MASTER

DOE/ET/27163-7
Distribution Category UC-66f

BACA GEOTHERMAL DEMONSTRATION
PROJECT

- POWER PLANT DETAIL DESIGN DOCUMENT

FROM A REPORT BY

BECHTEL POWER CORPORATION
June 1980

Summary Prepared By
WESTEC Services, Inc.
Albuquerque, New Mexico
February 1981

For

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

UNION GEOTHERMAL COMPANY OF NEW MEXICO

AND

PUBLIC SERVICE COMPANY OF NEW MEXICO

UNDER CONTRACT NO. GEO-CSL-25

Work Sponsored By

THE U.S. DEPARTMENT OF ENERGY
DIVISION OF GEOTHERMAL ENERGY

UNDER COOPERATIVE AGREEMENT NO. DE-FC03-78ET27163

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

"This report was prepared as an account of work performed by Union Geothermal Company of New Mexico, Public Service Company of New Mexico, and the U.S. Department of Energy, an agency of the United States Government. Neither Union Geothermal Company of New Mexico, nor Public Service Company of New Mexico, nor the United States Government nor any agency thereof, nor any of their employees or subcontractors, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by Union Geothermal Company of New Mexico, or Public Service Company of New Mexico, or the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of Union Geothermal Company of New Mexico, or Public Service Company of New Mexico, or the United States Government or any agency thereof."

Printed in the United States of America

Available from:

WESTEC Services, Inc.
505 Marquette N.W., Suite 1500
Albuquerque, NM 87102

Abstract

Bechtel Power Corporation has been contracted by Public Service Company of New Mexico to provide engineering, procurement, and construction management services for the Baca Geothermal Demonstration Power Plant. This Bechtel Detail Design Document presents the design criteria and detail design for power plant equipment and systems, as well as discussing the rationale used to arrive at the design. Where applicable, results of in-house evaluations of alternatives are presented.

TABLE OF CONTENTS

	Page
INTRODUCTION	1-1
DESIGN CRITERIA	2-1
DETAIL DESIGN	
DESIGN RATIONALE	3-1
CIVIL/STRUCTURAL	3-6
ARCHITECTURAL	3-10
MECHANICAL	3-12
INSTRUMENTATION AND CONTROLS	3-19
ELECTRICAL	3-22
PERFORMANCE	3-25
DESIGN FEATURES	
GENERAL	4-1
CIRCULATING WATER PUMP AND CONDENSER	4-2
CONDENSER DESIGN	4-4
CLEAN ROOM	4-7
CIRCULATING WATER CONCENTRATIONS	4-8
MAINTENANCE FACILITIES	4-12
CONTROL ROOM FACILITIES	4-13
USE OF FRP PIPE AND TANKS	4-14
ANTICIPATED H ₂ S DISTRIBUTION	4-16
GAS REMOVAL	4-20
PLANT WATER AND CHEMICAL BALANCE	4-21
ELECTRICAL SYSTEM COMPONENTS	4-29
ADVANTAGE OF THE FLASH DESIGN	4-34
TURBINE GENERATOR/STEAM GATHERING FIELD RESPONSE	4-35
TURBINE BLOW-OFF PIPING	4-38
MATERIAL SELECTION	4-39
DRAWINGS AND DIAGRAMS	APPENDIX A
DESIGN DATA SUMMARY SHEETS	APPENDIX B

INTRODUCTION

Public Service Company of New Mexico (PNM) has contracted Bechtel Power Corporation to provide engineering design services for the Baca Geothermal Demonstration Power Plant. Bechtel's scope of work for power plant design includes everything from the turbine inlet valves through the generator busbar leads, the power building structure, cooling tower, and H_2S abatement equipment as well as major equipment procurement and construction management. PNM is directly responsible for and performs its own electrical switchyard and transmission system design and construction.

This Detail Design Document was prepared by Bechtel to present the engineering and design criteria developed by them for the Baca project. Bechtel's detail design effort had progressed to approximately 72 percent completion when this report was prepared in June, 1980. While design in many areas was considered final at this point, changes may be employed as a result of on-going investigations and operating experience from existing geothermal plants. Accordingly, this document will be updated or supplemented by topical reports to reflect major design modifications.

DESIGN CRITERIA

LOCATION

The plant site is located on the Baca Ranch in north central New Mexico in an area known as the Valles Caldera, in Sandoval County. Approximate coordinates are North $35^{\circ}-53'$, West $106^{\circ}-35'$. Access is by an unpaved gravel road on the Baca Ranch which connects to State Highway No. 4.

SITE DESCRIPTION

The site is in a valley adjacent to and west of Redondo Creek. The Valley runs generally from the north-northeast to the south-southwest. The gravel access road runs between the creek and the site. A hill rises above the site to the northwest, to an elevation of 9800 feet. The existing elevation of the site area varies from about 8720 to 8760 feet. On the other side of the creek, the land rises to elevation 11,254 feet at the top of Redondo Peak, two miles to the southeast. The site is near and northeast of Union Geothermal Well No. 6.

WEATHER

Wind — The predominant wind direction at the site is up and down the valley, parallel to Redondo Creek. The down-valley winds — from the north-northeast — occur at night. The up-valley — from the south-southwest — occur during the day.

Rainfall — The 100 year maximum 24 hour rainfall is 4.2 inches; rainfall 25 inches per year (maximum).

Snowfall — The site is in an area characterized by deep winter snows. Snow survey records for three snow courses near the site, published by the Snow Survey Unit of the Soil Conservation Service, U.S. Department of Agriculture, are summarized in Table 1. The last two columns are the calculated ground snow loads for the 50 and 100 year mean recurrence intervals.*

*Calculated by Bechtel Power Corporation, using probability methods and the data referred to above.

Table 1

SUMMARY OF SNOW SURVEY RECORDS

Station Name	Elevation, Feet	Distance from Site, Miles	Years of Record	Maximum Depth, Inches	Ground Snow Loads, PSF		
					Maximum	50 Year	100 Year
Quemazon	9100	11	30	76	108	122	140
Sandoval	9100	11	20	59	76	89	103
Fenton Hill	8900	4	20	28	43	64	74

GEOTECHNICAL

A two strata geotechnical profile underlies the site. Alluvial soils composed predominantly of sandy clays and clayey sands, but containing lesser stratifications or lenses of silty sands and highly plastic clays, overlie weathered volcanic tuff. Stiffness of the overburden soil varies erratically, with some material being relatively firm. Very extensive relatively soft zones, however, are present and are distributed in an erratic manner. Cobbles and boulders are present in the overburden. Highly organic material was encountered in a localized area.

The depth to firm tuff varies from about 20 to 30 feet below finished grade (elevation 8730 feet) in the power block area and about 10 to 30 feet below finished grade (elevation 8750 feet) in the cooling tower area.

Free ground water is present at or just below the surface over much of the site.

The Geotechnical Consultant, Sergent, Hauskins and Beckwith, recommended the following:

1. The turbine pedestal and turbine building should be supported on drilled, cast-in-place concrete piers, extending a minimum of 5 feet into the firm tuff.
2. Mat foundations should be used below the cooling tower, H₂S abatement facility and miscellaneous light structures.
3. Free draining granular fill should be placed in the upper 5 feet below finished grade or 2 feet below the base of the mat, whichever is deeper, below the turbine pedestal and turbine building. Three feet of granular fill should be placed below the cooling tower basin and five feet below the H₂S abatement mat and miscellaneous equipment mats.
4. Free draining granular fill should be placed in the upper 2 feet immediately below all paving.
5. Perimeter drains, at least 10 feet in depth, with filters to prevent clogging, should be placed around the uphill portions of the structures to intercept any shallow seepage of water that may be occurring. Drains should also be provided to remove water from the zones of granular fill.

The geotechnical summary and recommendations described above are excerpted from the Final Geotechnical Investigation Report by Sergent, Hauskins and Beckwith, dated September 26, 1979.

CIVIL/STRUCTURAL CRITERIA

The complete civil/structural criteria are in the Civil/Structural Design Parameters for Baca Geothermal Project, by Bechtel Power Corporation, issued May 1979. Foundation design criteria are based on the recommendations of the geotechnical consultant and are summarized in the Geotechnical Section, above. The snow, wind and seismic loads are as follows:

Snow — Structures shall be designed for roof snow loads in accordance with Building Code Requirements for Minimum Design Loads in Buildings and Other Structures, ANSI A58.1-1972. For design purposes, the ground snow load shall be 140 psf. Roof snow loads shall be determined by multiplying the ground snow load by an appropriate coefficient, as determined by ANSI A58.1. The basic coefficient is 0.8. It may be increased or decreased based on specific conditions.

Wind — Structures shall be designed for wind loading in accordance with ANSI A58.1-1972. For design purposes, the basic wind speed shall be 90 mph, based on a 100 year mean recurrence interval, at "Exposure B." The resulting wind pressures on an ordinary building or structure are:

Height Feet	Pressure On		
	Windward Wall PSF	Leeward Wall PSF	Total Building PSF
<30	10.4	7.8	18.2
30	12.8	9.8	22.4
50	15.2	11.4	26.6
100	19.2	14.4	33.6

Seismic — All structures shall be designed for seismic loads in accordance with the Uniform Building Code requirements for Seismic Zone 2. The Occupational Importance Factor shall be 1.5 as required for "Essential Facilities."

ENVIRONMENTAL

As discussed in the Environmental Impact Statement it is necessary to prevent contamination of Redondo Creek with effluent from the plant drainage system. Furthermore, the H₂S content of the gases discharged from the plant H₂S abatement system will satisfy the requirements of the New Mexico Environmental Agency of 10 ppm maximum, at the plant boundary.

GEOHERMAL STEAM DATA

Turbine entry pressure/temperature 113 psia/337 F. (Inlet of Wye-strainers immediately upstream of the turbine stop valves.)

The turbine back pressure design is 4 inches Hg absolute.

Chemical Analysis of the Steam (Without Scrubbing):

	Avg. Conc., Mg/1
pH	4.5
Suspended Solids	7
Dissolved Solids	
SiO ₂	7-15
HCO ₃	5
SO ₄	2

	Avg. Conc., Mg/1
C1	21
Na	8
K	3
Ca, Mg, Ba, B, F	<1.0

Non-condensible Gases:

	Avg. ppm by wt.	Avg. ppm by mol.
CO ₂	28,250	12,000
H ₂ S	300	184
N ₂	56	37
H ₂	2	14
CH ₄	2	2

Weighted Average of Non-condensible Gases = 2.64 percent of steam; 3.0 percent will be used as a design maximum.

COOLING WATER SUPPLY

Steam condensate is used as the eventual source of cooling water supply. The expected circulating water analysis during periods of maximum cooling tower evaporation is as follows:

pH		4.5 (minimum)
Suspended Solids		49 ppm
Dissolved Solids		
Silica	SiO ₂	49-105 ppm
Bicarbonates	HCO ₃	35 ppm
Sulfate	SO ₄	14 ppm
Hydrogen Sulfide	H ₂	6 ppm
Chloride	Cl	147 ppm
Sodium	Na	56 ppm
Potassium	K	21 ppm
Calcium,	Ca,	7 ppm
Magnesium,	Mg,	
Barium, Boron,	Ba, B,	
Fluorine	F	

The water is assumed to be completely saturated with atmospheric gases.

IN-LINE VELOCITIES

Steam	— 9,000 to 12,000 FPM
Condensate	— 4 to 8 FPS
Gasses	— 12,000 to 15,000 FPM
Cooling Water	— 6 to 10 FPS

ELECTRICAL

115 kV external source power

13.8 kV generated power

4.16 kV plant maximum auxiliary power

MAIN GENERATOR

Power will be generated at 13.8 kV and stepped up to 115 kV through a generator circuit breaker, non-segregated phase bus duct, and a main 3 phase step-up transformer. An overhead span will connect the transformer HV terminals to PNM's switchyard.

PLANT AUXILIARY SYSTEM

The plant auxiliary system will be energized from a unit auxiliary transformer, through a tap in the 13.8 kV non-segregated phase bus duct. The secondary of this transformer will feed the auxiliary system metal clad switchgear at 4.16 kV through a main secondary circuit breaker. The circulating water pump drivers will operate at 4.16 kV; the remaining plant loads will be fed from 480 V motor control centers, energized from a single ended 480 V loadcenter substation. There will be no start-up transformer; start-up power will be obtained from the switchyard through the main step-up and unit auxiliary transformers, with the generator circuit breaker open.

A page/party intercom system will be provided in the plant, with conduits only for installation of public telephone conductors and equipment by others.

Complete grounding system is included. Transmission line relaying and revenue metering is not included. Generator breaker is utilized rather than a separate startup transformer. High voltage circuits beyond the main transformer high voltage bushings are not included.

The plant battery will be sized to include switchyard loads.

PLANT OPERATION

The power generation plant is to be manned with plant operators. Remote operation is not considered at this point in time. It is contemplated that operators will commute to and from the plant and therefore minimal provisions have been made for personnel comfort and hygiene.

Routine plant maintenance facilities will be provided as typical for the remote plant location. Office, lunchroom, and chemical testing laboratory facilities are required.

DETAIL DESIGN DESIGN RATIONALE

GENERAL

The design comprises a "grassroots" geothermal steam electric generating plant located approximately 34 miles west of the city of Los Alamos.

The plant is located on the Baca Ranch in the Redondo Creek area some 4-1/2 miles north of the southwest entrance of the ranch. This plant will utilize the geothermal brine well system that has been explored by the Union Geothermal Company of New Mexico.

The gross plant capacity will be approximately 50,000 kW and will not be expanded since well gathering beyond a 50 MW generating capacity is considered uneconomical. The plant is generally comprised of four (4) major building blocks namely the power building, the cooling tower and intake structure, the switchyard and the H₂S abatement system.

During the Preliminary and the Detail design some twelve (12) alternatives were studied for economic and technical feasibility. The majority of these studies were shown in the Preliminary Design Document, Volume II. In addition, some innovative design concepts were applied to arrive at a functional and cost effective design.

The plant incorporates a hydrogen sulfide emission abatement system, the design of which has been guaranteed by the equipment manufacturer to meet the environmental standards proposed by the state of New Mexico.

PLANT SITE ARRANGEMENT

Relative Position of Major Plant Components

In deciding on the space requirements, location and orientation of the major plant components, maps of the particular area under consideration were used.

In arranging the major plant components, which are the cooling tower, power block, switchyard and the H₂S abatement system, the following factors are emphasized:

- The available level ground space.
- Wind direction with respect to cooling tower location.
- The approximate site location as provided by Union Geothermal.
- Best relative location of power block, cooling tower, switchyard and H₂S abatement system.

The power block is arranged to accommodate the supply of geothermal steam from the Plant West boundary of the plant site.

A service water tank is located near the power block to provide moderate storage for the service water supply system.

Supply for the firewater system is from the cooling tower basin. Motor-driven firewater pumps are located in the power block.

Plant sewage disposal equipment is located immediately adjacent to the Plant West boundary.

Disposal of cooling tower blowdown and excess condensate will be made via the Plant West boundary to Union Geothermal.

POWER BUILDING ARRANGEMENT

The development of the power building is based on the dimensions of the turbine generator and its components laid down on the operating deck during a major unit overhaul as well as the space requirements of the auxiliary equipment at the ground floor elevation.

The auxiliary equipment is mainly located on the ground floor with a small portion of the equipment located on the mezzanine level. The auxiliary equipment arrangement that has been achieved provides an almost perfect balance between the building space requirements for auxiliary equipment at the ground floor and the turbine generator equipment laydown space requirements at the turbine floor.

