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IDO-19030
CEND-135
Vol. I of VI
PLANT DESIGN

PL FINAL DESIGN REPORT

June 30, 1961

Contract AT-(10-1)-967
U. S. ATOMIC ENERGY COMMISSION

NUCLEAR DIVISION
C·E COMBUSTION ENGINEERING, INC.

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Approved:

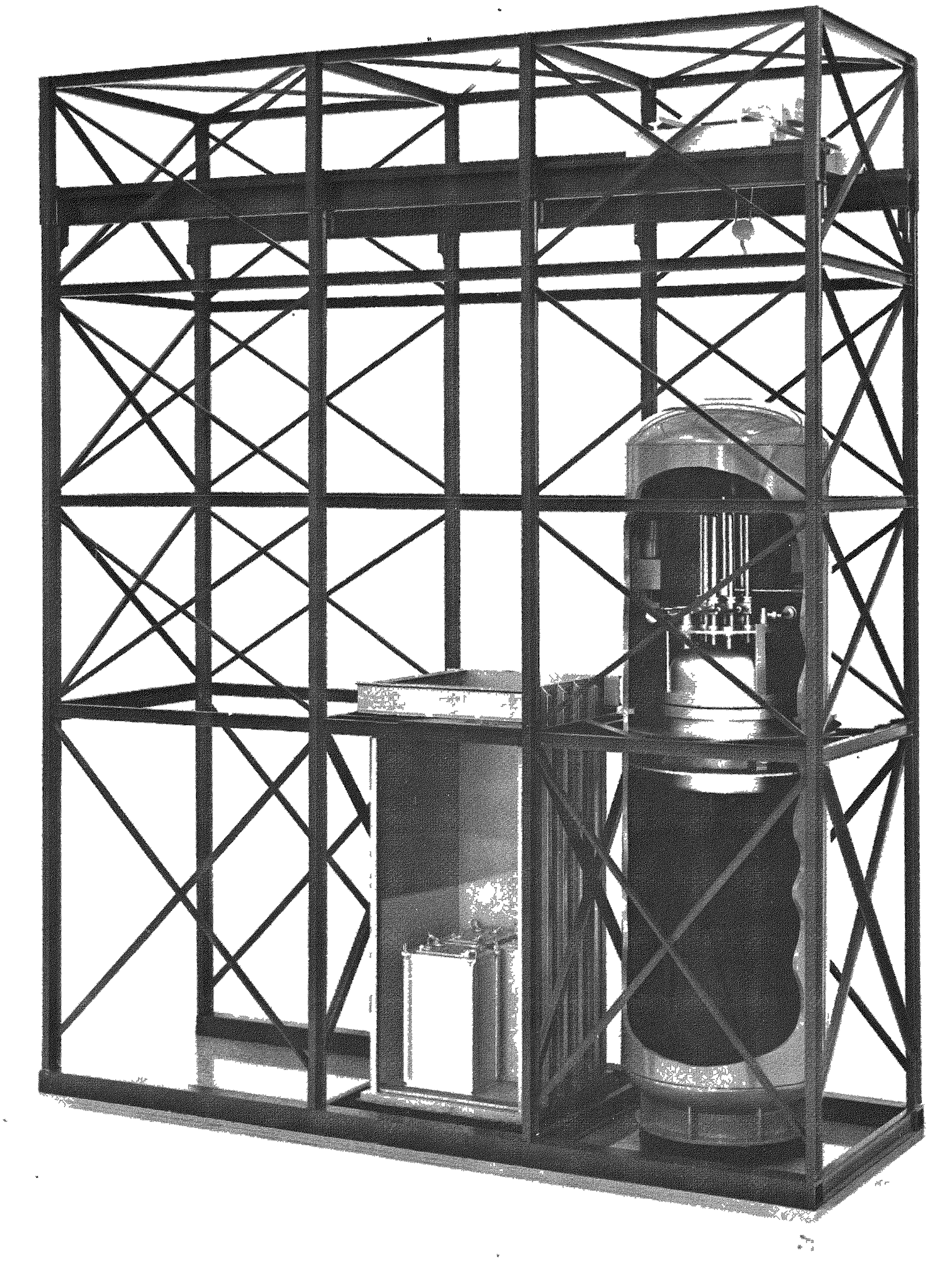
____

B. Gitlow
Supervisor, Plant Design

____

Varick Schwartz
Ass't ABWR Project Manager

COMBUSTION ENGINEERING, INC.
Windsor NUCLEAR DIVISION Connecticut



PL 2 REACTOR COMPLEX ASSEMBLY

FOREWORD

This is Volume I of a six volume Final Design Report for PL-2, a 1000 KW net electric direct cycle boiling water nuclear power plant. PL-2 is one of a series of boiling water reactor plants in the Army Boiling Water Reactor Program, and has been designed for installation in a snow tunnel at Byrd Station, Antarctica.

This report is an account of work performed under contract AT(10-1)-967 between the U. S. Atomic Energy Commission and Combustion Engineering, Inc. The six volumes are:

Volume I	Plant Design
Volume II	Plant Drawings
Volume III	Plant Equipment Specifications
Volume IV	Reactor Design
Volume V	Core Drawings and Specifications
Volume VI	Plant Performance Analysis

Volumes I through V are dated June 30, 1961. Volume VI will be issued at a later date.

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ATTN: Associate Director
Reactor Projects Division

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INTRODUCTION

On December 10, 1953, The Joint Chiefs of Staff established development requirements for nuclear power plants to supply heat and power at remote, relatively inaccessible military installations. Principal objectives are air transportability and minimum erection time. The use of nuclear power at such installations results in a reliable power source which is not dependent on continuous logistic support.

At many installations the use of nuclear power results in significant economic savings when compared to plants using conventional fuels. The single most significant factor in the economic comparison is the delivered cost of conventional fuel.

The Army Boiling Water Reactor (ABWR) Program was established to develop boiling water reactor plants to meet this application. The natural circulation boiling water reactor concept offers an opportunity for significant reductions in over-all system complexity when compared with pressurized water plants. The pressurized water plant is the more tested concept, largely as a result of its application to the naval reactors program.

The SL-1 was the first operational plant in the ABWR Program. The SL-1 operated at power for 9,819 hours at an average power level of 2.3 MW thermal. Operation of SL-1 answered several important questions with regard to the operation of a small direct cycle boiling water reactor plant. Operation and maintenance of the plant was performed without radiation hazard to the operating crew or environment. The maximum annual exposure of crew members was much less than the limits currently established in the Army Nuclear Power Program. The exposure period included a major plant inspection program during which the main turbine shell was opened for inspection. There was no significant activation of steam plant components which could interfere with maintenance operation. Automatic control of reactor pressure by rod motion proved to be an effective and reliable means of maintaining constant throttle pressure during power demand transients. Direct steam to air condensing was demonstrated; the concept of recirculating a portion of the hot exhaust air to temper the incoming air was entirely satisfactory.

The SL-1 aluminum core did not adequately meet the requirements of the ABWR Program. An oxide pellet core in stainless steel tubing has been designed for PL application. This core is conservatively designed and relies on proven methods of fabrication for power reactor cores. Production tooling and fabrication process have been developed through the fabrication of three production lead assemblies. The control rod blades are stainless steel clad Ag-In-Cd cruciforms. A prototype control rod has been fabricated. All design tolerances and requirements were achieved. An improved rack and pinion control rod drive has been designed, fabricated and has completed dry scram testing. Production fuel rods are being fabricated for use in critical experiments which are scheduled to begin in November 1961. This development work is covered in detail in Volumes IV and V of this final design report.

The air cooled condenser at SL-1 while functionally adequate did not meet design rating, was difficult to ship, and required extensive field erection. To permit high power testing of the SL-1 core and ultimately full power tests of PL type cores, an additional heat dump loop of approximately 4 MW (t) capacity was added to the SL-1. The main heat exchanger in this loop was a PL type air cooled steam condenser and subcooler. This unit successfully completed a design test program. The results of these tests are published in IDO-19031, "PL-2 Condenser Evaluation Report".

The two most difficult site applications are installation of the reactor plant on permafrost underburden and in a snow tunnel. Installation of the steam plant is difficult but relatively straightforward. Installation of the nuclear steam generating system is a difficult problem which requires extensive design development to obtain a practical and workable design which meets the requirements of air transportation and field erection without heavy construction equipment. Shield design must consider the effect of heat generated by radiation on the foundation of snow or permafrost. It is in this area of design that the advantages of Boiling Water Plants are most apparent. The addition of a containment requirement resulted in a very compact but high pressure containment vessel for the ABWR plant. The containment vessel is air transportable and provided with a bolted closure. No field welding is required.

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I SUMMARY

The PL-2 is a direct cycle, natural circulation boiling water nuclear power plant. It is designed to deliver 1000 kw (e) net electric power and 1,365,000 BTU/hr of net thermal power for process and space heating. The plant machinery is arranged in air transportable factory assembled and tested modules.

This final design is based on installation of PL-2 in a snow tunnel at Byrd Station, Antarctica. The PL-2 is contained in a single, high-pressure containment vessel which is shipped in two air transportable sections.

Erection of the PL-2 does not require heavy construction equipment. It is assumed that one or two D-8 tractors will be available.

Complete liquid and gaseous waste disposal facilities are provided which will process all plant effluent so that the stringent requirements of the Antarctic treaty are complied with.

The PL-2 design includes all buildings, foundations and structures required for the installation of the plant in a snow tunnel. The only service required by the plant is a supply of raw water.

The simplicity of the natural circulation boiling water plant has made possible and extremely compact reactor installation (see frontispiece). All the machinery required for the generation of steam is contained within the single containment vessel. Feed water is supplied and steam is delivered at 600 psig dry and saturated. The containment vessel is supported by a short skirt which is integral with the bottom head. The lower half of the containment vessel serves as the primary shield tank. Stainless steel canned lead shield rings also serve as the support for the reactor vessel. A bottom supported spent fuel tank is provided to facilitate refueling and storage of spent fuel. Bottom support of the major equipment directly on a timber foundation mat has reduced the structure so that it may be erected without heavy construction equipment. Specifically, no external crane is required.

The shield design is a key element in the application of nuclear power for snow tunnel installations. The compact nature of the boiling water reactor is particularly advantageous in permitting an efficient shield design which will permit safe access to the reactor complex after shutdown for maintenance and refueling. Radiation heating of the snow has been reduced to a level which will not

significantly affect foundation stability.

The structural design described in the report is based on standard structural steel shapes. This structure has been redesigned using built-up aluminum members which results in a structure weight about half of that required for steel at no appreciable change in cost. More significantly, almost all of the structural members can be handled in the field by two men without the aid of chain falls or tackle of any kind. The erection of the reactor complex and installation of equipment is described in detail in the Arrangement Section of this volume.

Steam generated in the reactor vessel at 600 psig, is discharged through a 4-inch main steam line to a geared turbine-generator set rated at 1250 Kw gross. Turbine exhaust steam is discharged to two air-cooled condensers through a 14" turbine exhaust line. Subcooled condensate drains to a hot well. One of two installed motor driven condensate pumps discharge to an auxiliary cooling water supply header which supplies cooling water (condensate) to the various plant auxiliary heat exchangers. These heat exchangers discharge to the reserve feed tank through a common return header. A three-way valve in this header is automatically controlled by level in the reserve feed tank to return a portion of the condensate to the sub-cooling section of the main condensers so that adequate cooling water is available for auxiliary cooling under all conditions of plant load. One of two installed feed pumps return feedwater to the reactor. All vital pumps are provided with installed spares. These spare units are automatically started in the event of interruption of service to the operating unit. The plant systems are described in detail in the Mechanical System Section of this volume.

The PL-2 delivers 1000 Kw net electric power to an external bus. An additional 250 Kw is available to operate all the power plant equipment. The maximum power plant requirements are about 220 Kw. Power is distributed to the plant through wall mounted bus ducts. At each equipment module, two plug-in circuit breakers are provided. Plug-in feeder cables provide two independent power circuits to each module. A transfer switch permits equipment which is not duplicated to receive power from either circuit. Control and instrument wiring is carried in multiconducter cables between the plant control console and the equipment modules. Two control cables and two instrument cables are required for each module. All the electrical field connections are made by polarized multipin cable connectors thus preventing incorrect field connections.

Emergency power is supplied from a D.C. bus. Power to the D.C. bus is normally supplied by the main or auxiliary generator through twin static rectifier regulators. A bank of nickel-cadmium batteries which float on this bus pick-up all vital loads if A.C. power is interrupted; this assures a smooth transient free power supply for the following vital services: nuclear and process instrumentation, control rod drive supply power, circuit breaker control and radiation monitoring, without the action of mechanical switches or relays. Twin static inverters provide vital A.C. power from the D.C. bus.

An auxiliary diesel generator is provided to supply plant electric power requirements whenever the turbine-generator is not available. This unit will start automatically on reduction of generator bus voltage. Power may also be received from the station back-up diesel through the station bus.

All components of the PL-2 can be relocated by air after extended operation except the lower half of the containment vessel with the lead shielding and the reactor vessel with the head removed. This remaining equipment must be moved by sled. It will, however, be adequately shielded to reduce radiation from activated components. The low center of gravity of this unit will facilitate transportation.

Please note that the <u>curves</u> and <u>photographs</u> referred to in this text can be found at the end of this volume. The <u>figures</u> referred to are in Volume II.

II PL-2 PLANT DATA

A. Reactor:

Thermal Power	7.48 MW
Core Lifetime, full power years	3
Maximum Burnup, MWd/metric ton of U	33,000
Average Burnup, MWd/metric ton of U	7,650
Steam Production	23,143 lbs./hr.
Operating Pressure	600 psig
Operating Temperature	489°F
Feedwater Enthalpy	126.6 Btu/lb.

B. Electrical:

Net Output	1000 KW
Voltage	480Y/272
Frequency	60 cycles
Phase	3
Power Factor	0.8
Standby Power (diesel-generator)	200 KW

C. Environmental:

Ambient Temperature	60 to -125°F
Wind Velocity (Sustained)	125 Knots
Altitude	0-10,000 ft.

D. PL-2 Core Numerical Data:

1. Fuel Element

Fuel Composition	UO_2
Fuel Loading, Metric Tons U	1.14
Fuel Enrichment	4.8%
UO_2 Pellet Diameter	0.420 inches
UO_2 Pellet Density	10.50 gm/cm^3
Clad Material	AISI 348 SS
Clad Thickness	0.020 inches
Fuel Tube Inner Diameter	0.426 inches
Number of Fuel Tubes Per Assembly	59
Number of Poison Rods Per Subassembly	3
Number of Fuel Elements in Core	1416
Number of Poison Rods in Core	72

2. Core Geometry:

Equivalent Core Diameter	36.3 inches
Active Core Length	38.3 inches
Number of Assemblies	24
Fuel Assembly Width	5.590 inches (sq.)
Fuel Assembly Length	47.86 inches
Tube Spacing (pitch)	0.732 inches
Riser Height	3 feet

3. Control:

Number of Rods	9
Rod Type	Cruciform
Overall Length	53.768 inches
Overall Span	11.44 inches
Overall Thickness	0.250 inches
Length of Travel	38.4 inches
Control Material	AG-In-Cd
Clad Material	AISI 348 SS
Length of Active Section	40.125 inches
Span of Active Section	10.578 inches
Thickness of Active Section	.135 inches

4. Thermal and Hydraulic: (Based on reactor design output of 8.5 MW)

Average Power Density, KW/liter of Active Core	13.75
Average Power Density, KW/liter of Coolant in Active Core	21.0
Heat Transfer Area	551 ft^2
Average Heat Flux	52,600 Btu/hr-ft^2
Maximum Heat Flux	281,000 Btu/hr-ft^2
Burnout Heat Flux	1,300,000 Btu/hr-ft^2

E. Main Steam System:

Total Steam Flow	23,143 lb/hr.
Steam Pressure	600 psig
Steam Temperature	489°F
Turbine-Generator Steam Flow	20,920 lb/hr.
TG Steam Inlet Pressure	585 psig
TG Steam Exhaust Pressure	8" Hg. Abs.
Space Heat Exchanger Steam Flow	1743 lb/hr.
Space Heat Exchanger Steam Pressure	25 psig
Heat Transferred in Space Heat Exchanger	1.715×10^6 Btu/hr
Air Ejector Steam Flow	360 lbs/hr.
Air Ejector Steam Pressure	150 psig
Service Water System Evaporator Steam Flow	70 lbs/hr.
Service Water System Evaporator Steam Pressure	150 psig
Turbine Seal Steam Pressure	2-3 psig

F. Condensate System:

Air Cooled Condenser and Subcooler	19,811 lbs/hr.
Steam Flow	21,068 lbs/hr.
Steam Pressure	8" Hg. Abs.
Steam Temperature, In	152°F
Condensate Temperature, Out	92°F
Condensate Recirculated	3,472 lbs/hr.
Condensate Recirculation Temperature	143°F
Air Flow (Two Units)	2.88×10^5 CFM @ 50°F and 6000 ft.
Air Temperature, In	50°F
Heat Transferred (Two Units)	19.40×10^6 Btu/hr.
Number of Fans (Two Units)	8
H.P. per Fan	20
Fan Head	1.77" H_2O @ STP
Precooler and After Condenser	
Motive Steam Flow	360 lbs/hr.
Motive Steam Pressure	150 psig
To Precooler	
Steam	55.4 lbs/hr.
Air	23 lbs/hr.
Temperature	190°F
From Precooler	
Steam	3.2 lbs/hr.
Air	23 lbs/hr.
Condensate	52.2 lbs/hr.
Temperature	120°F
To After Condenser	
Steam	389 lbs/hr.
Air	28.8 lbs/hr.
Decomposition Gases	1.2 lbs/hr.
From After Condenser	
Condensate	383.7 lbs/hr.
Temperature	140°F
Vent	
Steam	5.4 lbs/hr.
Air	28.8 lbs/hr.
Decomposition Gases	1.2 lbs/hr.
Temperature	140°F
Coolant	
Flow Rate	10,000 lbs/hr.
Temperature, In	100°F
Temperature, Out	147°F
Heat Transferred	473,700 Btu/hr.

Hotwell	
Condensate Flow	23,262 lbs/hr.
L.P. Drain Cooler Flow	6662.8 lbs/hr.
Condensate Pumps	
Capacity	65 GPM
Suction Pressure	8" Hg. Abs.
Discharge Pressure	40 psig
Total Head	47.8 psig
Condensate Temperature	100°F
Motor Horsepower	5

G. <u>Feedwater System</u>:

Reserve Feed Tank	
Condensate Flow	23,393 lbs/hr.
Condensate Temperature	143°F
Feedwater Recirculation Flow	2300 lbs/hr.
Feedwater Pumps	
Capacity	54 GPM
Suction Pressure	0 psig
Discharge Pressure	700 psig
Feedwater Temperature	143°F
Motor Horsepower	60

H. <u>Purification System</u>:

First Stage Heat Exchanger	
Purification Flow	1488 lbs/hr.
Temperature, In	489°F
Temperature, Out	220°F
Coolant Flow	1488 lbs/hr.
Coolant Temperature, In	120°F
Coolant Temperature, Out	400°F
Heat Transferred	426,000 Btu/hr.
Second Stage Heat Exchanger	
Purification Flow	1488 lbs/hr.
Temperature, In	220°F
Temperature, Out	120°F
Coolant Flow	1855 lbs/hr.
Coolant Temperature, In	100°F
Coolant Temperature, Out	180°F
Heat Transferred	149,000 Btu/hr.
Demineralizer	
Purification Flow	1488 lbs/hr.
Water Temperature	120°F
Resin Capacity	2.8 ft^3

Purification Pumps	
Type	Canned rotor
Capacity, Normal Flow	3 GPM
Suction Pressure	599 psig
Discharge Pressure	641 psig
Water Temperature	120°F
Motor Horsepower	1.5
Eductor	
Motive Water	7.2 GPM
Lift Water	5 GPM
Total Operating Head	155 ft.
Motive Water Temperature	120°F
Lift Water Temperature	170°F
Total Discharge Head	35 ft.
NPSH	13.7 ft.

I. Shield Cooling System:

Shield Cooler	
Coolant Flow	7,150 lbs/hr.
Coolant Temperature, In	100°F
Coolant Temperature, Out	141°F
Heat Transferred	290,000 Btu/hr.

J. Raw Water Purification System:

Makeup Water Storage	95 gals.
Makeup Water Pump	
Capacity	5 GPM
Suction Pressure	9.8 psia
Discharge Pressure	34.0 psia
Motor Horsepower	0.50
Raw Water Demineralizer	
Flow Rate	5 GPM
Water Temperature	40 - 70°F
Resin Capacity	3.0 cu. ft.

K. Lube Oil Cooling System:

L.O.System Intercooler	
Fluid Flow	6690 lbs/hr.
Fluid Temperature, In	140°F
Fluid Temperature, Out	115°F
Coolant Flow	5860 lbs/hr.
Coolant Temperature, In	100°F
Coolant Temperature, Out	128°F
Heat Transferred	167,000 Btu/hr.

L.O. Cooler	
Lube Oil Flow	14,624 lbs/hr.
L.O. Temperature, In	155°F
L.O. Temperature, Out	130°F
Coolant Flow	6690 lbs/hr.
Coolant Temperature, In	115°F
Coolant Temperature, Out	140°F
Heat Transferred	167,000 Btu/hr.
Lube Oil Coolant Pump	
Capacity	15 GPM
Head	25 psig
Fluid Temperature	115°F
Motor Horsepower	0.50

L. HP Drain System:

Capacity, Normal Operating	120 lbs/hr.

