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CONCEPTUAL DESIGN REPORT

HGP-A WELLHEAD GENERATOR PROOF-OF-FEASIBILITY PROJECT

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Submitted to:

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of the
University of Hawaii

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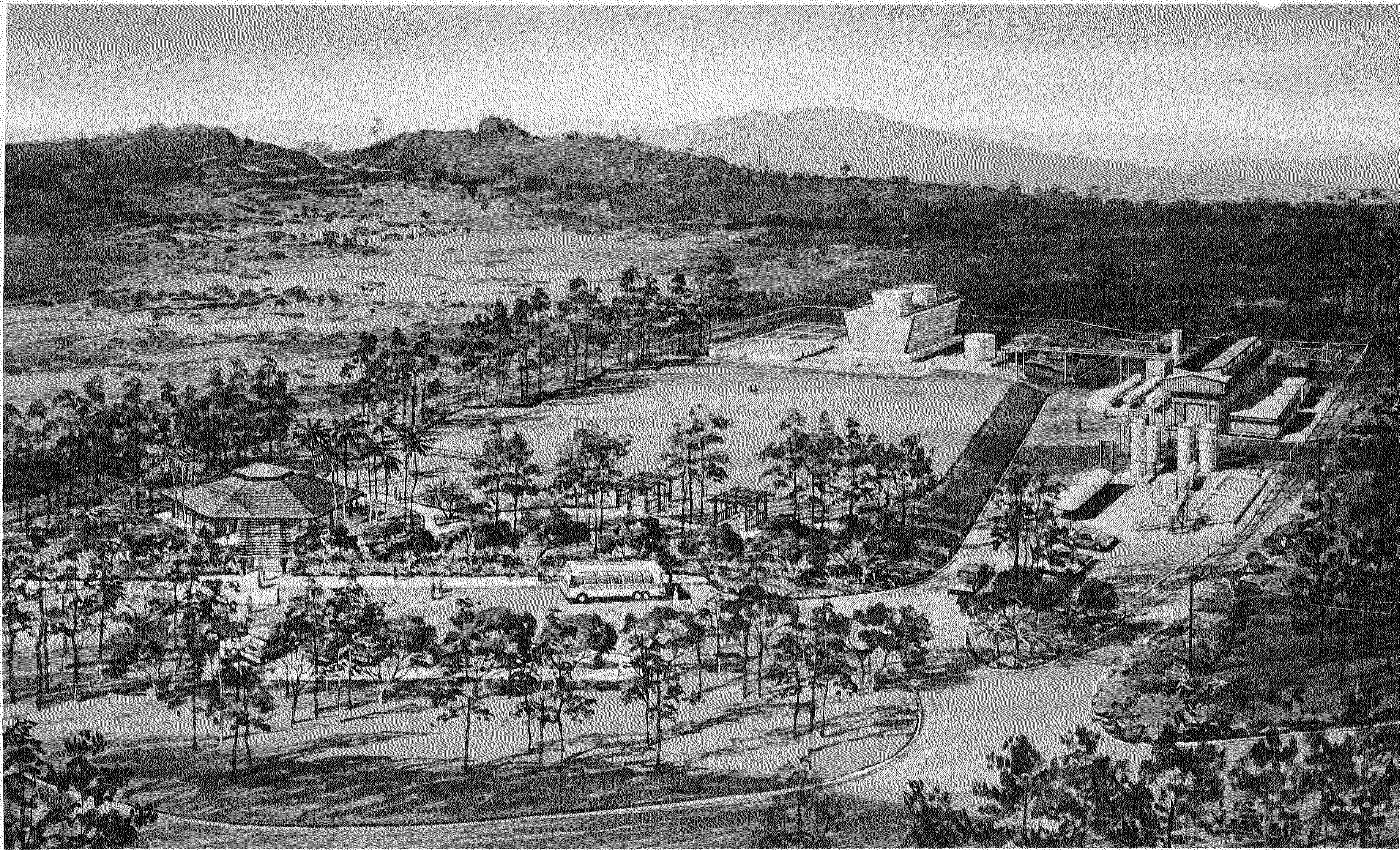

HGP-A WELLHEAD GENERATOR PROOF-OF-FEASIBILITY PROJECT

RESEARCH CORPORATION OF THE UNIVERSITY OF HAWAII

ROGERS ENGINEERING CO. INC. ENGINEERS · ARCHITECTS SAN FRANCISCO

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1.0 INTRODUCTION

The "Geothermal Wellhead Generator Proof-of-Feasibility Project" includes the installation of a 3 Megawatt generating facility and a visitor center. The plant is being constructed as a research and development project to evaluate geothermal steam as a viable resource to be considered for larger commercial electric power generating stations in Hawaii. The initial tasks of site selection, resource development and well testing have been accomplished by the Research Corporation of the University of Hawaii (RCUH) with grants from the National Science Foundation, the Hawaii Geothermal Project-A (HGP-A) development group and ERDA. RCUH was selected by the HGP-A development group to undertake the implementation of the wellhead generating facility. The HGP-A development group consists of: 1) The State of Hawaii, Department of Planning and Economic Development; 2) The County of Hawaii; and 3) The University of Hawaii. Site selection and resource development and well flow testing data have been provided to Rogers Engineering Co., Inc. (ROGERS) by RCUH. The proof-of-feasibility aspects of the power plant installation tends to emphasize "plant reliability" as the key factor in the facility design.

ROGERS was selected on the basis of qualifications and signed a contract with RCUH on September 14, 1978 to perform the following engineering services:

- Design Development
- Preliminary Design (First two months of detail design period)
- Procurement
- Detail Design
- Construction Management
- Start-Up and Operator Training At Site

In order to accomplish this project in two years the "Procurement" and "Detail Design" phases run concurrently after the "Conceptual Design" phase, followed by the "Construction Management" and "Start-up" phases.

1.1 Conceptual Design Purpose and Scope

1.1.1 Concept Purpose

The purpose of the conceptual design is to: 1) Present the facility design to be implemented in the detail design; 2) determine the environmental controls to protect the existing environment; 3) determine the construction cost; and 4) define the design, procurement and construction schedule throughout the project.

The tasks required to accomplish this are:

a. Accumulation and analysis of all available data and information, supplied by RCUH, in order to design a site-specific power generating facility.

b. Implementation of optimization studies and cost benifit analyses to determine sizes, capacities and state points to be subsequently used in the the design of material and equipment for the power plant based upon the HGP-A well conditions.

c. Preparation of process flow diagrams and analyses in sufficient detail to illustrate the power plant operating and control systems.

d. Determination of ancillary mechanical and electrical systems required for plant operations. Determine station power requirement and approximate net kilowatt output of the power plant.

e. Preparation of a conceptual design of the turbine building, support facilities and the visitor center.

f. To describe the structural and architectural design characteristics of the generating facility required to assure functional servicability and maintain aesthetic appearances compatible with the surrounding environment.

g. Determination of environmental safeguards to be included in the plant design to ensure compatibility with the surrounding area at the site.

h. To conduct site risk analysis of building a power plant in an active rift zone.

i. To prepare a personnel and equipment evacuation program.

j. To prepare project activity schedules illustrating timing of design, procurement and construction phases of the project.

k. To prepare construction budget cost estimate of the complete generating facility installation.

1.1.2 Project Scope and Scope Boundaries

This project includes the engineering design, procurement and construction management and start-up activities associated with the installation of the following facilities:

a. The geothermal steam-electric power generation facility including:

- The steam gathering and effluent water disposal systems including the steam supply system from the mating flange at the wellhead valve assembly and the effluent water disposal and the noncondensable gas collection and treatment system. The scope does not include the wellhead Christmas tree, steam treatment tower or chemical treatment plant; however, the steam treatment tower and chemical treatment plant have been utilized in the power plant operational design.

- The turbine-generator unit and its auxiliary systems.

- Central control room and administration offices, maintenance shop, laboratory and change room.

•The 34 kV substation, deadend structure and transmission line within the facility property line.

b. Visitor Center including information and display areas as well as provisions to allow general site viewing.

c. The project scope requires a site risk analysis describing the risks involved in siting the facility in an area where there has been considerable previous seismic and volcanic activity.

1.2 Responsibilities

1.2.1 ROGERS has been retained by RCUH to supply engineering design, equipment and material procurements, and construction management services for the HGP-A Wellhead Generator Proof-of-Feasibility project.

1.2.2 ROGERS has retained W.A. Hirai and Associates (HIRAI), located in Hilo, Hawaii to provide design of site improvements, buildings, miscellaneous auxiliary system structures, foundations and supports and to provide construction management services for certain elements of the project as described on Drawing E-07-001-0, dated November 3, 1978, Design Procurement Schedule.

1.2.3 Engineering Decision Analysis Corporation (EDAC) of Palo Alto, California, has been retained by ROGERS to supply risk assessment and siting studies for the power plant facility. Engineering design decisions based on results of EDAC investigatons are the responsibility of ROGERS.

1.2.4 HIRAI and EDAC report directly to ROGERS with ROGERS being the prime contractor for the supply of engineering, procurement and construction management services.

2.0 SUMMARY

2.1 The HGP-A Wellhead Generator Proof-of-Feasibility Project consists of a nominal 3 Megawatt geothermal steam turbine electric power generating facility. This will be the first geothermal power plant in Hawaii. The plant is being constructed as a research and development project to evaluate geothermal steam as a viable resource to be considered for larger commercial electric power generating stations in Hawaii.

2.2 The project facilities include a turbine building, with a contiguous service area for plant operations and maintenance, visitor center, and the power plant equipment.

2.2.1 The power plant comprises a single inlet steam condensing turbine-generator, surface condensers, steam supply system, noncondensable gas removal equipment, mechanical draft cooling tower, hydrogen sulfide abatement system and the effluent water disposal system. The hydrogen sulfide (H_2S) abatement is accomplished by an inceration-absorption process. The effluent water from the facility is disposed of by percolation. No special treatment of the water is required as the H_2S content in the water is below critical limits. Major power plant equipment, electrical and mechanical, are designed to be portable in case of a volcanic eruption requiring evacuation of personnel and equipment from the site.

2.2.2 Power generated by the facility will feed into the HELCO 34 kV transmission system. Off peak load, which cannot be accepted by HELCO, will be fed into a load bank provided at the power plant. The generator will be able to operate independently of the HELCO system, allowing off-line testing of the power plant, or connected to the 34 kV outgoing transmission line feeding all or only a portion of its power into the system. The HELCO system dispatcher will have load control over the HGP-A plant input to the system via supervisory and telemetering equipment provided by HELCO.

2.2.3 The turbine building will be a steel framed structure and the visitors' center will be a wood structure. Natural ventilation will be used except in areas where operating personnel comfort is required or where equipment requires filtered air conditioning. The visitor center contains informative displays that describe the facility systems and their impact on the environment and the significance of geothermal power to the overall energy plan.

2.3 The site risk analysis indicated that seismic studies conclude that the buildings are to be designed according to the Uniform

Building Code requirements, 0.2g to 0.3g peak ground acceleration (PGA), and primary components, comprising major power plant equipment, supports require the use of 0.41g PGA as the design criteria. No effort is to be made to protect the site from a lava flow; however, major equipment is to be as portable as physical characteristics allow to facilitate an emergency salvging process in the event of a volcanic eruption.

2.4 Every effort has been made to provide necessary environmental controls to ensure the safety of the installation relative to the surrounding environment. Environmental controls are provided to limit water and noise pollution, chemical contamination of the air and to make the facility architectural and landscaping characteristics compatible with the surroundings at the site.

2.5 Fire protection for the facility includes a general fire loop and hydrant system as well as carbon dioxide or water sprinkler systems for selected equiment and areas. The general fire loop will be supplied by an electric fire pump, backed up by an engine driven fire pump.

2.6 The total estimated capital cost of the generating facility is $6,671,900.

2.7 A new well test program has been planned to take place in 1979. The previous well test was conducted without benefit of the wellhead steam flash separator and steam treatment system in place. The results of such a test provides preliminary data for general resource evaluation. The test with the wellhead steam separator installed will provide the more accurate resource data required for confirmation of the process system state points required for final design of the power plant. The costs of the steam treatment tower and the chemical treatment necessary for treatment of the H_2S in the steam has not been charged to the project; however, equipment purchased for the well test program has been utilized to benefit the power plant design.

3.0 BASIS FOR DESIGN

3.1 Site Considerations

3.1.1 Site Location and Access

The HGP-A Wellhead site is located in Pohoiki, in the Puna District on the Island of Hawaii, State of Hawaii. The site encompasses an area of 4.1 acres, referenced to by Tax Map Key 1-4-01:2, and is leased to RCUH by Department of Land and Natural Resources (DLNR), State of Hawaii.

The land parcel consists of an elevated section and a lower section; the Visitor Center will be on the former, while the wellhead and power plant will be on the latter.

The surface material is primarily volcanic cinder, and most of the area is overgrown with small brush and some trees.

The project site is approximately 30 miles from Hilo, at elevation 600 feet and is accessible via Pohoiki Road. Visitors will arrive by buses or privately owned vehicles. Parking for both buses and automobiles will be provided.

Additional site requirements are as follows:

- Security fencing
- Landscaped buffer zone along access road
- Provision for erosion control
- Inclusion of experimental planting program

3.1.2 County of Hawaii Requirements

Requirements by the County of Hawaii include the following:

- Only two road connections to Pohoiki Road will be permitted.
- Road connections must not exceed 36 feet where it joins the edge of pavement of Pohoiki Road.
- The low lying shrubbery along the Pohoiki Road frontage must be removed to allow a better line of sight distance for vehicles approaching and leaving the facility.

All new on site road construction will include an all-weather surfacing. Pavement striping and traffic signs will be installed to provide positive traffic control measures to aid motorists.

All grading will comply with the provisions of the Hawaii County Grading Ordinance.

3.2 Meteorological Data

3.2.1 Basis for design for air conditioning and ventilating systems:

Outside: 87°F Dry Bulb

74°F Wet Bulb

Inside: 76° Dry Bulb

Relative Humidity: 60%

3.2.2 Prevailing Wind:

Average Speed: 5 MPH

Direction: Southwest

3.2.3 Rainfall: 4 1/2" per hour

T_m = 10 years

3.3 Resource Data

The resource data given herein are based on the 1000-hr. (42-day) test reported in the QTR report of July 1, 1977, supplied to ROGERS by the University of Hawaii. These data have been established by RCUH as the design criteria for the power plant conceptual design.

3.3.1 Well Data

Data Description	Value
Wellhead Pressure	161 psig (175.7 psia)
Steam Fraction	0.737 at 1 atmosphere
Fluid Enthalpy	900 Btu/lb.
Total Flow Rate	81000 lb./hr.
Wellhead Temperature (saturated condition) at Wellhead Pressure	371°F

3.3.2 Noncondensable Gas in Steam

Percentage of Noncondensable Gas in Total Steam Flow	0.21%
Noncondensable Gas Composition by Weight	
Carbon Dioxide (CO_2)	60.3%
Hydrogen Sulfide (H_2S)	21.7%
Nitrogen (N_2)	17.3%
Hydrogen (H_2)	0.6%
	99.9%

3.3.3 Well Effluent Water

Percentage of Dissolved Solids in Well Effluent Water	0.4 by wt.
pH	5.5
Dissolved Solids Composition % by Weight	
Sodium	33.0%
Calcium	5.6%
Potassium	1.3%
Chloride	57.6%
Silica	2.3%
Other	.1%
	99.9%

3.4 Facility Building Requirements

3.4.1 All buildings will be designed to meet the rules and regulations of the latest issue of the revised ordinances of the County of Hawaii. Wind load will be taken at 15 psf and the seismic loading will be as required for Zone 3. Soil bearing pressure will be 4,000 pounds per square foot. The area will drain to 3 dry wells on the site.

3.4.2 Visitor Center:

This building and area will have facilities for visitors including display material, rest areas, toilet facilities and walkways to allow touring and viewing of the site premises. The facility is to serve 250 persons/hr during its peak usage. This building is of compact design and shall provide efficient visitor flow.

Displays will include the following:

- Description of significance of Hawaii's first well, acknowlegments and credits
- Local geothermal history
- Power plant cycle description
- Environment and pollution control measures

3.4.3 Turbine Building -- This structure is to house the turbine generator and its support systems and shall include a bridge crane. The functional areas included are a turbine room, equipment lay down area, maintenance shop, storage, office, toilet/locker room, laboratory. This structure will be designed to accommodate a maximum of 5 operating personnel.

3.5 Station Service Electrical Requirments

3.5.1 Station service power will be provided by the 3 megawatt steam-turbine generator during normal operating conditions. Power required for plant start-up will be back-fed through the 34 kV substation. Station service loads will be supplied at 480 volt from the motor control center which is located in the switchgear and motor control center unit.

3.5.2 Motors 1/3 horsepower and above will be supplied three phase power with motors under 1/3 horsepower being supplied single power from various station service panelboards.

3.5.3 Power for the visitor center building and area lighting and convenience outlets will be supplied to a panelboard located at the visitor center, fed from the 480 volt motor control center.

3.5.4 Power plant auxiliary load, building service and area lighting power will be supplied either by direct connection to the 480 volt motor control center or local distribution panelboards fed from the motor control center.

3.5.5 Electrical construction will be designed according to the National Electrical Code, The National Electrical Safety Code and State of Hawaii Public Utility Commission's General Order No. 6.

3.6 Steam Supply System

3.6.1 The steam supply system will conform to the following criteria:

a. Wellhead piping will be arranged so that the well cellar could be filled with cinders to protect the wellhead in the event of a lava flow.

b. Provide a full flow bypass at the flash separator station.

c. Consider aesthetics when selecting and siting the wellhead steam flash separator.

d. Design will include a final stage inline moisture separator.

e. Well start-up will require 1 hour full flow blowdown.

3.7 Equipment Design Criteria

The optimized state points for the plant process systems are shown below. These figures have been calculated based upon the well conditions of 161 psig and 81,000 lbs./hr. total flow, as provided by RCUH for the conceptual design. These figures will be confirmed during the preliminary design with final conditions to be set after the 1979 well test, with the wellhead flash separator in place.

3.7.1 Wellhead Steam Flash Separator

Working Pressure (psig)		Total Flow Rate (lb./hr.	Liquid Entrainment Not to Exceed
(Min.)	50	150,000	.3%
(Max.)	375	131,000	.1%
(Normal)	161	81,000	.1%

Materials of Construction

Carbon Steel Plate for Unfired Pressure Vessels

Carbon Steel Pipe

Carbon Steel Flanges

Structural Steel

Stainless Steel Plate for Wear Ring and Internals

3.7.2 Steam Treatment Tower

Data provided below is for system operations only. Specification of materials of construction are not included in the scope of the conceptual design.

Total Flow Rate:	55,368 lbs./hr.
Pressure:	1 Atmosphere
Temperature:	209°F
Recirculation Flow Rate:	154 gpm

3.7.3 Steam Turbine

Inlet Pressure:	160 psia
Inlet Flow Rate:	52,800 lbs./hr. (including 1% Liquid Entrainment
Inlet Temperature:	356°F
Exhaust Pressure:	4" Hg. Abs.
Exhaust Temperature:	125°F
Materials:	All 11-13% Chrome Steam Path

3.7.4 Main Condenser

Type:	Surface Condenser
Inlet Flow Rate:	51,453 lbs./hr.
Inlet Temperature:	122°F
Noncondensable Gas Approach Temperature:	7°F
NCG Removal System:	Inter- and After-Condensers Operated By Ejectors
Materials:	
Tubes	Type 316 Stainless Steel Seamless or Titanium
Tube Sheet Shell & Baffles	Type 316L Stainless Steel

3.7.5 Cooling Tower

Type:	Induced Cross Draft Flow
Wet Bulb:	75°F
Approach Temperature:	10°F
Heat Transfer Duty:	50,000,000 Btu/Hr.
Wind:	Hurricane Area, Up to 100 MPH
Materials:	Redwood or Impregnated Fir

3.8 Power Plant Spare Equipment

100% standby equipment will be supplied for the following:

- Steam Ejectors (Warehoused Spares)
- Main Condensate Pump (Installed)
- Effluent Disposal Pump (Installed)
- Cooling Water Circulating Pumps (Installed)
- Chemical Treatment System Pumps (Installed)
- H_2S Abatement System Pumps (Installed)

3.9 Effluent Water Disposal

The requirements of the Federal Environmental Protection Agency and the State of Hawaii require that the geothermal steam/water removed from the well be treated to remove obnoxious chemicals, principally hydrogen sulfide, prior to disposal. The disposal method established for this project is disposal of effluent water by means of a percolation basin, after first passing through a settling pond to allow the water to cool and settle out the precipitate (silica). No chemical treatment of the water is contemplated.

3.10 Utility Interface

HELCO will accept continuous power, up to 3 megawatts from 6:00 p.m. to 8:00 p.m. each day and up to 2 megawatts the remainder of the day.

3.10.1 Connections

Interconnection with the Hawaii Electric Light Co.'s (HELCO) system will be through a 34-kV, 3 phase, 3 wire line connected to HELCO's Puna Substation near Hilo City. This is a 17-mile long radial circuit that supplies three existing substations -- Hawaiian Paradise, Hawaiian Beaches and Kapoho. The 34-kV line does not have an overhead ground wire. The incoming line will be 3/0 AAAC. The present fault duty at the Puna substation is 77.2 MVA or 1292 amperes.

HELCO proposes to build the line extension from Kapoho Substation to the project site property line. HELCO will construct the extension to a dead-end structure provided by the project within the 34 kV substation. However, the cost of this extension will be charged to RCUH.

3.10.2 Metering

In accordance with normal utility practice HELCO will supply revenue metering consisting of a watthour meter for metering power in and a watthour demand meter for power out of the plant and var-hour meters for measuring volt-ampere-hours reactive in and out of the plant. RCUH will provide instrument transformers, small wiring and space in the 4-kV switchgear for the meters.

3.10.3 Supervisory Control and Data Acquisition

The project will provide space for mounting telemetering transducers, contacts, motor operators for governor and voltage regulator control and small wiring within switchgear and control panel provided with the project. In addition space will be provided for HELCO to install receiver-transmitter facilities. HELCO will provide and install telemetering transducers.