The first stage air ejector equipment is located at the mezzanine level for reasons of keeping the large size air off-take piping short and enhance dumping the discharge into the ejector inter-condenser mounted at ground level.

The levels of the ground floor, mezzanine and operating floor are set at 15 ft intervals. This requirement is mainly dependent on the height of ejector condenser and space to permit their removal if maintenance is required in the future.

Each floor level can be reached by two separate stairways, one at each end of the power building.

Operator traffic through the plant is accomplished by adequate walkways throughout the ground floor level and adequate platforms and walkways at the mezzanine level.

To accommodate maintenance of the condenser and the ejector condensers, tube pulling can be accomplished through removable wall panels to the outside. This design feature is commonly applied by Bechtel on numerous plants and results in functional tube pulling without having to add valuable building space.

SUPPORTING FACILITIES

Location and space allowances for supporting facilities for the major equipment have been treated as follows.

Turbine

The auxiliary equipment of the turbine consists of the turbine lube oil reservoir, lube oil coolers, lube oil conditioner, and the Electro-Hydraulic Control Unit. This equipment has been located in front of the turbine pedestal columns.

The turbine oil storage tanks (dirty and clean) and the transfer facilities have been eliminated for the following reason. The oil change is a function of regular maintenance and the oil change can be accomplished by ordering this service from an oil refining company. This approach has been practiced before for much larger units, and we believe that a small-generating unit can be operated successfully without incurring the cost burden of this storage and transfer facility. Furthermore, this generating unit is not intended to be expanded to a multiple unit plant in which case these facilities would be shared and the cost per unit would then be halved.

Condenser and Ejector Condensers

The condenser and ejector condensers have been arranged for a two pass flow pattern. This design permits inlet and outlet connections to be located on the same end of the heat exchangers; hence the large cooling water lines from the cooling tower can be located on one side of the turbine pedestal and can be kept short.

The ejector-condensers have been kept in close proximity to the main condenser in order to keep the large piping runs minimal.

Also the large piping for gas extraction from the condenser is kept as short as possible. This is accomplished by splitting the gas extraction lines inside the condenser into four (4) lines of 18 inches each. These lines penetrate the condenser dome at the supply water box end in a box type header arrangement.

Ejectors

From the condenser the gas extraction lines are routed to the primary steam ejectors which are mounted on the mezzanine and their discharge is dumped into the inter-condenser. Gas transfer from the inter to after condenser is accomplished by two (2) secondary steam jet ejectors which also raise the gas pressure above atmospheric pressure in order to send the remaining non-combustibles to the H₂S abatement system via a 12 inch transfer line.

Electrical Equipment

The generator circuit breaker is located in the switchgear room on the mezzanine floor to allow for a straight run of bus-duct from the generator.

All switchgear and motor control centers, except the H₂S motor control center, are placed in the switchgear room adjacent to the generator breaker on the mezzanine floor and directly below the control room. The H₂S motor control center is located in a clean room in the H₂S abatement system area.

The switchgear room is a part of the clean room concept and is provided with filtered ventilation air to minimize H₂S attack.

The battery room is located at the south side of the building on the mezzanine floor, adjacent to the switchgear room. This room will be mechanically ventilated to outdoors. The station battery will be sized to accommodate both station and switchyard loads.

The standby diesel generator set is located in the southeast corner of the building on the grade elevation below the switchgear room. The plant east wall will be provided with louvers for discharge of cooling air from the engine radiator.

All the above locations minimize the requirements for cabling and raceway.

The transformers are placed as close to the power block as feasible and are positioned to use the power building as a baffle to cooling tower mist to minimize coating of the equipment insulators.

Compressed Air System

The compressed-air system for this unit consists of two nonlubricated teflon ring compressors with a single receiver. This system and its associated drying and filtering facilities are used for service air as well as instrument air requirements. Both instrument and shop air is dried to minimize moisture problems.

The installation is located south of the main condenser.

Service Water

The service water storage tank is located outside near the southwest corner of the power building.

The service water pumps are located along the south wall of the power building; however, these pumps are located inside the building.

Fire Water

The electric driven firewater pumps are located inside in the northwest corner of the power building.

MAINTENANCE FACILITIES

The power building is equipped with a bridge crane having a main hoist capacity of 40 tons and an auxiliary hoist capacity of 10 tons. This crane is capable of serving the turbine-generator and other associated equipment. In addition, a maintenance shop and warehouse bay have been provided in the design.

Equipment Removal Opening

The location and size of the equipment removal opening is based on the governing requirements of the turbine generator and was so placed to provide easy access upon plant site entry.

EQUIPMENT LAYDOWN FOR MAJOR OVERHAUL

Equipment laydown area requirements have been given full consideration in the overall design of the plant. Drawings of turbine-generator components were used to establish the adequacy of the operating deck for an organized and effective component laydown. The supporting capacity of the operating deck has been designed for turbine laydown loads.

Laydown space requirements have been provided for the following:

- Major Turbine Components
- Major Generator Components
- Space Allocation for Miscellaneous Turbine-Generator Parts
- Space Allocation for Cable Sling Laydown
- Space Allocation for Tool Room
- Space Allocation for Small Parts
- Space Allocation for Work Benches for Turbine Area and the Generator Area

The turbine rotor can be located at grade in the equipment removal area so that temporary canvas partition walls can be placed around them to allow sandblasting of the blading, should that be necessary.

OPERATING FACILITIES

The control room is located on the turbine operating level at the southeast corner of the power building.

The control room is provided with a bench type console for starting, monitoring, and shutdown of the turbine-generator as well as for startup and control of the balance of plant equipment.

A vertical auxiliary board serves the switchyard, miscellaneous balance of plant equipment, turbine-generator supervisory instrumentation, miscellaneous instrumentation, and protective relaying, and is located in the control room east wall. Rear access to the panel is from the relay room. Both the control room and adjacent relay room are provided with filtered conditioned air to minimize H₂S attack.

The plant fire protection system monitor panel is located on the south wall of the control room.

DETAIL DESIGN CIVIL/STRUCTURAL

SITE DEVELOPMENT

Layout

The plant is located in a valley adjacent to and west of Redondo Creek. The layout, as shown on Drawing C-001, is designed to accommodate the required facilities with minimum impact on the existing terrain. The power block — including the power/administration building, switchyard, H₂S removal facility and parking areas — will be located at elevation 8730 feet. The edge of the developed power block area is about 105 feet east (based on plant north) of Union Geothermal Well No. 6. The cooling tower is on a plateau 20 feet above the power block, at elevation 8750 feet. The plant covers a 3 acre site.

Roads

Access to the site is by an existing unpaved gravel road that connects to State Highway No. 4. The road runs along Redondo Creek and, in the plant area, is between the Creek and the site. There will be an entrance from this road directly to the power block area. A second access to the opposite corner of the power block area will be provided by a ramp connecting to an existing loop in the road. The latter, which will be interrupted by the power plant, will also provide access to the cooling tower area.

Fencing

Aluminum chain link fencing will be installed around the site boundary. Onsite, a similar fence will enclose the switchyard. Aluminum is used, instead of galvanized iron, to forestall corrosion.

Water Supply

Investigations have been undertaken by PNM to determine the feasibility of providing part of the service water requirement, 3 acre-feet per year, from a well to be located on or near the site. The balance will be supplied by truck from an off-site source. The total requirement is 8 acre-feet per year. The water will be stored on-site in two 20,000 gallon tanks.

Fire Protection

Fire protection lines will be provided within the site to form two loops, one around the power block and one around the cooling tower. Water will be supplied from the cooling tower basin. The pipeline will be fiberglass reinforced plastic (FRP) pipe, designed for 125 psi static pressure and 200 psi test pressure. Hydrants and hose houses will be provided as required.

Site Drainage

Runoff from the watershed above the site will be diverted from the site by a drainage channel and pipeline to a discharge point near Redondo Creek. Onsite runoff will be collected by a drainage system (catch basins and pipeline) to also be discharged near Redondo Creek. Provisions will be made to divert onsite drainage to the nearby Union Geothermal pond in case of accidental contamination. Flow from the deep drains, used to lower the groundwater table, will discharge to an existing drainage channel north of the road. All of the natural and uncontaminated drainage, as described above, will flow to Redondo Creek.

During the construction period, onsite surface drainage will flow to existing ponds, which will function as settling/evaporation basins for removal of sediment. The effluent will either evaporate or be channeled to Redondo Creek.

Sewage and Waste Disposal

An extended aeration package treatment plant will treat domestic sewage. The effluent will flow to the Union Geothermal pond and, from there, to the reinjection area for injection into the ground. Floor drains from the turbine building and the H₂S abatement system drain will also flow to the Union pond.

Switchyard

An area, approximately 60 by 80 feet, between the turbine building and the southern site boundary (based on plant north), is reserved for the switchyard. The transformers are located in the switchyard. Provisions will be made to collect transformer oil leakage in a gravel filled concrete diked area with a catch basin connecting to the underground drainage system. This drainage system discharges into the Union pond. Union has approved this arrangement.

Structures

Power Building

The power building is a structural steel diagonal braced framed structure with insulated steel siding and roof deck. The building has three floor levels — ground floor, mezzanine and operating deck. The ground floor and operating deck are concrete slabs. The ground floor is supported by concrete piers and is the base mat for the building and turbine pedestal. The operating deck is supported on the steel frame. The mezzanine floor will include concrete areas and steel grating areas, both supported on the steel frame. The mezzanine and operating decks are 15 and 30 feet, respectively, above the ground floor. A truss supported high roof will provide 38 feet of clear space above the operating deck.

Turbine Pedestal

The turbine pedestal is a massive reinforced concrete rigid frame structure supporting the turbine generator. The turbine pedestal is enclosed within the power building but is structurally isolated from it, except at the base mat.

Foundations

The foundation design essentially follows the recommendations of the geotechnical consultant. (See Design Criteria, Geotechnical.)

The turbine building base mat is supported on 85 three foot diameter drilled concrete piers. The piers vary in length from 41 to 56 feet and extend into the firm volcanic tuff 17 to 28 feet. Load per pier varies from 150 to 350 kips. The base mat varies in thickness from 3 to 12 feet, the latter at the circulating water lines, where the mat also serves as an anchor block. Two feet of free draining crushed rock will be placed below the mat.

The cooling tower will be supported by a concrete mat above three feet of free draining crushed rock. The H₂S abatement facility structure and equipment, other than the absorber, will be supported on a concrete slab above five feet of crushed rock. The bearing pressure below these structures will be less than 1000 psf.

The H₂S facility absorber, the service water tanks and the transformers will be supported on drilled piers, similar to those under the turbine building. The geotechnical consultant recommended that these structures be supported without piers, the same as the cooling tower and H₂S facility. However, Bechtel's engineers, after observing the poor quality and saturated condition of the soil during site preparation activities, decided that there would be a danger of excessive settlements if piers were not used.

In accordance with the geotechnical consultant's recommendations, two feet of free draining granular fill will be used below all paving. Perimeter drains, a minimum of 10 feet deep, have been constructed. Drains will be provided to remove water from all granular fill zones.

CIRCULATING WATER SYSTEM

General

The circulating water system includes a cooling tower and basin, two intake structures, piping to the two circulating water pumps, condenser and two return lines to the cooling tower. The cooling tower is on a plateau 20 feet above the power block. The circulating water pumps are installed in-line, immediately ahead of the condenser. Butterfly valves are installed on each line between the pumps and the condenser.

Intake Structures

Two intake structures connect to the side of the cooling tower basin. Each structure channels the flow into one circulating water pipe line. The structures are reinforced concrete with sacrificial concrete similar to that in the basin. Slots are provided for screens and stop gates. A hoist and jib crane are provided for removal and replacement of screens and gates.

Piping

The circulating water lines are fiberglass reinforced plastic (FRP) pipe, designed for an operating pressure of 75 psig. Two intake and two discharge lines between the cooling tower and the power block are 42 inches diameter. Six risers adjacent to the tower are 30 inch diameter. Four 42 inch diameter stainless steel elbows, in lieu of FRP pipe, are embedded in the turbine building base mat at the inlet to the pumps and at the discharge from the condensers.

Cooling Tower and Basin

The cooling tower is a wood framed rectangular structure, 60 feet wide by 330 feet long. It is supported on the concrete cooling tower basin. The basin walls, piers and floor will include 2 inches of sacrificial concrete as a protection from the acidic nature of the water ($\text{ph} > 4.5$). The sacrificial concrete will be able to deteriorate without jeopardizing the integrity of the structure. Acid resistant grout pads will be used below each post to protect the concrete in these areas and to avoid damage to the tower from deterioration below the posts. High quality concrete, 5000 psi ultimate strength (fc'), will be used to minimize cracking.

DETAIL DESIGN ARCHITECTURAL

MATERIALS OF CONSTRUCTION

Exterior Walls

Exterior walls will be metal siding, consisting of prefinish exterior face sheets and insulated filled liner panels. A minimum U value of $0.045 \text{ Btu/hr/ft}^2/^{\circ}\text{F}$ shall be provided. Perforated liner panels shall be provided for acoustic treatment in noisy areas. Concrete where used as an exterior wall shall be unpainted.

Roofing

The roof shall be a continuation of the exterior wall incorporating equal to the wall. The roof shall have a minimum pitch of 3" in 12" to allow the roof to be self-cleaning of snow and rain water.

Interior

Interior materials and finishes shall be selected for their use and environmental exposure.

Floor Grating, Stairs and Handrails

All floor grating shall be galvanized steel. Galvanized non-skid type checkered plate flooring shall be provided over cable trays. Stair treads shall be galvanized grating with cast iron abrasive nosings. Handrails shall be steel pipe painted.

Coatings

All carbon steel surfaces not galvanized shall be either shop finish coated or field finish coated with a minimum of 2 coats of chlorinated rubber DFT 2:0 mils minimum to 4.0 mils maximum.

Chemical Resistant Paint

The bottoms of transformers, tanks and the condenser hotwell will be coated with a material specifically designed for the environmental exposure of the equipment. The floor and walls of the battery room shall be coated with a chemical resistive epoxy system.

Windows

Exterior windows fixed and operable shall have reflecting — insulating glass units.

Doors

Exterior equipment doors will be roll-up type chain operated. Man-doors will be hollow metal doors with pressed steel frames.

Control Room and Relay Room Area

A platform will be provided above the relay room approximately 12 feet above the operating level floor. This platform shall be capable of supporting air conditioning equipment or light storage load.

The control room shall have vinyl tile flooring and vinyl wall covering.

For sound control double glazing shall be provided at all windows looking out to the turbine generator. The control room shall have a suspended acoustic ceiling approximately 9 feet above the control room floor.

DETAIL DESIGN MECHANICAL

STEAM AND CONDENSATE SYSTEMS

The steam system begins at the property line which interfaces with the Union Geothermal Company. A nominal 36 inch steam line delivers saturated steam at 114 psia to the turbine-generator building where it splits into two nominal 24 inch lines which serve the turbine-generator. One line connects to the right hand turbine inlet strainer and the other connects to the left hand inlet strainer. A nominal 12 inch line furnishes auxiliary steam to the steam ejector system and the hydrogen sulfide (H_2S) abatement system. A nominal 1-1/2 inch line furnishes steam to the gland seal system. Gland seal steam is returned to the main condenser via a manually controlled valve and restriction orifice.

Steam enters the condenser through two 78.5 square foot openings at the top. The condenser is of a two-pass design featuring a unique gas removal system (described in the Design Features Section) to eliminate gas blanketing of the condenser tubes. The condenser is designed to handle a heat load of 796,300,000 Btu/hr at 4 inch HgA. 32,000,000 lb/hr of cooling water is delivered to the condenser through two 42 inch lines by two 50 percent capacity circulating water pumps at 70°F and returned to the cooling tower through two 42 inch lines at 96°F. The condenser hotwell has a capacity of 3,622 gallons.