M. Low Pressure Drain System:

L.P. Drain Eductor	
Motive Water	10.2 GPM
Lift Water	12 GPM
Total Operating Head	69.6 ft.
Lift Water Temperature	142°F
Motive Water Temperature	112°F
Total Discharge Head	8.5 ft.
NPSH	2 ft.
L.P. Drain Cooler	
Coolant Flow	3060 lbs/hr.
Temperature, In	100°F
Temperature, Out	112°F
Heat Transferred	36,590 Btu/hr.

N. Plant Heating System:

Operating	
Air Flow to Plant	1600 cfm
Ambient Temperature	0°F (tunnel)
Room Temperature	60°F
Heat Transferred	1.715×10^6 Btu/hr.
Space Heating Supplied	1.365×10^6 Btu/hr.
Plant Heating Supplied	0.350×10^6 Btu/hr.

Shutdown	
Air Flow to Plant	3260 cfm
Ambient Temperature	$0^{o}F$ (tunnel)
Room Temperature	$60^{o}F$
Heat Transferred	1.913×10^{6} Btu/hr.
Space Heating Supplied	1.365×10^{6} Btu/hr.
Plant Heating Supplied	0.548×10^{6} Btu/hr.
Space Heat Exchanger	
Steam Flow	1743 lbs/hr.
Steam Temperature, In	$294^{o}F$
Condensate Flow, Out	1743 lbs/hr.
Condensate Temperature, Out	$250^{o}F$
Vent Flow	Negligible
Coolant Water Flow	56,825 lbs/hr.
Coolant Temperature, In	$190^{o}F$
Coolant Temperature, Out	$220^{o}F$
Heat Transferred	1.715×10^{6} Btu/hr.
Plant Heating Pump	
Capacity	38 GPM
Suction Pressure	30 psig
Discharge Pressure	56 psig
Fluid Temperature	$190^{o}F$
Motor Horsepower	0.75

O. <u>Service Water System</u>:

Demineralizer	
Flow	2500 lbs/hr.
Water Temperature	$120^{o}F$
Resin Capacity	2.8 cu. ft.
Evaporator	
Capacity	200 GPD
Overhead Purity	Not more than 1×10^{-8} μc/cc
Bottom Solids Concentration	Not less than 30% solids by weight
Overhead Condensate Temperature to Storage	$120^{o}F$
Drain Tank Pump	
Type	Centrifugal
Capacity	5 GPM
Suction Pressure	Atm
Discharge Pressure	29.4 psig
Fluid Temperature	$40 - 200^{o}F$
Motor Horsepower	0.5

Waste Tank Pump	
Type	Sump
Capacity	2 GPM
Suction Pressure	Atm
Discharge Pressure	14.2 psig
Fluid Temperature	40 - 200^{o}F
Motor Horsepower	0.5

P. Shipping (Snow Tunnel)

	Plane Loads		
	Now	Was	Change
Containment	2	0	+2
Primary System (Nuclear Steam Generator) Reactor Vessel Shielding Control Rod Drives Control Rod Actuators Instrument Wells Interconnecting Pipe and Cable	5	3	+2
Core Servicing Spent Fuel Tank & Refueling Crane 3 Spent Fuel Casks & Refueling Plate Transfer Cask	5	5	0
Heat Rejection System 2 Condensers 2 Louver Assemblies	3	3	0
Purification Waste Disposal Gas Handling (Includes Decontamination Skid) Purification Skid & 1 Demineralizer	2	1	+1
Power Conversion Equipment Feed & Condensate Skid Turbine Generator Skid Generator & Second Demineralizer Electrical Skid Interconnecting Pipe & Cable	5	5	0
Utilities & Services Aux. Diesel, Aux. Boiler, Fire Protection	1	1	0
Total	23	18	5
Foundations, Structures Steel, & Enclosures	14	16	-2

III. PLANT DESIGN

A. ARRANGEMENT

The Pl-2 plant is designed for installation in a snow tunnel at an inland Antarctic site.

The general arrangement of the plant, Figure 1, consists of two parallel tunnels, the reactor complex tunnel and the equipment tunnel, separated by fifty feet of undisturbed snow and connected by a small access tunnel which contains interconnecting piping and wiring.

The reactor complex tunnel has an access ramp at the end away from the reactor.

The reactor complex tunnel contains the Reactor Complex Building and structure, Figures 2, 3 and 5. A ladder with safety cage will allow access to the reactor structure from the connecting tunnel.

The equipment tunnel contains the Condenser Building, Figure 71, the Power Plant Building, Figure 84, the Personnel Building, Figure 97, and the Service Building, Figure 99. The charcoal adsorption beds, Figure 198, are located in the tunnel adjacent to the Condenser Building at the ramp end of the tunnel. The fire protection system is located between the Condenser Building and the Power Plant Building.

The depths of both the reactor complex tunnel and the equipment tunnel have been established to provide an initial clearance of seven feet minimum between the top of the buildings and the tunnel roof arch.

The entire PL-2 plant including all necessary installation equipment can be transported in preassembled modules by C-130 aircraft operating under Antarctic conditions. The number of plane loads and the total weight of equipment to be transported have been held to a minimum.

Entrance to the reactor complex tunnel is made by means of an access ramp leading into the empty bay of the reactor structure. The equipment tunnel is entered through an access ramp adjacent to the Condenser Building. A small access tunnel connects the equipment tunnel to the main camp tunnel. Emergency escape hatches are provided near each end of the Power Plant Building. The hatches are offset from the main tunnel and consist of spiral stairwells projecting several feet above the snow surface, and connected at the base to the equipment tunnel by means of small access tunnels.

The plant, other than buildings, foundations and supporting structures, is capable of being installed in a single Antarctic construction season.

1. Reactor Complex

The reactor complex, Figures 2 and 3, contains the steel structure, Figure 5, the reactor containment installation, Figure 6, and the spent fuel tank, Figure 64.

The Reactor Complex Building is a steel structure enclosed with insulated prefabricated Arctic panels providing a 14 foot x 12 foot open bay at the floor level as a working and storage area.

A 15-ton overhead electrical traveling bridge crane is provided for use both during construction and for the refueling operation. A large 10 foot x 16 foot door at the ramp end of the building is provided for bringing sleds with shipping casks into the enclosed structure and for removing the top portion of the containment vessel during the refueling.

An operating level platform allows access to the equipment and a working level for the control of the crane. The floor of the building consists of 4-inch tongue and groove hardwood planking serving two purposes. It provides a flooring which supports the Reactor and Containment Vessels, the Spent Fuel Tank, the Refueling Index Plate, and heavy transfer and shipping casks; it also acts as an insulation blanket to maintain temperatures above $+50^{\circ}F$ inside the building, while the tunnel temperatures are well below zero. The bottom level of structural steel supporting the building will be fastened to the flooring.

The foundation for the Reactor Complex Building, Figure 4, consists of three separate timber mats. The main foundation mat supports the Reactor and Containment Vessels, the Spent Fuel Tank and the six adjacent columns of the structure. The center of the mat has been positioned so that the initial loading of three or six shipping casks in the Spent Fuel Tank will not result in an excessively eccentric foundation loading. The unit bearing loads are approximately equal and well within the design bearing pressure limits.

The remaining two columns of the structure on column line 1 have been placed on a combined footing mat.

The mats were designed with two layers of 12 inch x 12 inch timbers at right angles to each other and to the floor planking. The timbers are spaced so that tunnel air can circulate beneath the tongue and groove flooring and prevent the buildup of heat under the foundation mat.

The maximum snow bearing pressure used for design of the Reactor Complex Building foundation was limited to 1500 pounds per square foot under combined load, operating and live loads, and 1200 pounds per square foot under dead and operating loads only.

a. Containment Vessel

The containment vessel assembly, as shown in Figure 21, consists of upper and lower vessel sections. The containment vessel has been designed for welded construction with the exception of the closure flange, which is bolted. The containment vessel contains: the reactor vessel and control rod drive mechanisms, the lead shield and support cylinder and the control rod drive motors. The reactor containment installation is shown in Figure 6.

The containment vessel has been designed in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, including all nuclear code cases, and the Tentative Structual Design Basis for Reactor Vessels and Directly Associated Components (Office of Technical Services Report No. 151987). Design pressure and temperature for the vessel are 450 psig and 450°F, respectively. The vessel is designed to contain a major rupture of the reactor vessel. The 450 psig has been determined as the pressure that would result in bringing the internal energy released by the reactor at operating conditions to equilibrium. The available net containment volume is approximately 640 ft^3. This calculation has been made assuming an adiabatic process.

The containment vessel also serves as the shield tank. This shield water circulates around both sides of the lead shield as well as the sides and bottom of the reactor insulation. Flow holes are provided in the upper region of the reactor support cylinder and through the lower lead shield for this purpose.

The gasket used between the upper and lower containment closure flange is spiral wound stainless steel, asbestos filled flexitallic. The bolting flange has been provided with 328-3/4 inch diameter bolts for closure. The bolting material used is SA193B14.

Containment Vessel (lower half) - The containment vessel (lower half) as shown in Figure 22 consists of a cylindrical section terminating in a 2 to 1 ellipsoidal bottom head welded to the cylinder and a bolting flange at the top. A cylindrical support skirt is attached to the bottom head. This skirt has been designed to take aload of 250,000 pounds.

At two different levels in the vessel, support ledges are provided for an operating floor plate and for a support plate. The support plate holds the nuclear instrumentation and shield water heater-coolers. This support plate also serves as a sealed diaphragm plate which is the upper limit of the water in the shield tank. The floor plate is located such that it provides accessibility for bolting and unbolting the containment and the reactor vessel flanges. This floor plate consists of removable panels which permit access to the piping and wiring which are positioned immediately below.

The main steam, feedwater and purification lines have expansion loops between the reactor vessel and containment vessel. These expansion loops have been designed such that all piping stresses are within allowable limits for the condition of differential thermal expansion between the two vessels.

The ellipsoidal head is provided with a locating ring to position the reactor vessel support cylinder and shield. This lower head is also provided with a reinforcing pad on the outside on which the support cylinder is attached. The function of this reinforcing pad is to distribute the reactor and the lead shielding load more uniformly.

This lower half of the containment vessel is provided with twenty-one (21) penetrations. All these penetrations occur at the same level, 13-3/4 inches below the parting face of the containment vessel flange except for the shield water overflow line which is located at 23 inches below the parting flange. This overflow line is located slightly below the sealed diaphragm plate previously described. These penetrations are oriented as shown in Figure 22 and consist of the nuclear instrumentation wiring, shield water piping lines, the main steam line, feedwater line and purification line.

Containment Vessel (upper half) - The vessel as shown in Figure 24 consists of a cylindrical section terminating in a 2 to 1 ellipsoidal top head welded to the cylinder and a bolting flange at the bottom. The bolting flange must seal tightly and is machined with close tolerances for a gasketed closure. An 18-inch diameter manhole is provided in the head for accessibility into the upper containment to disconnect the control rod drive shafts from the motors and to unbolt the containment vessel inner flange. Eighteen (18) support pads are provided on the vessel wall on which the control rod drive motors will be mounted. Eighteen (18) penetrations have been provided in the vessel wall for control rod drive motor wiring, liquid level control wiring and seal water piping for the control rod mechanisms. The exact location and orientation of these penetrations are as shown in Figures 21 and 24.

Shipping - The containment vessel is shipped in two sections, the upper and lower containment vessels. This has been accomplished to enable shipment within the weight limitations of the C-130 aircraft. Both shipping modules as snown in Figures 23 and 25 meet all the size and shock requirements for air transport.

b. Reactor Shielding and Support Cylinder

The reactor shield and the reactor support cylinder have been designed as integral units. The shielding design is such that it permits personnel access to the lower reactor complex region at shutdown. The shield and support are put together inside the containment vessel in six (6) sections as shown in Figure 6. The shield is made up of circular lead segments canned with 304 stainless steel. The inner canning is 3/4 inch thick and serves as the reactor vessel, support cylinder. Between the inside of the support cylinder and the outside of the reactor vessel insulation canning is provided a 1-1/4 inch annulus to permit water flow around the vessel insulation. Thus water flows around the inside and outside of the lead shield. To enable this continuous flow around the sides and bottom of the reactor vessel flow holes have been provided in the upper region of the support cylinder and 8 1-inch diameter pipes have been inserted in the lower section of the shielding lead.

The reactor shield and support are assembled in the following sequence. First, the lower plate section, Figure 30, is put in place. Next, the lower cylindrical section of the support cylinder and shield, Figure 26, is put in place. The lower head of the containment vessel has a locating ring welded in place which positions these two lower shield sections. Finally, the remaining four cylindrical sections of the shield and support are put in place. These four sections are shown in detail in Figures 27, 28 and 29. The upper-most section, shown in Figure 29, has a 1-inch thick ring section at its upper end on which the reactor vessel support skirt rests. All the cylindrical lead sections are tongue-and-grooved to prevent streaming and for ease of erection. Each lead segment, with the exception of the lower ring section, has been provided with tapped holes into which lifting eyes can be screwed. The lower shielding ring has been provided with four (4) lifting eyes welded in place for loading.

These shielding and support cylinder sections have been sized such that each one can be packaged and shipped within the weight limits of the C-130 aircraft.

c. Reactor Vessel

The reactor vessel and head assembly, as shown in Figure 7, consists of a cylindrical vessel, a welded 2 to 1 ellipsoidal lower head, a 2 to 1 ellipsoidal flanged closure head and a cylindrical support skirt. The reactor vessel has been designed for welded construction with the exception of the head to vessel closure which is bolted. The closure head is provided with nine control rod mechanism nozzles, three water level control nozzles and a source nozzle. Three (3) penetrations are provided in the vessel wall for the steam outlet, the feedwater inlet and a purification outlet line. An integral steam dryer is mounted in the closure head cavity. A shield can is mounted on the closure head to hold a mixture for radiation shielding.

Both vessel and head have been designed in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, including all nuclear code cases, and the Tentative Structural Design Basis for Reactor Pressure Vessels and Directly Associated Components (Office of Technical Services Report No. PB151987). Design pressure and temperature for the vessel are 750 psig and 500^{o}F, respectively. The specific design of the vessel and head has been calculated using 304 stainless steel.

The reactor vessel support skirt rests on the lead support cylinder inside the containment vessel.

Reactor Pressure Vessel - The shell assembly, as shown in Figure 14, consists of a cylindrical section terminating in a 2 to 1 ellipsoidal bottom head welded to the cylinder and a bolting flange at the top. The vessel has an inside diameter of 52 inches and longitudinal inside dimension of 14 feet, 10-3/4 inches. The vessel is fabricated from SA167 Grade 3 - Type 304 plate.

The flange of the pressure vessel is a weld-neck flange forging of SA182 Grade F304 material. The flange is provided with fifty-eight (58) 1-1/2 inch diameter through bolts for closure. The bolting material is SA193B14. The flange has been provided with a double groove for placement of a stainless steel spiralwound asbestos filled inner gasket and a soft metallic outer gasket. Details of the inner gasket and outer filler are shown in Figures 17 and 18, respectively.

Three nozzles are provided in the side wall of the vessel. These are: (1) steam outlet, (2) feedwater inlet, and (3) the purification outlet. They are shown detailed in Figure 15.

The steam nozzle is designed to connect to a 3-inch schedule 80 stainless steel pipe outside the vessel. The inner end of the nozzle consists of a flush flange drilled to mate with a 3-inch 150-pound flange on the steam duct from the steam dryer.

The feedwater nozzle is of the thermal sleeve type. It is so designed that it accommodates a 2-inch schedule 80 stainless steel pipe. The feed piping after penetrating the vessel terminates in a 1-1/4 socket weld union. The vertical leg of the spray line ultimately connects to this union. The spray ring is so designed that it is removable when the core structure is in place.

The purification nozzle is of the double-wall type. It is designed to accommodate a 1-1/2 inch schedule 80 stainless steel pipe.

The steam, feedwater, and purification lines all penetrate the reactor vessel at the same vertical elevation, 20-1/4 inches below the parting face of the closure flange.

All nozzle penetrations meet the requirement of full reinforcement for primary vessel penetrations. (ASME Code Nuclear Case No. 1234.)

The reactor vessel has a circumferential support skirt for mounting in the vertical position. The top of the support skirt is welded to the vessel flange. The bottom of the support skirt is bolted to a support cylinder. Eight (8) lugs attached to the skirt distribute the load from the skirt to the support cylinder.

The nozzles for the steam, feed and purification lines penetrate the support skirt and are enclosed by flexible seals to prevent water from entering the insulation. A vent is furnished at the top of the support skirt to vent the insulation containment space.

A ring ledge has been provided on the outside of the reactor support skirt on which the walkway platform will be supported. This platform is located directly over the steam, feed and purification lines. It has removable sections for access to these pipe lines. It also permits accessibility for bolting and unbolting the reactor vessel closure flange.

The pressure vessel is covered with an insulating material having a service temperature of 500°F or greater and a minimum compressive strength of 70 psi, such as Johns-Manville 85% Magnesia or equal. The thickness of insulation is 2-inches between the support skirt and the reactor vessel and 2-1/2 inches for the remainder of the vessel. The insulation below the support skirt is canned with 1/8-inch stainless steel canning. The canning is continuously welded to the bottom of the reactor support cylinder.

Reactor Head - The reactor head assembly, Figure 8, utilizes a standard 2 to 1 ellipsoidal head fabricated from SA167 Grade 3 - Type 304 (Plate). The head flange is a SA182 Grade F304 forged bolting flange. Head thickness is uniform throughout except for the bolting flange which has a varying contour.

Head penetrations consist of thirteen (13) welded nozzles as follows:

Nine, 3-inch (nominal) control Rod Drive Nozzles
Three, 4-inch (nominal) Level Control Nozzles
One, 3-inch (nominal) Source Port Nozzle

The center control rod drive nozzle flange is 8 inches higher than the others to meet control rod drive mechanism installation requirements.

All nozzles terminate with bolted flanges at the upper end. Sealing is obtained by spiral-wound stainless steel, asbestos-filled gaskets. All nozzle flanges are standard, AISI 304 stainless steel, 600 pound welding neck flanges machined and oriented as shown in Figure 12. The control rod nozzles are machined to accommodate a holdown device for the shield plugs which fit inside the nozzles.

The reactor head shield container, as shown in Figure 9, is formed by welding four curves plates circumferentially to the outside diameter of the ellipsoidal head and longitudinally to the lifting lug flanges. The cylinder thus formed is approximately 57 inches I. D. by 23-1/2 inches high. This shield container houses the shielding which consists of concrete pellets approximately 1/4 inch diameter consisting of 64% magnetite, 9.3% boron and the remainder cement. Weep holes are provided at the base of the head shielding cylinder.

A flat, perforated circular plate, see Figure 10, bolted to the upper end of the reactor head shield container covers the cylindrical container. It allows the nozzle flanges to protude through the perforations.

Due to the condition of the elevated center nozzle, the cover plate will not fully contain the shielding material when this plate is lowered into place over the center nozzle flange. To completely contain this shielding the cover must be modified around this nozzle by bolting two rectangular plate segments into position, as shown in Figure 11.

Four (4) lifting lugs, formed to the shape of structural tees are welded to the head 90° apart. Each lifting lug has been designed to sustain the total closure head assembly weight under a 5 G shock loading.

Arrangement of Vessel Internals - The top of the thermal shield, Figure 14, is supported from the reactor vessel wall concentric with the vessel. The top of the thermal shield has a ring around the cylinder which rests on a ring ledge that is welded to the pressure vessel. The thermal shield supports the core support assembly by means of eight (8) equally spaced legs attached to its inner surface. The thermal shield is accurately positioned relative to the steam nozzle. After the thermal shield is welded in place, the lugs which support the core are machined concentric with the flange bolt circle and parallel to the flange reference surface. A jig is then positioned on the lugs and the holes located, as shown in Figure 14, are drilled. The same jig will be used to locate the matching holes on the core support assembly.

The steam transfer duct is flanged at its lower end for bolting to a boss on the inside wall of the pressure vessel. The steam dryer assembly is supported from the reactor head by means of thirteen 1-1/2 inch diameter studs.

The feed line after penetrating the vessel wall is bent at a 90° angle in the horizontal plane and terminates in a union. It is supported by one bracket at this elevation. The vertical leg of the spray line has a union connection at its upper end and at its lower end it expands into a 345° spray ring, as shown in Figure 16. This lower spray ring is supported from the reactor vessel by three brackets, as shown in Figure 15. This feedwater ring is not rigidly attached to the brackets and differential thermal expansions can be tolerated.

The purification line after penetrating the vessel bends 90° downward in the vertical plane and terminates in a straight vertical leg. A guide support bracket is provided around this vertical leg, as shown in Figure 15. This purification line serves as a line through which a portion of reactor coolant is circulated through the purification system continuously to remove radioactive contaminants from the main plant system.

The liquid level control stillwell, as shown in Figure 19, is supported from the pressure vessel at the top and the bottom. Both the upper and lower supports of the stillwell contain holes which fit into pin connections bracketed from the reactor. The details of these brackets, as well as the orientation relative to the steam nozzle, are shown in Figure 14.