In order to provide partial unattended operation of the plant by the system dispatcher in Hilo City, HELCO has requested the following:

- Control over generator watt output (remote control of governor)
- Control over generator var output (remote control of voltage regulator)
- Remote trip for generator circuit breaker and load bank
- 4 kV circuit breaker status indication
- Telemetering of watt, var and ampere output into 34-kV line

- Telemetering of bus voltage

- Alarm transmission (to be limited to a single master trouble and a single master trip alarm)

3.10.4 <u>Step-up Transformer Sizing and Rating</u>

The step-up transformer proposed for this project is rated 2500/3500KVA OA/FA 55/65C, 34.4-4.16Y/2.4 kV. This is the closest match to the generator rating of 3000 kW. HELCO has requested consideration of a transformer rated 5000/6500 kVA, 67x33.5 ± 2-2 1/2% taps - 13.094/7.56 x 4.36Y/2.52 kV ± 10% and load tap changing since this particular rating has been adopted by HELCO as a system standard.

Estimated cost (material only) of the 2500 kVA transformer is $34,000; the cost of the 5000 kVA transformer is $99,000.

HELCO has no plans to convert the present line from 34 to 69 kV and voltage regulation on the line does not require additional regulation provided by the extra features on the 5000 kVA transformer. The added cost to obtain these features does not appear to be warranted against this project.

3.10.5 The 34 kV substation will be designed for requirements of the National Electrical Safety Code and Hawaii Public Utility Commission's General Order No. 6.

3.11 Environmental Requirements

The environmental compatibility is broken down to three major components:

- Noise suppression
- Plant liquid effluent disposal
- Hydrogen sulfide (H_2S) abatement
- Aesthetic appearance

3.11.1 Noise Suppression

The total attenuation of all noise from an industrial plant is physically unobtainable. Guidelines have been set up by OSHA to protect personnel from harmful noise. It is the intention of the design to comply with these requirements.

The main areas of concern which are currently apparent are the steam bypass, noncondensable gas exhaust, the turbine, ejectors and cooling tower.

3.11.2 Hydrogen Sulfide Abatement

The Hawaiian Pollution Investigation and Enforcement Branch of the Department of Health requires that the H_2S, as well as SO_2, emission be kept below 400 grams per MWh. This is equivalent to 93% collection efficiency on the emission from the well. Three process schemes were considered to accomplish the emission limits. The processes considered are:

(1) The Holmes-Stretford process

(2) An incineration process followed by a venturi wet scrubber operated with alkaline water

(3) Incineration-absorption process

The incineration-absorption process is selected as the best suited for this application and must be in compliance with environmental requirements but it need not demonstrate the feasibility of commercial systems such as the Holmes-Stretford Unit.

3.12 Portability

Selected major equipment and materials will be designed to be as portable as possible in the event of local volcanic activity requiring removal of the equipment from the site.

3.13 Risk Analysis

The Island of Hawaii has experienced considerable previous seismic and volcanic activity. The seismic and volcanic occurrences have taken place often enough in recent times to require a risk analysis of the site to determine the earthquake intensity which might be expected at the site and probable lava flow dangers to the facility.

3.13.1 Seismic Requirements

The basic methodology used was similar to that employed by Algermissin and Perkins, United States Geological Survey (USGS) in the seismic risk mapping of the contiguous United States, and used by the Applied Technology Council (ATC-3) to develop seismic coefficient maps. The ATC-3 study was conducted by the Applied Technology Council associated with the Structural Engineers Association of California and was sponsored by the National Science Foundation and the National Bureau of Standards. The ATC-3 report contains tentative provisions for seismic regulations for buildings for all parts of the United States. These regulations are more stringent than current provisions of the Uniform Building Code. However, the regulations of ATC-3 report have not yet been adopted by the UBC.

The basic technique employed in seismic risk analysis is that of determining the likelihood of different levels of ground shaking intensity at the site from the historical record of earthquakes. The future occurrence of different levels of ground shaking can then be forecast from the properties of the historical record. It has been shown that the basic methodology is reliable and engineering procedures exist to translate such forecasts into economical design of engineered structures to resist the forecast loads. The recommendations of this report are in accord with the current state of the art. The facility life is assumed to be 30 years with a non-exceedance of 90%.

3.13.2 Lava Flow

The lava flow risk evaluation was based on published data, informal conversations with engineers and scientists, and visual reporting based on visits to the site and surrounding area.

3.14 Procurement

Purchasing of all equipment and materials will be from domestic manufacturers in accordance with the buy American provisions of the United States Department of Energy.

4.0 FACILITY DESCRIPTION

The facility description included in this section is limited to the site, including site traffic, grading and drainage, utilities, landscaping and area lighting and the visitor center, turbine building and service building area, architectural, structural and building services design description.

4.1 Site

The general site arrangement provides the most efficient use of the land based upon several factors including; grading, vehicle access, equipment layout and aesthetic appearance.

4.1.1 Site Traffic

Once at the site, vehicles will follow a one-way traffic pattern: the entry will be from the easterly driveway connection to Pohoiki Road, and exit will be from the westerly connection. Visitor traffic, service vehicles and traffic to the farm behind the wellhead site will use this roadway. Access to the referenced farm will be from a 20-ft. road easement along the HGP-A property.

4.1.2 Grading and Drainage

Grading will be designed for a minimum of excavation as the deeper subsurface material is generally very hard fractured basalt rock. There are no major off-site drainage tributaries directed toward the site; hence, drainage facilities will be primarily for on-site waters. Accordingly, the site grading is developed in a manner which controls most of the surface flows to one of three drainage drywells.

4.1.3 Excavation Methods

Excavation by conventional methods will be difficult below a depth of approximately 18 inches. Below this depth blasting or use of pneumatic tools might be required. The site layout has been planned with the idea of limiting severe grading and excavation where possible.

Where blasting is necessary the General Contractor will be required to meet all OSHA requirements and consider the time of day so as to provide a minimum of inconvenience to surrounding property owners.

4.1.4 Utilities

There are no potable water systems near the project site; therefore, water will have to be trucked in, and stored in 5,000-gallon tank. Cooled geothermal water from the retention pond will be used for all toilet facilities on the site.

Similarly, there are no sewer systems in the area; therefore, the domestic sewage will be disposed of in a cesspool near the southeasterly section of the parcel. This method of disposal has been approved by the State's Department of Health.

Auxiliary power for general site electrical loads will be supplied from the 480 volt motor control center.

4.1.5 Area Lighting

Emergency lighting units will be located in all personnel areas, stairways, exits, and at selected equipment locations. The Visitors' Center area will have minimum landscape/decorative lighting for the exterior areas and will be limited to the entry area only. Minimum parking lot lighting will be provided. The exterior process equipment areas will have lighting for general access and safety. Localized switched task lighting will be provided as required. Electrical wiring for exterior lighting systems shall be underground wherever mechanical equipment supports are not available to install wiring in conduit.

Area	Illumination Level (FC)	Type of Fixtures
Entrance, Walkways, Paved Areas Adjoining Building	5	High-Pressure Sodium
Roadways and Parking	3	High-Pressure Sodium
Process Equipment (Exterior)	5	Local Task Incandescent
Visitor Center	2	Incandescent/Decorative
Emergency Lighting		Individual Battery-Powered Lights

4.2 Landscape Concept

The landscaping proposed for the project is premised on the creation of a natural environment. The overall landscape treatment will vary greatly from an intense planting at the visitor center to a practical lava gravel base in the power plant area.

The visitor center and adjacent areas, including the parking lot, visitor area pathways and viewing areas, will be treated with an array of compatible plant materials common to the surroundings which will provide accents, interest and colors. Topsoil will be imported into these areas to provide proper growing conditions.

In the areas between Pohoiki Road and the parking lot, along the existing cinder road, the northern boundary and the open groundcover area of the reservoir, the landscape treatment will become less intense with use of trees and shrubs to provide for buffer - screen, enframing vistas and the continuation of the natural character of the surroundings. The ground condition will initially be lava base and through a selective herbicide program, the natural ferns (Narrow-leaf Sword fern, Sword fern, Uluhe fern and Lauae fern) will be allowed to provide a natural groundcover predominant in the area.

The power plant complex surface areas will either be paved or be provided with a lava gravel base for practical appearance and ease of maintenance with planters located to complement the installation's appearance.

Experimental planting will also be conducted with selected plant materials judiciously placed throughout the project site. This will test the sensitivity of plants to the atmosphere surrounding the power plant facility and provide a reference for future projects as well as reforestation and environmental constraints of plant materials within the area.

The intent of the landscape treatment is to create a setting natural to the unique and tropical character of the area. The proposed and newly planted materials will be relatively immature, but will eventually mature and adapt to the area. A maintenance period is necessary and essential to the overall landscape concept.

The maintenance period is an important phase of the landscaping which will ensure that the investment in plant materials is protected while establishing the desired effect of the overall landscaping. Landscape maintenance will be provided by local firms experienced in this type of activity.

4.3 Visitor Center

4.3.1 Architectural Design

The visitor center building is designed to represent a volcanic cone to symbolize the source of the geothermal energy. The shake roof simulates a cinder layer which converges at the top where a skylight is located. The skylight allows the natural light into the building cove where the prism reflects the light to the display area. Displays are to be arrayed for maximum visibility and smooth flow of visitor traffic through the Center.

This building is designed to serve as a visitors' information center and is to be equipped with informative fixed and audio-visual displays. The displays to be included are: (1) History of geothermal energy research and development; (2) descriptive display of the HGP-A geothermal well; (3) descriptive display of the geothermal power plant; (4) the future application and use of geothermal energy, and (5) the environmental concerns. The display and projection areas are divided with portable partitions to allow for rearrangement should the need arise.

4.3.2 Structure

The Visitors' Center building is 1,860 square feet and shall be basically of a pole and beam construction to allow for an open and movable display area. The pole (columns) will be buried about 5 feet in the ground and encased in concrete to give the building stability against wind and earthquakes. The roofing will consist of 2" x 6" tongue and grooved planks overlayed with plyboard and shakes. A 4" reinforced concrete floor will be used throughout the building. In the storage/restroom area the walls will consist of 2" x 4" studs with 5/8" douglas fir textured plyboard on the exterior, 5/8" gypsum on the interior, and ceramic tile in the toilet area.

4.3.3 Building Services

Potable and non-potable water and sewage systems will be connected to the site utilities described previously.

The visitor center building requires no air conditioning and will depend on natural draft for ventilation.

Electrical power for lighting, receptacles and other miscellaneous loads will be supplied from the 480 volt motor control center.

Visitors' Center Lighting

Area	Illumination Level (FC)	Type of Fixtures
Storage	10	Incandescent
Toilets	30	Fluorescent
Display	--	Fluorescent

4.4 Turbine Building

4.4.1 Architectural Design

The turbine building is a high bay structure to provide for the maintenance of the turbine generator. Adequate gravity ventilation will be provided to dissipate equipment heat losses. Sound control and natural lighting have been considered in the building design.

The turbine building orientation dictates the overall layout of the power plant facility. The turbine building layout is designed to allow sufficient laydown area for major pieces of equipment during construction and yearly turnaround maintenance. It is also designed to allow adequate access space on the sides of the all equipment, as well as lifting clearance above.

4.4.2 Structure

The turbine building, 24' wide x 72' long x 30' eave, will consist of a rigid steel frame supporting a 30/10 ton bridge crane. The rigid frame will be fabricated from standard rolled steel members (A36), sandblasted, primed, and coated with epoxy paint. The roof will be covered with galvanized pre-painted metal sheeting. The upper 8 feet of the building will be covered with galvanized pre-painted metal sheeting. Unlike the upper section, the lower 24 feet of the building will have textured redwood siding on the exterior with textured douglas fir plyboard on the interior. A 6" reinforced concrete floor will be used throughout the building, except for equipment pads. Foundations for the building will rest on fractured basalt having a soil bearing pressure of 4000 psf.

4.4.3 Building Services

Potable and non-potable water and sewage systems will be connected to the site utilities described previously.

The turbine building is designed for natural ventilation, with 10 air changes/hour. There will be no air conditioning in this building. Supply louvers are placed in the lower part of the building and open screen areas are provided for the full length of the building at an elevation of 24 feet. The air is exhausted through the air vents located on the top of the building. The turbine/generator room will be lighted to 50 footcandles using metal halide industrial high bay lighting. Electrical power for lighting, receptacles and other miscellaneous loads will be supplied from the 480 volt motor control center.

4.5 Service Building

4.5.1 Architectural Design

The service building will be a low profile structure contiguous to the turbine building. Selected areas will be air conditioned due to the requirements of comfort for operating and maintenance personnel and equipment protection.

The facilities within the turbine building service building will be maintenance shop areas, toilet and shower facilities, administration area and the wet lab. Personnel facilities are minimal due to the limited number of operators who will be attending the plant at one time.

4.5.2 Structure

The service area building, 30' x 35', will be constructed with 2" x 4" stud wall system with douglas fir textured plyboard on the exterior and gypsum board in the interior. Wooden trusses will be used to support the 24 gauge pre-painted galvanized roof sheeting. Ceramic tile will be used on the walls and floor in the bathroom/shower area. A 4" reinforced concrete slab will be used for the flooring in the office, toilet/ locker room, and wet laboratory area, while an 8" reinforced concrete slab will be used in the maintenance shop area.

4.5.3 Building Services

Potable and non-potable water and sewage systems will be connected to the site utilities described previously.

The office will be air conditioned exhausting conditioned air through the toilet and locker rooms. Natural ventilation will be provided for the maintenance room. The wet lab in the service area, as well as control room and switchgear rooms, will be provided with air conditioning with charcoal filters. Charcoal filtration is required because airborne hydrogen sulfide, humidity and particulate contaminants combined with diurnal temperature changes provide almost ideal conditions for corrosion and/or fouling of contactors, commutators, instruments and other regulating equipment.

Area	Illumination Level (FC)	Type of Fixtures
Office	75	Fluorescent
Toilet/Locker Room	30	Fluorescent
Wet Laboratory	100	Fluorescent
Maintenance/Storage	20	Fluorescent

Electrical power for lighting, receptacles and other miscellaneous loads will be supplied from the 480 volt motor control center.

5.0 Power Plant Process

The power plant systems are shown on the following drawings, which are included in Section 12.0.

(1) Steam Supply and Effluent Disposal, Dwg. No. E-02-101

(2) Power Plant, Dwg. No. E-02-102

(3) H_2S Abatement System, Dwg. No. E-02-103

The power cycle is shown on TABLE 5-1.

5.1 System Descriptions

5.1.1 Steam Supply and Effluent Disposal

The steam supply and effluent disposal system consists of the wellhead steam flash separator, steam supply pressure vent system, emergency steam treatment tower, well startup vent silencer and separator stack and associated piping.

The steam flash separator and emergency steam treatment tower with their associated piping are arranged to make use of the existing well silencer and separator stacks and will be used as installed for the planned well test. The steam flash separator vessel separates the steam and water phases flowing

TABLE 5-1

Cycle Data Sheet

3 MW Generation Unit

Flash Steam Flow lb./hr.	52,800
To Generator Turbine	51,100
To Auxiliaries	1,700
Flash Steam Conditions	
Temperature, F	371°
Pressure Inlet Flange, psia	160
Noncondensable Gas lb./hr.	170
To Turbine (lb./hr.)	165
To Auxiliaries (lb./hr.)	5
Pressure	
Main Condenser, Inches Hg Absolute	4.0
Enthalpy, Btu/lb.	
Throttle Inlet	1,196
Turbine Drop	202
Cooling Water	
Flow, lb./hr.	1,660,000
GPM	3,320
Temperature, F	
Cold	85°
Return	115°
Equivalent kW Values (Nominal)	
Turbine Power Gross Generator Terminals (Based on 17 lbs./kWh specific steam Consumption)	3,000
Cooling Water Circulation & Surface Condenser Condensate Pumps	87
Cooling Tower Fans	58
Miscellaneous Auxiliary Loads	47
Subtotal, Station Auxiliaries kW	192
DESIGN NET GENERATION kW	2,808

from the well. The pressure in the flash separator is controlled by means of the steam supply pressure vent system, which serves as back-up to the pressure control modulator on the inlet of the turbine in the event of reduced steam demand by the power plant. The water in the steam flash separator is level controlled by allowing discharge of the effluent water to the vent silencer and separator stacks where the flashed steam is vented to atmospheric pressure, and the remaining water is discharged to the cooling pond. No treatment of the effluent water for removal of H_2S is necessary. The steam treatment tower is used only during well warm-up periods and during particular upset conditions in: 1) the steam supply; 2) power plant operations or 3) H_2S abatement system operations.

5.1.2 Power Plant

The main material flow path through the plant is indicated by a broad heavy line on the flow diagram No. E-02-102.

The flash steam from the flash separator flows through a final in line steam separator before entering the turbine. Liquid carry-over of 0.3% and condensate formed by heat loss through the piping must be removed prior to delivery of the steam to the turbine inlet. The inline steam separator is installed for this function and is designed to remove 99% of the entrained liquid. However, for mechanical integrity the turbine is designed to take up to 1% entrained liquid for short durations.

The steam exits from the in line steam separator and passes through a main steam strainer which removes all the particles larger than ten microns carried along with the steam. The main control valve and stop valve are located downstream from the in-line strainer.

The steam piping to the turbine is bifurcated, with each parallel line containing a safety stop check valve and a modulating flow control valve. The lines combine into a single steam line entering the turbine. The two parallel control sets provide 100% redundancy of the steam control system and facilitate full load testing of the "Stem Free Test" on the safety stop check and control valves.

The turbine exhaust steam is condensed in the main condenser. The condensate is pumped to the cooling tower. The noncondensable gases which are present in the steam, flow through the gas cooling section of the condenser. The cooled gases are extracted from the main condenser by a two stage ejector system which consists of inter- and aftercondensers.

The gases leaving the aftercondenser flow to the hydrogen sulfide (H_2S) abatement system where H_2S is removed from the gas prior to discharge into the atmosphere.

5.1.3 H_2S Abatement System

The vent gases from the aftercondenser contain sufficient heating value to sustain combustion, so the gases are charged to the incinerator where the hydrogen sulfide is oxidized to sulfur dioxide gas. The flue gases from the incinerator are quenched with water, and the SO_2 is removed by absorption in water before the flue gases are vented to the atmosphere.

The sulfur dioxide bearing water from the absorber is pumped to the neutralization pit. Neutralization of the acid water is carried out by reaction with limestone. A precipitate of calcium sulfite is formed which is allowed to settle out in the settling basin. The clear neutralized effluent water is disposed by percolation. The calcium sulfite precipitate will be hauled to an off-site disposal area.

The limestone is brought in by dump truck and it is dumped directly into the limestone pit.

5.1.4 Effluent Water Flow

The hot water from the flash steam separator is flashed to atmospheric pressure through the vent silencer. The overflow water from the vent silencer is allowed to be cooled in the retention pond which is designed for a residence time of about one hour. On cooling the precipitated silica is allowed to settle out in the retention pond. Cooling tower blowdown also flows to the retention pond.

A portion of the cooled water from the retention pond is used as the absorbent for the removal of SO_2 from the noncondensable gas incineration-absorption system which is used for H_2S pollution control. The water from the absorber is neutralized and sent to the settling basins to settle the carryover limestone and calcium sulfite. Another portion of the water in the retention pond is used for the sanitary (non-potable) water supply to all the on-site toilet facilities and disposed to cesspool.

The clear neutralized overflow is disposed by percolation.

5.2 Power Plant Auxiliary Systems

5.2.1 Effluent Liquid Discharge from Steam Separator

The effluent liquid from the steam separator is discharged to the percolation pond for disposal.

5.2.2 Gland Seal Steam and Turbine Drains

A high pressure steam line feeds steam to the gland labyrinth seals on the turbine shaft, the discharge from these seals is removed by means of a gland seal ejector system which discharges into the main condenser. Liquid, from the interstage drains on the turbine drain into the gland seal drain tank, and is emptied by means of an ejector system which also discharges into the main condenser.

5.2.3 Fire Protection

Fire protection for specific power plant equipment will be provided in addition to the general area fire loop.

The turbine-generator unit will be protected by sprinkler and carbon dioxide systems. The electric equipment in the switchgear and motor control center unit and the control unit will have direct connections to the carbon dioxide system. The cooling tower will be protected by a spray wetting system.

5.3 Major Equipment

5.3.1 Steam Turbine

The turbine will be a single entry single or multistage machine exhausting at approximately 4" Hg Abs. The turbine design and material selection will be suitable for geothermal service and provides reliable low maintenance life under these conditions.

The lube oil system for the turbine generator will be furnished by the turbine generator manufacturer. This system consists of all lubrication equipment for the bearings and the hydraulic control oil for the governor and safety control features on the machine.

5.3.2 Condensing Equipment

The main condenser will be of the shell and tube type; constructed of Type 316L stainless steel. This material is required to prevent damage by the corrosive action of the geothermal condensate.

The design of the main condenser incorporates a gas cooling section which is required to handle the noncondensable gases which are part of the geothermal steam flow. The condenser gas cooling section subcools the gases below the condensing temperature of the steam in order to reduce the gas load to the ejection system.

The condensate collects in a well at the bottom of the condenser and it is pumped by the main condensate pump to the cooling tower as make-up water to the cooling tower.

The tubes of the condenser contain the cooling water which is pumped from the cooling tower basin cold well. The cooling water first enters the gas cooling section to provide gas subcooling then flows into the condensing section.

5.3.3 Ejectors

The two stage ejector system with an intercondenser and after-condenser, is designed to produce a vacuum in the main by removing the noncondensable gases entering with the exhaust steam. The first stage ejector draws down main condenser pressure to 4" Hg Abs; removing and exhausting the noncondensable gases to the intercondenser. The second stage ejector draws down the intercondenser pressure and exhausts to the aftercondenser. The gases from the aftercondenser flow to the H_2S abatement system and are vented to atmosphere. The second stage ejector is also used as a hogging ejector during the startup phase to assist in establishing the vacuum at initial startup of the turbine.

The condenser operating pressures are selected by optimization of thermal efficiency vs plant operating and capital cost.

The gland seal ejector minimizes air leakage by drawing seal steam across the turbine shaft seal gland, thereby producing a seal between the atmosphere and the turbine operating steam. This ejector exhausts into the main condenser.

