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BINARY CYCLE GEOTHERMAL DEMONSTRATION POWER PLANT

NEW DEVELOPMENTS

RP1900-1

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Background SDG&E has been associated with geothermal exploration and development in the Imperial Valley since 1971. SDG&E currently has interests in the four geothermal reservoirs shown in Figure 1.

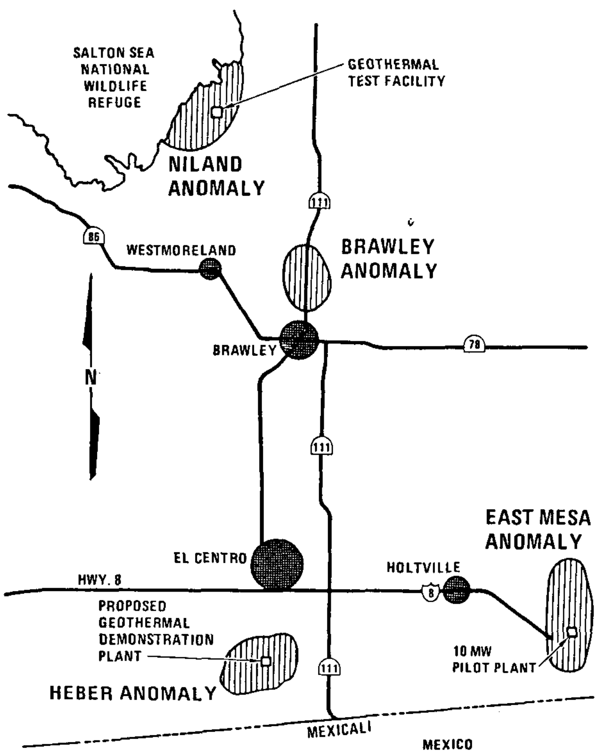

FIGURE 1
IMPERIAL VALLEY GEOTHERMAL RESERVOIRS LOCATION MAP

Major SDG&E activities (or activities of its subsidiary, New Albion Resources Co. [NARCO]) have included drilling and flow testing geothermal exploration wells, feasibility and process flow studies, small-scale field testing of power processes and equipment, and pilot plant scale test facility design, construction and operation. Supporting activities have included geothermal leasing, acquisition of land and water rights, pursual of a major new transmission line to carry Imperial Valley geothermal and other sources of power to San Diego, and support of Magma Electric's 10 MW East Mesa Geothermal Power Plant. Current planned SDG&E efforts emphasize commercial scale planning, risk reduction, and development.

EPRI-sponsored work leading to this project has been heavily relied upon. Field testing, environmental baseline, and feasiblity studies were used as a point of design departure for Heber Binary Project design, development, and optimization. In 1975, EPRI commissioned The Ben Holt Company and Procon, Inc., to perform a study (EPRI Research Project 580) of the feasibility of constructing and operating a geothermal demonstration power plant utilizing low-salinity, liquid-dominated hydrothermal resources. The study originally considered 16 reservoirs in the Western United States but narrowed the choice for detailed analyses to 3 potential sites. Briefly, the study concluded that the Heber geothermal reservoir in Southern California's Imperial Valley was the best location for the demonstration plant, that the binary cycle would produce power at a lower cost than the two other thermodynamic cycles evaluated for that site, and that a demonstration plant producing approximately 50 MWe should be constructed to demonstrate the commercial potential of power produced from liquid-dominated geothermal resources in the United States. The Heber Binary Project is based on the results of the feasibility study, and work has continued in reservoir analysis and plant design since that time.

SDG&E conducted heat exchanger tests at the Heber reservoir for EPRI beginning in 1974, which showed minimal problems in handling the Heber brine. In 1975, SDG&E's interest was further heightened when Chevron Resources Company, Inc., the major geothermal leaseholder at Heber, approached SDG&E with an offer to sell heat from the reservoir for use in a geothermal power plant. After the EPRI feasibility study selected the Heber reservoir as the best site for the demonstration plant, SDG&E began conducting an environmental baseline data acquisition study for gathering baseline environmental information at the reservoir to help assess the future potential impacts of geothermal development.