Shipping - The reactor head will be shipped as one unit and the reactor vessel as another unit. The reactor vessel head will be shipped with the steam dryer and shielding in place. The reactor vessel will be shipped with the stillwells, feedwater spray ring, purification line and core structurals in place. Details of the shipping packages are as shown in Figures 13 and 20.

d. Spent Fuel Tank

The spent fuel tank, as shown in Figure 64, is capable of housing six (6) spent fuel shipping casks. It is fabricated from SA212B material. It is formed from rectangular steel plates braced with structural tee sections. At the top edge is provided a peripheral angle section to which a hood section could be mounted. The vessel is to be fabricated for zero leakage. It measures approximately 8 feet square x 18 feet in height.

e. Initial Fueling

The following procedure is followed in installation of the initial core:

(1) The upper portion of the containment vessel, Figure 24, and the reactor head assembly, Figure 8, will not be installed until the initial core is in the installed position.

(2) The fuel elements and control rods will be shipped to the site in three shipping casks, Figures 65, each cask containing three control rods and eight fuel elements. The casks are designed to provide the maximum shielding consistent with the aircraft shipping requirements. Boral spacers are provided to separate the fuel elements and rods and maintain the fuel in the subcritical condition.

(3) The spent fuel cask shipping package, Figure 66, is skidded into the empty bay of the reactor complex, Figure 2, through the large access door. The cask cover bolts are removed and the cover is lifted off using the overhead crane.

(4) The three control rods are loaded individually into the reactor by means of the crane. Loading of all rods and fuel elements proceeds from the center outward. The fuel elements are then loaded one at a time. The cover is then replaced on the empty cask and secured. The cask is unbolted from the shipping skid, lifted into the spent fuel tank and positioned, as shown in Figure 2. The empty shipping skid is then pulled out of the complex

and stored in the tunnel. The above procedure is then repeated for the two other shipping casks necessary to complete a full core.

(5) The steam line internal section is then bolted in place in the reactor. The closure seal gasket, Figure 17, and filler, Figure 18, are fitted in the grooves in the reactor vessel flange. The head shipping skid, Figure 13, is then pulled into the reactor complex. The head is unbolted from the skid, lifted into place and positioned by the guide holes on the reactor. The head is then bolted down following the detailed bolting instructions in order to obtain the proper bolt loading.

(6) The three water levels detectors are mounted on the head flanges.

(7) The containment vessel upper portion shipping skid, Figure 25, is then skidded into the reactor complex, the vessel is unbolted from the skid, lifted into place and bolted.

(8) The control rod drive mechanisms are mounted to the head flanges and connected to their respective control rods; piping and electrical connections are made, see Figure 6, access to the equipment being made through the top manhole in the containment vessel.

f. Refueling:

(1) The covers are removed from the three shipping casks in the spent fuel tank.

(2) The spent fuel tank is filled.

(3) The manhole on the containment vessel is opened.

(4) The motor drives and all piping and wiring are disconnected as necessary for removal of the containment vessel upper portion.

(5) The control rod actuator assemblies are removed.

(6) The containment vessel flange is unbolted.

(7) The upper portion of the containment vessel is removed to the open bay, placed on a skid in the vertical position and skidded through the large access door into the tunnel.

(8) The water level instruments are removed.

(9) The reactor head is unbolted, and removed to the open bay and placed on a skid.

(10) The alignment ring and the refueling plate, Figure 69, are installed on the reactor flange.

(11) The refueling plate is indexed over the first fuel element to be removed.

(12) The transfer cask, Figure 68, is skidded into the open bay and unbolted from the skid.

(13) The cask is lifted into position on the refueling plate and the cylinder valve is opened.

(14) The gripper is lowered and connected to the fuel element. The viewing access holes in the plate are used during this operation.

(15) The element is retracted into the cask.

(16) The cylinder valve is closed.

(17) The transfer cask is lifted into the spent fuel tank and positioned.

(18) The cylinder valve is opened, the fuel element is lowered from t he cask and disengaged.

(19) The gripper is retracted, the cylinder valve closed and the cask is removed from the spent fuel tank.

(20) Positioning of the removed element in the shipping cask is then performed using manual tools.

(21) Steps 11 through 20 are then repeated for each spent fuel element and control rod.

(22) Refueling of the reactor is performed by the same procedure described in the initial fueling except that refueling will be done through the refueling plate due to residual activation of core structurals and pressure vessel.

(23) The reactor head is replaced and bolted up using new gasket and filler.

(24) The installation is then re-assembled following steps 15 through 23 of the erection procedure.

(25) The water level in the spent fuel tank is lowered to a level below the overflow connection from the containment vessel.

2. Condenser Building

The condenser building, Figure 71, contains two air-cooled steam condensers and the Gas Handling Skid, Figure 197.

The building is of arctic panel construction. Wall louvers allow entrance of fresh air from the equipment tunnel and trim insulated aluminum exhaust stacks, Figure 83, project through the building roof and tunnel arch above each condenser. The exhaust stacks and air plenum chambers at the base of the stacks are supported by aluminum structural members carried directly on the floor.

The floor of the building is located three feet higher then the floor of the power plant building in order to allow gravity drainage.

Since the condenser building is located next to the access ramp in the equipment tunnel, it is necessary during initial construction to omit the top three layers of foundation timber shown in Figure 73. This will place the floor of the condenser building at the same elevation as the floor of the Power Plant building and will allow for the easy movement of equipment skids through the condensor building with a minimum of field labor and modifications. After all of the modules are moved through the building, the top three levels of foundation timber will be installed by jacking under the floor framing steel and placing the timbers in position. The dimensions and weights of equipment in the condenser building are as follows:

Condenser skid	25'-6" x 8'-3½"	30,000#
Gas Handling skid	15'-0" x 4'-0"	8,500#

a. Air-Cooler Condenser Description

The two air-cooled condensers are connected in parallel. Each unit is designed as a complete skid package and has the overall dimensions of 8 feet-4 inches wide x 8 eight-6 inches high x 25 feet-6 inches long. To simplify steam piping, the units are mounted with the inlet headers adjacent to each other. Each has two 8-inch steam inlet nozzles, and a single 4-inch drain nozzle. The condenser is a two pass unit and the drain header is located directly below the steam inlet header.

The condensing section consists of six rows of horizontal 1-inch diameter stainless steel finned tubes, 24 feet long. There are 35 tubes per row staggered in a triangular pitch. Each tube has 11 fins per inch of tube length with an outside diameter of 2-1/4 inches. The tubes are roller expanded into stainless steel headers at each end, and supported in the upper portion of the skid. The condensing tubes are pitched to the rear header to allow proper drainage. A seventh row of identical tubes below the condensing section provides the subcooling features of the condenser in a second pass. Steam entering the inlet nozzles and header is condensed in the first six rows of tubes and the condensate drains to the rear header. The condensate then flows through the lower row of tubes and is cooled below the saturation temperature. The sub-cooled section is pitched to the rear header and is always kept flooded for maximum heat transfer.

Four propeller-type fans are mounted below the condenser. These are directly coupled to totally enclosed fan-cooled motors, which are supported from the condenser frame and protected with a wire mesh screen. The fans provide the necessary coolant air flow to remove the heat transferred in the condenser and the sub-cooler.

Positive protection against freeze-up is provided by automatic recirculation of a portion of the discharge air to mix with incoming air. The inlet air to the heat exchange surface is maintained at a safe temperature under all conditions of operation. The inlet air enters the condenser building through manually operated inlet louvers where it is mixed with recycled air from the condenser to obtain the mixed design inlet air temperature. The combined air then passes through the condenser fans, and across the heat transfer surface. The air stream leaving the condenser is divided such that some of this air is recirculated within the building and the remainder is exhausted to ambient through the plenum and the condenser stacks. The bypass and exhaust louvers are so linked that when one set is fully opened the other is fully shut. A constant air flow passes over the heat transfer surface independent of the louver position.

b. Stacks

Each condenser is furnished with two stacks for exhausting the heated air. The stack configuration was designed to permit the penetration of the smallest number of arch sections and provide clearance from the roof trusses.

The stacks and plenum, Figure 83, are fabricated from aluminum and are field assembled.

Fiberglas insulation covers the entire stack above the plenum chamber.

c. Snow Drift Wind Tunnel Tests

A series of tests have been in progress at N.Y.U. Engineering Laboratory to determine the effects of snow drifting on the various tunnel penetrations above grade. These tests were performed on a 50:1 scale model inserted in a specially designed wind tunnel using borax to simulate drifting snow.

In the event that the ramp becomes filled to a height which would restrict cooling air flow, sufficient air may be drawn through the various tunnel excape hatches to supply the necessary air. Approximately eight hatches are required to supply the full design air flow. For Antarctic installations where ambient air temperatures rarely exceed +10°F, approximately one half the air flow and, consequently, only four open hatches are required.

The following tabulation indicates the test conditions which resulted in the contours shown in Figures 157 through 160.

Test No.	Wind Velocity	Test Duration	Figure No.
19A	100 MPH	1 hr. 30 min.	157
20B	100 MPH	3 hrs. 15 min.	158
24A	100 MPH	4 hrs. 0 min.	159
25A	110 MPH	2 hrs. 45 min.	160

In addition to the contours, still photographs and lapse time motion pictures were also prepared. Typical photos are shown in Figures 161 through 168.

Results of testing to date indicate that drifting snow will not interfere with the operation of the exhaust stacks. The escape hatches also appear to have sufficient height such that snow entrainment by the cooling air is neglible.

When the wind either approached the entrance of the tunnel or was blowing across the ramp, heavy snow accumulation in the ramp was observed. Although generally this heavy accumulation did not restrict the available air flow to the condenser, a deliberately heavy precipitation rate and prolonged test period did produce a condition in which the required air flow could not be maintained without increasing blower input power. Under no test conditions did the ramp entrances become completely obstructed.

The tests conducted these far have suggested that a reduction in stack height is possible. A 20:1 scale model has been constructed of a new, shorter stack configuration. The change in scale was necessary to facilitate testing at lower wind velocities. Tests will shortly be resumed with the new model using wind velocities in the 40 to 70 MPH range. At the inland stations where the annual precipitation is low, the primary mechanism of snow movement is by saltation. Significant saltation, however, does not occur below approximately 40 MPH making tests below this threshold unnecessary.

d. Gas Handling Equipment

The gas handling equipment is mounted on a skid, Figure 197, which is located at the end of the condenser building. This is the last major piece of equipment to be installed in the equipment tunnel.

The skid contains a series of heat exchangers and activated carbon beds through which the condenser off stream gases are passed before exhausting to the condenser stacks, thus reducing the concentration of radioactive gases released to the atmosphere.

3. Power Plant Building

The Power Plant building, Figure 84, contains the purification skid, Figure 87, the feed and condensate skid, Figure 89, the turbine-generator skid, Figure 92, the decontamination skid, Figure 91, and the electrical skid, Figure 94. All skids are supported on the building floor except for the turbine generator skid which has independent foundations for vibration isolation. Interconnecting piping between the skids are carried on a steel pipe rack, Figure 86, behind the equipment. The wireways are carried on the opposite side of the building. A maintenance aisle with a minimum width of 5 feet, six inches is provided for removal of skid components.

The building is of arctic type panel construction. An airlock is located at the end of the building nearest to the Personnel Building. An access door is located at the other end.

The power plant exhaust stack is located next to the turbine generator skid near the center of the building. This stack passes through the roof and tunnel arch and vents to the atmosphere. An exhaust stack for the building is located near the purification skid.

a. Purification Module

The purification skid, Figure 87, carries the poison cylinder, the purification heat exchangers, pumps and demineralizer and the evaporator, demineralizer, pump, drain tank and waste tank for the service water system.

The waste tank is shipped in an inverted position on the skid. When the skid is positioned in the Power Plant Building, the tank is unbolted and installed in its proper position in an enclosed pit in the floor of the building.

Access to the skid equipment is from a center aisle at end A, Figure 87, and from an access space between the drain tank pump and the drain tank. The demineralizers are shipped separately because of their weight.

Bolting connections have been furnished on the skid, Figure 88, for attaching jacking or lifting equipment as required.

The piping, Figure 105, is designed to provide sufficient flexibility to facilitate field connection with the interskid piping. The arrangement has been designed to provide ready access to valves and equipment. Pull space has been provided where necessary and combined where possible with access space to facilitate maintenance and reduce over-all space requirements.

b. Feed and Condensate Module

The feed and condensate skid, Figure 89, carries the condensate pumps, hotwell, precooler and aftercondenser, the feed and make-up feed pumps, the plant heating pumps and space heat exchanger, the reserve feed tank, the lube oil intercooler, the raw water demineralizer and the low pressure drain tank.

Bolting connections have been furnished on the skid, Figure 90, for attaching jacks or jib cranes as required.

Because of the complexity of the piping on this skid, Figure 106, it was found convenient to utilize the pull space necessary for the precooler and aftercondenser as an access aisle to the center of the skid. This permits the grouping of valves for ready access by one operator.

c. Turbine Generator Module

This skid, Figure 92, includes the turbine generator, lube oil coolant pumps, purifier and a standby lube oil pump. The generator is shipped as a separate unit and mounted in the field.

d. Decontamination Module

The decontamination skid, Figure 91, includes facilities for decontamination of personnel and equipment, radiation monitoring equipment, a water chemistry equipment cabinet and personnel lockers.

e. Control Center

A control center is located on the electrical skid at the end of the Power Plant Building nearest to the main camp tunnel entrance. This enables a single operator to control the plant from a point most easily reached from the personnel area.

f. Interconnecting Piping

The interconnecting piping between the skids is carried on a pipe rack constructed from unistruts. The pipe bank is run behind the equipment skids. Piping elevations were selected to facilitate connections and shorten the over-all piping lengths as much as possible.

4. Personnel Building

The Personnel Building, Figure 97, contains office space, a toilet and a health physics dark room. The office space provides enough room for two desks, files, shelving and lockers. An exhaust stack services the lavatory and health physics areas. Access to the building is from either end. The air lock section is ample enough to allow storage space for clothing.

5. Service Building

The Service Building, Figure 99, contains two compartments, one for the emergency power equipment and one for a small maintenance shop.

The emergency power equipment consists of a diesel generator, auxiliary boiler, switchgear and a diesel fuel tank.

The shop contains a drill press, grinder, work bench, welding machine, lathe, pipe threader and parts bins. Boiler tubes can be pulled through the connecting door between the compartments.

The emergency power equipment compartment is provided with a 12-inch diameter exhaust stack.

Access to the building is from either end.

6. General

All buildings in the equipment tunnel are insulated prefabricated arctic panel type buildings with interconnecting platforms and stairs, as shown on Figure 101.

Building floors have a minimum clearance of 3 feet, 6 inches from the tunnel floor.

Building walls have a minimum clearance of 3 feet, 6 inches from the tunnel walls.

All foundations of buildings in the equipment tunnel have been designed for a maximum snow bearing pressure of 1,000 pounds per square foot under combined dead, operating and live loads and 750 pounds per square foot under dead and operating loads only.

The maximum snow bearing pressures equal approximately the weight of the excavated overburden at the tunnel floor level.

7. Erection Procedure

The following erection procedure is based upon the Antarctic construction period being limited to approximately 60 days. Tunnel construction will precede the work schedule and a Caterpillar D-8 truck with light boom and winch will be available for field erection. A second Caterpillar D-8 will be used for moving materials from storage to the working areas. Construction will be divided into two work seasons, the first for the erection of foundations, building, utilities and supporting structures, and the second for the installation, alignment, power and piping connections and testing of all equipment. Separate access ramps in Reactor Complex, and Equipment tunnels permit work simultaneously in both areas of the plant.

Procedure

a. Equipment Tunnel

First Work Season

(1) Tunnel survey work to locate foundation center lines and establish elevations in the tunnel with respect to a common bench mark.

(2) Erect foundation timbers for Service and Personnel Building.

(3) Erect steel floor framing for Service and Personnel Building.

(4) Erect foundation timbers for Power Plant Building and Turbine Generator.

(5) Check elevation at top of steel in Service and Personnel Buildings and erect floor panels.

(6) Erect steel floor framing for Power Plant Building and steel supports for Turbine Generator.

(7) Erect walls, partitions, roof trusses and roof panels in that sequence in Service and Personnel Buildings. Omit doors in walls.

(8) Place temporary timber supports between Condenser and Power Plant Buildings to the level of the building floors to provide a continuous surface upon which equipment skids, furniture and shop equipment may be moved from the ramp end of the Condenser Building through the Power Plant Building.

(9) Erect foundation timbers for Condenser Building in accordance with instructions on drawing to omit top three layers of timbers.

(10) Check elevation at top of steel in Power Plant Building and erect floor panels.

(11) Install 2-inch tongue and grove hard wood flooring in Service and Personnel Buildings.

(12) Erect steel floor framing for Condenser Building.

(13) Erect walls, partitions, roof trusses and roof panels in Power Plant Building. Omit doors in walls.

(14) Check elevation at top of steel in Condenser Building and erect floor panels.

(15) Install toilet fixtures and associated piping in Personnel Building.

(16) Install 2-inch tongue and groove hard wood flooring in Power Plant Building.

(17) Install electrical wiring and fixtures in Service, Personnel and Power Plant Buildings.

(18) Erect walls, including wall louvres, and roof trusses in Condenser Building. Omit doors in walls.

(19) Install 2-inch tongue and groove hard wood flooring in Condenser Building.

(20) Erect two Air Plenums chambers of Condenser Exhaust Stacks on floor of Condenser Building. Block off floor level in proper plan position so that later jacking of complete assembly will be feasible. Attach first section of exhaust stack to top of air plenum chamber. Add second section of stack above first section. Insulate both sections of stack.

(21) Jack each air plenum with attached first and second stack sections up through proper roof openings to elevation 12 feet, 4 inches clear of floor. Operation will involve timber shoring and several jacking lifts.

(22) Erect structural aluminum supports inside of Condenser Building and attach to channel sections of the air plenum chambers.

(23) Remove jacks and timber shoring from Condenser Building.

(24) Erect roof panels on Condenser Building.

(25) Install electrical wiring and fixtures in Condenser Building.

(26) Install small exhaust stacks in Service,Personnel and Power Plant Buildings.

(27) Install all interior and exterior doors in building walls.

Second Work Season

(1) Check elevation and true level conditions of building floors in Service, Personnel, Power Plant and Condenser Buildings. Make required adjustments.

(2) Place temporary rough planking on floors of Condenser, Power Plant and Service Buildings to prevent damage to floor when moving equipment.

(3) Roll equipment and skids through Condenser and Power Plant Buildings in this order:

Shop equipment including lathe, grinder, welding machine, work bench, drill press, grinder and pipe threader.

Diesel Generator.

Fuel Tank.

Office equipment and furniture.

Health Physics laboratory equipment.

After passing through the Condenser and Power Plant Buildings, the Service Building items can be moved through the 7 foot, 6 inch passage between the tunnel wall and the Personnel Building and then moved into the equipment area of the Service Building before final placement.

Personnel Building furniture and equipment can be moved directly from the Power Plant Building.

(4) Move the following skids through the Condenser and Power Plant Buildings in this order, and position properly.

Electrical skid.

Decontamination skid.

Turbine General skid.

Feed and Condensate skid.

Purification skid.

(5) Remove temporary rough floor planking from each area of Power Plant Building.

(6) Remove temporary timbers used for moving skids and equipment at floor level, from tunnel floor between Condenser and Power Plant Buildings.

(7) Erect foundation timbers for Fire Protection Equipment.

(8) Roll Fire Protection Equipment through Condenser Building and place in proper position on tunnel floor.

(9) Place jacks under Condenser Building and elevate to final floor position. Place top three levels of timbers.

(10) Erect pipe rack steel in Power Plant Building.

(11) Erect pipe support steel frames in pipeway and access tunnel.

(12) Install two condenser skids, with exhaust louvre assembly attached, and gas handling skid in Condenser Building.

(13) Piping and power connections can proceed at each equipment skid as soon as it is properly positioned and leveled.

(14) Install piping in Pipeway and Access tunnel.

(15) Erect foundations for Charcoal Adsorption Beds near ramp end of Condenser Building.

(16) Erect Charcoal Adsorption Beds on foundations and attach piping connections to Gas Handling skid in Condenser Building.

(17) Attach flexible connection between air plenum chamber and condenser exhaust louvre assembly on each condenser.

(18) Connecting platforms between the various buildings in the equipment tunnel can be erected with the attached stairs as soon as all equipment has been place in the buildings, and temporary timber work removed.

b. Reactor Complex Tunnel

<u>First Work Season</u>

(1) Establish center lines of foundations and elevations with respect to a common bench mark.

(2) The Reactor Complex Foundation comprises three mats. In the region of the foundation mats, cut the snow floor of the tunnel to a smooth, level surface at the proper grade.

(3) Place the 6 x 12 lower transverse timbers of the three mats with the 12 inch face against the snow surface. Lay closely together so that each mat forms a continuous surface. Secure the lower layer of timbers in position and place the longitudinal 12 x 12 timbers on the upper surface. Lag bolt to alternate timbers through pre-drilled holes counterbored for the heads. Stagger the connections. Place the upper transverse layer of 12 x 12 timbers and similarly lag bolt to the second layer to alternate timbers.