5.3.4 Condensate Pump

Condensate from the steam turbine and condensate formed from the gland seal steam system is collected in the main condenser. Also, the condensate formed in the inter-condenser and after-condenser drains to the main condenser. The total accumulation of condensate is pumped from the main condenser hot well by the condensate pump.

The flow of condensate from the main condenser is controlled by means of a condenser level control valve located downstream of the condensate pump.

5.3.5 Cooling Tower

The function of the cooling tower is to dissipate the heat removed from the condenser by forced evaporation cooling of the cooling water returning to the tower.

The incoming hot water is fed by means of a sparger or distribution header at the top of the tower. The warm cooling water which rains down the tower packing is contacted by cold air flowing across and up through the tower. Evaporation, hence cooling, of the water takes place and the cold water collects at the base of the tower, or the cold well.

The cooling tower circulation pump takes suction from the cooling tower basin cold well and pumps the cooling water back to the condensers and other auxiliary equipment which require cooling water.

The construction material of the cooling tower is generally wood, redwood or impregnated Douglas Fir. The tower packing is of fire retardant plastic. Fore bay and cooling tower basin are constructed of concrete and painted with a special coating to withstand the corrosive attack of the geothermal water.

As mentioned previously the level of water in the basin is controlled by means of a level control valve which regulates the cooling tower blowdown. Blowdown is required to limit the build up of dissolved solids in the circulated cooling water.

5.3.6 Flash Steam Separator and In Line Steam Separator

The flash steam separator is designed to separate the 2-phase flow from the wellhead into flashed steam and hot water. The flash separator has been designed for two purposes: initially to serve as a test vessel over a range of 50 psig to 375 psig in order to determine the full range characteristics of the well flow during the planned well test, and secondly, to operate at the normal operating conditions of the power plant for the duration of its useful productive life.

The in-line steam separator is located downstream from the flash separator and immediately upstream of the turbine. The intent of the in-line steam separator is to remove any moisture formed in the piping before the steam enters the turbine. The efficiency of the in line steam separator is approximately 99.7% and therefore the steam leaving the in line steam separator will be essentially dry saturated.

5.4 Auxiliary Equipment

5.4.1 Cooling Water Circulation Pump

This pump takes cold water from the cooling tower basin and circulates it through all equipment requiring cooling water. The material of construction will be type 316L stainless steel for protection against corrosion .

5.4.2 Lube Oil Cooler, Instrument Air Cooler and Generator Cooler

These three items of equipment provide the necessary cooling for the lubricating and hydraulic control oil system, the air compressor system, and the generator.

The lube oil cooler is a shell and tube heat exchanger. The cooling water flows through the tube side of the exchanger. This facilitates easy cleaning of the exchanger in the event of fouling on the water side. Control of the cooling effect is obtained by bypass control of the oil through the shell side of the exchanger. The material of construction is carbon steel for the shell and stainless steel type 316L for the tubes.

The air compressor cooling system is a water to water heat exchanger. The cooling water is on the tube side of the shell and tube exhanger. A clean water closed circuit system circulates on the shell side between the heat exchanger and the air compressor cooling jacket. The air compressor cooling system piping will be stainless steel. The materials for shell and tubes will be carbon steel and stainless steel, respectively.

The generator cooler is an air to water heat exchanger, and is located in close proximity to the generator in order that a closed loop circulating air system can be arranged between the generator and the heat exchanger. The cooling water circulates through the tubes of heat exchanger. The materials of construction will be the same as the air compressor cooling system previously described.

5.4.3 Piping Materials

The piping materials are broken down into two main groups: steam service and non-steam service. As a general rule all steam service will be carbon steel materials and all condensate service will be corrosive resistant materials, primarily stainless steels. However, other materials may be considered depending on the pressure and temperature of the service under consideration, except those made of copper or any copper bearing alloys. Copper reacts with H_2S to produce rapid oxidation of the surface and hence is unsuitable as a corrosion resistive material. This is of particular note in valve trim, as many valves use copper and brass for trim material.

5.5 Operating Conditions

The steam gathering system is designed to operate under the following conditions:

1. Well warm-up - Normalization period required to clear debris which accumulates in the well shaft.
2. Normal operating conditions.
3. H_2S abatement system shutdown.
4. Excess well flow.
5. Steam turbine shutdown.
6. Well Test

5.5.1 Well Warm-Up

Prior to allowing steam to flow to the turbine, the well flow must be established to clean debris and heat up the system. Initially, the steam/water two phase flow will be vented through the silencer and separator stack at the wellhead to remove debris accumulation in the well. In this operating mode, the chemical treatment system is designed to treat the steam/water flow to remove hydrogen sulfide before venting the gas to atmosphere. The treatment system is designed to remove 98% of the hydrogen sulfide in the steam.

5.5.2 Normal Operating Conditions

Under normal operating conditions the two phase flow from the well is separated in the wellhead steam flash separator with the steam going to the turbine inlet and the effluent water going to the well silencer and separator stack. The steam, with its inherent noncondensable gas component, is passed through the turbine and condensed in the main condenser. Air and noncondensable gases are removed from the main condenser by use of ejectors operated with inter-and after-condensers with the noncondensable gases going to the gas treatment system and the condensate is pumped to the cooling tower basin as make-up to the cooling tower. Effluent waste water is transferred to the cooling pond for cooling before discharge to the percolation pond.

5.5.3 Hydrogen Sulfide Removal

On tripout of the incinerator/absorber H_2S abatement system the bypass vent valve discharges the vent gas to the steam treatment tower and the power plant continues normal operation. Under the normal operating mode the chemical treatment system is automatically actuated to treat the gas with caustic and hydrogen peroxide.

5.5.4 Excess Well Flow

If the flow from the well is higher than required by the power plant the steam supply pressure vent system will open to relieve the excess pressure and allow the excess flow to be diverted to the steam treatment tower for treatment and water disposal as previously described. This will allow the power plant to continue to function normally.

5.5.5 Steam Turbine Shutdown

If the steam turbine is shut down due to an operating upset condition, the steam supply vent system is activated by the increased steam pressure in the line which will discharge the total uninterrupted flow of steam from the well to the steam treatment tower and activate the chemical treatment system.

5.5.6 Well Test Operation

The steam flash separator has been designed primarily to provide the means to accurately determine the well flows as a function of wellhead pressures over the range of expected operations.

Flow rates anticipated during the well test, are based upon the HGP Progress Report January 1, 1977, Page 38 by applying a factor of 1.25 to the 120,000 lbs./hr. flow for the 25 hour test period. The 1.25 factor provides an allowance for the known inaccuracies in two phase flow measurements. The steam treatment tower has been designed to remove hydrogen sulfide in geothermal steam, by the use of hydrogen peroxide and sodium hydroxide. This is a treatment process developed by FMC Corporation. Based upon the flow rate of 120,000 lbs./hr. total flow and the noncondensable gas content of 0.21%, the chemical cost for a 2 week well test is estimated to be $31,700 for 98% abatement of H_2S.

5.6 Operating Control Features

The plant design provides controls and instrumentation for complete automatic operation of the power plant after manually controlled start-up and synchronizing. Manual controls in the vicinity of the turbine are used to start the turbine and bring it up to operating speed. Plant synchronization and operation are then controlled from the control room. Emergency shut down can be actuated from the control room or the local control panel at the turbine.

5.6.1 Steam Supply System

Controls provided on the wellhead steam flash separator are:

1. Level Control
2. Pressure Control
3. Safety Relief
4. Steam Flow Indication
5. High Level Alarm and Trip

Controls provided on the steam treatment tower are:

1. Level Control
2. Pressure Control
3. Chemical Supply
4. High Level Alarm and Trip

5.6.2 Turbine Control System

The turbine control and stop valves are operated hydraulically by the turbine governor. The control valve is used to throttle the steam to the turbine for control of speed and/or load while the emergency stop valve serves to rapidly stop steam flow in the event of a turbine trip.

The turbine is protected by alarms and trips for low gland steam pressure, abnormal control valve positions, high turbine-generator bearing temperature, turbine vibration and turbine overspeed.

5.6.3 Condenser

The level in the condenser is maintained by throttling a valve in the discharge line from the condensate pump. Misoperation of the condenser does not effect the turbine, as the turbine is protected by alarms and trips for low or high condenser level, low vacuum in the condenser and condensate pump failure.

5.6.4 Cooling Water Supply

Cooling water flow and temperature are measured to indicate performance of the system. A level control system maintains the level in the cooling tower basin. Alarms are provided for low and high basin water level, basin water temperature and cooling tower fan failure.

5.6.5 Noncondensable Gas System

Controls are provided for intercondenser and after-condenser level. An alarm will indicate a low vacuum condition in the inter-condenser.

5.6.6 Lube Oil Processing System

The lube oil for the turbine-generator must be held within the proper temperature range and kept clean. Before start-up, the oil may be heated to maintain the minimum required temperature. During operation the oil will become heated and will require cooling. An alarm and trip are provided for low level in the lube oil reservoir and alarm for high oil level.

5.6.7 Compressed Air System

A clean dry air supply is required to operate pneumatic instruments and control valves. Since the instrument air supply is vital to the operation of the plant, a 100% standby will be furnished. A third compressor will supply utility air. If the instrument air compressor fails to maintain normal pressure, the backup compressor will automatically start and an alarm will sound. If the air pressure falls to the minimum allowable value, the turbine will be tripped.

5.6.8 Fire Protection System

Pressure in the fire pump system is maintained by a jockey pump. Pressure is sensed by a pressure switch. In the event of a drop in pressure with the jockey pump running, a second pressure switch will start the No. 1 main fire pump, open the discharge valve and sound the alarm. A continued drop in pressure will operate a third pressure switch to start the No. 2 main fire pump, which is engine driven, and open its discharge valve. As the pressure in the system is restored, the pumps will be stopped in the reverse order.

6.0 ELECTRICAL SYSTEM

6.1 General Description

Power will be generated at 4160 volts. Power plant auxiliaries will be supplied power at 480 volts through a step-down station power transformer. The transmission substation is provided with a 4.16-34 kV step-up transformer. HELCO will bring a 34 kV line to the deadend structure in the substation. The electrical system is shown graphically on the single line diagram, Drawing E-08-101-0, included in Section 12.7 of this report.

The principal components of the electrical system are the 4.16 kV resistance grounded generator, 4.16 kV switchgear, 4.16 kV-34 kV step-up transformer, station service transformer, 1600 kW load bank, the 480 volt motor control centers and the station battery. Several power plant operating modes are possible due to the presence of the 1600 kW load bank which will dissipate a portion of the generator output. The operating modes are detailed in Section 6.3.

The station service power for plant auxiliaries will be supplied at 480 volts through a step-down transformer fed from the generator 4.16 kV switchgear bus. DC supplies of 48 and

125 volts will be supply power for general control and emergency power. The battery chargers are fed from the 480 volt motor control center.

6.2 Major Equipment Description

6.2.1 Generator

The 3-phase generator will have a brushless exciter and rated as follows:

Capacity	3000 kW
Power Factor	0.80
Voltage	4160 volts
Frequency	60 Hz

A standard open air-cooled generator is proposed since materials that are subject to the corrosive effects of hydrogen sulfide are normally insulated, or can be given a suitable protective coating. Alternatively, an air cooled closed generator with an air/water heat exchanger is being considered.

6.2.2 Switchgear and Motor Control Center Unit

The 4.16 kV switchgear, 480-volt motor control center, 48 and 125 volt dc control center and battery charger and batteries are to be furnished factory installed in a portable metal building. Space will be provided as necessary for HELCO supervisory control equipment. The building itself will be fabricated with structural steel floor framing, steel floor, and steel or aluminum sheeting for side walls and roof. The building will be pressurized, weatherproof, insulated and provided with air conditioning unit with a charcoal filtered intake for temperature and humidity control and removal of hydrogen sulfide present in the outside air. Limited window space will be provided since this unit will not normally be attended. Interior lighting will be fluorescent with emergency dc lighting.

Since the 4.16 kV switchgear is usually rear access, exterior doors will be provided behind the switchgear line-up for inspection and maintenance. Suitable terminal boxes with receptacles will be provided on the ends of the building for low voltage cable connections to the control room, 34-4.16 kV step-up transformer, generator and various plant auxiliary equipment.

4.16 kV switchgear will be an assembly of air-break circuit breakers and load-break switches completely metal-enclosed. Bus rating will be 1200 amperes. Circuit breakers will have interrupting capacities of 29 kA. All relays, HELCO-supplied watt-hour and var-hour meters and such control and indication as is necessary for maintenance and test will be mounted in the front of the switchgear. Other meters and power plant controls will be located in a separate control panel in the control building adjacent to the switchgear and motor control center unit.

The 480-volt motor control center will be a NEMA Type I, Class C units. Motor starters will be the combination circuit breaker type, each with a 480-120 volt control power transformer.

The 125-volt dc equipment will consist of heavy duty plastic clad nickel-cadmium batteries, a solid state battery charger and a distribution panel. Battery capacity will be sized to permit one hour of operation of an emergency oil pump, miscellaneous control, emergency lighting and an inverter for dc supply of critical instrumentation.

A separate 48-v dc system consisting of a battery charger, battery and a small distribution panel will be provided to supply HELCO's supervisory control and communications system with power.

6.2.3 Step-up Transformer - Circuit Switcher Unit

The unit will consist of the 34-4.16Y/2.4-kV step-up transformer, a 34-KV circuit switcher and 34 kV voltage transformer. A separate dead-end structure will be provided to terminate the incoming 34 kV line and to support lightning arresters. The equipment, excluding the dead-end structure, will be assembled on a common steel base capable of being jacked and rolled to facilitate plant portability. Transformer fan power supply, alarm control and instrument transformer connections will be brought to a terminal box with suitable receptacles.

The transformer will be rated 2500/2800/3150/3500 kVA, OA/FA 55/65°C rise, 34-4.16Y/2.4-kV, 3-phase, and with manufacturer's standard impedance. Transformer will have cover mounted lightning arresters, bushing current transformers for relaying and a sudden gas pressure relay for protection. Receptacles will be supplied for use with non-load break connectors, instead of a standard air-filled terminal box having a wall bushing on the 4.16 kV side.

The circuit switcher will be rated 1200 ampere continuous, 8000 amperes interrupting, 34-kV and 200-kV BIL. The circuit switcher will be provided with an operator to permit remote opening and closing from the control room and opening on transformer fault.

6.2.4 Station Service Transformer Unit

The station service transformer is to be supplied from the generator 4-kV bus. The transformer will be of the pad-mounted type, oil filled, dead front, with provision for high voltage load break separable connectors. The station service transformer will be rated 1500/1668/1932, kVA, OA/FA, 65 C rise, 4160-480Y/277 volts, 3-phase.

6.2.5 Plant Control Unit

The main electrical and mechanical control panel is to be furnished in a portable metal building similar to that used for the 4-kV switchgear and motor control center unit. However, since this building is used for operators, improved interior furnishings and a view window will be provided.

This building will be air conditioned with charcoal filtered air intakes.

The Power Plant Control panel will consist of a multi-section sheet steel panel of adequate depth to hold auxiliary relays and other components necessary for plant control. Access to control panels will be through rear doors. Governor control and voltage regulator equipment will be installed in the panel. The panel will include both electric and pneumatic control and indicating lights.

The control panel will include process controls, gages, and metering; turbine/generator, controls, gauges, and metering; load bank control, outgoing line controls, synchronizing panel, and a mechanical flow diagram/electrical mimic bus with position indicating lights for principal valves, circuit breakers and switches.

6.2.6 Load Bank

The load bank will be rated 1600 kW, 480 volts, 3-phase. The load bank has been rated for the following two conditions: (1) 53% load while testing of the turbine-generator set independent of HELCO's system, and (2) absorbing any amount of generated power, up to its maximum rating, not accepted by HELCO in order to maintain rated output from the turbine-generator set. The load bank will consist of 480 volt switched resistors connected in parallel. Resistor type load banks do not affect other parts of the plant. However, load can be adjusted in increments of a nominal 300 kW.

6.2.7 Electrical Materials and General Installation

High voltage connections between the generator, switchgear, 34 kV step-up transformer and station service transformers will be single conductor, 5 kV copper, cross-linked polyethylene (XLPE) or ethelyne propylene (EP) rubber insulated. Separate non-load break connectors will be installed on these pieces of equipment and the cable.

Connections between pieces of electrical and mechanical equipment will be made with multi-conductor cable installed in overhead cable tray or cable trenches. Cable tray will be installed along the pipeway running to the well and to the cooling tower.

The scheme proposed here will permit ready disconnecting (electrically) of pieces of equipment for relocation, emergency evacuation, field electric testing, and troubleshooting.

Underground construction using a trench will be provided for interconnections between the generator and switchgear unit, and the switchgear unit to step-up transformer unit, station service transformer unit, and load bank unit. Underground duct will be used for the feeder to the visitors' center telephone service, and miscellaneous connections to area lighting. The 34kV outgoing line will be an overhead connection.

Application of supplemental sealing and coating to terminals and electrical equipment to prevent corrosion from hydrogen sulfide will be provided in the field. Selected electrical enclosures not located in rooms or units with charcoal filter air will be purged with charcoal filtered air to keep ambient air, containing hydrogen sulfide, from entering the enclosures in any concentration. Individual ground conductors from underground system or for bonding equipment together will be tinned copper with green insulation to prevent corrosion from hydrogen sulfide.

6.2.8 Communication

Three basic communications systems will be provided:

External - Commercial telephone service by Hawaiian Telephone Co. from the Visitors' Center (pay telephone), plant office and the control unit.

External - For use by HELCO for voice communication and supervisory control from system dispatcher in Hilo City. These facilities will be provided by HELCO and will consist of either a leased telephone from Hawaiian Telephone Co. and a mobile radio unit for backup, or, if a leased line is not available, a microwave transmitter/receiver unit.

Internal - Combination handset/talk-back speaker stations to be located (tentatively) at the well, administrative office, maintenance area, turbine-generator area, control unit, 4-kV switchgear unit, intercondenser area, cooling tower area, and visitors' center.

6.3 Operating and Control Features

6.3.1 Operating Conditions

A load bank will be provided to permit testing the turbine-generator set and to absorb any excess capacity (up to 1600 kw) not accepted by HELCO, who will have plant load control. The operating modes are:

(a) Power plant start-up, receiving station power from the 34 kV transmission line.

(b) the load bank disconnected, the generator supplying the HELCO system full generated output less station service.

(c) the generator supplying the load bank and station service only, HELCO disconnected (Limited Testing of Power Plant).

(d) the generator, the load bank, and HELCO's system interconnected. This arrangement permits operating the generator with the load bank absorbing the difference between generator output and HELCO's requirements.

6.3.2 System Protection - Electrical

Protection system provided for the generating facility is shown graphically on Drawing E-08-102-0 - Meter and Relay Diagram, in Section 12.9. The scheme shown for the generator is typical for a machine of this particular rating.

6.3.3 Metering

Principal facility metering will be installed in the control panel in the control unit. Metering to be provided is shown graphically on the Meter and Relay Diagram, Drawing E-08-102-0, in Section 12.9.

A recording wattmeter is provided for generator output and output to the 34 kV line, and a recording voltmeter for bus voltage.

In addition to the HELCO supplied watthour and varhour meters on the outgoing 34 kV line, watthour meters will be provided on the generator output, and the 480 v station service.

6.3.4 Control Features

Open-close controls will be provided for both the 34 kV circuit switcher and 4.16 kV circuit breaker, however, the control system will be interlocked to force closing the circuit switcher first and then closing the 4.16 kV circuit breaker if the 34 kV line is energized since automatic synchronizing will be at 4.16 kV. If the power line is dead then closing either the circuit breaker or switcher will be permitted.

Automatic synchronizing features will be provided to permit synchronizing across the 4.16 kV generator or 4.16 kV transformer breaker. Automatic synchronizing eliminates "bumps" on the system that occasionally occur with manual synchronizing.

6.3.5 Supervisory Control

Provisions will be made for supervisory control by HELCO over the turbine governor for control of generator output, for control of voltage regulator set point for control of generator var output, generator circuit breaker trip and status indicator and load bank circuit breaker trip.

7.0 ENVIRONMENTAL CONSIDERATIONS

7.1 Noise Suppression

Presently, there are no noise regulations for the County of Hawaii. However a noise level limitation has been set at 65 db (A-scale) at the property line or within a radius of 1/2 mile from the plant, whichever is closer. The source of noise in the buildings will be limited to less than 90 db(A-scale) as required for OSHA, based on a continuous 8 hour exposure.

7.2 Hydrogen Sulfide Abatement

The process of incineration of the vent gas followed by the absorption of the sulfur dioxide in an absorber utilizing with the cooled well effluent water from the separator as absorbent was chosen on the basis of least operating and investment costs to perform H_2S abatement. The absorber acid water will be neutralized before percolation. Operation and maintenance costs for the incineration/absorption process are approximately $30,000 annually. The recommended abatement system has been designed for site specific application. The possible use of the proposed system at another site would be highly dependent on plant size, resource characteristics and regional ground water quality.

7.3 Aesthetic Appearance

7.3.1 Turbogenerator Building

The turbogenerator building will be architecturally treated in an attempt to be compatible and complement or blend the surroundings. The typical box shape has been replaced with a building with a wider section on top, and a continuous vent on the roof which aesthetically blends into the building. To soften the appearance of the building, textured plywood siding is used on the lower three-fourths of its height, while a different pattern of non-corrugated metal sheeting is used on the upper one-fourth of its siding and roofing.

The color will be selected to blend into the environment.

7.3.2 Service Building

The service building blends into the turbogenerator building with its wooden textured plywood siding and metal roof pattern. The color of the building will be similar to the turbogenerator building.

7.3.3 Visitor Center

The visitor center will be designed to symbolize a volcanic cone. The shake roof indicates the cinder layer which converges to a peak at the skylight. At the same time the building is Polynesian in appearance with its high-pitched roof and open post colums. The landscape around the visitors' center is designed to blend with the building to complement the Hawaiian atmosphere.

7.4 Water Pollution

The effluent water from the power plant and wellhead has been determined to be clean enough to allow disposal by percolation without chemical treatment.

