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DISCLAIMER

GEYSERS UNIT 18

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INTRODUCTION Located in Northern California in Lake and Sonoma Counties about 90 miles north of San Francisco, Pacific Gas and Electric Company's (PGandE's) The Geysers Power Plant, which has at present fourteen units in service with a net generating capacity of 798MW, is the largest geothermal development in the world. Eight additional PGandE units now in construction, design, and planning will add 720MW of additional capacity by 1986. Figure 1 shows the location of this project and the locations of the existing and future units.

This paper discusses evolution of Geysers Unit 18 through resource and project planning, licensing, design, and what is expected during construction, and startup. While many of the experiences are unique to The Geysers units, some could be applicable to other geothermal developments. This unit is one of a series of 110MW units of standardized design which are being developed to reduce the cost and improve schedules. Construction has just commenced, and it is expected to be in commercial operation in October 1982.

RESOURCE PLANNING PGandE's long-range electrical resource program is continuously reviewed and updated in light of projected load growth and the availability and cost of alternative generating options and the resources they require. In order to minimize the cost of power production to serve varying electric demand, both peaking and base-load units are included in the resource program. Since The Geysers units currently are PGandE's least costly thermal electric resource they are operated in the base-load mode as much as possible.

Another factor in resource planning is the contractual obligations between PGandE and its steam suppliers at The Geysers, Thermogenics, Aminoil USA, and the Magma-Thermal-Union joint venture. This last group will furnish steam for Geysers Unit 18. Under our contracts, PGandE will install new generation at about 100MW per year if the steam suppliers prove up the geothermal resources required. In this phase of the Unit 18 planning, the suppliers provided resource data and PGandE's geothermal reservoir consultant confirmed the availability of steam.

Regulation also is a major consideration in resource planning. PGandE, as a regulated utility, must obtain approvals from the California Energy Commission (CEC), the California Public Utilities Commission (CPUC), the County Air Pollution Control Districts (APCD's), and other federal, state, and county planning and licensing agencies. Their regulation ranges from approval of long-range resource programs and rate of return on investment by the CEC and CPUC to environmental and reliability reviews on individual power projects. These reviews can change project lead times and costs which in turn can affect the selection of one type of generation over another.

PROJECT SITING AND LICENSING After its position in the resource program had been established and the steam reserves to support it confirmed, the siting and licensing phase of the Unit 18 project was initiated. In this phase the site was selected and the project cost and a schedule refined. Figure 2 shows the schedule for Unit 18.

Site Selection The topography of The Geysers area is characterized by northwest trending ridges and steep canyons. The ridges vary in elevation from 2,500 to 4,700 feet above sea level; the canyon floors are as low as 1,200 feet. Moreover, this area has widely varied sensitive environmental features. Site selection which must take into account the individual characteristics of each site is a dynamic process.

The Unit 18 site selection involved three phases and was done by a team of engineers, geologists, biologists, and architects who were responsible for selecting a site which is structurally, environmentally, and economically sound. In the initial phase of site selection, 18 potential power plant sites were identified after reviewing topographical and geological maps, aerial photographs, and carrying out field reconnaissance of the steam supply leasehold. Topographic and geologic features, soil characteristics, landslides, and faults were catalogued. Hydrologic features such as flooding potential, erosion, sediment transport, and the existence of groundwater, environmental impacts to water quality were identified. Aquatic and terrestrial ecology, noise, visual and air quality, and archaeological and other cultural resources within the leasehold were considered. Construction constraints such as accessibility, cut-and-fill requirements, and material disposal were noted. The steam supplier's surface and subsurface rights at the sites were confirmed. Potential transmission line routes were identified. Four months were required for this phase. After weighing these constraints, six sites warranted investigation in Phase II. In this phase a preliminary plant layout was prepared for each site which showed cut-and-fill slopes, access roads, retaining walls, and all areas of surface disturbance. These were distributed to the siting team members for more detailed reconnaissance. Evaluations of environmental and visual impacts and hydrological effects were updated in light of the more accurate information available on the extent of disturbance at the sites. Surveys by the biologists confirmed the assumptions on habitat types used in rating the sites during Phase I.