(4) Place the 4-inch tongue and groove deck. Fasten successive members together and fasten the deck to the foundation mats with wood screws through pre-drilled holes.

(5) The steel support beams, sills and bracing members comprising the support mat for the reactor vessel, spent fuel storage tank and adjacent building columns will be placed directly on the floor surface. Fasten the supporting members to the floor with lag bolts after they are joined and accurately positioned.

(6) Columns of bent No. 4 shall be attached to the longitudinal sills by means of the hinge pins. The bent shall be supported on temporary shoring while it is completely assembled in the horizontal position. The bent shall be rotated into an upright position and stayed.

(7) Bent No. 3 shall be assembled in a horizontal position, rotated into an upright position and stayed in a manner similar to that used for bent No. 4.

(8) Intermediate struts and diagonal bracing shall be erected to complete the building frame between bents No. 4 and No. 3, except for the operating floor, around the reactor.

(9) Bent No. 2 shall be hinged to the longitudinal sills and assembled in a horizontal position. For purpose of rotating bent No. 2 into a vertical position, the winch cable may be passed through sheaves mounted on columns of bent No. 3. Intermediate struts shall be erected to complete building frame between bents No. 2 and No. 3. Omit floor framing around spent fuel tank at operating level.

(10) Bent No. 1 and intermediate bracing between bents No. 2 and No. 1 shall be erected in a procedure similar to that described for bent No. 2 and bracing between bents No. 2 and No. 3.

(11) At each column base jack column under jacking bracket, remove hinge pins and assemble web and flange plates. Remove jacks after all field bolts are tightened.

(12) The bridge and crane shall be erected on the ground and hoisted to the top of the bay between bents No. 2 and No. 3. The crane girders and rails shall then be erected between bents No. 4 and No. 12. The crane bridge shall be lowered to the crane rail.

(13) Complete installation of crane girder and rail between column lines 1 and 2.

(14) Erect ladder with safety cage and platform at operating level for access to pipeway tunnel.

(15) Erect ladder from working floor area to operating level.

(16) Erect roof panels of structure.

(17) Erect wall panels, personnel and equipment doors.

(18) Erect bottom wall panels attached to flooring, encircling the building and providing a weather-tight enclosure when leveling the building structure. Install fiberglas packing between panels as shown in Figure 3.

(19) Install electrical wiring and fixtures in building.

<u>Second Work Season</u>

(1) The lower portion of the containment vessel, Figure 22, is the first major item of equipment to be installed. The shipping skid, Figure 23, is skidded into the open bay with the closure flange end inwards. The overhead crane is attached to the four lifting brackets on the flange cover plate. The skirt end of the vessel is attached, using a sheave block, to the lintel beam of the equipment door. The vessel is lifted into the vertical position, using the sheave block to

control the horizontal movement of the vessel. The vessel is then unbolted from the skid, moved to its final location, oriented properly, and bolted in place on the foundation.

(2) The operating floor and supporting steel framing is installed.

(3) The reactor shielding, lower plate, Figure 30, is then placed in the containment vessel.

(4) The annular lead shielding and support rings, Figures 26, 27, 28 and 29 are then installed and alignment checked. Ring E, Figure 29, must be placed to match the reactor orientation.

(5) The reactor vessel shipping package, Figure 20, is skidded into the end bay with closure flange inwards. The crane is attached to the 4-inch lifting pipe at the front (inward) end of the skid. The rear end of the skid is attached by means of a sheave block to the lintel beam and a D-8 if necessary in order to control movement of the vessel during lifting. The skid is then lifted slowly into a vertical position and stood on end. The crane hook is then detached from the skid and attached to the large eye bolt in the center of the closure flange lifting plate. The skid is then detached and the vessel is moved over the lower containment vessel and carefully lowered into position using the steam nozzle location to set the reactor vessel at the proper orientation, Figure 6. The vessel is then bolted in place.

(6) The support plate, Figure 6, is then installed.

(7) The nuclear instrument wells, Figures 31, 44 and 57 are installed.

(8) The steam pipe, feed pipe and purification pipe expansions loops are installed between the reactor vessel and the containment vessel.

(9) The fill line is installed inside the containment vessel.

(10) The wiring from the instrument wells to the penetration flanges is installed.

(11) The floor plates are installed.

(12) The spent fuel tank, Figure 64, is skidded into the open bay and lifted into its position in the reactor complex, Figure 2. The tank must be oriented, as shown in Figure 103.

(13) Initial fueling is performed following the procedure described in section A1C.

(14) The reactor head shipping skid, Figure 13, is skidded into the open bay. The head, Figure 8, is unbolted from the skid, attached to the crane by means of the four lifting lugs and installed in position. Correct orientation is obtained by alighnment of the guide holes. The head bolts are pre-stressed to the prescribed values.

(15) The containment vessel upper portion shipping package, Figure 25, is skidded into the open bay with the top end inwards. The crane is attached to the three lifting lugs on the vessel head and the vessel is lifted into the vertical position using a sheave block for control as in the erection of the reactor vessel. The vessel head is aligned and oriented as shown in Figure 6. The flange is then bolted on both inner and outer bolt circles.

(16) The control rod drive mechanisms are installed on the head nozzles.

(17) The three water level indicators are installed.

(18) The control rod seal water and leak-off piping are installed.

(19) The drive motors are connected to the control rod mechanisms.

(20) The electrical connections to the water level indicators lights, motors and instruments are connected.

(21) The assembly is now ready for installation of the neutron source and pre-critical testing.

(22) Piping and instrumentation are installed in the spent fuel tank.

(23) Piping and wiring are installed to the containment vessel.

B. MECHANICAL SYSTEMS

The plant is composed of thirteen major fluid systems. Each system is described as to its major functions and system design data. Individual components are described and component design data is listed. A brief summary of major system operations such as normal operation, startup, shutdown and infrequent or abnormal operation is also given.

A system diagram and associated process instrumentation diagram is included for each system. Where systems interconnect the nearest component in the connecting system is shown in phantom to facilitate the tracing of flow paths and to understand the interrelation of systems.

All components are identified by a component number which is composed of three parts. The first part identifies the system in which the component is located such as "MS" for Main Steam, "F" for Feedwater, etc. The second part identifies the function of the component such as "PU" for Pump, "HX" for Heat Exchanger, etc. The third part is simply a numerical designation assigned to similar components in numerical sequence starting with "01".

1. Main Steam System (MS)

Main Steam System Diagram - Project No. 2101 (Fig. 115)
Process Instrumentation Main Steam System Project No. 2101-11 (Fig. 116)

a. Introduction

<u>System Function</u> - The main steam system receives steam from the reactor and supplies it to the turbine generator and the auxiliary steam services. The auxiliary steam services include space heating, air ejectors, and the service water system. Steam is also provided for the gland seal system of the turbine generator. Over pressure protection for the reactor vessel, auxiliary steam services and the main condensers, is included in the main steam system.

<u>Brief Description</u> - The main steam line carries saturated steam from the reactor complex building, along the pipe bay to the turbine generator located in the power plant building. The turbine generator is located between the feed and condensate skid and the decontamination skid. A branch connection goes to the auxiliary service steam reducing station located on the feed and condensate skid. The reactor steam stop valve (MS-1) is installed

just outside of the containment vessel in the reactor complex. The main steam isolation valve (MS-2) and the by-pass around this valve, (MS-33) used for warmup are located just inside the power plant building. A manual shutoff valve (MS-34) is installed upstream of the turbine generator throttle and governor valves and a motor operated valve (MS-17) is located in the dump line which by-passes steam around the turbine to the condensers. Exhaust steam from the turbine passes through the main steam exhaust header, along the pipe bay to the two air-cooled condensers. An isolation valve in each of the two branch lines to the condensers enables the use of one condenser when the other is not available. Steam is admitted to the turbine generator through a strainer and combination trip and hand operated throttle valve. The throttle valve is normally held open by high-pressure oil supplied by the lube oil service system. The valve will trip shut on low oil pressure, high back pressure or turbine overspeed and must be manually reset. The governor valves automatically regulate steam flow to the turbine to maintain constant speed with changing electrical load demand.

The reducing station takes steam from the main steam line, at a point between the flow nozzle (MS-FS-01) and the turbine isolation valve. From the reducing station the steam is supplied to the space heat exchanger, air removal equipment, and the service water system. Service steam for the turbine gland seal system is taken from the main steam line upstream of the main steam strainer.

The gland seal system is included as part of the turbine generator skid. A gland seal regulator maintains the proper steam pressure in all parts of the gland seal system. During normal operation gland seal supply steam is taken from turbine high pressure leak-off. During startup sealing steam is supplied from the main steam line just before the main steam strainer. (MS-ST-01)

Two steam relief valves, tied into the main steam line between the reactor containment vessel and the motor operated stop valve, provide over pressure protection for the reactor. The relief valves discharge directly to the atmosphere through the reactor complex exhaust stack. The steam piping downstream of the reducing station is protected by a relief valve which discharges to the power plant exhaust stack. The relief valve on the turbine generator discharge line is vented to the power plant stack. Condensate from the reactor complex stack drains to the spent fuel tank. Condensate from the power plant stack drains to the waste tank in the service water system.

System Design Data

Steam Flow in the Main Header	23,143 Lbs./Hr. 30,000 Lbs./Hr. Max.
Pressure	
Design	750 psig
Operating	600 psig
Hydrostatic Test	1125 psig
Temperature	
Design	500°F
Operating	489°F

b. Component Description

Turbine Generator (MS-TG-01) - The multi-valve multi-stage turbine generator is located between the decontamination skid and the feed and condensate skid in the power plant building. For a detailed description of the TG set refer to the specification at the end of this section.

Design Data

Inlet Steam Pressure	585 psig
Inlet Steam Temperature	487°F
Steam Flow	20,920 Lbs./Hr.
Exhaust Pressure	8 inches Hg. Abs.
Steam Rate	16.74 Lbs/KW Hr.
Gross Electrical Output	1250 KW

Reactor Steam Stop Valve (MS-1) - The reactor steam stop valve is located just outside of the reactor containment vessel in the reactor complex.

Design Data

Size	4"

Type	Electro-Hydraulic Gate Valve
Fail Position	As is
Design Pressure	750 psig
Design Temperature	500°F
Design Flow	30,000 Lbs./Hr.

<u>Steam By-Pass Valve (MS-17)</u> - The steam by-pass valve is located in the piping rack behind the turbine throttle valve. Reactor steam is passed from the main steam header directly into the turbine exhaust line which carries the steam to the condenser.

<u>Design Data</u>

Size	1"
Type	Electro-Hydraulic Globe Valve
Fail Position	As is
Design Pressure	750 psig
Design Temperature	500°F
Design Flow	17,000 Lbs./Hr.

<u>Temperature Regulating Valve (MS-13)</u> - The temperature regulating valve is located on the feed and condensate skid in the auxiliary service steam line to the space heat exchanger.

<u>Design Data</u>

Size	1-1/2"
Type	Pilot Operated Temperature Regulator
Fail Position	Closed
Design Pressure	180 psig
Design Temperature	400°F
Design Flow	2,250 Lbs./Hr.

Auxiliary Steam Reducing Valve (MS-48) - The auxiliary steam reducing valve is located on the feed and condensate skid on the auxiliary service steam line.

Design Data

Size	2"
Type	Pilot Operated, Steam Reducing Valve
Fail Position	Closed
Design Pressure	750 psig
Design Temperature	500°F
Design Flow	2,600 Lbs./Hr.

Turbine Throttle Valve (MS-3) - The turbine throttle valve, is mounted on the turbine generator upstream of the steam chest. The valve is operated manually during startup, and is fully open during normal operation. It trips shut automatically with turbine overspeed, low lube oil pressure, or high back pressure. After tripping, the throttle valve must be manually reset. This valve cannot be opened unless normal turbine oil pressure is available.

Design Data

Fail Position	Closed
Design Pressure	750 psig
Design Temperature	500°F
Design Flow	30,000 Lbs./Hr.

Turbine Governor Valve (MS-4) - The turbine governor valve is in the steam chest of the turbine generator. The governor valves are arranged on a beam with passages from the valves to the first stage nozzles. These valves are of the poppet type, connected to their lifting device by means of valve stems and are set to lift sequentially.

Design Data

Fail Position	Closed
Design Pressure	750 psig
Design Temperature	500°F
Design Flow	30,000 Lbs./Hr.

c. System Operation

Normal Operation - The normal main steam system functions are automatically controlled, consequently no operator action is normally required other then periodic monitoring of process instrumentation.

Startup - During initial reactor warmup the disassociated gasses are periodically vented to the power plant exhaust stack thru the startup vent line.

When reactor steam pressure has reached approximately 150 psig the main steam header and auxiliary steam system may be warmed up by bypassing steam around the main steam stop valve (MS-2). The high pressure drain system should be checked to insure proper drainage of all points.

As main steam header pressure stabilizes at greater than 150 psig. the main steam stop valve may be opened and the gland seal regulator and air ejectors and space heat exchanger are put in service.

When reactor warmup is completed and the condensate and lube oil service system are in normal operation the turbine is slowly brought up to speed until governor action observed. After proper governor action is observed turbine control is turned over to the plant control station where the auxiliary and plant loads are applied.

Shutdown - After the plant electrical loads have been removed from the generator, the auxiliary plant load is transferred to the diesel generator.

At zero electrical load the turbine throttle valve is tripped and steam to the air ejectors and gland seal regulator, and auxiliary steam system is secured.

d. Turbine Generator Description

The following equipment as defined herein is in accordance with the applicable specifications for the turbine generator skid for a boiling water reactor plant:

One (1) - Type DRVM, multi-valve, multi-stage condensing steam turbine rated 1250 KW at 10,000 RPM designed for inlet steam conditions of 600 Psia, 486°FTT and exhausting at 8" HgAbs. The unit will be capable of operation at back pressures from 6" HgAbs to 15" HgAbs.

One (1) - Type S-280-A single helical, single-reduction gear rated 1250 KW at 10,000/1200 RPM.

One (1) - Open type A-C synchronous generator rated 1250 KW, 0.8 p.f., 1563 KVA, 3 phase, 60 cycle, 480 volts, 1200 RPM generator equipped with a static excitation system.

One (1) - Complete lubrication system as defined herein.

One (1) - Set of accessory equipment as defined herein.

The above equipment shall be mounted on a self-supporting fabricated steel base.

PERFORMANCE SPECIFICATIONS
FOR GEARED STEAM TURBINE-GENERATOR UNIT

TURBINE

Maximum Rating	Nameplate	Steam Pressure at Throttle	Steam Superheat at Throttle	Steam Temperature at Throttle	Back Pressure at Exhaust Outlet
Kw	Kw	Pounds Abs	Degrees F	Degrees F	Inches mercury - absolute
1250	1250	600	0	486	8

The steam supplied to the turbine shall be free from entrained moisture

SYNCHRONOUS GENERATOR

RATING	Kva	Power Factor	Kw	Rpm	No. Poles	Phase	Cycles	Volts	Amperes	Connections
Generator	1563	0.8	1250	1200	6	3	60	480	1880	Wye
Exciter	--	--	10			--	--	125	----	---

Static type combined exciter-voltage regulator

The stator insulation will be Class B and the rotor insulation will be Class B.

TEMPERATURE RISE						DIELECTRIC TESTS		EXCITATION	
		Temperature Rise (C) not to Exceed				Between Coils and Frame A-c Voltage for 1 Minute		Maximum Required	
Ventilation Cu Ft Air per Minute	Hours Run at Rating	Armature Coils		Collector	Field Coils				
		By Temperature Detector	By Thermometer	By Thermometer	By Resistance	Armature	Field	Kw	Volts
5100	until constant	60° C	50° C	85° C	80° C	1960	1500	10.0	125

TURBINE-GENERATOR SET

STEAM RATES

The steam rates including all losses in the unit, including field rheostat, will be not more than the following with the steam conditions specified above:

Output of Generator		Pounds of Steam per Kilowatt-hour
Kilowatts	Power Factor	
1250	0.8	16.7
937.5	0.8	17.1
625	0.8	17.9
312.5	0.8	20.4

BASIS OF CALCULATIONS

Steam performance data in this proposal are based on Keenan and Keyes Steam Tables (1936).

ALLOWABLE PRESSURE AND TEMPERATURE VARIATIONS--GENERAL

The following allowable pressure and temperature variations are intended to provide for operating exigencies and it is expected that steps will be taken to minimize their occurrence, and expecially their occurrence simultaneously.

ALLOWABLE PRESSURE VARIATION

The steam pressure at the turbine main steam valve shall average not more than 630 Psia over any 12 month operating period. This permissible variation from rated pressure of 600 Psia merely recognizes the increase in pressure with decrease in steam flow encountered in operation, and is not to be interpreted as permitting operation above rated pressure to obtain more than rated output. In maintaining this 12 month average, the pressure shall not exceed 660 Psia except during abnormal conditions when the pressure may swing momentarily to 720 Psia but the aggregate duration of such swings shall not exceed 12 hours per 12 month operating period.

ALLOWABLE TEMPERATURE VARIATIONS

The steam temperature at the turbine main steam valve shall average not more than 486 FTT over any 12 month operating period. In maintaining this average, the temperature shall not exceed 501 FTT except during abnormal conditions resulting in temperatures not in excess of 511 FTT for operating periods not more than 400 hours per 12 month operating period nor 536 FTT for swings of 15 minutes duration or less, aggregating not more than 80 hours per 12 month operating period.

TURBINE-GENERATOR DATA

GENERAL

Physical data, for the turbine-generator skid can be obtained from the outline drawing No. 135R105BB. (Fig.-145)

The System controls diagram is drawing No. 509E222DF. (Fig.-120)

The performance of the turbine-generator has been defined with the features and accessories of the system delineated in subsequent material. Design data for gear and generator which does not lend itself to other parts of the proposal is given below.

GEAR DATA

Offset	Horizontal
Ratio	8.372549/1.0
Number of teeth on pinion	51
Number of teeth on gear	427
Speed	10,047/1200 RPM
Diametral pitch	9.95833
Pitch diameter of pinion	5.1213
Pitch diameter of gear	42.8787
Helix angle	23° 32 minutes 57.52 seconds
Pitch line velocity	13480 feet/minute
Pinion bearing size	3.5" x 3.0"
Gear bearing size	5.0" x 4.0"

Description of the gear can be found by referring to gear assembly drawings. (Fig.-137, 138, 139)

GENERATOR DATA

Transient reactance X'_d - .26

Sub-transient reactance X''_d - .20

Synchronous reactance X_d - .14

Negative sequence reactance X_2 - .23

Armature resistance per phase at 25° C - .00097 ohms
at 115° C - .00131 ohms

Field resistance at 25° C R_f cold - 1.13 ohms
at 120° C R_f hot - 1.54 ohms

Time constant of the field with the armature
open-circuited T'_{do} - 3.0 seconds

Time constant of the field with the armature
short-circuited T'_d - 0.56 seconds

Time constant of the direct axis amortisseur winding with
the armature short-circuited T''_d - 0.014 seconds

The physical data for the generator can be obtained from drawing No. 847D380. (Fig.-147)

STATIC EXCITATION DATA

Information for the static excitation system can be obtained from the following drawings:

44F240522	Sheet 1 - 3
44X240672	Sheet 1 - 2
44X240671	

FEATURES AND ACCESSORIES

ITEM	SYMBOL	NOMENCLATURE	APPLICABLE DRAWING
1.	MS-ST-01	Steam strainer with removable perforated monel metal sleeve.	Trip throttle valve, Item 26
2.	MS-3	Combined trip and throttle valve.	Trip Throttle valve
3.	MS-SG	Constant speed governor, oil relay type.	Governor assembly
4.	MS-4	Automatic steam control valve gear, multi-valve type.	Valve gear assembly
5.	MS-EG	Bolt-type, nonsparking emergency speed governor.	Emergency governor
6.	MS-SD	Motor and hand-operated synchronizing device.	Synchronizing device
7.	MS-IP	Metallic labyrinth interstage packing.	B-4066016-46BD
8.	MS-SP	Metallic labyrinth shaft packing.	B-4066016-46BD
9.	MS-HJ	Provision for hand jacking unit.	135R105BA (shown but not designated)
10.	MS-SR	Automatic steam seal regulator.	Regulator
11.	MS-ST-09	Steam strainer for sealing steam.	Not shown
12.	MS-MP	Moisture Protection	B-4066016-46BD
13.	MS-MS	Moisture separation	B-4066016-46BD
14.	LO-PO-01	Gear type, main oil pump, driven from reduction gear.	Mail oil pump
15.	LO-PU-02	Gear type auxiliary motor driven oil pump.	135R105BB
16.	LO-PU-05	Gear type, emergency oil pump, hand operated.	Hand oil pump
17.	LO-HX-01 LO-HX-02	Oil coolers, twin, tube type	101B106AF
18.	LO-TK-01	Oil reservoir	135R105BB
19.	LO-LI	Oil level indicator	135R105BB
20.	LO-ST-01	Duplex oil strainer	Oil strainer
21.	LO-6	Bearing pressure reducing valve.	509E222DF

FEATURES AND ACCESSORIES
(Continued)

ITEM	SYMBOL	NOMENCLATURE	APPLICABLE DRAWING
22.	LO-16	Auxiliary oil pump pressure reducing valve.	509E222DF
23.	LO-9	Pump pressure reducing valve	509E222DF
24.	LO-SF-01, etc.	Sight flow indicators	Sight flow indicators
25.	MS-HT	Hand trip	Tripping device
26.	MS-T	Solenoid trip	509E222DF
27.	MS-BPT	High back pressure trip	509E222DF
28.	LO-PS	Low lube oil pressure switch	Pressure switch
29.	LO-PR	Oil purifier	135R105BB
30.	MS-CP-01 and 02	Couplings	135R105BB
31.	LO-TM-01, etc.	Thermometers, as req'd.	509E222DF
32.	MS-RG	Single reduction gear	Gear assembly
33.	LO-PU-03 and 04	Coolant circulating pumps	135R105BB
34.	MS-Gen.	Generator	847D380
35.	MS-SExS	Stator excitation system	44F240522
36.	MS-PB	Pedestal bearing	Bearing and pedestal
37.	MS-JB	Journal bearings, similar design for turbine and gear.	Turbine bearing
38.	MS-THB	Thrust bearing	Thrust bearing

List of materials used in manufacture of turbine shown on drawing No. 135R105BA. (Fig.-145, 146)

DESCRIPTION OF TURBINE-GENERATOR UNIT

General Description:

The General Electric Company proposes to furnish a Navy type geared turbine-generator unit with complete lubrication system and auxiliary equipment mounted on a fabricated steel base to be used for a boiling water reactor power plant. The turbine and gear shall be designed and manufactured to currently applicable Navy Standards and Practices with proven reliability as demonstrated by successful operation on board Naval craft. Modification will be made only as required to meet the specific requirements of this application. The voltage requirement of 480 volts negates the possibility of a Navy generator since the standard Navy voltage is 450 volts. Therefore, a commercial generator designed and manufactured to standards equalling Navy requirements shall be supplied.