8.0 SEISMIC AND LAVA FLOW RISK ANALYSIS

8.1 Seismic Risk

The basic technique employed in seismic risk analysis is that of determining the likelihood of different levels of ground shaking intensity at the site from the historical record of earthquakes. The future occurrence of different levels of ground shaking can then be forecast from the properties of the historical record. It has been shown that the basic methodology is reliable and engineering procedures exist to translate such forecasts into economical design of engineered structures to resist the forecasted loads. Inspection of the historical record showed that between 1834 and 1978, 93 earthquakes occurred on or near the Island of Hawaii which were associated with significant levels of ground shaking at the site. Table 8-1 contains a list of these earthquakes along with the intensity level associated with the epicenter and the estimated intensity level at the site. The intensity levels are given in terms of the Modified Mercalli Intensity (MMI) scale in Table 2. Magnitude data on these earthquakes are generally scarce. Such magnitude data as are available are also given in Table 8-1.

The historical record of the intensity levels of the site was analyzed statistically and the results are shown in Figure 8-1 and Table 8-1. The latter table gives the estimated MMI levels and the associated peak ground accelerations for specified return periods. The conversion of MMI intensity to peak ground acceleration was based on a study by Tribunac and Brady.

Figure 8-2 contains the basic information for establishing the peak ground acceleration design criteria for the site. The basic methodology used was similar to that employed by Algermissin and Perkins, United States Geological Survey (SUGS) in the seismic risk mapping of the contiguous United States and used by the Applied Technology Council (ATC-3) to develop seismic coefficient maps. The USGS and ATC-3 seismic risk studies are based on a ten percent exceedance probability in 50 years. That is, it is assumed that the useful life of the building is 50 years and it is acceptable that the peak ground acceleration can be exceeded with a probability of ten percent in that fifty year life. The instrumental records obtained in the 1973 and 1975 earthquakes have been analyzed to relate the instrumental peak ground acceleration to the criteria for which important facilities should be designed. The results of these studies are given in the criteria response spectra of

Figure 8-3. For the site a fifty year life and ninety percent of non-exceedance is associated with a peak ground acceleration of about 0.6g. With the assigned thirty year life of the facility, ninety percent non-exceedance is associated with a peak ground acceleration of 0.41g. The recommended criteria is then 0.41g for primary components of the facility. A primary component is one either whose failure involves severe economic loss and/or possible loss of life or severe injury.

Only a very few components in the system need to be designed for this level of ground shaking. Ordinary timber and steel buildings designed in accord with the Uniform Building Code have proven to be able to sustain a peak ground acceleration of 0.2g to 0.3g more or less without significant damage. If losses associated with structural damage are acceptable from rare earthquakes, it appears reasonable to design these buildings in accordance with current codes.

It is recommended that the design of primary components be analyzed for adequacy using response spectrum procedures, and structures of less critical importance can be designed using conventional structural engineering procedures of the Uniform Building Code or the superior provisions of the ATC-3 report.

The recommendations of this report are in accord with the current state-of-the-art.

8.2 Lava Flow Risk

The risk analysis for lava flow is based on the historical occurrence of lava flows in the North Rift Zone of Kiluaea. The rift zone is identified by a series of lave flow sources and associated geologic features. The rist zone lies on a gradually curving, generally east-west line as shown in Figure 8-4. The basic mechanism by which lave flows occur appears to first involve the penetration of lava from Kiluaea at depths more or less below the rift zone. The lava is then pushed through zones of weakness in the rift zone to the surface as a result of hydrostatic pressure.

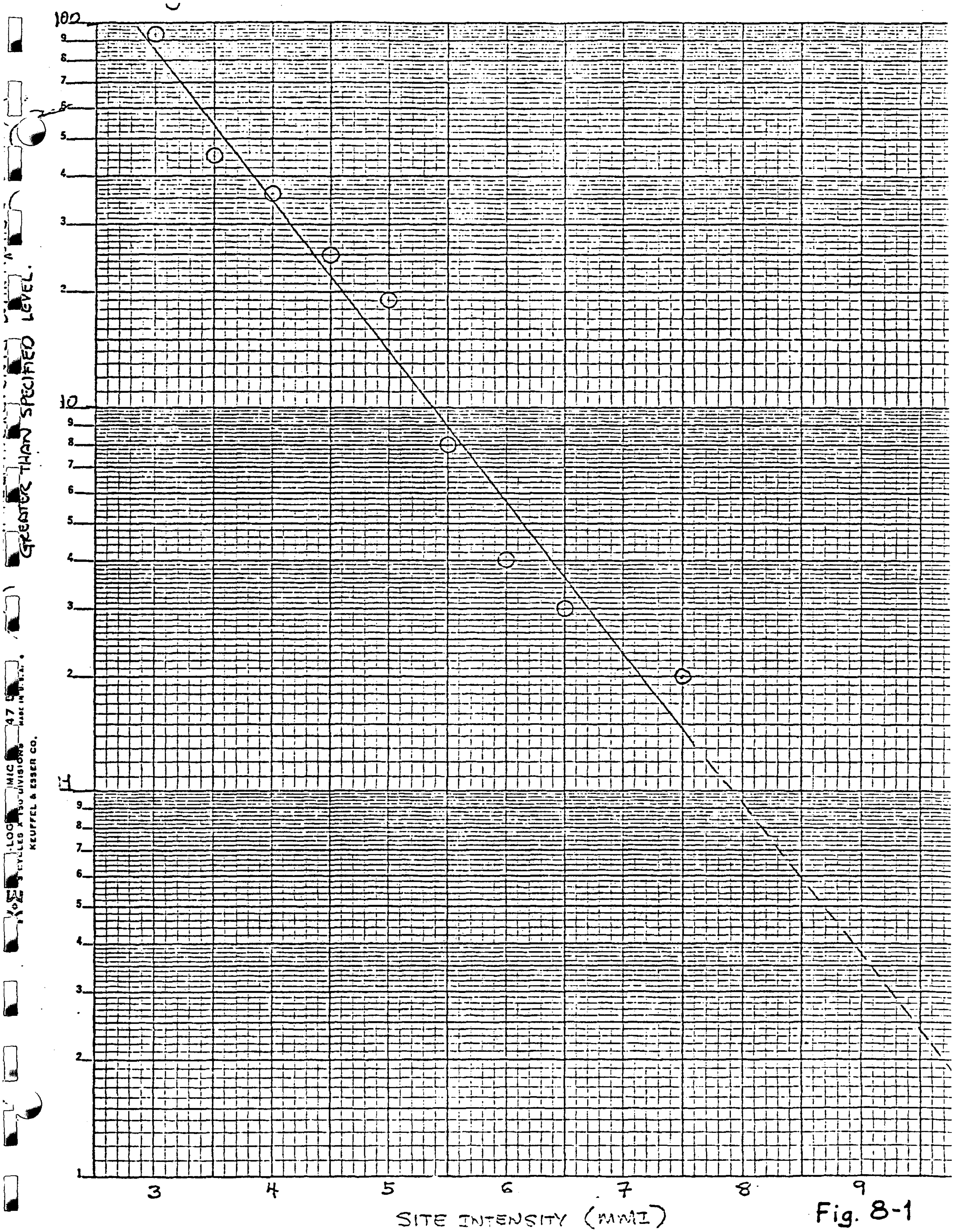
The early historically recorded flows took place between 1700 and 1840 and have vented along a narrow line source in the rift zone indicating that succeeding eruptions of lave take place along a developed common line of weakness.

Examination of the 1700 - 1840 flows also show that the source line is relatively continuous. That is, over a period of time, gaps in the source line become filled by succeeding events.

The second cycle of eruptions began in 1955 with successive flows in 1955, 1961 to 1969, 1969 to 1974, and 1977. The flows from near Kiluaea to about 15 km west of the site all originate along the same general line as do the earlier cycle of flows, 1700 to 1840.

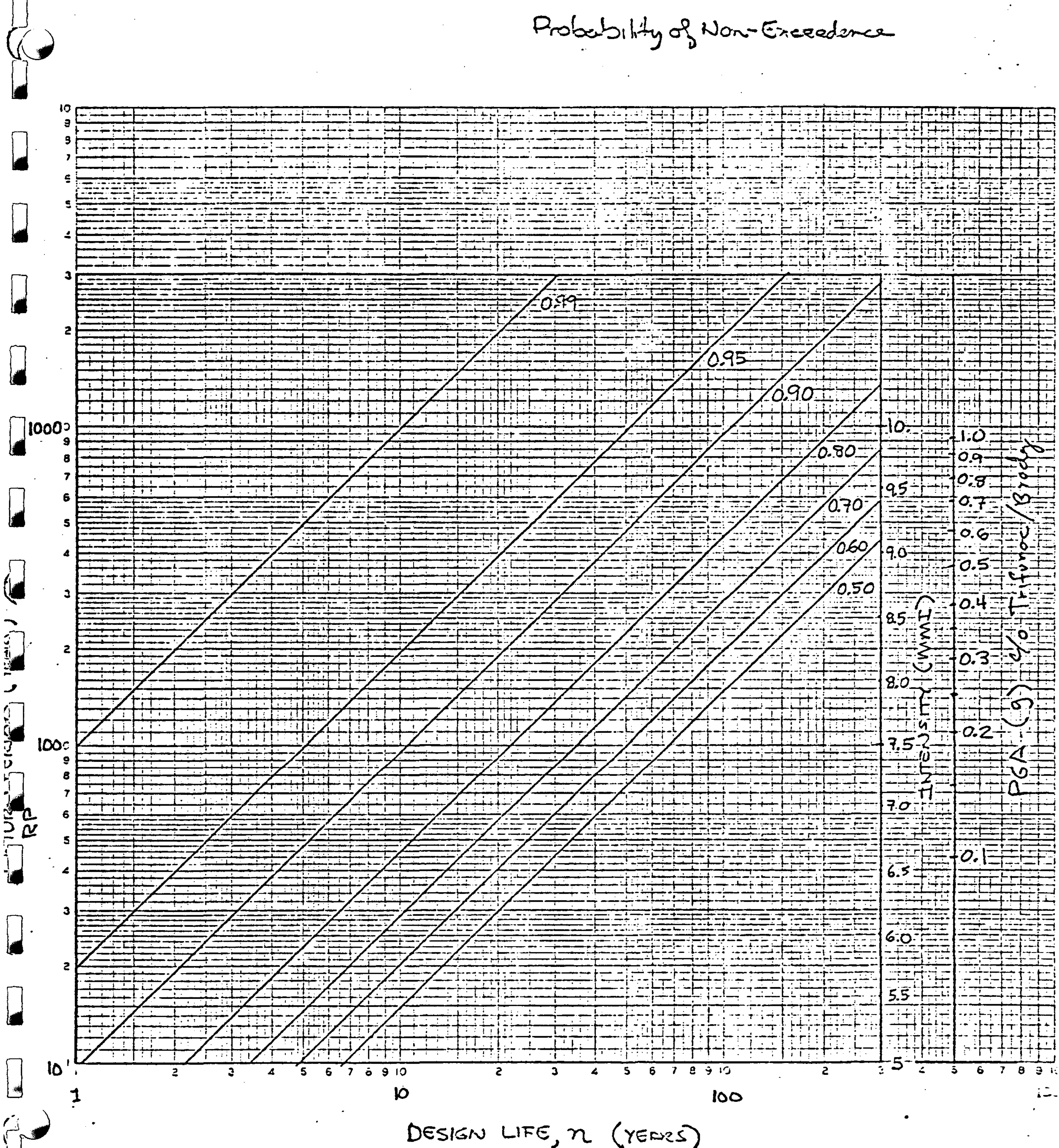
Beginning about 15 km west of the site to 15 km east of the site, a different line source of lava flow has developed that is roughly parallel to that of the earlier source. This line source runs more or less thorugh the HGP-A site which is on the edge of one of the 1955 lava flows and close to the source of that flow (Fig. 8-5). A 5 km gap in the recent occurrence of flows exists just to the west and south of the site. If a lava flow originates in this gap, the lava could flow by gravity downhill either toward the site or to the north of the site. This is dictated by the area topography. While successive eruptions may not originate on exactly the vent, the 1977 source is very close to that of the 1961 - 1969 flow so that it is not possible to say that multiple events cannot take place from the same basic source. Therefore it is also possible that a repetition of the 1955 flow could take place from a vent close to the site.

The lava flow hazard is difficult to mitigate, particularly if the source is close to the site. If the source of the flow is in the lava flow gap to the west of the site and some distance away, it is possible that the flow could be diverted by providing a dike or channel to control the flow away from the site.



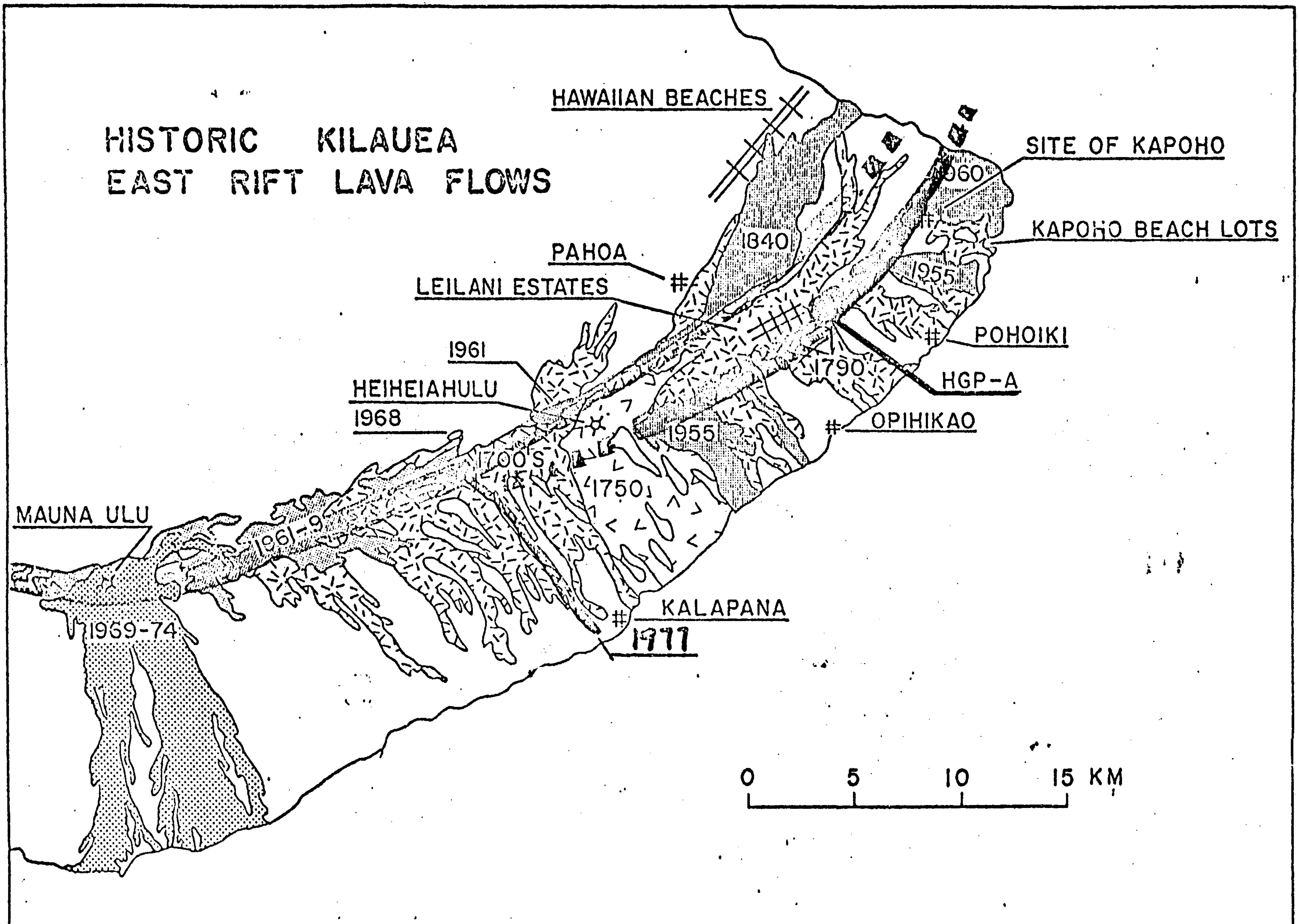
GREATER THAN SPECIFIED LEVEL.
100
10
1
SITE INTENSITY (MMI)
3
4
5
6
7
8
9
KEUFFEL & ESSER CO.

Fig. 8-1



Probability of Non-Exceedence
0.99
0.95
0.90
0.80
0.70
0.60
0.50
RP
DESIGN LIFE, n (YEARS)
INTENSITY (MMI)
PGA (g) c/o Trifunac/Brady

Fig. 8-2


HISTORIC KILAUEA
EAST RIFT LAVA FLOWS
HAWAIIAN BEACHES
SITE OF KAPOHO
1960
KAPOHO BEACH LOTS
1840
PAHOA
1955
LEILANI ESTATES
POHOIKI
1961
1790
HGP-A
HEIHEIAHULU
1968
OPIHIKAO
1955
1700'S
1750
MAUNA ULU
1961-9
1969-74
KALAPANA
1977
0
5
10
15 KM

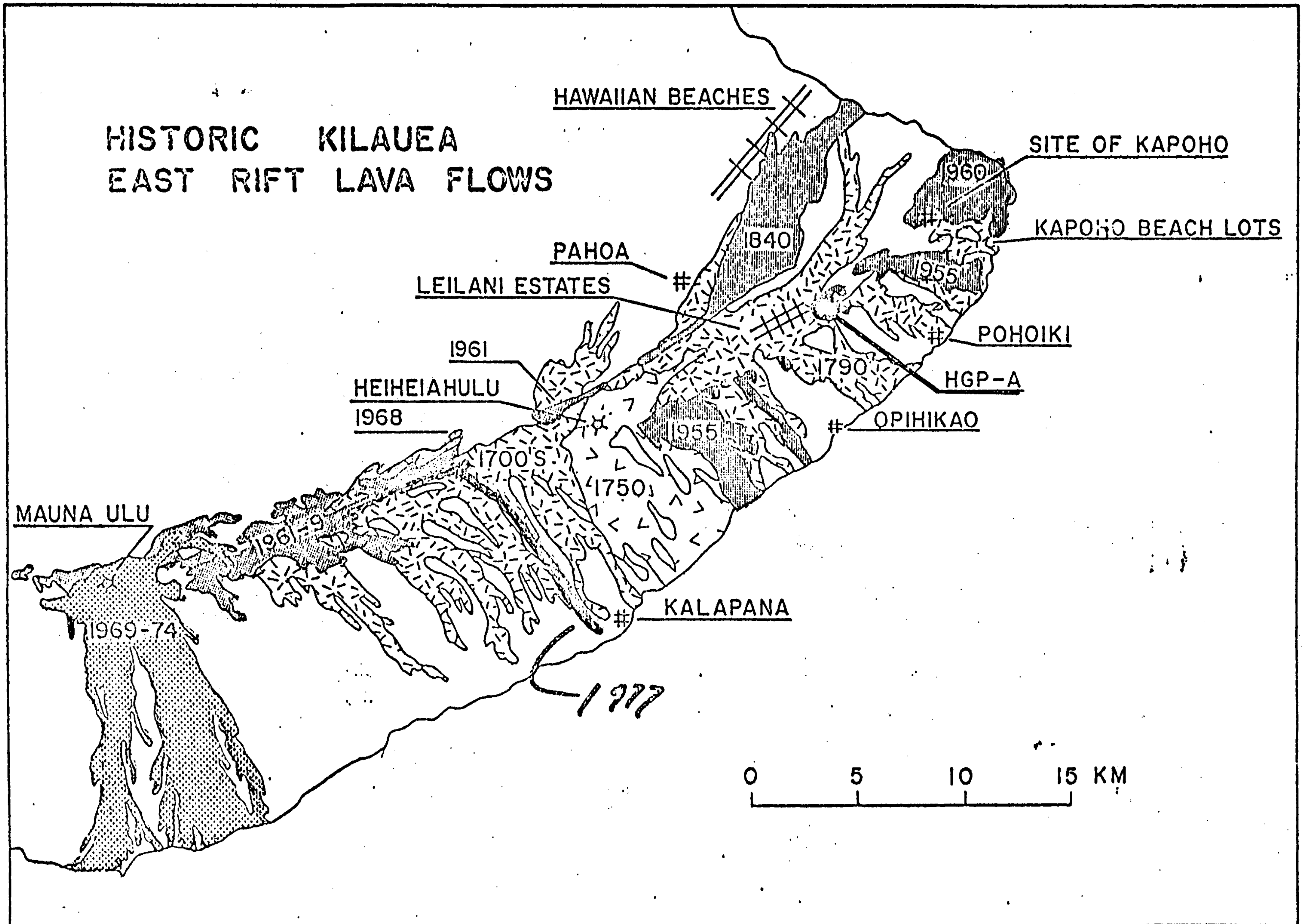

HISTORIC KILAUEA
EAST RIFT LAVA FLOWS
HAWAIIAN BEACHES
SITE OF KAPOHO
1960
KAPOHO BEACH LOTS
1840
PAHOA
1955
LEILANI ESTATES
POHOIKI
1961
1790
HGP-A
HEIHEIAHULU
OPIHIKAO
1968
1955
1700'S
1750
MAUNA ULU
1961-?
KALAPANA
1969-74
1977
0
5
10
15 KM

TABLE 8-1

EARTHQUAKES

			EPICENTER					Site
		Time		N.	W.	Intensity		Intensity
Year	Date	(HST)	Locality	Lat.	Long.	(MMI)	Magnitude	MMI
1834	Feb 19		Island of Hawaii					4-6
1838	Dec 12		Island of Hawaii					4-6
1868	Apr 2	about 16:00	South Coast of the Island of Hawaii	19.0	155.5	10		7-8
1909	Mar 13		Island of Hawaii					2-4
1912	Oct 13		Hawaii					2-4
1913	Sept 8	12:08	Kilauea			5		3-4
1913	Oct 25	01:08	Kilauea			5		3-4
1918	Nov 2	00:03	Mauna Loa			7		4-5
1919	Jan 28	17:53	Hawaii			5		2-4
1919	Aug 26	02:34	Island of Hawaii			5		3-4
1919	Sept 14	17:50	Kilauea			7		5-6
1923	Jan 14	02:58	Island of Hawaii					2-4
1923	Feb 9	21:11	Island of Hawaii					2-4

