SAN/RA 50239-SDG&E-0013

HEBER GEOTHERMAL BINARY DEMONSTRATION PROJECT

QUARTERLY TECHNICAL PROGRESS REPORT FOR THE PERIOD OCTOBER 1, 1982 - DECEMBER 31, 1982

SDGE

San Diego Gas & Electric
Post Office Box 1831
San Diego, California 92112

Prepared for
The Department of Energy
Under Cooperative Agreement No. DE-FC03-80RA50239

DISCLAIMER

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DISCLAIMER

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ABSTRACT

The purpose of this quarterly technical progress report is to document work completed on the nominal 65 Megawatt (Mwe gross) Heber Geothermal Binary Demonstration Project, located at Heber, California, during the period of October 1, 1982, through December 31, 1982. The work was performed by San Diego Gas & Electric Company under the support and cooperation of the U. S. Department of Energy, the Electric Power Research Institute, the Imperial Irrigation District, the California Department of Water Resources, the State of California, and the Southern California Edison Company. Topics covered in this quarterly report include progress made in the areas of Wells and Fluid Production and Injection Systems, Power Plant Design and Construction, Power Plant Demonstration, and Data Acquisition and Dissemination.

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SUMMARY

Recognizing the desirability of demonstrating the operation of the binary cycle process for commercial-scale electric production, San Diego Gas & Electric Company (SDG&E), the United States Department of Energy (DOE), the Electric Power Research Institute (EPRI), the State of California, the California Department of Water Resources (DWR), the Imperial Irrigation District (IID), and the Southern California Edison Company (SCE) joined together to carry out the Heber Geothermal Binary Demonstration Project.

The purpose of the Heber Binary Project is to design, construct, and operate a nominal 65 MWe (gross) commercial-scale, binary cycle power plant to demonstrate the technical and economic feasibility of geothermal power generation. The Project will be the first commercial-scale hydrothermal generating facility in the United States utilizing liquid-dominated resources and the binary energy conversion process. It is expected that information developed by this demonstration project will be applicable to a wide range of moderate-temperature, low-salinity hydrothermal reservoirs. Geothermal generation from the Project offers the possibility of displacing 525,000 barrels of oil per year that would otherwise have to be burned in Southern California. Picture 1 shows an artist's rendering of the Project and Figure 1 shows the location.

This report describes the Project's progress for the period of October 1, 1982, through December 31, 1982, in the areas of wells and fluid production development, engineering design and construction, power plant demonstration, and data acquisition and dissemination.

During this period negotiations on Amendment No. 2 to the Geothermal Sales Contract were completed with Union; the Amendment was executed on November 2. The major change of Amendment No. 2 was a six-month acceleration of the full brine flow date, which satisfactorily resolved DOE's concerns.

At the California Public Utilities Commission (CPUC), a revised Application was submitted incorporating Amendment No. 2. In addition, the revised Application requested that SDG&E's share of heat costs be passed through the Energy Cost Adjustment Clause (ECAC) process and to offset total Project costs with an energy credit equal to heat costs. Subsequent to the application, a CPUC staff report was issued that was generally favorable, however, during hearings held on December 20-23, staff from the Policy and Revenue Requirements Divisions submitted additional testimony modifying the recommendations in the staff report by seeking a limitation on SDG&E expenditures far below the minimum amount acceptable for SDG&E to continue the Project. Staff from the Utility Division continued to support an approach similar to that used by SDG&E. Contract hearings were not completed and additional dates were scheduled for January 1983.

On November 22, a groundbreaking ceremony was held at the Project site. The activity was well attended by government, industry, local dignitaries, and media. Keynote speakers included U.S. Congressmen Clair

Burgener and Don Fuqua, DOE's Robert San Martin, SDG&E's Tom Page, EPRI's Dwain Spencer, IID's Jerry Moore, and Imperial County's Supervisor Luis Legaspi. The ceremony was well received by the public in San Diego and Imperial Counties.

In the area of design, several changes were made to the process and instrumentation diagrams to reflect improvements in detailed operation, performance, and control. The addition of system piping to the model continued as the detailed design moved ahead and composite piping drawings were initiated.

Significant equipment modifications were implemented on the brine system design and procurement. An analysis was performed comparing the use of three 33-1/3% capacity brine return pumps versus four 25% capacity pumps. Based on this analysis, it was decided to use four 25% capacity pumps with constant speed induction motors, and variable speed, hydraulic couplings. In addition, a small, local cooling tower will be used to cool the brine return pump variable speed drive units and the brine used to fill the brine system. This approach eliminated the need to install piping from the main cooling tower and will result in a $65,000 savings.

Construction efforts focused on receiving and evaluating Site Development Part A proposals, and preparing bid packages for Part B. However, because of changes to the construction schedule it was decided to recombine Parts A and B into one contract. Because of this, all proposals for Part A were rejected and documents for Part B were withdrawn.

INTRODUCTION

The scope of the Heber Binary Project is to design, construct, and operate a commercial-size, binary cycle geothermal power plant at the Heber reservoir for a two-year demonstration period. The goal of the Project is to demonstrate the technical and economic feasibility, as well as the environmental acceptability, of geothermal power generation using the binary process. Our work plan for the Project consists of four major tasks, or Work Breakdown Structure (WBS) elements (see Figure 2), that are described below:

WBS 1.1 - WELLS AND FLUID PRODUCTION AND INJECTION SYSTEMS

Primary responsibility for this task has been assigned to the heat supplier. The task consists of well drilling, the construction of surface facilities for geothermal fluid production and injection, and operation of the field facilities to support plant operation.

WBS 1.2 - POWER PLANT DESIGN AND CONSTRUCTION

This task consists of the work by SDG&E, the architect/engineer, and a construction manager to manage the design, procurement, construction, and start-up of the power plant systems and the associated switchyard, distributing system, and the brine return pipeline. The task includes obtaining necessary permits, associated monitoring, design, procurement, construction, start-up, and project management activities.

WBS 1.3 - POWER PLANT DEMONSTRATION

This task consists of the work by SDG&E to operate the power plant for a two-year period to achieve the basic objectives of the Project. The task includes services, repairs, facilities, overhaul, cleaning, consumables, testing, spare parts, and the tools necessary to operate the plant in a safe and reliable manner.

WBS 1.4 - DATA ACQUISITION AND DISSEMINATION

This task consists of the work by SDG&E in gathering, reducing, evaluating, and reporting on reservoir and plant performance data.

The WBS will serve several functions. It divides the work into discrete and manageable work packages which, taken in the aggregate, will constitute Project implementation. To some extent, it will dictate organizational lines, and will be an important management tool. It provides a method of accounting for all work that must be performed, and is the basis for manpower loading and scheduling. In addition, it will be used for cost and schedule control and progress audit.

WBS 1.1

WELLS AND FLUID PRODUCTION AND INJECTION SYSTEMS

WBS 1.1.1 - DESIGN AND CONSTRUCTION

Objective:

This WBS element will be performed and funded entirely by the heat supplier. It will include work to design, build, and test production and injection systems necessary to deliver fluid from the reservoir to the power plant and, after use, return the fluid into the reservoir.

Status:

Following DOE's expressed concerns over the length of time required to achieve full brine flow under Amendment No. 1 of the Geothermal Sales Contract, SDG&E resumed negotiations with Union Oil Company to attempt to accelerate the date that full brine flow is achieved. In late October, agreement was reached with Union on acceleration of the brine delivery schedule. Drafts of the new agreement were shown to DOE and were found to satisfactorily resolve their critical concerns. On November 2, Union signed Amendment No. 2 to the Geothermal Sales Contract.

The major changes of Amendment No. 2 were a six-month acceleration of the date of full brine flow, the implementation of an incremental demand charge for the second half of the field facilities, the elimination of the "Diesel Index" from the heat cost escalation factor, and the receipt of well data with the drilling of the first well. The implementation of an incremental demand charge was the concession granted Union for the six-month acceleration of the schedule, and the charge will only apply to the fluid capable of being delivered in excess of 50% flow.

While the negotiations for Amendment No. 2 were in progress, San Diego was involved with briefing the California Public Utilities Commission (CPUC) staff on the features and costs of the Geothermal Sales Contract under Amendment No. 1. Although no specifics were discussed, the staff was informed of the negotiations with Union to accelerate the schedule. Once Amendment No. 2 was signed in early November, a second round of staff briefings was conducted on the new amendment and a revised Application was filed with the CPUC. In addition to reflecting the new amendment, the revised Application requested to pass SDG&E's share of heat costs through the Energy Cost Adjustment Clause (ECAC) process, and to offset total Project costs with an energy credit equal to heat costs.

Hearings on the revised Application were held on December 20, 21, 22, and 23. At the request of the staff, SDG&E hired an outside consultant to testify on the concept of "non-quantifiable benefits."

The staff report on the revised Application was generally favorable, and the recommendations in the report were essentially what San Diego requested in their Application. However, during the hearings, members from the Policy and Revenue Requirements Divisions submitted additional testimony modifying the recommendations in the staff report. These new recommendations set limits on the gross costs that San Diego could recover from ratepayers for Heber, and would result in a shortfall of recovery of Project expense. The staff of the Utilities Division also submitted additional testimony recommending limits be set on the net costs the San Diego recovers. While this limit was numerically close to the other limit, it would not result in a shortfall, since it recognized the value of the energy received by San Diego ratepayers. The hearings were not completed in the allotted four days, and additional hearing dates were scheduled for early January.

As preparations for the hearings were underway in November, work was begun on a letter agreement with Chevron, which would enable Chevron to commence engineering work even though the Contract was not in effect. This agreement would provide that San Diego would pay Chevron for certain engineering work if San Diego does not obtain the necessary consents from DOE and CPUC.

WBS 1.2

POWER PLANT DESIGN AND CONSTRUCTION

WBS 1.2.1 - ENVIRONMENTAL STUDIES AND PERMITS

Objective:

The objective of this WBS element is to obtain the necessary permits and provide environmental studies and monitoring to facilitate plant design and ensure compliance with government regulations for plant construction and operation.

Status:

Imperial County Air Pollution Control District (ICAPCD) Permit

Following an explanatory meeting with the ICAPCD on October 14 (reference DOE Quarterly Report for the period July 1-September 30, 1982), the ICAPCD issued a revision to the Authority to Construct permit on October 27, with the following conditions:

1. All isobutane relief valve emission shall be vented through the flare stack.

2. Sampling of the relief valve emissions shall be conducted utilizing a gas chromatograph twice a day for the first month of operation.

3. The Air Pollution Control Officer (APCO) shall be informed of the isobutane relief valve emission rate as determined by Condition 2. and a suitable monitoring schedule will be arranged.

4. The APCO shall be notified of the isobutane storage tank loss on a monthly total pounds basis. The APCO shall be also notified of the recharge schedule.

5. Upon determining that hydrocarbon emissions are in excess of 250 lbs/day, SDG&E shall obtain offsets under the direction of the APCO.

As indicated with these revised conditions, the ICAPCD agreed to San Diego's proposed method of measuring the hydrocarbon leakages from the relief valves; this is reflected in Condition 2. They have also agreed to our proposed method for monitoring total hydrocarbon loss at the tank level; this is reflected in Condition 4.

To satisfy these conditions, a sample point will be provided in the flare header for the hydrocarbon analysis, and a positive displacement meter will be added for measuring purge nitrogen going to the flare header.

Cooling Tower Blowdown Waste Discharge Permit

An application was filed on October 23, 1982, with the California Regional Water Quality Control Board (RWQCB) to discharge waste water under the National Pollutant Discharge Elimination System (NPDES). Our application for an NPDES permit covers the discharge of the cooling tower blowdown only (approximately 1,364,000 gallons per day). The NPDES does not cover any other plant liquid wastes such as:

1. Neutralized sulfuric acid or corrosion inhibitor contaminated water and oily waters; such liquids will be treated as hazardous waste disposal.

2. Sanitary discharges; such liquids will be released to the Heber Public Utilities District sewer system.

3. Rainwater; such runoff will be collected and pumped to the Beech Drain.

The RWQCB staff has reviewed our application and minor changes have been made to obtain clarification and additional information. Issuance of a permit is expected in July 1983.

Hydrocarbon Storage Sphere Variance

In August, representatives from Fluor and San Diego met with the acting Imperial County Fire Chief to acquaint him with the Plant and its fire protection system. The Imperial County Fire Chief is "the authority having jurisdiction" as defined by the National Fire Codes. In addition to discussing the overall fire protection system, the Fire Chief was briefed on the hydrocarbon storage tank, and our planned request for a variance from the California Occupational Health and Safety Board (Cal-OSHA) to the LPG tank capacity limitation of the California Safety Orders. The concurrence of the local fire authorities is considered an essential step in the variance procedure. In addition to the fire prevention and safety features of the tank, examples of similar and larger sized tanks in California were cited, and names of contacts at these facilities were given to the Fire Chief for his reference.

While the Fire Chief was in agreement with the fire protection system design, in his "acting" position he was very reluctant to give his concurrence to the single hydrocarbon storage tank realizing that a permanent Fire Chief would eventually take his place. In order to make some progress in obtaining the variance, some preliminary contacts were made with Cal-OSHA, and a meeting was set for early January with a representative of the State Department of Industrial Relations to discuss the hydrocarbon storage tank, and the required steps for obtaining the variance.

WBS 1.2.2 - POWER PLANT ENGINEERING, DESIGN, AND PROCUREMENT

Objective:

The objective of this WBS element is to prepare engineering and design specifications and procure major equipment to build a nominal 65 Mw (gross) electrical geothermal power plant. Special studies also will be accomplished whenever required.

Status:

PROCESS/MECHANICAL ENGINEERING

Several changes were made to the system process and instrumentation diagrams (P&ID's) to reflect improvements in detailed operation, performance, and control. System criteria and performance requirements have been established and served as the basis of these changes in the detailed design. In general, the addition of system piping to the model continued as the detailed design moved ahead and composite piping drawings were initiated.

San Diego reviewed latest revisions of system P&ID's for operability, controlability, pump logic and features. All findings were discussed in detail with Fluor process, mechanical, and I&C engineers to resolve differences and establish action to be taken. Findings and conference notes were documented and distributed.

Hydrocarbon System

1. Overall control of the hydrocarbon flow will be based on load demand, throttle temperature, and pressure as follows:

    a. The load demand output will be ramped by the Elliot electro-hydraulic system for increasing or decreasing the turbine flow.

    b. The flow to the turbine will be ratioed to the liquid-side control valve(s) controllers.

    c. The hydrocarbon gas header pressure will be utilized as the setpoint for the hydrocarbon flow controller.

    d. The hydrocarbon gas flow will be in proportion to the brine flow and used as input to the brine return pump control.

    e. On a load pick-up, the brine return pump controls will be ramped up by the hydrocarbon gas temperature.

    f. The turbine bypass valve will be controlled by the hydrocarbon gas header pressure controller, which will be set at 590 psia.