Condensate is pumped from the condenser hotwell by the two 100 percent capacity condensate pumps. The condensate pumps are vertical dry pit, multistage turbine type. These pumps discharge the condensate into the 12 inch cooling water return header downstream of the condenser which returns to the cooling tower via the 42 inch cooling water return line.

GAS EXTRACTION SYSTEMS

The gas extraction system includes (1) the gas removal steam ejectors, (2) the ejector condensers and (3) interconnecting piping and valves.

The gas removal capability of the condenser is most important in a geothermal plant with its high level of non-condensable gases. This condenser incorporates a unique design that utilizes the cooler circulating water in the two pass gas removal section. Refer to the Design Features Section, Surface Condenser for a complete description of the condenser gas removal system.

Air and other noncondensables enter the condenser along with the steam and through leaks. These gases are removed from the condenser shell by four, 25 percent capacity first stage steam jet ejectors. The noncondensable gas plus water vapor (approximately 30,000 lbs/hr) plus driving steam (35,600 lbs/hr) are discharged to the intercondenser where the steam and water vapor is condensed and returned to the main condenser above the hotwell via a loop seal. Two second stage steam jet ejectors remove the noncondensate gases from the intercondenser. The noncondensable gases plus water vapor (36,000 lbs/hr) plus driving steam (39,200 lbs/hr) are discharged

into the after condenser where the steam and water vapor is condensed and returned to the main condenser above the hotwell via a control valve. The noncondensables from the after condenser are discharged to the hydrogen sulfide abatement system through a 12 inch line at an over-pressure of 2.15 psi or approximately 12.75 psia.

The intercondenser is a horizontal shell and tube bundle two pass with 22 BWG, 304 stainless steel tubes. The shell and water boxes are 304L stainless steel, the channel covers are carbon steel with the inner surface clad with stainless steel.

The after condenser is a horizontal shell and tube bundle single pass with 22 BWG, 304 stainless steel tubes. The shell and water boxes are 304L stainless steel, the channel covers are carbon steel with the inner surface clad with stainless steel.

REINJECTION

The cooling tower blowdown returns to the Union Geothermal reinjection system via a 6 inch line. The 0.5 gpm of waste from the hydrogen sulfide abatement system is also returned to the reinjection system through the same 6 inch pipe.

HEAT SINK SYSTEM

The heat sink system includes (1) the cooling tower, (2) the circulating water pumps, (3) the condenser, (4) the ejector condenser, (5) the hydrogen coolers, (6) the lube oil coolers, (7) EHC coolers and (8) air compressor coolers.

The cooling tower/cooling water system removes that portion of heat from the station cycle which is rejected to the condenser by the condensation of turbine exhaust steam. The cooling tower also removes heat from water used in the cooling of various station components such as the lube oil coolers, ejector condenser and hydrogen coolers.

Water at approximately 70°F is circulated by the two circulating water pumps through the cooling water system piping. Heat transfer takes place at the various station components as mentioned above. The heated cooling water then flows back to the cooling tower, enters near the top, and cascades down the tower into a concrete basin at the bottom. Air is drawn through the sides of the cooling tower, through the vertically cascading water, and out through the top of the towers by fans located at the top of the tower. The heat is transferred from the water to the air by means of convection and evaporation.

The cooling tower is a field erected, mechanical-draft, multiple cell, wet type tower. The design parameters are as follows:

Approach	14F
Range	26F
Wet-Bulb Temperature	56F
Dry-Bulb Temperature	70F

"Approach" is the temperature difference between the cooled water leaving the cooling tower and the wet-bulb temperature of the air entering the cooling tower. "Range" is the temperature difference between the cooling water entering and leaving the cooling tower. The tower is fire protected with a deluge sprinkler system.

The concentration of impurities in the cooling water is limited by cooling tower blowdown. The blowdown will be activated when high cooling water level is sensed. Since the condensate generated is greater than the water lost through evaporation, the impurity build-up is a function of the blowdown rate not concentration of impurities.

Two 50 percent capacity circulating water pumps are provided. The pumps operate in parallel to provide circulating water to the condenser. Each pump is rated to deliver 36,000 gpm of 70°F water at 40 feet of water with a 500 HP motor. The pumps are of the single stage, mixed flow, vertical type.

The ejector condensers, the hydrogen cooler, the lube oil coolers, EHC coolers and air compressor coolers are all installed in parallel with the condenser. The designed cooling water side pressure drop through each of the above mentioned components is less than that through the condenser. This feature facilitates control of cooling water flow through these heat exchangers simply by throttling their downstream butterfly valves. Therefore, separate pumps to induce flow water through these heat exchangers are not required.

SERVICE WATER SYSTEM

A 20,000 gallon capacity vertical cylindrical fiberglass reinforced plastic tank is installed to provide the necessary service water reserve for plant uses. An air cushion pressure tank furnishes the system pressure. The lead service water pump is activated upon low water level in the pressure tank. The plant water supply is to be provided by motor transport which will be partially augmented by an off-site water well if the well development proves successful.

FIRE SYSTEMS

The Power Building and site area is supplied with a fire protection system to combat the station's fire risks. An underground fire water loop complete with dry barrel hydrants and hose houses are provided at strategic locations to assure complete coverage of the area. Fixed pipe, water spray systems are provided in the turbine lube oil reservoir, oil conditioner and hydraulic power unit area, the hydrogen cooling and storage areas, the seal oil area, over the transformers and within the cooling tower. The water spray systems will be supplied from the underground fire water loop and are of the dry pipe design.

Fire hose cabinets and portable fire extinguishers are placed at strategic points throughout the power house building. A fire and smoke detection system for spray system actuation and alarm is provided complete with control room annunciation board. In addition, the relay room is provided with a Halon 1301 fire suppression system.

Fire water is supplied to the underground fire water loop by one of two fire water pumps located within the power building structure (one pump in standby). Each pump is sized for the station's largest single fire risk and will take suction via a direct suction line from the cooling tower basin. A backup water source is provided from the service water storage tank and the Union Geothermal reinjection system.

PLANT HEATING, VENTILATING AND AIR CONDITIONING

Comfort conditioning is provided in areas constantly in use by plant personnel. Heating and ventilation only is provided for the remaining enclosed areas of the power house structure. The control room, relay room, administrative offices, lunch room, instrument shop, chemical lab and mech./elec. office will be maintained at a temperature of 75°F; the remaining portions will be kept at a minimum temperature of 50°F.

The combination heating and air conditioning system (comfort conditioning) mounted atop the relay room is composed of a 5 ton centrifugal refrigeration machine supplying chilled water via a 1/2 HP circulating pump to a fan coil unit equipped with a 40 kW electric duct heater. The air handling unit is fitted with an outside air supply duct complete with activated carbon filters, a return air mixing plenum and air distribution fan. Supply and return air distribution ducting is sized to adequately handle the flow of air to and from the areas served. Duct terminations are fitted with ceiling diffusers, complete with dampers for air flow balance. Temperature level is controlled by centrally located manually adjustable wall mounted thermostats.

Ventilation and heating for the switchgear/motor control center room and the battery room is provided by individual air handling units one serving each room. The fan coil unit is located remote from the switchgear room with distribution ducting to the points of discharge and mounted within the north wall of the battery room with direct discharge into the room. Each fan coil unit is complete with electric heating elements and utilize 100 percent outside air supply entering the units through activated carbon filter banks. The spent air is exhausted from these rooms by wall mounted propeller fans discharging through the south wall of the plant structure.

Ventilation and heating for the machinery areas of the plant structure is provided by four (4) fan coil units located upon a platform structure erected above the bottom chord of the building roof truss system. These units, complete with electric heating elements, air distribution fans and inlet air filters, are supplied outside air from two air inlet ducts each supplying two machines and emanating from the north side of the structure at eave height. Air discharging from the units is distributed through ducts to each floor of the building near the east and west walls to assure the best possible coverage. Exhaust air is discharged from the plant area by four wall mounted belt driven propeller fans located in pairs in the east and west ends of the building directly below the roof line.

Ventilation fans are provided for the toilet room areas in accordance with building code requirements.

H₂S ABATEMENT SYSTEM

The hydrogen sulfide abatement system is designed based on the patented "Holmes-Stretford" process licensed by Peabody Process Systems. The system consists of a knock-out drum, venturi gas scrubber, absorber, reaction tank, oxidizer tanks, air blowers, sulfur froth tank and all necessary pumps, filter, controls, piping, chemical storage, and other appurtenances necessary for the process.

The gas entering the H₂S abatement system consists of the following:

Component	Quantity
CO ₂	29,562 lbs/hr
H ₂ S	215
N ₂	57
H ₂	3
CH ₄	3
Water Vapor	2183
Air	60
Total	32,084 lbs/hr

The noncondensable gas enters the knock-out drum where excess moisture is removed. The gas is next scrubbed in the venturi scrubber and then transferred to the absorption tower where it is mixed with an alkaline Holmes-Stretford solution. A holding tank in the lower section of the tower gives the solution the necessary residence time to complete the reaction. The reduced liquor containing the elemental sulfur then flows to the two oxidizer tanks operating in parallel in a low concentration sulfur slurry state. Here air is blown through the liquor to restore the vanadium to its pentavalent form where the sulfur is separated by floatation as a thick froth on the surface of the liquid. This froth is skimmed off the oxidizers, filtered and washed to produce a wet cake of sulfur to be stored in the sulfur pit. The clear liquid beneath the froth in the oxidizer tanks which consists of the oxidized Stretford solution is recycled to the absorption tower. Compressed air for the oxidizer tanks is provided by positive-displacement rotary air blowers.

The oxidized and clarified Holmes-Stretford liquor flows by gravity from the oxidizer tanks to a pump tank which serves as a reservoir of Stretford liquor for the system and as a pump suction tank for recycling the solution back to the absorption tower.

The sulfur froth from the top of the oxidizer tanks overflows to an agitated slurry tank fitted with slurry pumps for transfer of the slurry to a centrifugal filter system which discharges the sulfur as a wet cake containing approximately 50 percent solids by weight. This sulfur cake is dumped into a reslurry tank where it is again placed into a slurry condition and then pumped through a melter where it is heated to about 280°F. The sulfur melts and separates from the water in a decanter. The water phase is flashed and sent back to the reslurry tank and the molten sulfur is sent to the storage tank (approximately 30 days storage) to await shipment from the plant site.

Since the chemical reactions involved in the process generate water, this water must be removed in order not to dilute the Holmes-Stretford liquor. This is accomplished by running a side stream from the main liquor loop through an evaporator to dispose of this excess water. Further, to maintain a stable liquor circulating temperature, a heater/cooler is installed to compensate for seasonal temperature variations.

The plant consists of tank yard composed of the knock-out drum, venturi scrubber, oxidizer tanks, slurry tank, the sulfur storage pit and the sulfur loading station. Adjacent to the tank yard is a single story building (50 x 65 feet) with a filtration mezzanine which houses the blowers, pumps, chemical solution preparation equipment, chemical storage and electrical switchgear.

The liquid waste from the H_2S abatement system ties into the cooling water blowdown discharge line and returns to the reinjection system. The purge rate is 0.5 gpm. The chemical components of the waste are listed below:

Component	Percent by Weight
ADA	0.16
$NaVO_3$	0.75
Na_2CO_3 (equiv.)	1.18
Na_2SO_4	7.10
$Na_2S_2O_3$	15.81
Water	75.00
	100.00

COMPRESSED AIR SYSTEM

A compressed air system is provided to supply plant instrument air as well as plant service air. The system consists of two double acting single stage water cooled compressors equipped with nonlubricated cylinders to assure instrument-quality oil free air. A single receiver is provided for the compressors. The discharge of each compressor is manifolded into common supply headers adequately valved to offer complete flexibility in the supply of both instrument and service air. The instrument and service air supply headers are equipped with air dryers and air filters to alleviate water damage to all pneumatic equipment served.

EMERGENCY GENERATOR

An emergency generator unit will be installed within the power building to provide essential electrical services in the event of system power failure. The emergency generator will be of sufficient capacity to support the fire pump(s), air compressor(s), battery chargers, HVAC Systems, electrical heat tracing system, emergency lighting and the communication system.

The emergency generator will be driven by a turbocharged, water cooled diesel engine and will be complete with fuel storage and supply system, batteries and battery charger and generator and engine control panel. Sufficient fuel storage is provided to maintain the unit in continuous operation for seven (7) days.

SYSTEM INTERFACE

A project interface document has been prepared to define the interfaces between Bechtel-PNM and Union to maintain the necessary engineering information required to insure proper plant boundary interconnection of steam supply, reinjection water, drainage and electrical power. Each point of interface is defined by location, pipe or conduit size and flow requirements.

DETAIL DESIGN INSTRUMENTATION AND CONTROLS

GENERAL

Control and instrument devices are provided in the control room to allow automatic or manual control for on-line operation, and normal shutdown of the major plant equipment; i.e., turbine-generator, cooling tower fans, condenser, ejector condensers, air compressors, circulating water pumps, condensate pumps, service water pumps, and fire water pumps. Turbine start is manual from the Steam Turbine Control insert panel located on the control console. Immediate actions necessary to minimize personnel hazard or major equipment damage will be taken by automatic systems. Actions necessary to complete a shutdown or initiate a startup are to be taken by the operator. Standby equipment will be put into service automatically wherever practicable to maintain continuity of service. Local control boards, such as for the H₂S abatement system, emergency diesel generator, generator hydrogen control, and instrument air compressors, complete with alarm annunciation, are provided and are located in the system area. Minor auxiliary equipment that is normally in continuous or automatic operation or used only for maintenance will be controlled from local control stations only.

CONTROL CONSOLE AND AUXILIARY BOARD

Miniaturized control and instrument devices are used on the control room control console to assure maximum reliability. The size and location of devices on the console will allow the operator to view the alarms and major variables while seated at the operator's desk. The control console is a bench type for operation by a standing operator. Voltages over 125 volts and steam, water, or gas are not used in the control room.

A vertical auxiliary board will be located in the east control room wall. Indicating, recording, and protective devices related to the turbine-generator, as well as control devices for switchgear and switchyard, and the mimic bus, will be mounted on this board. Rear access to the auxiliary board will be from the relay room, with the protective relays, turbine and generator temperature recorders located on the rear of the auxiliary board.

LOCAL CONTROL BOARDS

Major service systems are provided complete with local control boards by the vendor of the system equipment. These will include:

- H₂S Abatement
- Generator Static Exciter Regulator
- Generator Hydrogen Control
- Generator Seal Oil Control

- Turbine-Generator Lube Oil Reservoir
- Turbine EHC System
- Instrument Air Compressors
- Instrument Air Dryers
- Water Sample System

Local instruments and controls will be installed individually wherever practicable.

TURBINE CONTROL SYSTEM

The electro-hydraulic control (EHC) system is provided for start and on-line control of the turbine from the control board insert panel. The electro-hydraulic control system will include high pressure hydraulic pumps, controls, reservoir, with the associated governors, speed/load changers, speed relays and trip devices. Two remote pushbuttons mounted on the Steam Turbine Control insert panel will allow remote turbine tripping. These manual-remote pushbuttons along with the other protective devices will deenergize two electro-hydraulic devices to dump the control pressure and close the turbine stop valves.

The generator static exciter regulator unit for regulation of the generator voltage is located in the switchgear room.

A local hydrogen control cabinet will be provided to control the H₂ and CO₂ generator system. A local control panel for the generator seal oil system is located directly below the generator. A set of supervisory instruments will be provided for control room mounting to allow monitoring of normal operation and shutdown.