SDG&E has been planning a commercial-sized geothermal demonstration plant for a considerable length of time. An option for SDG&E or the Federal government to fund a 50 MW demonstration power plant was included in a 1975 contract for the Niland Geothermal Loop Experimental Facility. Because of the encouraging results of the EPRI feasibility study, field tests, and environmental studies, SDG&E decided in mid-1976 to begin assembling a project team to pursue Federal government support for the construction and operation of a commercial-scale demonstration plant at the Heber reservoir. From the outset, SDG&E recognized that substantial external funding support would be needed to reduce the risks of undertaking this first-of-a-kind demonstration project to an acceptable level. Since the benefits would be representative and applicable to a broad section of the industry, Federal assistance appeared to be well justified. Participation in the construction and operation of the Heber Binary Project was also solicited from 26 western utilities and several California State governmental agencies.

Following the request for Federal financial assistance, it was decided that SDG&E would act as the project manager and the principal owner of the power plant. Other utilities interested in participating as plant owners included the Imperial Irrigation District, Los Angeles Department of Water and Power, and Southern California Edison Company. EPRI was to be the major contributor. Other contributors to the project were to be Nevada Power Company, Portland General Electric, Republic Geothermal, Inc., Geothermal Resources International, Inc., California Department of Water Resources, and the California Energy Commission. Although the financial risk was spread among a number of owners and contributors, it was clear that major Federal support would still be required.

In early 1977, in order to present a comprehensive proposal to the Federal government, SDG&E began negotiations with the participants and with the Chevron Resources Company, which was to supply the geothermal energy from the reservoir.

At about that time, DOE requested an Expression of Interest (EOI) from organizations desiring to participate in a demonstration project for the utilization of geothermal energy for electric power generation. SDG&E and other participants submitted an EOI in June 1977, to obtain Federal funding. It was assumed that because the proposed Heber plant had unique merits, proven need, and was well enough defined to meet all of the qualifying criteria, Federal funding was highly likely. Therefore, planning proceeded on the assumption that DOE would quickly become a participant in the Heber project. However, DOE requested detailed design responses to a Program Opportunity Notice (PON) for a geothermal demonstration project with an unspecified process utilizing an unspecified geothermal fluid at unspecified conditions.

SDG&E and the other participants then submitted a response to the PON in January 1978. Preliminary design and engineering activities were suspended until DOE made its announcement of which of the candidate projects would receive Federal cost sharing.

It was learned in July 1978 that DOE had elected to co-fund a high resource temperature, single stage, flash power plant project and that Federal funding would not be available to develop the higher risk, but potentially more widely applicable, commercial-size binary cycle demonstration plant project. Although additional funding was sought from various sources (including the existing participants, EPRI, and other interested parties), sufficient funding was not available and the original project was terminated at the end of 1978.

Recent Events To expedite the development of the binary cycle plant, in August 1979, the Congressional managers of an appropriations bill directed DOE to "proceed without further delay with the development of a 50 MW binary-cycle conversion geothermal demonstration plant...[and] to select a site for this demonstration plant within three months." (Energy and Water Development Appropriation Bill, 1980, Conference Report No. 96-388, 96th Cong., 1st Sess., p. 22.) DOE was thus required by Congress to select a plant site and to begin negotiations for the construction and operation of a binary cycle plant.

SDG&E was greatly interested in these developments because of its extensive earlier involvement in proposing a binary cycle demonstration plant at the Heber reservoir. SDG&E consulted with other utilities and interested parties and decided to again solicit government funding for a binary plant at Heber.

SDG&E obtained expressions of interest from other utilities to participate in a new Heber binary cycle demonstration plant. The Imperial Irrigation District, Southern California Edison Company, and California Department of Water Resources all expressed an interest in sharing in the power output, as well as the construction and operation costs of the project. In addition, EPRI also indicated that it would again consider a proposal to contribute funds to a binary cycle demonstration plant at Heber on behalf of the United States electric utility industry.

In December 1979, SDG&E submitted an unsolicited proposal to DOE and EPRI to obtain financial assistance for the design, construction, and operation of a commercial-sized nominal 50 MW binary cycle demonstration plant. This proposal was based upon the previous project, but was updated to current information on the site, participants, scope, regulatory approvals, cost, and schedule.