2. The condensate and booster pump pairs will be provided with a permissive to prevent starting a condensate pump with a closed suction valve. A position limit switch will be provided on each condensate pump suction valve. A signal from this switch, indicating an open valve, will permit the pump to be started. Until a contact closure in the switch is made, the pump cannot be started. Indication of valve position (open or close) will be provided in the control room.

3. The turbine exhaust piping drip pot pumps will be provided with automatic shutoff when a low level is achieved in the drip pot. The pump is automatically started on high drip pot level. Valves were added to the suction and discharge of the pumps to isolate them for maintenance (refer to Figure 3).

4. The effects of plant operation on hotwell level were analyzed to verify if there would be any control problems with the present logic. Under certain conditions the hotwells could operate with unequal levels. The analysis was done to identify these conditions and determined if (1) the hotwell equalizing line was properly sized and (2) the hotwell level controls would function properly with these conditions (refer to Figure 4). It was determined that:

   a. The current logic will not work with three pump operation or two pump operation with one condenser out of service.

   b. The logic should be changed to activate either the transfer valve or pump on a signal from either hotwell.

   c. The hotwell equalizing line is adequately sized.

   d. The valve in the equalizing line should be closed before shutting down one condenser.

Brine System

Refinements were made to the system design on the basis of better defined operational functions and also cost of equipment and operation. These refinements will be inplemented on subsequent revisions of the P&ID's. The following covers the more significant modifications that have been made, which involve equipment and system features.

1. The analysis of using three 33-1/3% capacity brine return pumps versus four 25% capacity pumps was performed and completed by Fluor. The basis of the evaluation was operational requirements, installed cost, and operating costs. The findings of this analysis showed that three 33-1/3% capacity pumps were less costly overall than the four 25% pumps, either with constant speed or variable speed. However, when matched with the system performance requirements, the four 25% pumps

had several advantages over the three pump configuration, which were:

a. Only three pumps would be required to achieve start-of-run conditions and one could be a spare;

b. Loss of one pump would not result in excessive runout of those remaining in operation.

c. As a result of 1. and 2. above, the reliability of the plant and brine system would be improved.

On this basis, the plant will have four 25% brine pumps, with constant speed induction motors and variable speed, hydraulic couplings.

2. A block valve will be installed on the bypass line to reduce the amount of brine that needs to be drained from the system during maintenance. This would also serve to limit the amount of pipe that could be exposed to air and potential for oxygen corrosion. Additional nitrogen purge connections were added to the brine piping.

3. Heat exchanger vents and drains will be manifolded to a common header for disposal to the brine sump.

4. The brine return pumps will be provided a small bypass around the check valve and block valve at the discharge of each pump. This bypass will be used to warmup each pump without the need to open the discharge valves.

5. The pump logic was modified such that a trip of one operating brine return pump will automatically start a standby pump. This was done to minimize transients on the entire system, which could result in potential damage to Chevron's downwell pumps.

6. Low pressure switches on the discharge header of the brine return pumps were eliminated because they simply were not required for protection or operating intelligence. A low pressure suction switch will be provided to trip the pumps and prevent mechanical damage due to loss of available suction head and cavitation.

7. The design and equipment selection for brine system warm-up provisions were further evaluated with the objective of establishing the worth of being able to start-up two trains of heat exchangers simultaneously. The result of this analysis indicated that installing the support equipment to cool, store, and pump enough brine to warm-up the two trains in the same time as it is expected to take for one train was not cost effective. It would be cost effective if the plant were to require more than six shutdowns per year and each shutdown lasted long enough for the heaters to cool below about 250°F.

It does not, in our collective judgment, appear that this many shutdowns each year will occur and be of such duration that a "quick" return to service would not be possible and, therefore, justify dual train warmup capability.

As a reminder, it will be possible to perform a two-train warmup, but it will take about twice as long as one train warmup since it will be done in series fashion, one train at a time. It is anticipated that about 8 to 10 hours per train will be required, including generator synchronization.

8. A small, two-cell, forced-draft cooling tower will be used to cool water used for cooling the hydraulic coupling oil, pump bearing lube oil, and 100 gpm of 360°F brine for filling the brine system. The duty for the tower is 20 million btu/hr. About 12 million is for cooling the 100 gpm from 360°F to 150°F, plus about 8% margin and about 8 million btu/hr for oil cooling. Using this approach, rather than routing piping from the main cooling tower, should result in a savings of about $65,000. Refer to Figure 5 for the system flow diagram.

9. Filtered pond water will be used for the brine return pump seal fluid. Make-up to the brine system cooling tower will be from the main cooling water ponds with a small (approximately 40 gpm) self-priming pumps. Blowdown from this tower will be about 5 to 10 gpm.

10. The warmup of the brine/hydrocarbon heat exchangers was reviewed in a meeting with the vendor. The objective was to verify the adequacy of the brine flow and hydrocarbon flow during warmup to meet the intended function and not damage the heat exchangers; i.e. not overstress tube-to-tube sheet joints, shell, and heads.

    The vendor's analysis indicated that the 3500 gpm recirculation rate with the warmup stream gradually increasing in temperature from 150°F, at start, to 360°F at end of the warmup operation was satisfactory. They requested that the ratio of hydrocarbon flow to brine be a minimum of 1.6. It was agreed to use 2.0 times brine flow or 7000 gpm hydrocarbon during warmup at all times to provide some margin in the piping design and because the 7000 gpm would best match the turbine synchronizing flow. The vendor also verified that the transverse temperature gradient in the hottest heater should not exceed 200°F and that a warmup rate of 50°F per hour was satisfactory. Refer to Figure 6 for a representation of the vendor's estimate of the brine and hydrocarbon temperature profiles across the heat exchanger train.

<u>Hydrocarbon Recovery And Unloading System</u>

An in-line suction heater for the hydrocarbon recovery compressor will be added. Refer to Figure 7 for the proposed installation.

This heater will be needed to "dryout" saturated vapor from the system entering the compressor suction. If the vapor were to remain "wet" at the suction, the compressor could sustain damage from the moisture formation during compression. Even if damage should not occur, the efficiency or performance of the compressor would be reduced due to the presence of liquid hydrocarbon. The details of control logic and the specific type of heater will be developed by Fluor and issued at a later time.

Relief and Flare System

Several small changes in instrumentation were made regarding flow measurement and sampling of the nitrogen/hydrocarbon gas mixture in the relief header. The following changes were implemented (refer to Figure 8):

1. Continous monitoring of emissions from the relief valves is not required, only the flare stack.

2. A sample tap will be provided in the flare header such that samples can be taken manually and analyzed in the plant laboratory.

3. A split-range, mass flow element will be provided in the flare header. Two transmitters will also be provided; one for the low range and the second for the high flow range. This will cover the entire flare header flow regime from 0 to 190,000 pounds per hour. Pressure and temperature measurement will be provided at the flow element location so as to establish density and mass of the gas mixture stream and sample.

4. Data will be stored in the DAS and a hard copy could be obtained at any time.

5. A positive displacement meter will be provided to measure the amount of purge nitrogen flowing to the flare header.

Inert Gas System

The following changes were made to the system P&ID to improve maintenance and achieve better purging operation at the hydrocarbon condensate pump:

1. A gate valve will be added downstream of the pressure control valve (PCV) on the line from the storage tank to the star-fin vaporizers. With this valve and the one upstream of the PCV, the PCV could be isolated for maintenance purposes without venting gaseous nitrogen from the connected purge piping.

2. Two additional purge connections and piping will be added to booster pump P-13D. One connection will be for nitrogen supply to the pump and the second will run from the pump to the

suction header of the vacuum pump (which will discharge a mixture of nitrogen and hydrocarbon to the flare stack).

3. Two more connections for nitrogen purging and evacuation will be provided at condensate pumps P-12C and P-12D.

Brine and Wastewater Disposal System

The system design was updated to further implement the dual function of the brine collection portion of the system. Specifically, this dual function is to drain either hot brine or cold brine (about 160°F to 200°F) from the brine system piping and equipment. A second function, required of only a portion of this system, is to store about 25,000 gallons of cold brine. In order to accomplish hot or cold drainage, drain lines and valving will be provided to the brine collection sump directly in addition to the brine flash/storage tank (refer to Figure 9).

In order to also use the brine flash/storage tank for holding cooled brine during warmup, a relief valve will be needed on the vent to prevent the escape of the nitrogen used to blanket the cooled brine during storage in the vessel. This nitrogen "cap" is intended to minimize, if not prevent, corrosion of the carbon steel vessel.

Emergency Diesel Generator System

Several small modifications involving primarily control and mechanical features were made to the system to improve operation and maintenance. They are:

1. A generator bearing high vibration trip function will be provided to automatically shutdown the diesel.

2. A flame arrestor for the diesel fuel tank will be supplied by the vendor of the unit.

3. The fuel tank will be elevated above grade.

4. Stainless steel, type 304, braided flex fuel lines will be used and supplied by the vendor.

5. The vendor will provide a local annunciator panel which will also include "Diesel Tank Fuel Oil-High" and "Diesel Tank Fuel Oil-Low."

Power Actuated Valves

There are several large block and bleed, gate, and high-performance butterfly valves which are not used for modulating control functions but for open-close isolation. Primarily, because of their large physical size, Fluor was requested to analyze and evaluate what valves should have power actuators, local and remote actuation, and type.

Evaluation criteria ultimately agreed upon include the following:

1. Nominal valve size - 18" and over.

2. Frequency of operation.

3. Time required for operation. Larger valves, especially double block and bleed type, would require up to 500 turns to open or close.

4. Location of the valves. With large (30") valves the valve operator will be well above an operator's reach.

5. Environment. Potential for hydrocarbon leakage, exposure to process heat and/or ambient temperature.

6. Type of operation with respect to other valves and/or process control requirements. For example, a sequence of valve operations may require the field operator to be in two places at once.

The following valves are being considered for power actuators:

1. Brine System

    a. Plant 30" brine inlet; 1 valve with local control.
    b. Brine bypass 30" inlet; 1 valve with local control.
    c. Brine return pump 18" discharge; 4 valves with remote control.

2. Hydrocarbon System

    All double block and bleed valves for isolating the condensate and booster pumps; 20 valves with remote control.

3. Cooling Water System

    Condenser inlet and outlet 54" valves; 4 valves with local control.

Piping Model

The design of all systems discussed in this report is being modeled in a 3/8"-to-the-foot scale model at the offices of Fluor. The model reflects the items presented in this report with the exception of the power actuators and to the limits that control items can be modeled. Pictures of some of the key process areas modeled to date are presented at the end of this report.

ELECTRICAL AND I&C ENGINEERING

Equipment Specification for Centralized Plant Control and Data Acquisition Systems

The evaluation of bid proposals for the Central Control System (CCS) was conducted during this quarter. Announcement of the successful bidder is pending completion of pre-award contract negotiations.

The technical portion of the evaluation was based on overall compliance with functional requirements and hardware design criteria incorporated into the system specification. The commercial portion of the evaluation recognized the importance of vendor technical support during system design, start-up, and operation.

A discussion of the salient technical and commercial features of the CCS specification follows:

1. System Definition: CCS Functional Block Diagram

   The functional block diagram for the CCS is shown in Figure 10. The arrangement of major functional blocks is for overall system definition purposes only. Each bidder's proposal includes a modified version based on actual equipment capabilities.

   Major equipment features of the functional block diagram outlined include:

   Plant Control System Equipment

   DCS - Digital Control System

   - Microprocessor Controllers
   - Input/Output Multiplexers
   - Input/Output Termination Cabinets
   - Operator CRT's/Keyboards
   - Alarm and Utility Printers; CRT Copiers

   BOIC - Back-Up Operator Interface Console

   - Critical Process Alarm Annunciator
   - Critical Process Displays (hardwired)
   - Critical Process Controls (hardwired)

   EC - Electrical Console

   - Critical Electrical System Alarm Annunciator
   - Electrical System Monitoring
   - Circuit Breaker Controls

PCS - Programmable Controller System

- Input/Output Cabinets
- Primary Controller
- Back-Up Controller
- Programmer CRT

Data Acquisition System Equipment

- Computer
- Input/Output Cabinets and Electronics
- Operator CRT's/Keyboards
- Line Printer; CRT Copiers
- Bulk Memory (Disk Drives)
- Tape Drive (DAS Points List Output)
- Modems and Remote Terminal Installations

2. Single Supplier Responsibility for CCS

Functional requirements for centralized plant control and data acquisition systems were integrated into a single procurement specification. The specification also included many hardware and operational features necessary for clarification of the detailed functional requirements.

An alternative approach would have been to separate the functional requirements into two or three procurement specifications (plant control/programmable logic controller system(s) and the data acquisition system).

Single supplier responsibility eliminates the coordination problems inherent with multiple control system contracts. There is also reduced potential for warranty disputes since the major equipment supplier administers its own subcontracts. A single technical services agreement covering all equipment maintenance is another advantage. But perhaps most important, the single supplier approach draws on the experience on an established controls equipment vendor in optimizing overall system implementation.

On the side of caution, considerable attention must be paid to development of the specification so that individual functional criteria are not compromised in the integrated system design.

3. Functional Separation of Plant Control and Data Acquisition Systems

The Data Acquisition System (DAS) makes use of plant control and monitoring instrumentation inputs when available. This reduces overall costs by eliminating needless hardware redundancies. However, the functional requirements for plant control differ from those for Project data acquisition and must not be compromised by integration of the hardware. For example, it is required that loss of the DAS computer have no impact on the normal plant monitoring and control functions. Likewise, data accuracy and scan rates required by the DAS cannot be limited by access to this data from the plant control system.

4. Single Point Failure Criteria

Distributed digital control technology was specified for the primary plant control system. This technology uses various forms of multiplexing for reasons of economy, flexibility, and standardization. But with multiplexed data channels, a single component failure can result in the loss of large amounts of plant control and monitoring functions. Hardware redundancy and automatic transfer features are typically used to avoid this problem.

For any single failure within the CCS, at most one "critical" plant monitoring and control function will be affected. A "critical" function is one, which, if lost, could result in a plant trip, possible equipment damage, or hinder the operator's ability to safely and effectively control the process. Failure of an automatic control loop must result in a "bumpless" transfer to the manual mode.

5. Minimize Custom Hardware/Software

The use of standard off-the-shelf hardware and software is to be maximized. At least two years field experience is required for all hardware and software.

Configuration of the digital control system (DCS) and programmable control system (PCS) is to be done using fill-in-the blanks type programming procedures. DAS operation is to maximize the use of standard software packages.