The siting team evaluated transmission line routes from the preferred sites to ensure that they are feasible from a construction standpoint and that environmental impacts can be mitigated. Near the end of Phase II geotechnical evaluations, the best apparent sites were investigated by core drilling, seismic refraction surveys, and trenching to confirm their underlying geological features. This revealed that our assumed best site required costly foundations and retaining walls and it was rejected.

Because of the extreme topographic features at The Geysers, PGandE has been unable to make precise models of dispersion patterns for air pollution by mathematical means. Therefore, during Phase II, wind tunnel model tests were conducted to evaluate air pollution impacts for those sites where a precise analysis was

FIGURE 1

MAP OF THE GEYSERS AREA

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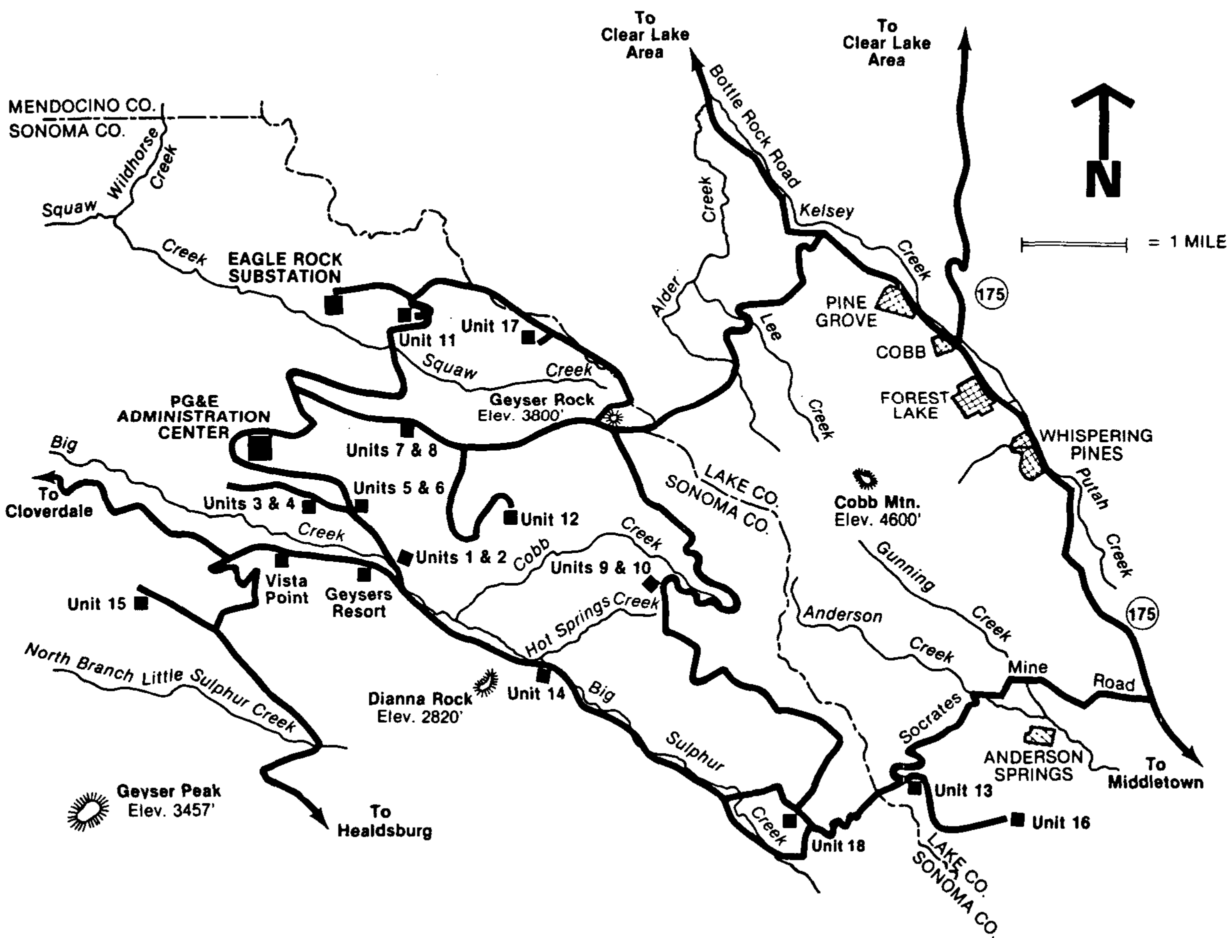
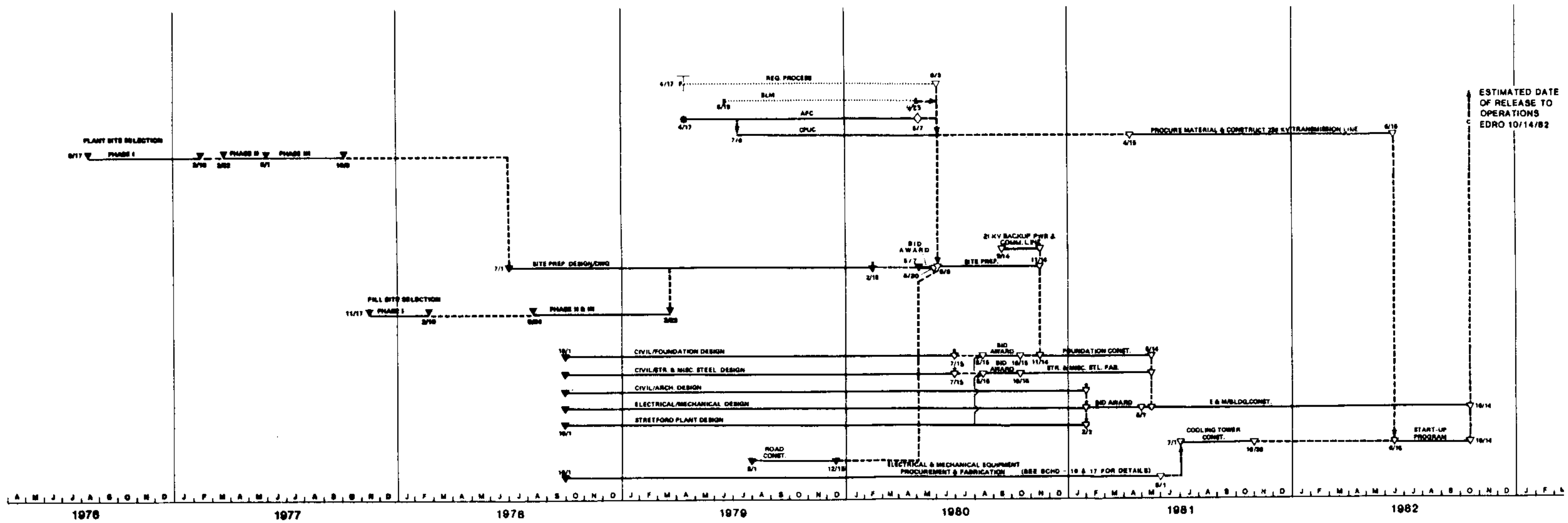
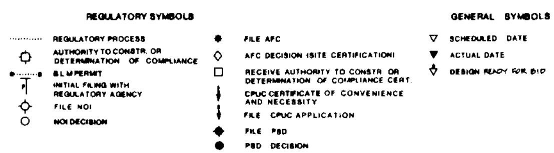