The turbine lube oil reservoir is provided with a local control panel for indication and testing of the automatic pump controls. The electro-hydraulic control power unit is provided with a local control panel for indication and testing of the automatic pump controls.

ANNUNCIATION SYSTEM

An annunciation system will be provided to give trouble information by visible and audible indication on the control console and auxiliary board. The windows will be arranged logically and in relation to the adjacent control board devices wherever possible.

The annunciator system will be of the illuminated-window type with approximately 152 windows, with 80 windows on the auxiliary board and 72 windows on the control console, each about 1-1/2 by 3 inches in size. The system logic is the solid-state type. Two 120 volt ac power sources are provided from the 120 volt regulated ac system and the station inverter with diode load sharing in the system cabinet.

A repeating alarm chime and silencing, resetting, and testing pushbuttons will be located on the control console and auxiliary board. It will be possible to relamp individual windows without disturbing the other windows.

The annunciator logic, terminations, and power conditioning equipment is located in system cabinet in the relay room.

Local annunciators will provide detailed information on trouble in systems such as the generation hydrogen system. Trouble in such systems will be indicated repeatedly in a window of the control room annunciator to draw attention to the local annunciator.

The annunciator system has first-out capability and provision to alarm remotely.

FIRE PROTECTION SYSTEM

The water spray systems and fire detection and alarm system controls, indication and alarms are located on a monitor panel installed on the south wall of the control room. The Halon 1301 fire suppression system controls, indication and alarms are located on a control panel installed adjacent to the fire protection monitor panel. All fire protection systems are provided by the vendor as a completely engineered, fabricated, installed and checked out system.

WATER SAMPLING SYSTEM

A water sampling system complete with sample pressure and temperature conditioning, flow control, analyzers, recording and alarm devices is provided for three input sample streams. The sample streams are analyzed for conductivity, pH, and in some cases H₂S content. The system is located on grade elevation southeast of the condenser.

STANDBY DIESEL GENERATOR

The standby diesel generator is provided with a local control panel containing automatic starting controls, loading controls, protective devices, and alarm annunciator. The diesel generator is automatically started on loss of the 480 volt vital MCC breaker with synchronizing and loading accomplished at the local control panel.

POWER PLANT MONITORING INSTRUMENTATION

The performance data for this geothermal plant will be prepared and made available for distribution by PNM's data subcontractor WESTEC. Early in the project design phase, PNM and WESTEC determined the plant performance parameters to be monitored and the method and frequency of monitoring, all required monitoring instrumentation has been incorporated into the plant design.

DETAIL DESIGN ELECTRICAL

MAIN POWER

The generator 13.8 kV power is distributed to the low voltage side of the Main Transformer via 3000 ampere nonsegregated phase bus duct and a Generator Circuit Breaker. The main transformer is sized to transmit the maximum output power of the turbine generator, less the minimum anticipated auxiliary system load. The maximum possible output of the turbine generator at maximum anticipated steam conditions is 55 megawatts at 0.9 power factor; the minimum auxiliary plant load is anticipated to be 3 megawatts. The main transformer is therefore rated at 55.4/62 MVA at 55/65C temperature rise. Power is stepped up to 115 kV (nominal) and connected by an overhead span to the switchyard. The voltage rating of the main transformer is 13.2-115 kV, with 5-2-1/2 percent full capacity taps, two above and two below normal.

PLANT AUXILIARY POWER

The auxiliary transformer is rated at 4.5/5.6 MVA OA/FA at 55C, and 5/6.25 MVA OA/FA at 65C, 13.8/4.16 kV with 5-2-1/2 percent taps, two above and 2 below normal. A 1200 amp bus duct tap connects the high voltage side of the Auxiliary Transformer to the main 3000 amp duct. This allows plant power to be obtained from the 115 kV source with the generator breaker open, and from the generator when the plant is operating and breaker closed. The auxiliary transformer is sized to carry the full plant auxiliary load, with approximately 15 percent spare capacity for future loads. The secondary of the transformer is connected by nonsegregated phase bus duct to the plant 4160 volt switchgear through a main drawout circuit breaker. Loads connected to the 4160 volt bus include the circulating water pump drivers, the Union Geothermal reinjection pump drivers, and a single-ended 4160/480 volt loadcenter substation. The loadcenter transformer is rated at 2500/3125 kVA OA/FA at 65C, having sufficient capacity to energize all the plant 480 volt loads, with about 10 percent spare capacity. The 480 volt plant loads are all supplied from seven (7) motor control centers connected to the loadcenter feeder circuit breakers, which are all 800 ampere frame drawout air circuit breakers.

An emergency 480 volt bus, which feeds the plant vital loads, is supplied from a backup 500 kVA offsite source and a 360 kW diesel engine generator. Upon failure of the normal plant ac system, the vital loads will automatically be transferred to the offsite back-up source, and the diesel generator will start. Should the back-up source fail, the diesel generator will be connected to the vital loads. The vital loads include two fire pumps, one service water pump, the plant battery chargers, essential lighting, a back-up source for the plant vital instrumentation loads (normally fed from the plant dc battery through a solid-state inverter), and various small but important loads, such as the diesel generator fuel transfer pump, the plant communications system and the main turbine turning gear driver. The plant dc loads are fed from a 125 volt station battery, with main and back-up battery chargers. DC loads include the switchyard control power, plant switchgear control power, emergency oil pump, plant inverter, plant annunciator system, and the plant emergency lighting system.

RACEWAYS

All external cabling is routed via underground duct. Within equipment areas outside the power block, cables are routed in conduit suitable for the area involved.

Cabling inside the power building will be routed in cable tray or conduit as required. Cables will be installed in trays arranged as follows:

Power — Top Tray

Control — Middle Tray

Analog/Digital (Low Signal) — Bottom Tray

Analog and digital cables will be separated by a 3-inch metal barrier.

Cable tray fill will be limited to 30 percent of the tray capacity for power trays, and 40 percent of the tray capacity for control trays. Ampacities of cables in trays will conform to the requirements of ICEA publication P-54-440.

CABLE AND WIRE

Multiconductor cabling is used to the maximum extent possible and with the number of different cable types kept to a minimum.

All cables are flame retardant per IEEE Standards and sized per IPCEA Requirements for the particular service.

COMMUNICATIONS

The plant communicator system will be a combination page/intercom system, with conduits only for the installation of public telephones.

PLANT GROUNDING

The plant will be grounded by means of a grid of copper wire interconnected to a counterpoise copper cable around the perimeter of the plant. The building steel, the perimeter fence, switchgear and panel ground busses, the 480 volt loadcenter transformer neutral, the 4160 volt neutral grounding resistor, the 115 kV transformer neutral and surge arrester grounds, and the cooling tower lighting arrester grounds are all connected to this ground grid.

PLANT LIGHTING

Plant lighting has been designed using high pressure sodium, fluorescent and incandescent fixtures. Exterior lighting is supplied by 480 volt feeders installed below grade. Interior ac lighting is fed through dry type transformers and lighting panelboards at 120 volts from motor control centers. DC emergency lighting will be installed in the control room, the diesel generator room, and at stairways, entrances and exits which could be hazardous in a sudden power failure. Designed lighting levels in the plant are as follows:

Area	Illumination Levels, ft candles
Shop, TG Bldg., El. 100	100
Warehouse, TG Bldg., El. 100	30
Chemical Lab, TG Bldg., El. 100	100
Mech./Elect. office, TG Bldg., El. 100	100
Floor area, TG Bldg., El. 100	30
Lunch room, TG Bldg., El. 115	50
Instrument shop, TG Bldg., El. 115	100
Offices, TG Bldg., El. 115	100
Battery room, TG Bldg., El. 115	20
Switchgear room, TG Bldg., El. 115	50
Floor area, TB Bldg., El. 115	20
Relay room, TG Bldg., El. 130	50
Control room, TG Bldg., El. 130	100
Floor area, TG Bldg., El. 130	80

DETAIL DESIGN PERFORMANCE

1.	Turbine Generator Output at Generator Loads	50,000 kW
2.	Auxiliary Power	
	H ₂ S Abatement System	187 kW
	HVAC	240
	Cooling Tower Fans	608
	Circulating Water Pumps	656
	Miscellaneous Pumps, Compressors, etc.	90
	Miscellaneous Lighting, etc.	65
	Auxiliary Transformer Losses	38
3.	Step-up Transformer Losses	185
		2,069
	H. = Net Power to High Voltage Line	47,931
4.	Geothermal Steam Consumption/NKW = $\frac{925,100 \text{ lbs/h}^*}{47,931} = 19.30 \text{ lbs/NKWH}$	

TURBINE GENERATOR PERFORMANCE

Turbine entry pressure (psia)	} Inlet of steam strainers	113
Turbine entry temperature (F)		337
Steam flow (lbs/hr)		849,800
Expansion efficiency (percent)		75.7
Mechanical losses (percent)		1.9
Generator efficiency (percent)		98.7
Turbine back pressure (inches Hg absolute)		4

CONDENSER PERFORMANCE

Condenser pressure (inches Hg absolute)	4
Condensate flow (lbs/hr)	894,230
Extracted gases (includes water vapor (lbs/hr))	25,476

*Includes 74,800 lbs/hr ejector steam

Cooling water flow (lbs/hr)

32,000,000

COOLING TOWER PERFORMANCE

Range (F)

26

Approach (F)

14

Design wet bulb temperature (F)

56

Design dry bulb temperature (F)

70

Circulating water pumps flow (lbs/hr)

35,879,370

MASS FLOW BALANCE

Geothermal Steam Consumption (lbs/hr)

925,100

Cooling Tower Water Consumption (lbs/hr)

773,330

Noncondensables (lbs/hr)

27,738

Condensate Reinjection (lbs/hr)

120,910

H₂S Abatement Steam Consumption (lbs/hr)

500

DESIGN FEATURES GENERAL

During the evolution of the detail design, certain particular circumstances or conditions impacted the design; sometimes with adverse affects and sometimes these adverse affects have been turned around through innovative design and have resulted in advantageous design concepts.

Certain concepts foreign to conventional steam power plant design have been introduced to cope with the presence of hydrogen sulfide.

The extensive use of fiberglass reinforced plastic pipe is also a throw off of the presence of H_2S and chlorides.

H_2S emission is discussed and its concentrations leaving the cooling tower stack are compared with the permissible H_2S concentration in New Mexico.

In addition, other points of interest in the course of the design are discussed in this section.

A listing of the topics of Design Features is as follows:

- Circulating Water Pump and Condenser
- Condenser Design
- Clean Room
- Circulating Water Concentrations
- Maintenance Facilities
- Control Room Facilities
- Use of FRP Pipe and Tanks
- Anticipated H_2S Distribution
- Gas Removal
- Plant Water and Chemical Balance
- Plant Color Selection
- Effect of Altitude on Electrical Components
- Advantage of the Flash Design
- Turbine Generator/Steam Gathering Field Response
- Turbine Blowoff Piping
- Material Selection

DESIGN FEATURES CIRCULATING WATER PUMP AND CONDENSER

AFFECT OF SITE DEVELOPMENT

The development of the site had an interesting effect on the location selection of the circulating water pump at the Baca plant.

In turn, the location selection of this pump had an advantageous affect on the final design of the condenser respective to its ability to collect the hydrogen sulfide containing condensates as further discussed herein.

The geographic location caused the power plant to be built in part against a hill, being the assigned power plant site on the privately owned Baca Ranch.

Notwithstanding the soil problems encountered by the hillside location, the following gains were made during the evolution of the Baca design:

- To effect an economical site layout, two levels were developed, one for cooling tower and one for power plant, H₂S Abatement and Switchyard. The difference in the two levels, approximately 20 ft., enhanced locating the circulation water pump inside the power building and provided the pump with some 20 ft. of static suction head resulting in ample available NPSH.
- The vertical, mixed flow, circulating water pump was made an integral part of the circulating water conduit to the condenser and placed inside the power building. The otherwise separate pump structure and associated support facilities were eliminated and the intake structure was substantially simplified. This design approach resulted in the most economical pump arrangement.
- Another advantage of this design is that the system is self-priming and pump operation is precluded until complete priming has been accomplished. Consequent hydraulic transients or pumps are constrained or kept minimal.
- The pump being inside the power building facilitates maintenance and pump overhaul.
- Space requirements for housing the pump are minimal as a result of making the pump part of the circulating water conduit.
- The waste heat of the pump motor provides part of the power building heat in the winter time.
- The location of the pump forced a high inlet connection on the condenser. This condition was optimized by the condenser manufacturer who devised a steam path and gas path inside the condenser permitting the collection of the H₂S gas laden condensate on trays in the upper part of the condenser. This condensate can be kept separate from the hotwell condensate and, if necessary, it can be returned directly to the reinjection system thereby keeping the cooling tower makeup of the lowest H₂S concentration possible.

In summary, the advantages can be listed as follows:

- High available NPSH for circulating pumps
- Most economical circulating water pump arrangement
- Indoor pump maintenance and overhaul
- Self-priming circulating water system
- Pump motor waste heat warms power building
- New condenser design permitting collection of H_2S laden condensate, if necessary
- Pump space requirements minimal
- No separate pump crane or hoist required

The moral of the story is "make the hill work for you."

DESIGN FEATURES CONDENSER DESIGN

SURFACE CONDENSER

The purpose of this special design of geothermal surface condenser is to employ features for the removal of the high level of noncondensable gases, and which will limit and reduce, as much as possible, the tendency for the hydrogen sulfide to go into the condensate in the main condenser.

The attached sketch shows a cross section end view of the tube bundles for the BACA condenser. The steam and gases enter the tube bundles at the sides and at the bottom so that the falling condensate is in opposite direction to the steam as far as it is possible to do so. The gas vapor outlet is at the top of the tube bundles. The two pass water circuit has the cold water pass around the periphery of the tube bundle and the warm water pass through the center of the tube bundles. The gas vapor mixture leaves the tube bundles along the full length of the condenser, enters the gas vapor duct, and is then discharged to the gas removal ejector equipment. The gas cooling section of the condenser is in the cold water pass. The condensate drain trays in the residual and gas cooler areas of the condenser have means for separately draining off the condensate in these areas of possible high hydrogen sulfide concentration. Although this has no bearing on the special geothermal design requirement of keeping the hydrogen sulfide in the condensate to a minimum, the condenser has a patented method of supporting the tubes along their length without the need for conventional tube support plates.

The advantages of this design over a conventional surface condenser are:

1. The maximum gas concentration is in contact with the least condensate flow which will result in minimum contamination of hydrogen sulfide in the main body of the condensate.
2. The condensate from this area of high gas concentration can be separately led outside the condenser for separate treatment, if necessary.
3. The first water pass (i.e., the cold pass) occurs at the periphery of the tube bundle where the gas concentration is the least (i.e., the maximum condensation rate occurs with the steam having the least gas concentration).
4. The gases do not cascade to the cold end of the condenser where, not only is the gas concentration the greatest, but where the condensate is most likely to be subcooled or be subjected to depression. Instead, venting is all the way along the length of the condenser from each compartment and directly into the gas vapor duct; therefore, only a minimum of gas comes in contact with the condensate formed and dropping from the tubes.
5. Since falling condensate is generally in the opposite direction to the steam flow, maximum stripping of condensate will occur with the hottest steam, which also has the minimum gas concentration.

6. Particular care has been taken by the condenser manufacturer to effect a path of continuous sweeping action to route the gases to the gas off-take. This is of major importance to handle the large quantities of noncondensable gases.