In conjunction with this proposal, SDG&E requested and was granted special rate treatment for SDG&E costs associated with this project by the California Public Utilities Commission in January 1980. R&D funds will be used by SDG&E to support this project.

DOE selected Heber as the site for binary cycle demonstration in January 1980. In March 1980, DOE accepted SDG&E's proposal as a basis of negotiation for a Cooperative Agreement. Negotiations with DOE were initiated on March 27, 1980.

The EPRI Geothermal Program Committee approved the project in January 1980. Their Renewable Energy Systems Task Force approved the project in February 1980, and the Advanced Power Systems Divisional Committee also approved the project during March 1980. Final EPRI Board of Directors approval of the project occurred in May 1980.

Project Description The objectives of the Heber Binary Project are (1) to demonstrate the potential of moderate-temperature geothermal energy to produce economic electric power with binary cycle conversion technology; (2) to allow the scaling-up and evaluation of the performance of binary cycle technology in geothermal service; (3) to establish schedule, cost and equipment performance, reservoir performance, and the environmental acceptability of such plants; and (4) to resolve uncertainties associated with the reservoir performance, plant operation, and economics.

Such a demonstration plant would be the first large-scale power generating facility in the U.S. utilizing the binary conversion process. It is expected that information resulting from this demonstration plant will be applicable to a wide range of moderate-temperature, low salinity hydrothermal reservoirs. Eighty percent of U.S. geothermal reservoirs fall into this category.

The binary cycle energy conversion process to be employed is an advanced concept that has the major advantage of being capable of converting a greater amount of geothermal heat from moderate temperature brines into new electric power. Heber beginning-of-life and end-of-life conditions, shown in Table 1, indicate that the binary cycle may be capable of utilizing approximately 40% less geothermal fluid per net kilowatt generated than the dual flash cycle.

DESCRIPTION	BINARY CYCLE BOL	BINARY CYCLE EOL	DUAL FLASH CYCLE BOL	DUAL FLASH CYCLE EOL
Brine Supply Mode	Liquid Phase	Liquid Phase	Two Phase	Two Phase
Brine Flow Rate, MM Lbs/Hr	7.14	8.88	9.8	12.7
Brine Supply Temperature Degrees F	360	338	293	293
Brine Return Temperature Degrees F	160	160	215	215
Net Cycle Eff., Percent	11.2	11.0	11.6	10.7
C.W. Flow Rate, GPM	129,500	134,300	145,900	161,500

TABLE 1
COMPARATIVE PERFORMANCE
(BINARY VERSUS DUAL FLASH)

As geothermal power plants become larger (to take advantage of economies of scale) and available high temperature resources become fully developed, the predominant cost associated with producing geothermal power will be related to brine supply and disposal costs which will be significantly reduced for a given size binary plant. In addition, if current research and development activities are successful (i.e., direct contact heat exchangers and down hole turbine driven pumps), this could further reduce costs. Binary cycle technology will also increase the total potential output of each geothermal resource.

However, to realize all of these potential benefits, binary cycle technology must be proven on a commercial size. Commercial reliability, safety, and costs must be established. Much of the technology is now in existence and being proven in geothermal pilot plants and other applications. However, this technology has not been proven on a commercial scale. The major plant components, such as the hydrocarbon turbine, have not been constructed in this size.

Power Cycle Description The power cycle consists of a geothermal brine loop and a hydrocarbon binary loop as shown on Figure 2. The geothermal brine is delivered to the power plant under liquid phase (nonflashing) conditions from pumped wells at a temperature of approximately 360°F and a pressure of 200 psig. Temperatures are expected to decline with time as the reservoir is developed. The brine loop contains a bank of eight shell and tube heat exchangers arranged in a series parallel configuration. The thermally spent brine is returned for injection to the geothermal reservoir at a minimum temperature of 160°F.

The binary loop contains the hydrocarbon working fluid and provides for the transfer of geothermal energy from the brine to the hydrocarbon turbine. The hydrocarbon is pressurized and heated under supercritical conditions before entering the turbine throttle at 575 psia and 305°F. The working fluid is expected to be a mixture of 90 mole percent isobutane and 10 mole percent isopentane.

