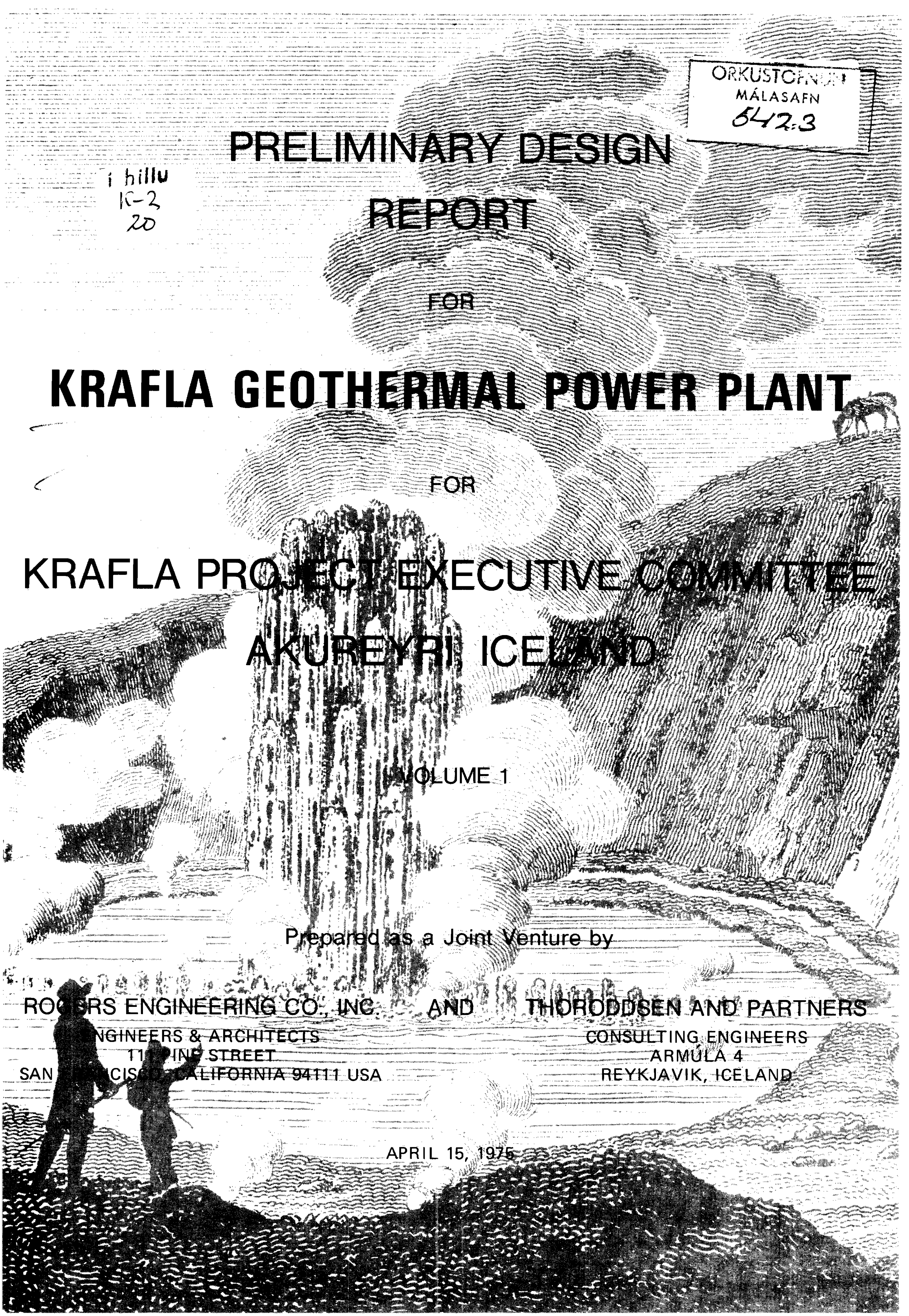

PRELIMINARY DESIGN REPORT

FOR

KRAFLA GEOTHERMAL POWER PLANT

FOR

KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND

VOLUME 1

Prepared as a Joint Venture by

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ARMÚLA 4
REYKJAVIK, ICELAND

APRIL 15, 1975

COPY 37

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1.0 SYNOPSIS

The purpose of this report is to present the design concepts and criteria, a budget cost estimate, and a design, procurement, and construction schedule for the Krafla Geothermal Power Plant to be built in Northern Iceland.

In addition, this report contains preliminary drawings showing the progress made to date in the execution of first stage of plant design.

The Plant consists of two (2) geothermal steam, double entry turbine driven, 30 MW electric generating units and ancillary equipment enclosed in a steel reinforced concrete power plant building. Cooling towers are provided for rejection of the latent heat from the turbine exhaust steam condensed in the low level direct contact condensers.

Plant design began in December 1974 and commercial operation of the first turbine-generator is scheduled for October 1976. In order to meet the 1976 winter peak load the completion of the first unit has been scheduled for the earliest possible date. The second unit is scheduled to begin commercial operation in February 1977.

The total estimated cost of the power plant complete is 3,826.5 million Icelandic Kronur ($25,510.100 U. S. dollars) excluding the cost of the electrical transmission line and the steam production facilities consisting of the steam gathering piping, steam water separators, and the steam wells. The detail of the budget cost estimate is presented in a separate binding as Appendix A to this report.

2.0 INTRODUCTION

The Joint Venture of Rogers Engineering Co., Inc. and Thoroddsen and Partners was selected by the Krafla Project Executive Committee to design, purchase equipment for and supervise construction of a 55 MW geothermal steam power plant to be located at Krafla in northern Iceland.

In order to assure completion of this project in the shortest possible time, it was agreed that the turbine-generators, which pace the construction schedule, should be purchased through negotiations rather than through the time consuming procedure of competitive bidding. To this end, turbine-generator specifications were prepared and invitations were presented to a selected list of manufacturers to submit proposals for supply of the turbine-generators. Of those solicited, five manufacturers responded with proposals. The Consultants reviewed the proposals and submitted the offers of two manufacturers with demonstrated experience in geothermal steam turbine design to the Executive Committee for consideration.

It was considered essential in this case that the successful manufacturer have experience in geothermal steam turbine design because of the remote location of the station and because of the importance of this power station to the power system on the Icelandic north coast.

Intensive negotiations were entered into with these two potential Suppliers by the Committee and a Letter of Intent was signed on February 7, 1975, with Mitsubishi Heavy Industries, Tokyo, Japan for the supply of two (2), 30 MW geothermal steam turbine driven generator sets each capable of a maximum continuous output of 35 MW.

The report presents the design concepts, methodology for design, cost estimate, and design, procurement and construction schedule for the Power Plant.

The body of the report is divided into Sections which deal with particular aspects of the project.

The Basis for Design Section presents the criteria upon which the Plant design is based. Power cycle data contained in this section are based upon most economical utilization of the estimated geothermal energy available at the Site for the production of electrical power.

The Power Plant Facilities Section describes the Power Plant building and equipment arrangement.

The Power Cycle Section includes a power cycle flow diagram, which includes heat and mass balance data for the Plant; piping and instrument diagrams, which show piping schematics and principal instrumentation and control. These diagrams are highlighted by text which describes the philosophy of operation and control for the mechanical equipment.

The Electrical Characteristics Section describes the philosophy of design and operation for the electrical equipment in the Plant and includes single line electrical diagrams.

The Design, Procurement and Construction Schedule Section included herein will be used as a guide to keep the project on schedule and to flag possible trouble spots.

The balance of the Plant equipment will be ordered in accordance with this Schedule in order to assure completion of the first unit by October 1976 and the second unit by February 1977.

The predicted power requirements for the north and east coast of Iceland is shown on Figures 2 and 3 and is included for general information and indicates the urgent need for firm power.

3.0 BASIS FOR DESIGN

3.1 Site Conditions

The Krafla Geothermal Power Plant will be located in the ~~Namafjall~~ Krafla Geothermal Field which is part of the more extensive KRAFLA - LEIRHNÚKUR field, which is approximately 40 square kilometers (Km^2) in area. This area lies on the Icelandic rift zone.

The site for the Power Plant has been selected. Survey borehole drillings have been performed to determine if the soil, which is a lava area, can adequately support the building and equipment foundations.

The Plant Site will be approximately level and the cooling tower basin and Power House will be located at the same elevation.

The proposed Site lies about 460 m above sea level and is located in a valley 600 to 1400 m southwest of the proposed production wells. The Site is in an area of recent volcanic and seismic activity and for this reason the permanent structures will be designed for earthquake Zone 1, Icelandic Building Code, or the corresponding Zone 3, United States Building Code.

3.2 Powerhouse Building

3.2.1 The Powerhouse building is a three level reinforced concrete building with prestressed concrete roof trusses.

A 40 metric ton bridge crane which spans the building width and runs full length of the building is supported by interior reinforced concrete columns.

The administration and services area will be housed in the south end bay of the Powerhouse building. This area will have three levels. All levels in this area will have access to the ground and operating floors of the Powerhouse building. The mezzanine floor is located midway between the ground floor and the operating floor, extends through five bays in the central section of the Powerhouse and is accessible from the ground and operating floors.

3.2.2 Powerhouse Dimensions:

The preliminary Powerhouse building dimensions are 69 meters long x 21 meters wide outside dimensions by approximately 20 meters high from the ground floor to the eaves. The operating floor height and mezzanine floor height are 8.0 meters and 4.0 meters above the ground floor respectively.

3.2.3 The following design parameters determine the height of the Powerhouse building and the elevation of the floors within the building:

The height of the top of the condenser determines the minimum elevation of the turbine in the Powerhouse. The operating floor level is set at the same level as the top of the turbine pedestal. The mezzanine floor and ground floor elevations are set to provide sufficient head room for the equipment located on each of these floors.

The height of the turbine building above the operating floor is determined by the minimum crane hook height required to disassemble the turbine-generator, plus the height of the crane and roof structure.

The minimum practical width of the Powerhouse building is determined by the location and dimensions of the major equipment considering required operating and maintenance clearances, major piping in the building, hot well pump dimensions and the crane access for maintenance. The derived width of the Powerhouse building also provides for electrical requirements.

The length of the Powerhouse building is determined by the following:

The in-line arrangement of the two turbine-generators, with space provided between the generators for rotor removal; space required for the steam supply piping to the turbine; the space required by the Control Room, Instrument Repair, Laboratory, and other ancillary rooms; the space allocation permits the location of the turbine lubricating oil tanks at the end of the turbines on the ground floor; and is coordinated with the width of the main entrance.

The Maintenance Shop is centrally located on the ground floor convenient to the major equipment access entrance with its roll up door. Parts Storage Rooms are located adjacent to the Maintenance Shop. A monorail hoist permits easy transfer of parts between the Maintenance Shop and each of the Parts Storage Rooms. A suitable bridge crane is installed over the Maintenance Shop for maintenance service. In addition, the main bridge crane has access to a portion of the Maintenance Shop.

The equipment arrangement established by the above considerations provides sufficient floor space on the operating floor to lay down the major turbine-generator parts and components for overhaul.

3.2.4 Design live loads are as follows (kg per square meter)

Roof	700
Operating Floor	600
Control Room	250
Riggers Loft/Spare Turbine Rotor Storage	600
Mezzanine	600
Instrument Repair and Wet Chemical Laboratory	250
Office Area	200
Ground Floor	3,000

3.2.5 The foundation design will be as required by the findings in the Soils Report.

3.3 Cooling Tower

The cooling tower is sited in such a way that during prevailing winds the steam is carried away from the Powerhouse and switchyard to minimize the danger of icing and corrosion. The foundation for the tower will be of concrete designed as a basin to contain a large quantity of cooling water. The materials in the cooling tower structure will be selected to withstand the corrosive action of the cooling water and the weather conditions of the area.

3.4 Meteorological Data

There are no sources of meteorological data which are directly applicable to the Krafla area. Meteorological data from the REYKJAHLID and GRIMSSTADIR Weather Stations, which are closest to the Site, were used to estimate the expected conditions shown below. In order to acquire more accurate meteorological data a portable automatic weather recording station should be set up as soon as possible at the Site. However, in the absence of this more accurate data, the most adverse weather conditions prevailing at either of the above mentioned weather stations has been used as design criteria for the Krafla Site.

Wind directional data available from GRIMSSTADIR Weather Station indicates that the prevailing wind direction in the Krafla area is from south in the winter and the north in the summer. The surface contours near the proposed Power Plant location undoubtedly will confine wind direction to either up or down the valley, which runs from north-northeast to south-southwest.

3.4.1 Wind pressure for design will be as stated in the U. S. Uniform Building Code for Wind Pressure Area 50 as follows:

Height, Meters	Pressure Kilo Newtons Per Square Meter
Less Than 9	1.92
9 to 14.9	2.39
15 to 29.9	2.87

3.4.2 For selection of design for the cooling tower, extreme temperature and humidity data were collected for the above weather stations for the last ten years. The average is shown on Figure 1, temperature chart, where the number of days/year is shown when the maximum temperature is above the design temperature. On the basis of this diagram the cooling tower parameters were selected as +15°C dry bulb temperature maximum and +11°C wet bulb temperature which corresponds to 63% Relative Humidity. From the chart it can be seen that on the average the dry bulb temperature will be exceeded approximately 30 days/year and a slight reduction in power would follow during the warmest part of the days (1-5 o'clock) when this happens.

3.4.3 Minimum ambient temperatures and humidity for design of Heating, Ventilating and Air Filtration Systems are as follows:

Temperature	-30°C
RH	60%

3.5 Geothermal Well Data

The geothermal well data used in the design is based on available information from the two exploration boreholes which were drilled during the fall of 1974.

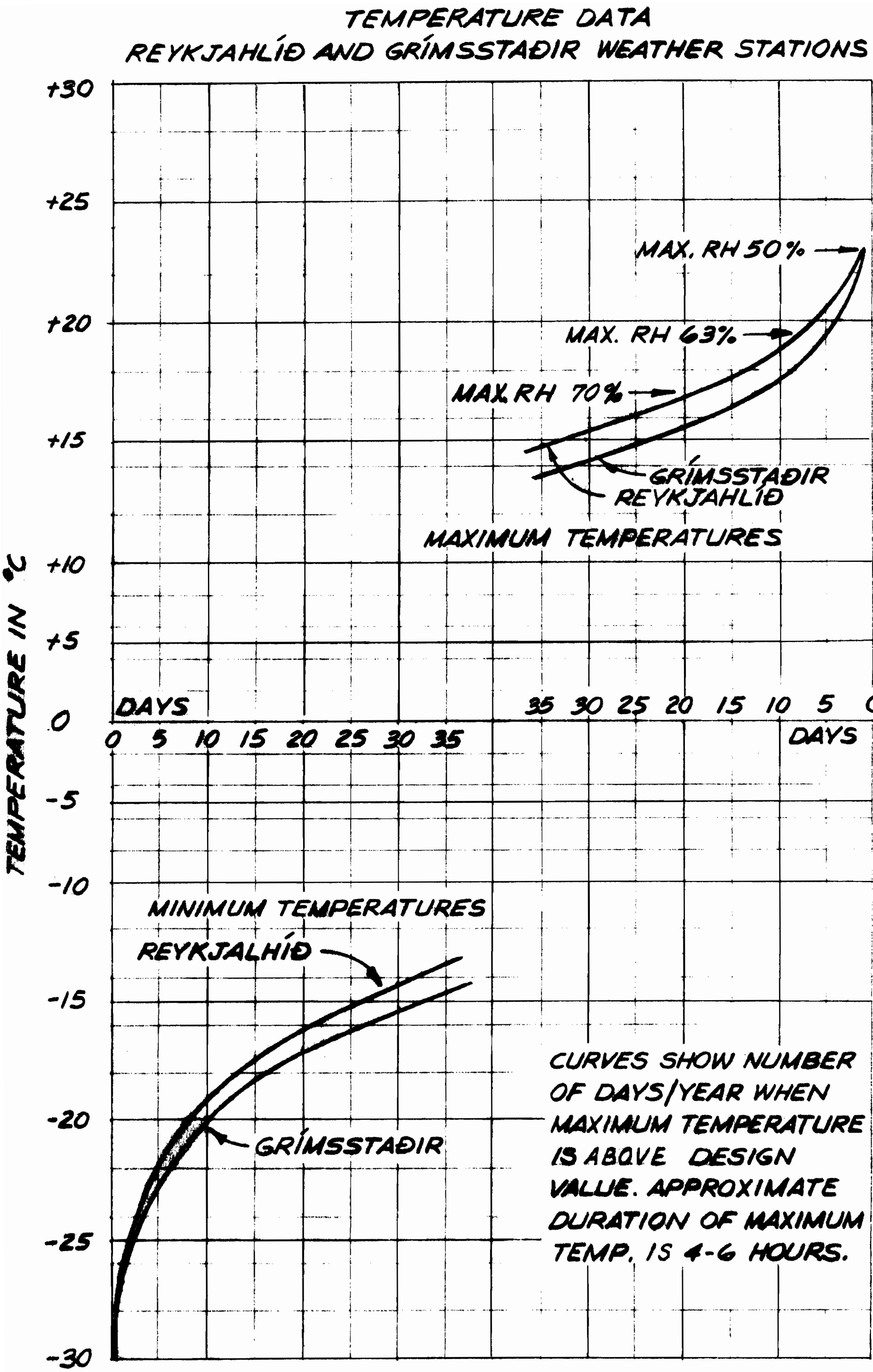

TEMPERATURE DATA
REYKJAHLÍÐ AND GRÍMSSTAÐIR WEATHER STATIONS
TEMPERATURE IN °C
+30
+25
+20
+15
+10
+5
0
-5
-10
-15
-20
-25
-30
MAX. RH 50%
MAX. RH 63%
MAX. RH 70%
GRÍMSSTAÐIR
REYKJAHLÍÐ
MAXIMUM TEMPERATURES
DAYS
35 30 25 20 15 10 5 0
0 5 10 15 20 25 30 35
DAYS
MINIMUM TEMPERATURES
REYKJALHÍÐ
GRÍMSSTAÐIR
CURVES SHOW NUMBER OF DAYS/YEAR WHEN MAXIMUM TEMPERATURE IS ABOVE DESIGN VALUE. APPROXIMATE DURATION OF MAXIMUM TEMP. IS 4-6 HOURS.

Figure 1

3.5.1 The deep water borehole average temperatures are assumed to be 270°C.

3.5.2 The noncondensable gas composition of the steam flashed at 10 Kg/square cm abs. is based on chemical analysis made on test borehole No. 1. The noncondensable gases in the geothermal reservoir water amount to 0.23% by weight of the water.

NONCONDENSABLE GAS COMPOSITION

Gas	Percent by Volume
Carbon Dioxide (CO_2)	76.4
Hydrogen Sulfide (H_2S)	15.1
Hydrogen (H_2)	7.4
Nitrogen (N_2)	1.0
Methane (CH_4)	.06
Molecular Weight	39.20

3.6 Power Cycle

The turbines utilize steam flashed from geothermal water at two different pressures. The double flash system reduces the hot water requirement from the wells by approximately 20 percent (20%) (as compared to a single flash system) and at the same time gives more flexibility of operation for possible future changes in steam conditions.

The plant consists of two units, each of which is capable of operating independently of, as well as, in parallel with each other. Each unit includes its own turbine-generator with auxiliaries, condensing system, cooling tower, and a substation to step up the voltage for transmission.

The following design parameters have been selected to provide a guaranteed generating unit output of 30 MW.

3.6.1 Turbine Design

First Flash Steam Pressure:	8.7 Kg per square cm abs.
Second Flash Steam Pressure:	2.2 Kg per square cm abs.
Turbine Entry Pressure:	
High Pressure	7.2 Kg per square cm abs.
Low Pressure	1.81 Kg per square cm abs.

3.6.2 The following conditions are required to produce a maximum continuous power output of 35 MW.

First Flash Steam Pressure	10.2 Kg per square cm abs.
Second Flash Pressure	2.7 Kg per square cm abs.
Turbine Entry Pressure:	
High Pressure	8.42 Kg per square cm abs.
Low Pressure	2.16 Kg per square cm abs.

3.6.3 Condenser Design

Turbine Exhaust Pressure	89 mm Hg absolute at 30 MW and approximately 120 mm Hg absolute at 35 MW
Turbine Exhaust Temperature	49.2°C

Condenser Type:	Low Level Direct Contact
Condenser Hot Well Temperature	45.3°C

Condenser Vacuum System: Removal of noncondensable gases amounting to approximately one percent (1%) by weight in the high pressure steam to the turbine. The expected pH of the condensing steam is 4.0.

3.6.4 Cooling Tower Design

Hot water to cooling tower 45.3°C

Cold water from cooling tower 22.0°C

Air temperature design condition:

Dry Bulb 15°C

Wet Bulb 11°C

The cooling water in the cold well of the cooling tower basin is assumed to be completely saturated with atmosphere gases.

The cooling water is to be treated to bring the cold well water pH up to approximately 6.5.

3.7 Electrical

The Krafla Plant will be the largest electric generating station in the northern Iceland electrical system during the early years of operation and will be interconnected through high voltage transmission lines with the hydroelectric generating stations to be built in the future.

3.7.1 The electrical design of this Plant provides for the following considerations:

Base load operation normally, with ability to control load.

Master frequency control for the northern electrical system.

Installation of two generators and three transmission lines.

Low maintenance and operation requirements due to remote plant location.

Atmosphere containing hydrogen sulfide and salt spray.

Central Control Room

Ability to start the Plant without any outside power source.

Operators in attendance at the Plant 24 hours per day.

Each generator, associated auxiliary station power system, and step-up transformer designed as a unit.

4.0 POWER PLANT FACILITIES

4.1 Building and Equipment Arrangement

The equipment is arranged within the building so as to facilitate maintenance and to make piping installation short and economical.

4.1.1 Floor Openings and Hatches

Access hatches are provided to move equipment from floor to floor. The large hatch located at the center of the Powerhouse is sized to accommodate the largest equipment component moving between the ground floor and operating floor.

The operating floor includes areas with removable steel grating to allow for maintenance access to piping, valves and pumps located beneath. The steel grating also provides ventilation around major equipment from lower floors.

4.1.2 Operating Floor Arrangement

The turbine-generator controls and generator coolant controls are located along the east wall, opposite their respective generators.

The location of the Control Room within the Plant at the south wall was selected for the following reasons:

A more central location either would have interfered with necessary clear maintenance space or would have entailed a building addition protruding from the east wall of the Powerhouse. This, in turn, would have extended the required safety clearances between the building and the switchgear in the yard and increased the length of cabling at considerable cost.

The south end of the Powerhouse building is provided with a concrete separation wall which accommodates the Control Room at the operating floor level. Its proximity to the operating floor equipment makes an economical installation from the standpoint of conduit and control wiring runs. The shift foreman's office is located adjacent to the Control Room and is convenient thereto. A staircase is provided for normal access to the operating floor, the laboratory and instrument repair rooms and is the emergency exit for the upper levels of the south side of the Powerhouse.

The Riggers Storage Room containing all rigger's equipment and the Spare Turbine Rotor Storage area is located in the south end bay of the building above the Control Room. This area will be serviced by the main bridge crane. Access is also by a staircase from the operating floor level.

4.1.3 Mezzanine Floor Arrangement

This floor extends through five (5) bays of the Powerhouse and is connected by stairs to the operating floor and to the ground floor. Unit Substations with Motor Control Centers No. 1A & 1B and No. 2A & 2B are located on the east side in enclosed rooms. The 11 kV switchgear for each turbine-generator is located on the west side in enclosed rooms. The rooms are constructed of light concrete bricks and are ventilated with filtered air maintained at positive pressure to prevent the entrance of hydrogen sulfide which could attack and corrode exposed copper contacts.

A separate battery is provided for each unit. The battery rooms are located on this floor on the east side of the generator pedestals. The battery rooms include special ventilation provisions to preclude accumulation of hydrogen gases.

A wet chemistry laboratory and instrument repair shop are located at the south end of the building at the mezzanine level of the service area.

4.1.4 Ground Floor Arrangement

The Ground Floor is fitted with the central east equipment entrance to the Powerhouse and a motorized roll up door designed to accommodate the largest equipment within the building. To the south of the entrance is an enclosed room which contains the cold startup generator equipment. The Maintenance Shop, Parts Storage and Supervisors areas are located in the central portion of the building close by the entrance.

The Ground Floor Plan includes two stairwells at the west wall providing access to the operating floor and mezzanine floor. The Power Plant office, reception, lavatories and locker room are also located on this level at the south end of the building.

4.1.5 Means of Exit

There are six (6) personnel doors on the ground floor on the west and east walls of the Powerhouse for emergency exit. Three (3) staircases from the operating floor lead to these exit doors. An exterior staircase on the north wall will be provided for the energency exit from the operating floor.

