process, and still maintain flow in the production and injection wells. The by-pass line will also come into play during system start-up. Once the entire brine system is filled with brine and flow around the plant is established in the by-pass line, the heat exchangers will be brought up to operating temperature by bleeding in hot brine from the by-pass line and draining cold brine from the heat exchangers back into the brine return line.

In the hydrocarbon loop, considerable cost savings were achieved by the elimination of the accumulator system and improved operability resulted from resizing the capacity of the booster pumps. The function of an accumulator present in earlier designs was accomplished by enlarging the existing condenser reservoirs and providing for the transfer of hydrocarbon between the reservoirs and storage tank to maintain proper liquid level. The resizing of the booster pumps was the result of studies, which recommended four 25% capacity booster pumps, rather than an earlier design of three 33-1/3% percent pumps. Each booster pump is now paired with a single condensate pump to form four individual pumping units. This scheme provides improved rangeability at reduced load operation, and simplifies the requirements for minimum flow protection, since only the pumping units require protection rather than individual pumps.

In the area of electrical/I&C, a major milestone was the decision to use a digital microprocessor based control system rather, than a more conventional analog control system. The digital system provides more system flexibility, and a reduced control room size over the analog system. In addition, the digital system more easily accommodates the data collection requirements of the Project. On the electrical system, a generator breaker was used to eliminate the need for a separate start-up transformer. Because the high plant auxiliary load would require a very large start-up transformer, a significant savings was achieved by using a circuit breaker to isolate the generator from the plant grid during start-up. In the switchyard, improved operational flexibility was achieved by shifting from an earlier proposed radial bus arrangement to a ring bus.

Turbine Generator: The specification and procurement of a hydrocarbon turbine generator for the Heber Project has always involved some measure of uncertainty because of the lack of similar size machines in service. The eventual specification called for a turbine generator package rated at 70 MWe. Major items included in this package were turbine stop and throttle valves, a speed control governor, separate turbine lubrication and shaft seal systems, direct coupling of the turbine and generator, and a hydrogen cooling system for the generator. The supplier was also asked to guarantee the throttle flow and the generation of 70 MWe for a given set of turbine inlet and exhaust conditions.

Following an extensive commercial and technical evaluation, the Elliott Company, a division of United Technologies, was selected as the successful bidder. The Elliott machine is a four-stage, 3600 RPM, double flow, axial turbine whose rotor is encased in a horizontal split shell contained within a barrel enclosure. The outer barrel casing does not restrict the orientation of the dual 60" turbine outlet, eliminating the elevated foundation required to accomodate a downward exhaust. In addition, the inner shell can be removed through the end of the barrel casing, allowing access to the rotor without disturbing the inlet and outlet piping. An Electric Machinery Company hydrogen cooled generator with brushless excitation will be mated to the Elliott turbine.

Heat Exchangers & Condensers: The heat exchangers and condensers are the major capital components within the plant representing about 30 percent of the total investment in plant equipment. These items were the subject of an extensive optimization study which, in the end, reduced the cost of the heat exchangers by about 42 percent and the condensers by about 12 percent from the cost of the original designs.

The original heat exchanger design called for three shells per heat exchanger train with four passes per shell. The most significant cost savings was achieved by reevaluating and lowering both the brine and hydrocarbon fouling factors. It was determined that the factors used in the original design were overly conservative and heavily weighted to the colder side of the heat exchanger where the values are higher. Other surface area reductions were achieved by a lower required heat exchanger duty due to higher than originally estimated turbine efficiencies quoted in the turbine generator proposals, and the use of the "no-tubes-in-the window" baffle design over the originally proposed rod baffles.

In the optimization of the heat exchangers, additional reductions in surface area were achieved by determining the relationship between area and brine flow rate, and optimizing the area at the lowest combination of capital and operating costs. All totaled, surface area reductions lowered the cost of the heat exchangers by 27 percent over the original design. Additional fabrication cost savings were achieved by reducing the number of shell passes to two from the original four, and increasing the number of shells per train from three to four. This increased number of shells per train was the result of optimizing the installed cost based on fixed surface areas and pressure drops. These combined savings resulted in a cost reduction of 15 percent over the original design.

The cost reduction effort for the condensers closely paralleled the work done on the heat exchangers, except that the basic design of two cross flow shells operating in parallel with two passes per shell was not changed. As with the heat exchangers, a reevaluation of the fouling factors resulted in a savings in condenser size. The improved turbine efficiency also reduced the required condenser duty and consequently reduced condenser size. The reduced fouling factors and improved turbine efficiency each contributed about a 6 percent reduction in cost over the earlier design.