The power cycle control system is designed for base load turbine generator operation with limited load variations resulting from daily and seasonal temperature changes and electrical system demand. The controls are capable of maintaining system frequency during periods when the plant output represents a major part of the power reserves on the grid.

The power plant is an outdoor-type station having a net power output of 45 MW. The outdoor concept provides for the turbine generator and other major equipment to be installed outside so as to reduce capital cost and minimize safety hazards associated with the handling and containment of the hydrocarbon working fluid.

The plant site contains both the power plant and brine production facilities. The brine reinjection wells are located about 2.5 miles northwest of the plant site. The power plant plot plan is shown on Figure 3. The combined power plant/production island requires just under 20 acres.

The long history of exploration and development of the Heber Reservoir has resulted in one of the most well understood hydrothermal resources in the United States. After early exploration and well testing by several resource developers, NARCO, Magma Energy Inc., and Chevron Resources Company agreed to join in a test program to evaluate the geothermal resources in the Heber area and to determine the potential for commercial development. The program was undertaken in 1973 to establish the size, and other characteristics, of the Heber geothermal reservoir and to determine the reliability and operating characteristics of well pumps and other equipment necessary for production and injection of the geothermal fluid.

The reservoir evaluation program continued in 1974, and two additional wells were drilled on a cost-sharing basis by Chevron, Magma, and NARCO. In 1976, Union Geothermal, which also holds leases in the Heber reservoir, commenced a drilling program on leases adjacent to those of Chevron, Magma, and NARCO. Data made available by Union's drilling were exchanged for drilling data collected by Chevron, Magma, and NARCO. In 1977, additional wells drilled by Chevron and Union provided a more detailed understanding of the geothermal reservoir. The subsequent full reservoir analyses indicated 500 MW of power production potential from the Heber reservoir.

After NARCO acquired Magma's lease interests at Heber, negotiations involving Union Oil, Chevron Resources Company, and NARCO began in 1977 for the unitization of the Heber geothermal field. These negotiations culminated in 1978 with the signing of the Heber Unit Agreement, with NARCO controlling 9.2%, Chevron 61.6%, and Union 29.2%. Chevron, acting as operator for the unit, filed with Imperial County for G-overlay zoning for the geothermal reservoir and conditional use permits for the development and operation of the geothermal field. The rezoning and the conditional use permits were granted by the County in mid-1978.

The Heber Binary Project is expected to be in service in the early 1980's with production of geothermal heat for the generation of power. SDG&E is negotiating with Chevron and Union for purchase of geothermal heat. In addition, Southern California Edison has signed a contract with Chevron for the supply of geothermal heat to a steam flash plant on the Heber reservoir by 1982.

Figure 4 shows some of the wells and includes the reservoir temperature profile to a depth of 6000 feet. Extensive well flow and injection testing and analysis gives high confidence that this resource will reliably support the project.

The master schedule is shown in Figure 5. A strong DOE funded data acquisition and dissemination effort is expected to continue throughout most of the project life. Plant activities are to be closely integrated with wells and field efforts.

Current Status Current project activities as of this writing consist predominantly of contract negotiations, associated contract support efforts, and detailed project planning and criteria definition. A Cooperative Agreement is being negotiated with the Department of Energy. Drafts of key sections have been circulated and key issues identified.

EPRI Cooperative Agreement and participation agreements are also being negotiated. Drafts are being prepared or revised. Key issues have also been identified.

Remaining subcontract negotiations are in process. A contract with IID to supply water is in place, with a backup water supply approved by the State of California. Heat sales and engineering contracts are being negotiated.

Activities supporting these negotiations are also in process. DOE-related activities requiring support include pre-award audits, environmental assessments, and cooling water review by the Water Resources Council. SDG&E and DOE activities include obtaining a letter of credit, review and approval of purchasing procedures, and support of DOE's data collection dissemination scope of work.

Detailed project planning, organization, and criteria definition are in process. SDG&E's project organization was internally approved and a chart of accounts is in place. Review and update of the seismic design criteria is being accomplished, along with soil tests at the site. Plans for a reliability engineering program and data collection/dissemination interface and support are being formulated. Project procedures are being updated and revised.