The overall dimensions shall not exceed 8 feet, 6 inches high by 8 feet 6 inches wide and 30 feet long. The generator will be shipped separately to insure compliance with the 30,000 pound total shipping weight requirements.

The following descriptive material and drawings completely define the equipment proposed to be used as part of a package nuclear power plant for remote locations.

DESCRIPTION OF TURBINE

General

The turbine will be a horizontal, multi-stage, axial flow, impulse type. The steam will enter through the inlet flange and, in sequence, pass through the steam strainer, throttle valve, and control valves, to the first-stage nozzles. The steam will then expand through the first-stage nozzles, pass through the first-stage bucket wheel, expand through the subsequent diaphragms and bucket wheels at each stage, finally passing out at the exhaust opening. The exhaust opening will be located at the top of the exhaust casing.

Casing

The steam inlet end of the turbine casing will be supported by brackets located on the reduction gear casing. The exhaust end of the turbine casing will be supported by standards which will be rigid in the direction perpendicular to the shaft, but will be flexible in the axial direction, thereby permitting unrestrained axial expansion of the turbine casing.

The casing will be made up of two parts; the high pressure head and stainless steel exhaust casing, bolted together at a vertical joint. Each of these parts will be made of an upper and lower section, bolted together at a horizontal joint located at the rotor centerline. The top sections of both parts bolted together can be lifted as a unit whenever the casing is opened. All joints will be made up metal to metal without the use of packing materials. All pockets will be drained to prevent the accumulation of water.

Nozzles

All nozzles will be made of erosion and corrosion resistant stainless steel. The first stage nozzles will be in a removable nozzle plate secured to the high pressure head. The nozzles for all the following stages will be located in the corresponding stage diaphragms.

Interstage Diaphragm and Packing

Each interstage diaphragm will be made of erosion and corrosion resistant steel and will have a ring of metallic labyrinth packing mounted in its bore. The diaphragms will be supported in such a manner that they will maintain concentric alignment with the turbine shaft under all operating temperature conditions. The metallic labyrinth packing mounted in the bore of each diaphragm will be held in correct radial position by means of corrosion resistant springs, and will retard the leakage of steam from stage to stage along the shaft. Each diaphragm and packing ring will be split on the horizontal centerline and arranged so that the top halves will be lifted with the top halves of the turbine casing as a unit.

The diaphragms will have corrosion resistant stainless steel in the steam passage ways in the sidewalls as well as the blades. They will be located on the outer periphery and the upstream face by raised crush pins insuring alignment, easy removal for inspection, repair or replacement. Replacement may be made with no machining (other than hand-fitting).

The labyrinth packing rings will be of the floating type, located by the diaphragms, but not fastened to the diaphragms, to insure that the initial close fit will be maintained and to minimize the shaft damage in case of shaft vibration or other disturbance.

Buckets

All buckets will be made of erosion and corrosion resistant stainless steel. These buckets will be secured to the wheels in accordance with General Electric Company standard practice, and will have erosion and corrosion resistant steel bands hand-riveted to their tips. These buckets will be secured to the wheel by outside dovetails, thereby protecting the wheel rims from erosion and corrosion. The nozzles and buckets will be designed with proper size, shape, number and spacing to avoid build-up of vibration resonances.

Shaft Packing and Sealing System

Packing boxes will be bolted to vertical joints on the outside of each end of the turbine casing through which the shaft extends. Each of these boxes will be equipped with metallic packing rings held in concentric alignment with the turbine rotor shaft by means of springs made of corrosion resistant material. Each packing box will be made in two halves, bolted and doweled together at a horizontal centerline joint so that the top half can be removed without disturbing the turbine casing, and thereby permitting ready access to the packing rings. All steam joints will be made up metal to metal without the use of packing material. Both packing boxes will be connected by stainless steel piping to a shaft sealing arrangement mounted on the set base.

The sealing system will be equipped with a connection through which auxiliary steam can be admitted to the packing boxes as required to prevent air leakage into the casing. It will also have a connection to the turbine exhaust casing. The sealing system will be equipped with an automatic steam regulator which controls sealing steam pressure by controlling the amount of auxiliary steam admitted to the system and the amount of steam bled from the system. The bleed steam will be piped to the turbine exhaust casing. A manual system parallels the automatic system so that the automatic steam seal regulator can be maintained while the turbine-generator is operating. Provision will be made for remote pressure indication to be supplied by the Purchaser.

Governing System

The turbine will be equipped with a hydraulically operated governing system which will automatically maintain the turbine speed approximately constant at any set speed within the normal operating range. A flyball speed governor will be mounted on a vertical shaft located in the reduction gear casing and driven by the low speed rotating element through gearing. (This vertical shaft will also drive the main oil pump).

The governor speed, therefore, will be directly proportional to the turbine speed. Movement of the governor weights in response to a change in turbine speed will vary the position of the steam admission control valves, through the medium of a rotating pilot valve connected to the governor weights, and an operating piston connected to the control valves. The top side of the operating piston will be loaded with a spring force which will tend to force the piston down to close the control valves. The piston will be forced upward to open the control valves by oil pressure supplied by the main oil pump, when the unit is running, and by auxiliary oil pump when the unit is being started and shut down. The pilot valve will be arranged in the high pressure line between the oil pump and the operating cylinder to control the oil pressure in the operating cylinder. As the position of the pilot valve is changed by the governor in response to turbine speed changes, the oil pressure under the piston of the operating cylinder changes, thereby changing the position of the piston and control valves. Follow-up and restoring devices are provided for system stability.

The turbine governing system will be equipped with a speed changing or synchronizing device which may be manually operated by means of a hand wheel or remotely operated by a motor mounted on the device. This device will be mounted on the reduction gear casing adjacent to the pilot valve housing.

Steam Admission Control Valves and Valve Chest

The multi-valve chest will carry governing valves arranged on a beam with passages from the valves which lead to the first-stage nozzles. These controlling valves will be of the poppet type, connected to their lifting device by means of valve stems. The valve stems will be of different lengths, inserted with clearance through vertical holes in the lifting beam, permitting opening and closing of the valves in sequence, with proper overlap, when the device is raised or lowered by the operating cylinder. This will permit the governor to automatically control the steam supply over the entire operating range of the unit and also will permit best economy at all loads by reducing throttling loss to a minimum.

The valves and valve seats will be hard surfaced. The lift rods will be provided with bushings of the labyrinth type. These bushings will be provided with steam leak-off piping for connection to the drain system, in order to minimize the leakage of steam along the lift rods.

Trip Throttle Valve

A combination trip and hand operated throttle valve will be mounted on the unit and located in the main steam line ahead of the control valves. This valve can be manually operated to control the steam when the turbine is being started and brought up to speed. It will also act as a quick closing valve when the unit is tripped by hand, or as an emergency valve when tripped automatically by action of the overspeed governor high back pressure, low oil pressure, and remote solenoid trip. When the throttle valve is closed as a result of the unit being tripped, before it can be opened, it will be necessary to reset by turning the hand wheel manually to the closed position.

The connection between the trip throttle valve and the overspeed governor will be hydraulic. To open the trip throttle valve it will be necessary to establish oil pressure under the spring loaded trip throttle valve piston. With oil pressure established, the hand wheel can be turned manually opening the throttle valve. Action of the emergency governor will dump the oil causing the piston to drop and the throttle valve to close.

The throttle valve will be of the poppet type, connected by lift rod and linkage to the throttle valve opening and closing device. The lift rod bushing will be of the labyrinth type and will be provided with steam leak-off piping connected to the drain system, for carrying off steam leakage which may occur during starting and periods of other than normal operation. The valve and valve seat will be hard surfaced.

Overspeed Governor

A bolt-type overspeed governor will be assembled on the turbine shaft at the exhaust end of the turbine rotor. This governor will operate to trip the throttle valve automatically when the turbine speed reaches approximately 10% above rated. The overspeed governor and flyball speed governor will be separate devices and will function independently of each other; however, the governing valves as well as the throttle valve will close when the unit is tripped by the overspeed governor.

Steam Strainers

A basket type steam strainer will be located in the steam line ahead of the trip throttle valve. The basket will be made of corrosion resistant material and will be arranged so that it can be removed for cleaning without breaking the steam line. A similar steam strainer will be located in the sealing steam line.

Oil System

The oil system will be self-contained in the unit. An oil tank will be built into the base and located under the reduction gear. The main oil pump will supply oil at 50 to 60 Psig which will be used at full pressure in the hydraulic relayed governor system and the trip throttle valve cylinder. This oil pressure will be reduced by an automatic pressure regulating valve to approximately 10 Psig for lubricating the turbine, gear and generator bearings and the gear mesh. A separate motor driven auxiliary oil pump connected through check and isolating valves to the oil system will be mounted on the unit to supply oil to the bearings, governor system and trip throttle valve cylinder when the unit is being started and shut down. Drain oil will flow back to the tank by gravity. The oil system will be complete with twin tube type oil coolers, duplex basket and magnetic type strainer, relief valves, pressure gages for lubricating oil system and for hydraulic system, all mounted on the unit.

A low oil pressure alarm contactor and low oil pressure trip will be included in the lubricating oil system.

Low oil pressure protection will also be incorporated into the governor system in that the normally closed trip throttle and governing valves all shall require oil from the same sources that supply lubricating oil for opening and holding them open. The arrangement will be such that if the lubricating oil pressure becomes too low, the oil pressure in the governing system will not be sufficient to hold the trip throttle and governing valves open and they will remain closed until adequate lubricating oil pressure is established.

Bearings

A bearing mounted in the gear casing will support the high pressure end of the turbine rotor. This bearing will be lined with babbitt and will be split on the horizontal centerline. The halves will be doweled for proper assembly. The lower half will be mounted in the lower half gear casing. With the bearing cap removed, the top half bearing may be removed and the lower half bearing may be rolled out without removing the rotor from the turbine casing. The turbine thrust bearing will be located in the gear casing at the generator end of the pinion. (An extension of the turbine shaft will pass through the bore of the hollow pinion and the thrust bearing will be located at the end of the turbine shaft extension). The thrust bearing will be adjustable for maintaining the turbine rotor in correct axial position. It will be oversized in capacity in the direction of steam flow to minimize the effects of accidental water slugs.

The low pressure end of the turbine rotor will be supported by a bearing mounted in a steel bracket, the lower half of which will be bolted to the lower half of the exhaust casing. The bearing will be mounted in a spherical seat and will be split on the horizontal centerline. The bore will be lined with babbitt. With the upper half of the bearing bracket removed, the top half bearing may be removed and the lower half bearing may be rolled out without removing the rotor from the turbine casing.

Rotor

The rotor will be a steel forging with shaft and wheels forged integral.

Balancing rings will be provided at such locations that they will be accessible for field balancing without removal of the upper half turbine casing.

Moisture Protection

The high pressure saturated steam necessitates that extreme precautionary measures be taken to avoid damage due to erosion and corrosion caused by moisture. The following provisions shall be incorporated in the proposed design:

a. Stainless steel exhaust casing.
b. Stainless steel external dovetail buckets.
c. Solid forged rotor.
d. Stainless steel first-stage nozzle blades.
e. Stainless steel first-stage inner and outer bands.
f. Stainless steel diaphragm blades.
g. Stainless steel inner and outer diaphragm bands.
h. Stainless steel governor valves and seats.
i. Stainless steel trip throttle valve trim.
j. Stainless steel trip throttle valve body.
k. Stainless steel inlay where moisture impinges on casing when thrown radially from the wheel due to centrifugal forces applied to the moisture particles.
l. Stainless steel moisture separation at each stage except first and last.
m. All labyrinth packing will seal against stainless steel surfaces.
n. All piping in contact with steam or condensate will be stainless steel.
o. The following areas will have mating sealing surfaces of stainless steel inlay.
    1. Valve chest cover and valve chest.
    2. High pressure packing box and casing.
    3. Diaphragm and wheel casing.
    4. Wheel casing horizontal point.
    5. First-stage nozzle plate and bridges on high pressure casing.
    6. Packing box horizontal joint.
    7. Diaphragm horizontal joint.
    8. Valve chest and high pressure head.

Drawing No. B-4066016-46BD shows the above features applied to the turbine-cross-section.

DESCRIPTION OF GEAR

The reduction gear is a single-reduction, single helical type with pinion horizontally offset to one side of the gear, and reduces the turbine speed to the generator speed of 1200 rpm.

Reduction Gear Casing

The gear casing is of fabricated steel construction and consists of two halves that are bolted and dowelled together at the horizontal centerline of the rotor in an oiltight metal-to-metal horizontal joint. The bearing seats for supporting both the gear and pinion bearings, the seating for the oil pump, and the supports for the high-pressure end of the turbine are fabricated integral with the lower-half-casing.

The upper-half casing serves as a cover for the gear unit and, as a support for the hydraulic control mechanism of the turbine. It also has the generator-end pinion and gear bearing caps integral with it. The turbine-end pinion and gear bearing caps are separate pieces and must be bolted in place before the upper-half casing is assembled in place. Two inspection openings are provided in the upper-half casing, one for the inspection of the gear teeth, and one for inspection of the speed governor.

Pinion

The pinion is of the quill design. The purpose of this pinion arrangement is to provide flexibility to allow for the slight misalignment between the turbine and gear experienced during operation. The pinion is a solid forging, hollow-bored with spline teeth machined in the thrust-bearing end, and an extension beyond the spline teeth on which a locating spacer, the thrust collar, and a locknut are assembled.

The spline teeth of pinion and quill are assembled in a size-to-size fit without outside diameter interference. The quill shaft is held in correct axial position with respect to the pinion by an integral shoulder surface-machined in the pinion bore. A locknut located on the generator end of the pinion assembly maintains this correct location of two parts. The pinion is thus held in a fixed axial position with respect to the quill shaft under all gear load conditions. The flexibility of this design is provided by the comparatively long quill shaft of a small diameter.

The quill pinion is supported by a generator-end bearing and a turbine-end bearing that is designed to support both the pinion and the turbine end of the quill shaft (the generator end of the quill shaft is supported by the spline). Since the turbine rotor is bolted rididly to the solid flange of the quill shaft, a portion of the weight of the turbine rotor is carried by the quill shaft portion of the turbine-end pinion bearing.

Gear Wheel

The gear wheel is a steel forging and is pressed and keyed on a forged steel shaft. One end of the gear shaft is solidly coupled to the generator shaft and part of the weight of the generator rotor is carried by the gear bearing at that end. The turbine end of this shaft is extended to carry the spiral gear that drives the oil pump and the governor.

Journal Bearings

The gear and pinion bearings are split and have dowels in the joint surfaces to prevent incorrect assembly of the two halves. All bearing joints are horizontal in the gear case.

The pinion and gear bearings are of the cylindrical, shoulder, steel-backed, babbitt-lined type.

The turbine-end pinion bearing is designed to have two journal surfaces separated by a machine relief in the bearing shell. The machined relief has drilled holes in the bottom, which lead back to the casing and serve as drain holes. The portion of this bearing that supports the quill shaft is of the "pressure type", having a wide groove machined in the babbit about two-thirds of the way around the upper surface of the bearing, starting with the deepest part at the joint, and gradually decreasing in depth in the direction of rotation. When the shaft rotates at high speed, this groove causes a wedge of oil to form in the upper half of the bearing, which exerts pressure downward and acts to stabilize the shaft.

Lubricating oil is supplied by the gear pump through machined passages to a feed slot in the joint surface of the bearing linings. Even distribution of oil over the bearing surfaces is assured by a distribution recess in the inner surfaces of the bearing liner. The gear mesh is oil-spray lubricated.

Thrust Bearings

The high-speed pinion thrust bearing is a pivoted shoe type, which consists of a rotating collar fixed to the pinion quill shaft and two sets of stationary pivoted segments called shoes. Normal-operating pinion thrust is carried on the outboard bearing, which consists of three shoes self-aligned by a spherical base ring support. A condition of water-slug thrust up to certain limits will be carried by the inboard bearing, which consists of six shoes self-aligned by leveling plates.

Oil, for lubricating the thrust surfaces of the high-speed thrust bearing, is supplied through drilled passages from the oil supply in the pinion bearing seat to machined rings on the outer diameter of the base ring and leveling plates, from which it passes inward to the inside diameter of the active and inactive thrust shoes. The rotation of the collar sweeps the oil outward over the shoes and discharges it to a tangential outlet oil passage located in the top of the bearing housing. Because of the top drain, the bearing operates in a flooded condition; oil discharged from the bearing flows through relatively large drilled passages back to the gear casing.

The axial position of the gear-generator rotor is maintained in the thrust faces on the gear bearing, which bear against the thrust surfaces machined on the ends of the gear hub. The low-speed-gear thrust bearing is lubricated by the oil that flows in toward the gear in the gear bearings. This oil passes over the thrust surfaces and then drains down into the casing.

Spiral Gears For Oil Pump and Governor Drive

A spiral pinion and gear drive the oil pump and the turbine governor. The driving gear is of steel and the driven gear is of cast bronze. Lubrication of these gears is supplied through a mesh nozzle.

Shaft-Driven Oil Pump

The oil pump assembly is supported by the lower-half horizontal joint of the reduction-gear casing. The driving and driven gears are submerged in the oil sump. The rotating members are supported and guided by five bronze bushings, three for the driving member and two for the driven. Rotation of these gears causes oil to be carried around in the spaces between the teeth and the pump body and then up to the outlet passage in the casing. One outlet discharges directly to the governing system and the other outlet to the lubricating system. The capacity of the pump is approximately 55 gpm when the oil temperature is 130°F.

Hand Oil Pump

The hand oil pump is mounted on the side of the gear casing. This pump draws oil directly from the reservoir and is used as an emergency supply of lubricating and governing oil only when the motor driven main oil pump is inoperative. The pump is a gear type similar to the main pump. The handle is hinged so that it can be turned aside when not in use.

DESCRIPTION OF GENERATOR

General

The generator will be a single bearing, open dripproof protected construction with a static excitation system.

Stator

The stator will consist of three main elements: A fabricated steel frame, a laminated core, and a 3 phase winding. The frame will be made of welded plate steel with steel ribs welded in it. Slotted punchings will be stacked on these ribs and securely held in place by flanges keyed to the ribs.

Coils of rectangular wire will be assembled in the slots of the laminated core. They will be Y connected to bus rings for a 3-phase output. The coils will be wound and preformed to fit the slots and coil span.

Six temperature detectors will be imbedded in the stator windings and leads from each of these detectors will be brought out to a terminal board.

Two 115 volt A.C. single phase 500 watt heaters will be mounted in the frame for use in preventing moisture condensation on the windings during shutdown periods.

Rotor

The rotor will consist of a shaft, a spider, six field poles, a collector, a centrifugal fan and a set of ventilating fans. The shaft will be a solid steel forging with a flange machined at one end for coupling to the gear and an extension at the other end for the collector.

The spider will be a hexagonal stack of laminations riveted together under pressure. It will be shrunk and keyed to the shaft. The field poles will be mounted on this spider by means of dovetails which fit slots in the spider. Steel keys will wedge each dovetail in its slot.

Each field pole will be made up of a coil and a pole piece of slotted laminations solidly riveted together between a pair of end plates. Field pole supports containing holes for ventilation will be bolted between the poles. The coils will be connected in series to the collector.

An amortisseur winding of copper bars connected together at both ends will be assembled in the top of each field pole. All six windings will be connected together to make a closed amortisseur winding.

At the collector end, a set of three ventilating fans will be bolted to the spider, and at the opposite end a centrifugal ventilating fan will be bolted to a flange on the shaft. Air will be circulated by this fan through the entire generator.

Pedestal Bearing

The bearing will be supported in a separate base mounted pedestal. The bearing will be spherical seated self-aligning type, babbitted and split on the horizontal centerline. This bearing will be pressure lubricated. An oil deflector will be provided at each end of the bearing.