4.2 Environmental and Architectural Considerations

The following environmental and architectural considerations will be given high priority in the execution of this project:

4.2.1 All structures included in the project will be designed to harmonize with the surrounding natural landscape.

4.2.2 The cooling tower will be located so that the prevailing wind blows across the tower and so as to prevent vapor from being blown across the high voltage substation and other structures.

4.2.3 The Plant and the construction facilities will be confined to the planned Power Plant area so as to maintain a clear definition between the untouched lava and the man made environment. Roads within the area will have permanent surface treatment.

4.2.4 Construction materials and color schemes will be selected to harmonize and blend with the surrounding environment.

4.2.5 An important design element considered in planning this structure is natural light. High windows have been incorporated along the east and west walls of the building which will be double glazed fixed sash for maximum thermal insulating value. The concrete walls between these windows are just wide enough to satisfy the structural integrity requirements of the building.

Entrance and exit doors are organized in a harmonious manner and are either recessed or have canopies for protection from the rain and snow.

Non-bearing interior partitions will be light concrete bricks.

4.3 Lighting

Fluorsecent lighting will be used generally throughout the building interior. Commercial type fixtures will be installed in the offices, Control Room and Reception Room to provide an illumination level of 100 footcandles. Industrial type fixtures with high output lamps will be provided in most other spaces to produce 75 footcandles in shop area and 50 footcandles elsewhere.

The exterior switchyard and cooling tower area will be illuminated with mercury vapor floodlights.

European type lighting switches and convenience receptacles will be used to suit 220 volts to ground circuits.

4.4 Ventilation, Heating and Air Filtration

The heating, ventilating and air filtering systems are designed to provide for three (3) main requirements.

4.4.1 Ventilation for the turbine-generator plant building generally will be sufficient to keep the generator and other electrical equipment from being subjected to excessive ambient air temperatures.

4.4.2 Ventilating systems for areas enclosing switchgear, motor controls, exciter control and other plant control equipment will protect these components from exposure to ambient air with corrosive contaminents. In addition to removal of the contaminents from the supply air the ventilation system will also heat the supply air as needed.

4.4.3 Ventilation to provide clean air and comforable working conditions in the maintenance, repair, and operating areas.

Area	Ventilation System	Exhaust System	Heating System	Filtering System Std.	Filtering System Specl
Ground Floor Areas					
Turbine Generator Foundation & Pit Area	x	x	x	x	
Shop Areas	x	x	x	x	
Parts Storage	x	x	x	x	
Cold Startup Generator Area	x	x	x	x	
Hot Well Areas	x	x		x	
Office	x	x	x	x	
Waiting Room	x	x	x	x	
Men's Room	x	x	x	x	
Locker Room	x	x	x	x	
Maintenance Shop	x	x	x	x	
Mezzanine Areas					
Switchgear Areas	x	x	x		x
Unit Substations & MCC Areas	x	x	x		x
Wet Chemistry Laboratory	x	x	x		x
Instrument Repair	x	x	x		x
Battery Rooms	x				x
Operating Floor Area					
Turbine Generator Areas	x	x	x	x	
Control Room	x	x	x		x
Shift Foreman	x	x	x	x	
Rigger Storage	x		x	x	

5.0 POWER CYCLE AND AUXILIARY SYSTEMS

5.1 Power Cycle Flow Diagram

The Power Cycle Flow Diagram, A1-02-001, shows the operating conditions for one unit of the Power Plant. The explanation given here briefly describes the operation of the system with reference to the design and operating parameters.

5.1.1 Steam Flash Separators

5.1.1.1 Operation of the First Flash Stage Separator: The Power Cycle Flow Diagram shows only one first flash steam separator for the purpose of simplicty and clarity. There will possibly be a steam separator at each well or one for several wells. Expected separator pressure is 8.7 kilograms per square centimeter absolute (Kg/cm^2a). The steam from several first stage flash steam separators will be manifolded and delivered to one turbine in the Power Plant. The other turbine will be served by another group of wells.

A level controller regulates the flow of liquid from the bottom of the separator. This water will be manifolded and brought to the second stage flash steam separator which may be located near the Power Plant. If the pressure in the first stage separator rises to approximately 11 kilograms per square centimeter absolute (Kg/cm^2a) the excess pressure is released to the atmosphere through the pressure control valve.

5.1.1.2 The second stage flash steam separator pressure will be approximately 2.2 kilograms per square centimeter absolute (Kg/cm^2a).

A level controller maintains a level in the separator to prevent the escape of steam out the bottom and to prevent the carry-over of liquid into the low pressure steam line to the turbine.

The liquid effluent from the second flash steam separator will be at the pressure of 2.2 kilograms per square centimeter absolute (Kg/cm^2a) and at a temperature of 122.9°C. The quantity will be 70% of the total borehole flow into the first flash steam separators.

5.1.2 Power Generation

5.1.2.1 A moisture separator located at the Plant removes condensate formed in the high pressure steam lines due to heat loss in the piping between the first stage flash separator and the Power Plant.

5.1.2.2 First stage (high pressure) turbine inlet pressure at full load (30 MW) will be approximately 7.2

kilograms per square centimeter absolute. (Kg/cm^2a). Design inlet pressure to the turbine from the second stage flash steam separator will be 2.0 kilograms per square centimeter absolute (Kg/cm^2a).

5.1.2.3 The main condenser design operating pressure is 89 millimeters of mercury (mm Hg abs.) absolute, corresponding to a saturation temperature of 49.2°C. Condenser water inlet temperature will be 22°C.

A two stage steam jet ejector system with a direct contact intercondenser is used for removal of the noncondensable gases from the condenser.

The main condenser contains a gas cooling section in which the noncondensable gases are further cooled so as to reduce the amount of steam mixed with them to the lowest practical quantity. Reducing the quantity of steam dissolved in the noncondensable gases reduces the load on the ejectors and the amount of motive steam which would otherwise be required.

5.1.2.4 The geothermal hot water contains dissolved noncondensable gases, most of which are released in the first flash steam separator and will pass through the turbine to the condenser. The design of the Power Plant is based on a noncondensable gas content of one percent (1%) by weight in the mixture of high pressure steam and noncondensable gases at the turbine inlet. A negligible amount will be present in the low pressure steam.

The noncondensable gases are removed from the condenser by a two stage steam jet ejector system with a direct contact intercondenser. The steam condensed in the intercondenser and the cooling water used in the intercondenser are cascaded to the main condenser. The 190 millimeters of mercury (mm Hg) difference in pressure between the intercondenser and the main condenser is maintained by a vertical water column contained in a loop seal which joins the main and intercondenser. The second stage ejector discharges to the atmosphere through a silencer.

5.1.2.5 The cooling water flow from the cooling tower basin to the main condenser sprays is controlled by a single large butterfly valve which is controlled by a signal from a pressure controller on the main condenser.

The mixture of condensate and cooling water is pumped from the condenser to the cooling tower by two hot well pumps through stainless steel piping. One of the hot well pumps (associated with each turbine-generator) has a noncondensing turbine driver and an electric motor driver. The use of a steam-turbine driver for cold start reduces the power demand which in turn reduces the size of the standby generator required. The condenser hot well water level is controled by throttling the discharge of the hot well pumps.

Cooled water flows to the condenser from the cold well of the cooling tower by the pressure differential between the atmosphere and the condenser vacuum. Excess condensate is pumped from the cooling tower cold well to the same disposal area as the water from the second stage flash steam separator.

5.2 Auxiliary Systems

Flow diagrams for auxiliary systems are included.

5.2.1 Auxiliary Cooling Water

Auxiliary cooling water is supplied from the cooling tower by two auxiliary cooling water booster pumps. A portion of the auxiliary cooling water is used to cool the lubricating oil and generator air cooling systems. This portion of the auxiliary cooling water flows subsequently to the main condenser. Another portion of the cooling water is used to cool the air compressor systems and is returned to the cooling tower cold well to permit running these systems when the turbine-generator is shut down. The balance of the auxiliary cooling water is pumped to the intercondenser and then returned to the main condenser.

5.2.2 Lube Oil

The lubricating oil system for the turbine generator will be furnished by the turbine-generator manufacturer. An auxiliary system (not furnished with the turbine-generator) for purification and storage of lubricating oil includes a centrifuge and transfer pumps for each turbine-generator unit. The system also includes two storage tanks, one for clean and one for dirty oil. These tanks serve both turbine-generators and are each more than double the capacity contained in a turbine lubricating oil sump tank.

Each centrifuge is sized to purify the contents of a turbine-generator lubricating oil sump tank in eight hours. Each centrifuge and oil transfer pump may be used for purification of oil in either turbine-generator sump.

5.2.3 Compressed Air System

Compressed air is provided by three compressors. One control air compressor normally supplies the instrument and control air required for both generating unit systems. One utility air compressor is provided for the Plant and supplies utility air for maintenance work.

The control air compressors are of the oil free type, single stage, water cooled, double acting, vertical, reciprocating type with stainless steel cylinder liners, and Teflon piston rings. The capacity of each compressor is 3.5 cubic meters per minute (m^3/min.) inlet air at 7.1 kilograms per square centimeter gauge (Kg/cm^2ga.) The motor driver size is 22 kW nominal.

The utility air compressor can spare either control air compressor in an emergency. In such an emergency the air from the utility compressor would be passed through a charcoal filter before entering the control air piping.

A dryer is provided to dry the control air to a -40°C dewpoint.

The air compressors are cooled by a separate water system which makes use of potable water in a recirculating system piped in carbon steel. The system contains two circulating pumps and two heat exchangers, each of which is capable of cooling the three compressore. These heat exchangers reject waste heat to the auxiliary cooling water system.

5.3 Fire Protection

5.3.1 The fire water system consists of an underground ring main surrounding the cooling towers and an interconnected ring main surrounding the Powerhouse and the high voltage transformers. The cooling tower cells are provided with individually controlled spray and wetting systems. Pump sizing is based on a two-hour fire wall between each cooling tower cell. There are twelve hydrant hose stations outside; two of which are foam hand hose line stations. In addition, there are eight hydrant hose stations within the Powerhouse. Isolating valves (post indicator section valves) are provided for full security in the event of a pipe failure.

The water supply for the system is from the cooling tower cold wells. Each main fire pump can take suction from either cold well. The capacity of each cold well at working level provides approximately three hours supply of fire fighting water using one main fire pump.

In order to protect against freeze up the above ground portions of the fire water system will be of the dry type filled with air under pressure.

The fire water system includes a jockey pump driven by a 4 kW motor to maintain pressure in the system and two main fire pumps, one driven by a 75 kW electric motor and the other is driven by a steam turbine.

5.3.2 In addition to its use for fighting fires, the fire water system is used to keep inactive sections of the cooling tower wet.

5.3.3 For areas protected by the automatic sprinkler system the design sprinkler water density in kilograms per second per square meter ($Kg/sec/m^2$) is as follows:

Cooling Tower Cell Fan Area (throat)	0.225
Cooling Tower Cell Fill Area	0.34
Turbine Areas	0.17
Power Transformers	0.17

5.3.4 Foam hand hose stations are provided as protection for the high voltage transformers in addition to the sprinkler system.

5.3.5 A CO_2 fire protection system provides automatic coverage for generator purge. The source of the gas is from a liquid CO_2 tank complete with necessary controls. The unit is supplied with heat detectors and alarms. The dampers which control the ventilating air supply to the switchrooms will be fitted with a spring loaded mechanism which will close the dampers and stop the fan motors in the event the CO_2 system is actuated. Each of the five switchrooms and the two exciter rooms are individually enclosed to localize damage in the event of fire.

Halon 1301 is being investigated as an alternative for the CO_2 system described above.

5.4 Operating and Control Features

Local controls will be provided for startup of the Plant in the vicinity of the turbine-generator and Plant auxiliaries. When the turbine-generator has reached synchronous speed, control will be turned over to the panels in the Control Room for synchronizing and loading. The emergency shutdown system can be actuated from the Control Room or from the local control panel on the operating floor.

An automatic fail-safe shutdown system is also included which will register the reason for shutdown on a first in annunciator system.

5.4.1 The Control Room will contain:

5.4.1.1 A control board for turbine-generators Units #1 and #2

5.4.1.2 A control board for auxiliary equipment controls

5.4.1.3 A control board for auxiliary equipment controls

5.4.1.4 A control board for the 132 kV O.C.B.

5.4.2 Operating controls will include:

5.4.2.1 Steam Stop Valves

The main steam stop valves are remote hand controlled, however, they are closed automatically in the event of an emergency turbine shutdown.

5.4.2.2 Condenser Level Control

The level in the main condenser is controlled by automatic operation of a valve in the discharge of the hot well pump. This control is supplemented by a bypass valve to return a portion of the discharge water from the hot well pump to the main condenser during conditions of extreme low flow to the condenser which occur during startup and shutdown.

5.4.2.3 Condenser Pressure Control

The pressure in the main condenser is regulated by a valve which controls the flow of cooling water to the sprays in the main condenser.

5.4.2.4 Noncondensable Gas Anti-Surge Control

Control is provided to admit ambient air to the suction side of the ejectors to prevent surging during reduced load operation.

5.4.2.5 Lube Oil Warm Up System

Control is provided to turn off the cooling water to the lube oil heat exchanger in order to provide a fast warm up of lube oil during a cold start.

5.4.2.6 Compressed Air System

Each control air compressor is sized to handle both generating plant units; however, if pressure falls to a predetermined point the standby control air compressor will start automatically. If pressure continues to fall a control valve will close, isolating the control air system of Unit No. 1 from Unit No. 2, thus preventing the defective system from shutting down both turbine-generators. A level control is provided in the air compressor cooling system surge tank to make up for losses by admitting water from the domestic water system.

5.4.2.7 Fire Pump System

Pressure in the fire pump system is maintained by the jockey pump which is automatically started and stopped by a pressure switch. In the event the pressure continues to drop with the jockey pump running, a second contact of the pressure switch will start the main fire pump and open the automatic discharge valve. A continued drop in pressure will operate a third pressure switch contact to start the No. 2 main fire pump and open its discharge valve. As the pressure in the system is restored, the pumps will be stopped in the reverse sequence.

5.4.2.8 Alarms

Alarms are provided to the Control Room annunciator to alert the operator to critical conditions. The most important of these include:

5.4.2.8.1 Turbine-generator high vibration; lube oil high or low pressure, low oil level, high oil temperature and high generator air temperature.

5.4.2.8.2 Main condenser, low level, high level, high pressure, and low pressure.

5.4.2.8.3 Intercondenser; high pressure, high level.

5.4.2.8.4 Lube oil centrifuge; breakover.

5.4.2.8.5 Control air pressure; low pressure.

5.5 Piping and Equipment

5.5.1 High and Low Pressure Steam Piping

The high pressure and low pressure steam piping systems design will provide for flexibility, easy access and economic pressure drops. It is assumed that the turbine requires double entry for both high pressure and low pressure steam. The second flash steam separator is located close to the main isolation valve to minimize pressure drop. For plant startup, a bypass line is provided around one high pressure steam control valve.

Since the maximum temperature of the steam is 190°C, dry and saturated, carbon steel pipe conforming to ASTM A53 and A134 specifications is suitable for all steam systems.

5.5.2 Circulating and Auxiliary Cooling Water Piping

Main circulating water and the auxiliary cooling water system water piping material is stainless steel type 304L to minimize the potential for chloride stress corrosion cracking in geothermal water service. Type 304L stainless steel was selected over the other types of stainless steels for economic reasons. This material has less than .03% carbon and for this reason is not as susceptible to intergranular corrosion as a result of welding. An investigation of the suitability of lined carbon steel or fiberglas reinforced pipe for these services is in progress and should any of these substitutes be found acceptable the use of one of these less expensive materials will be recommended.

5.5.2.1 Two vent pipes are included at the top of the main condensate piping system where it joins the cooling tower distribution manifold. These vents ensure that the piping to the hot well can not be exposed to negative pressure exceeding 0.07 kilograms per square centimeter (Kg/cm^2) in the event the hot well pumps trip out and their associated discharge valves do not close in time to prevent flow reversal.

Water from the cooling tower cold well enters the condenser supply piping through a strainer and vortex breaker in the pit adjacent to the cold well.

5.5.2.2 A separate auxiliary cooling water system serves each turbine-generator unit. However, provision is made for cross connection of individual subsystems so that one pump can serve either unit in the event of a failure or during maintenance periods. Butterfly valves are provided to balance the individual pressure drops to ensure the proper flows through each heat exchanger.

5.5.3 Lubricating Oil Purification System

The piping material for the lube oil system is carbon steel pickled, ASTM A53 Gr. A or B. The system includes several check valves to ensure separation of contaminated and clean oils under operating conditions.

5.5.4 Noncondensable Gas Removal Piping

The piping for the removal of noncondensable gases from the condenser is type 304L stainless steel to resist the corrosiveness of these gases.

5.5.5 Fire Protection System

The material in the firemain piping valves and pumps is stainless steel type 304L for compatibility with geothermal water. An evaluation is presently being made as to the suitability of fiberglass reinforced plastic piping for underground fire service in hazardous earthquake areas, and if it is found to be satisfactory, it will be recommended as it is significantly less costly than the stainless steel.

5.5.6 Compressed Air Systems

The control air system draws air from the charcoal filtered air supply to the air conditioning system.

The piping is stainless steel type 304L to ensure internal purity of the air in the event there is a malfunction of the dryers or charcoal filters which could cause corrosion. High quality plastic tubing (enclosed in conduit in open areas) is used for instrument lines. Piping routed from the Powerhouse to the cooling tower is underground.

5.5.7 Cold Start Generator

Either a steam turbine or a diesel engine driven startup generator rated 600 or 750 kW will be provided, dependent upon which is least costly. The unit will be installed within a suitable enclosure to protect it from the environment. The electrical switching equipment and instruments are purged by clean, charcoal filtered air from a system located within the generator enclosure.

The generator is sized for the starting loads and considers the sequence of starting auxiliary electric equipment for plant startup.

Sufficient reserve power will be available during Plant startup to start the fire jockey pump, and the first and second main fire pumps.

6.0 ELECTRICAL CHARACTERISTICS

6.1 General Design Parameters

6.1.1 The Plant will include two generators, each rated 30 megawatts gross output at eighty percent (80%) power factor.

6.1.2 The Plant is designed for ease of installation and a minimum requirment for highly specialized construction labor.

6.1.3 The Plant is designed on a unit system basis for maximum reliability. That is, each generator has its own station power equipment and its own step-up transformer with associated protective relaying.

The unit system design permits unified operation of the protective relaying, allowing all the components in one unit to be protected together as if they were a single component. This increases the power plant reliability since failure of one component will not disable the whole plant, but only the unit with which the faulty component is associated.

6.1.4 Startup of each generating unit will most frequently occur with the 132 kV bus being energized by the other generating unit or by a transmission line. Thus the capacity of each station power transformer has been selected so that it can supply not only its own auxiliary equipment, but also the auxiliary equipment essential for starting of another generating unit in the plant.

6.1.5 Because of the remote location of the power plant provision has also been made for the cold startup of each generating unit without the other generating unit or any transmission line being energized. One hot well pump for each generating unit has an electric motor for its normal driver, and a noncondensing steam turbine with angle gear drive and clutch to be used for cold plant startup.

A cold start steam turbine or diesel engine driven generator is provided to energize lighting, battery chargers, and auxiliaries required for the startup of one generating unit. The cold startup generator is arranged to serve as an emergency generator also. The generator will start automatically in case of power outage to supply lighting, control apparatus, and battery charging. In addition it can supply plant maintenance equipment, and housing loads, except during startup of a generating unit.

6.1.6 Copper is especially vulnerable to the corrosive effects of hydrogen sulfide and is therefore eliminated where possible. Copper connections and contacts, where used, are tinned or otherwise protected from corrosion. Since aluminum is resistant to hydrogen sulfide, aluminum buses and cables are used extensively.

6.2 <u>Generators</u>

6.2.1 The main generators are totally enclosed. They are cooled by forced recirculated and filtered air with air-to-water heat exchangers. This arrangement precludes corrosion of the generator by hydrogen sulfide. Hydrogen cooling of generators was considered, but rejected because the small increase in efficiency obtained would be offset by the cost of the extra equipment required and the difficulty in maintaining the hydrogen supply equipment at a remote location.

6.2.2 The generator excitation is the brushless type. Reasons for selecting brushless excitation include the following:

6.2.2.1 Reduced maintenance cost and increased reliability because there are no brushes, slip rings, commutators or field rheostats

6.2.2.2 No carbon dust problems

6.2.2.3 No hazard of maintaining brushes under load or need to shut down the machine to maintain brushes

6.2.2.4 No space required for external excitation systems

6.2.2.5 Easier and less costly to install than other types of generator excitation systems.

6.3 Auxiliary Equipment

6.3.1 The metalclad switchgear, unit substations, motor control centers, main control board, storage batteries, and associated equipment are located in protected spaces. These spaces are ventilated with forced air which has been passed through hydrogen sulfide absorbing filters. This minimizes the effect of hydrogen sulfide and permits the use of general purpose type enclosures resulting in adequate reliability at reasonable cost.

6.3.2 Motors with ratings of 0.50 kW and larger operate on 380 volts, 3-phase. Higher voltage for the largest motors can not be economically justified. Motors smaller than 0.50 kW, lighting, and miscellaneous small equipment operate on 220 volts, single phase, line to neutral, circuits.

6.3.3 A station battery provides 110 volts DC for emergency lighting, circuit breaker tripping power, instrumentation, and certain critical loads such as emergency lube oil pumps.

6.4 132 kV Substation

6.4.1 The substation 132 kV bus arrangement provides flexibility for the two generators and three transmission lines connected to it by permitting any of the generators or transmission lines to be completely isolated. The substation is designed for seismic loading.

6.4.2 Control cabinets which must be located outdoors have weatherproof enclosures with space heaters to prevent condensation and to assure reliable operation.

6.4.3 The high voltage substation is designed for reliable operation in storm driven salt spray.

Insulator and bushing surface leakage distances and clearance distances are designed to the pertinent Norwegian standards which are now in general use in Iceland.

6.5 Control Room

6.5.1 The main control board for the station is located in the Control Room. This main control board contains all essential controls, meters and protective relays for operation of the plant, including the high voltage substation. The main control board is designed to put generators on line, adjust load, monitor operation of the electrical equipment, and indicate the trouble if a protective relay takes a machine out of service.

6.5.2 Controls and instruments permit synchronizing between any two circuits where paralleling of generators and/or lines may be desired.

6.5.3 Provision is made for the Krafla plant to automatically and accurately control frequency to assure accurate time by electric clocks on the system. Provision is also made for the Krafla plant to operate at a pre-set base load with frequency being controlled at another power plant on the system.

7.0 DESIGN, PROCUREMENT, AND CONSTRUCTION SCHEDULE

The Major Activity Schedule is shown on Drawing A1-07-004. This Schedule accommodates the desires of the Krafla Project Executive Committee to build and have the Power Plant in operation for the 1976-1977 winter peak load period. At the present time the preliminary design is essentially completed. The Contract for the turbine-generator units has been awarded and bids have been solicited for all major equipment.

7.1 Methodology for Development

The Major Activity Schedule was developed around the 14 month turbine-generator delivery (FOB Japan) promised by the manufacturer and the need to have electricity generated from the geothermal resources on line for the peak power demands expected during the winter months of 1976-1977.

7.1.1 The Major Activity Schedule assumes that sufficient geothermal wells will be completed to power the first turbine-generator unit and the necessary power line will be completed and operational by August 1976.

7.1.2 One 30 MW unit will be sufficient to meet the projected power requirements for the 1976-1977 winter requirements and the project objective is to have the first unit on line by that time.

7.1.3 The installation of the second turbine-generator unit will be completed after the first unit is in commercial operation. Any additional geothermal wells needed to meet the steam requirements for both units can be completed during 1977.

7.1.4 The project starting date was 21 November 1974. The schedule indicates the alloted time periods for preliminary and final engineering design, bid preparation, evaluation and contract awards, manufacturing time for equipment, transportation, installation and check-out for major equipment and systems. The schedule indicates the construction completion requirements for the Powerhouse building and various equipment foundations or mats.

7.2 Major Activities

The turbine-generator units usually require the longest delivery time and therefore are the critical element of the schedule. However, the very short delivery promised (14 months FOB Japan) and already contracted for places several other major equipment items on critical paths. Careful attention must be paid to the time required for manufacture and delivery of these items, and if any slippage in schedules occurs, effective expediting procedures will have to be implemented without delay.