FIGURE 2

GEYSERS UNIT 18 SCHEDULE





NOTES

UNITS 17 AND 18 EARTHWORK CANNOT BE CONDUCTED BETWEEN NOVEMBER 1 AND MARCH 31 WITHOUT AUTHORIZATION FROM THE SONOMA COUNTY DIRECTOR OF PUBLIC WORKS. IN ACCORDANCE WITH COMMITTMENTS MADE DURING THE UNIT 17 CEC REGULATORY PROCESS, NO EARTHWORK IS PLANNED FROM DECEMBER 1 TO MARCH 1.

needed. This method has been found to give results similar to tracer studies at lower cost.

At the conclusion of these 10-month studies, one power plant site was selected for the Phase III study. In Phase III, more detailed geotechnical investigations were performed on the site to determine specific foundation design requirements and detailed environmental mitigation plans were prepared. Phase III required four months. Up to this point the investigation had been based on balanced cut-and-fill site designs. However, at this point there remained a diversity of opinion among the team members on the best way to dispose of material to be excavated from the plant site. Engineering and construction representatives favored on-site disposal while biologists favored disposal of this material in an old open-pit mercury mine nearby to avoid impacting an environmentally sensitive area adjacent to the plant site. To balance these views required essentially another 15-month, 3-phase study of both on-and off-site disposal alternatives. In the end it was determined that use of a combination of on-and off-site disposal was both environmentally and economically acceptable.