STATIC EXCITER - VOLTAGE REGULATOR SYSTEM

In this system alternator field current is supplied by a static exciter rather than by rotating DC exciter or amplifier. The output of the static exciter is controlled by a regulator which is controlled by a signal from the AC generator terminal voltages.

The static exciter - voltage regulator offered with this equipment offers a number of advantages not available on equipment with rotating exciters. These advantages include:

1. Low maintenance costs. The exciter has no moving parts, no bearings, and no commutator.

2. Greater reliability. Only highly reliable components such as transformers and rectifiers are used.

3. A shorter length turbine-generator set. There is no overhung exciter.

4. Better voltage regulation because of the compensation built into the exciter.

5. Faster response during load changes because the signal to increase or decrease excitation does not have to travel through the regulator circuit and exciter control winding. Instead the AC current feed changes the exciter output voltage almost instantaneously without the delays of the regulator and exciter time constants.

6. Less voltage dip during load changes because the generator field voltage is increased almost instantaneously after a load is added.

Following is a brief description of how the system operates. A more detailed description of operation is found on drawing number 44F240522.

1. AC generator voltage is first reduced by a transformer, rectified in a three phase bridge rectifier, and filtered.

2. The resultant filtered DC voltage is applied to zener diodes. The zener diodes are silicon rectifiers operating in the breakdown or zener region and have a constant voltage drop over a wide current range.

3. The resultant DC voltage from step 1 above is proportional to generator line voltage. In addition to providing a source for reference voltage it is fed to a simple voltage divider circuit. There it is compared with the constant reference voltage and the difference is applied to a transistor amplifier stage and then to a magnetic amplifier reactor.

4. The output of the magnetic amplifier goes to the control winding of a saturable current potential transformer (hereafter abbreviated SCPT). The SCPT is a 3 phase transformer, each phase having a current winding, a potential winding and a secondary winding. The secondary windings are connected to a 3 phase bridge rectifier and this output is directed to the AC generator field windings.

5. At no load the SCPT is energized from the AC generator terminal voltage through linear reactors. Under load the line current adds a component that is approximately proportional in magnitude and phase angle to the synchronous reactance drop in the generator. The SCPT control winding changes the output, as necessary, by saturating the cores.

6. The system is stabilized by feedback of a signal from the generator field voltage to the magnetic amplifier.

7. Equal division of reactive current, necessary for successful parallel operation, is accomplished by creating a droop in the generator voltage which is proportional to reactive line current. This is done by using a current transformer to add a voltage proportional to reactive current to the line voltage signal to the regulator. If the line current has a lagging reactive component the voltage signal to the regulator will be proportionately increased and the regulator will act to lower the generator excitation.

8. Since the static exciter cannot supply field current until some generator voltage is available, a separate 440V AC source is provided for generator field flashing.

DESCRIPTION OF FABRICATED STEEL BASE

A self-supporting fabricated steel base of "I" beam construction will be supplied to accomodate the geared turbine generator, lubrication system and auxiliary equipment. The oil reservoir for turbine gear shall be integral with the base. The oil reservoir shall be supplied with a dip stick oil level indicator. The base will be designed for side rail mounting.

DESCRIPTION OF OTHER EQUIPMENT

Auxiliary Motor Driven Oil Pump

Northern Ordnance, Model #4600-30 geared-type positive displacement pump of all steel flanged construction with mechanical seals rated 60 GPM at a discharge pressure of 45 Psig. The pump is started automatically by a pressure switch when the system oil pressure drops to 35 Psig. and stops automatically when system oil pressure rises to 45 Psig. The pump is driven by a General Electric 3 H.P., 1740 RPM, 440 volts - 3 phase - 60 cycle TEFC severe duty, chemical-type motor.

Oil Coolers

Two (2) Basco Size 10108, Twin Lube Oil Cooler Assembly, consisting of two (2) coolers, Kraissl transfer valve and interconnecting piping. Unit designed with materials of construction and performance in accordance with the specification sheet.

Oil Purifier

DeLaval Model 38-23. Turbine lube oil purifier having corrosion resistant bowl, integrally mounted inlet and discharge pumps; both centrifugal pumps driven by single 1/2 H.P., splash-proof motor, suitable for operation on 220 - 440 volts - 3 phase - 60 cycle current. Unit complete with one (1) set of special tools.

Twin Coolant Circulating Pumps

These pumps circulate coolant in a closed loop through the oil coolers and intercooler.

Ingersoll-Rand, No. 1-1/2 RV, all steel, flanged pump, rated 15 GPM at 45-foot head. The pump is driven by a General Electric totally enclosed, fan-cooled motor, rated 1-1/2 H.P. @ 3450 RPM for operation on 440 volts - 3 phase - 60 cycles.

2. Condensate System (C)
Condensate System Diagram - Project No. 2102 (Fig. 154)
Condensate System Process Instrumentation, Project No. 2102-11 (Fig. 155)

a. Introduction

<u>System Function</u> - The purpose of the condensate system is to condense the exhaust steam from the turbine, subcool the condensate, and pump the condensate through the various auxiliary plant heat exchangers where it is used as a coolant. After passing through these heat exchangers, the coolant is collected in the reserve feed tank. The system also removes non-condensibles from the condenser and the pre-cooler and maintains a vacuum in the condenser, the turbine generator gland exhaust, and reactor seal leak off lines.

<u>Brief Description</u> - Exhaust steam from the turbine passes through the exhaust steam header to the condenser building, and is diverted into each of the two air-cooled condensers (C-HX-01, C-HX-02). Valves are provided on the branch line to each condenser for isolation during maintenance. The steam enters each condenser through two inlet nozzle connections on the tube side of the condenser. The steam is condensed, and the condensate sub-cooled by forced air flow over the outside of the condenser tubes. The sub-cooled condensate drains by gravity and is collected in a separate hotwell tank (C-TK-01) located on the feed and condensate skid.

One of two condensate pumps (C-PU-01, C-PU-02) normally takes suction from the hotwell and delivers condensate through a discharge header to the system heat exchangers. Loss of discharge pressure will automatically transfer service to the standby pump. Globe stop-check valves on the discharge line of both condensate pumps allow the pumps to be started or stopped without changing valve positions. The discharge header then distributes the condensate for use as coolant to the following equipment:

After condenser and pre-cooler, connected in series.
Second Stage Heat Exchanger.
Shield Water Coolers.

Lube Oil Intercooler.

Evaporator Condenser.

Low Pressure Drain Cooler.

Condensate from the heat exchangers is delivered to the reserve feed tank (C-TK-02) through a common header. A three-way valve (C-40) in the line to the reserve feed tank automatically maintains the proper level in the tank by diverting the excess flow back to the sub-cooler. In this manner the full design flow rate is maintained through the sub-cooler and plant auxiliary heat exchangers independent of plant steam loads.

When required, make-up water can be added manually to the hotwell by a vacuum drag connection from the makeup feed tank or a connection from the makeup pump discharge header.

Two single stage air ejectors are provided to remove non-condensible gases from the two air-cooled condensers and hotwell to maintain the design condensing vacuum. One ejector has sufficient capacity for the system, and the second may be manually started when required. A second set of two single stage ejectors is operated in a similar manner to the main ejectors to remove non-condensibles from the shell side of the pre-cooler., (C-HX-05). Both ejectors discharge into the after condenser (C-HX-06) where the vapor carryover is condensed and returned to the low pressure drain tank.

System Design Data

Steam Flow into the Condenser	19,810 Lbs./Hr.
By-Pass Flow to Sub-cooler	3,470 Lbs./Hr.
Total Coolant Flow	29,925 Lbs./Hr.
Condensate Piping Pressure	
Design	250 psig
Hydrostatic	325 psig
Vapor Piping Pressure	
Design	50 psig
Hydrostatic	75 psig

b. Description of Components

Main Condenser (C-HX-01, C-HX-02) - The two air-cooled condensers are connected in parallel and are located in a single building. The condensers are designed to condense the turbine exhaust steam and to sub-cool the condensate. The condensing portion consists of six rows of horizontal 1" diameter finned tubes which are roller expanded into stainless steel headers at each end. The tubes are slightly pitched to the rear header to allow drainage. A seventh row of tubes below the condensing section provide the sub-cooling section of the condenser. The sub-cooler tubes are sloped downward from the outlet end and therefore remain flooded at all flow rates.

Four forced air propeller type fans are mounted below each condenser, and are coupled directly to electric motors. The fans provide the necessary coolant air flow to remove the heat given up by the condenser. The inlet air drawn from the tunnel enters the condenser building through fixed open inlet dampers mounted on the building side walls. It is then mixed with controlled amount of heated re-cycled air from the bypass louvers of the condenser to obtain the mixed air temperature set at the controller. The combined air then passes through the condenser fans, and heat exchange surface. A portion of the discharge air is recycled through the by-pass damper, and a portion is directed to atmosphere through the outlet damper to the exhaust stacks.

A prototype condenser identical to the above units has been successfully tested at NRTS. For complete performance data refer to "PL Condenser Evaluation Report, IDO-19031". It should be noted that this condenser can accept superheated steam without additional desuperheating equipment. 300 psig saturated steam was throttled to condenser pressure during all prototype performance tests.

Design Data

Design Pressure (full power)	8" Hg. Abs.
Design Inlet Air Temperature	50°F
Total Air Flow Rate Per Unit	540,000 Lbs./Hr.
Total Heat Rejected in Condenser	18.1×10^6 Btu/Hr.
Total Heat Rejected in Sub-Cooler	1.24×10^6 Btu/Hr.
Design Pressure	50 psig
Number of Tubes in Condenser	210
Number of Tubes in Sub-cooler	35
Total Heat Transfer Surface	35,292 Sq. Ft.
Tube Type	1" O.D. 18 Bwg

Condensate Pumps (C-PU-01, C-PU-02) - The condensate pump is a horizontally mounted single suction, centrifugal pump driven by a single speed close coupled motor. Sealing water is continuously supplied to the shaft packing of both the operating and idle pumps to prevent air leakage into the system. The sealing water also serves to lubricate the packing. The suction side of the operating pump is vented to the hotwell to prevent the formation of a vapor lock in the suction piping or pump casing.

Design Data

Rated Capacity	62 GPM
Total Head at Rated Capacity	112 Ft.
Motor Horsepower	5 HP
Power Requirements	440 V 3 Phase

Air Removal Equipment - The air removal equipment, mounted on the feed and condensate skid consists of two single stage steam jet air ejectors, a pre-cooler, after condenser, drainer and associated valves and piping. The pre-cooler condenses vapor from the turbine generator and gland seal exhaust system, while the condenser air ejectors remove air and decomposition gases from the air-cooled condenser, hotwell, and pre-cooler.

Design Data

Pre-Cooler and After Condenser: (C-HX-05, C-HX-06)

Type	Shell and Tube
Steam to Pre-Cooler	55 Lbs./Hr.
Air to Pre-Cooler	23 Lbs./Hr.
Condensing Pressure of Pre-Cooler	5" Hg. Vac.
Coolant Flow	10,000 Lbs./Hr.
Inlet Coolant Temperature	100^{o}F
Steam to After Condenser	360 Lbs./Hr.
Air to After Condenser	30 Lbs./Hr.
Condensing Pressure of After Condenser	1 psig (Nom.)

Condenser Air Ejector (C-EJ-03, C-EJ-04)

Type	Single Stage
Motive Steam Pressure	150 psig
Discharge Pressure	1 psig (Nom.)
Suction Pressure	8" Hg. Abs.
Suction Temperature	146^{o}F
Air to After Condenser	30 Lbs./Hr.

Gland Exhaust Air Ejector (C-EJ-01, C-EJ-02)

Type	Single Stage
Motive Steam Pressure	150 psig
Discharge Pressure	1 psig (Nom.)
Suction Pressure	5" Hg. Vac.
Air to After Condenser	23 Lbs./Hr.

Hotwell Tank (C-TK-01) - The hotwell tank collects and stores condensate from the air-cooled condenser and the low pressure drain cooler, receives makeup water from the makeup system, and supplies suction to the condensate pumps.

Design Data

Design Pressure	30 psig and 30" Hg. Vac.
Design Temperature	250°F
Shell Outside Diameter	36"
Internal Capacity	56.5 Cubic Feet

Reserve Feed Tank (C-TK-02) - The reserve feed tank collects and stores condensate after being used as a coolant for various plant heat exchangers and supplies suction to the feed water pumps.

Design Data

Design Pressure	15 psig and 30" Hg. Vac.
Design Temperature	250°F
Shell Outside Diameter	60"
Internal Capacity	70 Cubic Feet

Shield Tank Cooler (C-HX-07, C-HX-08, C-HX-09) - The shield tank coolers are immersed coils suspended into the shield tank from a hand hole cover in the top of the tank. The coolers remove heat from the shield water in the reactor shield tank.

Design Data	Tube Side
Design Pressure	150 psig
Design Temperature	250°F
Fluid	Water
Flow Rate Per Coil	2380 Lb./Hr.
Heat Transferred per Coil	96,700 Btu/Hr.

Condensate Control Valve (C-40) - The condensate control valve C-40 is a three way globe valve located on the feed and condensate skid. It receives a control signal from the liquid level in the reserve feed tank and diverts excess condensate back to the sub-cooler, thus maintaining constant flow to the heat exchangers served.

Design Data	
Size	2"
Type	3-way Electro-Hydraulic Globe Valve
Fail Position	As is.
Design Pressure	150 psig.
Design Temperature	200°F
Design Flow	33,000 Lbs./Hr.

c. System Operation

Normal Operation - The condensate system is a fully automatic system which requires no operator action other than a periodic monitoring of process instrumentation to confirm normal performance.

Startup - A condensate pump is started just prior to admitting warm-up steam to the main steam header during normal plant startup. Prior to starting a condensate pump, it should be properly vented, and all valves in the coolant flow path checked to insure flow to the heat exchangers served. Process instrumentation should be checked frequently during plant warmup to insure normal operation.

When steam is available at the reducing station the air ejectors may be started by opening the motive steam supply valve and then opening the corresponding suction valve. The discharge valve should remain open at all times except when the ejector is removed for service.

When the plant is ready for turbine warmup the main condensers are started up as follows:

Place louver control in manual in full recirculating position.

When steam is admitted to the condensers start fans in sequence to maintain approx. 15" Hg. Abs. in the condenser.

When all fans are on and the turbine is ready to take up load place louver control in automatic.

Shutdown - When turbine steam has been secured manually set condenser louvers in full recirculating position.

Shut condenser building inlet dampers.

Shut off condenser fans in sequence.

Shut operating air ejector suction valves and secure motive steam supply.

When cooling load on all heat exchangers has decreased to approximately zero the condensate pump may be secured.

Drain the subcooler section of each condenser to the drain tank in the Service Water System by closing valve (C-41) and opening valves (C-18) and (C-44.)

3. Feedwater System (F)
Feedwater System Diagram - Project No. 2103 (Fig. 169)
Feedwater System Process Instrumentation - Project No. 2103-11 (Fig. 170)

a. Introduction

System Function - The feed system takes suction from the reserve feed tank (F-TK-01) and delivers the feedwater to the reactor through a spray ring. A portion of the feedwater flow is diverted and used to supply sealing water at high pressure to the control rod drive seals. Water from the purification system is mixed with the feedwater before being delivered to the reactor. The boric acid poison cylinder (F-TK-02) is normally disconnected from the system, but when required can be valved in series with the feedwater entering the reactor.

Brief Description - Both feedwater pumps (F-PU-01, F-PU-02) are located on the feed and condensate skid. One is normally operated and the other is in standby. The feedwater pump takes suction from the reserve feed tank also located on the skid, and delivers feedwater to the discharge header. The reserve feed tank provides a positive suction head to the feed pumps and a ten minute reserve of feedwater in the event that condensate flow is interrupted. Loss of discharge pressure in the header will automatically transfer service to the standby pump. Both pumps are normally valved into the system so that they can be operated remotely without manual valve lineup. Globe stop check valves at the discharge of each pump prevent back flow through the idle pump. A fixed orifice by-pass line discharging back to the reserve feed tank ensures sufficient flow through the feed pump to prevent overheating under all operating conditions.

A feedwater control valve (F-6) in the feedwater header controls flow to the reactor. The reactor liquid level control system operates this valve. A portion of the feedwater flow is taken off before the control valve to supply the control rod drive seals. A replaceable cartridge type filter (F-FR-01) in the line protects the Control rod drive seals from damage due to foreign materials being carried along with the seal water.

An orifice meter (F-FS-01) is provided downstream of the feedwater control valve to indicate feedwater flow rate. The purification system discharges into the feedwater line downstream of the orifice meter and check valve. The check valve prevents backup of purification flow into the feed system. A fine screen strainer (F-ST-02) is provided in the feedwater line downstream of the purification system tie in to prevent any foreign material from entering the reactor. An electro-hydraulic stop-check valve (F-13) is located in the feedwater line near the containment vessel to prevent reverse flow from the reactor and permit remote isolation of the reactor at the control console.

System Design Data

Feedwater flow in the main header	23,800 Lbs./Hr.
Pressure:	
Design	750 psig
Operating	700 psig
Hydrostatic Test	1050 psig
Temperature:	
Design	250°F
Operating	145°F

b. Component Description

Feedwater Pump (F-PU-01, F-PU-02) - The feedwater pump is a vertically mounted, motor driven, multi-stage centrifugal type pump, located on the feed and condensate skid. Two pumps are installed in parallel. During normal operation one pump is operating and the other maintained in standby condition.

Design Data

Capacity	54 GPM
Discharge Pressure	700 psig
Suction Pressure	Atmosphere
Total Head	1650 Feet
Design Pressure	750 psig
Design Temperature	200°F

Feedwater Control Valve (F-6)- The feedwater control valve (F-6) is located on the feed and condensate skid in the feedwater line downstream of the take-off to the gland seal system.

Design Data

Size	1"
Type	Electro-Hydraulic Globe Valve

Design Pressure	800 psig
Design Temperature	200°F
Design Flow	60 GPM @ 150°F
Fail Position	as is

Feedwater Stop Check (F-13) - The feedwater stop check valve (F-13) is located just outside of the containment vessel in the feedwater line.

Design Data

Size	2"
Type	Electro-Hydraulic Stop Check
Design Pressure	800 psig
Design Temperature	500°F
Design Flow	63 GPM @ 150°F
Fail Position	as is

Poison Cylinder (F-TK-02)- The poison cylinder is located on the feed and condensate skid, and serves as a storage vessel for granular boric acid (H_3BO_3). When required feedwater is pumped through the H_3BO_3 bed to dissolve the acid and introduce the solution into the reactor vessel.

Design Data

Design Pressure	750 psig
Design Temperature	350°F
Shell Outside Diameter	18"
Capacity	6 $ft.^3$
Installed Position	Axis Vertical

Feedwater Strainer (F-ST-02) - The feedwater strainer is located downstream from the purification system tie in and prevents resin or foreign solids from entering the reactor.

Design Data

Type	Y Pattern Design
Size	2"
Strainer Size	U.S. Standard 200 Mesh
Design Pressure	750 psig
Design Temperature	200°F

Control Rod Seal Water Filter (F-FR-01) - The Control Rod Seal Water Filter is located in the supply line to the seals and prevents foreign matter from entering the rod drive mechanism.

Design Data

Type	Replaceable Cartridge Type
Size	1/2"
Filter Size	5 Micron
Design Pressure	825 psig
Design Temperature	250°F

c. System Operation

Safety Precautions - Before a feed pump is started, the isolation valve in the recirculation line should be checked open and reserve feed tank level checked to prevent the pump from overheating.

Normal Operation - Once started the feed system operates automatically. No operator action is required other than monitoring system instrumentation to ensure proper function.

Startup - During warm up of the main steam system, the feed system is started to supply the feedwater requirements of the reactor.

Line up all valves for flow to the reactor.

Open both feed pump suction valves and discharge valves.

Start one feedwater pump.

Shutdown - Press stop button for the operating feed pump.

4. Coolant Purification System (CP)
Coolant Purification System Diagram - Project No. 2104 (Fig. 172)
Process Instrumentation, Coolant Purification System - Project No. 2104-11 (Fig. 173)

a. Introduction

System Function - The Coolant Purification System removes soluble and insoluble impurities from the reactor coolant by continuously passing a portion of the coolant through a demineralizer column. The soluble matter is removed by ion exchange and the insoluble matter is removed by the filtering action of the resin bed. Removal of these impurities from the reactor coolant prevents fouling of the fuel element heat transfer surfaces and serves to maintain a low level of activity in the coolant.

The system can be utilized to cool down the reactor water to 150°F after a plant shutdown. During this operation, reactor water is circulated through the system and heat is rejected through the second stage heat exchanger (CP-HX-02). The system is also utilized to remove decay heat generated in the core during a reactor shutdown.

When it is desired to accomplish a chemical shutdown of the reactor plant, the system may be utilized to pump poison solution to the reactor vessel.

Brief Description - The system consists of a demineralizer (CP-IX-01), two heat exchangers (CP-HX-01, CP-HX-02), and two canned motor pumps (CP-PU-01, CP-PU-02) (one normally operating). These components are located on the purification module which is located in the Power Plant Building. Fluid from the reactor flows through the two heat exchangers to the ion exchange demineralizer. The canned motor pump then pumps the fluid through the first stage heat exchanger to the reactor feedwater line which returns the fluid to the reactor. Upon loss of discharge pressure on the operating pump, a pressure switch (CP-PX-01) which is located on the common pump discharge line will automatically start the standby pump.