Continuous sweeping is also very important to avoid gas blanketing or pocketing of the tube bundle over the entire length of the bundle. The radical departure from the conventional design to deal with the large volume of gases shows indeed a lot of promise.

SKETCH OF GEOTHERMAL CONDENSER
(SURFACE TYPE - TWO WATER PASS)
PUBLIC SERVICE OF NEW MEXICO - BACA

DESIGN FEATURES CLEAN ROOM

Hydrogen sulfide gas (H_2S) has a deleterious effect on equipment that contains components made of copper, copper alloys or silver. The H_2S attacks these materials and replacement is necessary in a relatively short period of time. Electrical equipment, control and instrumentation devices usually contain the materials susceptible to H_2S attack and alternate materials are generally not available.

To minimize this problem, a clean room approach has been incorporated in the design. The plant control room, relay room and office complex are provided with filtered, temperature and humidity controlled air from the plant heating, ventilating and air conditioning equipment. The electrical switchgear room is provided with filtered and heated air from the plant heating, ventilating and air conditioning equipment. Both areas utilize replaceable inlet air filters of the activated charcoal type suitable for the removal of a mildly contaminated atmosphere containing a maximum of 10 ppm of H_2S gas.

Therefore, the control console, auxiliary control panel, and fire protection supervisory panel — all equipment located in the control room — are protected from the effects of the H_2S atmosphere. The STC, Annunciator, Switchyard Control and Interposing Logic systems cabinets as well as the rear of the Auxiliary Control Panel are located in relay room subject to the clean room design protection. The Generator Static Exciter Regulator, 4 kV switchgear, 480 V Plant Auxiliary Loadcenter, Generator Breaker, Vital and Auxiliary Bus Controls, and Battery Chargers are located in the switchgear room subject to the clean room design protection.

This clean room design allows the use of standard design electrical, instrumentation and control equipment with resultant cost savings. Furthermore, these plant areas are maintained at a slight positive pressure to prevent the influx of mildly contaminated atmosphere.

DESIGN FEATURES

CIRCULATING WATER CONCENTRATIONS

The only source of makeup water for the circulating water system is the condensed steam from the unit hotwell. The chemistry of the circulating water system will be a function of the condensate chemical concentrations, the evaporation rates from the cooling tower and the available volumes of condensate for system makeup.

In order to maintain the optimum circulating water chemistry, the total available condensate will be used for circulating water system makeup. Therefore, the circulating water chemistry will vary depending upon the seasonal evaporation rates assuming that the steam chemistry does not vary and that the unit is base loaded.

Tables 1 and 2 give the condensate composition and the anticipated circulating water compositions based upon the summer and winter cooling tower evaporation rates. The chemistry is a direct result of the flows of Table 3. Blowdown will be used to maintain the cooling tower basin level with the required rate varying as a result of tower evaporation rates. The anticipated blowdown rates are 238 gpm in the summer and 763 gpm in the winter.

Potential fouling constituents normally of concern in circulating water systems are calcium carbonate, calcium sulfate, heavy metals such as manganese and iron, and silica. Accepted limits for these materials are:

• Calcium Carbonate	1,000 ppm at pH 8.0
• Calcium Sulfate	2.5×10^6 ion product
• Manganese	1.0 ppm
• Iron	5.0 ppm
• Silica	150 ppm

As long as these limits are not exceeded, the proposed method of operation can be maintained with a minimum of condenser tube fouling. An examination of Table 2 shows that limiting constituents with summer conditions are silica and iron. However, in all cases, the limits are not exceeded.

The calcium carbonate and calcium sulfate concentrations are well within the allowable solubilities and should not, even with significant condensate concentration increases, present scale formation problems. Manganese is not indicated as being present. Iron concentrations are within the accepted limit and up to 10 chemical concentrations could be carried without expecting fouling problems. If iron or manganese deposition were to become a problem, chemical dispersants could be utilized to control the deposition and permit carrying the metals in suspension for disposal by blowdown. A chemical feed system — including a dilution tank, metering pump, agitator, controls and piping — would be required to feed the dispersant.

Increases in condensate silica concentration and the resultant increase in the concentrated circulating water could present scale formation problems. With the contract steam limit of 15 ppm silica up to 10 chemical concentrations could be maintained without exceeding the accepted limit of 150 ppm. Since the maximum anticipated summer concentration factor is 7.2, silica scale should not present a problem. However, if silica concentrations increase and a low silica outside water source is not available as a supplemental makeup supply, two alternatives exist for controlling condenser tube scale formation.

First, the use of a chemical scale inhibitor may permit carrying silica concentrations to 250 ppm before scale formation. A chemical feed system consisting of a dilution tank and metering pump would be required to implement this program.

Secondly, if scale inhibitors are unsuccessful or if the silica concentration exceeds 250 ppm, warm lime treatment of either the condensate before introduction to the cooling circuit or a portion of the circulating water as it is discharged from the condenser would be required. The treatment system would be sized based upon the quantity of silica to be removed and could consist of a lime softener with associated chemical storage, tanks, pumps, controls and piping. The actual point of treatment would be determined, if required, by a detailed study.

Table 1

CONDENSATE COMPOSITION

Barium, as Ba	0.05 ppm
Calcium, as Ca	0.28 ppm
Iron, as Fe	0.47 ppm
Magnesium, as Mg	0.095 ppm
Sodium, as Na	12.4 ppm
Potassium, as K	1.4 ppm
Arsenic, Boron, Lithium and Strontium, as As, B, Li and Sr	0.428 ppm
Bicarbonate, as HCO_3	3.3 ppm
Chloride, as Cl	15.1 ppm
Fluoride, as F	0.2 ppm
Sulfate, as SO_4	8.7 ppm
Total Dissolved Solids	42.4 ppm
Silica as SiO_2	7-15 ppm
Turbidity	1.9 JTU
pH	4.8

Table 2

CIRCULATING WATER COMPOSITION

	Summer, ppm	Winter, ppm
pH	> 4.5	> 4.5
Suspended Solids	< 50	< 50
Barium, as Ba	0.36	0.11
Calcium, as Ca	2.0	0.62
Iron, as Fe	3.4	1.03
Magnesium, as Mg	0.68	0.21
Sodium, as Na	89.3	27.3
Potassium, as K	10.1	3.1
Arsenic, Boron, Lithium and Strontium, as As, B, Li and Sr	3.1	0.94
Bicarbonate, as HCO_3	23.8	7.26
Chloride, as Cl	109	33.2
Fluoride, as F	1.4	0.44
Sulfate, as SO_4	62.4	19.1
Total Dissolved Solids	305	93.3
Silica, as SiO_2	50-108	15-33

Table 3

CIRCULATING WATER SYSTEM FLOWS

	Summer, gpm	Winter, gpm
Makeup Condensate	1,708	1,708
Cooling Tower Evaporation	1,470	945
Blowdown	238	763
Cooling Tower Cycles of Concentration	7.1	2.2

DESIGN FEATURES MAINTENANCE FACILITIES

The power building is equipped with a cab mounted, single trolley, double girder overhead class A bridge crane having a main hoist capacity of 40 tons and an auxiliary hoist capacity of 10 tons. This crane is capable of serving the Turbine-Generator, Circulating Water Pumps, Condensate Pumps and Electrical Switchgear Components during periods of maintenance and servicing. Equipment removal openings in the operating floor and at the mezzanine level have been so placed as to provide hoisting access to the bridge crane. Access to the crane cab is via a vertical ladder and access platform located in the northwest corner of the power building

An area of approximately 700 square feet located at grade elevation has been dedicated as the Shop Area in which will be installed various bench and floor mounted machines such as a lathe, grinder, drillpress, welding and plating equipment suitable for rebuilding, repairing or servicing various small plant components. This area adjacent to both the storeroom and truck entrance is equipped with a manually operated monorail hoist for material and equipment handling.

The northwest corner of the mezzanine floor level has been established as the Instrument Shop. This shop centrally located to all areas of the plant will be fitted with a work bench, records and book cabinet, standard office furniture and the necessary tools and devices for cleaning, repairing, adjusting, testing and calibrating the station instruments. The work bench will be equipped with electrical receptacles and both service and instrument air terminals for use by service people while engaged in their work.

DESIGN FEATURES CONTROL ROOM FACILITIES

The control room contains those facilities typically found in a fossil power plant except the boiler systems are deleted and the turbine cycle is very much simplified. A control console, auxiliary control panel and fire protection supervisory panel are located within the control room. This unit is designed for operation under control room operator's supervision. The presence of trained personnel at the plant during both normal and abnormal conditions will result in a high degree of plant availability. This method will provide the control personnel with control devices for operating plant equipment, operations monitoring and alarms.

The unit control room also contains a plant intercom and paging system as well as a telephone station for outside communications.

The fire protection supervisory panel provides the control, indication and alarm functions of this system in a central location for ease of operator action and interface with this important system. This panel also provides indication of fire detector alarms. Systems cabinets in the relay will be protected with a Halon 1301 fire protection system.

The control room north wall will contain a double glazed window for surveillance of the Turbine-Generator. The floor will be covered with asbestos floor tile. The suspended reflected ceiling will utilize acoustic tile and recessed light fixtures to maintain the desired lighting level of the control room. Sound attenuation within the walls will be provided and the walls will be covered with a vinyl wall covering designed to maintain the overall light levels of the control room.

DESIGN FEATURES USE OF FRP PIPE AND TANKS

In the preliminary design, there was an extensive usage of stainless steel pipe for lines that were to transport H_2S bearing fluids. It goes without saying that the cost of such installation, even though considered very durable, was of very high cost. Similarly, storage tanks were considered to be fabricated from carbon steel and subject to the regular maintenance associated with such application. The tank in question is the water storage tank, subject to very normal and not extreme conditions. During the evolution of the design, it was learned that the use of stainless compared to the use of fiberglass reinforced pipe would result in substantially more costly piping installations. As a rule of thumb, it was found that if a 10 inch pipe installation of normal complexity were to cost \$22,000 for 304 type stainless steel and \$30,000 for 316 type stainless, the fiberglass installation would result in a cost of approximately \$10,000 to \$12,000. This situation was further complicated by the fact that in order to provide for successfully welded joints, the low carbon stainless would have to be selected in order to prevent the phenomenon of inter-granular stress corrosion. This additional requirement further increased the cost of the stainless steel pipe installation.

The piping that was mainly subject to the above considerations was the in-plant piping not embedded in concrete or buried in the soil. In our design of the plant piping, the piping was segregated into the following categories:

- The underground piping for services such as:
 1. Plant, floor and equipment drains.
 2. Pipe for fire protection.
- Exposed plant piping.
- Circulated water piping.

Particular care was used for embedments in concrete. It was decided to utilize stainless steel embedments for critical services such as the Circulating Water Piping.

The application of fiberglass for the exposed plant was mainly for condensate from the hotwell and the drains of the inner and after condenser of the gas ejection system as well as the gas line that transports the noncondensables to the H_2S Abatement facility.

For the in-plant and exposed fire protection pipe, carbon steel pipe was used to ensure that the fire protection piping itself would not be damaged by a fire adjacent to the fire suppression system.

Although the fiberglass piping system for the in-plant exposed pipe was carefully weighed, the final selection for this piping was based on a savings of approximately \$200,000 over the cost of the alternative application of stainless steel piping. Once the basic selection of the fiberglass material has been made, other facets associated with this pipe's particulars respective to connections, drain and vent connections, bonded connections and flange connections were subjected to close scrutiny to ensure that the possibilities of weak links in the system were properly recognized.

and accounted for. The various methods available from the various manufacturers for connecting pipe ends differ, and it is believed that the method of one manufacturer is superior to another. Also, the wall thickness selected by the various pipe manufacturers varies to a great extent where certain manufacturers are producing fairly thin walls that are indeed capable of taking fairly high pressures. However, the capability of these thin wall pipes to withstand crushing loads is not as good as the ability of the heavier pipe wall.

A point of interest is that because of the resilience of the fiberglass pipe, the affect of water hammer is not as pronounced in this type pipe as can be expected in a pipe of steel manufacture. It is also noteworthy that the coupled pipe joint of certain manufacturers by bonding results in amazing capabilities in hoop strength as well as strength in the longitudinal direction.

It is these considerations that were taken into account in the selection of fiberglass reinforced piping for the Baca Power Plant.

As stated herein before, both the service water tank and the diesel oil storage tank were originally considered to be of carbon steel construction. However, after a cost comparison was made, the obvious benefits of filament wound fiberglass tank construction became evident. The glass tanks eliminate the need for grounding or cathodic protection and in the case of the above grade installation eliminates the need for periodic repainting.

It is believed that Baca in the use of fiberglass pipe and tanks can be considered a first for geothermal service.

DESIGN FEATURES ANTICIPATED H₂S DISTRIBUTION

HYDROGEN SULFIDE CONSIDERATIONS

The hydrogen sulfide (H₂S) content of the steam is anticipated to vary from 200 to 300 ppm. A typical steam quality analysis is shown in Table 1. The H₂S upon entering the condenser can either redissolve in the condensate or be removed as a gas through the gas ejector system.

A Stretford process is being installed to treat the gaseous H₂S emissions from the plant. Maximum H₂S partitioning (percent H₂S removed as a gas/percent H₂S dissolved in the condensate) in the condenser is required to make the most effective use of the Stretford system and to assure that condensate treatment for H₂S removal is not required. The H₂S partitioning is a function of the condenser design and the steam chemistry.

The condenser utilized for this project is constructed of the most advanced design currently available for geothermal service and assures the shortest residence time attainable. This makes it less likely that equilibrium conditions between the steam, gases and condensate will be established.

Even with the establishment of condenser equilibrium conditions, the steam chemistry is favorable for most of the H₂S being removed as a gas. The expected percentage of H₂S being present as a gas as opposed to the quantity dissolved as an alkaline sulfide is a function of the condensate pH. At a pH of 4, 98 percent of the sulfides are present as H₂S, at a pH of 7 approximately 33 percent, and about 1 percent at a pH of 8.7.

The Baca steam carbon dioxide gas concentrations and the lack of ammonia would verify the reported low pH value of 4.5 and indicate that the condensate pH value will be low.

With 215 ppm in the steam and operating at 55 mWe output, 5160 lbs/day of H₂S will enter the system. Assuming partitioning factors of 95/5 and 99/1 the distribution of H₂S between the condensate and the Stretford process are shown in Figure 1. Based upon the guaranteed 10 ppm effluent, the Stretford process will emit 7 lbs/day of H₂S. The cooling tower will potentially emit 258 lbs/day and 52 lbs/day with the two partitioning examples, at concentrations of respectively, 0.41 ppm and 0.08 ppm.

With a requirement to bypass the Stretford process, the gas will be sent to the cooling tower and admitted below the fan deck. The H₂S concentration in the fan stack under these conditions will be approximately 8.11 ppm.

These calculations are based upon G.E. turbine efficiency at maximum output. The 215 ppm concentration was selected based upon the gas loading as displayed in Paragraph G.22.2 of the PNM Scope of Work Document and upon the nominal design capacity of the Stretford Unit. It is to be noted however, that H_2S gas concentrations within the incoming steam supply as high as 300 ppm can be accommodated by the Holmes-Stretford Unit.

If, with operation, the required partitioning is not obtainable, treatment of the condensate for hydrogen sulfide removal may be required to meet environmental discharge restrictions. A number of treatment alternatives are available to remove hydrogen sulfide from the condensate.

The most reasonable alternative for retrofit from a practical and economic view is the hydrogen peroxide destruction method. This method is a chemical process operating in the liquid phase with iron used as a catalyst at approximately 1 ppm. Equipment required for the process includes hydrogen peroxide tanks and pumps, ferrous sulfate tanks and pumps, and possibly condensate filters. With this process, hydrogen sulfide effluent concentrations to less than 0.1 ppm can be obtained.