TABLE 8-1

EARTHQUAKES continued

			EPICENTER					Site
		Time		N.	W.	Intensity		Intensity
Year	Date	(HST)	Locality	Lat.	Long.	(MMI)	Magnitude	MMI
1923	Dec 14	06:04	Island of Hawaii					2-4
1924	Aug 20	06:50	Island of Hawaii					2-4
1925	Jul 8	06:15	Island of Hawaii					2-4
1926	Feb 28	07:11	Island of Hawaii					3-5
1926	Mar 19	23:03	Island of Hawaii					2-4
1926	Apr 22	05:02	Mauna Loa					2-4
1926	June 9	10:05	Island of Hawaii					2-4
1927	Mar 20	05:22	Island of Hawaii					4-6
1927	Aug 3	10:12	Island Hawaii					4-6
1929	Sept 25	18:51	Kona	19.75	156.0	7	5.5	2-5
1929	Sept 28	07:40	Hilo			7		5-6
1929	Oct 5	21:52	Holualoa	19.75	156.0	7	6.5	2-5
1930	May 20	19:22	Hualalai Region			5		3-5
1930	May 25	20:47	Kilauea			5		3-5
1931	Jan 30	00:08	Waiohinu			5		2-4

TABLE 8-1

EARTHQUAKES continued

Year	Date	Time (HST)	Locality	EPICENTER N. Lat.	W. Long.	Intensity (MMI)	Magnitude	Site Intensity MMI
1933	Dec 2	06:30	Hilo			6		4-6
1934	May 10	10:39	Near Hakalau	19.6	155.4	5		2-4
1935	Jan 2	07:17	Kilauea	19.4	155.3	5		3-4
1935	June 28	09:30	Mauna Loa	19.6	155.2	5		4-5
1935	Sept 30	23:06	Mauna Loa	19.4	155.7	5		2-4
1935	Oct 1	00:28	Mauna Loa	19.6	155.4	5		2-4
1935	Nov 21	01:41	Mauna Loa	19.5	155.5	5		2-4
1936	Apr 15	08:57	Kilauea	19.4	155.2	5		2-4
1938	Jan 22	22:33	North of the Island of Maui	19.5	156.8	8	6.75	3-5
1938	Feb 17	02:48	Mauna Loa	19.6	155.4	5		2-4
1939	May 15	10:58	Kilauea	19.4	155.1	5		4-5
1939	May 23	14:44	Kilauea	19.5	155.4	5		2-4
1939	May 24	13:29	Kilauea	19.4	155.2	5		2-4
1939	May 31	21:21	Kilauea	19.6	155.2	5		2-4

TABLE 8-1

EARTHQUAKES continued

Year	Date	Time (HST)	EPICENTER Locality	N. Lat.	W. Long.	Intensity (MMI)	Magnitude	Site Intensity MMI
1939	June 12	01:41	Kau Desert			5		2-4
1939	July 14	04:21	Kilauea	19.3	155.1	5		5
1940	June 17	00:27	North of the Island of Hawaii	20.5	155.3	6	6.0	3-5
1940	July 15	17:18	North of the Island of Hawaii	20.9	155.1			2-4
1941	Sept 25	07:48	Mauna Loa	19.2	155.5	7	6.0	4-6
1941	Nov 18	03:26	Near Waimea			5		2-4
1944	Nov 12	05:26	Southwest of Halemaumau			5		2-4
1944	Dec 27	04:12	Mokuaweoweo	19.5	155.5	6		3-5
1945	Mar 4	00:00	Mauna Loa			5		2-4
1945	May 19	01:48	Mauna Loa			5		2-4
1945	Sept 19	05:33	Saddle area			5		2-4
1947	Sept 30	04:04	Island of Hawaii			5		2-4

TABLE 8-1
EARTHQUAKES continued

Year	Date	Time (HST)	EPICENTER Locality	N. Lat.	W. Long.	Intensity (MMI)	Magnitude	Site Intensity MMI
1949	Feb 26	13:54	Mauna Loa			5		2-4
1949	May 2	05:02	Mauna Loa			5		2-4
1950	Mar 25	05:43	Mauna Loa			5		2-4
1950	May 29	15:16	Mauna Loa	19.5	156.0	6	6.25	3-5
1951	Apr 22	14:52	Kilauea	19.0	155.5	7	6.5	5-6
1951	Aug 21	00:57	Kona	19.75	156.0	9	6.9	4-6
1951	Sept 16	01:43	Kaoiki Fault	19.2	155.5	5		4-5
1951	Nov 8	09:34	Mauna Loa	19.2	155.5	6		3-5
1952	Feb 2	01:16	Near Kaumana			5		2-4
1952	Mar 17	17:58	Off coast of the Island of Hawaii	19.1	155.0	5		2-4
1952	May 23	12:12	Kona	19.5	155.5	6	6.0	2-4
1952	July 12	13:53	Kona			5		2-4
1953	Jan 9	21:10	Mauna Loa	19.4	155.5	5		2-4
1953	Jan 15	02:05	Mauna Loa	19.3	155.4	5		2-4
1953	Aug 21	19:47	Island of Hawaii			5		2-4

TABLE 3-1

EARTHQUAKES continued

Year	Date	Time (HST)	Locality	EPICENTER N. Lat.	W. Long.	Intensity (MMI)	Magnitude	Site Intensity MMI
1954	Mar 30	06:40	Near Kalopana	20.0	155.0	5	6.0	5-6
1954	Mar 30	08:42	Near Kalopana	20.0	155.0	7	6.5	6-7
1954	July 3	11:53	Kilauea	20.5	155.5	6		4-5
1955	Mar 27	16:02	Kilauea			7		4-5
1955	Apr 1	04:24	Kilauea	19.5	155.0	5		2-4
1955	Aug 7	07:18	Off north coast of Island of Hawaii	20.5	155.5	5		2-4
1955	Aug 14	02:27	Kilauea	19.5	155.5			2-4
1955	Oct 26	16:56	Near Mokuaweoweo	19.5	155.5	5		2-4
1956	Oct 16	00:45	West of the Island of Hawaii	20.0	157.0	5		2-4
1957	Aug 18	00:42	Near Hono, Maui	21.0	156.0	5		2-4
1961	July 23	05:24	Off coast of the Island of Hawaii			5	5.1	3-4
1961	Sept 22	17:02	Kilauea	19.4	155.1	5		5

TABLE 3-1

EARTHQUAKES continued

Year	Date	Time (HST)	Locality	EPICENTER N. Lat.	W. Long.	Intensity (MMI)	Magnitude	Site Intensity MMI
1961	Sept 24	19:29	Kilauea	19.4	155.1	5	4.2	5
1962	June 27	18:27	Kaoiki Fault	19.4	155.4	6	6.1	3
1963	Oct 23	10:24	Kaoiki Fault	19.4	155.4	5	5.3	2-4
1973	Apr 26	10:27	Near north coast Island of Hawaii	19.9	155.1	8		6
1974	June 19	05:06	Kau District	19.4	155.4	5		4
1974	Dec 31	12:41	Kapapala Ranch	19.3	155.4	5	5.3	3-4
1975	Jan 2	03:28	Pahala	19.3	155.6	5		3-4
1975	Jan 3	07:33	Pahala	19.2	155.6	5		3-4
1975	Jan 4	15:32	Pahala	19.4	155.6	5		3-4
1975	Nov 29	04:48	Kalapana	19.3	155.0	8	7.2	7-8
1977	June 6	0:42		19.4	155.1	5		5

TABLE 3-2

ESTIMATED SITE INTENSITIES SINCE 1834

Intensity MMI	No. of Occurrences	Cumulative No. of Occurrences
7.5	2	2
6.5	1	3
6.0	1	4
5.5	4	8
5.0	11	19
4.5	6	25
4.0	11	36
3.5	9	45
3.0	48	93

9.0 FACILITY EVACUATION

9.1 General Site Characteristics

The site is capable of handling several equipment removal crews working concurrently. Facility layout permits expeditious entrance and egress from the site by a low boy required for removal of power plant equipment.

9.2 Civil/Structural

The turbine building structural design is predicated upon the support of a 30/10 ton bridge crane which will be used to remove the turbine and the generator.

9.3 Mechanical Equipment

Following disconnection of power plant support systems from major equipment described in the section, selected equipment will be removed from the site.

9.3.1 Removal Procedure

The major mechanical components of the power plant which will be removed in the event of a volcano eruption, are listed in the following order of priority:

(1) Turbine/Generator Module

(2) Condensers-Ejector Module

(3) Control Room Unit

(4) Switchgear and MCC Unit

(5) Step-up Transformer-Circuit Switcher Unit

(6) Major Pumps

All other equipment would probably be sacrificed due to the lack of time available for removal. One item of equipment of major value which will be sacrificed is the cooling tower. The size and complexity of the installation prohibits dismantling it in the expediitious manner necessary.

9.3.2 Turbine Removal

The Turbine/Generator removal will be accomplished in the following manner. A 30/10 bridge crane has been provided to allow lifting the turbine or the generator off its foundation. At this point the Turbine/Generator will be set on a lowboy for shipment out of the danger area.

9.3.3 Major Pump Removal

Major pumps are the condensate pump and the cooling water circulatory pump. As both of these pumps are located in the yard adjacent to the Turbine Building they would easily be removed by a mobile crane and loaded onto a waiting truck.

9.3.4 Ejector Removal

The ejectors are also located in the yard adjacent to the Turbine Building and these items would be moved at the same time that the major pumps are removed.

9.3.5 Condenser Removal

The condenser, inter-condenser and after-condenser are fairly bulky items and will require a special truck for hauling.

9.4 Electrical Equipment

Electrical equipment has been grouped together into units. The plant control equipment and 4-kV switchgear and 480-volt motor control centers will be installed in two portable buildings which will be truck loaded for removal. The station service transformers, the load bank, and the 4.16-34 kV step-up transformer and circuit switcher will be assembled onto a series of skid-mounted assemblies that will permit rolling, jacking or lifting by crane.

Electrical connections to all equipment -- electrical and mechanical -- will be made with multi-conductor cable with plugs at either end, if needed. This will permit rapid disconnection if equipment must be removed in an emergency and also will permit convenient reinstallation at a new location if the plant equipment retains the same physical arrangement.

Provisions will be made for convenient connection of an auxiliary generator to the switchgear unit to provide power at site in the event that the 34 kV transmission line is out of service or following removal of the 34 kV substation equipment.

10.0 Design, Procurement and Construction Schedule

Drawings E-07-001, Rev. 0 and E-07-002, Rev. 0, dated November 1978, show the relationships between project phases, as performed by Rogers and its subcontractors, and material and equipment design, procurement and construction activities.

10.1 Development

10.1.1 Project Phases

The conceptual design phase of the project is scheduled for completion during November of 1978.

The detail design and procurement project phases will begin immediately following submittal of the concept report. DOE and RCUH review comments will be incorporated into the final design. Two months later Rogers will submit a preliminary design which will form the basis for the development of the detail design and specifications. Procurement and engineering design activities will proceed throughout the entire project schedule.

Construction management activities will begin in June 1979 when contracts for site preparation will commence.

"Start-up and Operator Training at Site" will be conducted by the resident inspectors who will begin arriving at the site four (4) months prior to plant start-up.

10.1.2 <u>Design, Procurement-Equipment Construction Schedule</u>

Engineering design and requirements specifications for long delivery items will be completed at the submittal of the preliminary design. Long delivery items are as follows:

Mechanical:

- Turbine generator package
- H_2S abatement system
- Condenser, inter-condenser and after-condenser packages
- Cooling water pump
- Cooling towers

Electrical

- Step-up transformer and high voltage circuit switcher unit
- Plant control unit
- Switchgear and motor control center unit

Bid packages for long delivery items will be prepared and sent out for competitive bidding by mid April 1979. All long delivery equipment contracts will be awarded to manufacturers during the months from May thru July of 1979.

Detailed design drawings based on receipt of certified vendor drawings, are to be completed 5 months later (December 1979). The preparation of project books, manuals and relay calculations will follow during the subsequent 6 months (January thru June 1980).

Major equipment will start to arrive at the construction site in March of 1980, 5 months before plant start-up with award of the electrical, mechanical, instrumentation and millwright contracts taking place during the previous month. The various contractors and resident inspectors will then arrive at the site as indicated on Drawings E-07-001-1, Design Procurement Schedule and E-07-002-0, Bid Construct and Equipment Delivery Schedule.

ROGERS' home office engineering support will be available throughout the construction period. Resident inspectors will be engineers intimately familiar with the facility design.

10.2 The following Milestone Log describes the proposed activity schedule throughout the entire project schedule.

MILESTONE LOG

DESCRIPTION	PLANNED COMPLETION DATE
Concept Design Complete	11/17/78
Concept Design Approval	12/09/78
Concept Project Construction Cost Estimate Complete	11/11/78
All Long Lead Equipment PO's Issued	7/07/79
Purchase of Aux. Equipment Complete	9/29/79
Preliminary Plant Design Complete	1/27/79
Preliminary Plant Design Approval	3/10/79
Final Plant Design Complete	12/01/79
Final Plant Design Approval	12/15/79
Project Manuals Complete	3/29/80
Establish Construction Office	6/02/79
Site and Structures Construction Contract Award	6/16/79
Visitors' Center Complete	12/01/79
Turbine and Facilities Building Complete	12/29/79
Award Mechanical, Electrical and Instrument Construction Contracts	2/16/80
Cooling Tower at Site	3/01/80
All Auxiliary Equipment at Site	4/26/80
Turbine Generator at Site	5/31/80
Plant Start-up	8/01/80

Start Operator Training	4/12/80
Training Manuals Complete	5/10/80
Operator Training Complete	8/01/80

11.0 CONSTRUCTION COST ESTIMATE

The construction cost estimate which is a budget estimate, is summarized using the Federal Energy Regulatory Commission's (FERC) uniform system of accounts. This system of accounts is applicable to utilities engaged in the generation and sale of electricity for ultimate distribution to the public. Accounting for plant construction cost in this manner will facilitate convenient transfer of the facility or similar future facilities to public utilities. The FERC uniform system of accounts is also an efficient method of organizing a power plant construction cost estimate.

11.1 Modeling of Cost Estimate

The construction cost estimate has been developed with the aid of a computer program devised by ROGERS. Cost factors contributing to the total installed construction cost of a power plant can be divided into two categories: Definite Cost Factors, which are not functions of time, and Variable Cost Factors, which are functions of time.

11.1.1 The Definite Cost Factors which contribute to the total installed construction costs are listed and described as follows:

a. Tax or duty rate -- sales tax (4.0%) or import duty to be applied to all material and equipment to be purchased.

b. Contractor profit -- contractor profit can be applied at two levels: subcontractor (10%) and general contractor (5%).

c. Labor crew rates -- Labor crew rates to install equipment and material are based upon the most recent union labor rates for construction work in Hawaii; base rate plus fringe benefits. Labor crew and rates are as follows:

d. Labor overhead rates -- subcontractors overhead rates for installation of equipment and materials are selected and applied to the total direct labor costs. The overhead rates are 60% of direct labor for all categories of work with the exception of electrical which is 45%.

Contractor overheads include the following:

a. Unemployment insurance, workmen's compensation, Social Security, and liability insurance

b. Temporary construction facilities including field office, warehousing, security, first aid stations, etc., scaffolding and other items similar in nature

c. Small tools and construction supplies

d. Field supervison, all personnel required other than a job foreman (working foreman) who is included with the labor crew

e. Home office costs including estimating, purchasing, administrative and all other miscellaneous costs.

5. Freight and Insurance -- costs associated with material and equipment if they are not FOB or CIF site.

11.1.2 The Variable Cost Factors, which are time dependent, are listed and described as follows:

1. Escalation -- Projects of duration greater than one year require serious consideration with regard to the effects of inflation. The project is 25 months in length. An inflation rate of 7% per year applies to material and equipment and 8% per year for construction labor. Quoted material and equipment costs and labor rates are escalated until the time of purchase for material and equipment and time of the installation of labor expenditure.

2. Period of material or equipment purchase -- The material or equipment estimated cost is escalated to the month of the 25-month period in which it is to be purchased. For purposes of determining project cash flow partial payment

for materials can be specified at the time of the estimate.

3. Labor period -- At the time of the cost estimate, the labor period is specified as a function of the overall project period. Present labor crew rates are escalated until the time of expenditure during the labor contract.

11.2 Construction Cost Estimate Summary

The following tables, which are included in this section, summarize the budget construction cost estimate for the steam turbine generating facility:

- Table 11-1 -- Construction Cost Estimate Summary

  This table summarizes the installed cost of all material and equipment, escalation, engineering, procurement and construction management and contingencies. The budget estimate does not include allowance for interest during construction. The escalation figure shown includes only escalation on installed material and equipment. The engineering, procurement and construction management figure includes escalation.

- Table 11-2 -- Account Summary

- Table 11-3 -- Major Equipment Cost at Site

  Equipment costs include state sales tax and freight and insurance to the site. The figures reflect quoted prices for November of 1978. Escalation is not included.

TABLE 11-1

Construction Cost Estimate

Summary

Item	Cost
Owner Furnished Equipment and Materials	$2,660,100
Contractor Furnished Equipment and Materials	890,700
Direct Labor	346,600
Indirects and Contractor Profit	415,700
SUBTOTAL (1)	4,313,100
Escalation on Construction Cost	319,800
SUBTOTAL (2)	4,632,900
Engineering, Purchasing and Construction Management	1,168,700
SUBTOTAL (3)	5,801,600
Contingency (15%) on Subtotal (3)	870,300
TOTAL	$6,671,900

TABLE 11-2

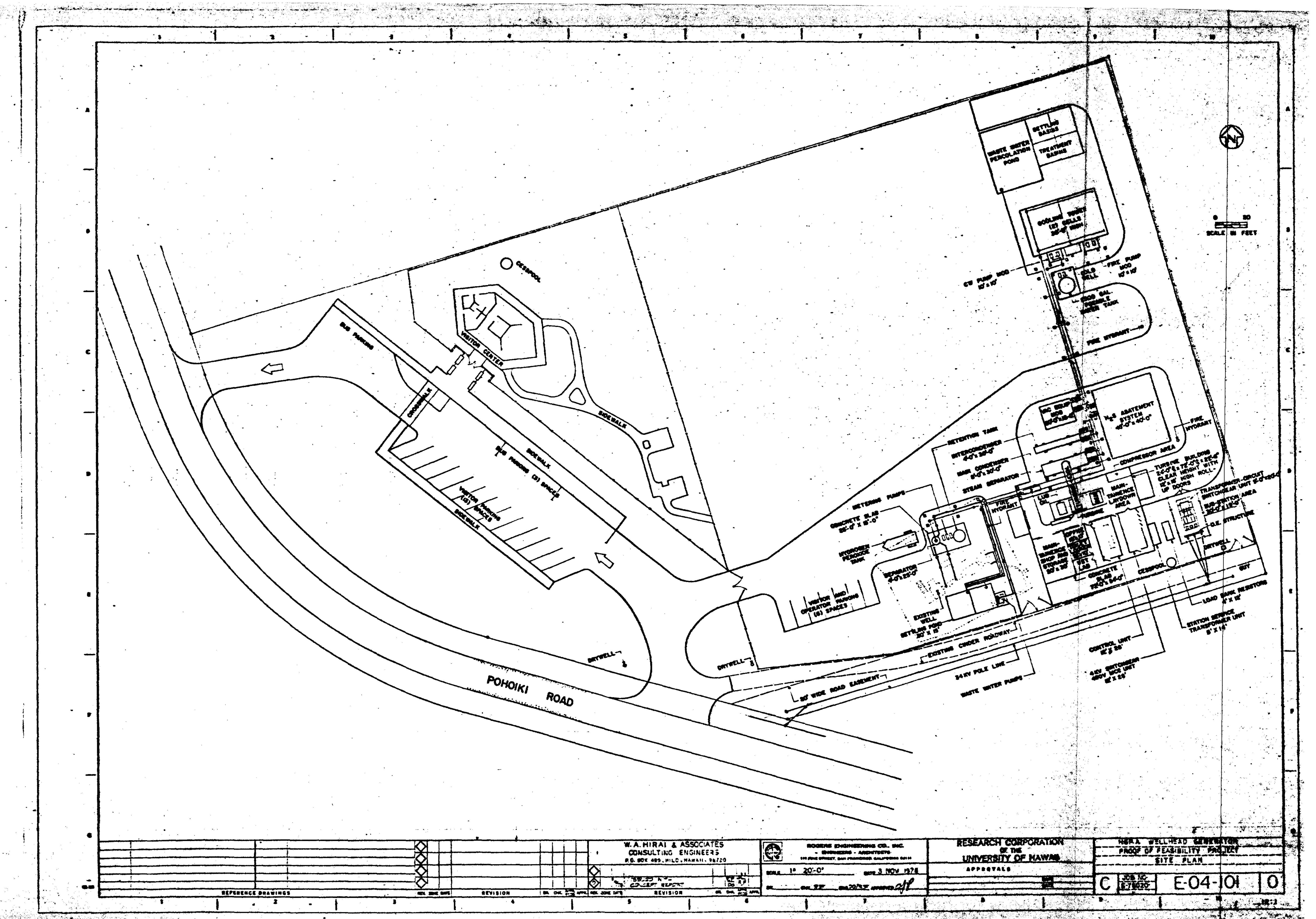
Account Summary

Account Number	Description	Owner Furnished Equipment	Contractor Furnished Equipment	Direct Labor	Overhead & Profit	Total Account Cost
311	Site Improvements					
311.1	Visitor Center					$ 314,000
311.2	Power Plant					640,000
312	Steam Supply System	$ 143,600		$ 54,000	$ 42,000	239,600
314	Turbine Generator & Aux. Equipment	1,655,000	$124,200	134,400	153,900	2,067,500
315	Accessory Electrical Equipment	429,900	26,800	46,400	41,000	544,100
316	Miscellaneous Power Plant Equipment	177,700	82,400	47,200	51,000	358,400
353	34 kV Substation	125,300	11,500	5,200	4,800	146,800
355	Transmission Line Poles and Fixtures		700	400	400	1,500
356	Overhead Conductors and Devices		300	400	500	1,200
	SUBTOTAL					4,313,100
	Escalation					319,800
	TOTAL					$4,632,900