The demineralizer is provided with shielding which is sufficient to meet ICC radiation shipping regulations. The packaged demineralizer concept permits the unit to be housed on the purification skid without radiation hazard. It also permits non-hazardous handling of the spent unit.

A thermocouple (CP-TT-01) and resistance thermometer (CP-RT-01) are located in the inlet to the demineralizer. They provide indication and high temperature alarm functions. Where the demineralizer inlet temperature exceeds 140°F, the purification pump is automatically stopped to prevent damage to the resin. A flow measuring orifice is located in the purification return line to provide indication of the purification flow rate.

Two sampling taps, one located upstream and the other located downstream of the demineralizer are provided to allow coolant samples to be taken to check the performance of the demineralizer.

An eductor (CP-ED-01) is also provided in the system to circulate water to the second stage heat exchanger for decay heat removal during shutdown of the reactor plant. The eductor is located in the reactor complex. Eductor motive water is provided by recirculating a portion of the purification pump discharge during this operation.

A by-pass line is located around the demineralizer to allow the fluid to by-pass the demineralizer during a chemical shutdown of the reactor plant.

A line located downstream of the coolant purification pumps connects the system with the Service Water System. This line allows primary plant water to be pumped to the drain tank in the Service Water System when it is desired to dispose of excess reactor coolant.

Decontamination connections are located on the reactor side of the first stage heat exchanger. They allow decontamination fluid to be pumped through the two heat exchangers and coolant purification pumps to decontaminate these components.

<u>System Design Data</u>

Demineralizer Resin Capacity	2.8 $Ft.^3$
Demineralizer Lifetime	1 Year
Purification Flow Rate	3 GPM (at 120°F)
Equilibrium Total Solids in Reactor Water	1.25 PPM, Max.
Reactor Water pH	6.5 - 7.5
System Design Pressure	750 psig
System Hydrostatic Test Pressure	1125 psig

b. Component Description

1) Radioactive Demineralizer (CP-IX-01

Component Description - The demineralizer vessel nominal diameter is 14 inches and about 53 inches high. It contains

2.8 cubic feet of resin. The demineralizer is housed in a lead shield cask. The demineralizer and shield cask are an integral unit. The radioactive demineralizer is removed from shield cask after shipment to a disposal area. A fresh demineralizer is inserted in the shield cask and the unit is shipped back to the plant. Both the inlet and outlet piping extend through the top head of the demineralizer. The unit is installed in the system by connecting the inlet and outlet piping through union connections to the system piping. The unit is air vented during initial fill by back filling through the outlet line, and venting through a weep hole located in the inlet line near the top head. The vented air is purged from the inlet system piping through vent valve CP-28 located in the inlet piping line.

Component Design Data

Demineralizer

Demineralizer Resin Volume	2.8 $Ft.^3$
Demineralizer Resin Type	Nuclear Grade Strong Acid-Strong Base Equivalent to NR-14.
Normal Flow Rate	1488 Lbs./Hr.
Operating Pressure	600 psig
Operating Temperature	120°F
Design Pressure	750 psig
Design Temperature	500°F

Shield Cask

Lead Thickness	3 7/8"
Inner and Outer Steel Casing Thickness	1/4" Carbon Steel

2) 1st Stage Head Exchanger (CP-HX-01)

Component Description - The 1st stage heat exchanger is a helical coil unit, i.e., the tubing is wound in a helix. The type of exchanger has a large space advantage over a straight through or U-Tube exchanger.

Component Design Data

	Tube Side	Shell Side
Fluid Circulated	Water	Water
Total Fluid Entering	1488 Lbs./Hr.	1488 Lbs./Hr.
Inlet Temperature	489°F	120°F
Outlet Temperature	220°F	400°F
Operating Pressure	600 psig	635 psig
Pressure Drop	5 psi, Max.	5 psi, Max.
Design Pressure	750 psig & 30" Hg. Vac.	750 psig & 30" Hg. Vac.
Design Temperature	500°F	500°F
Duty	4.26×10^5 Btu/Hr.	

3) 2nd Stage Heat Exchanger (CP-HX-02)

Component Description - The 2nd stage heat exchanger is also a helical coil unit.

Component Design Data

	Tube Side	Shell Side
Fluid Circulated	Water	Water
Total Fluid Entering	1488 Lbs./Hr.	1855 Lb./Hr.
Inlet Temperature	220°F	100°F
Outlet Temperature	120°F	180°F
Operating Pressure	600 psig	40 psig
Pressure Drop	See Below	See Below
Design Pressure	750 psig & 30" Hg. Vac.	150 psig & Hg. Vac.
Design Temperature	500°F	250°F
Duty	1.49×10^5 Btu/Hr.	

The exchanger is also designed for the following performance:

Fluid Flow Rate	10745 Lbs./Hr.	6020 Lbs./Hr.
Inlet Temperature	100°F	133°F
Operating Pressure	40 psig	15 psig
Pressure Drop, Max.	20.0 psi	6.0 psi
Duty	1.52 x 10^5 Btu/Hr.	

4) Coolant Purification Pump (CP-PU-01, CP-PU-02)

Component Description - The Coolant Purification Pump is a canned motor centrifugal pump. It is located in the purification skid in the Power Plant Building.

Component Design Data

Normal Operation

Fluid	Water
Capacity	3 GPM
Discharge Pressure	640.7 psig
Suction Pressure	598.7
Head	97 Feet
NPSH	597.0 psig
Pumping Temperature	120°F

Infrequent Operation

Fluid	Water
Capacity	12.2 GPM
Discharge Pressure	78.5 psia
Suction Pressure	4.9 psia
Head	170 Feet
Pumping Temperature	120°F

5) Eductor (CP-E-01)

Component Design Data

Fluid	Water
Suction Water Capacity	5.0 GPM
Motive Water Flow	7.2 GPM, Max.
Total Discharge Head	35 Feet
Total Operating Head	155 Feet
NPSH	13.7 Feet
Temperature of Motive Water	120°F
Temperature of Suction Water	170°F
Design Pressure	750 psig
Design Temperature	500°F

c. System Operation

Normal Operation - A purification flow of 3 gpm (rated at 120°F) flows from the reactor to the 1st stage heat exchanger where the flow is cooled to 220°F. The flow passes to the 2nd stage heat exchanger where it is further cooled to 120°F. The flow must be cooled to below 140°F prior to entering the demineralizer in order to prevent deterioration of the ion exchange resin. Passing through the demineralizer the purified water is pumped by the canned motor pump to the shell side of the 1st stage heat exchanger where it serves as a cooling medium for the hot flow coming from the reactor. The fluid flows from the 1st stage heat exchanger to the feedwater line where it is returned to the reactor. Sub-cooled steam condensate is used as the cooling medium for the 2nd stage heat exchanger.

Startup Operation - Check for adequate condensate flow to the shell side of the 2nd stage heat exchanger. Open system isolation valves CP-1 and CP-13. Start purification pump. Adjust purification flow to 3 gpm as read on system flow indicator (CP-FT-01) by throttling valve CP-11.

Shutdown Operation - Secure purification pump. Close valves CP-1 and CP-13.

Cooldown Operation - The system is utilized to cool the reactor plant to 150°F if it is desired to cool the plant after a reactor shutdown. Heat is rejected through the 2nd stage heat exchanger. The rejected heat includes sensible heat from the reactor coolant and metal and decay heat generated in the core.

Condensate flow to the 2nd stage heat exchanger is increased to 21.5 gpm. The purification flow is increased to 7.5 gpm. The flow path is the same as for normal operation. When reactor temperature drops to 250°F, the 1st stage heat exchanger is by-passed by closing valve CP-1 and opening valves CP-25 and 26. Flow is diverted directly to the 2nd stage heat exchanger.

The makeup water pump in the Raw Water Purification System is lined up to the feedwater system by inserting the spool piece downstream of RWP-26. The makeup water pump will provide the head for the coolant purification pump when the reactor water temperature falls to 201°F. This head is provided by filling the reactor completely with water and running the makeup water pump at shut off head. The reactor is now cooled to 150°F.

During reactor head removal it is necessary to circulate reactor water to the purification system to remove decay heat. At atmospheric pressure the eductor is put into service to provide sufficient NPSH for the coolant purification pump. The eductor will pump water from the reactor through the 2nd stage heat exchanger and demineralizer to the coolant purification pump. Motive water for the eductor is provided by recirculating a portion of the purification pump discharge to the eductor. A motive water flow to the eductor of 7.2 gpm is required to pump 5.0 gpm from the reactor.

Chemical Shutdown - The reactor can be chemically shut down by injecting a boric acid solution into the reactor vessel. This operation is performed by diverting the purification flow through the poison cylinder to the reactor vessel. The purification water will dissolve boric acid in the poison cylinder, the solution then flows to the reactor vessel. The demineralizer is by- passed during this operation to prevent removal of the boron by the demineralizer. Purification flow samples are taken to determine boric acid concentration.

5. Raw Water Purification System (RWP)
   Raw Water Purification System Diagram - Project No. 2105 (Fig. 175)
   Process Instrumentation, Raw Water Purification System-
   Project No. 2105-11 (Fig. 176)

   a. Introduction

   System Function - The Raw Water Purification System purifies base water to reactor grade quality for use in the reactor plant by means of an ion exchange demineralizer (RWP-IX-01). The system is operated intermittently, dependent on makeup water requirement.

The makeup water pump is also utilized during a plant cooldown operation to provide a suction head to the coolant purification pumps.

<u>Brief Description</u> - Raw water from the base water main is passed through an ion exchange demineralizer, where ionic impurities such as Ca^{++}, Mg^{++}, CO_3^{--}, Cl^- are removed by use of a hydrogen - hydroxl form resin. Insoluble non-ionic impurities are removed by the filtering action of the resin bed. Since the resin will not remove dissolved non-ionized impurities such as Cl_2, the raw water is tapped off the base water main upstream of the chlorinator.

Demineralizer effluent flows to the makeup water tank for storage prior to usage in the reactor plant. The makeup water pump (RWP-PU-01) takes suction on the makeup tank and pumps water to the following plant locations:

1. Main Condenser Hotwell
2. Feed System
3. Spent Fuel Tank
4. Shield Water Tank

The main condenser hotwell is normally under vacuum therefore it is not necessary to pump makeup water to this unit. A vacuum drag line which bypasses the makeup pump is provided for this service. Conductivity cells (RWP-C-01, RWP-C-02) are located directly downstream of both the demineralizer and the makeup tank to indicate the purity of the water. A conductivity of greater than 2 mhos from the demineralizer indicates the resin is expended. The conductivity cell downstream of the makeup tank indicates whether the water in the tank is suitable for use in the reactor plant. Reactor plant water specifications are:

Conductivity	2 mhos, max.
pH	6.5 - 7.5

If the water in the makeup tank does not meet specification it can be recirculated back through the demineralizer for cleanup. A sample tap is located on the makeup tank, so that a sample can be drawn for analysis.

A differential pressure cell (RWP-LT-01) is located on the makeup water tank to provide signals for level indication and high and low level alarms at the plant control panel.

The shield water tank which is an integral part of the reactor containment vessel is shown diagramatically on the Raw Water Purification System diagram. In addition to its function as a containment vessel, it also serves as the reactor shield tank. The water volume of the tank is 325 ft^3. A level sensor RWP-LS-01 and differential pressure transmitter RWP-LT-02 provide signals for shield water tank level indication and high and low level alarms at the control panel. A line from the shield water tank to the spent fuel tank accommodates shield tank expansion water overflow. Because the shield tank is part of the reactor containment vessel a pressure actuated trip valve in the overflow line will close on a pressure buildup caused by leakage or rupture of the primary vessel. Fluid containment through the shield water tank makeup water line P-9 is provided by check valve RWP-15.

The makeup pump provides a head for reactor cooldown flow to the Coolant Purification System during a reactor shutdown operation. Reactor heat is rejected from the plant through the 2nd stage heat exchanger during this operation. When cooling the reactor below 201°F, the reactor is first filled with makeup water from the Raw Water Purification System; then the makeup pump is run at shutoff head to provide sufficient head for cooldown flow to the Coolant Purification System. A recirculation line around the pump prevents damage to the pump when it operates at shutoff head. The pump discharge is connected to the feedwater line during this operation thru a spool piece downstream of RWP-26.

System Design Data

Demineralizer resin capacity	3.0 ft^3
Demineralizer resin lifetime	1 year
Purification flow rate	5 GPM
Reactor plant makeup water specification conductivity	2 mhos
pH	6.5 - 7.5
Raw Water Purity (total)	194 PPM

b. Component Description

1) Raw Water Demineralizer (RWP-IX-01)

Demineralizer Description - The raw water demineralizer is a cartridge type unit.

The resin is contained in a cartridge which can be loaded and removed from the demineralizer shell. It is not intended to regenerate the resin on site therefore the cartridge unit eliminates regeneration facilities which require acid and caustic handling and storage. The demineralizer is mounted vertically on the feed and condensate skid.

Demineralizer Design Data

Flow rate	5 GPM @ 120°F
Resin volume	3 ft^3
Resin type	Strong acid - strong base equivalent to Amberlite MB-1 or MB-2
Pressure drop through demineralizer	5 psi, max.
Operating pressure	30 - 60 psig
Operating temperature	40 - 70°F
Design pressure	100 psig
Design temperature	200°F
Vessel O.D.	16 inches, max.

2) Makeup Tank (RWP-TK-01)

Makeup Tank Description - The makeup tank stores makeup water prior to usage in the plant. Makeup water from the raw water demineralizer or the drain tank can be charged to the makeup tank. The tank is cylindrical and is mounted in a vertical position on the feed and condensate skid.

Makeup Tank Design Data

Design Data

Design pressure	15 psig
Design temperature	200°F
Material	304 stainless steel
Shell Diameter	24 inches
Internal Capacity	12.5 cubic ft.
Manhole	As per ASME code Section VIII

Performance Data

Fluid	Demineralized water
Pressure	Atmospheric
Temperature	60°F nominal 40°F minimum 200°F maximum

3) Makeup Pump (RWP-PU-01)

Makeup Pump Description - The makeup pump will be operated in intermittent service to pump reactor grade makeup water to the reactor plant. It will also be operated at shutoff head to provide a pressure head during a reactor cooldown operation. It is a close-coupled, motor driven, centrifugal type pump located on the feed and condensate skid. A recirculation line is provided around the pump to prevent damage while the pump is operating at shutoff head.

Makeup Pump Design Data

Capacity	5 GPM @ 120°F
Total head	55 feet
NPSH available	21 feet
Design pressure	100 psig
Motor data	
Enclosure	open drip-proof
Voltage	440

c. System Operation

Normal Operation - Reactor plant makeup water will normally come from the drain tank in the Service Water System. When the makeup water tank level drops to 8 inches (12 gal.), the tank is re-filled with water from the drain tank. Prior to filling, samples are taken of drain tank water to insure that it meets reactor grade quality. The makeup tank is filled to the 35.0 inch level (62 gal.). If makeup water from the drain tank is not available, base water is purified to reactor grade quality in the raw water demineralizer. Prior to filling the makeup tank, the demineralizer effluent conductivity is checked to insure that it meets reactor grade specification (2 μmhos.) This operation is performed by closing valve RWP-3 and letting demineralizer effluent run to the skid drain through line P-14. Conductivity cell (RWP-C-01) reading is checked to insure effluent water of reactor grade quality.

Makeup water to the primary plant is discharge to the main condenser hotwell. Since the condenser hotwell is under vacuum, makeup water can be vacuum dragged to the hotwell through line P-5. Makeup water can also be discharged to the hotwell with the makeup pump through lines P-6 and P-5. Prior to filling to the hotwell, a sample of makeup tank water is taken and checked. If reactor grade specification is not met, makeup tank water is recirculated to the demineralizer through line P-4 until it is within specification.

Makeup water charged to the spent fuel tank and the shield water tank is pumped to these tanks through lines P-10 and P-9 respectively.

Startup and Shutdown - The Raw Water Purification System is operated as required. Startup of the system involves valve lineup to the system to be filled. The pump is operated and secured manually when the desired quantity of water has been transferred.

Demineralizer Cartridge Recharge - When the demineralizer is no longer able to purify water to reactor grade specification, the resin cartridge is expended and must be replaced.

Replacement procedure is as follows. Valves RWP-2 and 3 are secured. The cap on vent line P-15 is removed and vent valve RWP-24 is opened. The demineralizer water level is brought below the top head flange by draining 5 gallons through line P-14 to the skid drain. Valve RWP-23 is secured and the union connection on the influent line P-1 is broken. The top head is next removed. The expended resin cartridge is removed and replaced and bolted down. The union connection on line P-1 is next made up. Valve RWP-2 is opened and base water is allowed to flow to the demineralizer until water exits from vent line P-15. Vent valve RWP-24 is closed and the vent cap is replaced. Valves RWP-2 and 23 are opened and water is allowed to drain to the skid drain through line P-14 until conductivity cell RWP-C-01 on the demineralizer effluent line indicates a conductivity of less than 2 μmhos. Valve RWP-3 is reopened, and the demineralizer is now ready to operate.

In the event of a complete loss of electric power water can be supplied by the hand pump (RWP-PU-02) for decay heat removal. This pump can be lined up to take suction either from the makeup tank or the hotwell.

6. High Pressure Drain System (HPD)
High Pressure Drain System Diagram - Project No. 2106 (Fig. 178)

a. Introduction

System Function - The high pressure (HP) drain system continuously removes condensate formed in the steam piping and components during normal plant operation to prevent water from entering the turbine or regulating equipment. The system also provides for removal of condensate formed during plant warmup.

Water collected by the HP drain system is passed to the low pressure (LP) drain cooler (LPD-HX-01) from which it is returned to the condensate system.

Brief Description - Two HP drain headers, one in the pipe bank and one on the feed and condensate skid are located in the power plant building. The header located in the pipe bank collects the drains from various high pressure drain points on the purification and turbine generator skids. The header located on the feed and condensate skid collects the drains from various high pressure drain points on the feed and condensate skid. The various drain points are connected to the headers by continuous drain lines containing impulse or thermostatic traps. The traps operate automatically to pass condensate but limit the passage of steam. The traps are sized to pass the high condensate loads encountered during plant warmup. Manual by-passes are provided around each trap to permit manual control in the event of trap malfunction and during maintenance or replacement of the trap. Stop-check valves prevent reverse flow through the continuous drain lines.

The drain headers contain a mixture of steam and condensate. They join on the feed and condensate skid and discharge to a float operated trap (HPD-TP-14). This trap continuously passes the condensate to the LP drain cooler, and vents the steam to the reserve feed tank, thereby maintaining approximately atmospheric pressure in the drain headers. A manual by-pass is provided around the float trap to permit passing the drains from the HP drain headers directly to the LP drain tank in the event the float trap malfunctions.

System Design Data - HP drain header located in the pipe bank (normal operating conditions):

Pressure (minimum)	- Atmospheric
Temperature	- 201°F
Flow	- 275 lbs/hr of wet steam

HP drain header located on feed and condensate skid (normal operating conditions):

Pressure (minimum)	-	Atmospheric
Temperature	-	201°F
Flow	-	30 lbs/hr of wet steam

b. Component Description

Impulse Traps - Two (2) types of impulse traps are installed in the HP drain system. Both types are pressure operated valves which freely pass condensate and non-condensible gases but limit the passage of steam.

Thermostatic Steam Traps - Thermostatic steam traps are installed in atmospheric drain lines such as, the drain line from the relief valves. These traps are bellows operated valves which pass condensate but prevent the passage of steam.

A stainless bellows in each trap is partially filled with a volatile liquid which vaporizes at a temperature slightly below the boiling point of water. As long as the trap is cool, the valve is held open by the bellows. When steam enters the trap the liquid forces the bellows to expand downwards closing the valve. The valve remains shut until condensate collects in the trap and is cooled through the uninsulated walls of the trap.

Float Traps - A float operated trap is installed in the drain header connecting the HP drain system to the LP drain cooler. The operating mechanism consists of a float connected to a multi-port cylindrical valve. When the condensate has passed the valve, the float drops, closing the ports and restricting the passage of steam. A vent line is installed between the condensate inlet connection on the trap and the reserve feed tank to vent steam and prevent building up back pressure in the drain headers.

c. System Operation

Normal Operation - The HP drain system is normally in operation to receive condensate from the steam plant equipment and piping and pass it to the LP drain cooler. The inlet and discharge valves to each trap are normally open and the by-pass valves are normally closed. The vent valve to the reserve feed tank is normally open. No operator action is normally required.

Startup - No special startup procedures are required for the HP drain system. The traps are sized to handle the startup load. All valves are left in their normal operating positions.

Shutdown -No special shutdown procedures are required for the HP drain system. All valves are left in their normal operating positions.

Abnormal or Infrequent Operation - A manual by-pass valve is provided around each trap station to permit maintenance or repair to the trap or cleaning of the strainer without securing the steam system. Maintenance or repair of the trap or strainer may be accomplished by closing the inlet and discharge valves and cracking the by-pass valve to permit drainage of condensate during the maintenance period.