The condenser design permits removal of condensate from high gas concentration condenser areas for separate treatment outside the condenser, if required.

Pacific Gas and Electric is conducting tests on the hydrogen peroxide destruction method at the Geysers. Bench scale tests have demonstrated that the reaction can be accomplished in less than 5 seconds with a 2 to 1 hydrogen peroxide to hydrogen sulfide mole ratio. The preliminary tests have also demonstrated the use of a chelate such as hydroxy acetic acid effectively prevents the deposition of sulfur in the system thus possibly negating the need for condensate filters. The results obtained at the Geysers will be utilized as required.

Table 1
ANTICIPATED STEAM QUALITY

pH		4.5
Suspended Solids		7 ppm
Dissolved Solids		
Silica	SiO ₂	7–15 ppm
Bicarbonates	HCO ₃	5 ppm
Sulfate	SO ₄	2 ppm
Chloride	Cl	21 ppm
Sodium	Na	8 ppm
Potassium	K	3 ppm
Calcium, Magnesium, Barium, Boron, Fluoride	Ca, Mg, Ba, B, F	less than 1.0 ppm
Carbon Dioxide	CO ₂	28,250 ppm
Hydrogen Sulfide	H ₂ S	215 ppm
Nitrogen	N ₂	56 ppm
Hydrogen	H ₂	2 ppm
Methane	CH ₄	2 ppm

**FIGURE 1
H₂S FLOW DIAGRAM**

DESIGN FEATURES GAS REMOVAL

VACUUM PUMPS/EJECTORS

The original design philosophy called for vacuum pumps to be utilized for the second stage of the gas removal system. Steam jet ejectors were used for the following reasons:

- Space limitation resulting from vacuum pump growth.
- Differential first costs.
- No geothermal experience.
- Untried ceramic coating on internal surfaces.
- Stainless steel fabrication would have required foreign purchase.
- Long lead-time for spare parts would have required large capital expenditures for spare parts that may not be used.
- Differential down-time for maintenance.
- Reduced complexity in plant control systems and operation.
- No moving parts thus no spares required.
- Simplified plant piping.

DESIGN FEATURES

PLANT WATER AND CHEMICAL BALANCE

By using the available steam quality data, cooling tower evaporation rates and data on various process waste flows, the plant water and chemical balance has been developed. The water balance with average and maximum flows is shown in Figure 1. Table 1 presents the flows in tabular form.

The largest source of water supply to the plant is condensed steam which is used as makeup to the circulating water system. Therefore, the condensate quality is a major factor in the balance. Significant steam quality requirements are defined by:

1. PNM/Union Steam Contract which specifies that the steam total dissolved solids content will be less than 40 ppm.
2. PNM letter to Bechtel of May 21, 1979, which states that the steam silica concentration will range from 7 to 15 ppm.

The condensate quality used in establishing the balance is based upon data collected from November 1975 through January 1977, which has been chemically balanced. This analysis is shown in Table 2.

The condensate will be corrosive to carbon steel and copper alloys; therefore, corrosion resistant alloys and FRP will be used throughout the condensate system. As a result, no chemical treatment for corrosion protection will be required.

Hydrogen sulfide abatement will be accomplished solely by the Stretford process providing the H_2S offgas/condensate partitioning (percent H_2S in offgas/percent H_2S in the condensate) is adequate. The Stretford process uses steam and generates waste water which impacts the plant chemical balance.

Makeup to the circulating water system will be the total flow from the condensate system and therefore the circulating water chemistry will vary depending upon the seasonal evaporation rates.

A detailed discussion of the circulating water chemistry is contained in the section titled, Circulating Water Concentrations.

Blowdown will be used to control the cooling tower basin level with the rate varying as a result of evaporation losses from the cooling tower. The anticipated blowdown rates are 238 gpm in the summer and 763 gpm in the winter.

Materials of construction — stainless steel, concrete and fiberglass reinforced pipe — of the circulating water system have been selected for their corrosion resistance. Scales formation will

FIGURE 1
WATER AND LIQUID WASTE FLOWS

Table 1
SYSTEM WATER AND WASTE FLOWS

	Average Flow gpm (24 Hours)	Maximum Flow gpm
Water Supply		
1. Cooling Tower Makeup	1700	—
2. Service Water	3	60
3. Potable Water	2	58
Waste Water		
1. Cooling Tower Blowdown	238 ⁽¹⁾	763 ⁽²⁾
2. Sanitary Wastes	0.5	11
3. Floor Drains	3.0	60
4. Hydrogen Sulfide Abatement Wastes	0.5 ⁽³⁾	—
(1) Summer Cooling Tower Evaporation Rates		
(2) Winter Cooling Tower Evaporation Rates		
(3) Plus Condensed Steam		

Table 2
CONDENSATE COMPOSITION

Barium, as Ba	0.05 ppm
Calcium, as Ca	0.28 ppm
Iron, as Fe	0.47 ppm
Magnesium, as Mg	0.095 ppm
Sodium, as Na	12.4 ppm
Potassium, as K	1.4 ppm
Arsenic, Boron, Lithium and Strontium, as As, B, Li and Sr	0.428 ppm
Bicarbonate, as HCO ₃	3.3 ppm
Chloride, as Cl	15.1 ppm
Fluoride, as F	0.2 ppm
Sulfate, as SO ₄	8.7 ppm
Total Dissolved Solids	42.4 ppm
Silica, as SiO ₂	7-15 ppm
Turbidity	1.9 JTU
pH	4.8

not be a problem with the anticipated condensate chemistry, condensate production rate and the cooling tower evaporation rates. Circulating water treatment for biological growth control may be required.

Results of operations at Unit 15 at the Geysers where chlorination is not practiced will be used to determine the need at Baca.

Water requirements in excess of those required for cooling tower makeup are for the potable water, service water and emergency fire protection water systems. A dependable water supply of adequate quality will be developed to supply a 20,000 gallon service water storage tank. The hydrogen sulfide abatement system water requirements will be supplied from the condensate system.

The potable and service water systems will provide the plant personnel needs for the normal operating staff of 14 persons or the maintenance staff requirement during overhaul on-site of 22 persons (K. Schenck letter of 4/25/79). As shown in Table 1, the maximum and average 24-hour anticipated flows to be supplied from the service water tank are respectively 118 gpm and 5 gpm.

Treatment of the service and potable water will consist of chlorination to maintain a measurable 0.2 ppm residual throughout the system with a minimum 10-minute contact time provided in the storage tank.

Normal firefighting water is supplied from the cooling tower basin. When the cooling tower basin is empty for maintenance, the water will be stored in the Union Geothermal pond from which firefighting water will be supplied. A limited emergency backup supply of 20,000 gallons is available from the service water storage tank at a rate of 1500 gpm (1 fire pump in operation).

The well water pump will operate off level control in the service water storage tank at a rate of 250 gpm. Two 100 gpm service water pumps will supply water from the service water storage tank upon demand from the level control in the hydropneumatic tank.

Plant wastes include the circulating water system blowdown, the sanitary waste system flows, floor drain system flows, and discharges from the hydrogen sulfide abatement system. The waste volumes are given in Table 1, and the chemical compositions are given in Table 3. Union Geothermal, as indicated by letter of August 15, 1979 from Union to PNM, has agreed to accept all wastes except the sanitary wastes without treatment for reinjection. Sanitary wastes will be treated by an extended aeration package treatment plant for BOD and suspended solids removal.

The hydrogen sulfide abatement system wastes will consist of the blowdown to control system chemistry and condensate from the steam used for chemical and system fluid heating.

Table 3

WASTE WATER COMPOSITION

	H ₂ S System	Sanitary Wastes	Floor Drains	Sump Discharge
ADA, weight percent	0.16	—	—	0.16
NaVO ₃ , weight percent	0.75	—	—	0.75
Na ₃ CO ₃ (equiv.), weight percent	1.18	—	—	1.18
Na ₂ SO ₄ , weight percent	7.10	—	—	7.10
Na ₂ S ₂ O ₃ , weight percent	15.81	—	—	15.81
Suspended Solids, ppm	—	< 10	200 (max.)	< 200
Oil and Grease, ppm	—	Nil	50 (max.)	< 50
BOD, ppm	—	< 20	Nil	< 20

The following conclusions are a result of the plant water and chemical balance:

1. With the anticipated steam quality, adequate condensate will be available to meet the cooling tower makeup requirements and maintain a nonscaling circulating water chemistry.
2. Supplemental water supplies are necessary to provide the service and potable water requirements. Chlorination of the water supply will be required for potable use.
3. With adequate H_2S removal as a condenser offgas, no condensate or circulating water chemical treatment is required. Circulating water chlorination requirements will be determined by the operating results of Unit 15 at the Geysers.
4. Waste disposal will be by well reinjection with the only in-plant waste treatment required being for the sanitary wastes.

DESIGN FEATURES ELECTRICAL SYSTEM COMPONENTS

EFFECTS OF ALTITUDES

Types of power plant equipment whose ratings are effected by altitude include the following:

- Power Transformers
- Switchgear and Metal Enclosed Bus
- Induction Motors
- Engine-Driven Generators

The Baca power plant comprises equipment in all of the above categories, which will be installed at the site elevation of 8750 feet above mean sea level, and which will be affected in varying degrees by the plant altitude.

The effects of altitude upon power equipment are due primarily to two causes:

- The reduced density of air at higher elevations, which reduces its ability to remove heat from energized apparatus, and decreases the mass of oxygen per unit volume of air available for combustion.
- The reduced dielectric strength of air at higher elevations, which reduces its effectiveness when used as an insulating medium.

The effects of these two properties of high-altitude air are summarized below for each type of equipment listed above.

Power Transformers

- Main Step-up Transformer — No derating necessary.
- Unit Auxiliary Transformer — No derating necessary.
- Loadcenter Transformers — No derating necessary.
- Dry Type Lighting Transformers — Derate 5 percent.
- Transformer HV Bushings — Extra creepage required.

Switchgear

- Medium Voltage Switchgear — Derate current to 97 percent
 - Derate interrupting capability
 - Use surge arresters for reduced BIL
- Nonsegregated Phase Bus — Derate current to 97 percent
- Low-Voltage Switchgear — Derate current to 99 percent
 - No voltage derating necessary
 - No interrupting capability derating necessary

Induction Motors

- All Motors — Derate in accordance with NEMA MG-1

Engine-Driven Generators

- Emergency Generator — Derate for altitude in accordance with DEMA

Following is a more detailed discussion of the above.

POWER TRANSFORMERS

Reference (1) states that "The effect of the decreased air density due to high altitude is to increase the temperature rise of transformers which are dependent upon air for the dissipation of heat losses." The main stepup transformer, the unit auxiliary transformer, the loadcenter transformer and the dry type lighting transformers to be installed at the Baca plant all fall within this category. Reference (1) also states, however, that "Transformers can be operated at rated KVA at altitudes greater than 3300 feet without exceeding temperature limits, provided the 24-hour average temperature of the cooling air does not exceed the values of Table 2 for the respective altitudes." Table 2 lists the maximum allowable average temperatures at an altitude of 3000 meters (9900 feet) for operation of OA, OA/FA or FOA, and AA transformers at full load to be 25C, 23C and 15C, respectively.

Reference (2) indicates that the maximum 24-hour average temperature at the Baca site for the 12 month period from October 19, 1974 to September 9, 1976 was 11.9C. In the case of the outdoor oil-filled transformers, i.e., the main-step and unit auxiliary transformers, there is thus a margin of approximately 100 percent in the maximum allowable average ambient air temperature, so that no derating due to altitude is required. The loadcenter transformer, also oil-filled, will be installed indoors in a force-ventilated room, where the maximum 24-hour average temperature is estimated not to exceed 19C. In this case, the temperature margin is approximately 20 percent, again indicating that no derating due to altitude is required for the loadcenter transformer. The small dry-type transformers will be installed indoors, and in this case their maximum rated loads must be decreased by 4.95 percent in order to avoid exceeding their rated temperature rise (Table 3 of Reference 1).

This is not believed to be significant in that lighting transformers are seldom loaded to their nameplate ratings and a 5 percent margin may be easily maintained.

The current ratings of bushings of the main and unit auxiliary transformers are not required to be derated for altitudes up to 10,000 feet if the temperature of the ambient air "is not likely to exceed the values given in Table 2," or 30C, per Reference (3). The maximum temperature recorded in Reference (2) is 20C, so that a substantial safety margin exists. Bushings are, however, also affected by the reduced dielectric strength of the ambient air.

Table 1 of Reference (4) gives the minimum creep distances of outdoor power apparatus bushings applied at altitudes of 3300 feet or less as 11 inches for 15 kV bushings and 79 inches for 115 kV bushings. The LV and HV bushings supplied with the main transformer were specified to meet the applicable ratings of Reference (3) at the plant elevation of 8750 feet; they have creep distances of 17 and 195 inches, respectively. The HV bushings of the unit auxiliary transformer will also have a minimum creep distance of 17 inches.

SWITCHGEAR

Switchgear and metal-enclosed bus are affected by both the reduced cooling capacity and the reduced dielectric strength of high altitude air. The reduced cooling capacity results in a decrease in rated continuous current of the bus and of the individual circuit breakers, while the reduced dielectric strength of the ambient air reduces the normal, maximum and withstand voltage ratings of the switchgear.

The correction factors to be applied to the voltage and continuous current ratings of the medium-voltage switchgear and metal-enclosed bus for application at the Baca project, may be obtained by interpolation of the values tabled in Section 3 of Reference (5). They are 0.84 and 0.97, respectively.

The 15 kV generator circuit breaker and nonsegregated phase bus are rated to carry 3000 amperes continuously, at altitudes less than 3300 feet. Applying the current correction factor of 0.97, the continuous current carrying capacity of these components is reduced to 2910 amperes at the Baca site. The maximum output of the 64 MVA generator, operating at 5 percent undervoltage, is 2811 amperes, so that overheating of the generator circuit breaker and nonsegregated phase bus will not be a problem.

The 4.16 kV switchgear and nonsegregated phase bus are rated to carry 1200 amperes continuously at altitudes less than 3300 feet. The derated value, for installation at the Baca site, is 1164 amperes, while the maximum output of the 6.25 MVA unit auxiliary transformer at 5 percent undervoltage is 911 amperes. Again, overheating will not be a problem.

A standard 15 kV class metalclad circuit breaker has nominal and maximum voltage ratings of 13.8 and 15 kV, respectively, at altitudes below 3300 feet. Applying the voltage correction factor of 0.84, these voltage ratings become 11.6 and 12.6 kV, respectively. Since the generator at Baca is rated at 13.8 kV + 5 percent, it may be seen that this method of derating would not

permit the use of a standard 15kV class metalclad circuit breaker as a generator breaker at the Baca plant.

Similar considerations apply to standard metalclad 4.15 kV switchgear, whose derated nominal and maximum voltage ratings are 3.49 and 4.0 kV, respectively.

The manufacturer of the medium-voltage switchgear was, however, able to offer equipment having nonderated voltage ratings for use at the Baca plant by reducing the permissible interrupting duty to 22,100 rms amperes (for the generator breaker), and 21,200 rms amperes (for the 4.16 kV switchgear), both at 5 percent overvoltage. These values of interrupting capability are acceptable for use at the Baca plant. The close and latch ratings are not affected by altitude.

The voltage correction factor of 0.84 also applied to the BIL of the switchgear. At the plant altitude, the derated BIL of the 13.8 kV circuit breaker is 79.8 kV, and that of the 4.16 kV switchgear is 50.4 kV. The required values are 95 kV and 60 kV, respectively. Surge arresters will be installed in the switchgear enclosures to restore the BILs to their specified levels.