7.2.1 The Major Activity Schedule reflects the delivery time quoted by major equipment suppliers. Recent communications with suppliers indicates that many of the major equipment items may be possibly obtained ahead of schedule.

Items that can be procured with shorter delivery times than indicated in the Schedule will be shipped to the Site as soon as ready to allow installation and check-out at the earliest possible date. If equipment arrives before the Contractor is ready for it, or if weather conditions interfere with immediate transport to the Site, it will be temporarily stored at Húsavík.

7.2.2 The Schedule indicates that the exterior shell of the Power Plant will be completed during the summer and fall of 1975, so that interior concrete work and the installation of equipment can continue through the winter months.

7.3 Conclusion

The schedule is considered realistic but very tight and will require closely coordinated design, procurement and construction management.

8.0 SYSTEM POWER REQUIREMENTS

The power requirements shown on Figure 2 for the north-coast and on Figure 3 for the north and the east-coast combined have been estimated for the next five years. It is expected that by 1980 eighty percent (80%) of the oil heating systems will have been replaced by electrical heating systems. This expectation is confirmed by a study made by Landsvirkjun, the National Power Company (NPC) for all of Iceland.

8.1 North-Coast Electrical System

The projected power demand on the north-coast alone is 48 MW in 1977, 55 MW in 1978, 65 MW in 1979 and 77 MW in 1980.

The existing hydroelectric and the new steam generated power (Krafla geothermal plant) will provide 88 MW of prime generating capacity to meet the projected loads. The existing and planned 20 MW of diesel generation will be retained as reserve capacity to cover possible outages of a unit at the Krafla plant and 8 MW of hydroelectric capacity at the Laxá plant which is frequently not available due to ice or low water conditions.

The total installed capacity will be 108 MW during the period between 1977 and 1980 the firm capacity will be 70 MW which is determined by deducting the capacity lost due to an unscheduled outage of a 30 MW unit at Krafla simultaneously with an 8 MW curtailment at Lavá. This capacity is estimated to be sufficient through the summer of 1980.

With the completion of the interconnecting transmission line from the north to the NPC system, 15 MW of additional power will be available to the north coast system resulting in 85 MW of firm capacity. This capacity should be sufficient to meet projected load through the summer of 1981.

8.2 North and East-Coast Electrical System

The projected power demand on the north and east-coast combined is 63 MW in 1977, 76 MW in 1978, 95 MW in 1979 and 115 MW in 1980. The existing hydroelectric generation (39 MW) and the new Krafla geothermal steam plant generation (60 MW) will provide prime capacity of 99 MW for the combined north and east coast system. In addition there are 29 MW of diesel capacity which if retained in reserve will bring the total installed capacity to 128 MW. Expected curtailment of 10 MW of hydroelectric power and a simultaneous unscheduled outage of one unit at Krafla (30 MW) reduces the firm power available for this combined area to 88 MW.

This capacity does not provide sufficient firm power to the area during 1979; however, the transmission line connecting the NPC system to the north and east coast system will provide 6 MW of additional firm power bringing the total firm power available to 94 MW. This is sufficient to meet the 1979 power requirement of 95 MW.

8.3 Conclusion

The Krafla Power Plant Project is an important part of the planned electrical system and will contribute significantly to the immediate need for additional firm capacity in the north coast and/or north and east coast electrical systems.

The load growth curves demonstrate that planning for additional generating capacity must be undertaken in the very near future in order to assure an adequate power supply beyond 1980.

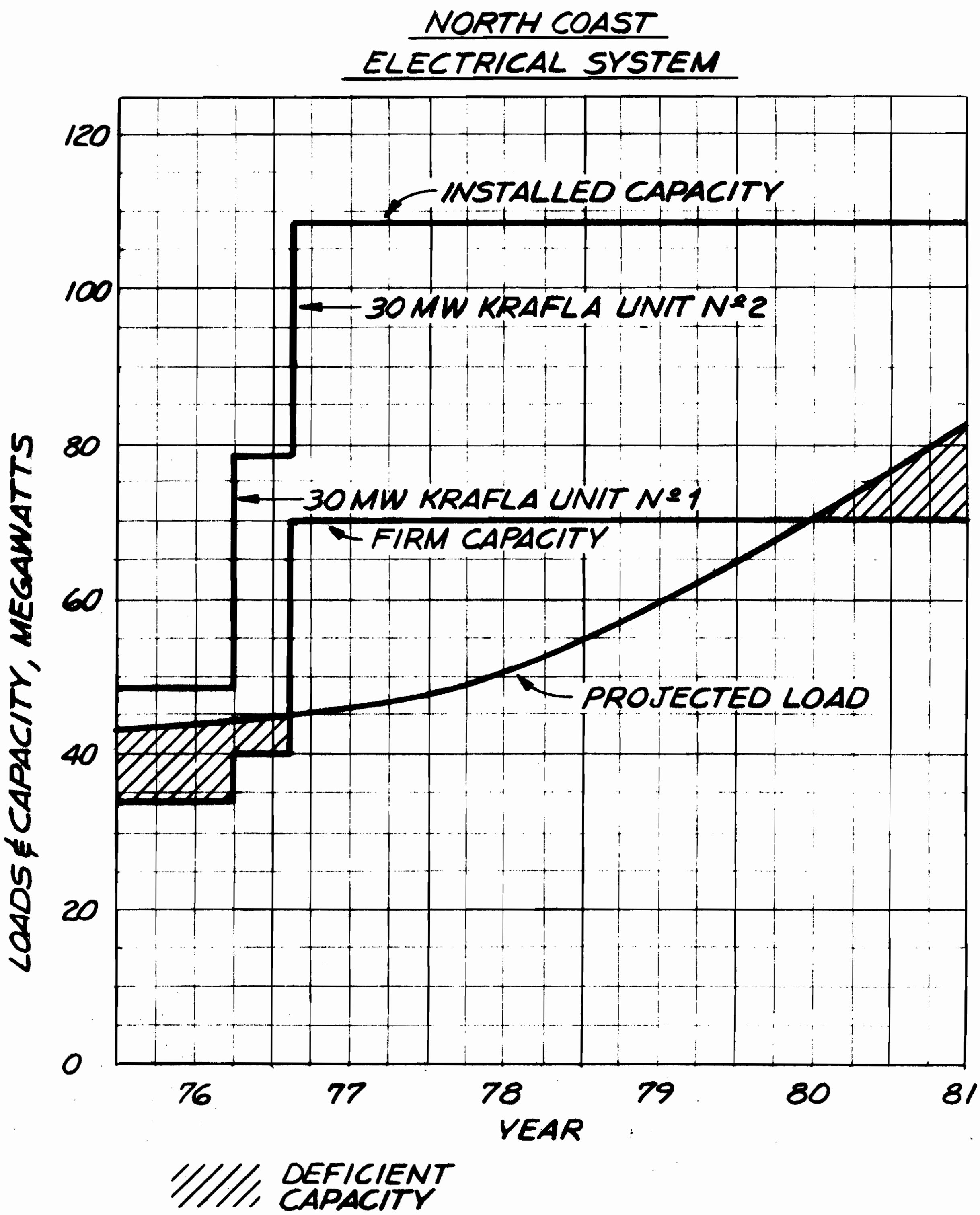

NORTH COAST
ELECTRICAL SYSTEM
120
100
80
60
40
20
0
LOADS & CAPACITY, MEGAWATTS
INSTALLED CAPACITY
30 MW KRAFLA UNIT Nº 2
30 MW KRAFLA UNIT Nº 1
FIRM CAPACITY
PROJECTED LOAD
76
77
78
79
80
81
YEAR
DEFICIENT
CAPACITY

Figure 2

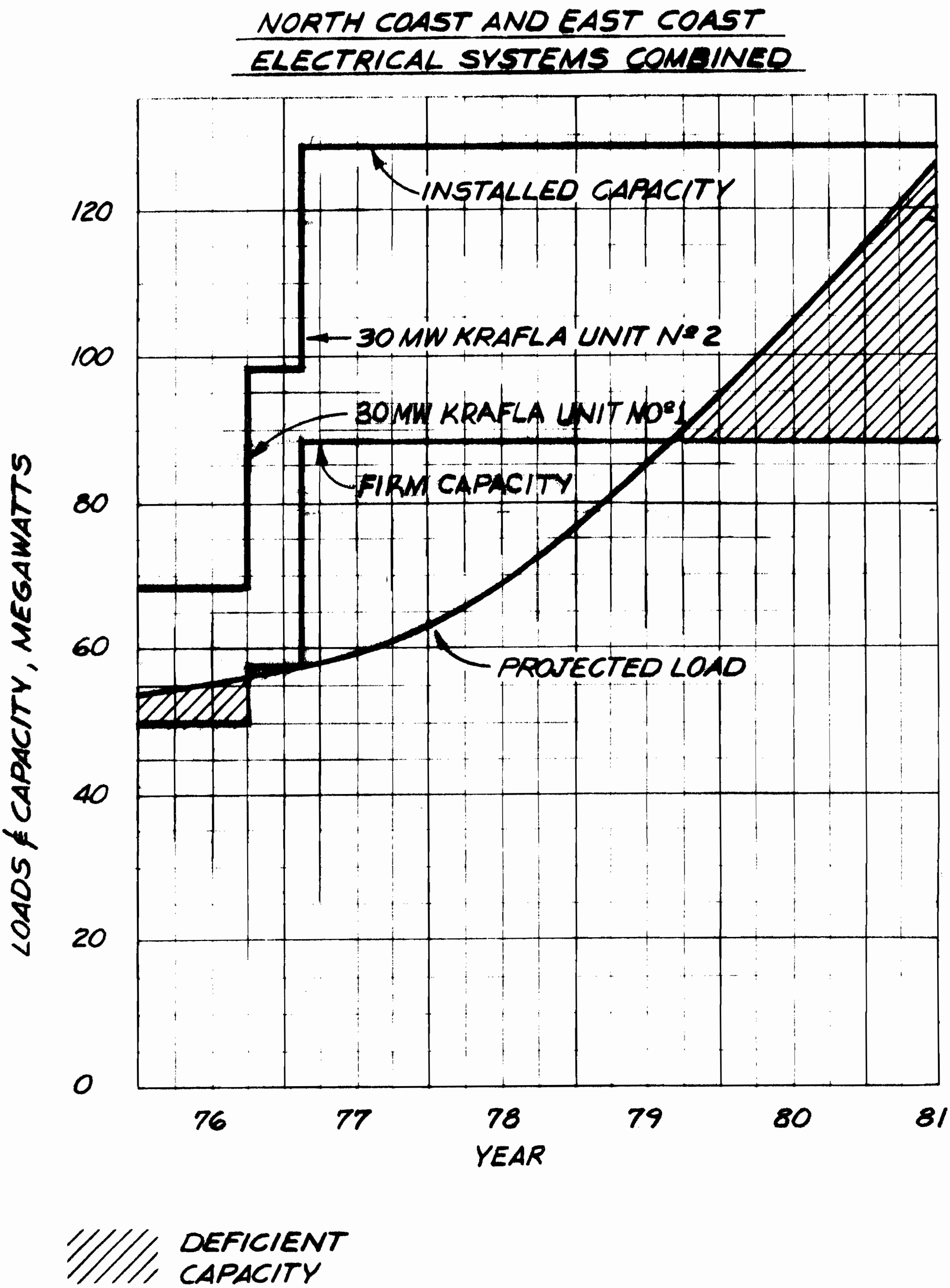
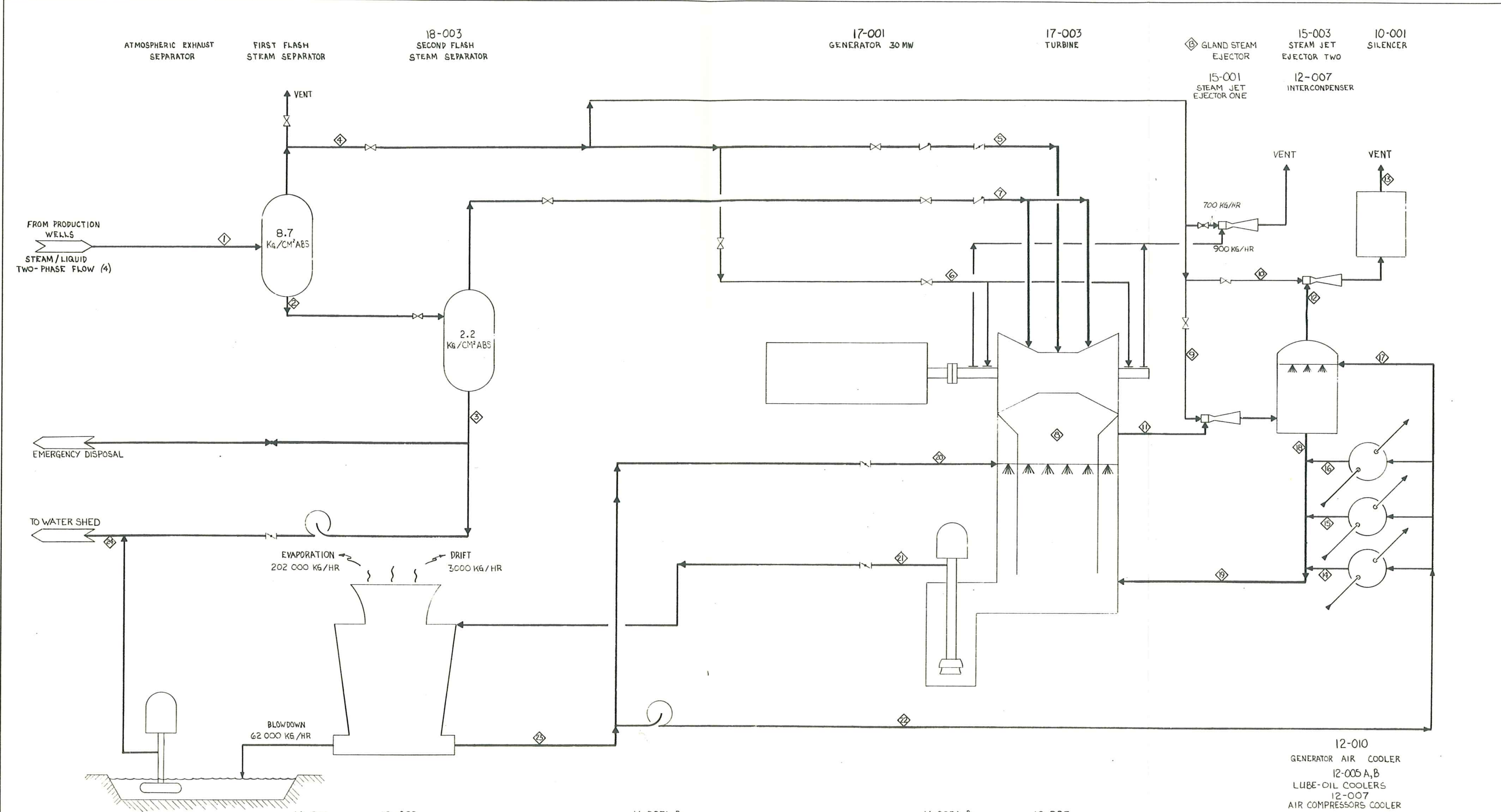

NORTH COAST AND EAST COAST
ELECTRICAL SYSTEMS COMBINED
INSTALLED CAPACITY
30 MW KRAFLA UNIT Nº 2
30 MW KRAFLA UNIT Nº 1
FIRM CAPACITY
PROJECTED LOAD
LOADS & CAPACITY, MEGAWATTS
0
20
40
60
80
100
120
76
77
78
79
80
81
YEAR
DEFICIENT
CAPACITY

Figure 3



STREAM NO. →	1	2	3	4	5	6	7	8	9	10	11	12	13
STEAM FLOW (KG/HR)	915 000			203 100	191 500	1600	70 500	262700	5000	4300	400	100	4400
WATER FLOW (KG/HR)		711 900	641 000	-	-	-	-		-	-	-	-	-
NON-CONDENSABLE GAS FLOW (KG/HR)	2100	-0-	-0-	2100	1990	20	-0-	2000	50	40	1990	2040	2080
AIR FLOW (KG/HR)											200	200	
TEMPERATURE (°C)	173.2	173.2	122.9	173.2	165.1	165.1	119.7	49.2	165.1	165.1	25	25	—
PRESSURE (KG/CM² ABS.)		8.7	2.2	8.7	7.2	7.2	2.0	—	7.2	7.2	—	—	—
PRESSURE (MM HG. ABS.)	—	—	—	—	—	—	—	89	—	—	87	280	
ENTHALPY (KCAL/KG)	283.1	175.1	123.2	661.1	659.7	659.7	646.2	554.9	659.7	659.7			
DENSITY (KG/M³)	19.6		940.5		3.68		1.111	0.0800 (5)					

STREAM NO. →	14	15	16	17	18	19	20	21	22	23	24
STEAM FLOW (KG/HR)											
WATER FLOW (KG/HR)	3000	90 000	165 000	135 000	140 000	398 000	5561000	6 221 000	393 000	5 954 000	
NON-CONDENSABLE GAS FLOW (KG/HR)											
AIR FLOW (KG/HR)							130				
TEMPERATURE (°C)	32	24.9	26.1	22	46.0	32.9	22	45.2	22	22	
PRESSURE (KG/CM² ABS.)											
PRESSURE (MM HG. ABS.)											
ENTHALPY (KCAL/KG)	32	25.0	26.2	22	46.0	32.9	22	45.2	22	22	
DENSITY (KG/M³)	995	997	997	998	990	995	998	990	998	998	

• NOTES •

1. FLOW QUANTITES ARE GIVEN FOR ONE 30 MW UNIT AT GUARANTEED THROTTLE FLOW CONDITIONS.
2. ASSUMED DOWNHOLE EFFECTIVE TEMPERATURE: 270°C.
3. ASSUMED NONCONDENSABLE GASES QUANTITY: 0.23% (BY WEIGHT) OF GEOTHERMAL WELL WATER FLOW.
4. STEAM SEPARATOR AND STEAM LINE PRESSURES ARE FOR STEAM ONLY —— PARTIAL PRESSURE OF NON-CONDENSABLE GASES NOT INCLUDED.
5. DENSITY GIVEN FOR STEAM ONLY.
6. ASSUMED EFFICIENCIES
   - TURBINE THERMAL EFF: 75.5%
   - TURBINE MECHANICAL EFF: 99.0%
   - GENERATOR EFF: 97.4%
7. ASSUMED CONDENSER AIR LEAKAGE: 70 KG/HR.
8. TURBINE-GENERATOR WILL PRODUCE APPROX. 35 MW WITH GREATER WELL FLOW AND INCREASED STEAM AND CONDENSER PRESSURES.

REV.	ZONE	DATE	REVISION	DR.	CHK.	APPR. RECO	APPR.
B		4/11/75	ADDED GLAND STEAM EJECTOR REVISED FLOW DATA FINAL REPORT ISSUE	SRS	FDD		
A		1/16/75	ISSUED FOR REVIEW				

REFERENCE DRAWINGS

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE NONE   DATE 12/31/74
DR. SRS   CHK.   ENG.   APPROVED

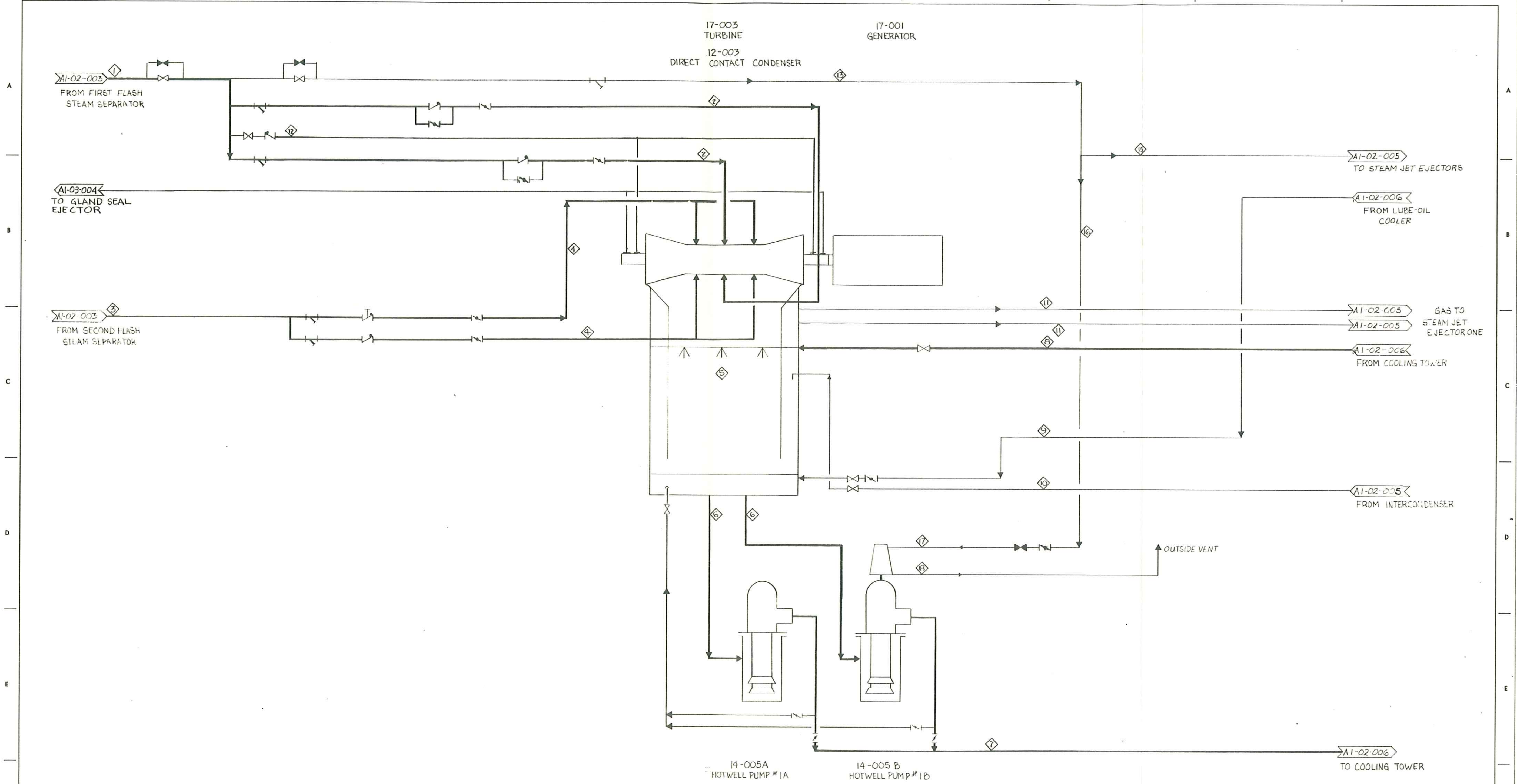
KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA   GEOTHERMAL PROJECT
APPROVALS
DATE
DATE
DATE

FLOW DIAGRAM
DOUBLE-FLASH STEAM CYCLE
KRAFLA GEOTHERMAL POWER PLANT
UNIT I 30 MW

JOB No. S-74028   A1-02-001   B

DG-005

PRINTED ON DIEFO NO. 1000H CLEARPRINT



STREAM No. →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
STEAM FLOW (KG/HR)	228 500	108 750	81 800	40 900	267 100						250	800	10 200		10200				
WATER FLOW (KG/HR)	-	-	-	-	33000	3 527 500	7 052 000	6 341 000	255 000	156 000	-								
NONCONDENSABLE GAS (KG/HR)	2470	2350	- 0 -	- 0 -	2360						1180	10	110		110				
AIR FLOW (KG/HR)	-	-									100								
TEMPERATURE (°C)	178.4	169.7	129.8	126.7	49.2	45.3	45.3	22	25.8	46	25	169.7	169.7		169.7				
PRESSURE (KG/CM² ABS.)	—	8.0	—	2.5	-							8.0	8.0		8.0				
PRESSURE (MM HG ABS.)					89														
ENTHALPY (KCAL/KG)	662.8	660.8	649.6	648.6	554.0	45.3	45.3	22	25.8	46	25	660.8	660.8						
ALL PRESSURES ABSOLUTE																			