6. Flexibility

Because of the R&D nature of the plant, it is important to have flexibility in the plant control system. The microprocessor based control system can be easily reconfigured to accommodate changes in control strategy without changing hardware. New CRT displays can be created to provide for additional controls and operating modes.

The input/output and data processing capability of the CCS has 20% implemented hardware spares. An additional 20% empty rack space is provided for further input/output additions.

7. Hybrid Operator Interface Design

The plant operator normally uses CRT's and keyboards to interface with the digital plant control system. However, "critical" and frequently used monitoring and control functions are accessed through conventional discrete devices arranged in mimics on operator consoles. This hybrid approach to the operator interface design allows maximum operator access to important displays and controls with a minimum amount of interface hardware.

The Back-Up Operator Interface Console (BOIC) provides for the manual start-up and shut-down of major process systems. The Electrical Console (EC) provides for monitoring auxiliary system and switchyard functions. Both the BOIC and EC layouts and hardware are described in detail in the CCS specification.

8. Data Acquisition System Functional Requirements

The DAS will function independent of the plant control system to provide the following:

a. Continuous monitoring and recording on magnetic tape of approximately 350 analog and digital data points for historical record. These tapes will be used in the subsequent analysis, reduction, and reporting of plant performance.

b. Pre- and post-trip review logs.

c. Sequence-of-events logs (resolution to 4 millisecs).

d. On-line process graphics (supplements plant operator interface).

e. Summary reports and logs for plant use.

f. Performance calculation routines.

g. Remote terminal access.

9. Technical Support

Reliable, qualified technical support services are critical to success of sophisticated control and data acquisition systems. The supplier must have established a running track record of servicing similar installations. The supplier is required to include in his proposal a quotation for an emergency service and maintenance contract covering all equipment furnished for a period of two years. Pricing and descriptions of maintenance and training courses is also required. Six months of start-up assistance is to be quoted in addition to the maintenance contract provisions.

Change in Switchyard Configuration

Following a meeting with IID in December 1982, second consideration was given to the proposed radial bus switchyard arrangement as shown in Figure 11. The major drawback with this scheme is the lack of operational flexibility when any one of the three 34.5 KV oil circuit breakers (OCB) is out for maintenance.

When the main transformer OCB is taken out, the unit must be off line with only the essential "hotel" loads being powered from the emergency 480 volt bus. With either the Calexico or Valley line OCB out and the line disconnect switch closed, the unit can still be operated. However, IID operations are adversely affected in two ways. First, relay crews have to be dispatched to re-adjust settings on the distance relays at Valley, Calexico, and Heber in order to maintain adequate transmission line protection. Second, the ability to sectionalize a fault on either half of the line and maintain Heber unit output and customer loads is lost.

Because of these deficiencies in the radial bus scheme, a ring bus arrangement, as shown in Figure 11 has been adopted. The ring bus provides for normal protective relaying and transmission service with any one of the OCB's out for maintenance. No resetting of relays is required and an alternate feed is available for the main transformer.

The ring bus requires a more complex relaying scheme to monitor line current and initiate tripping of two OCB's to clear a fault. However, this complexity is offset by elimination of the need for differential bus protection required with the radial bus design. In addition, the ring bus configuration allows for a more compact physical arrangement of the OCB's and disconnect switches.

As a final consideration, the change from radial to ring bus does not affect any equipment procurements in progress or engineering/ design schedules.

CIVIL/STRUCTURAL ENGINEERING

Turbine Generator Pedestal

A model analysis for the turbine generator pedestal was performed using finite-element technique. The purpose of the analysis was to define the natural frequencies of the soil-structure system and to preclude resonance between the turbine generator and support structure. The analysis verified proper pedestal design in the area of resonance due to machine vibrations.

Flare Stack and Foundation

The supplier is required to perform a dynamic seismic analysis for the stack and foundation. A preliminary design of the foundation has been given by Fluor to the supplier for analytical purposes.

Civil Structural Construction Package

Design of Civil/Structural drawings and specifications continued. For the Heber Project, all structures and foundations are designed for a seismic load of 0.3g in one direction, concurrent with 0.1g in the other two perpendicular directions. Type II cement is used for all concrete mix to prevent attack by sulfate contained in the site soils. Because of the expansive nature of soils, bottoms of major foundations are placed 3' minimum below grade where swelling of soils due to moisture changes is unlikely to happen.

AVAILABILITY/RELIABILITY ENGINEERING

Having completed all of the requirements under their Phase I scope of work with the exception of the final report, Pickard, Lowe, and Garrick, Inc. devoted all their attention to completion of the final report on the plant availability. Included in their efforts were updated system availability assessments based on approved-for-design issue drawings, and identifying preliminary quantities of spare parts for availability critical items. Completion of the final report is expected in February 1983.

QUALITY ASSURANCE/QUALITY CONTROL

Vendor Surveillance Program (VSP)

During this period planning, documentation, and reporting requirements were established for the VSP. Surveillance activities concentrated on the turbine generator contract, where the Brown Boveri Turbomachinery (BBT) generator was accepted as a substitution for the originally proposed Electric Machinery generator. With the award of more equipment contracts in the next few months, vendor surveillance activitiy is expected to increase.

Turbine Generator Contract

Factory acceptance tests were conducted for the BBT generator, seal oil console, and hydrogen console. Testing proved satisfactory and these units were officially accepted. However, several correctable deficiencies were found during tests and inspections. These were given to Elliott for corrective action. Dravo will re-inspect the units during storage, and at that time verify the corrective action.

On November 11, 1982, a pre-inspection meeting was held at Elliott's facility with the purpose of formulating a vendor surveillance plan and schedule for this contract. Table 1 shows the inspection requirements and the preliminary schedule established.

PROCUREMENT

Turbine Generator Contract

Amendment No. 3 to the turbine generator contract was executed. This amendment provides for the purchase of the alternate generator produced by Brown Boveri Turbomachinery (BBT).

Following factory acceptance tests conducted in late September (reference DOE Quarterly Report for the period July 1-September 30, 1982), test data were reviewed and found acceptable. The decision was made to accept Elliott's substitution of the existing BBT generator; this resulted in a $235,000 cost reduction in the Elliott contract.

Procurement Status

This quarter, the following contracts were executed by SDG&E and the vendor:

- Hydrocarbon Condensers - Southwestern Engineering Company
- Hydrocarbon Condensate Pumps - Johnston Pump Company
- Fire Pumps - Aurora Pump Company
- Segregated Phase Bus - Abbott Power Corporation

It is expected that several contracts will be executed in the month of January 1983, these are:

- Hydrocarbon Booster Pumps - Ingersoll-Rand Company
- Service Water Circulation Pumps - Gould Pumps, Inc.
- Non-Segreated Phase Bus - Westinghouse Electric Corporation
- Generator Breaker - Westinghouse Electric Corporation
- Vertical Water Pumps - Gould Pumps, Inc.
- Cooling Tower - Lilie-Hoffmann Cooling Towers, Inc.
- Furnishing Screens and Sluice Gates - Production Steel Company, Inc.

WBS 1.2.3 - POWER PLANT CONSTRUCTION

Objective:

The objective of this WBS element for Phase I is to provide construction input to the architect/engineer during the design of the power plant to allow construction in an orderly, cost-effective manner. In Phase II, efforts will focus on actual construction of the geothermal binary power plant.

Status:

Reporting in this section includes progress made as construction input to the power plant design and preparation for actual constuction.

During this quarter, the major construction effort was in preparing and receiving proposals for Parts A and B of the Site Development contract. Proposals for Part A were received from six contractors on September 3. Bid documents were issued to nineteen contractors on September 3 for Part B, with proposals due October 25. Based on the current construction schedule, the Project decided on October 25 that it would be an advantageous to combine Parts A and B into one contract. Therefore, all proposals for Part A were rejected and documents for Part B were withdrawn.

Pursuant to this effort, the following work was accomplished during the quarter:

Document Review

Final reviews of Fluor design documents were performed on Site Development contract drawings and specifications. The main purpose of these reviews is to reduce the potential for contract changes during the course of performance of the work by lump-sum contractors. Emphasis is placed on constructability, construction cost, contract interfaces, and correction of design errors.

Reviews continued on miscellaneous documents for future contract packages.

Contract Administration

Contract documents for the Site Development package were finalized. This included the scope of work; special, general, and miscellaneous provisions; contract exhibits; detailed drawings; technical specifications; and prevailing wages.

Document Development

Specifications and drawings were revised for laydown area grading, construction power distribution, and a temporary warehouse building. A construction analysis of proposals received for the erection of the cooling tower was made and submitted to Fluor.

Cost and Scheduling

Cost breakdown/progress billing forms were developed for Site Development contract.

The Project Master Control Network (PMCN) was updated for inclusion in the Site Development bid package. This schedule is a bar chart form indicating schedule for all major activities for the entire project. Refer to Figure 12 for a summary of the construction schedule.

The Construction Detail Activity Schedule (CDAS) was developed for the Site Development contract. This schedule is a precedence network showing individual tasks within major activities.

The Work Breakdown Structure was revised to incorporate many additions and deletions of SDG&E furnished equipment.

Estimating

A fair cost estimate was being prepared for the Site Development contract.

WBS 1.2.4 - POWER PLANT START-UP

Objective:

The objective of this element is to start-up, check-out, and test the completed power plant. This effort shall include the necessary personnel training and the correction of equipment or system problem areas identified during plant start-up.

Status:

During this period, SDG&E in-house work continued on the start-up planning and procedures manual.

WBS 1.2.5 - PROJECT MANAGEMENT

Objective:

The objective of this WBS element is to provide Project management by establishing interfaces and control between SDG&E, the heat supplier, the architect/engineer, the construction manager, other subcontractors, and the Sponsors; defining schedules and reporting progress based on actual accomplishments; finalizing procedures for management, engineering, start-up, and design, construction cost and scheduling, accounting, procurement, and reporting; providing cost control by combining estimating, recording, reporting, analyzing, forecasting, and trending of cost data; monitoring work package budget estimates and reporting progress; negotiating and administering Project agreements and contracts; coordinating legal, public information, geothermal heat supply, and procurement activities; and preparing, reviewing, and publishing information regarding the technical status, cost, and schedules of the Project.

Status:

SDG&E/IID Heber Line Construction Agreement

Work continued on drafting a Line Construction Agreement between SDG&E and IID, and final review draft was sent to IID in December.

SDG&E/IID Heber Plant Connection Agreement

Work also continued on drafting a Plant Construction Agreement between SDG&E and IID. A draft was sent to IID in early October and they responded with comments later in the month. It was agreed that SDG&E and IID would try to work out a two-phase approach to service field demand for the agreement. The phases would correspond to the demonstration and commercial periods, of the Project operations.

The Line Construction Agreement and the Plant Connection Agreement will not be signed until the Geothermal Sales Contract has been approved by the CPUC and DOE.

Additional Participation

During August, Project Manager Bob Lacy had a telephone conversation with Lee Keilman of the Sacramento Municipal Utility District (SMUD), and gave him a verbal update on the current Project status. Mr. Lacy followed up with a letter, which transmitted a copy of a paper he was to present, which gave more information on the status of the Project, and a draft Contribution Agreement for SMUD's review.

In early November, SDG&E received a letter from SMUD declining our offer to participate in the Project. They cited their participation in the NORVEV 10 Mw binary project in the northern Nevada and its close proximity to their service territory as the primary reason. They also recently signed an agreement in the Geysers to develop some 60,000 acres of potential dry steam on hot water resources. SDG&E will continue to seek additional funding for the Project.

Sponsors' Meetings

The Sponsors' Technical Committee meeting was held on October 27 in Irvine. The meeting was comprised of a power cycle review, review of the model, discussion on the engineering status and progress, update on the Geothermal Sales Contract, and Site Development Package.

The Sponsors' Management Committee meeting was held on October 28 in San Diego. Discussion was held on federal funding, modifications to the Cooperative Agreement, engineering and construction status and progress, Project costs and 1983 annual budget, and the Geothermal Sales Contract.

Groundbreaking Ceremony

On November 22, a groundbreaking ceremony was held at the Project site. The activity was well attended by government, industry, locals, dignitaries, and media. Keynote speakers included U.S. Congressmen Clair Burgener and Don Fuqua, DOE's Robert San Martin, SDG&E's Tom Page, EPRI's Dwain Spencer, IID's Jerry Moore, and Imperial County Supervisor Luis Legaspi. The ceremony was well received by the public in both San Diego and Imperial Counties.

Definitive Estimate Extension (Phase II)

The Geothermal Sales Contract with Union Oil Company was renegotiated in order to be in compliance with the SDG&E/DOE Cooperative Agreement. The initial contract did not meet DOE contractual requirements because of the length of time required to deliver 100% brine flow. The contract, as a result of Amendment No. 2, extended the Project by nine months. Essentially the Definitive Estimate Extension is comprised of additional support effort for the extended period of time and a revised heat cost, energy credit, and an additional cost for field power for pumps.

The Definitive Estimate Extension summarizes the estimated cost by Work Breakdown Structure (WBS) as listed below:

WBS 1.2.1	Environmental Studies and Permits
WBS 1.2.2	Engineering, Design, and Procurement
WBS 1.2.3	Power Plant Construction
WBS 1.2.4	Power Plant Start-Up
WBS 1.2.5	Project Management
WBS 1.3.1	Demonstration, Operation, and Maintenance
WBS 1.4.1	Data Collection System
WBS 1.4.2	Data Acquisition, Analysis, and Dissemination

The Definitive Estimate Extension also contains cost plans, which project the estimated costs by federal (DOE) fiscal year. These plans categorize the costs both by element (material, direct labor, labor overheads, travel, consultant/subcontractor, other expense, and general and administrative expense) and by WBS. Also included is a Travel Plan (cost) and a Manpower Plan by WBS.

Project Schedule

Efforts proceeded at a controlled pace to keep the Project on schedule until continued federal funding was assured and the heat sales negotiations were completed. Major Project milestones were revised slightly and are shown below:

March 1982	Preliminary Design Review
June 1982	Turbine Generator Contract
June 1982	Definitive Estimate
July 1982	Final Power Cycle Review
August 1982	Phase I Completion
November 1982	Commence Construction (Groundbreaking)
March-April 1983	CPUC Approval of Geothermal Sales Contract
April 1983	Site Development Contract
September 1983	Issue Electrical Construction Package
February 1984	Award Electrical Contract
June 1984	Cooling Tower Construction Complete
October 1984	Turbine Generator Construction Complete
January 1985	Turbine Rolls
December 1987	End Demonstration

WBS 1.3

POWER PLANT DEMONSTRATION

WBS 1.3.1 - DEMONSTRATION, OPERATION, AND MAINTENANCE

Objective:

The objective of this WBS element is to demonstrate reliable and economic geothermal power generation.