TABLE 11-3

Major Equipment Cost at Site

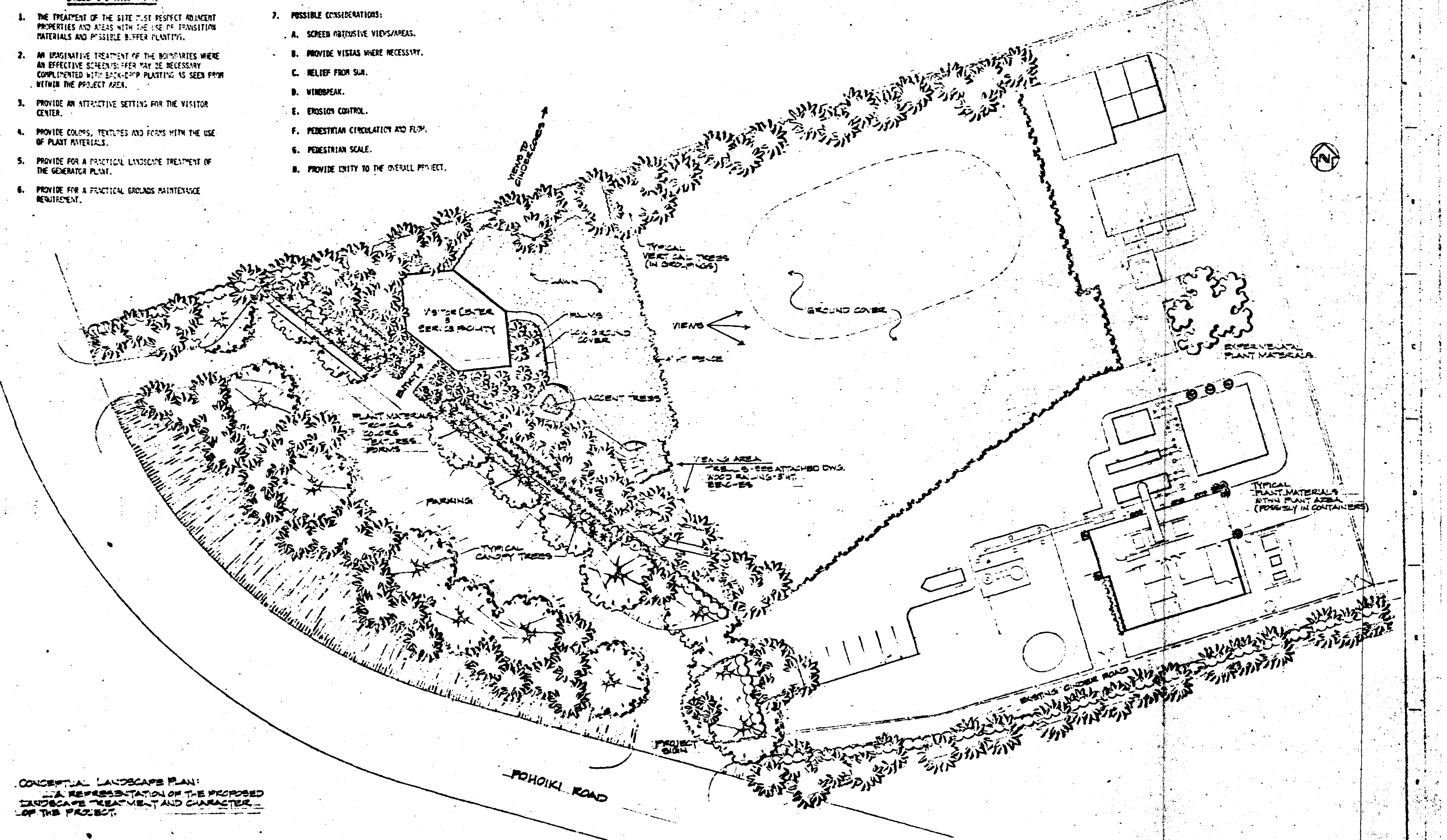
Item	Cost at Site
Steam Separator (Wellhead)	$ 75,200
In Line Steam Separator	19,800
Turbine Generator	648,000
Bridge Crane	88,600
Surface Condensers and Ejectors	378,000
Condensate Pumps	4,300
Cooling Tower	106,900
Cooling Water Pumps	25,100
H_2S Abatement Package	184,500
Switchgear and Motor Control Center Module	291,000
Control Room Module	99,400
Main Step-up Transformer-Circuit Switcher	50,000
Fire Pumps	11,700



POHOIKI ROAD
VISITOR CENTER
CESSPOOL
SIDEWALK
BUS PARKING
VISITOR PARKING
DRYWELL
WASTE WATER PERCOLATION POND
SETTLING BASINS
TREATMENT BASINS
COOLING TOWER
FIRE HYDRANT
H2S ABATEMENT SYSTEM
RETENTION TANK
COMPRESSION AREA
TURBINE BUILDING
STEAM SEPARATOR
METERING PUMPS
HYDROGEN PEROXIDE TANK
VISITOR AND OPERATOR PARKING
EXISTING WELL
EXISTING CINDER ROADWAY
34 KV POLE LINE
WASTE WATER PUMPS
CONTROL UNIT
LOAD BANK RESISTORS
STATION SERVICE TRANSFORMER UNIT
SCALE IN FEET
W. A. HIRAI & ASSOCIATES
CONSULTING ENGINEERS
P.O. BOX 485, HILO, HAWAII, 96720
ROGERS ENGINEERING CO., INC.
ENGINEERS - ARCHITECTS
SCALE 1" 20'-0"
DATE 3 NOV 1978
RESEARCH CORPORATION
OF THE
UNIVERSITY OF HAWAII
APPROVALS
HGP-A WELLHEAD GENERATOR
PROOF OF FEASIBILITY PROJECT
SITE PLAN
C
JOB NO. 6-79020
E-04-101
0
REFERENCE DRAWINGS
REVISION
CONCEPT REPORT

LANDSCAPE CONSIDERATIONS

1. THE TREATMENT OF THE SITE MUST RESPECT ADJACENT PROPERTIES AND AREAS WITH THE USE OF TRANSITION MATERIALS AND POSSIBLE BUFFER PLANTING.
2. AN IMAGINATIVE TREATMENT OF THE BOUNDARIES WHERE AN EFFECTIVE SCREEN/BUFFER MAY BE NECESSARY COMPLIMENTED WITH BACK-DROP PLANTING AS SEEN FROM WITHIN THE PROJECT AREA.
3. PROVIDE AN ATTRACTIVE SETTING FOR THE VISITOR CENTER.
4. PROVIDE COLORS, TEXTURES AND FORMS WITH THE USE OF PLANT MATERIALS.
5. PROVIDE FOR A PRACTICAL LANDSCAPE TREATMENT OF THE GENERATOR PLANT.
6. PROVIDE FOR A PRACTICAL GROUNDS MAINTENANCE REQUIREMENT.
7. POSSIBLE CONSIDERATIONS:
   - A. SCREEN OBTRUSIVE VIEWS/AREAS.
   - B. PROVIDE VISTAS WHERE NECESSARY.
   - C. RELIEF FROM SUN.
   - D. WINDBREAK.
   - E. EROSION CONTROL.
   - F. PEDESTRIAN CIRCULATION AND FLOW.
   - G. PEDESTRIAN SCALE.
   - H. PROVIDE UNITY TO THE OVERALL PROJECT.



CONCEPTUAL LANDSCAPE PLAN: A REPRESENTATION OF THE PROPOSED LANDSCAPE TREATMENT AND CHARACTER OF THE PROJECT.

IWAMOTO & ASSOCIATES
LANDSCAPE ARCHITECTS

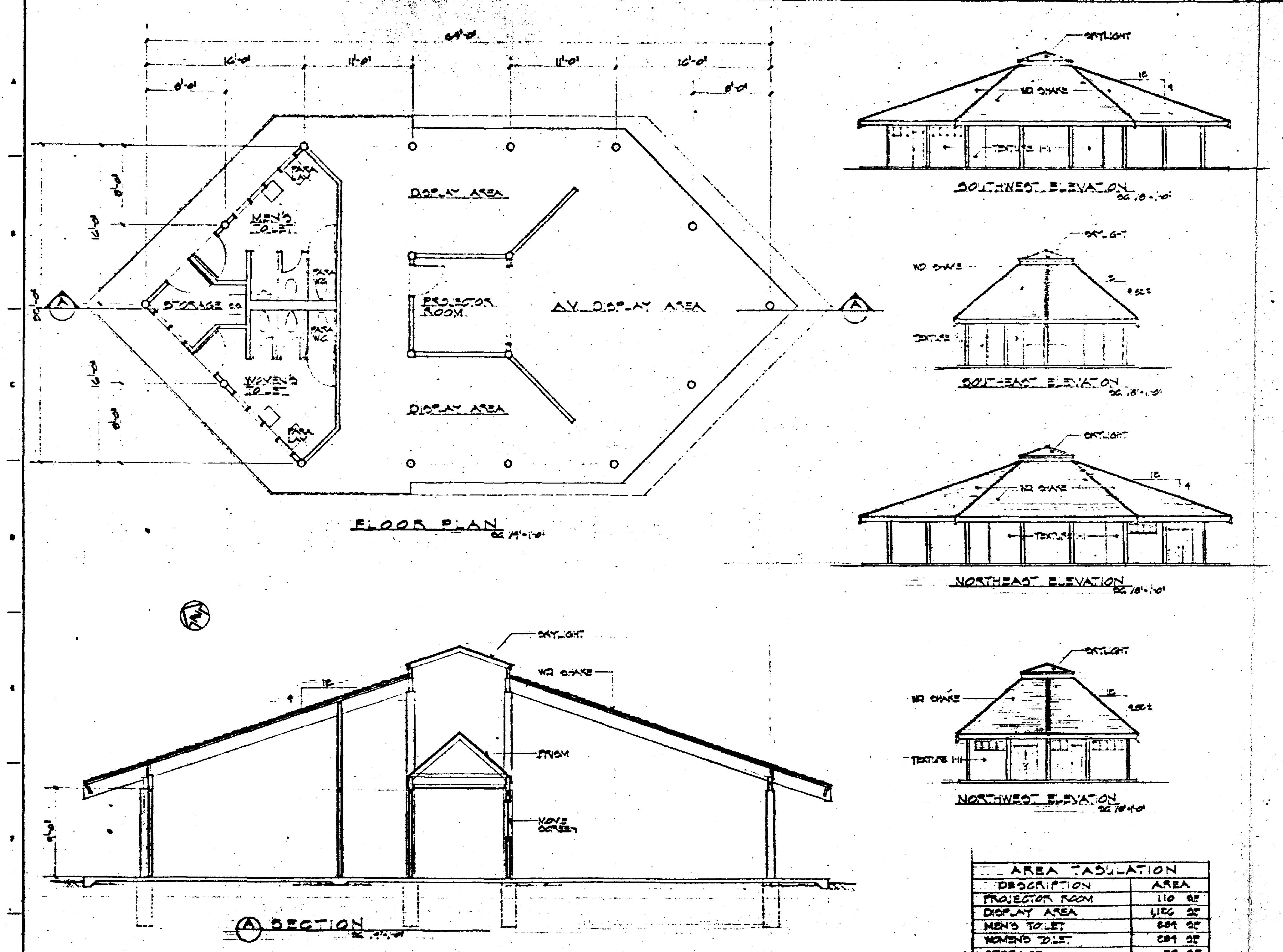
REFERENCE DRAWINGS

3 NOV. 1978

RESEARCH CORPORATION OF THE UNIVERSITY OF HAWAII

HGP-A WELLHEAD GENERATOR PROOF OF FEASIBILITY PROJECT
LANDSCAPING PLAN

A JOB NO. 578020 E-04-102 0



AREA TABULATION	
DESCRIPTION	AREA
PROJECTOR ROOM	110 SF
DISPLAY AREA	1,126 SF
MEN'S TOILET	284 SF
WOMEN'S TOILET	284 SF
STORAGE	58 SF
TOTAL	1,862 SF

RONALD N. NAGATA A.I.A.
ARCHITECTURE & PLANNING
290 POHAKAWAI ST. HILO, HAWAII, 96720

CONCEPT REPORT

REVISION

REFERENCE DRAWINGS

ROGERS ENGINEERING CO., INC.
ENGINEERS - ARCHITECTS
SAN FRANCISCO, CALIFORNIA

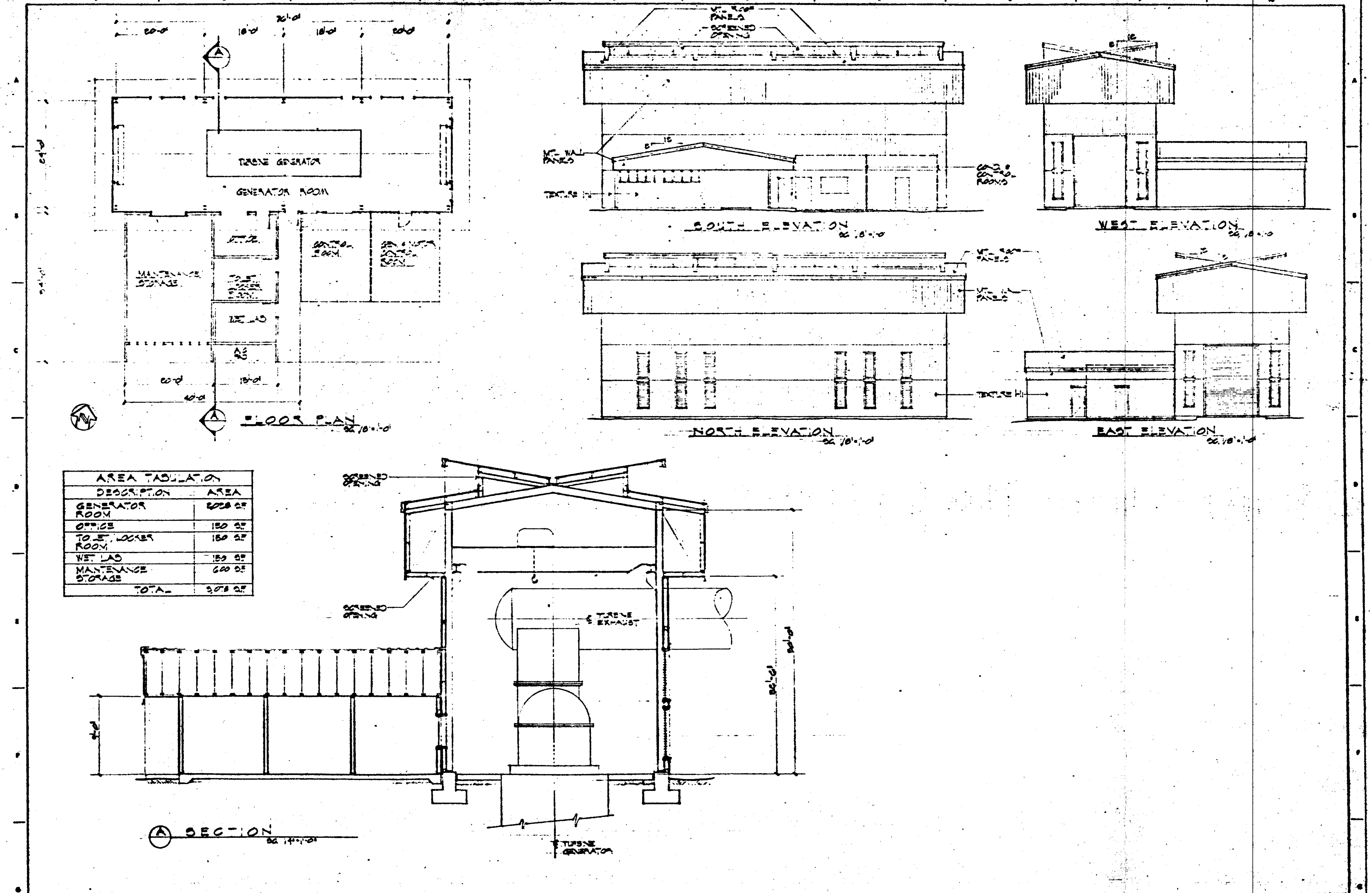
SCALE AS NOTED DATE 3 NOV 1978

RESEARCH CORPORATION OF THE UNIVERSITY OF HAWAII

APPROVALS

HGP-A WELLHEAD GENERATOR
PROOF OF FEASIBILITY PROJECT
VISITOR CENTER BUILDING
PLAN, ELEVATIONS & SECTION

A | JOB NO. 576020 | E-80-102 | 0



AREA TABULATION	
DESCRIPTION	AREA
GENERATOR ROOM	2028 SF
OFFICE	150 SF
TOILET, LOCKER ROOM	150 SF
WET LAB	150 SF
MAINTENANCE STORAGE	600 SF
TOTAL	3,078 SF

RONALD H. HAGATA A.I.A.
ARCHITECTURE & PLANNING

ROGERS ENGINEERING CO., INC.
ENGINEERS • ARCHITECTS

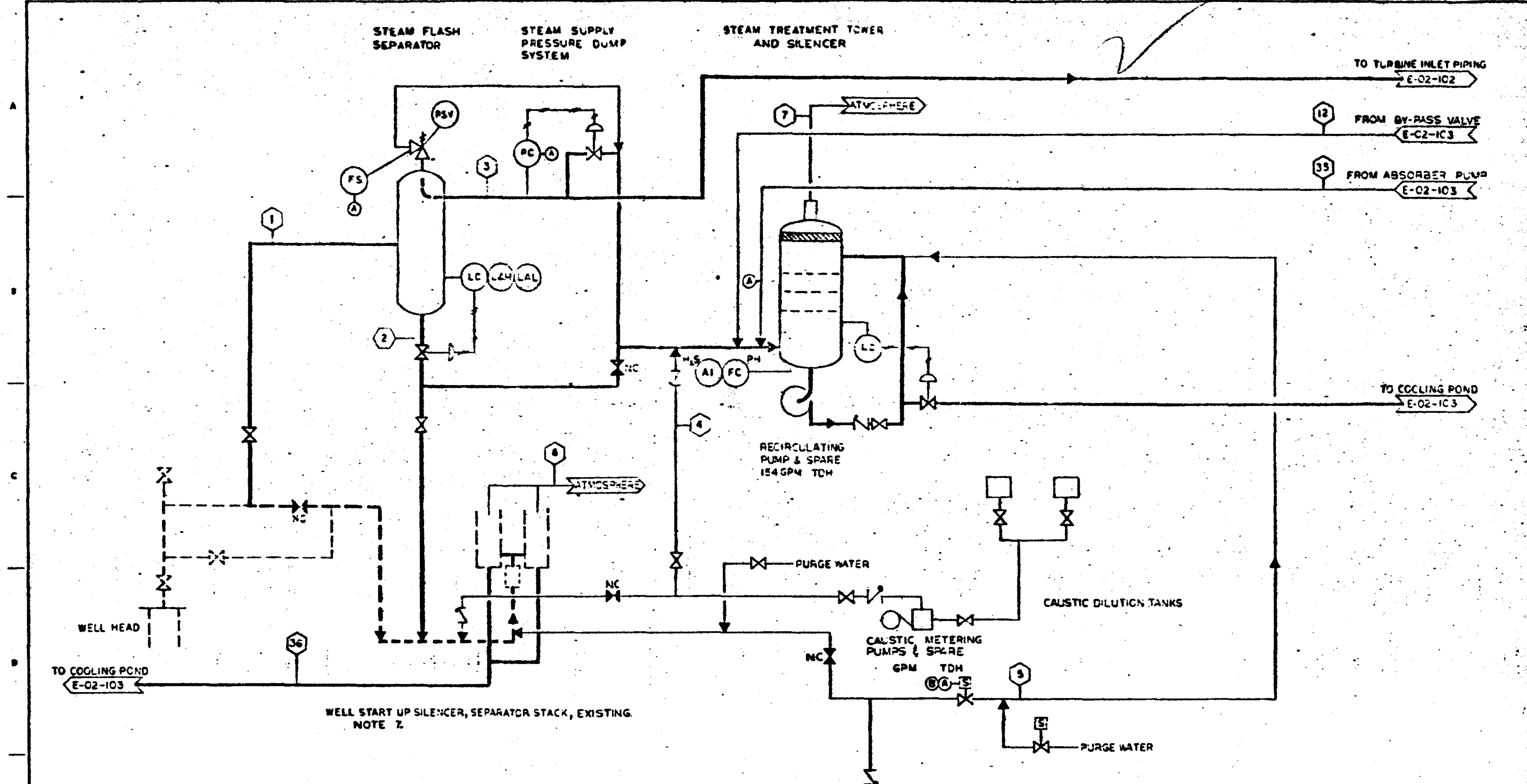
SCALE AS NOTED DATE 3 NOV. 1978

RESEARCH CORPORATION OF THE UNIVERSITY OF HAWAII

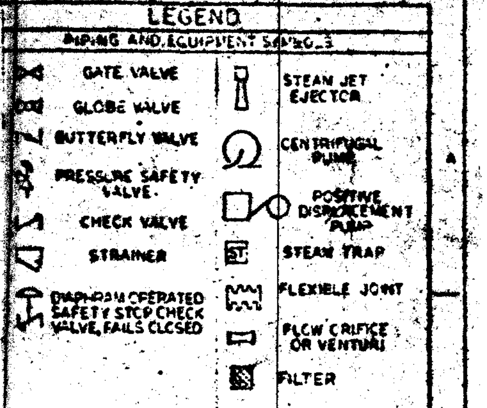
APPROVALS

HGP-A WELLHEAD GENERATOR
PROOF OF FEASIBILITY PROJECT
TURBINE GENERATOR BUILDING
PLAN, ELEVATIONS & SECTION

A JCB NO. S-78020 E-80-101 0



STREAM No.	1	2	3	4	5	6	7	12	35	36
FLOW IN LB/HR										
STEAM	52630		52630			4848	55234	8.5		
NON CONDENSABLE GAS	170		170			* 2	* 134	170		
AIR (LEAKAGE)								53		
COOLING TOWER WATER										
COOLING TOWER BLOWDN WATER				263	1330				2559	
FLASH WATER	28089	28089								23241
DISSOLVED SOLIDS	111	111							11	111
SODIUM HYDROXIDE				87						
HYDROGEN PEROXIDE					150					
TOTAL FLOW LB/HR	81000	28200	52800	350	1480	4850	55368	231.5	2570	23350
TEMPERATURE - °F	371	371	371	80	80	209	209	103		209
PRESSURE - PSIA	178	175	166			13.7	13.7	16.7		13.7
PRESSURE - INCH Hg ABS										
DENSITY - LB/FT³										
TOTAL - MOLS/HR								7.3		
ENTHALPY - BTU/LB	900	344	1196							
H_2S EFFLUENT LB/HR	37					* 0.12	* 0.74			
				NOTE 5&6	NOTE 5&6		NOTE 5	NOTE 6		



NOTES:

1) CONTROL SYMBOLS & ABBREVIATIONS SEE DWG. E-02-102
2) PLANT ELEVATION — 2070 FEET
   ATMOSPHERIC PRESSURE — 13.7 PSIA
3) DISSOLVED SOLIDS IN FLASH WATER BY WEIGHT FRACTION AS FOLLOWS:

Na^+	.330
K^+	.056
Ca^{++}	.013
Cl^-	.576
SiO_2	.023
OTHER	.001
	1.000

4) NON CONDENSABLE GAS BY WEIGHT FRACTION

CO_2	.603
H_2S	.217
N_2	.173
H_2	.006
	1.000

5) FLOW IN PRESSURE VENT LINE ACTIVATES CONTROL CIRCUIT (A). CHEMICAL AND WATER FLOW RATES PROPORTIONAL TO STEAM FLOW. LINE 4 AND 5 QUANTITIES ARE THE MAXIMUM TREATMENT CHEMICALS REQUIRED. THE EFFICIENCY OF H_2S TREATMENT IS 98%.
6) BY PASS OF GAS TREATMENT PLANT LINE 34, DWG. E-02-103, ACTIVATES CONTROL CIRCUIT (B) LINE 4 AND 5 QUANTITIES ARE THE MAXIMUM TREATMENT CHEMICALS REQUIRED.
7. DURING WELL WARM-UP, THE WELL FLOW MAY BE PASS DIRECTLY TO THE SEPARATOR STACKS. THE CHEMICAL TREATMENT FOR H_2S ABATEMENT IS PROPORTIONAL TO FLOW RATE.