REV.	DATE	REVISION
B	4/11/75	FINAL REPORT ISSUE
A	3/14/75	ISSUED FOR PRELIMINARY REPORT

REFERENCE DRAWINGS

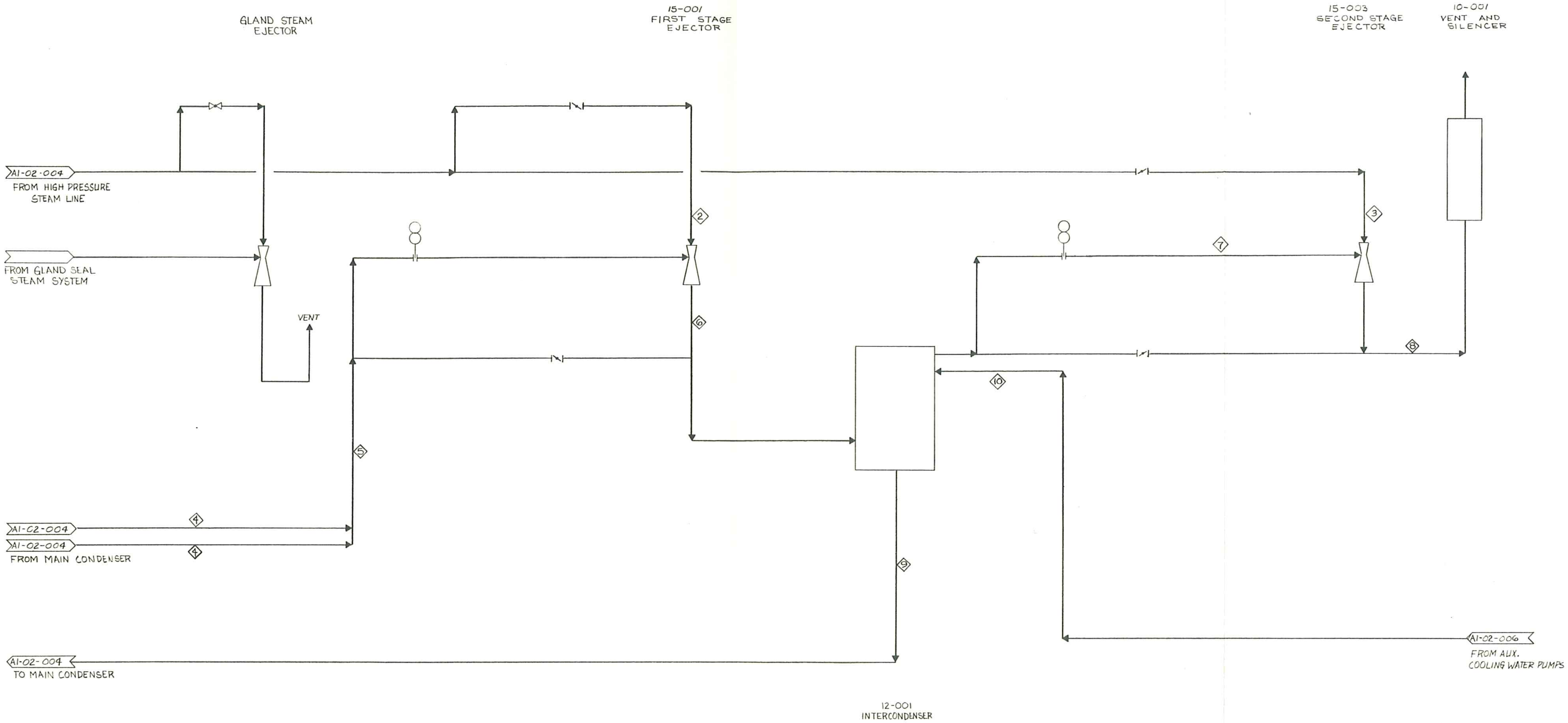
CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE NONE DATE 3/14/75

KROFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS

KRAFLA GEOTHERMAL POWER PLANT
FLOW DIAGRAM
TURBINE AND CONDENSER

JOB NO. S-74028 — A1-02-004 B



STREAM No →	1	2	3	4	5	6	7	8	9	10
STEAM FLOW (KG/HR)	10 200	5500	4700	250	500	6000	100	4800		
WATER FLOW (KG/HR)									156 000	150 000
NON CONDENSABLE GAS (KG/HR)	110	60	50	1180	2360	2420	2420	2470		
AIR FLOW (KG/HR)				100	200	200	200	200		
TEMPERATURE (°C)	169.7	169.7	169.7	25	25		25	100	46	22
PRESSURE (KG/CM²)	8.0	8.0	8.0							
PRESSURE (MM HG ABS)				89	89					
ENTHALPY (KCAL/KG)	660.8	660.8	660.8						46	22

ALL PRESSURES ABSOLUTE

REFERENCE DRAWINGS

REV.	ZONE	DATE	REVISION	DR.	CHK.	APPR. RECO	APPR.
B		4/11/75	ADDED GLAND STEAM EJECTOR FINAL REPORT ISSUE	SRS			
A		3/14/75	ISSUED FOR PRELIMINARY REPORT	SRS			

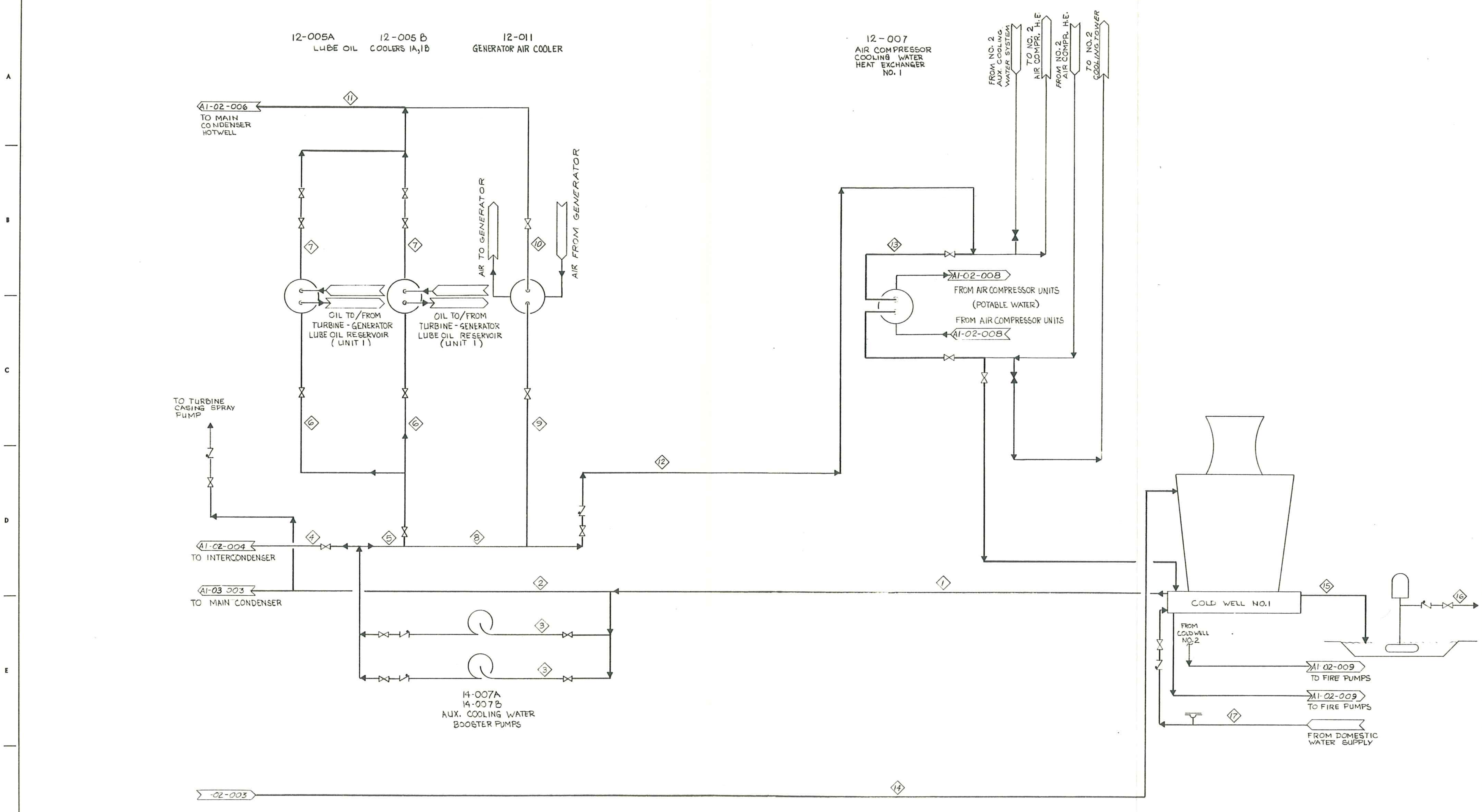
CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE NONE DATE 3/14/75
DR. SRS CHK. ENG. APPROVED

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS
DATE
DATE
DATE

KRAFLA GEOTHERMAL POWER PLANT
FLOW DIAGRAM
NON-CONDENSABLE GAS REMOVAL SYSTEM

JOB NO. S-74028 A1-02-005 B



STREAM NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WATER FLOW (KG/HR)	6,749,000	6,341,000	408,000	150,000	258,000	90,000	90,000	168,000	165,000	165,000	258,000	3,000	3,000	7,055,000	80,000	80,000	
TEMPERATURE (°C)	22	22	22	22	22	22	25.5	22	22	25.9		22	32	45.3	22	22	
PRESSURE (KG/CM² ABS.)	1	1	1														

REFERENCE DRAWINGS

REV.	DATE	REVISION	DR.	CHK.	APPR. RECO	APPR.
B	3/1?/75	REVISED FLOW PATHS TO 12-007 FINAL REPORT ISSUE				
A	3/14/75	ISSUED FOR PRELIMINARY REPORT				

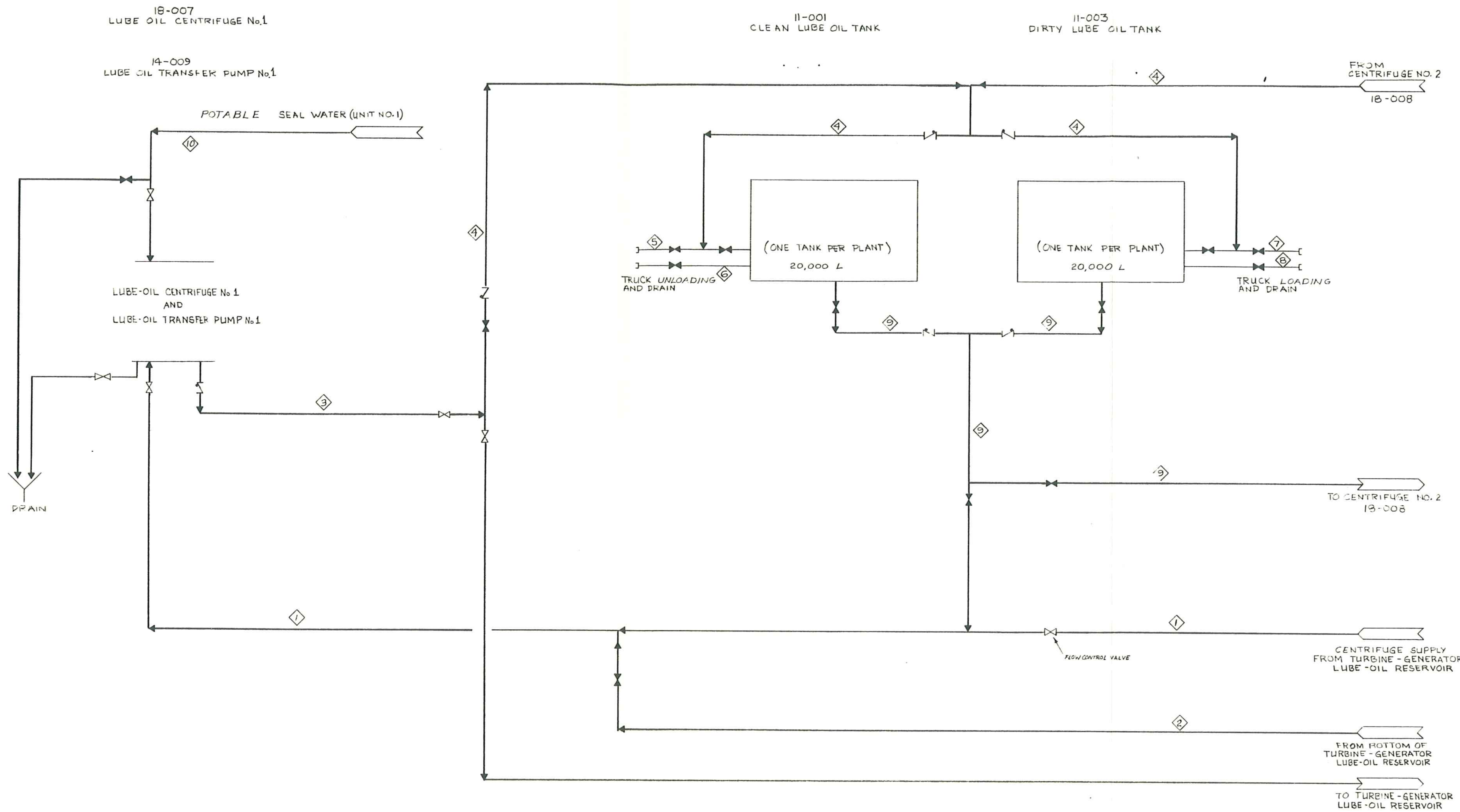
CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE NONE DATE 3/14/75
DR. CHK. ENG. APPROVED

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS
DATE
DATE
DATE

KRAFLA GEOTHERMAL POWER PLANT
FLOW DIAGRAM
MAIN & AUX COOLING WATER SYSTEM

JOB NO. S-74028 A1-02-006 B



STREAM NO.	1	2	3	4	5	6	7	8	9	10
OIL FLOW (L/HR)	1000	1000	1000	1000	6700	6700	6700	6700	1000	
WATER FLOW (M^3/HR)										1
TEMPERATURE (°C)	60	60	70	70	16	16	16	16	16	60
PRESSURE (KG/CM^2 ABS.)	1	1	2.5	2.5	1	1	1	1	1	4.0

NOTE:
UNIT ONE SHOWN; UNIT TWO SIMILAR

REFERENCE DRAWINGS

REV.	ZONE	DATE	REVISION	DR.	CHK.	APPR. RECO	APPR.
B		3/3/75	FINAL REPORT ISSUE				
A		3/4/75	ISSUED FOR PRELIMINARY REPORT				

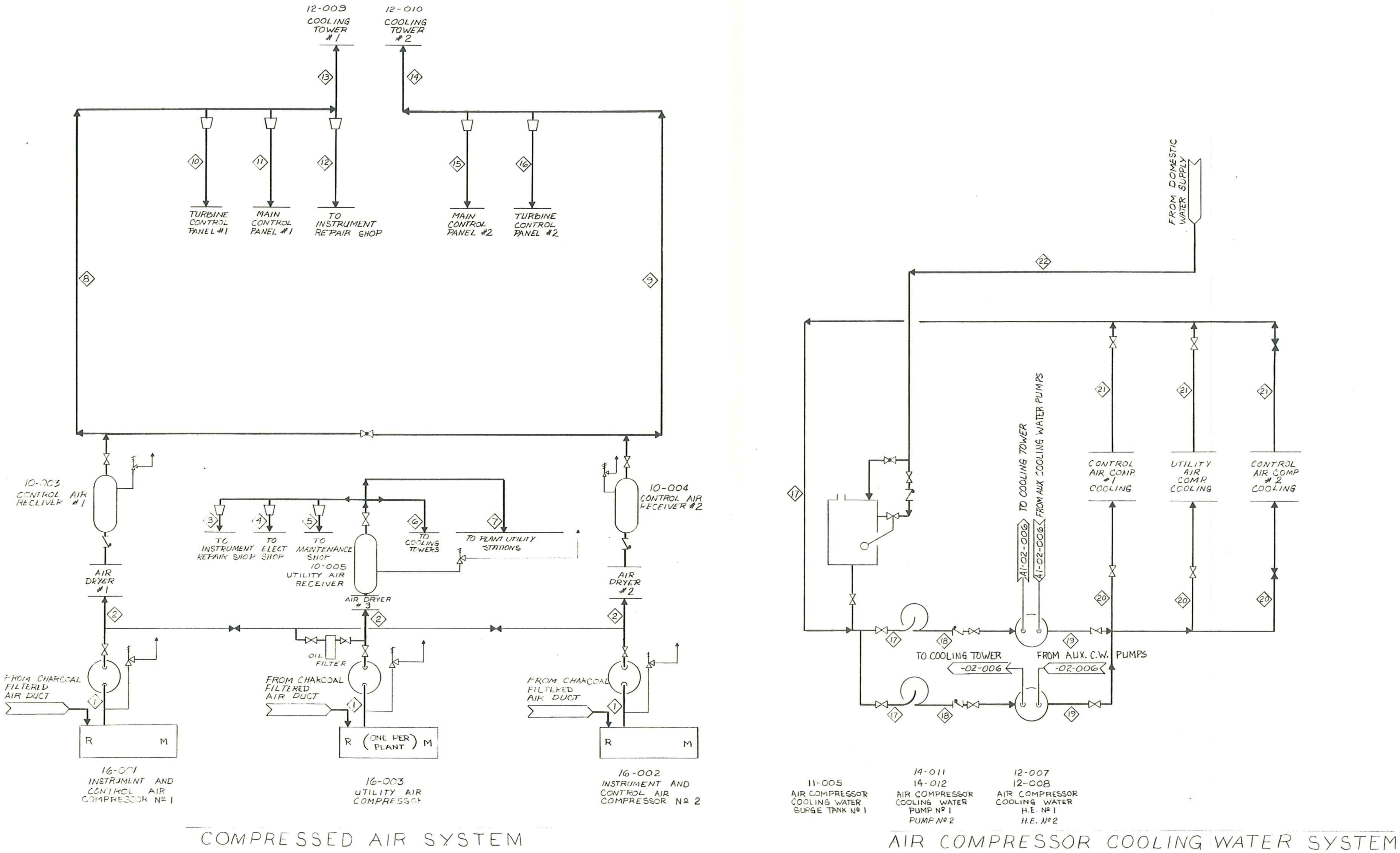
CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE NONE DATE 3/14/75
DR. CHK. ENG. APPROVED

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS
DATE
DATE
DATE

KRAFLA GEOTHERMAL POWER PLANT
FLOW DIAGRAM
LUBE OIL PROCESSING SYSTEM

JOB NO. S-74028 A1-02-007 B



STREAM NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22			
AIR FLOW (M^3/MIN.)	* 3.54	* 3.54	0.57	0.85	0.85	0.28	0.85	1.64	1.33	0.34	0.71	0.31	0.28	0.28	0.71	0.34									
WATER FLOW (KG/HR)																	3000	3000	3000	1500	1500				
TEMPERATURE (°C)	150	31	31	30	30	30	30	30	30	30	30	30	30	30	30	30	37	37	27	27	37	23			
PRESSURE (KG/CM^2 ABS.)	8.06	8.06	8.06	8.06	8.06	8.06	8.06	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	1.06	3.87	2.95	2.53	1.06	3.16			

* INDICATES COMPRESSOR CAPACITY

REFERENCE DRAWINGS

REV.	ZONE	DATE	REVISION	DR.	CHK.	APPR. RECO	APPR.
B		4/11/75	FINAL REPORT ISSUE				
A		3/14/75	ISSUED FOR PRELIMINARY REPORT				

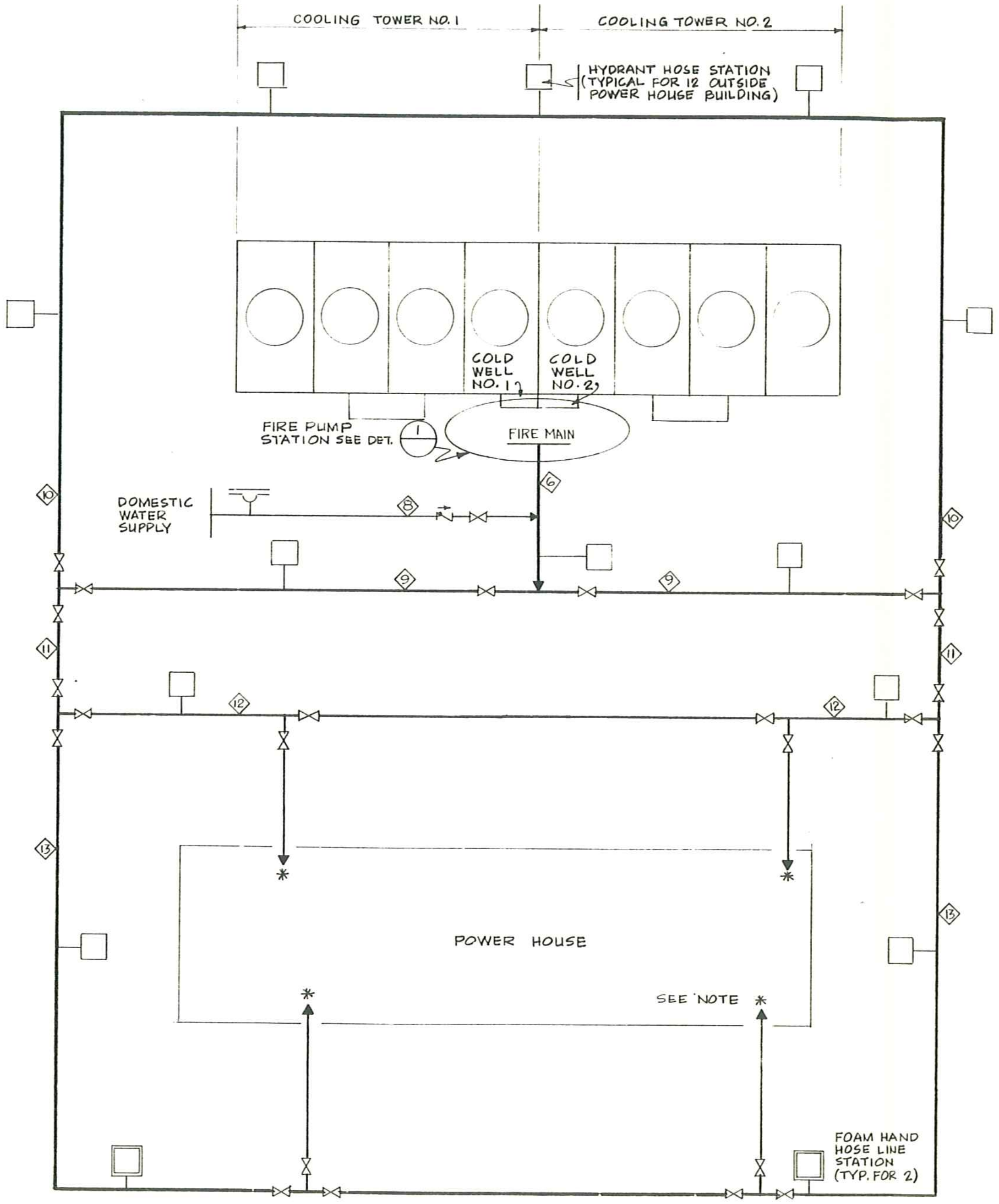
CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE NONE DATE 3/14/75
DR. CHK. ENG. APPROVED

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS
DATE
DATE
DATE

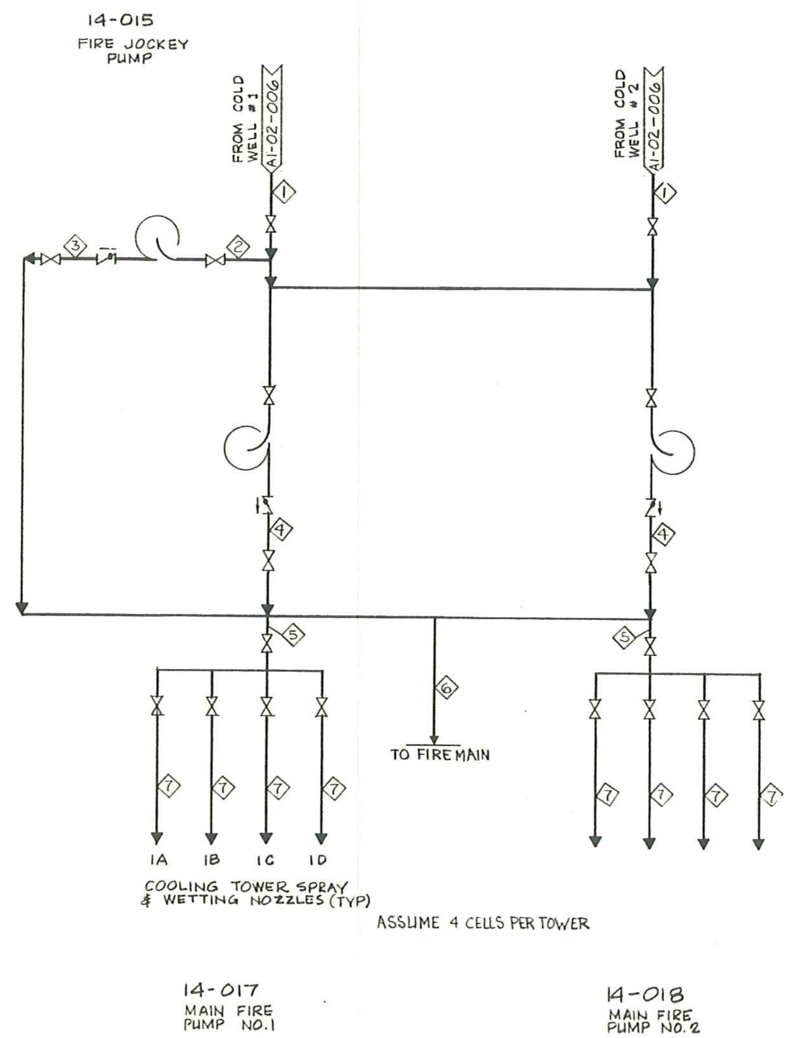
KRAFLA GEOTHERMAL POWER PLANT
FLOW DIAGRAM
COMPRESSED AIR & COMPRESSOR COOLING WATER SYSTEM

JOB NO. S-74028 A1-02-008 B



FIRE PROTECTION SYSTEMS

NOTE: * 4 HYDRANT HOSE STATIONS FOR UNIT #1 TURBINE GENERATOR AREAS & 4 HYDRANT HOSE STATIONS FOR UNIT #2 TURBINE GENERATOR AREAS. (TOTAL NUMBER OF HYDRANT HOSE STATIONS IN POWER HOUSE = 8)



FIRE PUMP STATION DETAIL (1)

STREAM No. →	1	2	3	4	5	6	7	8	9	10	11	12	13
WATER FLOW (M^3/HR)	170	4.5	4.5	170	170	340	85		170	170	170	170	170
TEMPERATURE (°C)	22	22	22	22	22	22	22		22	22	22	22	22
PRESSURE (KG/CM^2)	1.03	1.03	9.8	9.8	9.8	9.8	9.8		9.8	9.8	9.8	9.8	9.8

REV.	DATE	REVISION	DR.	CHK.	APPR. RECO	APPR.
B	4/11/75	FINAL REPORT ISSUE	SAS	FDD		
A		ISSUED FOR PRELIMINARY REPORT	SRS			

REFERENCE DRAWINGS

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE NONE DATE 3/14/75
DR. CHK. ENG. APPROVED

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS
DATE
DATE
DATE

KRAFLA GEOTHERMAL POWER PLANT
FLOW DIAGRAM
FIRE PROTECTION SYSTEM
(WATER)

S-74028 A1-02-009 B

GENERAL NOTES

1. INSTRUMENTATION SYMBOLS & IDENTIFICATION ARE IN ACCORDANCE WITH I.S.A. STANDARD S-5.1. STANDARD GRAPHIC SYMBOLS ARE FROM ANSI - Y32.10
2. ALL ITEMS THAT DO NOT SPECIFICALLY REFER TO TURBINE GENERATOR UNIT 2 OR PLANT SERVICE WILL BE DUPLICATED FOR TURBINE GENERATOR UNIT NO. 2.