Status:

On October 20, a meeting was held between Fluor, SDG&E, and EG&G Idaho (operators of the Raft River Project). The purpose of the meeting was to have an EG&G team review the Project's start-up, maintenance, and operating plans.

EG&G presented a list of problems encountered by them during the start-up and testing of Raft River. Subsequent indepth discussions on specific problems provided Project engineers with valuable design and operational perception. In the area of maintenance, EG&G found the Project's plans to be acceptable. It was also found that many of the recommended actions on the Raft River problems list were already under consideration by the Project. EG&G also promised to transfer several of their operating documents to SDG&E.

On November 5, the Raft River operating procedures, training requirements, and emergency action plans were received. Also included were three fire fighting training films. SDG&E Operations personnel reviewed and will continue to review these documents for inclusion into the Project's operational training plan (whenever their content is applicable).

WBS 1.4

DATA ACQUISITION AND DISSEMINATION

WBS 1.4.2 - DATA ACQUISITION, ANALYSIS, AND DISSEMINATION

Objective:

The overall objective of the data management effort is to acquire, store, evaluate, and report Project data to the energy generation industry and to their parties interested in liquid-dominated geothermal power plant performance. The intended result is to stimulate commercial development of hydrothermal resources in the United States.

Status:

The majority of the Data Acquisition System effort centered on Battelle's design and fabrication of prototype hydrocarbon, and water leak detection units. The preliminary design for the units was completed and reviewed by SDG&E and Fluor, and in the late summer, Battelle began detail design. Detailed design was completed in November, and bids for fabrication of the units were issued. Delivery of the units is expected in January 1983, and operational testing should commence at Magma in February 1983.

The design of the units is such that both the water and hydrocarbon detectors utilize a similar separator vessel. In the case of detecting a hydrocarbon in water/brine, the pressure in the separator is reduced such that the hydrocarbon will vaporize. The vaporized hydrocarbon is then detected by a gas chromatograph (GC) or infrared (IR) detection unit. In the case where the base fluid is brine, a GC unit may be required to detect the working fluid hydrocarbon over the background of naturally occurring hydrocarbon. For the cooling water case, the IR unit, which is less expensive than the GC unit, can be used. Where the unit is to detect water in hydrocarbon, the sample is cooled such that both the hydrocarbon and water are in liquid phase. The separator allows the heavier water to accumulate in a narrow section extending from the bottom of the separator. A capacitance level device is then used to detect rising water levels.