Geothermal Licensing Processes Before Unit 18 construction could commence, several regulatory documents needed approval. Preparation of these documents began soon after the start of site selection. Since the passage of the Warren-Alquist Act, projects with a net generation capacity of 50,000 kilowatts or more are under the jurisdiction of the CEC's process which requires approval of two documents: the Notice of Intention (NOI) and/or the Application for Certification (AFC). These documents describe the proposed project, its purpose, need, design, construction, operation, and assess the physical, economic, and sociological impacts of geothermal resource utilization at that site. Also included in these is information sufficient to satisfy an Authority to Construct (A/C) with the local Air Pollution Control District, and Use, Grading, Building, and Sanitation Permits with the appropriate local county agencies.

Because the CEC has designated geothermal energy a preferred resource, it has initiated an expedited license procedure that is shorter than other energy sources. A nine-month NOI review process and a nine-month AFC review process are required for a geothermal unit for which a steam supply is not proven or an expedited twelve-month AFC review process can be followed if the proposed leasehold has been proven to be capable of providing steam in commercial quantities. Since the steam supply for Unit 18 had been proven, it followed the one-year AFC process. The AFC was approved on May 7, 1980.

In addition to CEC certification, a Certificate of Public Convenience and Necessity (CPCN) must be granted by the California Public Utilities Commission (CPUC) prior to the construction of a new power plant. This contains the location and a general description of the proposed generating facility and related facilities, a list of the agencies responsible for approving the plant, load and resource data, and estimated cost information, including plant and fuel costs. By regulation, the CPUC must issue its decision on these applications no later than 30 days after the CEC has issued its final decision on the AFC. The Unit 18 CPCN was issued June 3, 1980 and Power plant site preparation started June 5.

Even after the regulatory agencies have approved the plant they continue to play a key role as they closely follow the project through design, construction, and operation through a Compliance and Monitoring program prepared as part of the CEC process.

Although the Legislature, the CPUC and the CEC, have attempted to expedite geothermal power plant licensing within the confines of the Warren-Alquist Act (which established the CEC), the excessive number of reports required have made the regulatory process and post-approval requirements quite burdensome.