The voltage and current derating factors for low-voltage switchgear are given in Section 3 of Reference (5). They are 0.95 and 0.99, respectively. Since the sea-level voltage rating of the switchgear is 600 volts, and the plant operating voltage is 480 volts, there is no problem with voltage derating. The derated current capability is also not a problem, as the derated continuous current ratings of all circuit breakers and power bussing in the low-voltage switchgear are more than adequate to carry the plant loads, with a margin for future expansion.

INDUCTION MOTORS

The temperature rise of induction motors increases with altitude for a given load. Reference (6) limits the sea-level temperature rise of motors to be used at altitudes exceeding 3300 feet, and provides a formula for calculating the permissible sea-level temperature rises for such motors. All motors were specified to have temperature rises not to exceed those permissible under Reference (6) while operating understated conditions at the site elevation.

ENGINE-DRIVEN GENERATORS

The Diesel Engine Manufacturers Association (DEMA) recommends the derating of engine horsepower, i.e., power producing capabilities in a direct relationship to the installed altitude of the unit: up to 5000 foot elevation, no derating is required; however, above this level, a 3-1/2 percent decrease in rated horsepower is recommended for each additional 1000 feet of added elevation. This derating is a measure to offset a decrease in aspirating air volume and the associated over-speed of the turbocharger resultant therefrom. This requirement has been utilized in the size selection of the diesel generator set purchased for this project.

REFERENCES

- (1) IEEE Standard 462-1973, IEEE Standard General Requirements for Distribution, Power and Regulating Transformers.
- (2) Baca Weather Data, File BG-C-107/G.100, March 12, 1979.
- (3) IEEE Standard 21-1976, IEEE General Requirements and Test Procedure for Outdoor Apparatus Bushings.
- (4) IEEE Standard 24-1977, IEEE Standard Electrical, Dimensional and Related Requirements for Outdoor Apparatus Bushings.
- (5) IEEE Standard 27-1974, IEEE Standard for Switchgear Assemblies Including Metal-Enclosed Bus.
- (6) NEMA MG-1, Motors and Generators.

DESIGN FEATURES ADVANTAGE OF THE FLASH DESIGN

A benefit of a flash design, geothermal plant, whether flashing down hole or at the surface, is the yield of water in the condenser, which can be used for cooling tower makeup when using evaporative cooling. This benefit is predicated by the quality of the condensate and if, of acceptable quality, the condensate can be used as makeup.

This benefit has been utilized at the Baca Geothermal Plant as its condensate is of an acceptable quality for use in the cooling tower as makeup; this is of particular advantage in that the Baca Geothermal Plant is located in an area where external water supplies are scarce and costly.

Only the plant service water needs to be imported and its consumption has been limited to the purposes of drinking, domestic and maintenance use.

In this regard, the plant uniquely fits in with what the environment can offer.

The allotment of water for potable and service water usage at the Baca Plant is 3 acre feet per year. The remaining 5 acre feet per year will be supplied by truck transport from an off-site source, or from treated condensate, as appropriate.

DESIGN FEATURES

TURBINE-GENERATOR/STEAM GATHERING FIELD RESPONSE

The geothermal plant is required to respond to certain loading rates and operating conditions. This plant represents a small portion of the capacity of the total Public Service Company of New Mexico system. Steam cost and operation considerations of the steam gathering field require that this plant be operated in the base load condition. Load following would be required if the geothermal plant were isolated with its own load network.

The Turbine-Generator can respond much faster than the field and the Turbine-Generator is not the determining factor in geothermal plant response. Therefore, the Turbine-Generator output follows the steam gathering field in all modes of operation; startup, initial loading, turbine ramping, full load operation, low load operation and load rejection.

The steam gathering field is designed to operate at rated flow with long term flow changes handled by adding or removing satellite stations.

The single flash design incorporated in this plant design is susceptible to moisture carryover from the steam gathering system especially on rapid load increases. The rapid load increases reduce the turbine inlet pressure and allow the wells to increase their steaming rate to greater than rated flow. The increased steam flow from the wells causes rock particles, well casing deposits and piping deposits to be carried over into the flash system. To preclude these effects it is imperative that the Turbine-Generator steam flow changes not exceed the allowable flow rates and rates of change of the steam gathering field.

The operating characteristics of the steam gathering field during the various plant modes of operation are described below:

Maximum Steam Supply Pressure

Under normal full load operation, steam supply pressure will conform to contract specifications of 114 psia turbine inlet. Any other load conditions will require trimming steam supply, which is accomplished automatically by pressure controlled vent valves. Any reduction in desired steam flow rate will raise inlet pressure, which will modulate vent valves to vent steam through a muffler in proportion to pressure. Additional load reduction will open vent valves farther due to higher pressure. The vent valves modulate and control pressure in steam line over a pressure band. Turbine must therefore be able to sustain higher input pressures ahead of its turbine control valve to allow Union's vent valve to trim flow. See Union Drawing D-RC1-MP-09, which is a graphical representation of this relationship. Another result of pressure increase, as it is reflected back to satellite stations, is to cut back on steam flash, although this effect will be minor. Union plans to have a satellite station pressure regulator valve by which it will manually increase satellite separation pressures above the normal steam line pressures (without affecting steam line pressure) to raise wellhead pressures and cut back production. This will conserve the geothermal fluid resource, and allow the vent valves to continue normal operation, but with less steam flow.

Turbine Ramping and Allowable Rate of Change Steam Flow

Normally, Union will have steam available for startup by passing it through air operated vent valves upstream of the turbine stop valves in anticipation of turbine startup. The allowable rate of change of turbine steam flow up to the amount of steam available is limited only by response time of vent control valves which close as turbine steam flow rate increases. If only one section of field is in operation (e.g., one Satellite Station) then turbine steam flow rate may not increase beyond available steam without reducing pressure to below trip levels. The rate of turbine loading at The Geysers is specified as below to allow geothermal field operators to monitor well behavior.

Percentage for Unit Capacity	Unit Load (MW)	Allowable Load Change Rate (MW/Min)
0-50	0-25	2
50-80	25-40	1
80-100	40-50	1/2

This is a very workable system which provides time for problem identification and correction before a trip is caused by low turbine inlet pressure or other cause. This loading schedule should be adopted, at least through the first year of operation as both field and plant operators learn how the system reacts. A decrease in turbine steam flow rate will be handled as a shutdown, where the vent valves open in response to pressure increases due to turbine steam flow rate decrease. The rate of change should not be a problem for unit load decreases.

The rate of change of unit load is controlled by the PNM plant operators with the Turbine-Generator STC panel Raise/Lower pushbuttons. These pushbuttons position the turbine control valves. The Turbine-Generator manufacturer has been appraised of this limitation and will design the STC system accordingly.

Turbine Trip Conditions and the Union Requirements

In general, two things will happen:

1. The plant personnel, both on the Union side and the PNM side, must communicate. This will be handled in the operating document between the two companies.
2. Upon turbine trip, both turbine stop valves and turbine control valves close and the generator will be tripped after both turbine stop valves are closed. A dry contact indicating turbine trip will be available for Union's use. The Union vent valve will open to divert the wellhead flow to the blowoff pits. Wellhead steam production is then decreased by increasing steam pressure setpoint (manually closing the satellite pressure regulator) and allowing

the Union relief valves to operate in higher than normal operating pressure range. Union will handle steam blowoff during a turbine trip by putting in blowoff pits south of the Power Plant property.

The interface data sheets provide the current main steam design inlet working pressure versus the maximum allowable working pressure on the Turbine-Generator to size and specify the Union blowoff valve and rupture disk facilities to accommodate turbine trip and upset conditions.

Partial Load Rejection, Turbine Runback

Partial load rejection or turbine runback can be initiated manually by the PNM Plant operator with the use of the Raise/Lower pushbuttons on the Turbine-Generator STC panel. These push-buttons are subject to the same rate of change limitations as when used for turbine ramping.

DESIGN FEATURES TURBINE BLOW-OFF PIPING

In an effort to safely route steam discharges from the turbine casing shear diaphragms to outside the building, the Baca job is a first in displaying this feature. This additional safety feature was introduced to compensate for the possible failure of closing the turbine control and stop valves in the event of a load rejection accompanied by a noncondensing condition.

This design approach has been practiced in Europe in certain power stations, but is commonly not used in the United States.

Owing to the possible adverse affects that impurities in the steam have on the operation of the emergency stop and control valves it was reasoned to be a good investment to include this blow-off piping in the design to eliminate the possible hazards associated with the turbine blow-off in the power building.

The hazards that can be foreseen are twofold:

1. The first concern is about the safety of personnel inside the power plant.
2. The second concern is the damage that H₂S bearing steam can impose on power plant electrical equipment.

DESIGN FEATURES MATERIAL SELECTION

GENERAL

Recognizing the corrosive nature of geothermal fluids which contain salts (e.g., silica, sulfates, sodium, potassium, calcium, magnesium, bicarbonates, etc.), and gases (e.g., carbon dioxide, hydrogen sulfide, nitrogen, hydrogen, methane, etc.), the majority of which produce a damaging affect upon conventional power plant equipment materials of construction, the plant process equipment has been carefully selected to assure long life service in a hostile environment. The following tabulation displays those materials considered best suited by both manufacturer and Bechtel for this application:

MECHANICAL EQUIPMENT

Turbine-Generator

Steam Turbine

Turbine Shaft — Ni-CR steel

Steam Chest — Carbon steel

Turbine Casing — Carbon steel

Steam Nozzles — 12 percent chrome steel

Exhaust Trunk — Carbon steel

Turbine Blades — 12 percent chrome steel

Lube Oil Coolers

Shell — Carbon steel

Tubes — Type 304 stainless steel

Tube Sheets — Type 304L stainless steel

Water Boxes — Type 304L stainless steel

Hydraulic Power Unit

Shell — Carbon steel

Tubes — Type 316 stainless steel

Tube Sheets — Type 304L stainless steel

Water Boxes — Type 304L stainless steel

Hydrogen Gas Coolers

Tubes — Type 304 stainless steel

Tube Fins — Plate aluminum

Tube Sheets — Type 304L stainless steel

Water boxes — Type 304L stainless steel

Piping Systems

Hydraulic and Lubricating Oil Piping and Tubing — Type 304 stainless steel

Main Steam and Seal Steam Piping — Carbon steel

CONDENSER EQUIPMENT

Main Condenser

Shell — Type 304L stainless steel

Water Boxes — ASTM A 285 Gr. C carbon steel — Neoprene rubber lined

Tube Sheets — Type 304 stainless steel

Tube Support Plates — Type 304L stainless steel

Tube Bundle — Type 304L stainless steel

Hotwell — Type 304L stainless steel

Exhaust Neck — Type 304L stainless steel

Expansion Joints — Type 304L stainless steel

Extension Pieces — ASTM A 285 Gr. C carbon steel

Inter and After Condensers

Shell and Water Box — Type 304L stainless steel

Water Box Covers — ASTM SA 515-7 carbon steel with ASME 240 Type 304L stainless steel cladding

Tube Sheets — Type 304 stainless steel

Tube Bundles — Type 304L stainless steel

Tube Support Plates — Type 304 stainless steel

Steam Domes — Type 304L stainless steel

Steam Jet Ejectors

Primary and Secondary Ejectors — Type 304L stainless steel

Circulating Water Pumps

Discharge Heads and Columns — Type 316L stainless steel

Impellers and Bowl Assembly — Type 316 stainless steel

Shafts — Type 316 stainless steel

Expansion Joints — Neoprene rubber

Expansion Joint Tie Rods — Carbon steel

Condensate Pumps

Suction Barrel — Type 316 stainless steel plate

Discharge Head — Type 316 stainless steel plate

Bowl Assembly — ASTM A 296-CF-3M (316 stainless steel)

Impellers and Shaft — ASTM A 296-CF-3M (316 stainless steel)

Cooling Tower

Structural Framework — Douglas Fir — Pressure treated

Casing — Corrugated asbestos cement

Drift Eliminators — Polyvinyl chloride

Fan Stacks — Heavy ribbed fiberglass

Fill — Corrugated PVC sheets

Motor, Gear Reducer and Bearing Support — Weld steel frame — polyurethane coated

Distribution Piping — Fiberglass reinforced polyester

Fan Blades — Fiberglass reinforced epoxy

Structural Connectors — AISI Type 304 stainless steel

Fire Water Pumps

Pump Case — Cast iron

Impeller — Type 316 stainless steel

Shaft — Type 316 stainless steel

Shaft Sleeve — Type 316 stainless steel

Casing Rings — 11-13 CR steel

Service Water and Jockey Pumps

Pump Case — Duro metal (ductile iron)

Impeller — Type 316 stainless steel

Shaft — ASTM 1045 steel

Shaft Sleeve — Type 316 stainless steel

Service Water and Diesel Oil Storage Tanks

Tank Shell — Filament wound fiberglass

Heads — Filament wound fiberglass

All remaining mechanical equipment such as the Diesel Generator Set, Air Compressors, Filters, Dryers, Air Receiver and the Heating, Ventilating and Air Conditioning Equipment are constructed of standard materials. All external exposed ferrous metal surfaces of all mechanical equipment is finished in a chlorinated rubber base paint specially selected to resist the mildly saturated hydrogen sulfide atmosphere.

ELECTRICAL EQUIPMENT

Whenever feasible, electrical equipment has been located in "clean" rooms, supplied with air drawn through activated charcoal filters. Equipment located elsewhere has been protected by careful choice of materials, by local ventilation with filtered air, or by chemical means. Following is a tabulation of electrical equipment and the methods used for its protection:

Main and Auxiliary Transformers

Locally-Mounted Control Cabinets — Pressure-ventilated with filtered air

Neutral Grounding Resistor — Stainless steel

Switchgear and Motor Control Centers

Circuit Breakers — Located in clean room

Contactors and Relays — Located in clean rooms

Raceways

Cable Trays — Aluminum

Conduits, Above Grade — Aluminum

Conduits, Below Grade — PVC

Fittings — Aluminum or hot-dipped galvanized steel

Wire and Cable

Power, Control and Instrumentation — Tinned copper

Grounding, Above Grade — Aluminum

Grounding, Below Grade — Copper

Equipment Ground Busses — Tinned copper

APPENDIX A

DRAWING LIST
&

SELECTED
DRAWINGS AND DIAGRAMS

DRAWING LIST

<u>Drawing Number</u>	<u>Drawing Title</u>
Architectural	
—	Artists Rendering
A-98	Floor Plan at Grade — El. 100'-0"
A-99	Floor Plan at Mezzanine — El. 115'-0" and Operating Deck El. 130'-0"
A-100	1/4" Scale Plan Blow-Ups and Interior Elevations
A-101	Exterior Elevations
A-102	Wall Sections
A-103	Door and Finish Schedules and Miscellaneous Details
A-104	Special Interior and Exterior Details
Civil/Structural	
	<u>CIVIL</u>
◆ C-001	Site General Arrangement and Location Plan
C-006	Site Rough Grading Plan Sections and Details
C-022	Underground Utilities, Power Block Area
C-023	Underground Utilities, Cooling Tower Area
	<u>CIRCULATING WATER SYSTEM</u>
C-101	Cooling Tower Basin Plan
C-111	Circulating Water System Plan
C-112	Circulating Water System Profile, Sections and Details
C-113	Circulating Water System, Sections and Details
	<u>TURBINE PEDESTAL</u>
C-152	Turbine Pedestal, Top Deck and Column Reinforcement Plan, Sections and Details
	<u>TURBINE BUILDING STRUCTURAL STEEL</u>
C-204	Structural Steel Framing Plan, Mezzanine
C-205	Structural Steel Framing Plan, Operating Deck
C-207	Structural Steel Framing Plan, Roof Truss Bottom Chord
C-208	Structural Steel Framing Plan, Roof
C-211	Structural Steel Elevations, Sheet 1
C-213	Structural Steel Elevations, Sheet 3
	<u>TURBINE BUILDING CONCRETE</u>
C-251	Caisson Plan and Schedule
C-253	Foundation, Mat, Plan

◆ These drawings are included in Appendix A.