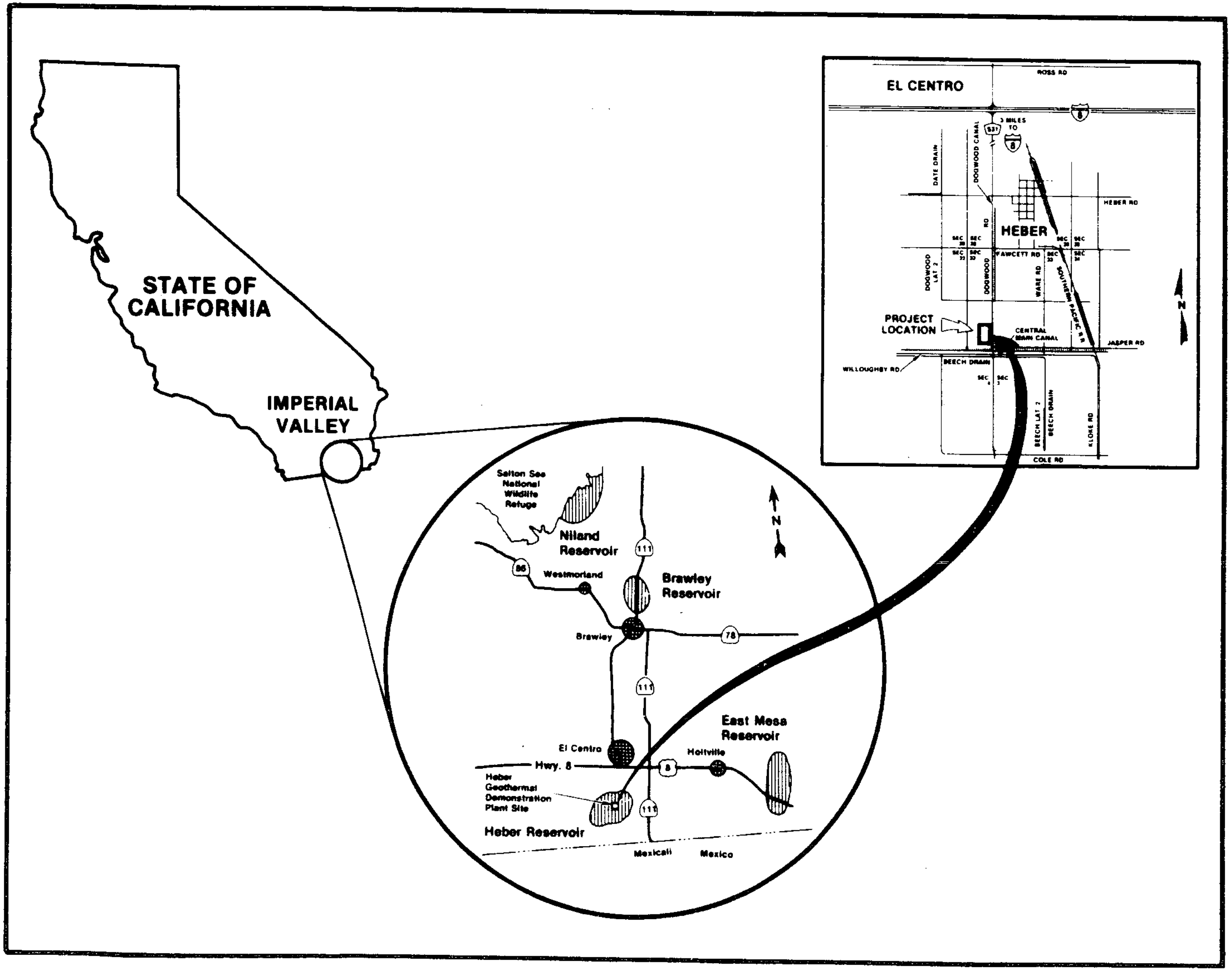


FIGURE 1
PROJECT LOCATION

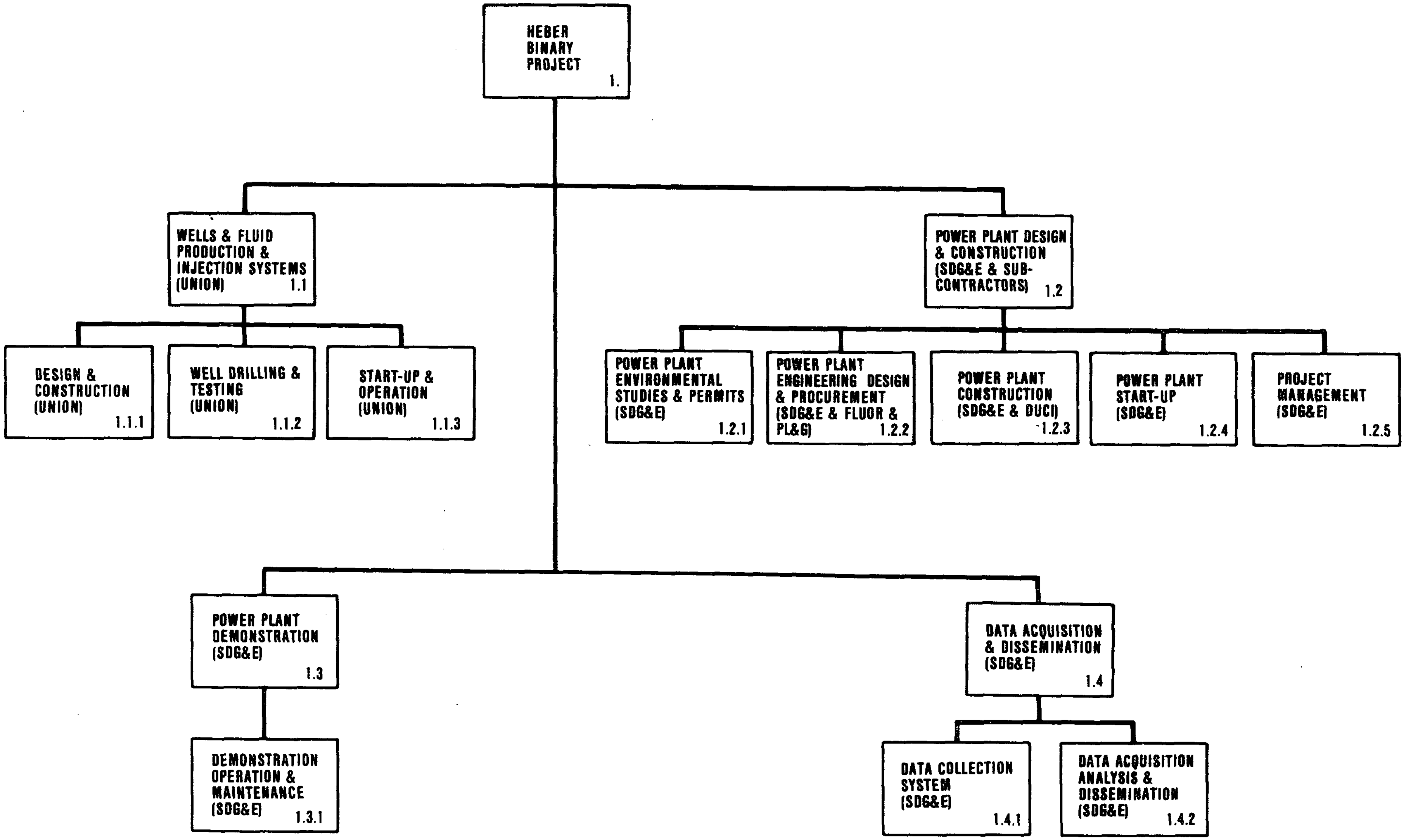


FIGURE 2
WORK BREAKDOWN STRUCTURE

GA 424

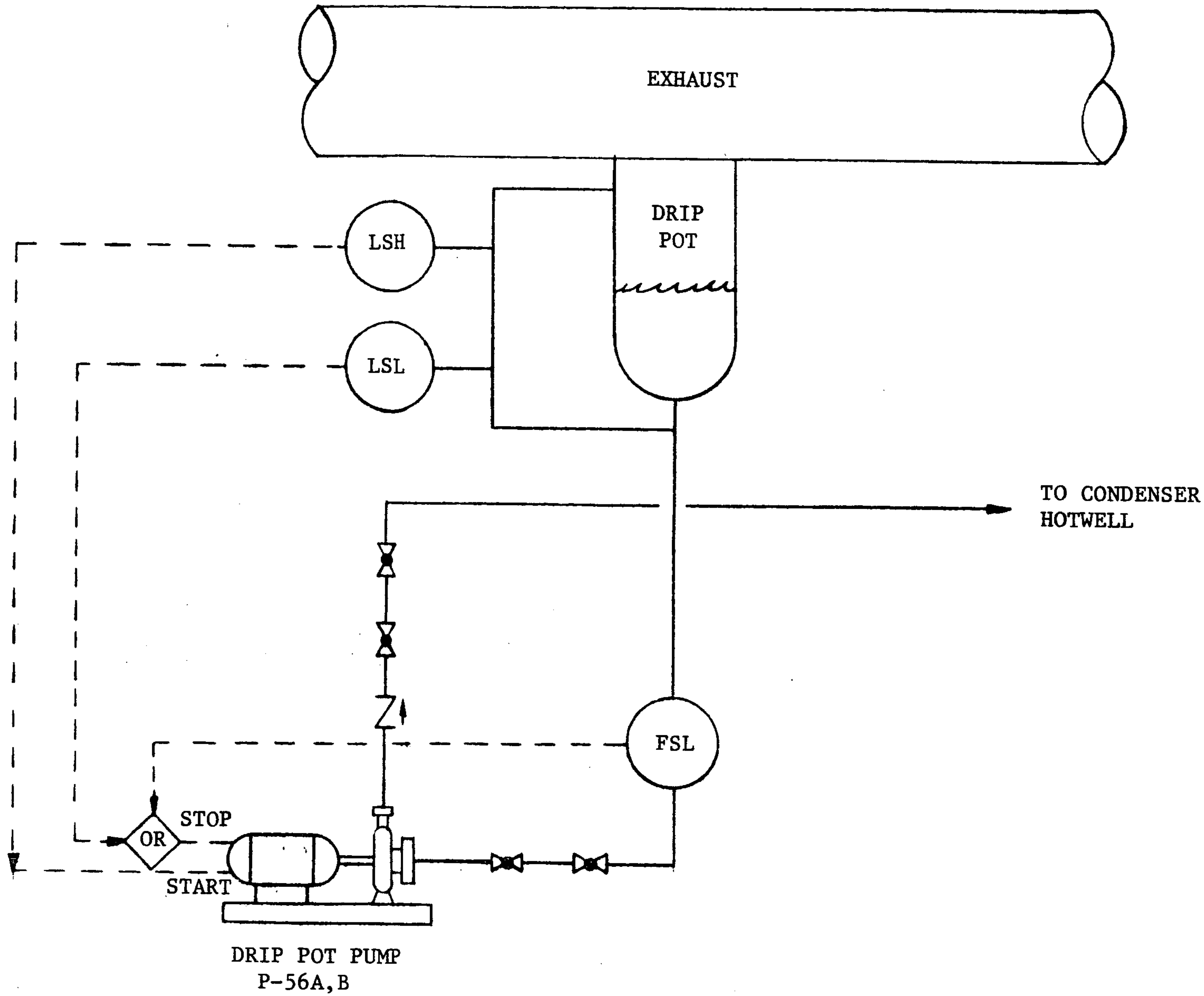


FIGURE 3
TURBINE EXHAUST DRIP POT PUMP CONSTROL

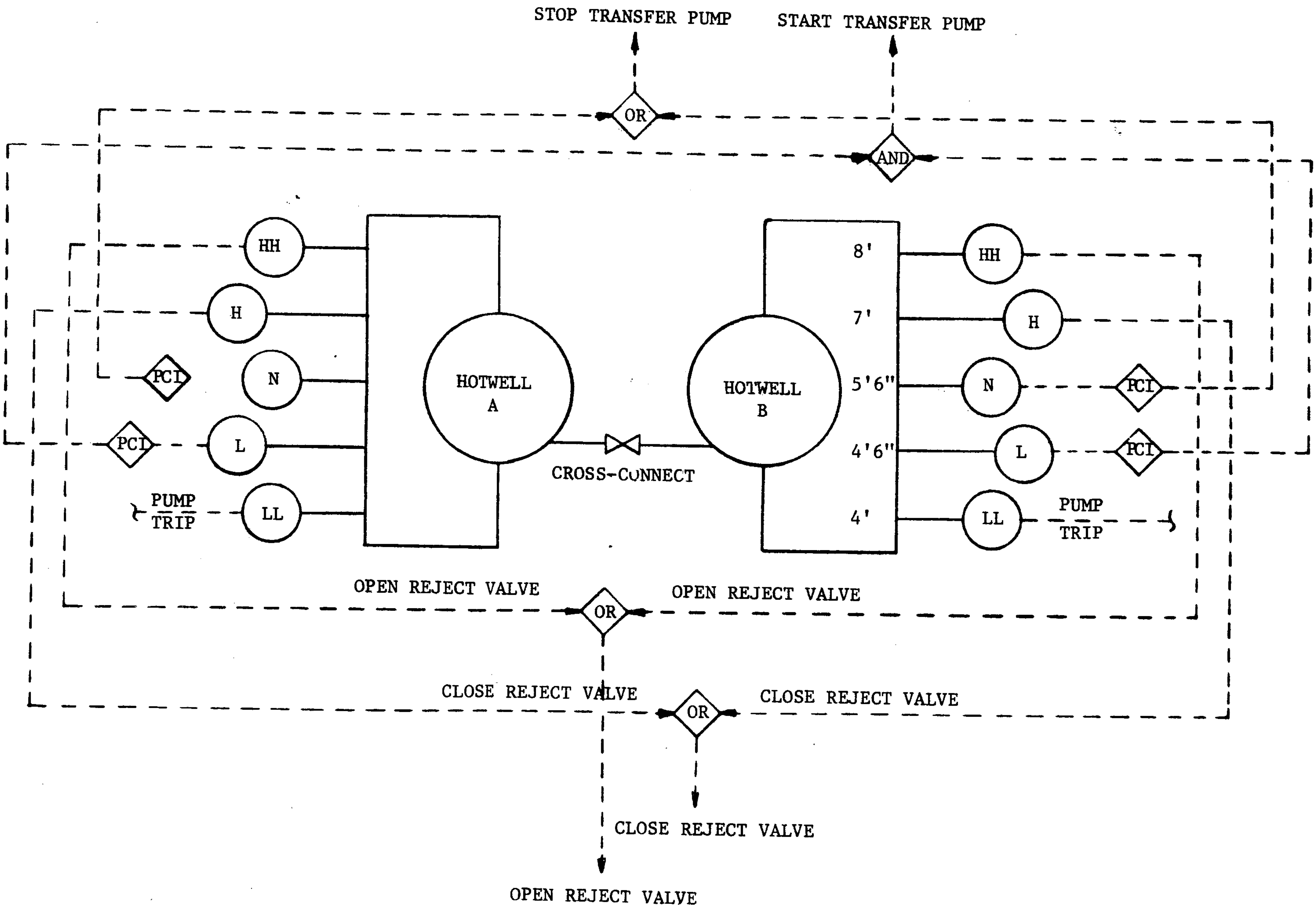


FIGURE 4
HOTWELL LEVEL CONTROL

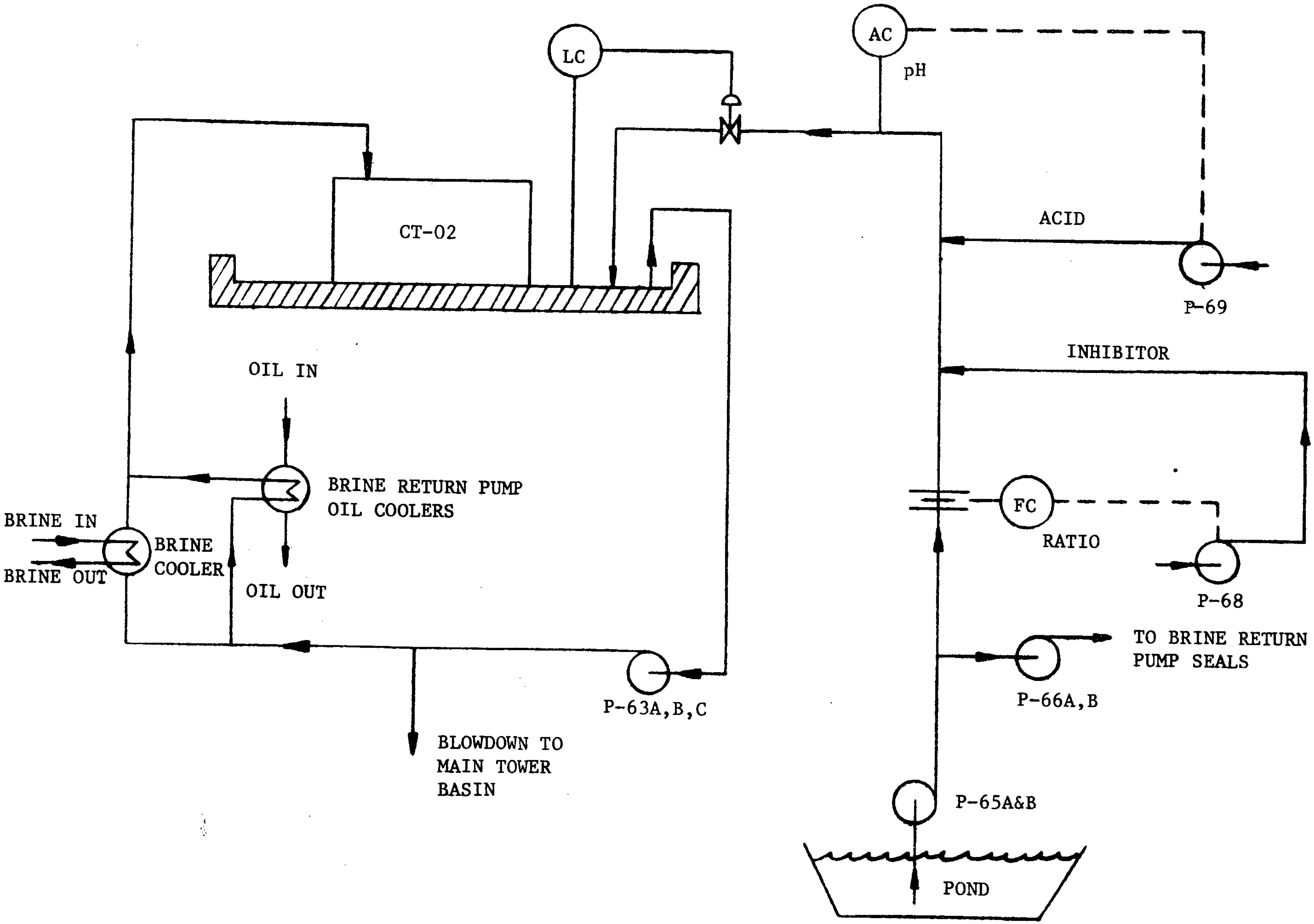
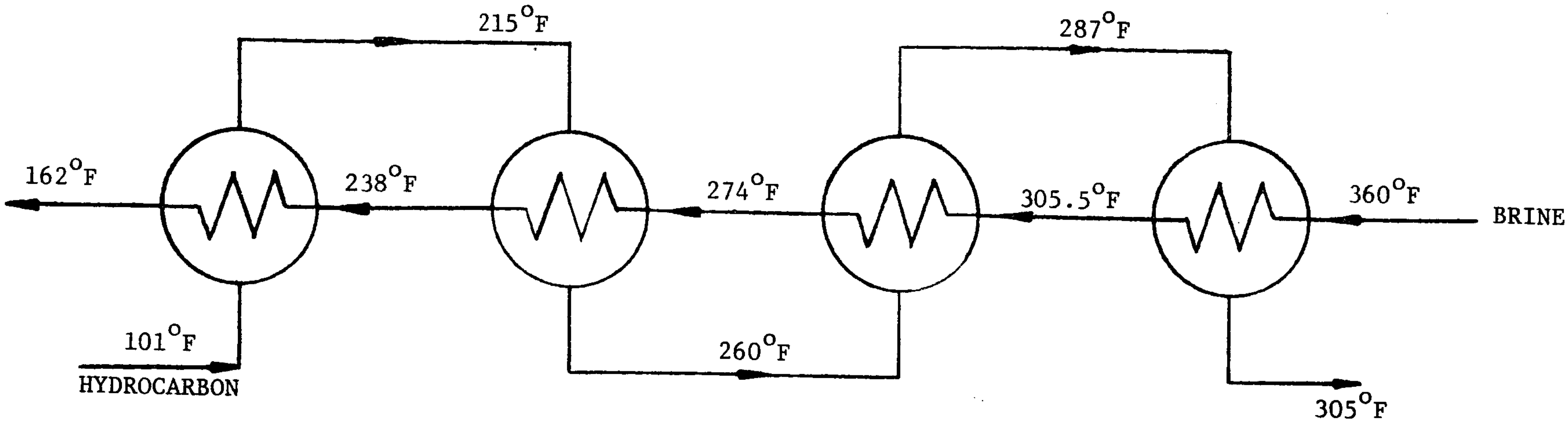
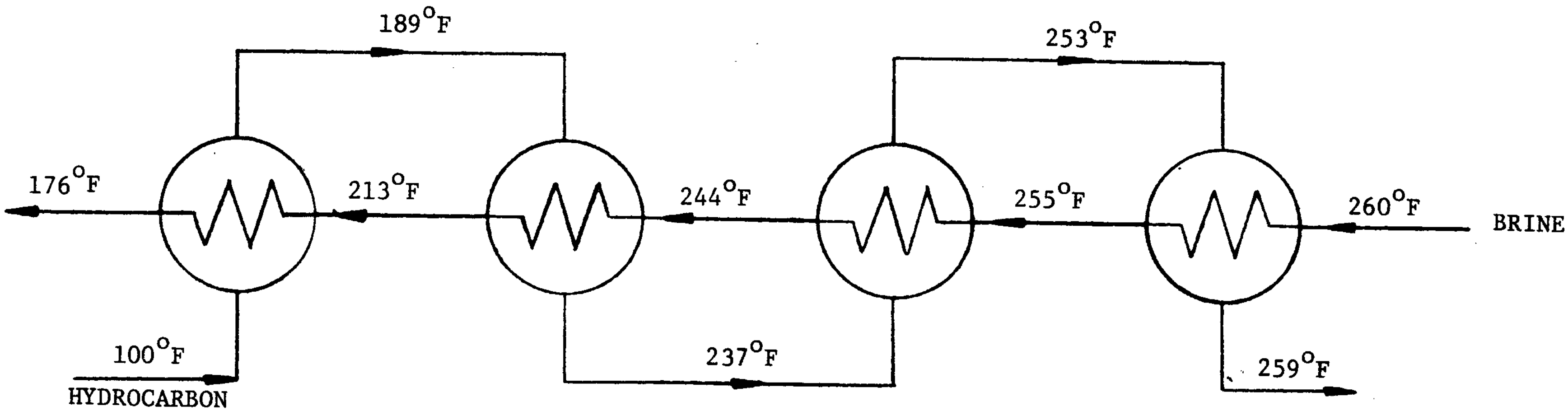