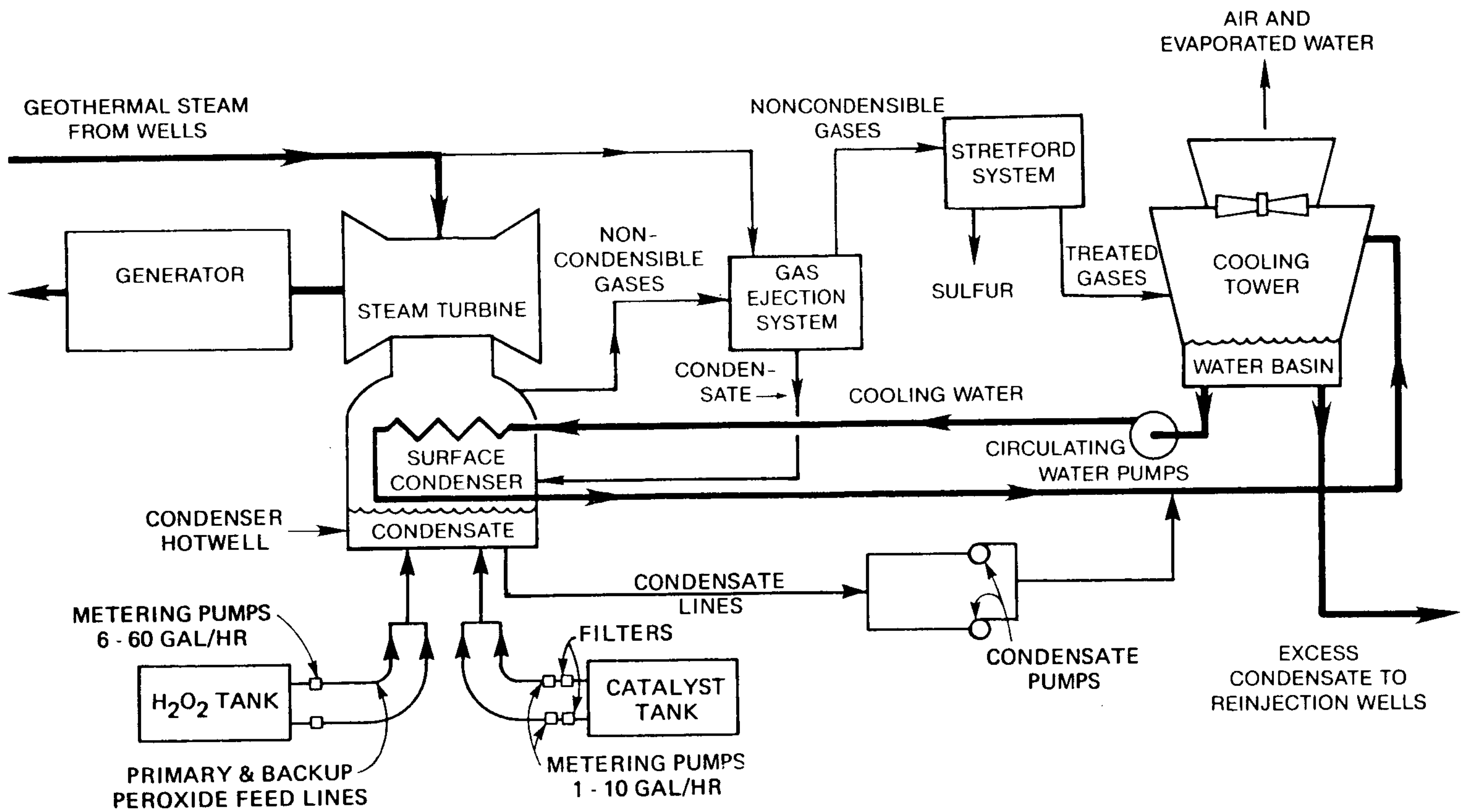
DESIGN AND EQUIPMENT PROCUREMENT Normally, the first items purchased are the turbine-generator unit and the condenser which largely determine the design of other equipment and the layout of the plant. However, Unit 18 is the second in a series of standard units so major equipment identical to that purchased for the first unit, was obtained on options. The standard units are 16, 17, 18, 20, and 21. The turbine building equipment and its arrangement and the cooling tower for these units are identical; however, the relative location of turbine buildings and cooling towers are varied to accommodate the optimum plant arrangement on individual sites. The Stretford H_2S abatement systems for these units have minor differences to accommodate the varying H_2S levels in the steam.

Figure 3 is a diagram of the power cycle.

Power Generation System The Toshiba turbine-generator units have a guaranteed gross capability of 120MW at a steam flow of about two million pounds per hour. Turbine inlet

FIGURE 3

UNIT 18 POWER CYCLE



pressure is 100 pounds per square inch gauge at a temperature of 338 degrees Fahrenheit; turbine design back pressure is 3.0 inches of mercury absolute. The turbine is a two-cylinder, four-flow design. Steam is admitted to the turbine through two main stop valves, two swing-check valves, and two butterfly control valves.

The generator is a 3,600rpm, hydrogen-cooled, three-phase, synchronous unit rated 137.8 MVA 13.8kV, 0.9 power factor, and 60 Hertz.

Condensate and Circulating Water Systems The major components of the condensate and circulating water systems are the surface condenser, condensate pumps, cooling tower, and circulating water pumps.

The surface condenser located directly beneath the turbine exhaust hoods has a design operating pressure of 3.0 inches of mercury absolute. The design cooling water flow rate is 141,000 gpm at 80°F inlet temperature.

Condensate is pumped from the condenser hotwell to the cooling tower by one of two 100 percent capacity vertical, canned-type condensate pumps. Each of these pumps is rated at 4,700 gpm at 119 feet head and is driven by a 200 hp, 1,200 rpm motor.