REFERENCE DRAWINGS — REVISION — REVISION

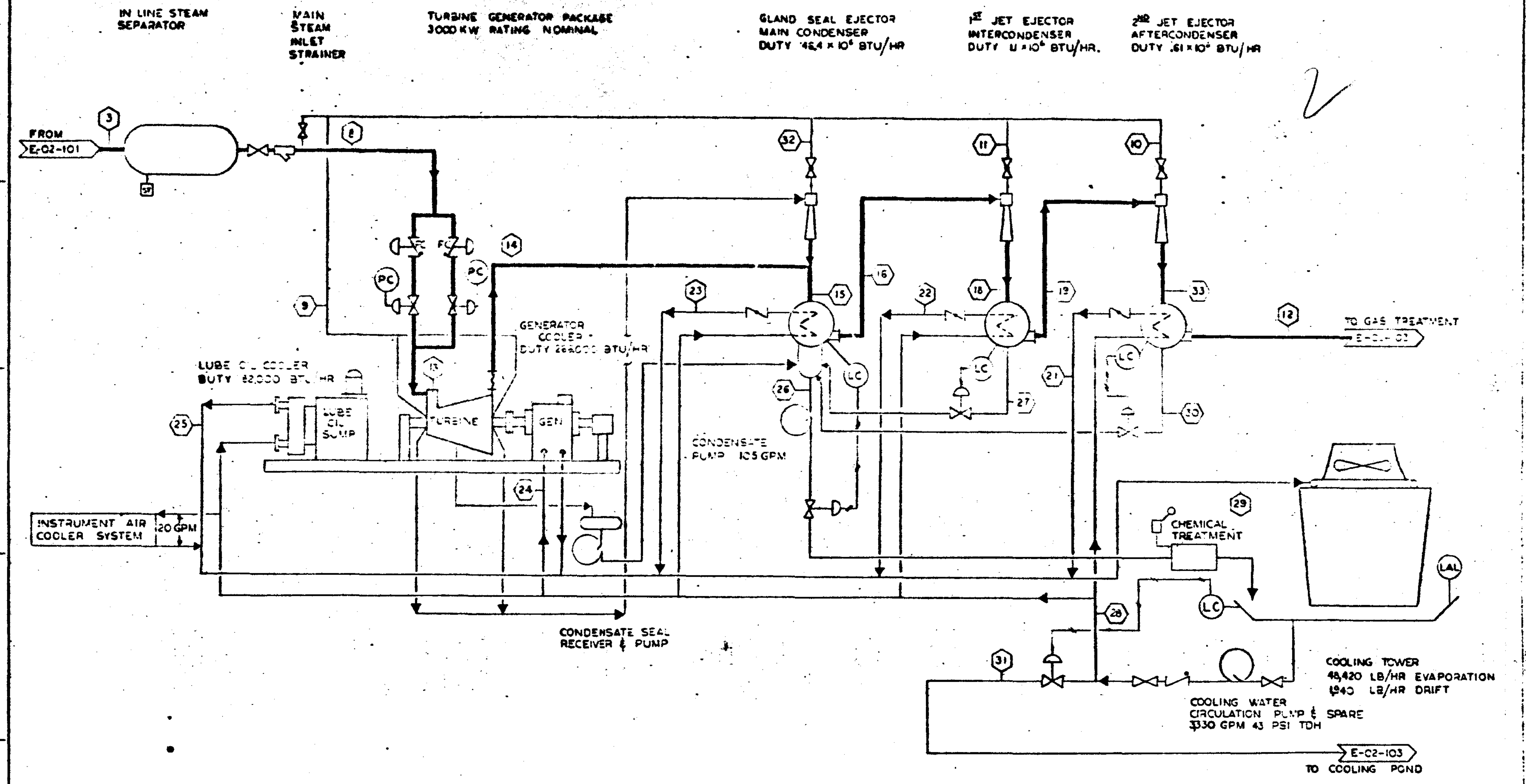
ROGERS ENGINEERING CO., INC.
ENGINEERS - ARCHITECTS
SAN FRANCISCO, CALIFORNIA

SCALE NONE — DATE NOV-3-1976

RESEARCH CORPORATION OF THE UNIVERSITY OF HAWAII
APPROVALS

HGP-A WELLHEAD GENERATOR
PROOF OF FEASIBILITY PROJECT
FLOW & CONTROL DIAGRAM
STEAM SUPPLY & EFFLUENT DISPOSAL

P — E-02-101 — 0



CONTROL SYMBOLS & ABBREVIATIONS

- (N) STREAM NUMBER
- (N) CONTROL CIRCUIT NUMBER
- ◯ INSTRUMENT
- SOLENOID OPERATOR
- DIAPHRAM OPERATOR

- AI ANALYZER INDICATOR
- FS FLOW SWITCH
- FCV FLOW CONTROL VALVE
- LC LEVEL CONTROL
- LAL LEVEL ALARM LOW
- LAH LEVEL ALARM HIGH
- NC NORMALLY CLOSED
- RC RATIO CONTROL
- PDI PRESSURE DIFFERENTIAL INDICATOR
- PC PRESSURE CONTROL
- PSV PRESSURE SAFETY VALVE
- PI PRESSURE INDICATOR

STREAM No.	3	8	9	10	11	12	13	14	15	16	17	18
FLOW IN LB/HR												
STEAM	52630	50935	180	598	798	8	50935	50935	51233	207		1007
NON CONDENSABLE GAS	170	165		2	2	170	165	165	165	65		170
AIR LEAKAGE						53		53	53	53		53
COOLING TOWER WATER												
COOLING TOWER BLOWDN												
WATER												
FLASH WATER												
DISSOLVED SOLIDS												
SODIUM HYDROXIDE												
HYDROGEN PEROXIDE												
CONDENSATE												
TOTAL FLOW LB/HR	52804	51100	180	600	800	231	51100	51153	51453	425		1230
TEMPERATURE °F	371		371	371	371	105		125	122	100		247
PRESSURE PSIA	175	167	168	168	168	16.7	160	2	1.8	1.5		4.9
PRESSURE INCH Hg Abs								4	3.7			
DENSITY LB/FT³												
TOTAL MOLS / HR.	2924											
ENTHALPY BTU/LB	1196	1196					1196	994				

STREAM No.	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
FLOW IN LB/HR															
STEAM	31													120	631
NON CONDENSABLE GAS	170														170
AIR LEAKAGE	53														53
COOLING TOWER WATER			20505	36980	1547000	38030	20500			1663015	1715641				
COOLING TOWER BLOWDN													2266		
WATER															
FLASH WATER															
DISSOLVED SOLIDS															
SODIUM HYDROXIDE															
HYDROGEN PEROXIDE															
CONDENSATE								52626	976			622			
TOTAL FLOW LB/HR	254		20505	36980	1547000	38030	20500	52626	976	1663015	1715641	622	2266	124	854
TEMPERATURE °F	100		115	115	115	92	89	121	130	85	115	130	85	371	270
PRESSURE PSIA	4.7							1.5	4.7			16.7		175	16.7
PRESSURE INCH Hg Abs															
DENSITY LB/FT³															
TOTAL MOLS / HR.															
ENTHALPY BTU/LB															

REFERENCE DRAWINGS | REVISION

ISSUED WITH CONCEPT REPORT

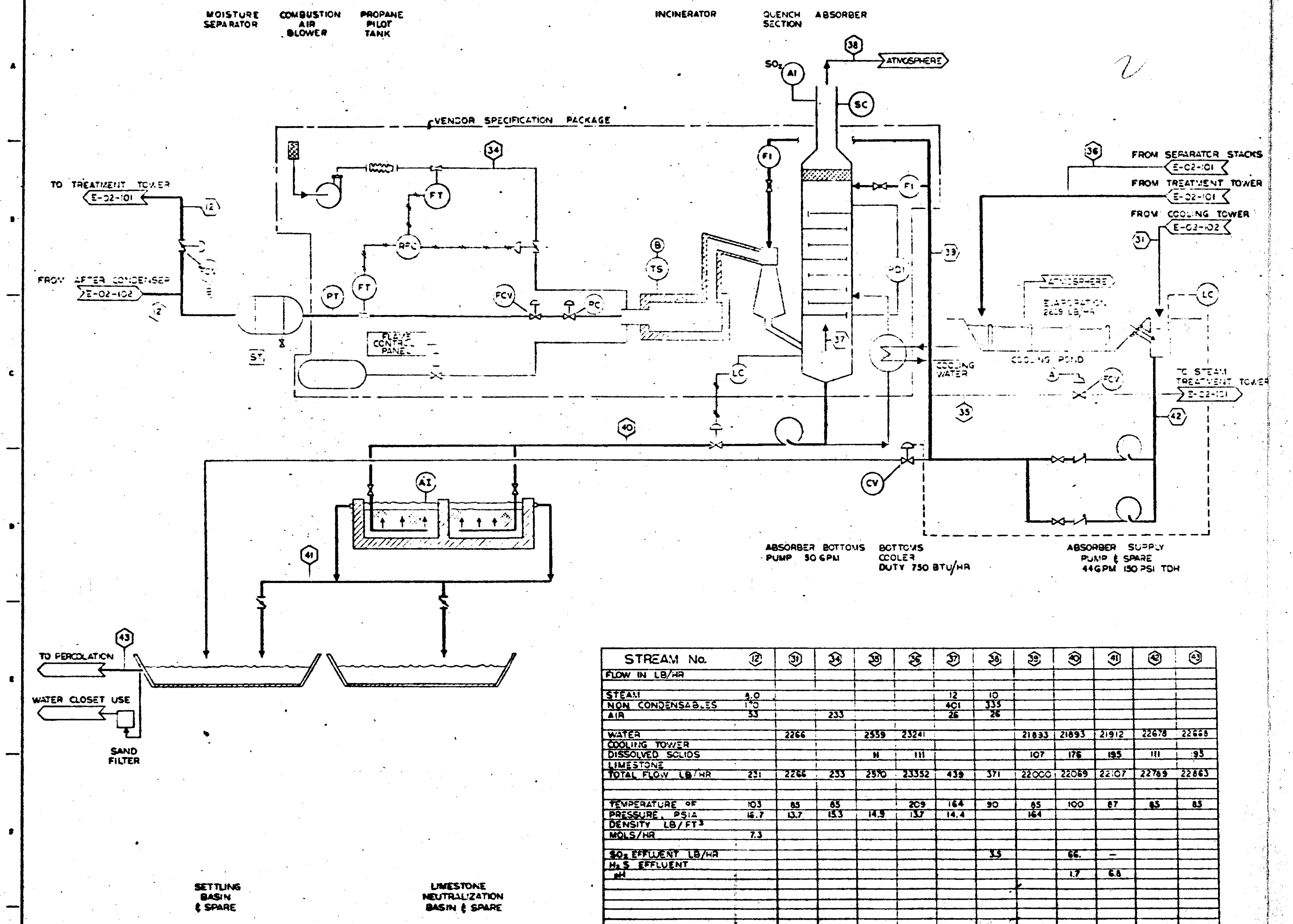
ROGERS ENGINEERING CO., INC.
ENGINEERS - ARCHITECTS
111 PINE STREET, SAN FRANCISCO, CALIFORNIA

SCALE NONE DATE NOV-3-1975

RESEARCH CORPORATION OF THE UNIVERSITY OF HAWAII
APPROVALS

HGP-A WELLHEAD GENERATOR
PROOF OF FEASIBILITY PROJECT
FLOW & CONTROL DIAGRAM
POWER PLANT

P | JOB NO. S-78C20 | E-02-102 | 0



STREAM No.	12	31	34	35	36	37	38	39	40	41	42	43
FLOW IN LB/HR												
STEAM	5.0					12	10					
NON CONDENSABLES	170					401	335					
AIR	33		233			26	26					
WATER		2266		2559	23241			21833	21893	21912	22678	22668
COOLING TOWER												
DISSOLVED SOLIDS				11	111			107	176	195	111	93
LIMESTONE												
TOTAL FLOW LB/HR	231	2266	233	2570	23352	439	371	22000	22069	22107	22789	22863
TEMPERATURE °F	103	85	85		209	164	90	85	100	87	85	83
PRESSURE, PSIA	16.7	13.7	15.3	14.9	13.7	14.4		164				
DENSITY LB/FT³												
MOLS/HR	7.3											
SO_2 EFFLUENT LB/HR							3.5		66.	—		
H_2S EFFLUENT												
pH									1.7	6.8		

ROGERS ENGINEERING CO., INC.
ENGINEERS · ARCHITECTS

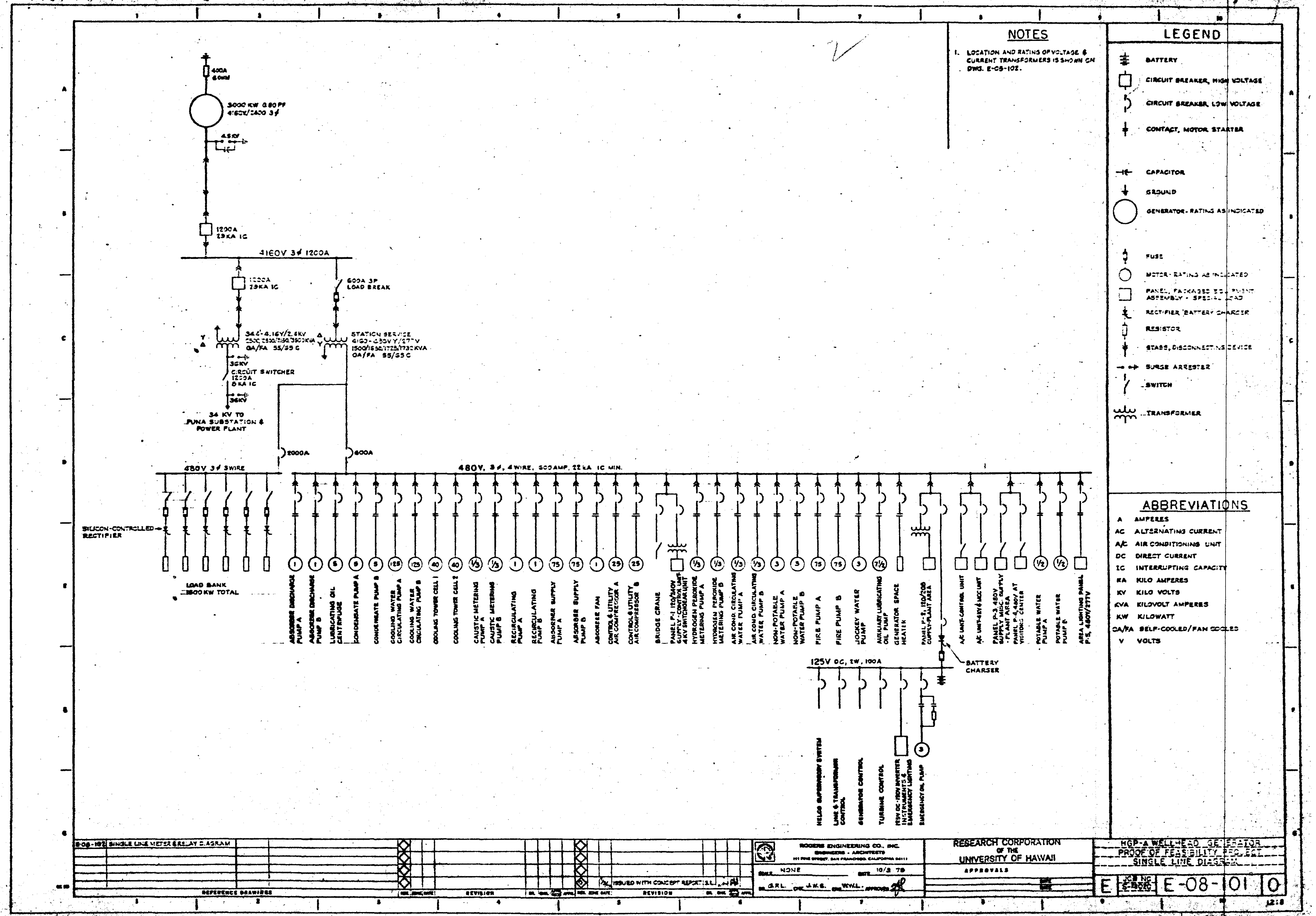
SCALE NONE
DATE NOV-3-1978

RESEARCH CORPORATION OF THE UNIVERSITY OF HAWAII

APPROVALS

HGP-A WELLHEAD GENERATOR PROOF OF FEASIBILITY PROJECT
FLOW & CONTROL DIAGRAM
H_2S ABATEMENT

P | JOB NO S-7620 | E-02-103 | 0



3000 KW 0.80 PF
4160V/2400 3∅
1200A
25KA IC
4160V 3∅ 1200A
600A 3P
LOAD BREAK
STATION SERVICE
CIRCUIT SWITCHER
34 KV TO
PUNA SUBSTATION &
POWER PLANT
2000A
600A
480V 3∅ 3 WIRE
480V, 3∅, 4 WIRE
SILICON-CONTROLLED RECTIFIER
LOAD BANK
BATTERY
CHARGER
125V DC
NOTES
1. LOCATION AND RATINGS OF VOLTAGE & CURRENT TRANSFORMERS IS SHOWN ON DWG. E-08-102.
LEGEND
BATTERY
CIRCUIT BREAKER, HIGH VOLTAGE
CIRCUIT BREAKER, LOW VOLTAGE
CONTACT, MOTOR STARTER
CAPACITOR
GROUND
GENERATOR - RATING AS INDICATED
FUSE
MOTOR - RATING AS INDICATED
PANEL, PACKAGED EQUIPMENT ASSEMBLY - SPECIAL LOAD
RECTIFIER BATTERY CHARGER
RESISTOR
DISCONNECTING DEVICE
SURGE ARRESTER
SWITCH
TRANSFORMER
ABBREVIATIONS
A AMPERES
AC ALTERNATING CURRENT
A/C AIR CONDITIONING UNIT
DC DIRECT CURRENT
IC INTERRUPTING CAPACITY
KA KILO AMPERES
KV KILO VOLTS
KVA KILOVOLT AMPERES
KW KILOWATT
OA/FA SELF-COOLED/FAN COOLED
V VOLTS
E-08-102 SINGLE LINE METER & RELAY DIAGRAM
REFERENCE DRAWINGS
REVISION
ISSUED WITH CONCEPT REPORT
ROGERS ENGINEERING CO., INC.
ENGINEERS - ARCHITECTS
SAN FRANCISCO, CALIFORNIA
SCALE NONE
DATE 10/3 79
RESEARCH CORPORATION
OF THE
UNIVERSITY OF HAWAII
APPROVALS
HGP-A WELLHEAD GENERATOR
PROOF OF FEASIBILITY PROJECT
SINGLE LINE DIAGRAM
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E-08-101
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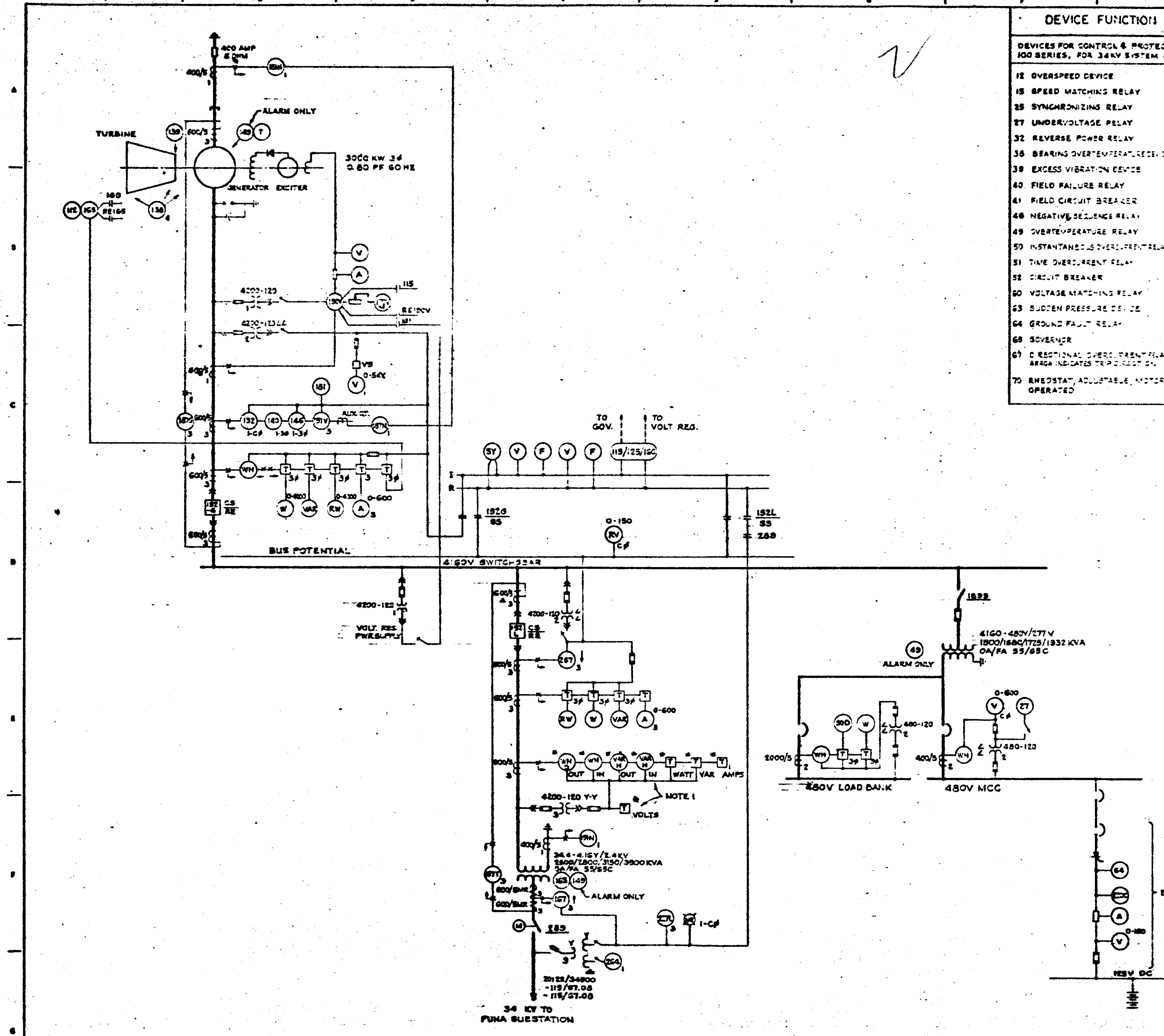


DEVICE FUNCTION NUMBERS & LETTERS

DEVICES FOR CONTROL & PROTECTION OF 4KV SYSTEM ARE IN THE 100 SERIES, FOR 34KV SYSTEM IN 200 SERIES.