PIPING SPECIFICATIONS

SPEC.	MATERIAL	DESIGN CONDITION				
		SIZE	WALL THICKNESS (MM) OR SCHEDULE	PRESSURE KG/CM²	TEMP. °C	

FORTHCOMING

LINE IDENTIFICATION

LINE NUMBER

1 HS 2 - 600 - CS - III

- INSULATION SPEC.
- PIPING SPEC.
- LINE SIZE NOM. IN MM
- LINE NUMBER
- COMMODITY
- UNIT NUMBER

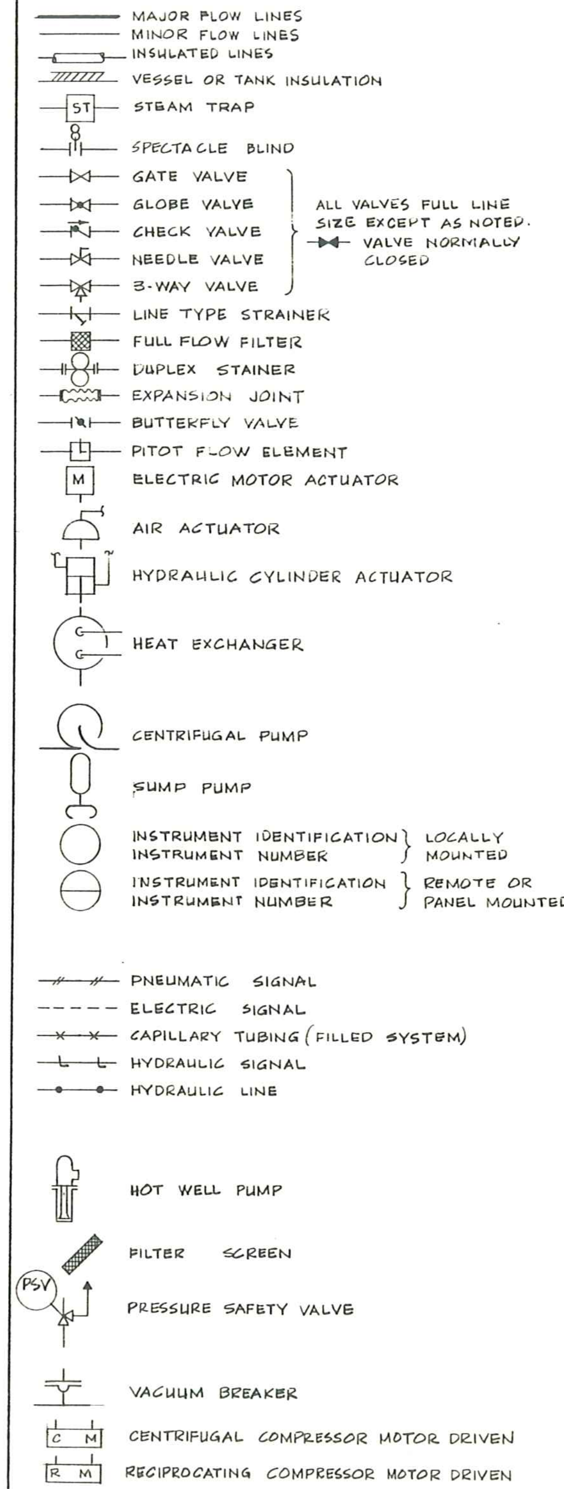
COMMODITY DESIGNATION

HS	H.P. STEAM
LS	L.P. STEAM
AS	AUXILIARY STEAM
DS	STEAM DRAINS TO CONDENSATE
ES	EXHAUST STEAM
AW	AUX. COOLING WATER
BW	BLOWDOWN WATER
CW	MAIN CONDENSER SPRAYS INPUT WATER
HW	HOT WELL CONDENSATE
PW	POTABLE WATER (INCLUDES MAKE-UP WATER)
FW	FIRE PROTECTION WATER (INCLUDES COOLING TOWER WETTING)
DW	DRAINS FROM SYSTEMS (EXCEPT STEAM TO CONDENSER)
SW	SEAL WATER
ACW	AIR COMPRESSOR COOLING WATER
CSW	TURBINE CASING SPRAY
DMW	DEMINERALIZED WATER
NG	NON CONDENSIBLE GAS
FG	FIRE PROTECTION CARBON DIOXIDE
AA	VACUUM BREAKER
CA	CONTROL AIR
IA	INSTRUMENT AIR
UA	UTILITY AIR
PO	TURBINE-GENERATOR LUBE OIL
TO	TURBINE GENERATOR LUBE OIL

INSTRUMENT IDENTIFICATION & ABBREVIATIONS

A/S	AIR SUPPLY (FILTER REGULATOR SET)
AC	AIR TO CLOSE
AO	AIR TO OPEN
ANX	ANALYSIS TAP
C	DRAIN TO CONDENSER
D	DRAIN (PIT)
FC	FLOW CONTROLLER
FE	FLOW PRIMARY ELEMENT
FI	FLOW INDICATOR
FIC	FLOW INDICATING CONTROLLER
FP	FLOW MEASURING TAP
FS	CONNECTED TO OR MOUNTED IN FRONT STANDARD
HS	HAND CONTROL SWITCH
HIC	HAND INDICATING CONTROL
II	AMMETER
LC	LEVEL CONTROLLER
LI	LEVEL INDICATOR
LIC	LEVEL INDICATING CONTROLLER
PC	PRESSURE CONTROLLER
PI	PRESSURE INDICATOR
PIC	PRESSURE INDICATING CONTROLLER
PAL/PAH	PRESSURE ALARM LOW / HIGH
SC	SPEED CONTROLLER
TC	TEMPERATURE CONTROLLER
TI	THERMOMETER TEMPERATURE INDICATOR
TIC	TEMPERATURE INDICATING CONTROLLER
TE	THERMOCOUPLE
TR	TEMPERATURE RECORDER
Y	SPECIAL CONTROL
Z	POSITION READ OUT
LAL/LAH	LEVEL ALARM LOW / HIGH
TW	THERMAL WELL
1	TURBINE GENERATOR UNIT NO. 1
2	TURBINE GENERATOR UNIT NO. 2
12	PLANT SERVICE
HP	HIGH PRESSURE
LP	LOW PRESSURE
AUX	AUXILIARY
S	STEAM
FY	FLOW COMPUTE FUNCTION
FT	FLOW TRANSMITTER
LAL	LEVEL ALARM LOW
LAH	LEVEL ALARM HIGH
LCV	LEVEL CONTROL VALVE
LS	LEVEL SWITCH
LT	LEVEL TRANSMITTER
PE	PRESSURE ELEMENT
PT	PRESSURE TRANSMITTER
PY	PRESSURE COMPUTE FUNCTION
TS	TEMPERATURE SWITCH

SYMBOLS



REFERENCE DRAWINGS

REV.	ZONE	DATE	REVISION	DR.	CHK.	APPR. RECO	APPR.
B	B-7	4/1/75	CHANGE 'HC' TO 'HS' FINAL REPORT ISSUE	SKS	FDD	FDD	[illegible]
A		3/14/75	ISSUED FOR PRELIMINARY REPORT	JLP	DRB	FDD	[illegible]

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

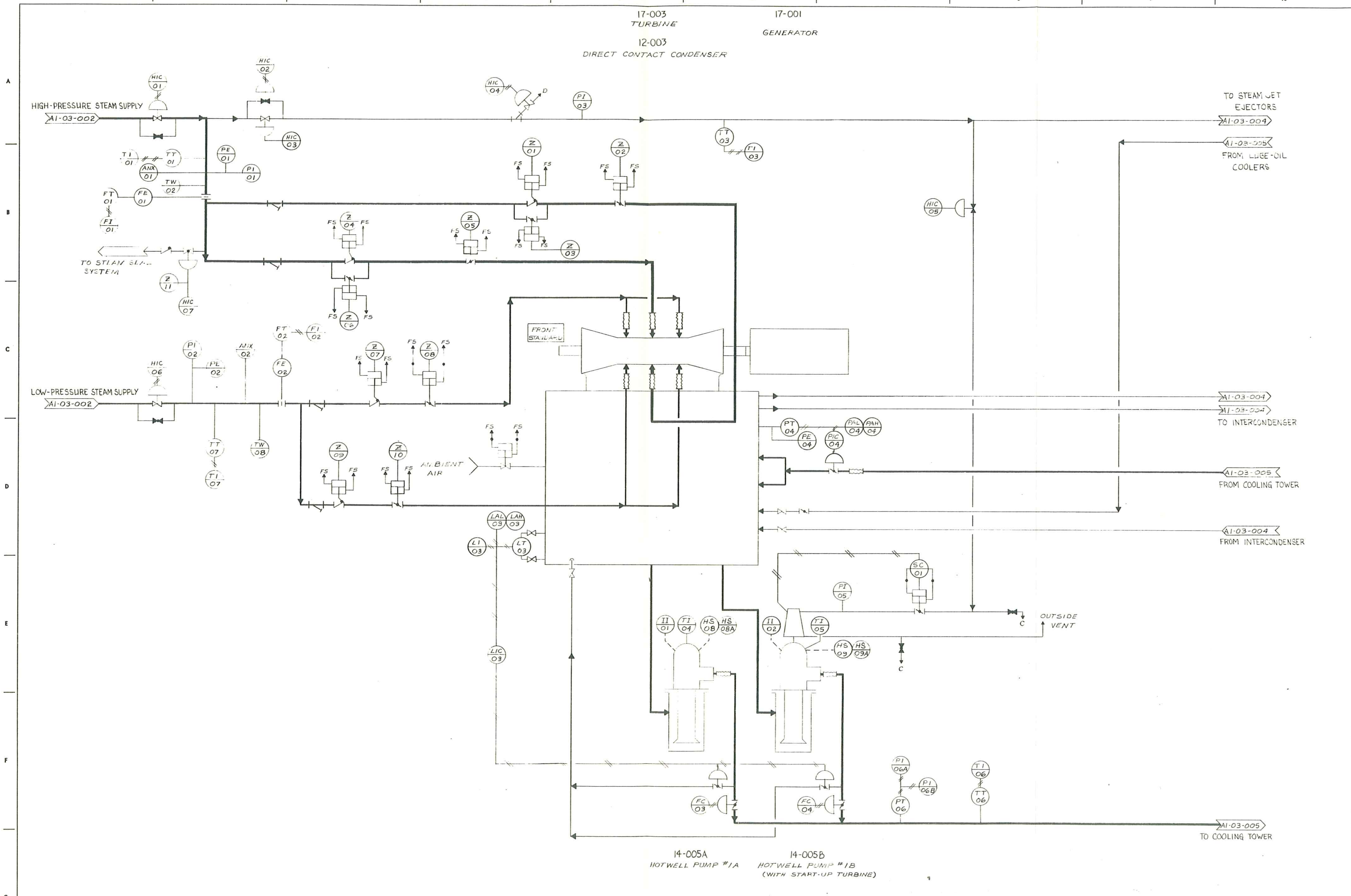
SCALE NONE DATE
DR. [illegible] CHK. ENG. APPROVED [illegible]

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS
DATE
DATE
DATE

KRAFLA GEOTHERMAL POWER PLANT
PIPING & INSTRUMENT DIAGRAM
LEGEND

JOB NO S 74028 | A1-03-001 | B

DG-005



REV.	DATE	REVISION
C	4/11/75	CORRECTED HS-08, HS-09 FINAL REPORT ISSUE
B	3/12/75	ISSUED FOR PRELIMINARY REPORT
A	1/23/75	ISSUED FOR REVIEW

REFERENCE DRAWINGS

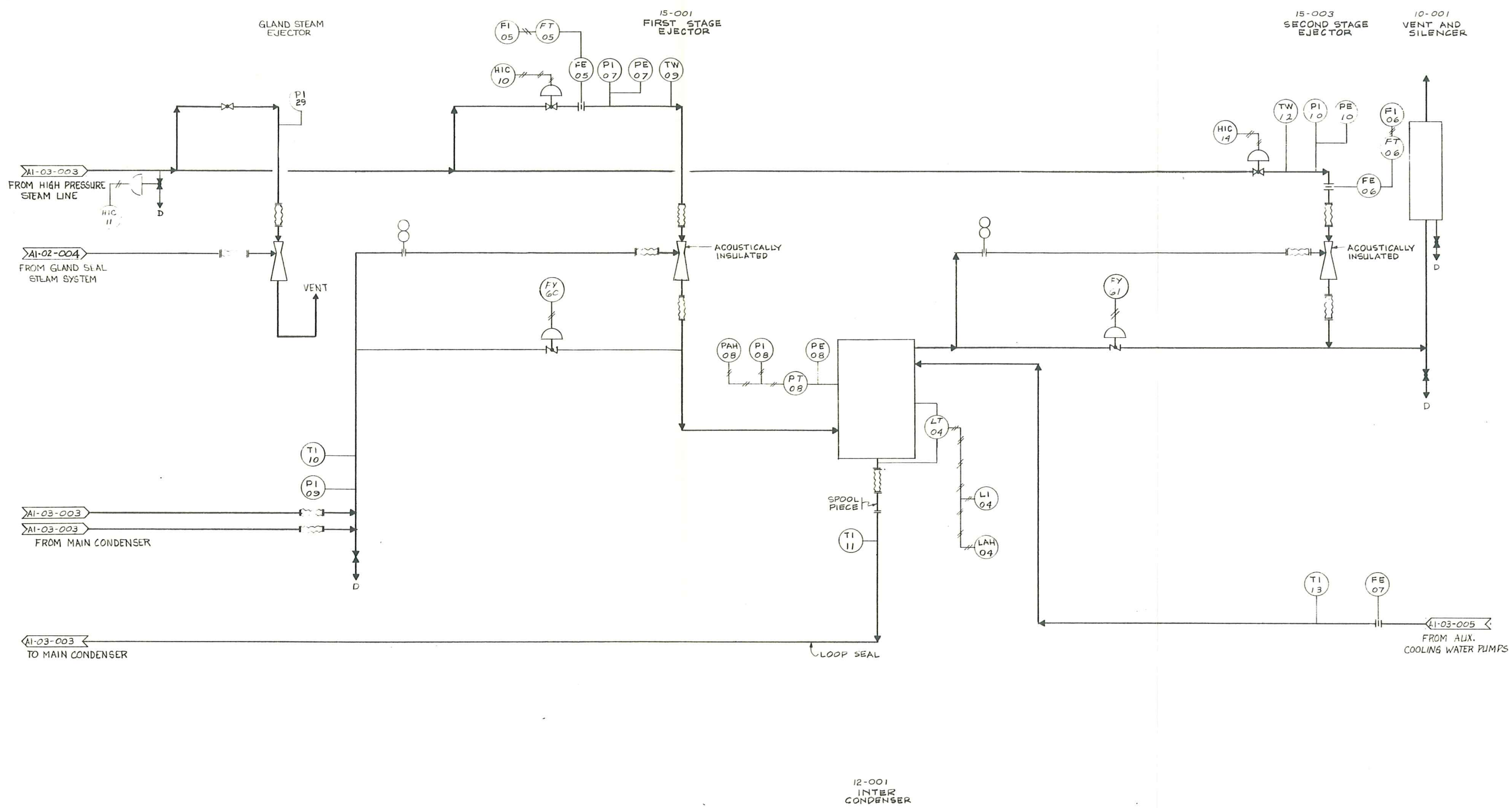
CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE NONE DATE 1-20-75

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS

KRAFLA GEOTHERMAL POWER PLANT
PIPING & INSTRUMENT DIAGRAM
TURBINE AND CONDENSER
UNIT I (DOUBLE FLASH)

JOB NO. S-74028 A1-03-003 C



REV.	DATE	REVISION
C	4/11/75	GLAND STEAM EJECTOR ADDED FINAL REPORT ISSUE
B	3/4/75	ISSUED FOR PRELIMINARY REPORT
A	1/23/75	ISSUED FOR REVIEW

REFERENCE DRAWINGS

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE NONE DATE 1-23-75

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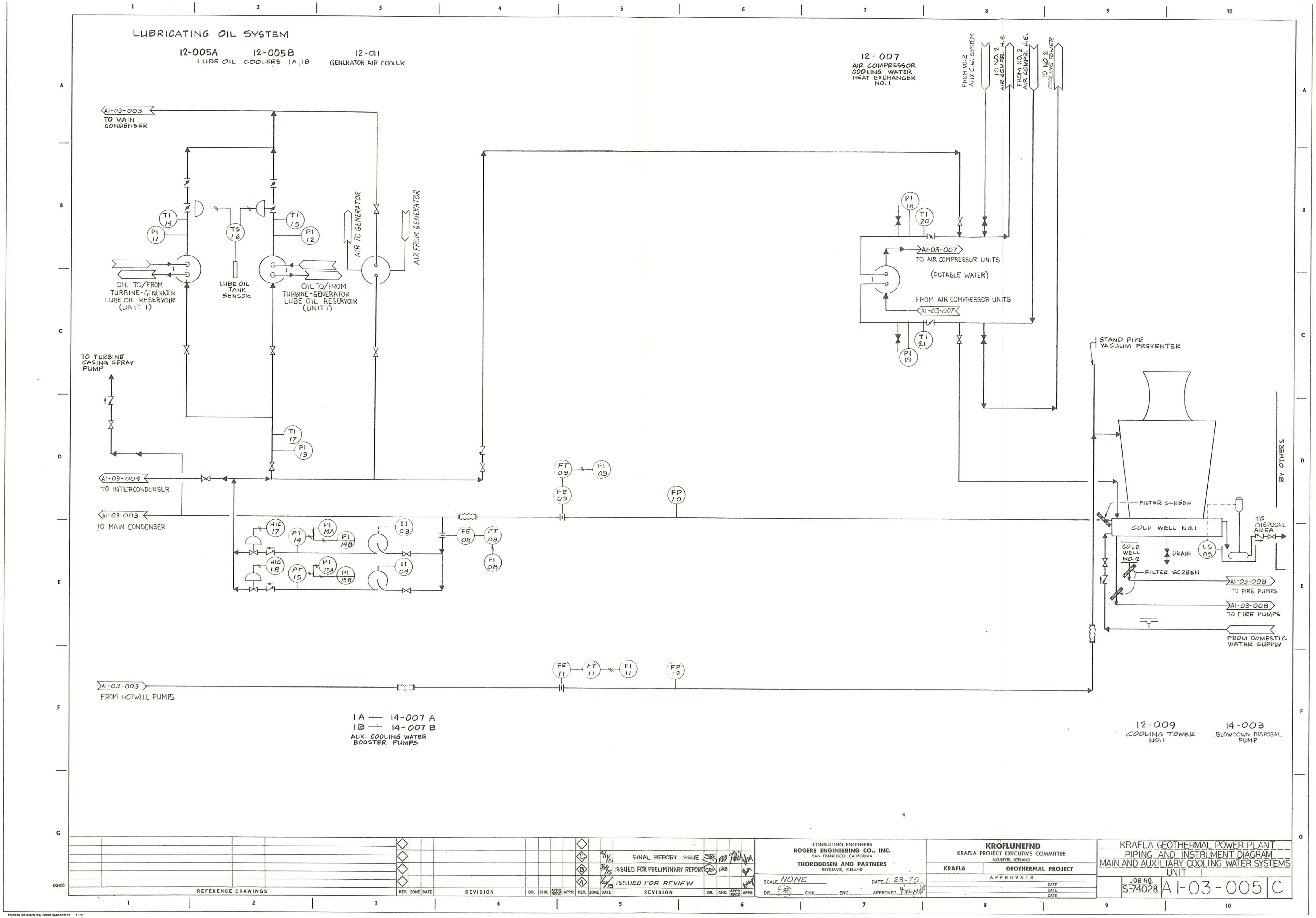
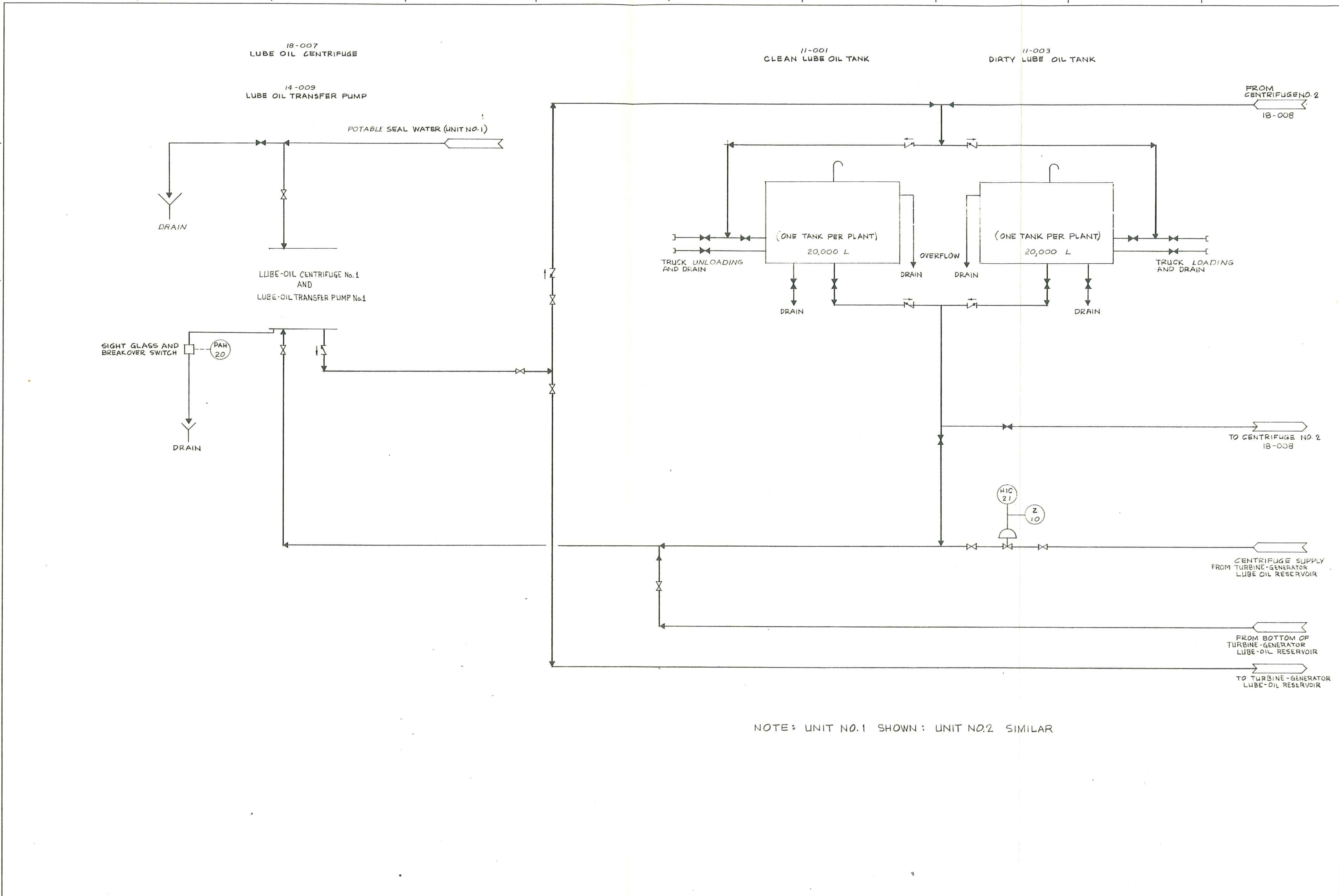
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA | GEOTHERMAL PROJECT
APPROVALS