Project Philosophy Demonstrating the commercial scale reliability and economics of the binary cycle process is the primary consideration for this project. This has resulted in a "simple and strong" approach to the power plant design. Use of only a single hydrocarbon loop and fresh water cooling are examples of this approach. The design will accommodate the anticipated range of brine temperatures and flow rates, rather than requiring retrofit modifications.

Process and equipment will utilize proven, off-the-shelf hardware wherever possible. Geothermal binary pilot plant and petrochemical industry experience will be carefully reviewed. Provisions for future modifications, replacement, or upgrading will be considered, but will not be allowed to compromise this philosophy.

Strong reliability, safety, and quality control efforts are being planned. Efforts will extend throughout the several phases of the project. SDG&E believes that economic impact of poor plant reliability and availability justifies a significant effort in these areas.

Summary SDG&E expects to begin design and construction of a binary cycle demonstration plant in the near future. The project is being supported by DOE, EPRI, four public and private utilities, as well as the California Public Utilities Commission. The project is expected to confirm the technical and economic superiority of the binary cycle process at a representative moderate temperature geothermal resource, stimulating nationwide geothermal development of these currently unused resources.

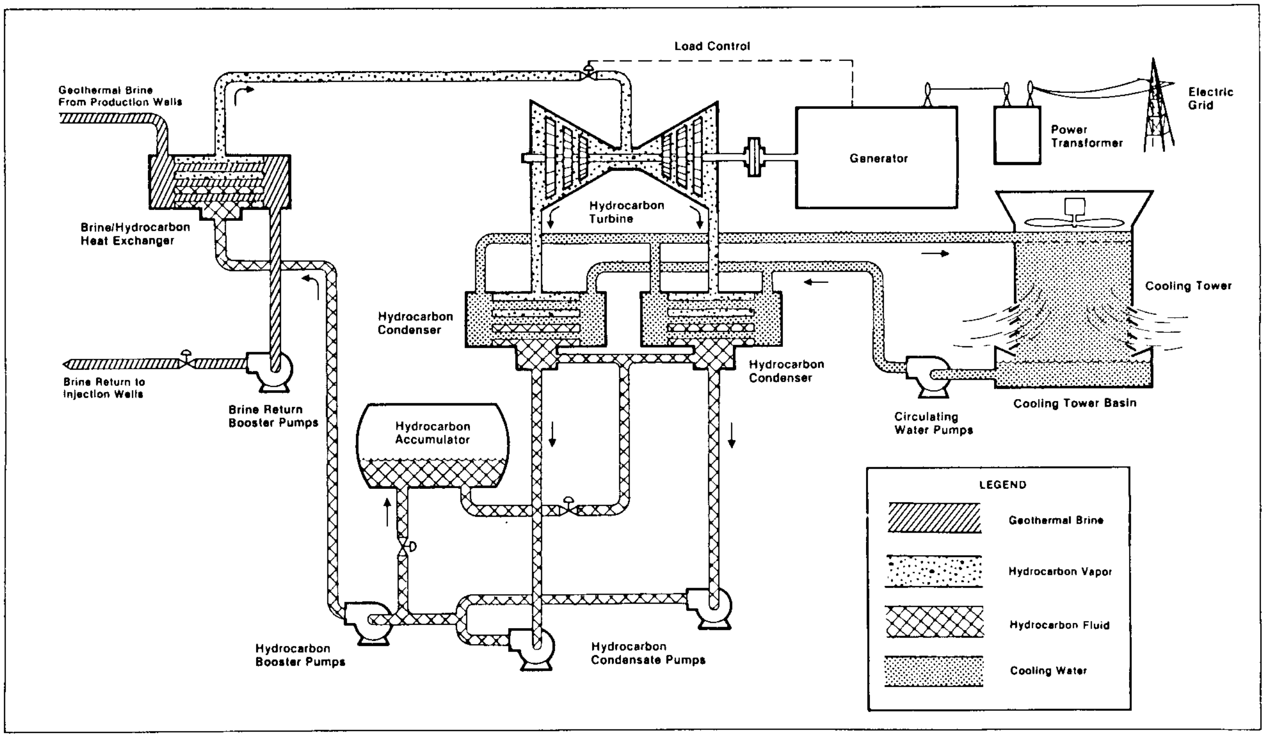

FIGURE 2 - POWER CYCLE

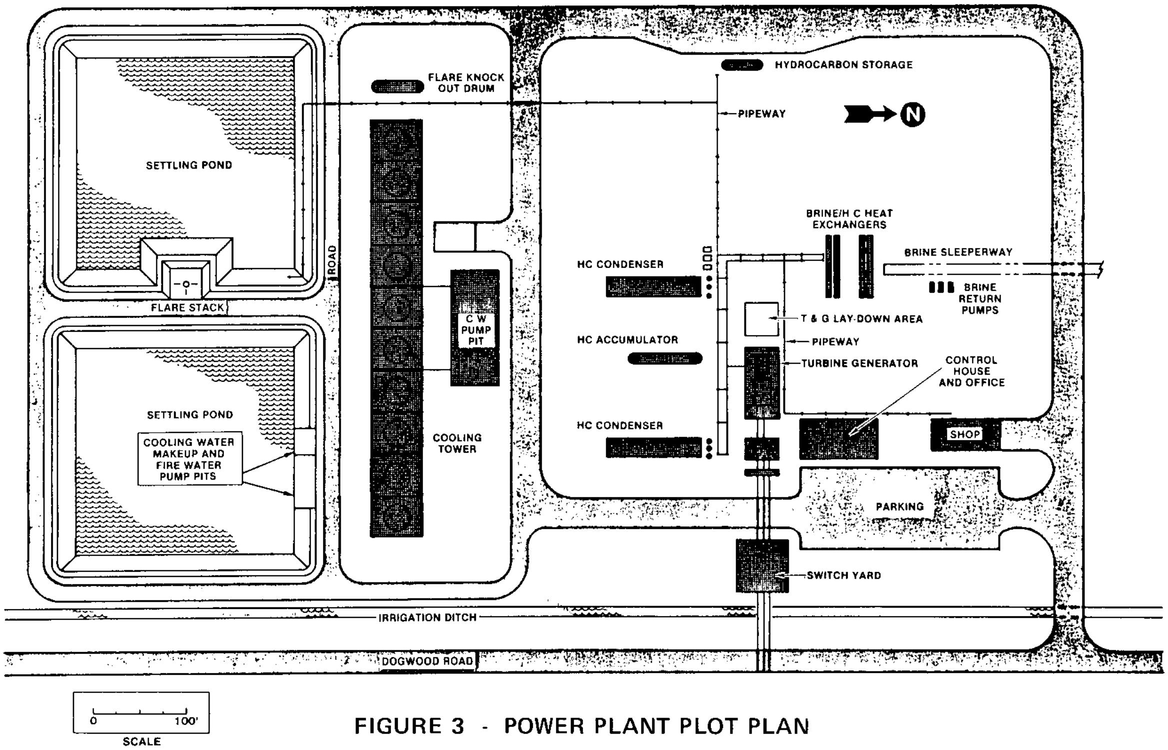

FIGURE 3 - POWER PLANT PLOT PLAN

Arrows indicate locations of exploratory wells.