FIGURE 5
BRINE SYSTEM-COOLING SYSTEM PROCESS FLOW DIAGRAM



START OF RUN - BRINE SUPPLY TEMPERATURE AT 360°F



MID-WARMUP PROFILE, 7000 GPM HYDROCARBON/3500 RECYCLE BRINE AT 360°F

FIGURE 6
BRINE/HYDROCARBON HEAT EXCHANGER TEMPERATURE PROFILES

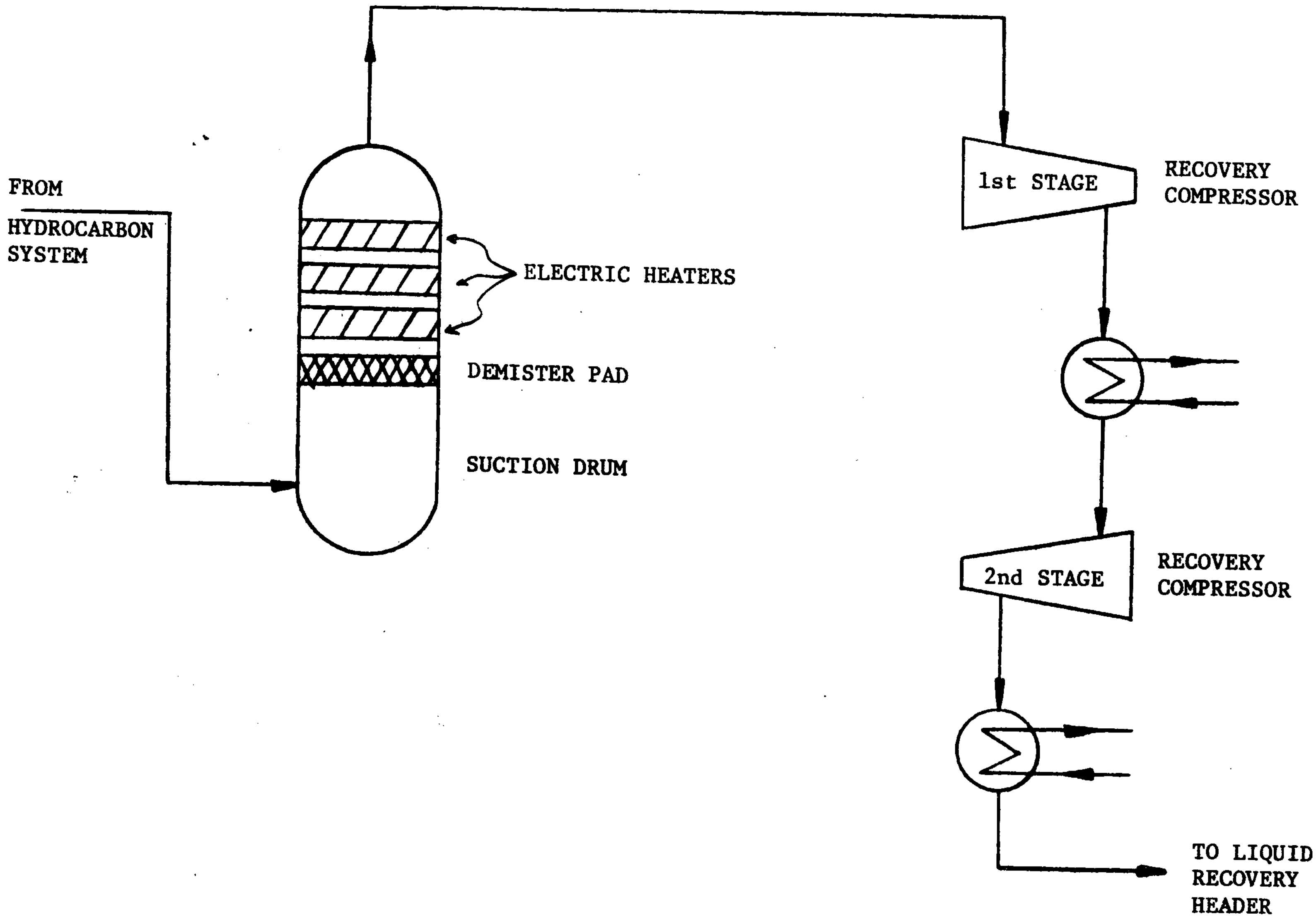


FIGURE 7
VAPOR RECOVERY SUCTION DRUM HEATERS

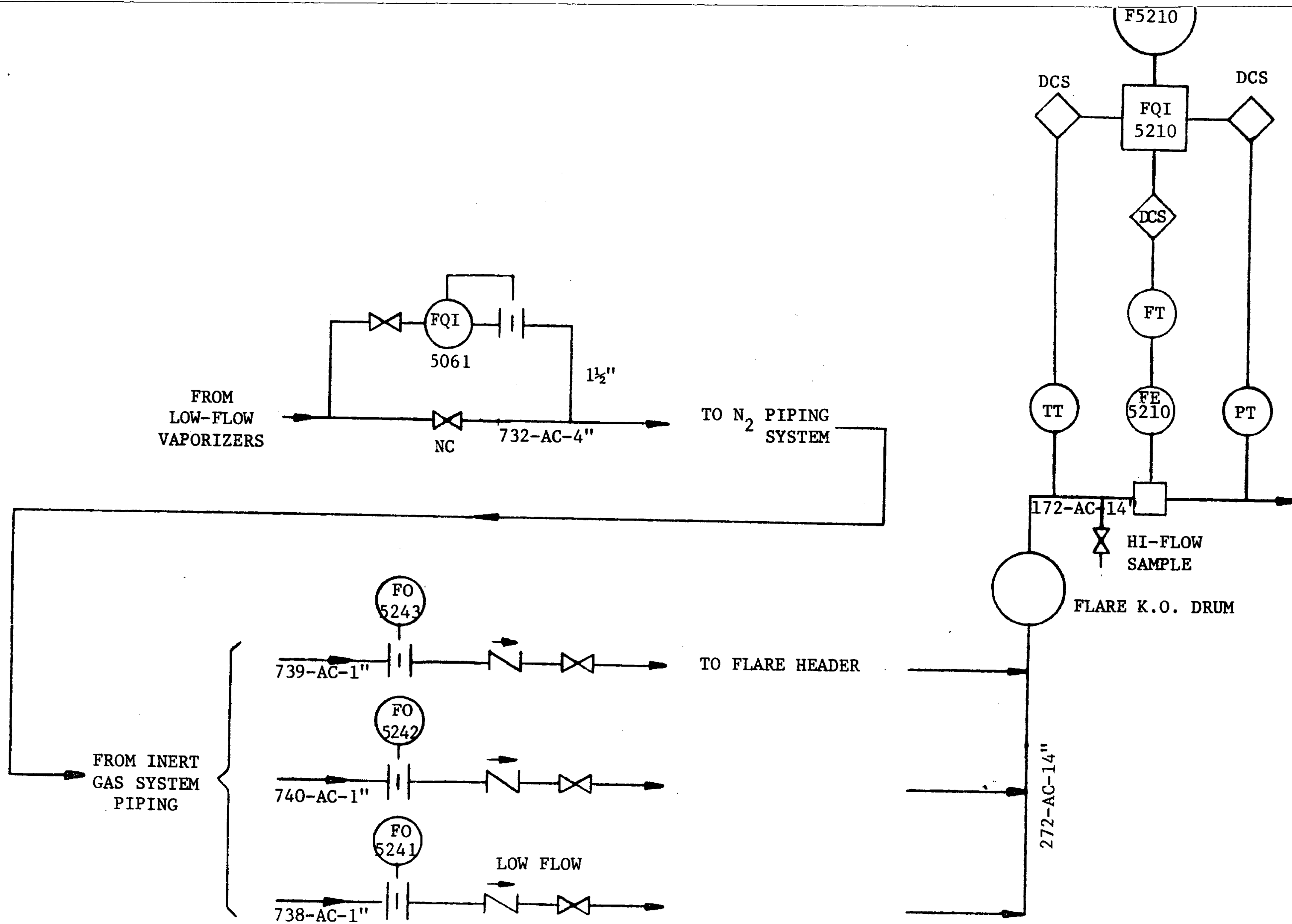


FIGURE 8
NITROGEN/HYDROCARBON FLOW MONITORING TO FLARE

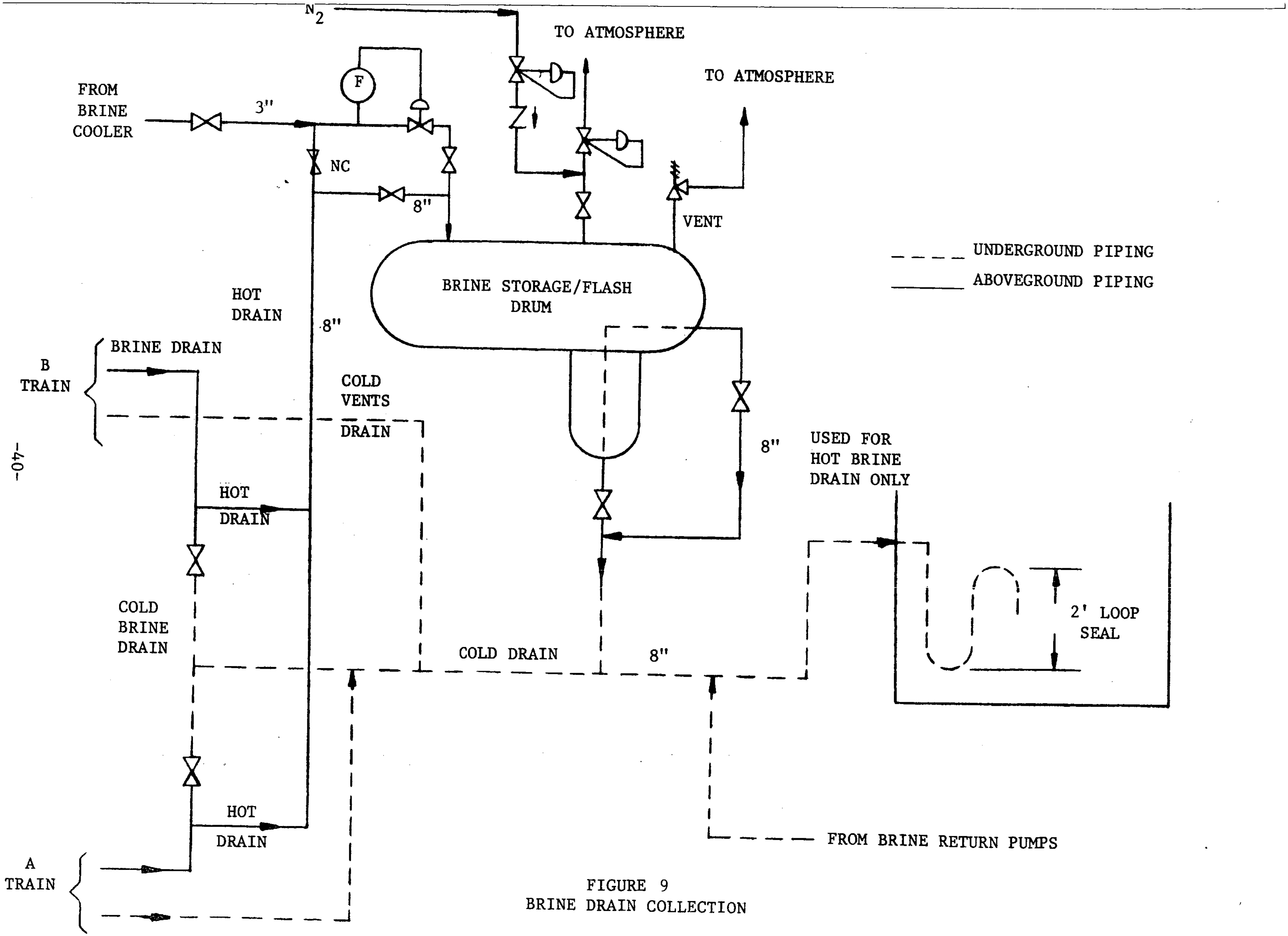
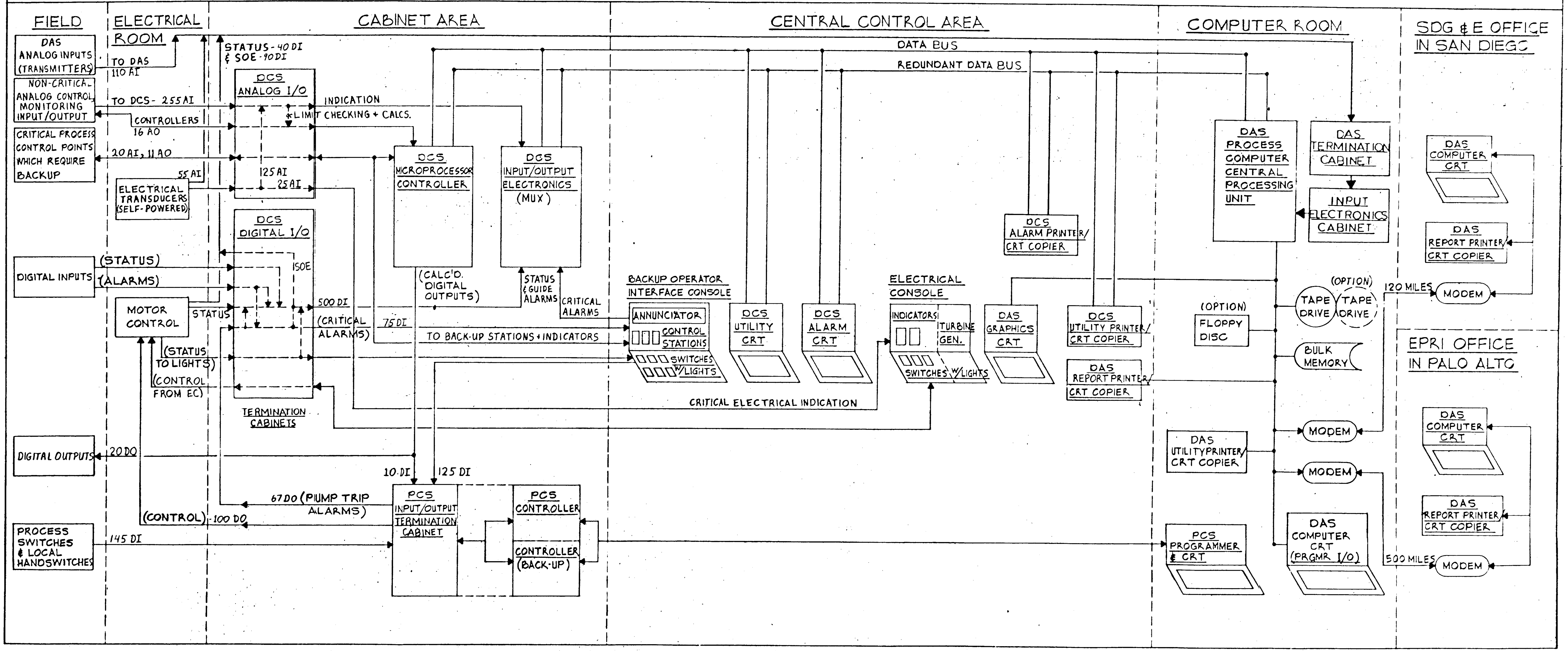