KRAFLA GEOTHERMAL POWER PLANT
PIPING AND INSTRUMENT DIAGRAM
NONCONDENSIBLE GAS REMOVAL SYSTEM
UNIT I DOUBLE FLASH

JOB NO. S-74028 A1-03-004 C



LUBRICATING OIL SYSTEM
12-005A 12-005B
LUBE OIL COOLERS 1A, 1B
12-011
GENERATOR AIR COOLER
12-007
AIR COMPRESSOR COOLING WATER HEAT EXCHANGER NO. 1
FROM NO. 2 AUX C.W. SYSTEM
TO NO. 2 AIR COMPR. H.E.
FROM NO. 2 AIR COMPR. H.E.
TO NO. 2 COOLING TOWER
A1-03-003 TO MAIN CONDENSER
AIR TO GENERATOR
AIR FROM GENERATOR
OIL TO/FROM TURBINE-GENERATOR LUBE OIL RESERVOIR (UNIT 1)
LUBE OIL TANK SENSOR
OIL TO/FROM TURBINE-GENERATOR LUBE OIL RESERVOIR (UNIT 1)
A1-03-007 TO AIR COMPRESSOR UNITS
(POTABLE WATER)
FROM AIR COMPRESSOR UNITS A1-03-007
TO TURBINE CASING SPRAY PUMP
STAND PIPE VACUUM PREVENTER
A1-03-004 TO INTERCONDENSER
A1-03-003 TO MAIN CONDENSER
FILTER SCREEN
COLD WELL NO. 1
COLD WELL NO. 2
DRAIN
TO DISPOSAL AREA
BY OTHERS
FILTER SCREEN
A1-03-008 TO FIRE PUMPS
A1-03-008 TO FIRE PUMPS
FROM DOMESTIC WATER SUPPLY
A1-03-003 FROM HOTWELL PUMPS
1A — 14-007 A
1B — 14-007 B
AUX. COOLING WATER BOOSTER PUMPS
12-009 COOLING TOWER NO. 1
14-003 BLOWDOWN DISPOSAL PUMP
REFERENCE DRAWINGS
REV. ZONE DATE REVISION DR. CHK. APPR. RECO APPR.
C FINAL REPORT ISSUE
B ISSUED FOR PRELIMINARY REPORT
A ISSUED FOR REVIEW
CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND
SCALE NONE
DATE 1-23-75
KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS
KRAFLA GEOTHERMAL POWER PLANT
PIPING AND INSTRUMENT DIAGRAM
MAIN AND AUXILIARY COOLING WATER SYSTEMS
UNIT 1
JOB NO. S-74028
A1-03-005 C



REV.	DATE	REVISION
C	4/11/75	FINAL REPORT ISSUE
B	3/1/75	ISSUED FOR PRELIMINARY REPORT
A	1/23/75	ISSUED FOR REVIEW

REFERENCE DRAWINGS

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

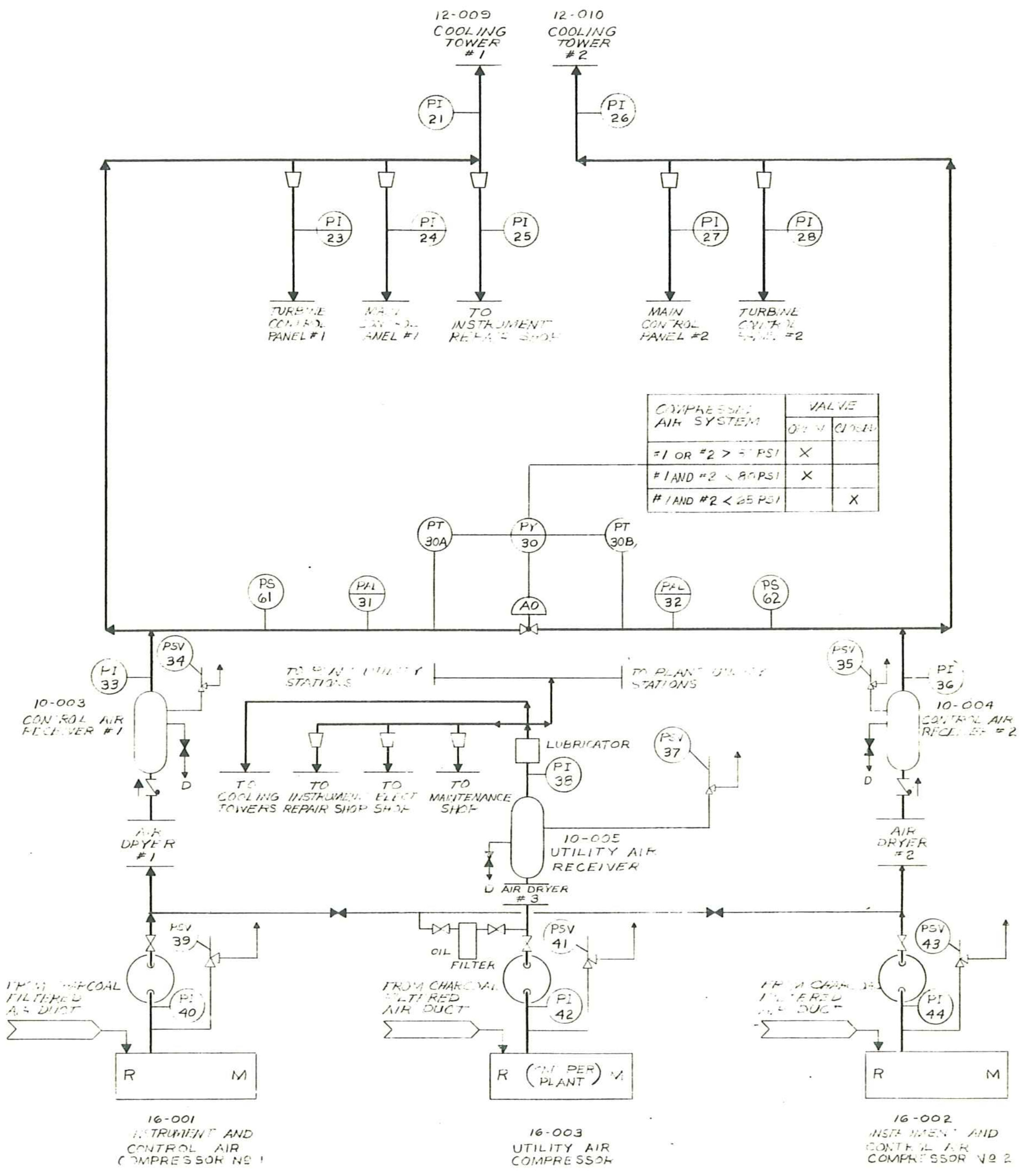
SCALE NONE DATE 1-23-75
DR. CHK. ENG. APPROVED

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS

KRAFLA GEOTHERMAL POWER PLANT
PIPING AND INSTRUMENT DIAGRAM
LUBE OIL PROCESSING SYSTEM

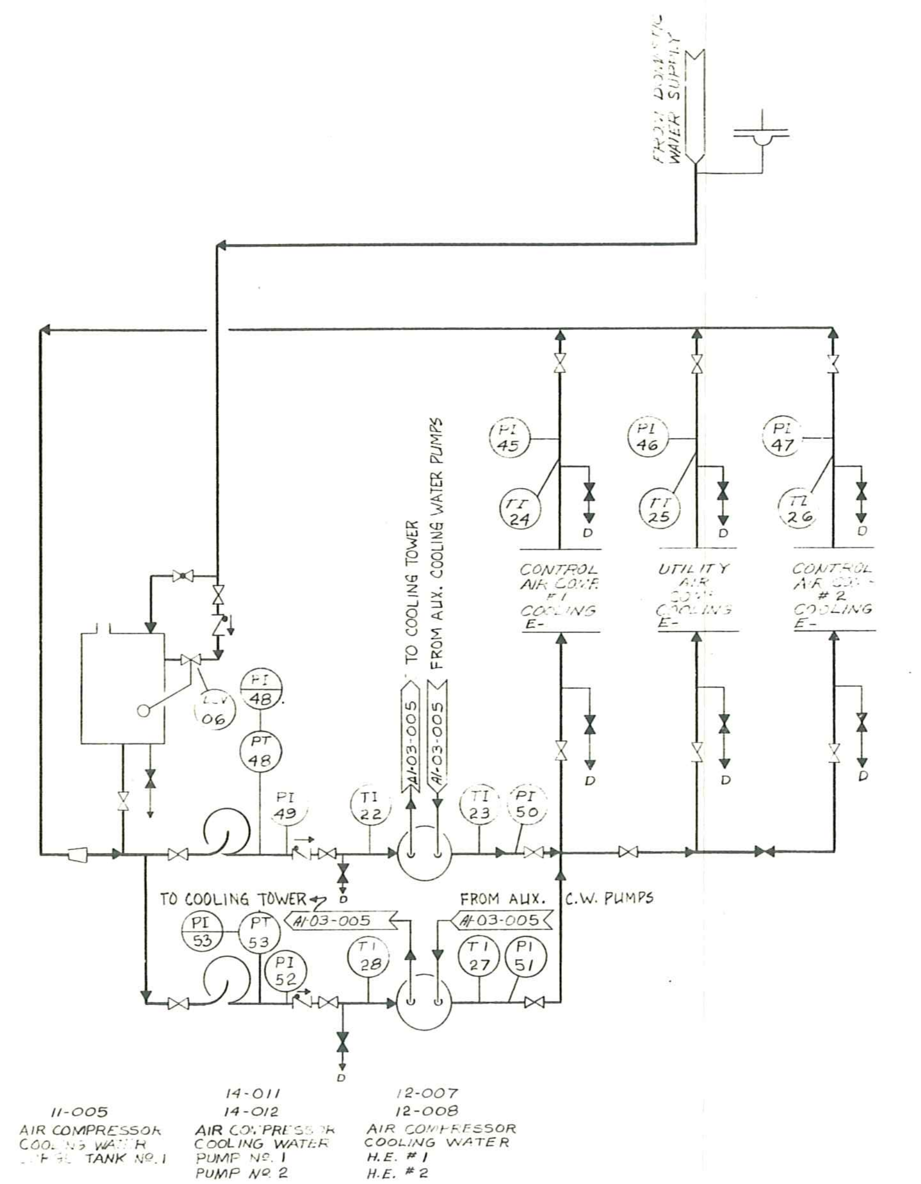
JOB NO S-74028 A1-03-006 C

DG-005



COMPRESSED AIR SYSTEM	VALVE	
	OPEN	CLOSE
#1 OR #2 > PSI	X	
#1 AND #2 < 80 PSI	X	
#1 AND #2 < 65 PSI		X

COMPRESSED AIR SYSTEM



AIR COMPRESSOR COOLING WATER SYSTEM

REV.	DATE	REVISION	DR.	CHK.
C	4/11/75	ADDED PS-61, PS 62 FINAL REPORT ISSUE	SRS	FDP
B	3/14/75	ISSUED FOR PRELIMINARY REPORT		
A	1/23/75	ISSUED FOR REVIEW		DRB

REFERENCE DRAWINGS

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

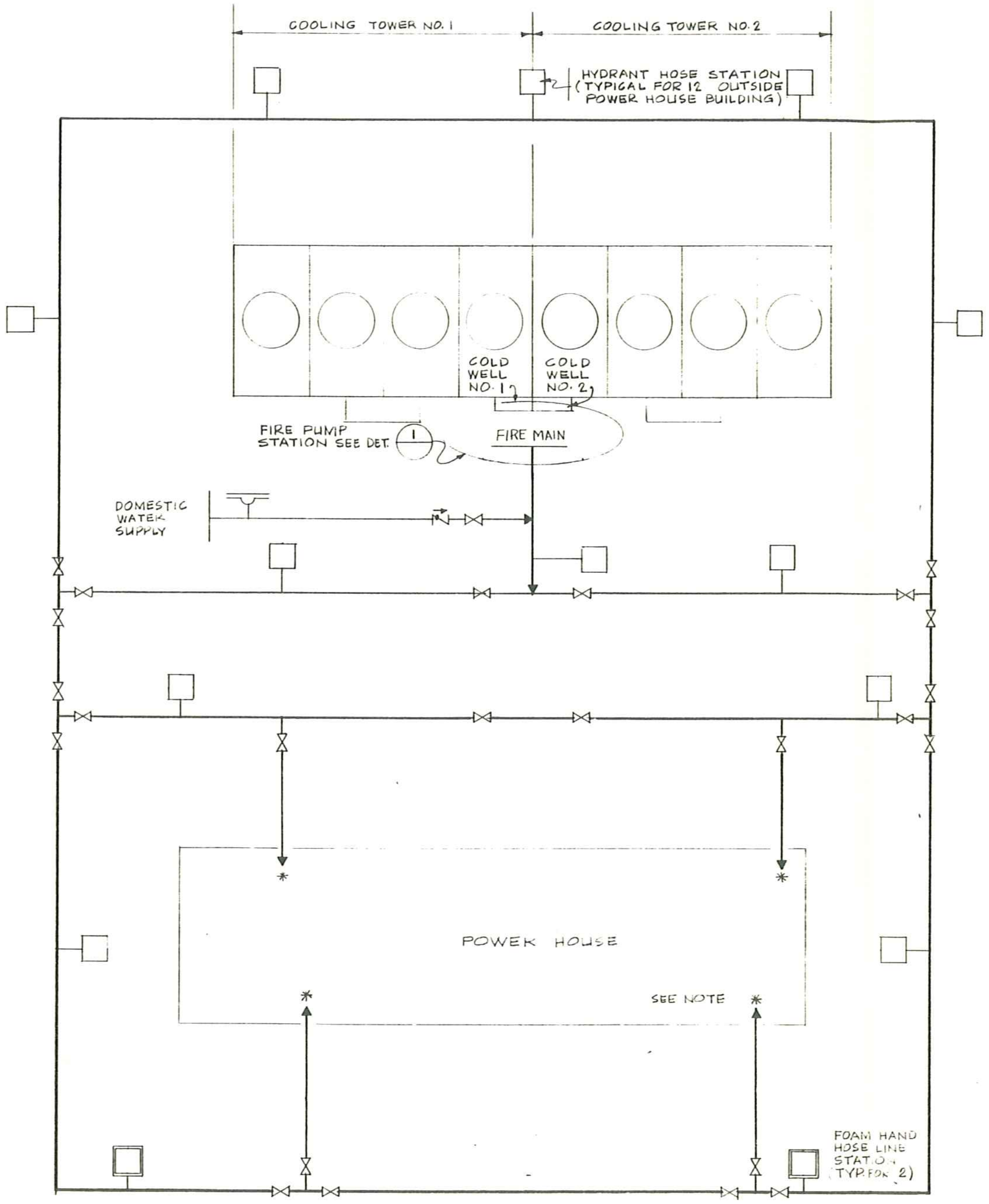
SCALE NONE
DATE 1-23-75
DR. CHK. ENG. APPROVED

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS
DATE
DATE
DATE

KRAFLA GEOTHERMAL POWER PLANT
PIPING & INSTRUMENT DIAGRAM
COMPRESSED AIR & AIR COMPRESSOR COOLING WATER SYSTEMS

JOB NO. S-74028
AI-03-007
C

DG-005



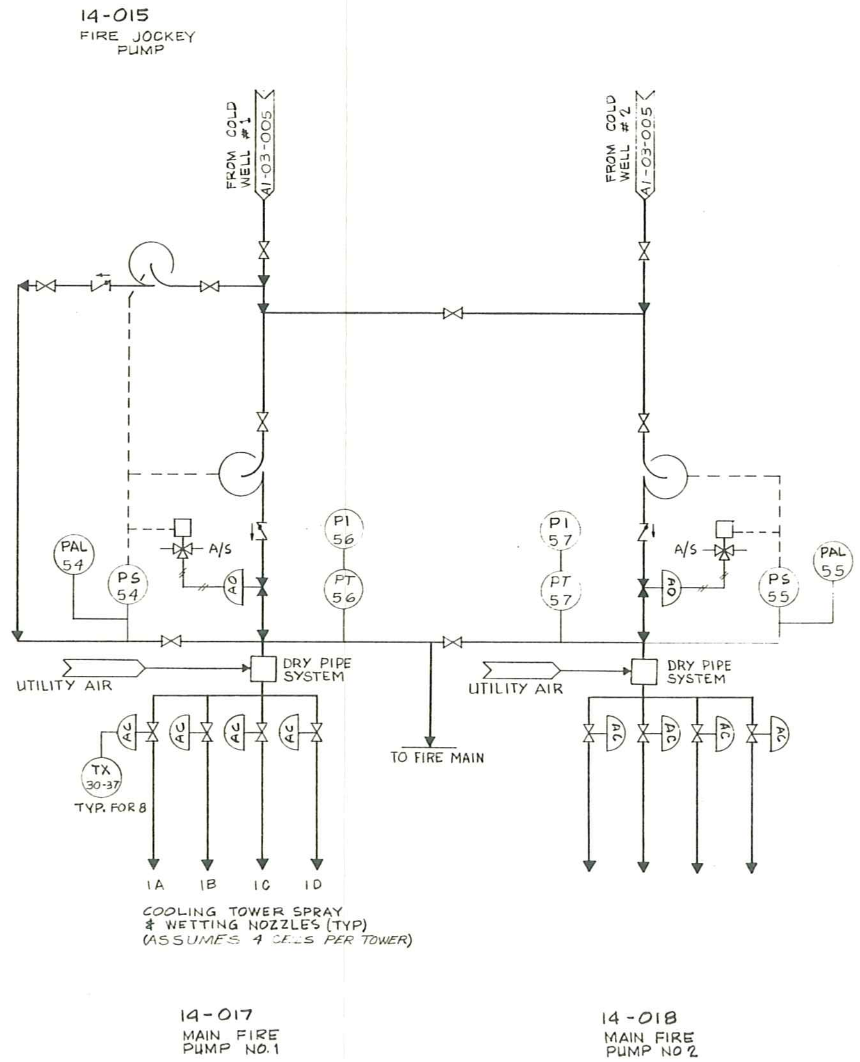
FIRE PROTECTION SYSTEMS

NOTE: * 4 HYDRANT HOSE STATIONS FOR UNIT #1 TURBINE GENERATOR AREAS & 4 HYDRANT HOSE STATIONS FOR UNIT #2 TURBINE GENERATOR AREAS. (TOTAL NUMBER OF HYDRANT HOSE STATIONS IN POWER HOUSE = 8)
4 DRY PIPE SYSTEMS
(1 AT EACH POWER HOUSE ENTRY)

SPRINKLER FIRE PROTECTION FOR:
- TURBINE OIL TANK (IN POWER HOUSE)
- CLEAN AND DIRTY OIL TANKS
- UNDER TURBINE
- TURBINE GENERATOR BEARINGS
- CONCRETE PEDESTAL SUPPORTS FOR T-G
- POWER TRANSFORMERS
- HEAD END OF TURBINE ABOVE OPERATING FLOOR
- UNDER GENERATOR
- FIRE PUMP STATION
- COOLING TOWER CELLS & FAN MOTORS

LIQUID CARBON DIOXIDE OR HALON FIRE PROTECTION FOR:
- CONTROL ROOM
- SWITCH GEAR ROOMS (7)
- EXCITER ROOMS (2)
- TURBINE OIL TANK PURGE (IN POWER HOUSE)
- AUXILIARY GENERATOR ROOM

FIRE PUMP OPERATION		
PUMP START FALLING PRESSURE	FIRE MAIN PRESS. KG/SQ. CM	PUMP STOP RISING PRESS.
JOCKEY PUMP START	7.0	
1ST MAIN F.P. START	6.6	
2nd MAIN F.P. START	6.0	
	6.5	2nd MAIN F.P. STOP
	7.1	1ST MAIN F.P. STOP
	7.7	JOCKEY PUMP STOP



FIRE PUMP STATION DET. 1

REV.	ZONE	DATE	REVISION	DR.	CHK.	APPR. RECO	APPR.
C		4/11/75	FINAL REPORT ISSUE	SRS	FDD		
B		3/14/75	ISSUED FOR PRELIMINARY REPORT	SRS	DRB		
A		1/23/75	ISSUED FOR REVIEW				

REFERENCE DRAWINGS

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

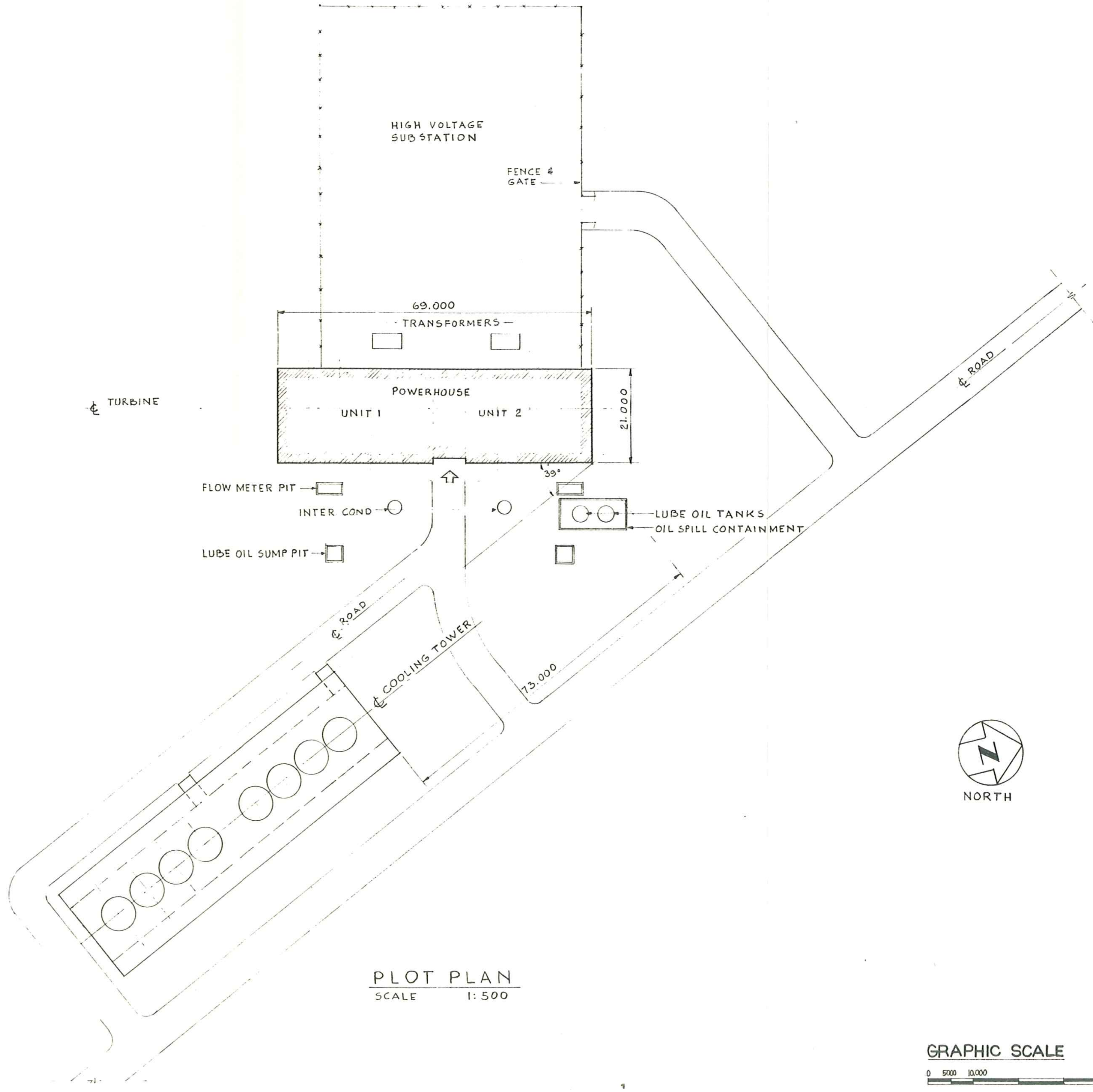
SCALE NONE DATE 1-23-73
DR. CHK. ENG. APPROVED