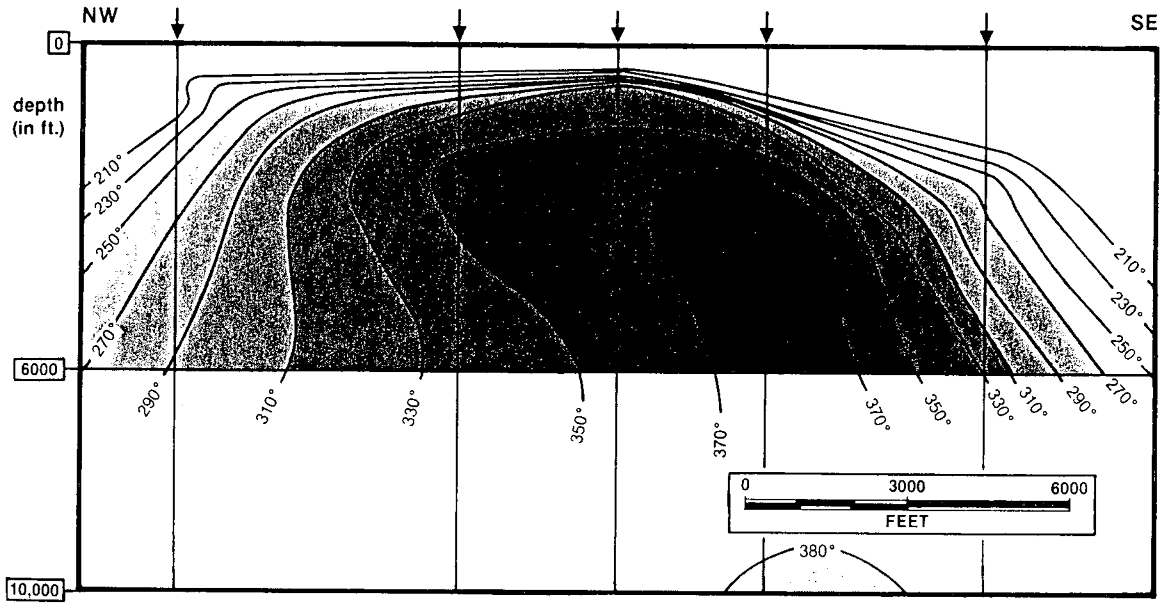

FIGURE 4 - NW-SE TEMPERATURE CROSS-SECTION OF THE UNIT AREA

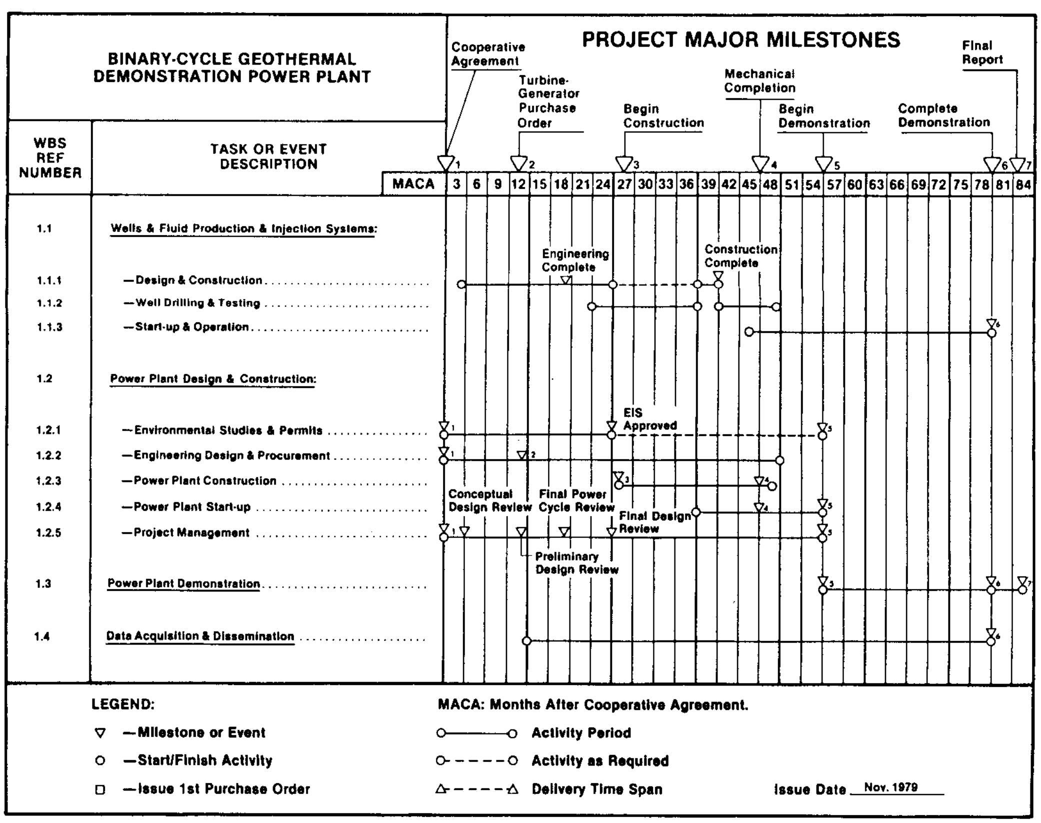

FIGURE 5 - MASTER SCHEDULE