DRAWING LIST (Continued)

<u>Drawing Number</u>	<u>Drawing Title</u>
C-257	Base Mat, Reinforcing Plan
C-261	Concrete Floor, Plan, Mezzanine
C-262	Concrete Floor, Plan, Operating Deck
Electrical	
◆ E-002	Main One-Line Diagram
	<u>ONE-LINE DIAGRAM</u>
E-005	One-Line Diagram, Auxiliary Power System 13.8 and 4.16 kV Switchgear
E-008	One-Line Diagram, Auxiliary Power System, 480 V Plant and Emergency Loadcenter
	<u>SCHEMATIC DIAGRAMS</u>
E-051	Schematic Diagram — Main Generation, Three Line Metering and Relaying Sheet 1
	Schematic Diagram — Main Generation, Three Line Metering and Relaying Sheet 2
	Schematic Diagram — Main Generation, Three Line Metering and Relaying Sheet 3
E-052	Schematic Diagram — Main Generation, Generator Tripping Sheet 1
	Schematic Diagram — Main Generation, Generator Tripping Sheet 2
	Schematic Diagram — Main Generation, Generator Tripping Sheet 3
E-053	Schematic Diagram — Main Generation, Generator Synchronizing
	<u>PHYSICAL DRAWINGS</u>
E-201	Outdoor Electrical Plot Plan
E-202	Electric Plot Plan (U.G. Duct Banks; Cooling Tower and Roadway Lighting)
E-209	Lighting Plan, Control Room, Relay Room and Offices
E-211	Underground Duct Banks, Plan at El. 100'-0"
E-212	Grounding Plan, Areas A and B, El. 100'-0"
E-213	Grounding Plan, Areas A and B, El. 115'-0"
E-214	Grounding Plan, Areas A and B, El. 130'-0"

◆ These drawings are included in Appendix A.

DRAWING LIST (Continued)

<u>Drawing Number</u>	<u>Drawing Title</u>
Instrumentation and Controls	
	<u>CONTROL LOGIC DIAGRAM</u>
J-101	Control Logic Diagram – General Notes
J-102	Control Logic Diagram – Typical Medium Voltage & Load Center Switchgear, Sheet 1
	Control Logic Diagram – Typical Medium Voltage & Load Center Switchgear, Sheet 2
J-103	Control Logic Diagram – Typical Non-Reversing Motor Starter Circuits, Sheet 1
	Control Logic Diagram – Typical Non-Reversing Motor Starter Circuits, Sheet 2
J-104	Control Logic Diagram – Typical Reversing Motor Starter Circuits, Sheet 1
	Control Logic Diagram – Typical Reversing Motor Starter Circuits, Sheet 2
J-106	Control Logic Diagram – Typical Control Mode Transfer Circuits
J-107	Control Logic Diagram – Circulating Water Pump A, Sheet 1
	Control Logic Diagram – Circulating Water Pump B, Sheet 2
J-108	Control Logic Diagram – Circulating Water Pump Discharge Valve A, Sheet 1
	Control Logic Diagram – Circulating Water Pump Discharge Valve B, Sheet 2
J-109	Control Logic Diagram – Cooling Water Supply Valve A, Sheet 1
	Control Logic Diagram – Cooling Water Supply Valve B, Sheet 2
J-110	Control Logic Diagram – Condensate Hotwell Pump A, Sheet 1
	Control Logic Diagram – Condensate Hotwell Pump B, Sheet 2
J-112	Control Logic Diagram – Service Water Pump A, Sheet 1
	Control Logic Diagram – Service Water Pump B, Sheet 2
J-113	Control Logic Diagram – Cooling Tower Fans, Sheet 1-6
J-115	Control Logic Diagram – Bearing and Seal Oil Pump A, Sheet 1
	Control Logic Diagram – Bearing and Seal Oil Pump B, Sheet 2
J-116	Control Logic Diagram – DC Emergency Bearing and Seal Oil Pump
J-119	Control Logic Diagram – Hydraulic Pump A, Sheet 1
	Control Logic Diagram – Hydraulic Pump B, Sheet 2
J-136	Control Logic Diagram – Plant Air Compressor A, Sheet 1
	Control Logic Diagram – Plant Air Compressor B, Sheet 2

DRAWING LIST (Continued)

<u>Drawing Number</u>	<u>Drawing Title</u>
<u>INSTRUMENT LOOP DIAGRAM</u>	
J-401	Instrument Loop Diagram — 24 V DC Power Distribution
J-402	Instrument Loop Diagram — 120 V AC Power Distribution
J-403	Instrument Loop Diagram — Main Steam Pressure "A"
J-404	Instrument Loop Diagram — Main Steam Pressure "B"
J-405	Instrument Loop Diagram — Main Steam Temperature "A"
J-406	Instrument Loop Diagram — Main Steam Temperature "B"
J-407	Instrument Loop Diagram — Main Steam Flow-Total
J-408	Instrument Loop Diagram — First Stage Pressure
J-420	Instrument Loop Diagram — Circulating Water Pump "A" Discharge Pressure
J-421	Instrument Loop Diagram — Circulating Water Pump "B" Discharge Pressure
J-422	Instrument Loop Diagram — Turbine Exhaust Pressure
J-423	Instrument Loop Diagram — Hotwell Level
J-424	Instrument Loop Diagram — Condensate Pump Discharge Flow
J-425	Instrument Loop Diagram — Cooling Tower Blowdown and Makeup Flow
J-426	Instrument Loop Diagram — Cooling Tower Basin Level
J-427	Instrument Loop Diagram — Instrument Air Compressor — Pressure

Mechanical

◆	MPD-1	Flow Diagram
◆	M-103	Steam and Turbine
	M-104	Compressed Air System
◆	M-105	Condensate and Circulating Water System
	M-106	Hydrogen and Carbon Dioxide System
◆	M-107	Sampling System
◆	M-109	Fire Protection System
◆	M-110	Service and Domestic Water System

General Arrangements/ Piping

	P-100	General Arrangement at Grade El. 100'-0"
	P-101	General Arrangements at Mezzanine El. 115'-0" and Operating Level El. 130'-0"
◆	P-102	General Arrangements Sections A-A and B-B

◆ These drawings are included in Appendix A.

DRAWING LIST (Continued)

<u>Drawing Number</u>	<u>Drawing Title</u>
P-200	Piping Turbine Area A Plan at Grade
P-202	Piping Turbine Area A Plan at Mezzanine
P-205	Piping Sections and Details Outside Areas
P-209	Turbine Building Floor, Floor and Equipment Drains
P-304	Isometric Fire Water System
P-440	HVAC Plan at Grade
P-441	HVAC Plan at Mezzanine
P-442	HVAC Plan at Operating Deck
P-443	HVAC Sections

This drawing and the design it covers are the property of P.H.V. They are hereby loaned and on the borrower's express agreement that they will not be reproduced, copied, loaned, exhibited, or used except in the limited way and purpose use permitted by the lender to the borrower.

This drawing and the design it covers are the property of PNM. They are hereby loaned and on the borrower's express agreement that they will not be reproduced, copied, loaned, exhibited, or used except in the limited way and precise use permitted by any written consent given by the lender to the borrower.

PRELIMINARY
NOT FOR CONSTRUCTION

BECHTEL LOS ANGELES	
PUBLIC SERVICE COMPANY OF NEW MEXICO BACA GEOTHERMAL PROJECT UNIT 1	
P.I. DIAGRAM STEAM AND TURBINE	
NO.	DATE
1	7/10/84
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	
51	
52	
53	
54	
55	
56	
57	
58	
59	
60	
61	
62	
63	
64	
65	
66	
67	
68	
69	
70	
71	
72	
73	
74	
75	
76	
77	
78	
79	
80	
81	
82	
83	
84	
85	
86	
87	
88	
89	
90	
91	
92	
93	
94	
95	
96	
97	
98	
99	
100	

5111

The diagram illustrates a complex industrial cooling water system. At the top right, a Cooling Tower Basin receives water from service water and has two gates at its base. Water flows through various pipes, some labeled with codes like CE-37-HUXA-20 and DA-25-HUXA-42. The system includes several pumps: Circulating Pump A and B, Condensate Pump A and B, and a Main Condenser. There are also three types of condensers: Inter Condenser, After Condenser, and Main Condenser. The system is heavily instrumented with numerous pressure gauges (PI), temperature sensors (TE), level indicators (LI), and control valves (XV). Key areas include the Hot Well, Sample Rack M-107, and connections to service water and fire pump discharge. The diagram also shows a vacuum breaker and a turbine trip mechanism.

PIN.	SCALE	JOB NO.	DRAWING NO.	REVISION
APP.		13395	M-105	
FILE-				

						P.N.	SCALE	JOB NO.	DRAWING NO.	R
	ISSUED FOR CONSTRUCTION	M/L				APP.		13395	M-105	(
NO	DATE	REVISIONS	DRN	CHK	DGS	ENG SA	PROJ ENG SA	FILE-		

This drawing and the design it covers are the property of PNM. They are hereby loaned and on the borrower's express agreement that they will not be reproduced, copied, loaned, exhibited or used except in the limited way and private use permitted by any written consent given by the lender to the borrower.

PRELIMINARY
NOT FOR CONSTRUCTION

LEGEND

- SR — SAMPLE RACK
- SP — SAMPLING PANEL
- AXB — AUXILIARY BOARD
- GSA — GRAB SAMPLE RACK
- AX — SAMPLE COOLER
- * — BY H₂S VENDOR

BECHTEL		LOS ANGELES	
PUBLIC SERVICE COMPANY OF NEW MEXICO		BACA GEOTHERMAL PROJECT UNIT 1	
P.I. DIAGRAM		SAMPLING SYSTEM	
NO.	DATE	REVISIONS	BY
1	10/1/80	ISSUE FOR BID	JAC
2	10/1/80	FOR CLIENT REVIEW	JAC

SCALE	JOB NO.	DRAWING NO.	REV.
1"=100'	13395	M-107	8

This drawing and the design it covers are the property of PHM. They are hereby loaned and on the borrower's express agreement that they will not be reproduced, copied, loaned, exhibited, or used except in the limited way and private use permitted by the lender to the borrower.

This drawing and the design it covers are the property of BNL. They are hereby loaned and on the borrower's express agreement that they will not be reproduced, copied, loaned, exhibited or used except in the limited way and private use permitted by the lender to the borrower.

PRELIMINARY
NOT FOR CONSTRUCTION

BECHTEL LOS ANGELES		PUBLIC SERVICE COMPANY OF NEW MEXICO BACA GEOTHERMAL PROJECT UNIT 1	
SERVICE AND DOMESTIC WATER SYSTEM			
NO.	DATE	ISSUED FOR CONSTRUCTION	SCALE
1			NONE
2			13395
3			M-110
4			0
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			
32			
33			
34			
35			
36			
37			
38			
39			
40			
41			
42			
43			
44			
45			
46			
47			
48			
49			
50			
51			
52			
53			
54			
55			
56			
57			
58			
59			
60			
61			
62			
63			
64			
65			
66			
67			
68			
69			
70			
71			
72			
73			
74			
75			
76			
77			
78			
79			
80			
81			
82			
83			
84			
85			
86			
87			
88			
89			
90			
91			
92			
93			
94			
95			
96			
97			
98			
99			
100			

APPENDIX B

BACA POWER PLANT DESIGN DATA

Turbine

Manufacturer	General Electric
Type	Condensing 2-flow
RPM	3600

	<u>Customary</u>	<u>SI</u>
Steam Consumption @ Guarantee	17.0 lb/kwh	7.7 kg/kwh
Throttle Conditions:		
Pressure	113 psia	.78 MPa
Temperature	337°F	170°C
Flowrate	849,840 #/hr.	107 kg/sec.
% Noncondensibles	3% by wt.	
Diameter of Last Stage Blades	20 in.	.5 m
Number of Stages	6	
Exhaust Pressure, Absolute	4 in Hg	100 mm Hg
Control System Type	Electro-Hydraulic	
Lubricating Oil System:		
Purification	Gravity Filter	
No. of Coolers & % Capacity	2 - 100%	

Generator

Manufacturer	General Electric
Gross Output - KW	50,000
Busbar Voltage - KV	13.8
H ₂ Cooling:	
Water Source	Circulating Water
No. of Coolers & % Capacity	4 - 25%
Tube Material	304 S.S.

Main Condenser

Manufacturer	Ecolaire Condenser	
Type	2 Water Passes	
Tubes:		
Material - Wall Thickness	304 S.S.-22 BWG	
Inside Diameter		
Tubesheet Material	304L S.S.	
Cooling Water Velocity	6-8 ft/sec.	1.8-2.4 m/sec.
Vacuum/Pressure Rating	30" Hg/15 psig	0/.1 MPa
% Partitioning	90% est.	
Cooling Water Inlet Temperature	70°F	21°C
	80°F	27°C
	32°F	0°C
Cooling Water Flowrate	64,000 gpm	4.1 m ³ /sec.

Gas Extraction System

Customary

SI

Ejector Manufacturer(s)

Number of Ejectors

Ejector Steam Conditions

Total Steam Consumption

Ejector Condensers:

Manufacturer

Cooling Water Flowrate

Tube Material - Wall Thickness

4 Primary, 2 Transfer

113 psia sat'd

.78 MPa sat'd

74,800 #/hr.

9.4 kg/sec

Ecolaire Condenser

5500 gpm

.35 m³/sec.

304 S.S.-22 BWG

Circulating Water System

Pumps:

Manufacturer

Number and % Capacity

Type

Capacity (Each Pump)

NPSH Available

Total Head

Location

Impeller Material

Casing Material

Cooling Tower Supply & Return Piping:

Diameter

Material

Johnston Pump

2 @ 50 %

Vertical Dry-Pit

36,000 gpm

2.3 m³/sec.

18 ft.

5.5 m

65 ft.

19.8 m

Adjacent to Condenser

316L S.S.

316L S.S.

42 in.

1.06 m

Fiberglass Reinforced Pipe

Cooling Tower

Type

Manufacturer

Construction:

Basin Material

Structure Material

Fill Material

Mist Eliminator Material

Number of Cells

Approach

Design Maximum Wet Bulb Temperature

Design Maximum Dry Bulb Temperature

Hot Water Temperature

Cold Water Temperature

Fans:

Number of Fans

Air Capacity (Each Fan)

% Drift (Design)

Maximum Evaporation Rate

Maximum Makeup Requirements

Counterflow Film Cooling

Research Cottrell

Treated Concrete

Treated Douglas Fir

PVC

PVC

6

14°F

7.8°C

56°F

13.3°C

80°F

26.7°C

96°F

35.6°C

70°F

21.1°C

6

1,473,000 ACFM

695 m³/sec.

.008% of Total Flow

2.09% of Total Flow

1540 gpm

96 l/sec.

H₂S Treatment System

Manufacturer
Treatment Process
Steam Requirements
H₂S Removal Efficiency

Customary

SI

	Peabody Process Systems	
	Stretford	
500#/hr.		.06 kg/sec.
	95% by wt.	