An eleven-cell, mechanical-induced draft, crossflow cooling tower provides circulating water for Unit 18. Each cell has a 28-foot diameter, 12-bladed fan powered by a 200 hp, 1,800 rpm motor. Space for an additional cell is provided if increased capacity is indicated after operational testing. The outside tower dimensions (including the extra cell space) are approximately 384 feet long, 60 feet wide at the base, and 65 feet high. The cooling tower is covered by corrugated fiberglass panel end walls and air intake louvers. The wood structural members are clear heart redwood or pressure treated Douglas-fir. The cooling tower is designed to reduce the circulating water temperature from 105 to 80 degrees Fahrenheit at a 65 degrees Fahrenheit wet bulb temperature. The cooling tower design flow rate is 168,000 gpm and the design evaporation rate is 3,400 gpm.

Two half-capacity vertical, wet-pit circulating water pumps pump cool water from the cooling tower basin, through the condenser tubes, and return it to the top of the cooling tower. Each pump is rated at 84,000 gpm at 105 feet head, and is driven by a 2,500 hp, 450 rpm motor. The circulating water pump sumps are adjacent to the tower cold water basin.

Gas Removal and Atmospheric Emission Control Systems The primary atmospheric emission control system consists of the surface condenser/noncondensible gas removal equipment and the Stretford system. In addition, a secondary abatement system will be provided.

The noncondensible gases are removed from the condenser by two-stage steam jet ejectors. This steam is condensed in separate surface-type inter and after condensers which, along with associated piping, are mounted on a steel structure outside the turbine building. This system is designed to exhaust approximately 10,000 pounds per hour of noncondensible gases from the main condenser.

The Unit 18 Stretford unit designed to scrub this noncondensible gas has two modules, each capable of processing 300 lbs per hour of H_2S. More than 99 percent of the H_2S flowing to the Stretford system is converted to elemental sulfur. The elemental sulfur is stored in the molten state in an 8,000 gallon enclosed storage tank until it can periodically be removed for sale or disposal in an approved disposal site.

The overall hydrogen sulfide abatement efficiency of the surface-condenser/Stretford process depends on the percentage of the hydrogen sulfide withdrawn from the surface condenser with the noncondensible gases. This percentage is referred to as the surface condenser "partitioning efficiency" or "split".

The surface condenser "split" is dependent on the chemical composition of the incoming steam, and to a lesser degree on the design of the condenser. Unfortunately, the exact steam composition cannot be determined in advance so PGandE will install a secondary abatement system to remove the H_2S in condensate before it can be released to the atmosphere in the cooling tower. This system introduces hydrogen peroxide and a catalyst into the condensate line ahead of the condensate pumps to oxidize the H_2S to largely soluble sulfur compounds.

Electrical Systems Power generated at 13.8kV is stepped up to the 230kV transmission voltage by a 137 MVA three-phase, power transformer, located adjacent to the turbine-generator building. The 13.8kV transformer terminals are connected through a power circuit breaker to the generator terminals by cables enclosed in a metal duct. The 230kV transformer terminals connect to the transmission line through a power circuit breaker and circuit breaker disconnect switch. Approximately 4,000 feet of new transmission line will tie Unit 18 to an existing transmission line.

The unit will use a dual-voltage station power system, a 4,160 volt system for the circulating water pump motors and a 480 volt system for the condensate pumps, the cooling tower fan motors, and other plant auxiliary equipment motors. One auxiliary transformer is rated at 5,600kVA with a 13.8 kilovolt primary and a 4,160 volt secondary and two others are rated 3,300kVA with a 13.8 kilovolt primary and a 480 volt secondary.

A 21kV distribution line installed on wood poles along with the communication lines supplies emergency standby power through a 750kVA transformer to essential loads such as plant lighting, battery chargers, and fire pumps. These loads will transfer to the standby source automatically on failure of the normal source.

Supervisory System Since the Geysers units are designed for attendance by roving operators, conditions that could lead to equipment damage will result in an automatic unit shutdown or reduced load operation. These operators provide around-the-clock coverage seven days a week and make rounds of the units in their assigned areas approximately twice each eight-hour shift.

To permit control and monitoring of all the units by the plant operator in the central control room at Units 5 and 6, a computer-based supervisory control system provides a summary of each unit's status, signals malfunctions, and provides certain control functions. The Unit 5 and 6 master station contains two cathode-ray tube displays which show unit status and alarms, a control console, a teletype events recorder, and a backup annunciator system. From each plant site a remote terminal unit transmits unit status, alarm, analog and accumulator information to the master station which alarms, logs, displays, or stores the data for the plant operator. A total of 40 analog values such as pressures, temperatures, voltages, currents are transmitted from each unit. Twenty status points are used for pumps, valves, and breakers. Ten accumulators at each station store kWhr meter information.