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS
DATE
DATE
DATE

KRAFLA GEOTHERMAL POWER PLANT
PIPING AND INSTRUMENT DIAGRAM
FIRE PROTECTION SYSTEM
UNITS 1 AND 2 DOUBLE FLASH

JOB NO. S-74028 | A1-03-008 | C

DG-005



PLOT PLAN
SCALE 1:500

GRAPHIC SCALE
0 5000 10,000 50,000 MM

REV.	ZONE	DATE	REVISION	DR.	CHK	APPR RECO	APPR.
C		4/11/75	GENERAL DRAWING REVISIONS FINAL REPORT ISSUE	E.A		[signature]	[signature]
B		2/27/75	ISSUED FOR PRELIM REPORT, POWER HOUSE DIM EXTER STAIRS TRANSFORMER LOCATION	E.A	E.K	D.C.	F.D. H.M
A		1/24/75	ISSUED FOR REVIEW	E.A	J.S	D.C	H.M

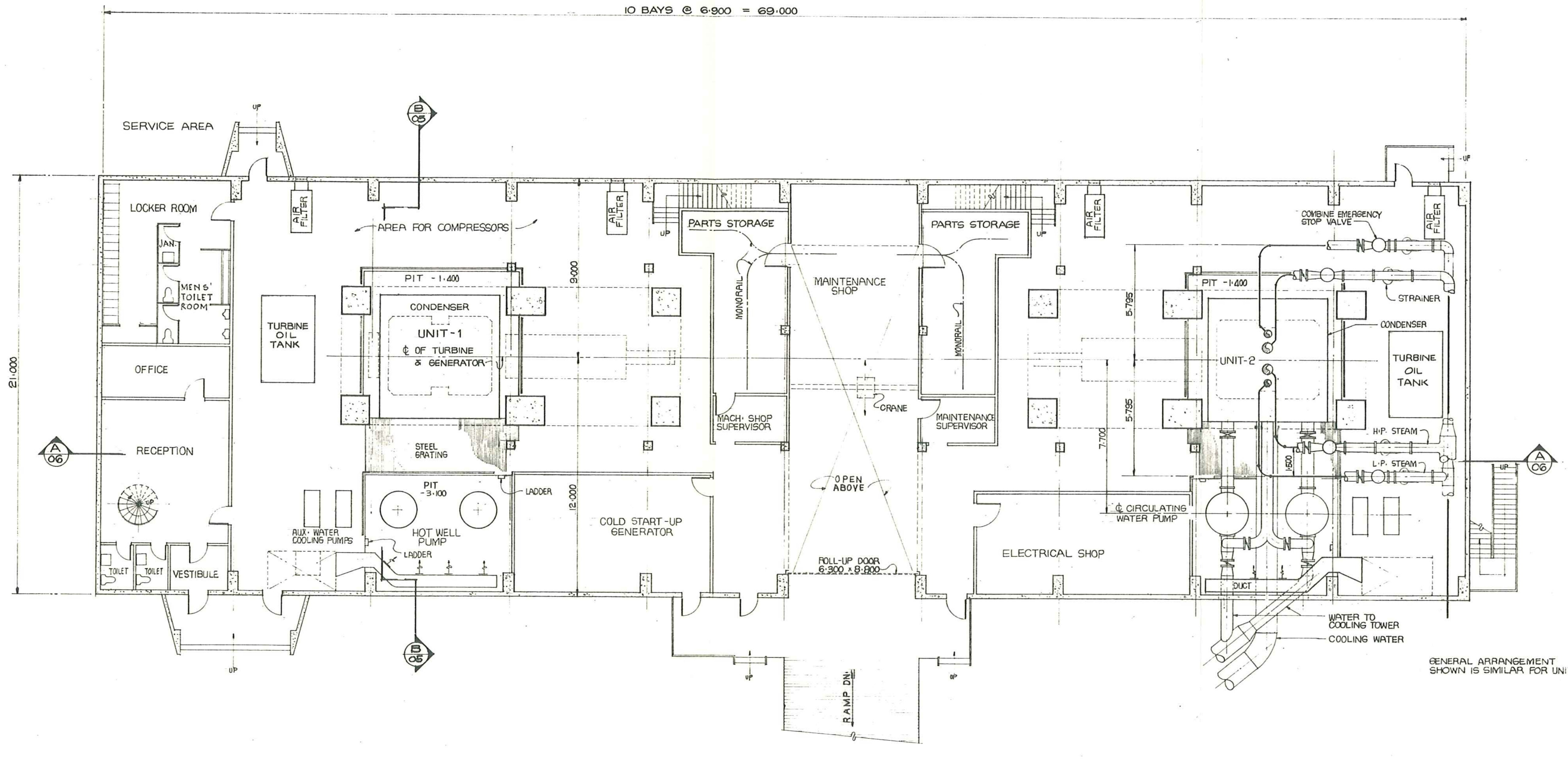
REFERENCE DRAWINGS

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE 1:500 DATE 4-11-75
DR. E.A. CHK. ENG. APPROVED

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS
DATE
DATE
DATE

KRAFLA GEOTHERMAL POWER PLANT
PLOT PLAN
UNITS 1 & 2 (30 MW EACH)
JOB NO. S-74028
A1-04-001 C



GROUND FLOOR PLAN

SCALE 1:100

REF. NORTH

GRAPHIC SCALE

0 1000 2000 3000 4000 5000 10.000 MM

REV.	ZONE	DATE	REVISION	DR.	CHK	APPR RECO	APPR.
C		4/11/75	GENERAL DRAWING REVISIONS FINAL REPORT ISSUE	CcO	E.A.		VKJ
B		3/14/75	ISSUED FOR PRELIM. REPORT WITH LATEST REVISIONS	E.A	G.P.		VKJ
A			ISSUED FOR REVIEW	CcO	E.A	D.C.	VKJ

REFERENCE DRAWINGS

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE 1:100 DATE 4-11-75
DR. CcO. CHK. E.A. ENG. E.a. APPROVED

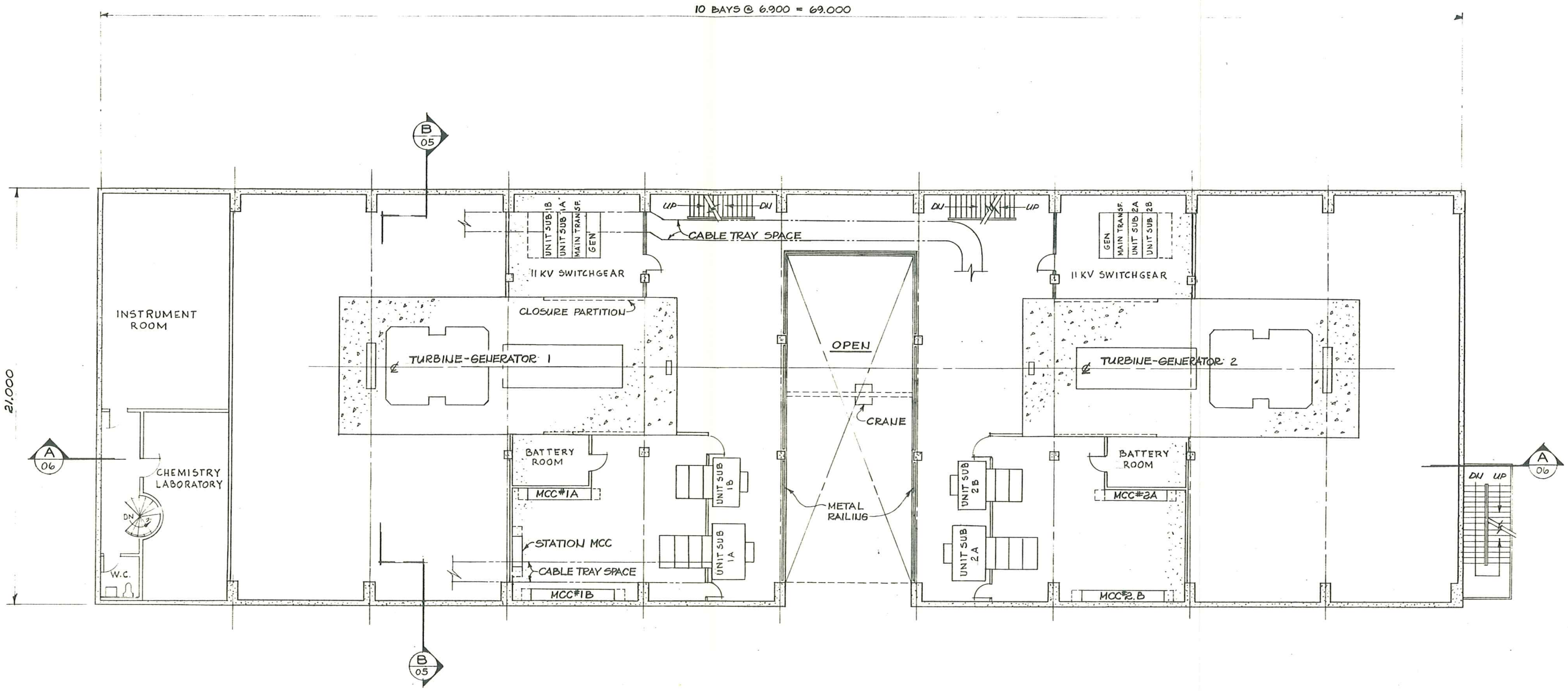
KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND

KRAFLA GEOTHERMAL PROJECT

APPROVALS
DATE
DATE
DATE

KRAFLA GEOTHERMAL POWER PLANT
GROUND FLOOR PLAN
UNITS 1&2 (30 MW EACH)

JOB NO. S-74028 | A1-04-002 | C



MEZZANINE FLOOR PLAN

SCALE 1:100

GRAPHIC SCALE
0 1000 2000 3000 4000 5000 10,000 MM

REV.	ZONE	DATE	REVISION	DR.	CHK	APPR RECO	APPR.
C		4/11/75	GENERAL DRAWING REVISIONS FINAL REPORT ISSUE	J.B.			
B		3/4/75	ISSUED FOR PRELIM. REPORT	E.A	JRS		
			T-G FOUNDATION REVISED; MEZZANINE FLOOR EXTENDED				
A			ISSUED FOR REVIEW	JBM	E.A	D.C.	

REFERENCE DRAWINGS

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

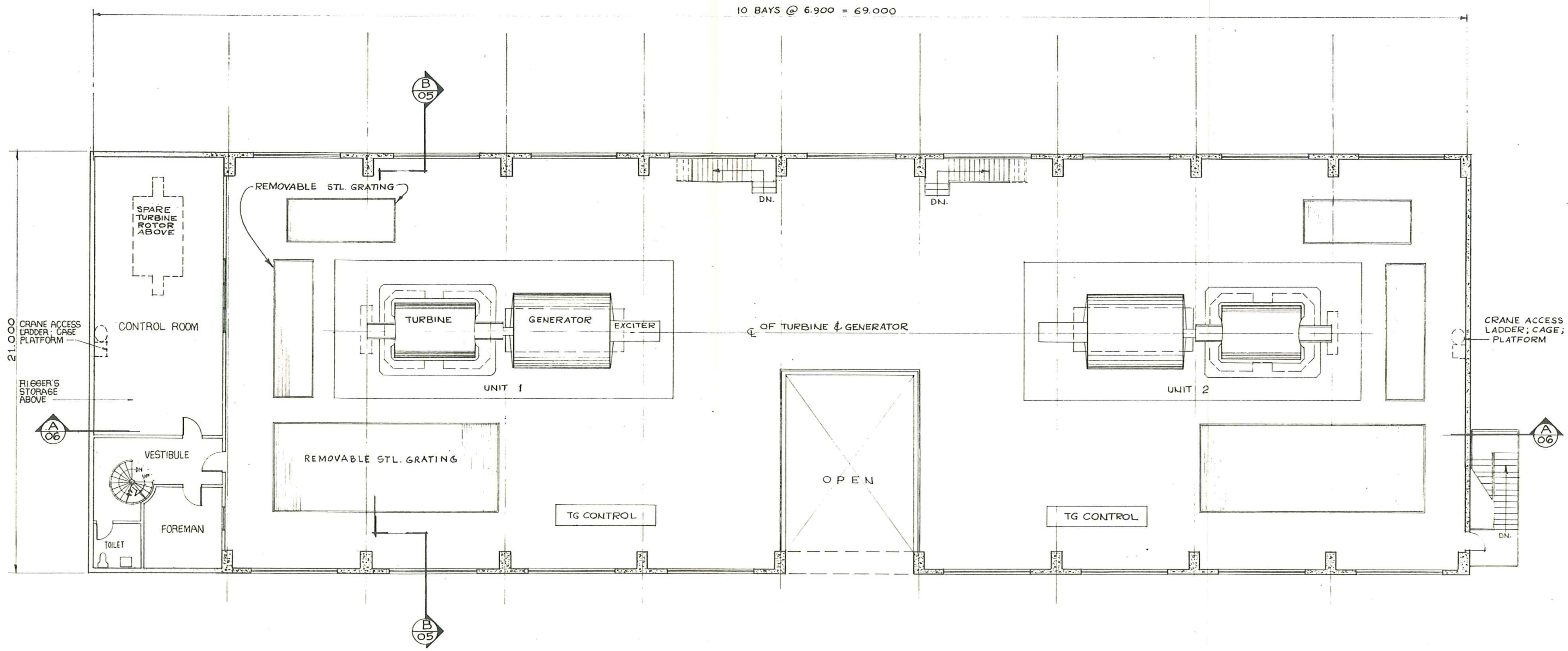
SCALE 1:100 DATE 4-11-75
DR. J.B-M CHK. E.A. ENG. E.a. APPROVED HM VKJ

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS
DATE
DATE
DATE

KRAFLA GEOTHERMAL POWER PLANT
MEZZANINE FLOOR PLAN
UNITS 1&2 (30 MW EACH)

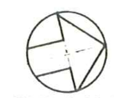
JOB NO. S-74028 A1-04-003 C

A-1



OPERATING FLOOR PLAN

SCALE 1:100



GRAPHIC SCALE

0 1000 2000 3000 4000 5000 10,000 MM

REV.	DATE	REVISION	DR.	CHK	APPR RECO	APPR.
C	4/11/75	GENERAL DRAWING REVISIONS FINAL REPORT ISSUE	H.E.	E.A.		VKJ HM
B		TURBINE GENERATOR SHOWN ISSUED FOR PRELIM. REPORT	E.A.	J.R.S.		VKJ HM
A		ISSUED FOR REVIEW	H.E.	E.A.	D.C.	VKJ HM

REFERENCE DRAWINGS

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE 1:100 DATE 4-11-75
DR. Hagob CHK. E.A. ENG. E.A. APPROVED HM VKJ

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND

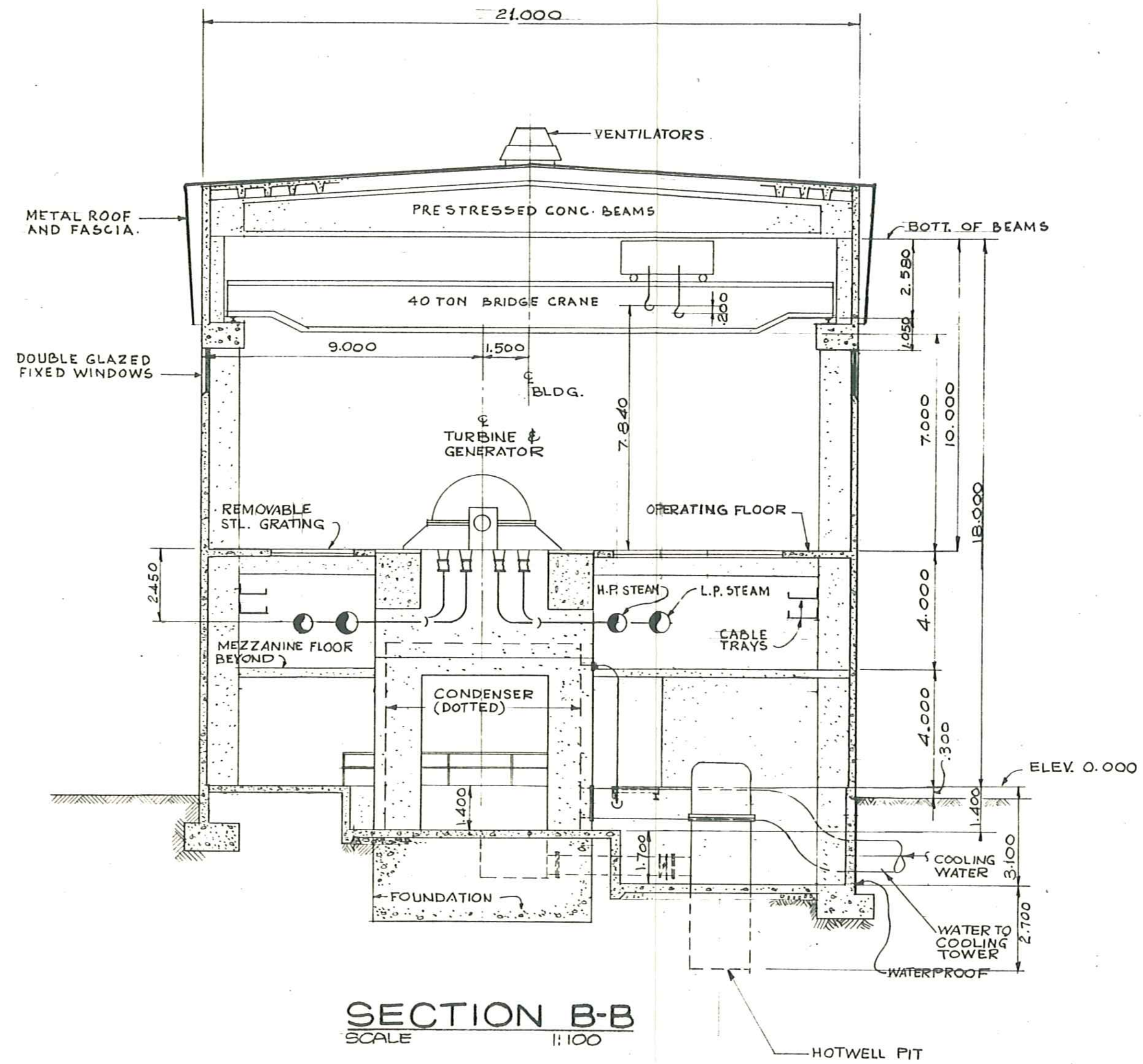
KRAFLA GEOTHERMAL PROJECT

APPROVALS
DATE
DATE
DATE

KRAFLA GEOTHERMAL POWER PLANT
OPERATING FLOOR PLAN
UNITS 1&2 (30 MW EACH)

JOB NO S74028 | A1-04-004 | C

A-1



SECTION B-B
SCALE 1:100

GRAPHIC SCALE
0 1000 2000 3000 4000 5000 10.000 MM

REV.	ZONE	DATE	REVISION	DR.	CHK	APPR RECO	APPR.
D		4/2/75	REVISED STEAM LINE ELEV.	E.A	G.P.		VKJ HM
C		3/14/75	REDRAWN TO SCALE ; ISSUED FOR PRELIM. REPORT	E.A.	G.P.		VKJ HM
B		2/21/75	ROOF VENTILATOR LOCATIONS BUILDING DIMENSIONS	E.A.			VKJ HM
A		2/11/75	ISSUED FOR REVIEW	E.A	J.R.S.	D.C	VKJ HM
E		4/11/75	GENERAL DRAWING REVISIONS. FINAL REPORT ISSUE	H.E.			

REFERENCE DRAWINGS

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE 1 : 100 DATE 4/11/75
DR. Hagob CHK. E.A. ENG. EA APPROVED HM. VKJ.