FIGURE 9
BRINE DRAIN COLLECTION

FIGURE 10

FUNCTIONAL BLOCK DIAGRAM OF DCS/DAS/PCS/BACK-UP CENTRAL CONTROL SYSTEM



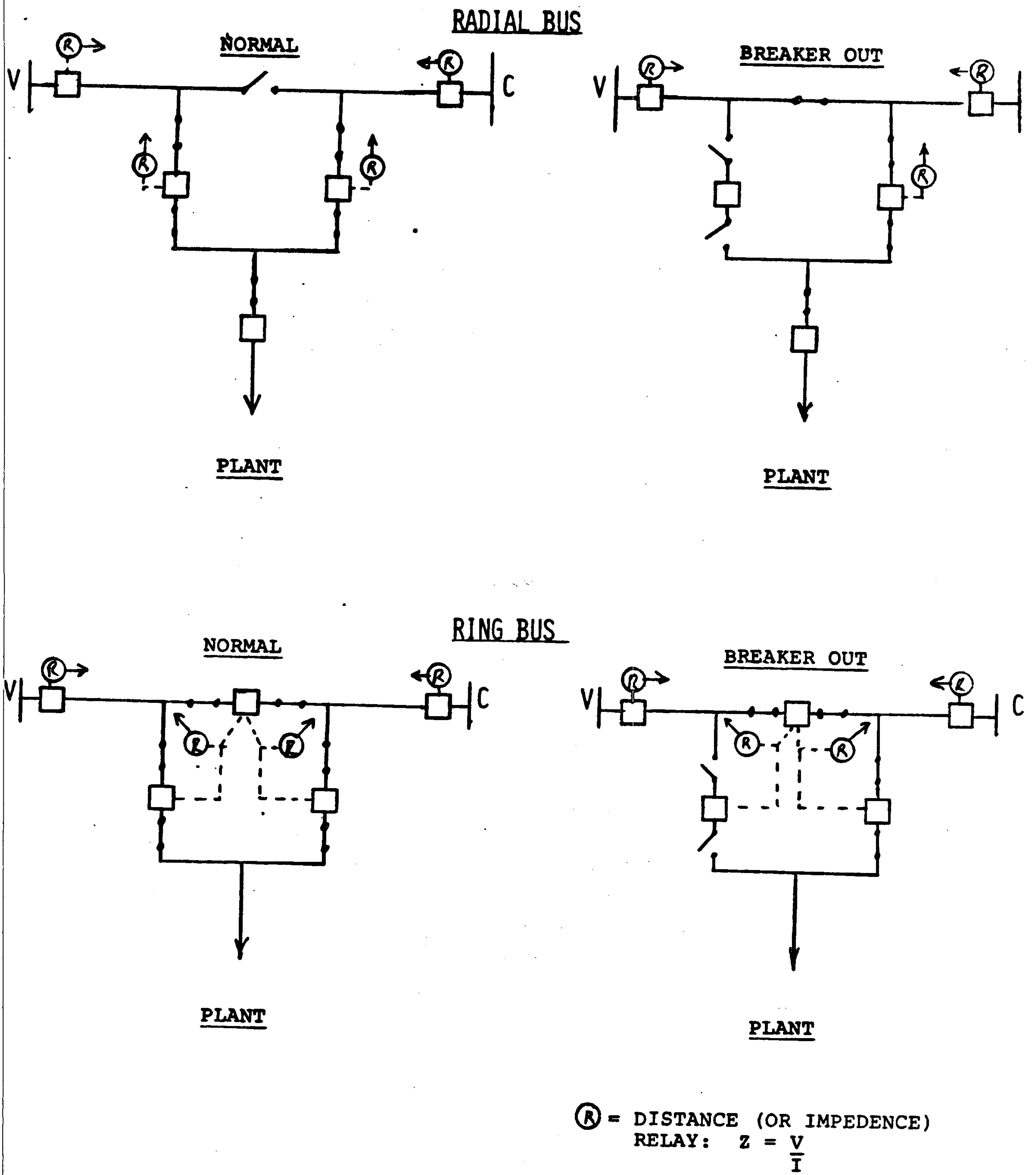
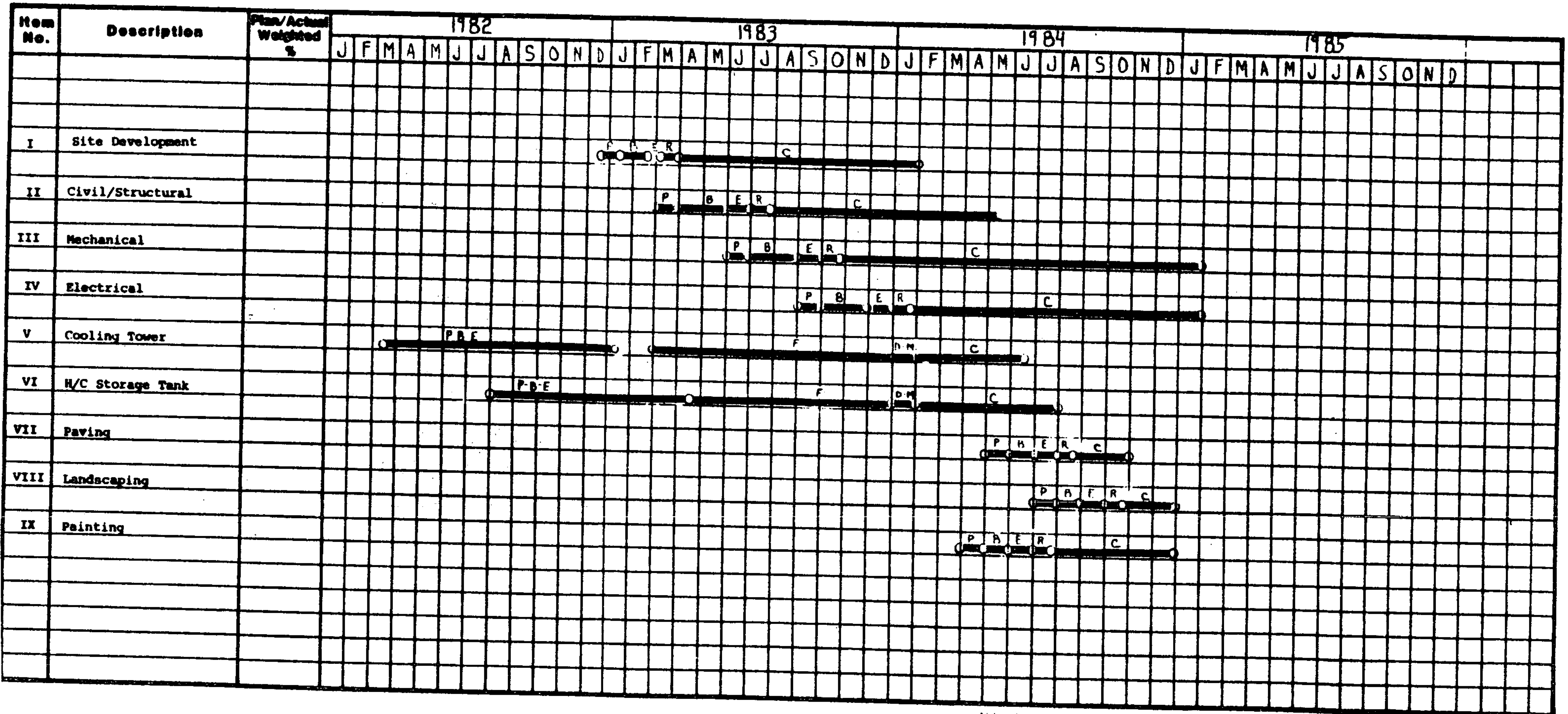


FIGURE 11
COMPARISON OF 34.5 KV SWITCHYARD ARRANGEMENTS

DATE 11-23-82



LEGEND

P - Prepare Bid Documents
B - Bid
E - Evaluate
M - Mobilize
C - Construction
F - Fabricate
D - Deliver
R - SDG&E Review

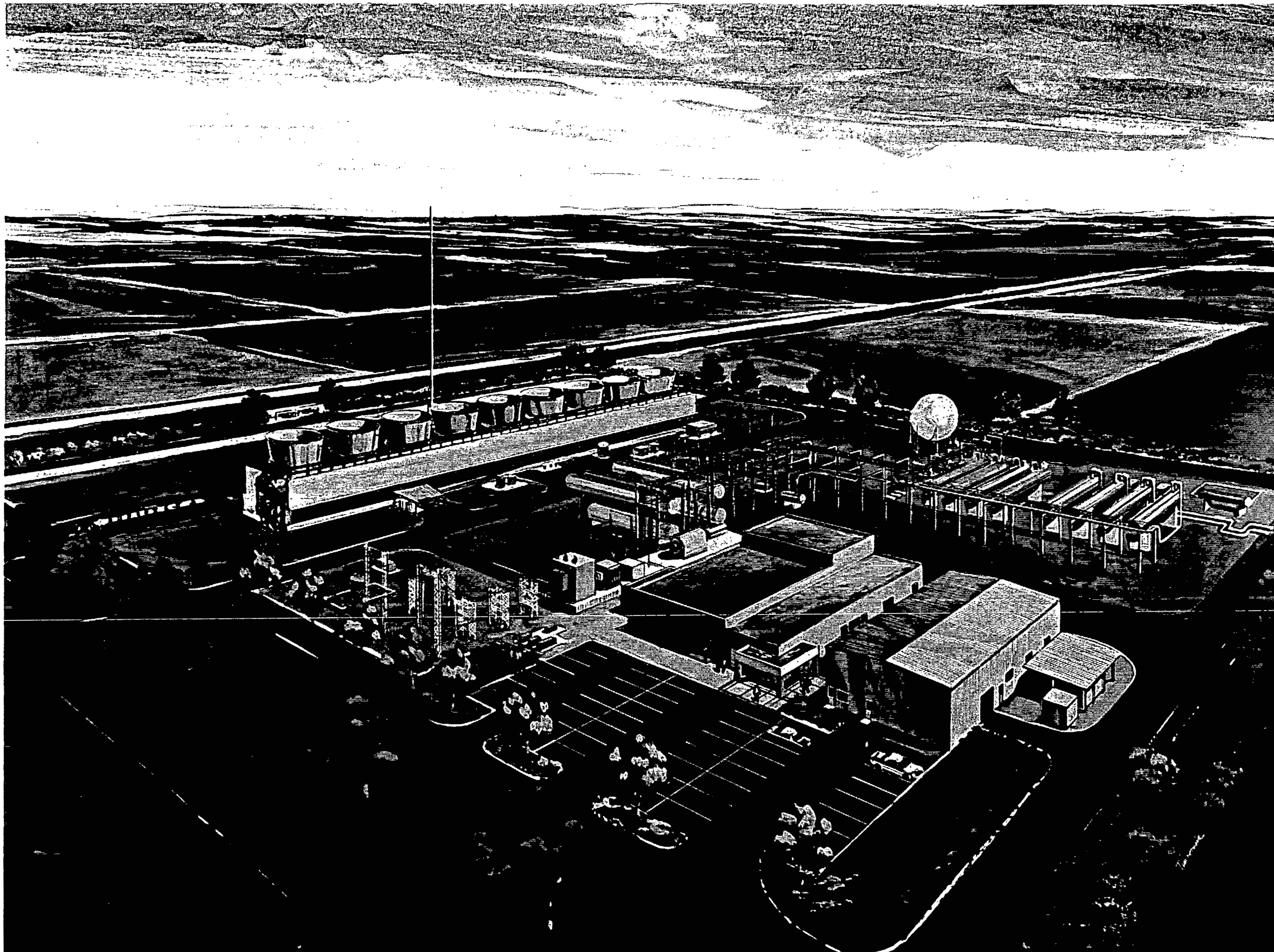
LEGEND

Plan
Actual
Forecast
Delay
Revision

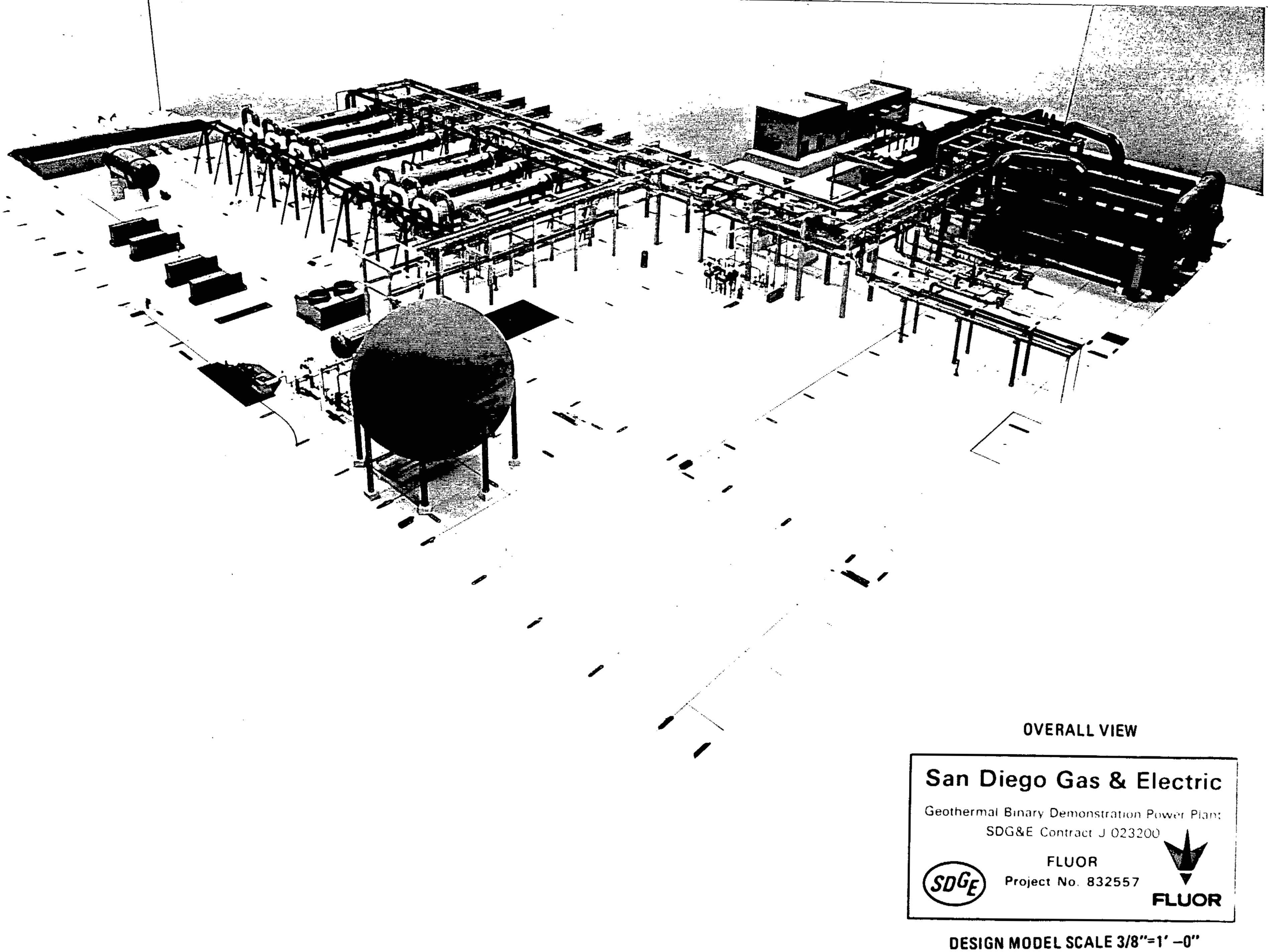
FIGURE 12
SUMMARY OF CONSTRUCTION SCHEDULE

	WITNESS/HOLD POINT REQUIREMENTS	PROJECTED DATE
1.	Ultrasonic Testing of Shaft Forging	1/21/83
2.	Utlrasonic Testing of: Turbine Casing Welds Lube Oil Console Piping Welds Seal Oil Console Piping Welds	2/21/83
3.	Hydro Test of Turbine Casing	5/14/83
4.	Turbine Rotor Balancing	5/21/83
5.	Inspect Turbine Internals for Cleanliness Prior to Installation and Closing of Turbine	8/07/83
6.	Mechanical Test of Turbine, Inspection of Turbine Bearings and Seals After Mechanical Test	9/01/83
7.	Turbine Gas Leakage Test	9/03/83
8.	Lube Oil Console: Flushing of Performance Test Hydro Test	9/01/83
9.	Seal Oil Console: Flushing of Performance Test Hydro Test	9/01/83
10.	Governor Functional Test	Not Yet Established
11.	Control Panel Functional Test	Not Yet Established
12.	Stop and Control Valves Hydrostatic Pressure Test Seat Leakage Test	Not Yet Established
13.	Functional Test of Hydraulic Power Units Omit Hydraulic Activator Installed On Valves	Not Yet Established