Materials Selection: In addition to the heat exchanger and condenser optimization, considerable attention has been given to the selection of suitable tube materials. As the result of a study that evaluated numerous tube materials based on material cost, corrosion resistance, and a 30-year plant life, Fluor selected a group of high chromium ferritic stainless steels as most suitable for use in the plant. Recommended for the heat exchangers was Alleghany Ludlum's AL 29-4 and AL 29-4c, and for the condensers, Trent Tube's "Sea Cure" was included with the AL 29-4 series as recommended materials. All are ferritic stainless steels with chromium contents in excess of 26 percent. Other materials that were found suitable for use as tube material but not recommended, were carbon steel and titanium. Carbon steel had one of the lowest first costs, but only an expected 8 to 10-year tube life. Titanium was suitably corrosion resistant, but, in general, had a cost higher than the ferritic stainless steels. Both the AL 29-4c and "Sea Cure" are significantly lower in price than the AL 29-4, and both have recently completed an extensive review by ASME, which resulted in their inclusion as ASME code approved materials. The heat exchangers are currently being fabricated with AL 29-4c tubes, and the condensers are being constructed with "Sea Cure" tubes.

The remainder of the plant equipment and piping will be, for the most part, carbon steel with appropriate corrosion allowances. Some exceptions are the cooling water piping, which will be buried fiberglass reinforced plastic, and the service water cooler, which will be a plate type heat exchanger using titanium plates. Some of the other measures that will be taken to reduce the potential for corrosion and scaling will be an extensive cooling water treatment program, provisions for nitrogen blanketing the brine system during shutdowns to prevent oxygen intrusion, maintenance of the brine at sufficient pressures to prevent gas breakout, and the installation of instrumentation on the brine and cooling water systems to monitor chemistry and corrosivity.

Heat Sales Contract: SDG&E's goal at the start of negotiations was to enter into a contract for the long-term supply of geothermal fluid from the Heber KGRA to provide heat to operate a binary cycle power plant. Additionally, the contract needed to reflect the Project's R&D nature and DOE involvement.

The contract, which eventually evolved between SDG&E and Union Oil Company of California, features a phased approach to the development of the geothermal reservoir. Initial geothermal fluid delivery of 250,000 lb/hr will occur in November 1984. This rate of delivery is required to begin the filling and checkout of the in-plant brine handling equipment. The rate of delivery will periodically increase during plant startup until 50% (3,750,000 lb/hr) of the full load requirements is reached in May, 1985. Assurming the plant and reservoir facilities are functioning is expected, additional wells will be drilled to supply 100% (7,500,000 lb/hr) of the plant full load requirements by the January-May, 1986 time frame.

The cost of heat will be made up of a commodity charge and a demand charge. Included in the pricing formula for both charges is a factor which removes from the payment the cost of heat used to generate the electric power for the brine production and injection pumps, since the Project is supplying the power for those pumps. During the demonstration phase, the Project will pay the heat supplier's actual operations and maintenance (O&M) expenses in addition to the cost of heat. The base price for heat, which is $1.15 per million BTU's during most of the demonstration phase, excludes the heat supplier's O&M costs, and before the plant goes into commercial operation, an increment to account for field O&M will be negotiated and added to the $1.15 price. The base price is also adjusted by an escalation factor, which is a composite of several indices that relate to the heat supplier's cost of doing business.

The contract makes no attempt to specify the "quality" of the geothermal fluid. Minimum and maximum delivery pressures are specified, as well as a maximum return pressure at the plant boundary. The contract also establishes a technical committee to coordinate the activities between the parties, and resolve any technical problems that may arise.

Construction: Following a favorable decision on the Heat Sales Contract by the California Public Utilities Commission, the Project has commenced the award construction contracts. The first construction contract, Site Development, includes rough grading of the site, installation of the settling ponds and intake structure, and construction of main and shop buildings. This contract was awarded in June and the Contractor is on-site. The next contract to be let was be the Civil/Structural package. This contract which was awarded in August, encompasses all foundations and underground piping. The remaining contracts are the Mechanical and Electrical contracts, which will entail the bulk of the construction, and three smaller contracts for paving, painting, and landscaping the Plant, which will allow participation in the construction by small contractors. Erection of the cooling tower and hydrocarbon storage tank will be by the equipment suppliers themselves. The construction schedule is geared to support a turbine roll in the first quarter of 1985.