From the master station the plant operator also can control the following functions for each unit: generator power output, voltage regulation, main breaker, and main steam valve. A communications link between PGandE's Power Control Center in San Francisco and master station allows the direct transmittal of kW, var, volt, kWhr, data, and breaker status. The master station also has a backup annunciator system that allows the plant operator to recall the full display of 20 alarm (annunciator) groups for any other unit and acts as a backup system when the computer is not in service.

Two-way radio communication between the plant control operator and the roving operators provides rapid response to problems.

Civil-Structural Features The Unit 18 turbine building, housing the turbine-generator and most of the mechanical and electrical equipment, is approximately 195 feet long, 85 feet wide, and 66 feet high. It is of steel frame construction with fluted metal siding. A level parapet at the top screens the view of the roof ventilators. Several ground level entry doors and a 21-foot wide rolling overhead door provide personnel and equipment access.

All foundations will be constructed of reinforced concrete. They are designed to the requirements of the Uniform Building Code (UBC) and Uniform Building Code Standards, 1976 Edition, and the Building Code Requirements for Reinforced Concrete (ACI 318-77) by the American Concrete Institute. Foundations will be designed using the strength method to resist all applicable loads, dead loads, live loads due to wind, seismic, and operating equipment.

Steel structures are also designed to resist all applicable loads--dead loads, live loads, and lateral loads.

Equipment will be designed for a combination of normal steady state operating stresses and seismic stresses. Seismic design will be based upon the supporting structure having constant simultaneous accelerations of 0.20g in a horizontal direction and 0.13g in a vertical direction. The turbine-generator and condenser designs are not based solely on seismic considerations, but on factors such as operating forces and core vibration. Based on seismic experience at other installations, the Toshiba's equipment will not suffer damage with a seismic acceleration of up to 0.5g.

CONSTRUCTION AND STARTUP Unit 18 construction started June 5 with site preparation work which will continue until next November. The site for Geysers Unit 18 requires excavating approximately 224,000 cubic yards of soil and rock. An additional 60,000 cubic yards of landslide debris will be removed from the onsite disposal area. Approximately 120,000 cubic yards of excavated material will be disposed of at Socrates Mine about one mile from the site, and the remaining 164,000 cubic yards will be disposed of on-site. Excavation to subgrade elevation requires some ripping, and it likely that light blasting also will be necessary. A concrete crib or reinforced earth retaining wall approximately 425 feet long with an average height of approximately 30 feet will be constructed on the west side of the site.

After completion of site grading, foundations will be placed. This takes about six months to complete. An on-site concrete batch plant will be provided to facilitate this work.

Erection of the structural steel and turbine building shell will require about four months. About four months is also required to complete the cooling tower.

Since equipment lay down area at the site is limited, major electrical and mechanical equipment for the unit will be delivered by rail to the construction storage yard in Healdsburg about 35 miles from Unit 18 and will be forwarded to the site as required during construction. Smaller equipment will be shipped by truck to Healdsburg or directly to the site.

Major equipment installation requires approximately six months. Startup testing will begin about 24 months from the start of construction. Following startup testing, initial turbine roll and a 48-hour full-load run, the unit is shut down for turbine-generator bearing inspection. At the end of a two-week bearing inspection period, the unit will be returned to service and released for commercial operation which is scheduled for October 1982.

A 4,000-foot transmission line to connect Unit 18 to an existing line will be built simultaneously with the major equipment installation. Transmission line construction consists of building access roads to tower locations, tower erection, right-of-way clearing, and conductor stringing. Each tower must have an access road for the delivery of material and equipment. Existing roads and spurs will be used whenever practicable. The transmission line traverses brushy and heavily timbered terrain so conductor stringing trails, 3 to 5 feet wide, will be cut continuously along the right-of-way. Approximately one-fourth acre at each tower location will be cleared to provide working space for tower assembly and erection. Trees within the 120-foot right-of-way will be cut or trimmed as necessary to provide electrical and physical clearance for the line's successful operation.

The overall construction period from the start of site work to commercial operation is about 30 months and the overall project from the start of site selection to commercial operation is 74 months.