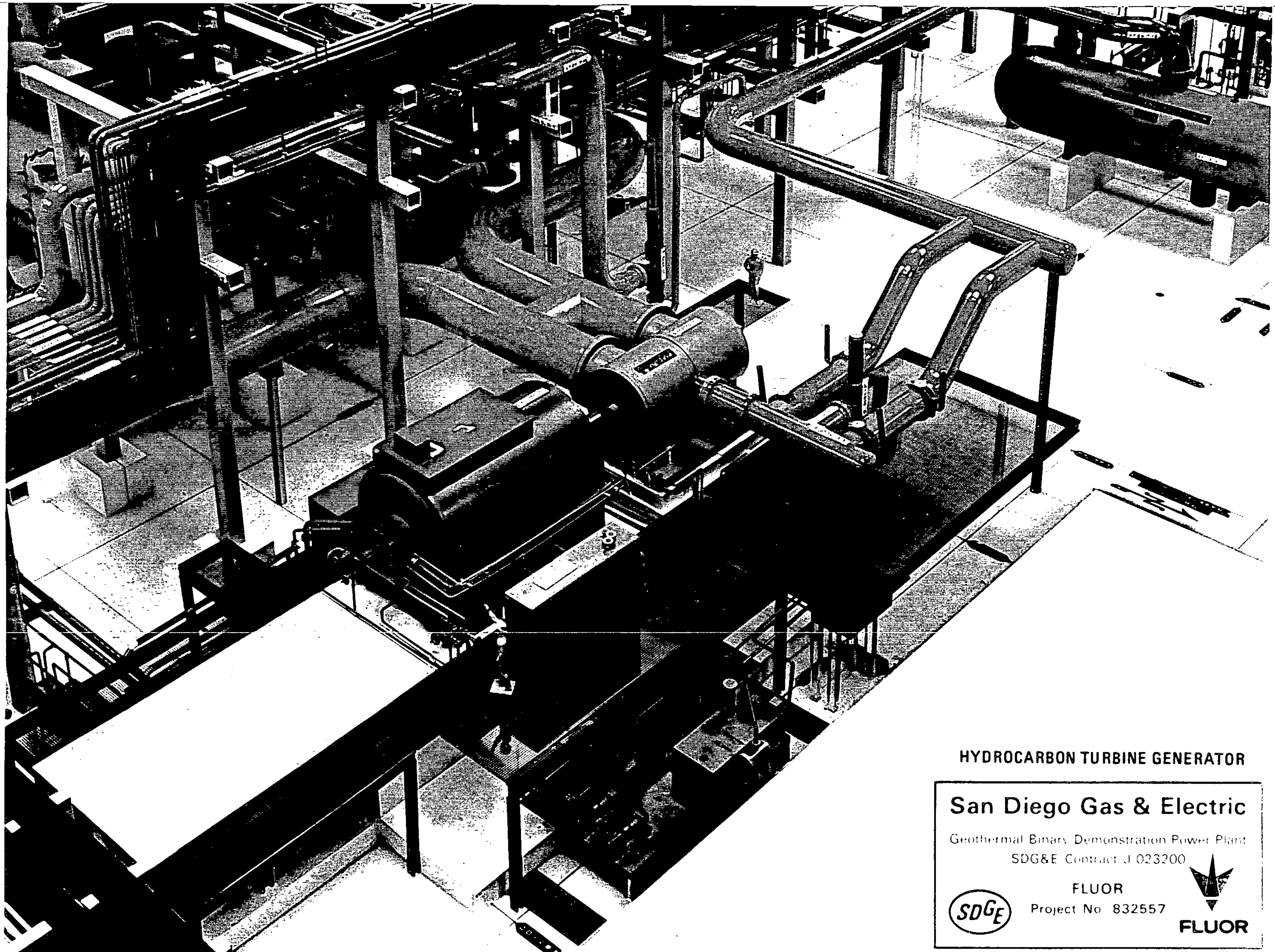
TABLE 1
TURBINE GENERATOR MANUFACTURING
WITNESS/HOLD POINT REQUIREMENTS AND SCHEDULE



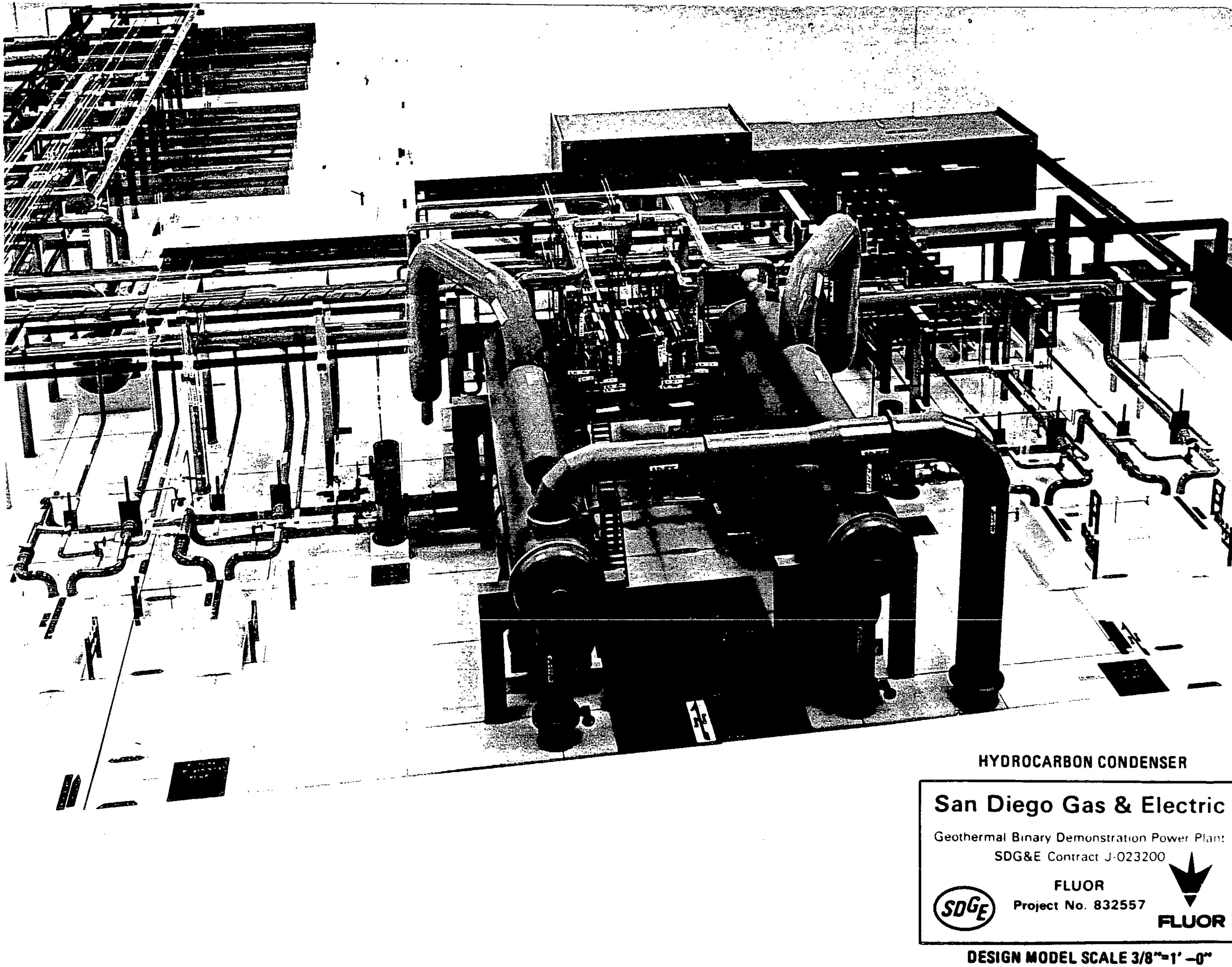
PICTURE 1
ARTIST'S RENDERING



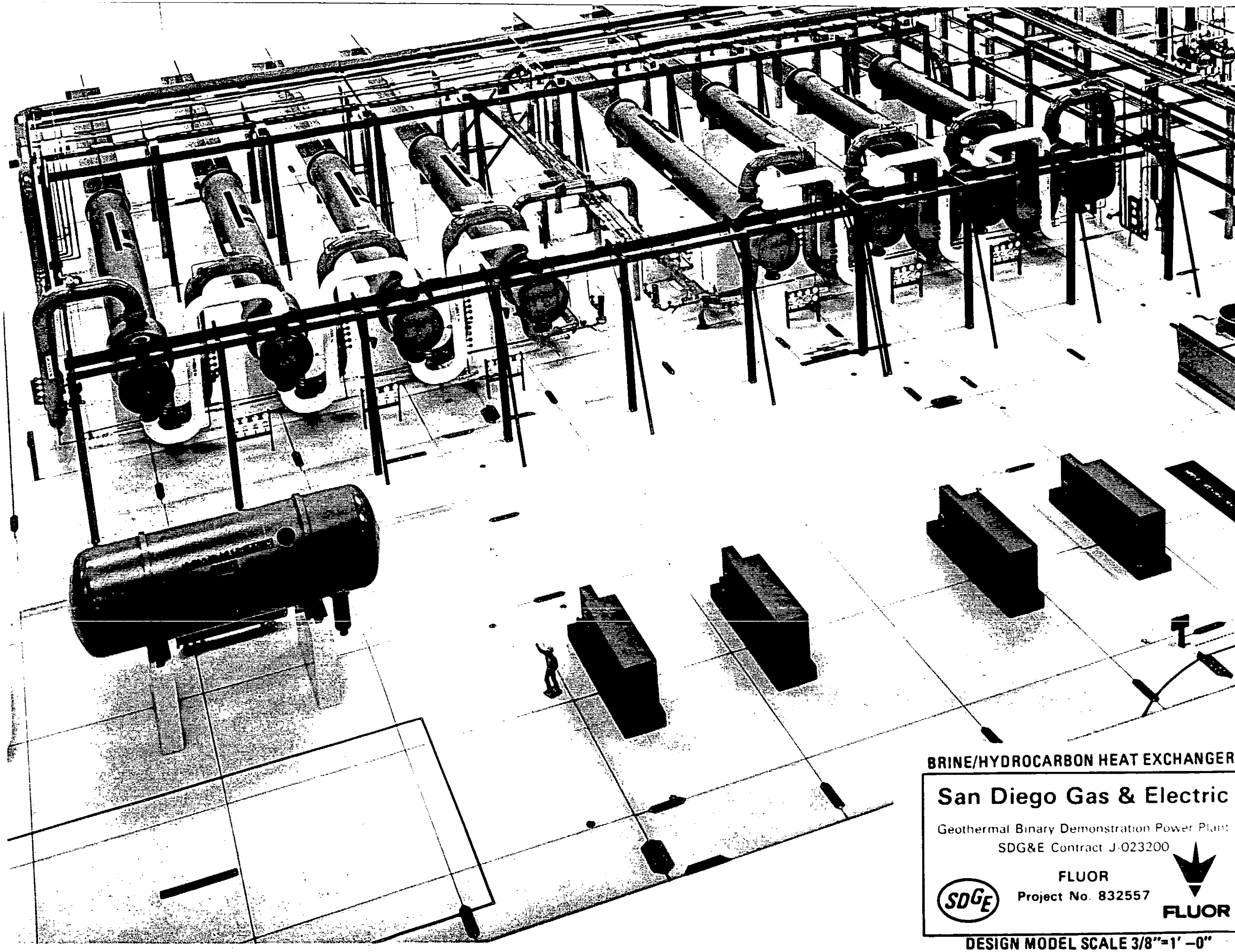
PICTURE 2
PLANT PIPING MODEL-OVERALL VIEW



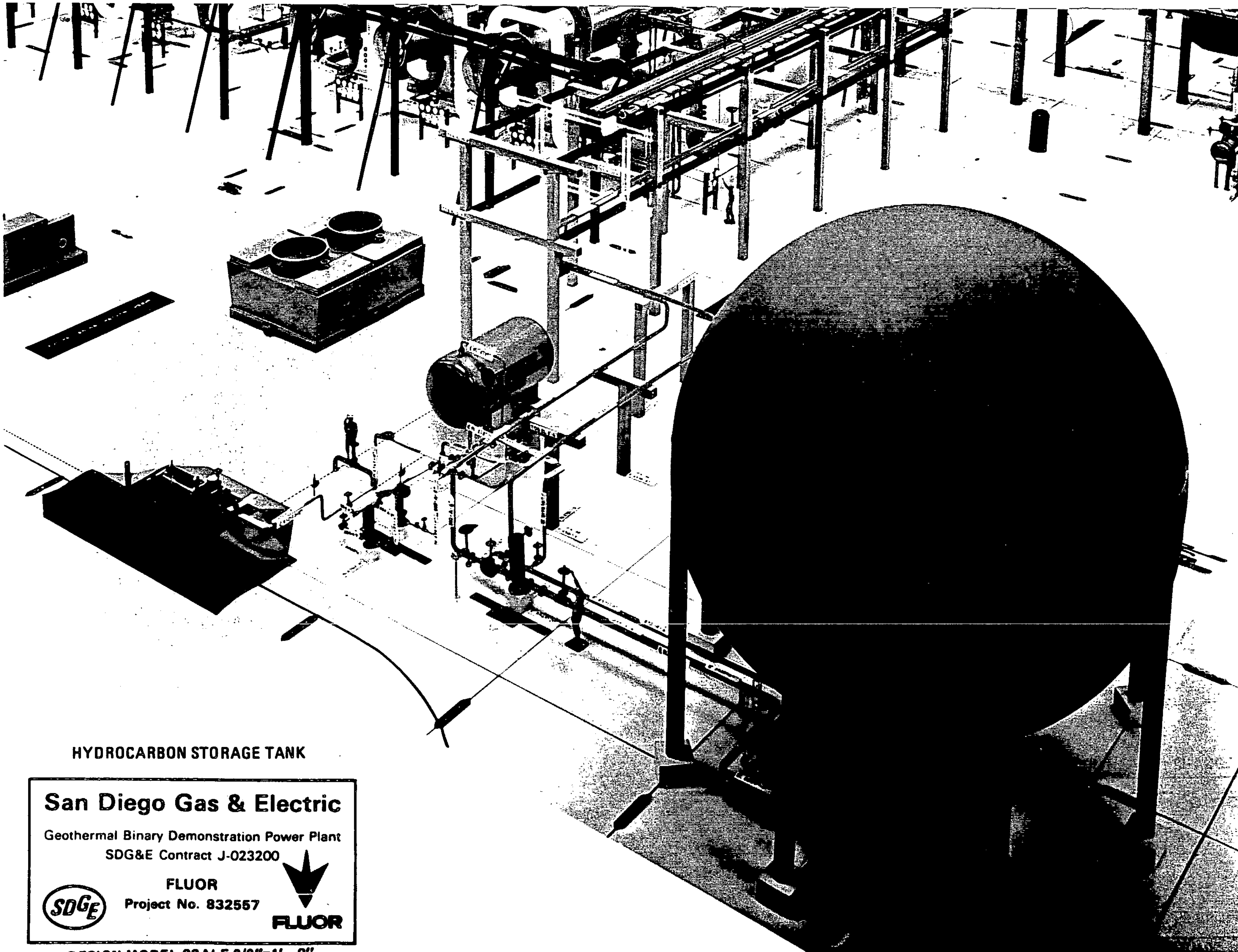
PICTURE 3
HYDROCARBON TURBINE GENERATOR



PICTURE 4
HYDROCARBON CONDENSERS



PICTURE 5
BRINE/HYDROCARBON HEAT EXCHANGERS



PICTURE 6
HYDROCARBON STORAGE TANK