12	OVERSPEED DEVICE	81	UNDERFREQUENCY RELAY
15	SPEED MATCHING RELAY	87	DIFFERENTIAL PROTECTIVE RELAY TRANSFORMER OR GENERATOR
25	SYNCHRONIZING RELAY	89	DISCONNECTING SWITCH
27	UNDERVOLTAGE RELAY	90	REGULATOR FOR VOLTAGE (V) OR LOAD (D)
32	REVERSE POWER RELAY		
38	BEARING OVERTEMPERATURE DEVICE		
39	EXCESS VIBRATION DEVICE		
40	FIELD FAILURE RELAY	CS	CONTROL SWITCH
41	FIELD CIRCUIT BREAKER	RE	REMOTE OR SUPERVISORY CONTROL
46	NEGATIVE SEQUENCE RELAY	SS	SYNCHRONIZING SWITCH
49	OVERTEMPERATURE RELAY	D	LOAD BANK
50	INSTANTANEOUS OVERCURRENT RELAY	DC	DIRECT CURRENT
51	TIME OVERCURRENT RELAY	G	GENERATOR
52	CIRCUIT BREAKER	L	LINE
60	VOLTAGE MATCHING RELAY	M	MOTOR
63	SUDDEN PRESSURE DEVICE	N	NEUTRAL
64	GROUND FAULT RELAY	T	TEMPERATURE
65	GOVERNOR	V	VOLTAGE
67	DIRECTIONAL OVERCURRENT RELAY ARROW INDICATES TRIP DIRECTION	S	STATION SERVICE
70	RHEOSTAT, ADJUSTABLE, MOTOR OPERATED		

SYMBOLS

- CURRENT TRANSFORMER, NUMBER & RATIO AS MARKED
- CURRENT TRANSFORMER, BUSHING TYPE, MULTI RATIO
- VOLTAGE TRANSFORMER, RATIO WINDINGS & CONNECTIONS AS INDICATED
- TEST SWITCH, VOLTAGE CIRCUIT
- TEST SWITCH & BYPASS CIRCUIT, CURRENT CIRCUITS
- WITH LETTER: METER, SEE BELOW
- WITH NUMBER: CONTROL OR PROTECTIVE DEVICE, SEE BELOW
- TRANSDUCER, TYPE AS INDICATED
- NEON LIGHT

METERS

A	AMMETER
F	FREQUENCY METER
RV	RECORDING VOLTMETER
RW	RECORDING WATT METER
SY	SYNCHROSCOPE
T	TEMPERATURE METER
V	VOLTMETER
VAR	VARMETER
VAR-H	VAR HOUR METER
W	WATTMETER
WH	WATT HOUR METER
WH-D	WATT HOUR METER WITH DEMAND
VS	VOLTMETER SWITCH

TRANSFORMER CONNECTIONS

YY	WYE-WYE
ΔY	DELTA WYE
	OPEN DELTA
	OPEN DELTA, ZERO SEQUENCE VOLTAGE

NOTES

1. ITEMS MARKED WITH AN ASTERISK ARE FURNISHED & INSTALLED BY HAWAII ELECTRIC LIGHT CO.
2. FOR SYMBOLS NOT IDENTIFIED SEE DWG. E-08-101.
3. ALL VOLTAGE & CURRENT TRANSFORMER GROUNDS ARE AT 4KV SWITCHGEAR.

E-08-101 SINGLE LINE DIAGRAM

REFERENCE DRAWINGS

0 ISSUED WITH CONCEPT REPORT

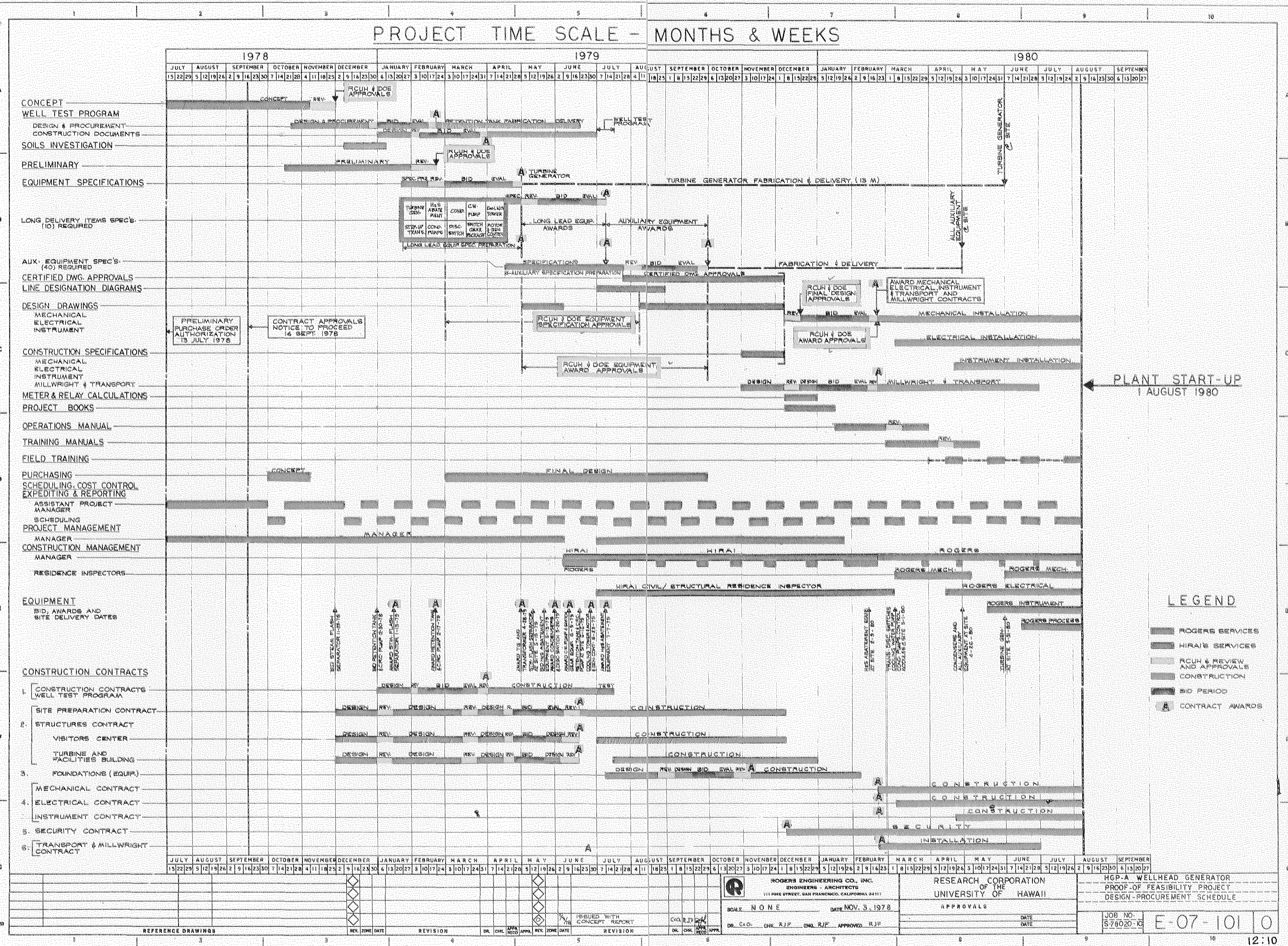
ROGERS ENGINEERING CO., INC.
ENGINEERS - ARCHITECTS
SAN FRANCISCO, CALIFORNIA

SCALE NONE DATE 10/3/75
DR. G.F.L. CHK. J.W.S. ENG. W.W.L.

RESEARCH CORPORATION OF THE UNIVERSITY OF HAWAII
APPROVALS

HGP-A WELLHEAD GENERATOR
PROOF OF FEASIBILITY PROJECT
SINGLE LINE
METER & RELAY DIAGRAM

E | JOB NO. S-7362C | E-08-102 | 0


PROJECT TIME SCALE - MONTHS & WEEKS
1978
1979
1980
CONCEPT
WELL TEST PROGRAM
DESIGN & PROCUREMENT
CONSTRUCTION DOCUMENTS
SOILS INVESTIGATION
PRELIMINARY
EQUIPMENT SPECIFICATIONS
LONG DELIVERY ITEMS SPEC'S. (10) REQUIRED
AUX. EQUIPMENT SPEC'S. (40) REQUIRED
CERTIFIED DWG. APPROVALS
LINE DESIGNATION DIAGRAMS
DESIGN DRAWINGS
MECHANICAL
ELECTRICAL
INSTRUMENT
CONSTRUCTION SPECIFICATIONS
MECHANICAL
ELECTRICAL
INSTRUMENT
MILLWRIGHT & TRANSPORT
METER & RELAY CALCULATIONS
PROJECT BOOKS
OPERATIONS MANUAL
TRAINING MANUALS
FIELD TRAINING
PURCHASING
SCHEDULING, COST CONTROL EXPEDITING & REPORTING
ASSISTANT PROJECT MANAGER
SCHEDULING
PROJECT MANAGEMENT
MANAGER
CONSTRUCTION MANAGEMENT
MANAGER
RESIDENCE INSPECTORS
EQUIPMENT
BID, AWARDS AND SITE DELIVERY DATES
CONSTRUCTION CONTRACTS
1. CONSTRUCTION CONTRACTS WELL TEST PROGRAM
SITE PREPARATION CONTRACT
2. STRUCTURES CONTRACT
VISITORS CENTER
TURBINE AND FACILITIES BUILDING
3. FOUNDATIONS (EQUIP.)
MECHANICAL CONTRACT
4. ELECTRICAL CONTRACT
INSTRUMENT CONTRACT
5. SECURITY CONTRACT
6. TRANSPORT & MILLWRIGHT CONTRACT
RCUH & DOE APPROVALS
PRELIMINARY PURCHASE ORDER AUTHORIZATION 13 JULY 1978
CONTRACT APPROVALS NOTICE TO PROCEED 14 SEPT. 1978
TURBINE GENERATOR FABRICATION & DELIVERY (15 M)
TURBINE GENERATOR @ SITE
ALL AUXILIARY EQUIPMENT @ SITE
LONG LEAD EQUIP. AWARDS
AUXILIARY EQUIPMENT AWARDS
FABRICATION & DELIVERY
RCUH & DOE EQUIPMENT SPECIFICATION APPROVALS
RCUH & DOE EQUIPMENT AWARD APPROVALS
RCUH & DOE FINAL DESIGN APPROVALS
RCUH & DOE AWARD APPROVALS
AWARD MECHANICAL, ELECTRICAL, INSTRUMENT & TRANSPORT AND MILLWRIGHT CONTRACTS
MECHANICAL INSTALLATION
ELECTRICAL INSTALLATION
INSTRUMENT INSTALLATION
MILLWRIGHT & TRANSPORT
PLANT START-UP
1 AUGUST 1980
FINAL DESIGN
MANAGER
HIRAI
ROGERS
HIRAI CIVIL/STRUCTURAL RESIDENCE INSPECTOR
ROGERS MECH.
ROGERS ELECTRICAL
ROGERS INSTRUMENT
ROGERS PROCESS
CONSTRUCTION
SECURITY
INSTALLATION
LEGEND
ROGERS SERVICES
HIRAI'S SERVICES
RCUH & REVIEW AND APPROVALS
CONSTRUCTION
BID PERIOD
CONTRACT AWARDS
REFERENCE DRAWINGS
REVISION
ISSUED WITH CONCEPT REPORT
ROGERS ENGINEERING CO., INC.
ENGINEERS - ARCHITECTS
SCALE NONE
DATE NOV. 3, 1978
DR. C.O. CHK. RJF ENG. RJF APPROVED RJF
RESEARCH CORPORATION OF THE UNIVERSITY OF HAWAII
APPROVALS
HGP-A WELLHEAD GENERATOR
PROOF-OF FEASIBILITY PROJECT
DESIGN-PROCUREMENT SCHEDULE
JOB NO. S-78020-IC
E-07-101
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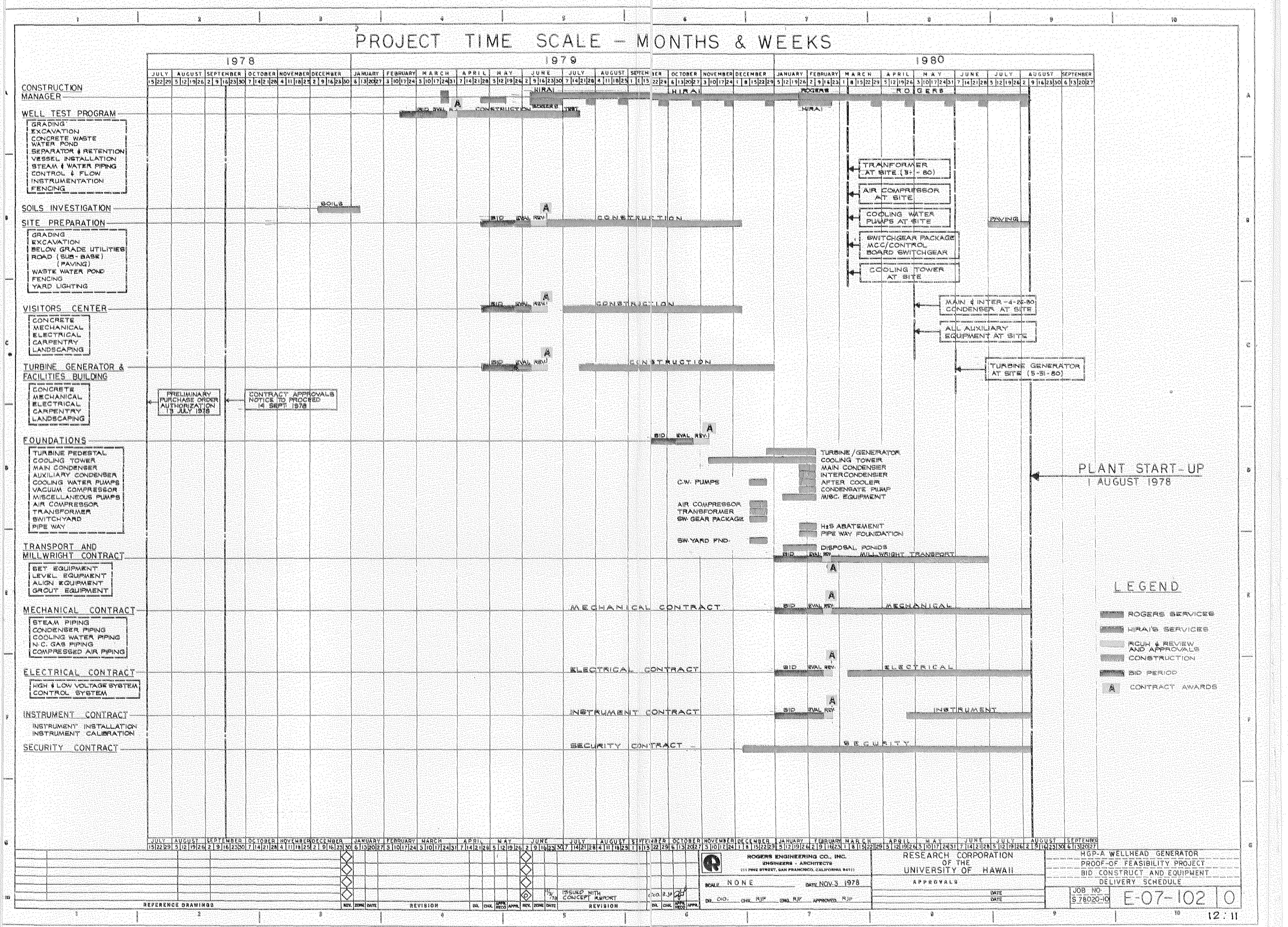
12:10


PROJECT TIME SCALE - MONTHS & WEEKS
1978
1979
1980
CONSTRUCTION MANAGER
HIRAI
ROGERS
WELL TEST PROGRAM
GRADING
EXCAVATION
CONCRETE WASTE WATER POND
SEPARATOR & RETENTION VESSEL INSTALLATION
STEAM & WATER PIPING
CONTROL & FLOW INSTRUMENTATION
FENCING
SOILS INVESTIGATION
SOILS
SITE PREPARATION
GRADING
EXCAVATION
BELOW GRADE UTILITIES
ROAD (SUB-BASE) (PAVING)
WASTE WATER POND
FENCING
YARD LIGHTING
PAVING
VISITORS CENTER
CONCRETE
MECHANICAL
ELECTRICAL
CARPENTRY
LANDSCAPING
TURBINE GENERATOR & FACILITIES BUILDING
CONCRETE
MECHANICAL
ELECTRICAL
CARPENTRY
LANDSCAPING
BID
EVAL
REV
CONSTRUCTION
PRELIMINARY PURCHASE ORDER AUTHORIZATION 13 JULY 1978
CONTRACT APPROVALS NOTICE TO PROCEED 14 SEPT. 1978
FOUNDATIONS
TURBINE PEDESTAL
COOLING TOWER
MAIN CONDENSER
AUXILIARY CONDENSER
COOLING WATER PUMPS
VACUUM COMPRESSOR
MISCELLANEOUS PUMPS
AIR COMPRESSOR
TRANSFORMER
SWITCHYARD
PIPE WAY
C.W. PUMPS
AIR COMPRESSOR
TRANSFORMER
SW. GEAR PACKAGE
SW. YARD FND.
TURBINE/GENERATOR
COOLING TOWER
MAIN CONDENSER
INTERCONDENSER
AFTER COOLER
CONDENSATE PUMP
MISC. EQUIPMENT
H2S ABATEMENT
PIPE WAY FOUNDATION
DISPOSAL PONDS
TRANSPORT AND MILLWRIGHT CONTRACT
SET EQUIPMENT
LEVEL EQUIPMENT
ALIGN EQUIPMENT
GROUT EQUIPMENT
MILLWRIGHT TRANSPORT
MECHANICAL CONTRACT
STEAM PIPING
CONDENSER PIPING
COOLING WATER PIPING
N.C. GAS PIPING
COMPRESSED AIR PIPING
MECHANICAL
ELECTRICAL CONTRACT
HIGH & LOW VOLTAGE SYSTEM
CONTROL SYSTEM
ELECTRICAL
INSTRUMENT CONTRACT
INSTRUMENT INSTALLATION
INSTRUMENT CALIBRATION
INSTRUMENT
SECURITY CONTRACT
SECURITY
TRANFORMER AT SITE (3-1-80)
AIR COMPRESSOR AT SITE
COOLING WATER PUMPS AT SITE
SWITCHGEAR PACKAGE MCC/CONTROL BOARD SWITCHGEAR
COOLING TOWER AT SITE
MAIN & INTER-4-26-80 CONDENSER AT SITE
ALL AUXILIARY EQUIPMENT AT SITE
TURBINE GENERATOR AT SITE (5-31-80)
PLANT START-UP 1 AUGUST 1978
LEGEND
ROGERS SERVICES
HIRAI'S SERVICES
RCUH & REVIEW AND APPROVALS
CONSTRUCTION
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111 PINE STREET, SAN FRANCISCO, CALIFORNIA 94111
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PROOF-OF FEASIBILITY PROJECT
BID CONSTRUCT AND EQUIPMENT
DELIVERY SCHEDULE
JOB NO. S 78020-10
E-07-102 0
12:11