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND

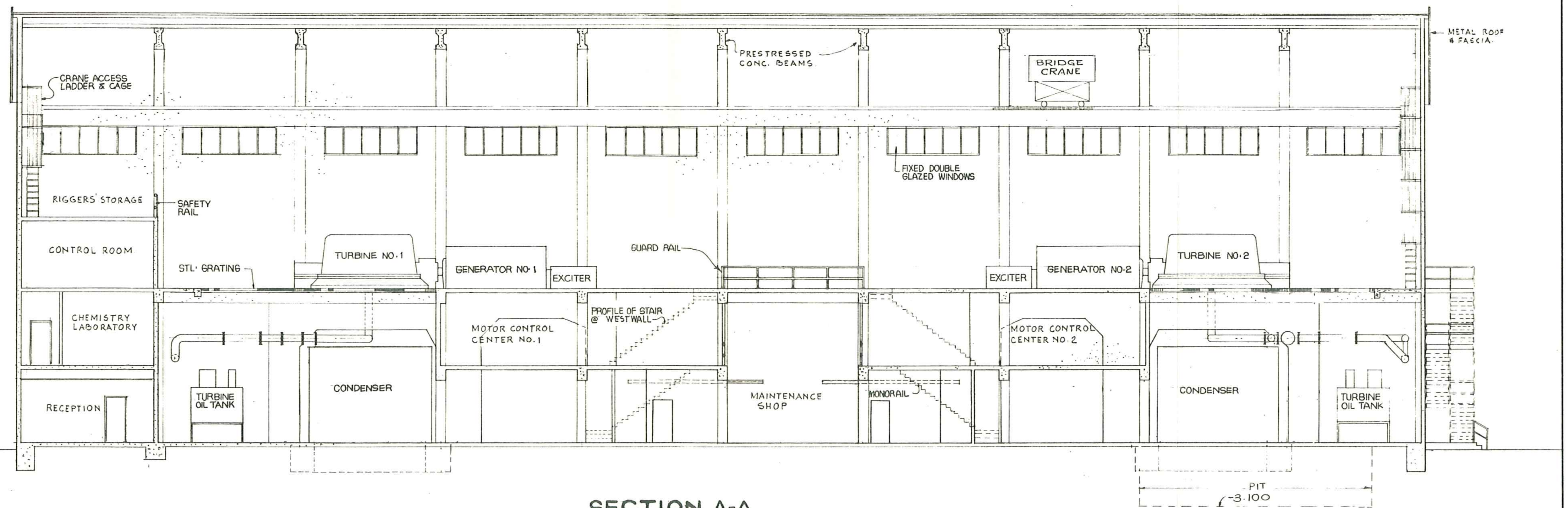
KRAFLA **GEOTHERMAL PROJECT**

APPROVALS
DATE
DATE
DATE

KRAFLA GEOTHERMAL POWER PLANT
SECTION B-B
UNITS 1 & 2 (30 MW EACH)

JOB NO. S 74028 | A1-04-005 | E

A-1



SECTION A-A

SCALE 1:100

GRAPHIC SCALE

0 1000 2000 3000 4000 5000 10,000 MM

REFERENCE DRAWINGS	REV.	ZONE	DATE	REVISION	DR.	CHK.	APPR RECO	APPR.
	A		4/4/75	FINAL REPORT ISSUE	CcO	E.A.		VKJ HM

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE 1:100 DATE 4-4-75
DR. CcO. CHK. E.A. ENG. ea APPROVED VKJ

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND

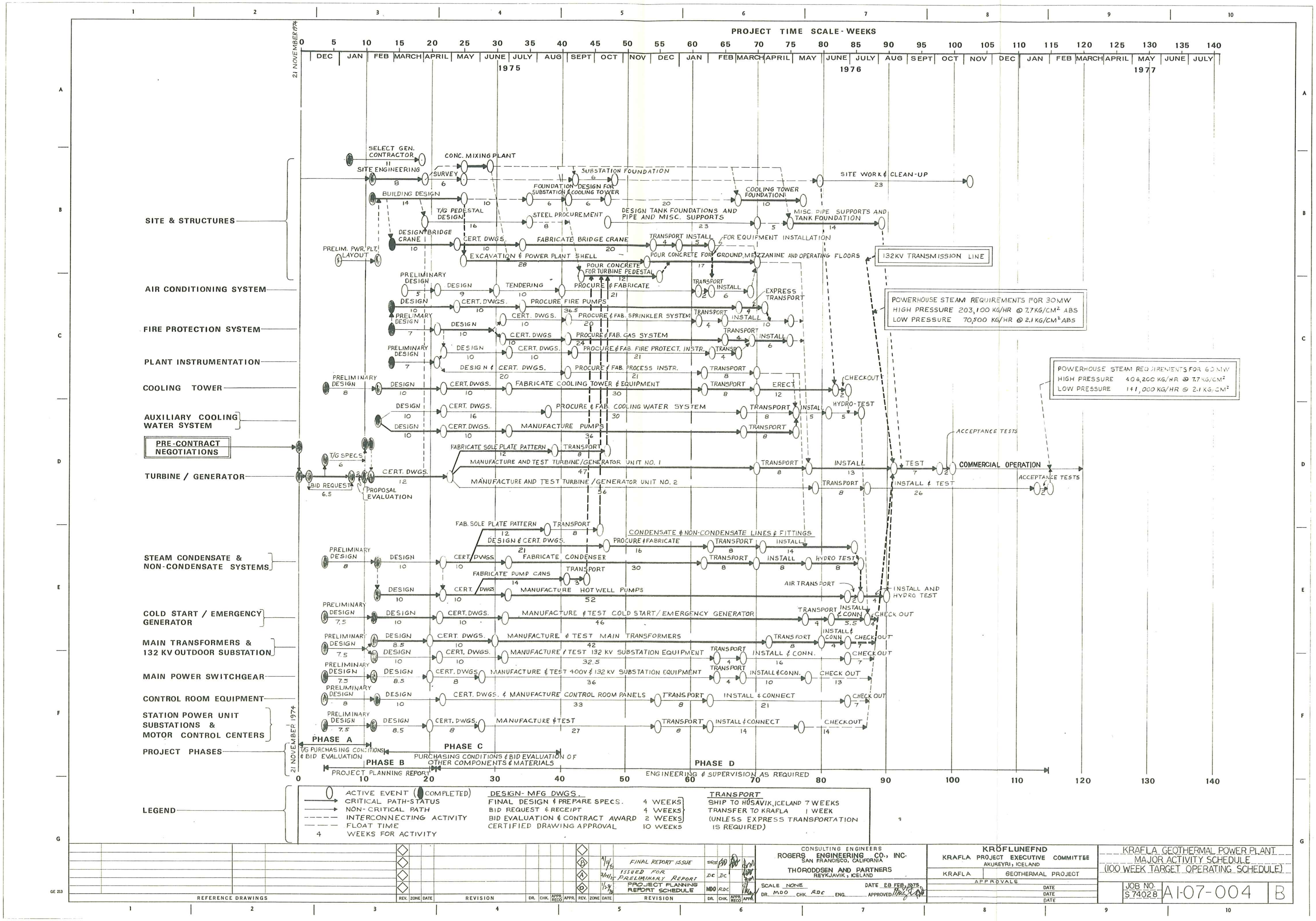
KRAFLA GEOTHERMAL PROJECT

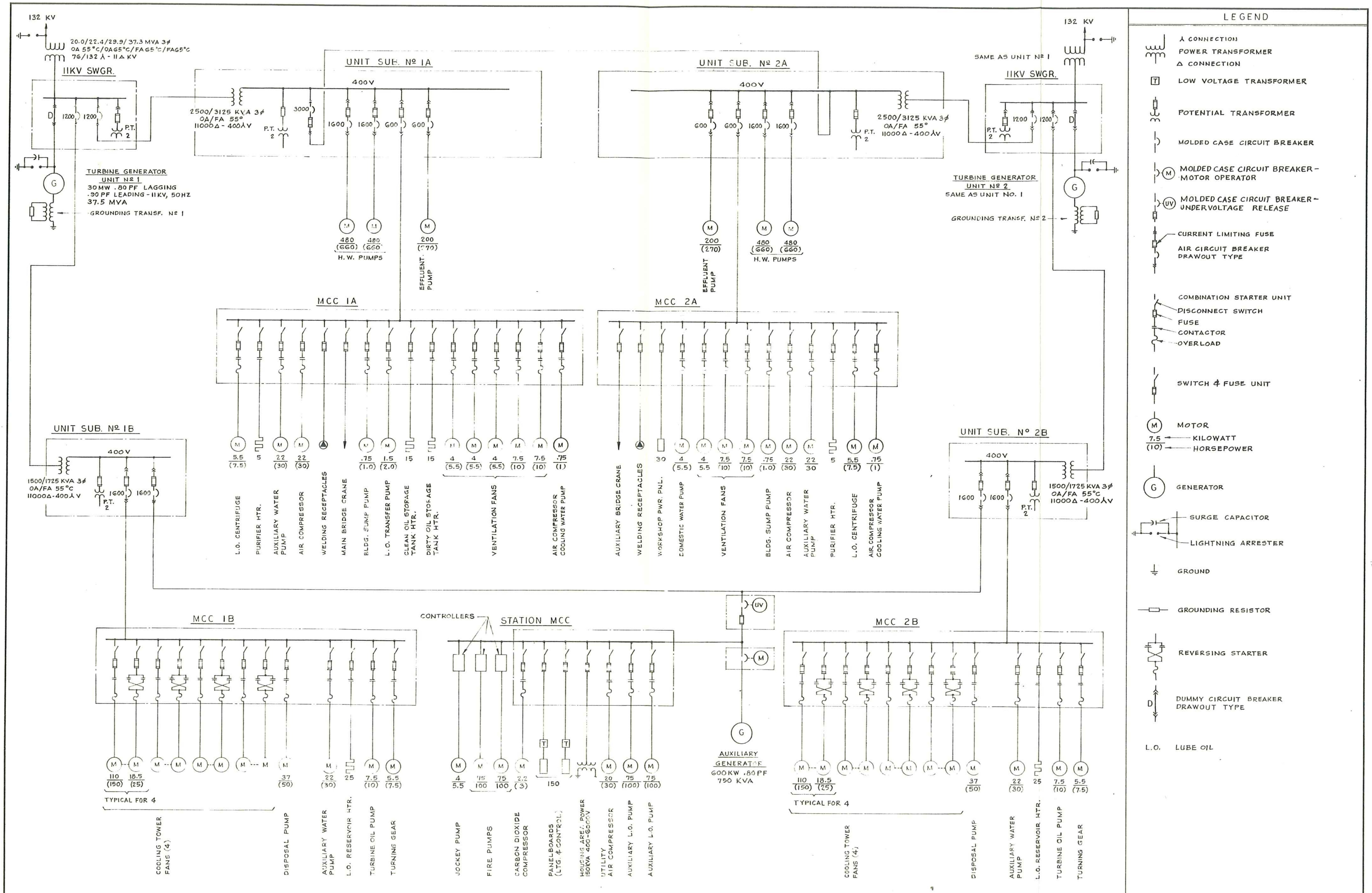
APPROVALS
DATE
DATE
DATE

KRAFLA GEOTHERMAL POWER PLANT
SECTION-AA
UNITS 1&2 (30MW EACH)

JOB NO S-74028 | A1-04-006 | A

A-1


PROJECT TIME SCALE - WEEKS
21 NOVEMBER 1974
DEC JAN FEB MARCH APRIL MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB MARCH APRIL MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB MARCH APRIL MAY JUNE JULY
1975
1976
1977
SITE & STRUCTURES
AIR CONDITIONING SYSTEM
FIRE PROTECTION SYSTEM
PLANT INSTRUMENTATION
COOLING TOWER
AUXILIARY COOLING WATER SYSTEM
PRE-CONTRACT NEGOTIATIONS
TURBINE / GENERATOR
STEAM CONDENSATE & NON-CONDENSATE SYSTEMS
COLD START / EMERGENCY GENERATOR
MAIN TRANSFORMERS & 132 KV OUTDOOR SUBSTATION
MAIN POWER SWITCHGEAR
CONTROL ROOM EQUIPMENT
STATION POWER UNIT SUBSTATIONS & MOTOR CONTROL CENTERS
PROJECT PHASES
LEGEND
SELECT GEN. CONTRACTOR
CONC. MIXING PLANT
SITE ENGINEERING
SURVEY
SUBSTATION FOUNDATION
SITE WORK & CLEAN-UP
BUILDING DESIGN
FOUNDATION DESIGN FOR SUBSTATION & COOLING TOWER
COOLING TOWER FOUNDATION
T/G PEDESTAL DESIGN
STEEL PROCUREMENT
DESIGN TANK FOUNDATIONS AND PIPE AND MISC. SUPPORTS
MISC. PIPE SUPPORTS AND TANK FOUNDATION
DESIGN BRIDGE CRANE
CERT. DWGS.
FABRICATE BRIDGE CRANE
TRANSPORT INSTALL
FOR EQUIPMENT INSTALLATION
PRELIM. PWR. PLT. LAYOUT
EXCAVATION & POWER PLANT SHELL
POUR CONCRETE FOR GROUND, MEZZANINE AND OPERATING FLOORS
132KV TRANSMISSION LINE
POUR CONCRETE FOR TURBINE PEDESTAL
PRELIMINARY DESIGN
DESIGN
TENDERING
PROCURE & FABRICATE
EXPRESS TRANSPORT
PROCURE FIRE PUMPS
PROCURE & FAB. SPRINKLER SYSTEM
PROCURE & FAB. GAS SYSTEM
PROCURE & FAB. FIRE PROTECT. INSTR.
PROCURE & FAB. PROCESS INSTR.
POWERHOUSE STEAM REQUIREMENTS FOR 30MW
HIGH PRESSURE 203,100 KG/HR @ 7.7KG/CM² ABS
LOW PRESSURE 70,500 KG/HR @ 2.1 KG/CM² ABS
POWERHOUSE STEAM REQUIREMENTS FOR 60 MW
HIGH PRESSURE 406,200 KG/HR @ 7.7KG/CM²
LOW PRESSURE 141,000 KG/HR @ 2.1 KG/CM²
FABRICATE COOLING TOWER & EQUIPMENT
ERECT
CHECKOUT
PROCURE & FAB. COOLING WATER SYSTEM
HYDRO-TEST
MANUFACTURE PUMPS
FABRICATE SOLE PLATE PATTERN
T/G SPECS
BID REQUEST
PROPOSAL EVALUATION
MANUFACTURE AND TEST TURBINE/GENERATOR UNIT NO. 1
MANUFACTURE AND TEST TURBINE/GENERATOR UNIT NO. 2
ACCEPTANCE TESTS
TEST
COMMERCIAL OPERATION
INSTALL & TEST
FAB. SOLE PLATE PATTERN
CONDENSATE & NON-CONDENSATE LINES & FITTINGS
DESIGN & CERT. DWGS.
PROCURE & FABRICATE
FABRICATE CONDENSER
HYDRO TEST
FABRICATE PUMP CANS
AIR TRANSPORT
MANUFACTURE HOT WELL PUMPS
INSTALL AND HYDRO TEST
MANUFACTURE & TEST COLD START/EMERGENCY GENERATOR
INSTALL & CONN
CHECK OUT
MANUFACTURE & TEST MAIN TRANSFORMERS
MANUFACTURE & TEST 132 KV SUBSTATION EQUIPMENT
INSTALL & CONN.
MANUFACTURE & TEST 400V & 132 KV SUBSTATION EQUIPMENT
CERT. DWGS. & MANUFACTURE CONTROL ROOM PANELS
INSTALL & CONNECT
MANUFACTURE & TEST
PHASE A
T/G PURCHASING CONDITIONS & BID EVALUATION
PHASE B
PROJECT PLANNING REPORT
PHASE C
PURCHASING CONDITIONS & BID EVALUATION OF OTHER COMPONENTS & MATERIALS
PHASE D
ENGINEERING & SUPERVISION AS REQUIRED
ACTIVE EVENT
COMPLETED
CRITICAL PATH-STATUS
NON-CRITICAL PATH
INTERCONNECTING ACTIVITY
FLOAT TIME
4 WEEKS FOR ACTIVITY
DESIGN-MFG DWGS.
FINAL DESIGN & PREPARE SPECS. 4 WEEKS
BID REQUEST & RECEIPT 4 WEEKS
BID EVALUATION & CONTRACT AWARD 2 WEEKS
CERTIFIED DRAWING APPROVAL 10 WEEKS
TRANSPORT
SHIP TO HÚSAVIK, ICELAND 7 WEEKS
TRANSFER TO KRAFLA 1 WEEK
(UNLESS EXPRESS TRANSPORTATION IS REQUIRED)
REFERENCE DRAWINGS
REVISION
FINAL REPORT ISSUE
ISSUED FOR PRELIMINARY REPORT
PROJECT PLANNING REPORT SCHEDULE
CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND
SCALE NONE
DATE 28 FEB. 1975
KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND
KRAFLA GEOTHERMAL PROJECT
APPROVALS
KRAFLA GEOTHERMAL POWER PLANT
MAJOR ACTIVITY SCHEDULE
(100 WEEK TARGET OPERATING SCHEDULE)
JOB NO. S74028
A1-07-004
B



REV.	DATE	REVISION	DR.	CHK.
B	4/11/75	REDRAWN REARRANGED FINAL REPORT ISSUE	G.L.	M.O.
A	3/3/75	FORMERLY E-17-001-A ISSUED FOR PRELIMINARY REPORT		KIRK

REFERENCE DRAWINGS

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE NONE DATE 4/10/75
DR. G.F.L. CHK. M.O. ENG. W.S. APPROVED

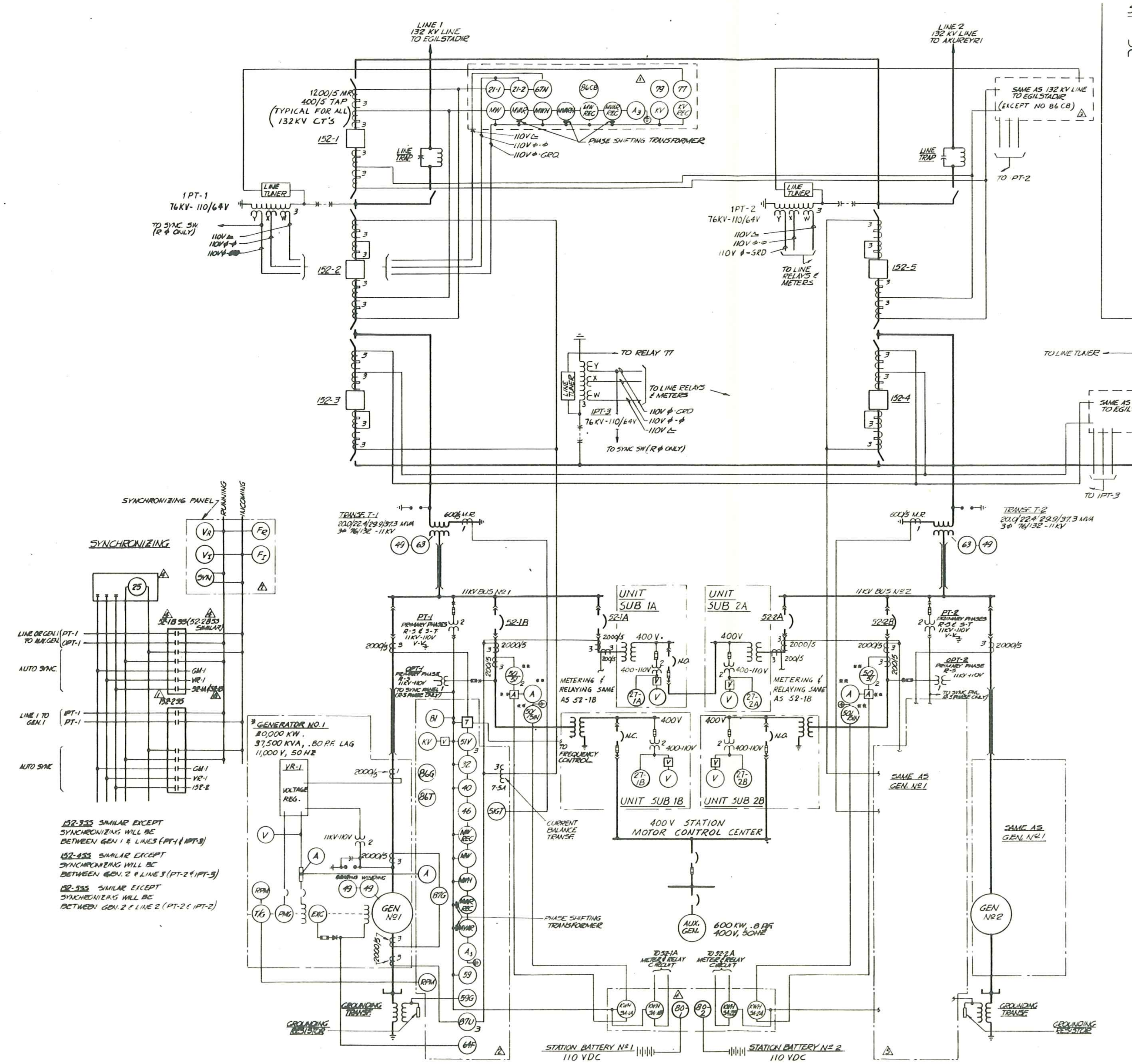
KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND

KRAFLA GEOTHERMAL PROJECT

APPROVALS

KRAFLA GEOTHERMAL POWER PLANT
SINGLE LINE POWER DIAGRAM

JOB NO. S-74028 AI-08-001 B



SYMBOLS (CONTINUED)

GROUNDED WYE CONNECTED TRANSFORMER DELTA CONNECTED

SYMBOLS

METER, RELAY OR DEVICE

A	AMMETER - 1φ (A3 INDICATES 3-φ)
EXC	EXCITER
F	FREQUENCY METER
KV	KILOVOLT METER
KV/REC	RECORDING KILOVOLT METER
KWH/SA	KILOWATTHOUR METER - STATION AUXILIARY
MVAR	MEGAVAR METER
MVARH	MEGAVAR-HOUR METER
MVAR/REC	RECORDING MEGAVAR METER
MW	MEGAWATT METER
MWH	MEGAWATT HOUR METER
MWH/SA	MEGAWATT HOUR METER - STATION AUXILIARY
MW/REC	RECORDING MEGAWATT METER
PMG	PERMANENT MAGNET GENERATOR
RPM	TACHOMETER
SYN	SYNCHROSCOPE
T/G	TACHOMETER GENERATOR
V	VOLTMETER
21-1	ZONE 1 DISTANCE RELAY - 3φ
21-2	ZONE 2 DISTANCE RELAY - 3φ
25	AUTO SYNCHRONIZING RELAY
27	AC UNDERVOLTAGE RELAY
32	DIRECTIONAL POWER RELAY 3φ
40	FIELD EXCITATION RELAY - 3φ
46	PHASE BALANCE RELAY (NEGATIVE SEQUENCE)
49	THERMAL RELAY
50/51	PHASE OVERCURRENT RELAY - TIME & INSTANTANEOUS
51V	PHASE OVERCURRENT RELAY WITH VOLTAGE RESTRAINT
50/51N	RESIDUAL GROUND OVERCURRENT RELAY - TIME & INSTANTANEOUS
51GT	GROUND OVERCURRENT RELAY
51N	RESIDUAL GROUND OVERCURRENT RELAY
59	AC OVERVOLTAGE RELAY
59G	GENERATOR GROUND FAULT RELAY (OVERVOLTAGE)
63	BUCHHOLZ RELAY
64F	FIELD GROUND RELAY
67N	DIRECTIONAL GROUND RELAY
77	PULSE TRANSMITTER
79	RECLOSING RELAY
80	DC UNDERVOLTAGE RELAY
81	UNDERFREQUENCY RELAY
86CB	CIRCUIT BREAKER LOCKOUT RELAY
86G	GENERATOR LOCKOUT RELAY
86T	TURBINE LOCKOUT RELAY
87G	DIFFERENTIAL RELAY - GENERATOR - 3φ
87U	DIFFERENTIAL RELAY - UNIT - 1φ

OIL CIRCUIT BREAKER

AIR CIRCUIT BREAKER - DRAWOUT TYPE
- DUMMY
- WITH CURRENT LIMITING FUSE

CURRENT TRANSFORMER
- BUSHING TYPE

BROKEN DELTA POTENTIAL TRANSFORMER CONNECTION

POTENTIAL TRANSFORMER
- DRAWOUT TYPE WITH PRIMARY FUSE
- WITH PRIMARY FUSE

MOLDED CASE CIRCUIT BREAKER
- WITH CURRENT LIMITING FUSE

V-V OPEN DELTA WITH GROUNDED SECONDARY

CAPACITANCE POTENTIAL DEVICE WITH POTENTIAL TRANSFORMER.

LIGHTNING ARRESTER

SURGE PROTECTIVE DEVICE

BUS DUCT

GROUND — SWITCHBOARD GROUND

AMMETER SWITCH

VOLTMETER SWITCH

DENOTES EQUIPMENT LOCATED ON SWITCHBOARD IN CONTROL ROOM. NUMBER INDICATES SWITCHBOARD SECTION

WATTS TRANSDUCER

φ PHASE

* DENOTES EQUIPMENT PROVIDED BY GENERATOR MANUFACTURER

** DENOTES EQUIPMENT LOCATED ON 11 KV SWITCHGEAR

℄ CENTERLINE

NOTE

1. INSTRUMENT TRANSFORMERS ARE CONNECTED GROUNDED WYE EXCEPT AS NOTED.
2. 86G & 86T RELAYS EACH OPEN AND LOCKOUT 2 132KV AND 2 11KV CIRCUIT BREAKERS. 86CB RELAYS EACH OPEN & LOCKOUT 2 132KV CIRCUIT BREAKERS.

ROTATION

R S T

ABBREVIATIONS

AC	ALTERNATING CURRENT
AUTO	AUTOMATIC
AUX	AUXILIARY
B/M	BILL OF MATERIAL
BRKR.	BREAKER
CKT.	CIRCUIT
CONT	CONTROL
DC	DIRECT CURRENT
DIFF.	DIFFERENTIAL
DIRECT.	DIRECTIONAL
DWG.	DRAWING
EQUIP.	EQUIPMENT
FREQ.	FREQUENCY
GEN	GENERATOR
GM	GOVERNOR MOTOR
GOV	GOVERNOR
GRD	GROUND
HZ	HERTZ
KV	KILOVOLT
MAN	MANUAL
M/A	MANUAL/AUTOMATIC
MFR	MANUFACTURER
MR.	MULTI-RATIO
MW	MEGAWATT
N.T.S.	NOT TO SCALE
OVERCUR.	OVERCURRENT
P.F.	POWER FACTOR
PNL	PANEL
PROTECT	PROTECTIVE
P.T.	POTENTIAL TRANSFORMER
REC	RECORDER OR RECORDING
REG	REGULATOR OR REGULATING
R/L	RAISE/LOWER
RLY	RELAY
SS	SYNCHRONIZING SWITCH
SYNC	SYNCHRONIZING
SUB	SUBSTATION
TRANSF.	TRANSFORMER
TRANSM.	TRANSMITTER
V	VOLT
VOLT	VOLTAGE
VR	VOLTAGE REGULATOR

REFERENCE DRAWINGS	REV.	ZONE	DATE	REVISION	DR.	CHK	APPR RECO	APPR.
	B			FINAL REPORT ISSUE	TWJ			
	A			ISSUED FOR PRELIMINARY REPORT	KT			

CONSULTING ENGINEERS
ROGERS ENGINEERING CO., INC.
SAN FRANCISCO, CALIFORNIA
THORODDSEN AND PARTNERS
REYKJAVIK, ICELAND

SCALE NONE DATE 10 APRIL 75
DR. K.T. CHK. H.L. ENG. RAE. APPROVED

KRÖFLUNEFND
KRAFLA PROJECT EXECUTIVE COMMITTEE
AKUREYRI, ICELAND

KRAFLA | **GEOTHERMAL PROJECT**

APPROVALS
DATE
DATE
DATE

KRAFLA GEOTHERMAL POWER PLANT
SINGLE LINE
METER AND RELAY DIAGRAM

JOB NO. S-74028 | A1-08-002 | B