The float trap connecting the HP drain system to the LP drain cooler is provided with a gauge glass which will permit visual determination of the proper functioning of this trap. Isolation valves and a manual by-pass is provided around this trap to permit maintenance or repair to this trap without securing the HP drain system.

7. Low Pressure Drain System (LPD)
Low Pressure Drain System Diagram - Proj. No. 2107 (Fig. 179)
Process Instrumentation - Low Pressure Drain System
Project No. 2107-11(Fig. 180)

a. Introduction

System Function - The low pressure (LP) drain system:

(1) Collects seal water leak-off from the control rod drive seals,
leakage from reactor vessel head seal, and turbine gland exhaust and drains the collected condensate to the LP drain cooler.

(2) Collect condensate from the after-condenser, precooler, space heat exchanger, turbine casing and exhaust line.

(3) Receives condensate collected by the high pressure drain system.

(4) Returns collected condensate to hot well.

Brief Description - Leak-off connections from the control rod drive shaft seals and reactor vessel head seal and the turbine gland exhaust connection join to a common header.

Condensate from this header is drained to the LP drain cooler (LPD-HX-01) through a float operated trap (LPD-TP-01). Vapors and non-condensible gases are vented from this header to the pre-cooler where the vapors are condensed. The gland exhaust ejector removes non-condensibles from the precooler and maintains approximately 5 inches Hg vacuum in the precooler shell.

Steam condensed in the precooler and after-condenser is drained to the LP drain cooler through a duplex drainer (LPD-DD-01). The shell side of the space heat exchanger is drained to the LP drain cooler by a float operated trap (LPD-TP-02). The turbine casing and exhaust line drain to the LP drain cooler by gravity. Condensate collected by the HP drain system is drained to the LP drain cooler.

Condensate collected in the LP drain cooler is returned to the hotwell by the LP drain eductors (LPD-E-01, LPD-E-02). The LP drain cooler is maintained at approximately turbine exhaust pressure by a vent line to the turbine exhaust line. This line also permits flash steam and any non-condensibles to return to the main condensers. To provide sufficient net positive suction head to insure proper operation of the eductors, the low pressure drains are sub-cooled approximately 10^{o}F by the LP drain cooler. Eductor motive water is first utilized as coolant for the LP drains.

Eductor operation will be self-regulating. The design of the LP drain cooler is such that the cooling coils will become uncovered as the condensate level is lowered. This will reduce the amount of sub-cooling which, coupled with the reduction in elevation head, will reduce the net positive suction head causing a reduction of suction flow to the eductor. As the condensate level rises again, sub-cooling and elevation head will increase and eductor suction will tend to increase.

A local indicating level instrument (LPD-LI-01) is provided on the LP drain cooler to indicate condensate level in the cooler and actuate the high level alarm switch at a pre-set level.

<u>System Design Data</u> (normal operation)

Gland exhaust and rod drive leakoff

Pressure	5" Hg. Vac.
Temperature	190^{o}F
Flow	258 Lbs./Hr. Steam and Air

LP Drain Header	
Pressure	8" Hg. A.
Temperature	152°F
Flow	
After Condenser and precooler	435 Lbs./Hr.
Gland Exhaust and seal leakoff	258 Lbs./Hr.
HP Drain system	120 Lbs./Hr.
Space Heat Exchanger Drain	
Pressure	8" Hg. A.
Temperature	250°F
Flow	1743 Lbs./Hr.

b. Component Description

Duplex Drainer (LPD-DD-01)- The duplex drainer is used to drain the after condenser and pre-cooler. It consists of two float traps in a common body having a separate inlet and vent for each unit being drained and a common discharge. The trap body is divided into two chambers which are connected to a common discharged chamber by two float operated cylindrical valves. An inlet and vent connection is provided in the top of each chamber. Condensate entering either chamber causes the float in that chamber to rise. This causes the valve casing to rotate and match its ports with those of the valve permitting the condensate to discharge. When the condensate has passed thru the valve the float drops, closes the ports and restricts the passage of steam. A gage glass is provided on each chamber to permit checking the operation of the drainer. Removable covers are provided on both sides of the drainer body to permit access for maintenance and repair.

Float Trap (LPD-TP-01, LPD-TP-02) - Float traps are provided to drain the turbine gland exhaust and control rod seal water leak off header and the space heat exchanger. These traps are mechanical float operated valves which permit the passage of condensate but restrict the passage of steam. Condensate enters the top of the trap body flooding the trap chamber and causing the float to rise. This causes the valve to open permitting the condensate to discharge. When the condensate is discharged the float drops, closes the valve and restricts the passage of steam.

LP Drain Cooler (LPD-HX-01)- The LP drain cooler consists of a cylindrical tank installed on the feed and condensate skid with its axis horizontal. Cooling is provided by a coil in the bottom of the tank. The coil is attached to the cover of a 12 inch manhole in one end of the tank and may be removed for maintenance and repair if necessary.

Drains from the LP drain system, except the space heat exchanger, enters the LP drain cooler through a nozzle in the side of the tank slightly above the centerline. Drains from the space heat exchanger enter through a nozzle in the top of the cooler.

Part of the drains entering the cooler will flash to steam because the drain temperature is above the saturation temperature of the condensate in the LP cooler.

A vent nozzle is provided in the top of the cooler shell to remove this flash steam.

The cooler is sized to handle approximately twice the volume of LP drains normally expected during full power operation. This is done to insure adequate capacity to handle startup drain loads.

Design Data

	Shell Side	Tube Side
Design Pressure	30 Psig & 30" Hg. Vac.	250 Psig
Design Temperature	250^{0}F	500^{0}F
Operating Pressure	8" Hg. A	30 Psig
Operating Temperatures		
Inlet	152^{0}F	100^{0}F
Outlet	142^{0}F	112^{0}F
Design Flow Rate	6000 #/hr.	5100 #/hr.
Heat Transferred	60,000 BTU/hr.	

LP Drain Eductor (LPD-E-01, LPD-E-02)- The LP Drain eductor is a water jet pump used to transfer the drains from the LP drain tank to the hot well. Two eductors are installed for reliability. One eductor is normally operated, the other is maintained in standby condition. The eductor utilizes the cooling water from the LP drain cooler as motive water

Design Data

Design Pressure	250 psig
Design Temperature	500^{O}F
Motive Water Pressure	30 psig
Suction Pressure	8" Hg. A.
Discharge Pressure	15.8" Hg. A
Total Discharge Head	12 Feet H_2O
NPSH Required	3 Feet H_2O

c. System Operation

Normal Operation- The LP Drain system is normally in operation to receive condensate from the turbine gland seal exhaust system, the control rod drive seal water leak off, the turbine exhaust casing, turbine exhaust line drains, the space heat exchanger drain, and the HP drain system drains. All valves in the system except trap by-pass valves and one eductor motive water control are normally open. One eductor is normally in operation to transfer the collected condensate from the LP drain cooler to the hotwell. The other eductor is normally maintained at a standby condition with the suction and discharge valves open and the motive water valve closed. No operator action is required.

Startup- At the start of the steam plant warmup the LP drain system is placed into operation by placing all valves in their normal operating position and opening the motive water to one of the eductors.

Shutdown- The LP drain system is shut down by closing the motive water valves to the eductors. All other valves are left in their normal operating positions. The eductor motive water valves are closed to prevent flooding of the LP drain cooler by draining the condensate system to the LP drain cooler.

Abnormal or Infrequent Operation- Transfer from one LP drain eductor to the other during system operation may be accomplished by opening the motive water control valve to the standby eductor and then closing the motive water control valve to the eductor that was in operation. An eductor may be removed for maintenance or repair by closing the suction, discharge and motive water valves, unbolting the flanges and removing the eductor from the line.

The float traps serving the space heat exchanger and the gland exhaust and control rod drive seal water leak-off headers may be isolated for maintenance and repair by closing the isolation valves before and after the trap and using the manual by-pass valve to control the drain flow from the units served.

8. Gas Handling System (GH)

Off-Gas Handling System - Project No. 2108 (Fig. 194)

Gas Handling Power Wiring - Project No. 2108-11 (Fig. 195)

a. Introduction

System Function - During normal operation radioactive gases evolved are limited to short lived isotopes of Nitrogen and only trace amounts of Argon. Should a fuel cladding failure occur, however, fission gases such as Xenon and Krypton will evolve with the steam and be expelled from the system at the air ejector vent.

The system is capable of permitting full power operation of the PL-2 plant with failure of the clad on 3% of the fuel rods and still maintain the effluent concentration less than 1×10^{-14} μC/ml which is the background level presently encountered in the Antarctic. The release activity is measured at the point of discharge to the atmosphere without considering the effects of diffusion which will occur. Because the release activity is always less than or equal to the lowest expected background level, no detectable radioactive contribution to the region is possible.

Brief Description - The gas handling system components except for the adsorption bed are skid mounted and located at one end of the Condenser Building. Off-gas from the after-condenser is delivered by a booster fan (GH-FA-02) through a first stage heat exchanger (GH-HX-01), separator (GH-S-01), second stage heat exchanger (GH-HX-02, GH-HX-03), two charcoal adsorption beds (GH-AD-01, GH-AD-02) to the main condenser stacks. The first stage heat exchanger reduces the off-gas temperature from 140°F to 40°F and condenses most of the moisture carried with the off-gas. The moisture is collected in the separator where it is drained to the waste tank. Tunnel air is the cooling medium to the first stage heat exchanger and the required flow is provided by cooling fan (GH-FA-02). A temperature controlled damper regulates the flow of cooling air to hold the cooler outlet gas temperature at 40°F. The off-gas flow then enters one of the two second stage exchangers which further reduces the off-gas temperature and causes the remaining moisture to freeze out on the internal surfaces of the unit. A refrigeration system (GH-R-01, GH-R-02) provides the low temperature coolant for the second stage heat exchanger and for the charcoal adsorption beds, maintaining -90°F in each. When flow through the operating second stage heat exchanger is restricted due to the ice buildup, the off-gas flow and refrigerant are diverted to the second unit. The discharge of the first unit is shut and a heater is automatically turned on to melt the accumulated ice which drains back to the waste tank. A second refrigeration system is available for standby service.

The off-gas then flows to two charcoal adsorption beds connected in parallel and located in the tunnel on the ramp side of the Condenser Building. Here the radioactive gases are delayed relative to the sweep gas to allow time for the radioactivity to decay. The effluent then passes through an air radiation monitor and the flow is split between the four condenser stacks. The effluent is diluted with condenser cooling air such that the activity for all radioactive components other than Kr^{85} is 1×10^{-14} μC/ml. Kr^{85} activity is 8×10^{-13} μC/ml. The half life of Kr^{85} is 10.6 years and it is therefore not practical to provide charcoal adsorber capacity to allow decay of this component to 1×10^{-14} μC/ml. A by-pass line is provided to vent flow directly to the condenser stacks when the gas handling system is not required.

System Design Data

Design Flow Rate	5 SCFM Off-Gas Saturated with Water Vapor at 140°F
Design Adsorber Influent Activity	
Xe^{133}	2.65×10^{-4} μC/ml
Xe^{135}	3.41×10^{-3} μC/ml
Xe^{135m}	1.15×10^{-2} μC/ml
Xe^{138}	1.89×10^{-2} μC/ml
Kr^{85m}	1.79×10^{-3} μC/ml
Kr^{88}	3.19×10^{-3} μC/ml
Design Activity from Plant Condenser Stacks	
Sum of Activity of All Radioactive Components with Exception of Kr^{85}	1×10^{-14} μC/ml
Kr^{85}	8×10^{-13} μC/ml
Activated Charcoal Required	2.4 Tons

b. Component Description

First Stage Heat Exchanger (GH-HX-01) - The first stage heat exchanger is an air to air exchanger utilized to cool reactor off-gas from the after condenser vent. Tunnel air is used as the cooling medium. The exchanger is a finned tube and shell unit, and is equipped to control the flow of cooling air to the unit.

The exchanger is located on the gas handling skid in the Condenser Building.

Design Data	Tube Side	Shell Side
Fluid	Air	Air
Total Fluid Entering	5 SCFM Air (Saturated)	2280 Lbs./Hr.
Inlet Temperature	140°F	29°F
Outlet Temperature	40°F	39°F
Operating Pressure	12 psia	12 psia
Pressure Drop	0.2 in. H_2O	2.3 in. H_2O
Duty	6,000 Btu/Hr.	

Second Stage Heat Exchanger (GH-HX-02, GH-HX-03) - The second stage heat exchanger is an air to freon finned tube heat exchanger used to further cool the off-gases and freeze out the remaining moisture. Water released during the defrosting cycle drains freely through the air inlet piping to the water separator.

Design Data

	Tube Side	Shell Side
Fluid	Freon 22	Air
Inlet Temperature	-100°F	40°F
Outlet Temperature	-92°F	-90°F
Design Temperature	40°F	40°F
Design Pressure	12 psia	12 psia
Duty	900 Btu/Hr.	
Cycle Length - Cooling	6 Hrs.	
- Heating	1 Hr.	
Defrosting Heaters	4 - 200 W Electric Heaters	

Water Separator (GH-S-01) - The water separator collects the condensate accumulated by the first and second stage heat exchangers.

Design Data

Process Fluid	Water and Off-Gas

Condensate Removal	5 Lbs./Hr.
Design Temperature	40°F
Design Pressure	50 psig

First Stage Heat Exchanger Fan (GH-FA-01) - The fan provides coolant for the first stage heat exchanger. The fan is driven by a 3/4 HP electric motor, manually controlled.

Design Data

Fluid Pumped	Air
Capacity	2,280 Lbs./Hr. at 2.3 in. H_2O
Size	8"
Motor Rating	3/4 HP, 230 V, 60 Cycle, 1 Phase
RPM	3450

Main System Fan (GH-FA-02) - This unit will circulate the off-gas through the system and adsorption beds. The unit is an enclosed, multistage fan to assure no leadage and sufficient capacity to move the off-gases through the system.

Design Data

Fluid Pumped	Off Gases, Air, Xenon, Krypton
Capacity	5 SCFM @ 3 in. H_2O
Design Temperature	140°F
Design Pressure	12 psia
Type	Multistage
RPM	3450

Refrigeration (GH-R-01, GH-R-02) - Two refrigeration units are provided, one for standby. The unit is sized to provide refrigeration for the second stage heat exchanger and the adsorption beds. The units consists of a low stage and top stage compressor in series with an intercooler between compressors. The refrigerant from the top stage compressor flows to a receiver and then to the load.

Design Data

Fluid Refrigerant	Freon 22
Capacity	1600 Btu/Hr.

Design Temperature	$-100^{\circ}F$
Design Pressure	2.2 psia

Adsorption Bed (GH-AD-01, GH-AD-02) - The two adsorption beds are identical and each contains 2400 lbs. of activated charcoal. The units are fabricated of carbon steel and are three feet in diameter by fourteen feet in over-all length mounted vertically. The carbon bed path is 11.3 feet in length. Cooling is provided to maintain temperature at $-90^{\circ}F$ and the beds are covered with 12 inches of fiberglass insulation. Distribution plates are provided for uniform gas flow distribution through the cross sectional area of the bed. Provisions are made to charge or replace the carbon in each bed.

Design Data

Bed

Material	Activated Carbon 8 - 14 Mesh
Quantity	2400 Lbs.
Process Fluid	Gases; Air, Xenon, Krypton
Effluent Gas Activity	2×10^{-10} μC/ml Krypton 85m
	1.7×10^{-8} μC/ml Krypton 85
Design Temperature	$-90^{\circ}F$
Design Pressure	12.3 psia

c. System Operation

Normal Operation - The system is lined up to provide the normal off-gas flow path to the system fan, first and second stage heat exchangers, adsorption beds and to the main condenser stacks. The control of freezing and defrosting cycle is automatic. The switchover of off-gas flow from one second stage heat exchanger to the other and cycling from freezing to defrosting is accomplished by a cycle controller (GH-CC-01) and relays to control solenoid valves (GH-SV-01, GH-SV-03, GH-SV-04) and electric heaters. A pressure diaphragm in the inlet piping of the second stage heat exchangers (HTR-02, HTR-03) senses an increase in pressure due to ice formation and trips a micro switch to activate the cycle controller. Interlocks are provided to prevent operation of both exchangers at the same time. Condensate from the first and second stage heat exchangers is drained to the plant waste tank.

Startup - The system is lined up to provide the normal flow path through the system. The refrigeration system is started and coolant is supplied to the two adsorption beds and one second stage heat exchanger. When operating temperatures have been reached, the first stage heat exchanger fan (GH-FA-01) and the main system fan are turned on. The system is now ready to receive gases from the reactor plant.

Shutdown - The system is never completely shut down. When the reactor plant air ejectors have been secured the system fans are shut down. The refrigeration system, however, remains in service to cool the beds to prevent release of adsorbed gases due to bed warmup.

Infrequent Operation - If one adsorption bed is taken out of service the total off-gas is directed to the second bed. If both adsorption beds are inoperative, off-gas flow is vented directly to the condenser stacks through the by-pass line.

9. Lube Oil Service System (LO)

Lube Oil Service System - Project No. 2109 (Fig. 182)

Process Instrumentation - Lube Oil Service System - Project No. 2109-11(Fig. 183)

a. Introduction

System Function - The lube oil service system provides:

(1) Lubricating oil to the turbine, gear and generator bearings.

(2) Control oil to the governor system and trip throttle valve.

(3) Oil cooling for the lube oil supply to the bearings.

(4) Oil supply to the gland seal regulator.

Brief Description - The lube oil service system consists of two parts:

(1) The lube oil system;

(2) The lube oil cooling system.

The lube oil system is a self-contained part of the turbine generator skid. A lube sump tank is constructed integral with the reduction gear. The main oil pump (LO-PU-01) supplies oil at 50 - 60 psig which is used at full pressure in the hydraulic relayed governor system and the trip throttle valve cylinder. This oil pressure is reduced by an automatic pressure regulating valve to approximately 10 psig for lubricating the turbine and generator bearings and the reduction gear. A motor-driven auxiliary oil pump (LO-PU-02) connected through a check valve and a locked-open stop valve to the oil system is used to supply all oil requirements during startup and shutdown of the turbine-generator. A separate hand oil pump (LO-PU-05) mounted on the gear casing and connected through check valves to the oil system may be used to supply oil to the bearings, governor system and trip throttle valve cylinder when the unit is being started in the event the motor-driven auxiliary pump is inoperative. Drain oil flows back to the sump by gravity. The oil system complete with twin tube and shell type oil coolers (LO-HX-01, LO-HX-02), duplex basket and magnetic type strainer (LO-ST-01), relief valves, and instrumentation is mounted on the turbine generator skid. A centrifugal lube oil purifier (LO-PR-01) is also provided to maintain oil purity. Low oil pressure and high oil temperature alarm contactors are included in the lubricating oil system.

Low oil pressure start up protection is incorporated into the governor system such that when the lubricating oil pressure is too low, the oil pressure in the governor system is not sufficient to hold the trip throttle and governing valves open and they will remain closed until adequate lubricating oil pressure is established. A low oil pressure trip is also provided which opens a solenoid valve in the oil supply line to the trip throttle valve cylinder and dumps the oil to the oil sump.

A high turbine back pressure trip which dumps the oil from the trip throttle valve cylinder is also included in the lubricating system.

The lube oil cooling system forms an intermediate loop between the lube oil system and the condensate system to prevent the possibility of oil contamination of the condensate system. Twin coolant pumps (LO-PU-03, LO-PU-04) are installed on the turbine generator skid and circulate cooling water through the lube oil coolers and the intercooler located on the feed and condensate skid.

Twin lube oil cooling pumps are provided to circulate coolant through the lube oil cooler and the lube oil intercooler (LO-HX-03). The coolant removes heat from the lubricating oil system in the lube oil coolers and rejects heat to the condensate system in the lube oil intercooler. A surge tank (LO-TK-02) is provided on the lube oil cooling system to absorb system volume changes. Thermometers for monitoring the outlet temperature from the lube oil coolers and the lube oil intercooler, a pressure gage for monitoring lube oil cooling pump discharge pressure, a pressure switch for automatic transfer of lube oil cooling pumps, and manual control valves complete the lube oil cooling system. The lube oil intercooler and surge tank are mounted on the feed and condensate skid.

System Design Data

Pressure (normal operation)	
Main LO Pump Discharge	- 55 psig
Control Oil to Turbine	- 55 psig
LO to Bearings	- 8 - 10 psig
Temperature (normal operation)	
LO to Cooler	- 155°F
LO from Cooler	- 130°F
Cooling Water to Cooler	- 115°F
Cooling Water from Cooler	- 140°F
Flow (normal operation)	
Main LO Pump Discharge	- 59 gpm
LO to Bearings	- 32 gpm
Control Oil to Turbine (max. during transients)	- 27 gpm
Cooling Water to LO Cooler	- 15 gpm
LO Sump Capacity	- 200 Gals.
Lube Oil Type	- Navy Symbol 2190 TEP
Power Supplies	
AC Components	- 440 Volts, 60 cps, 3 Phase
DC Components	- 64 Volts
Instruments and Controls	- 115 Volts, 60 cps

b. Component Description

Lube Oil Sump Tank (LO-TK-01) - The lube oil sump tank of approximately 200 gallons capacity is self-contained in the fabricated steel base directly beneath the reduction gear. The tank has the following functions:

To receive drain oil from the turbine generator components.
To provide a reservoir for oil.
To provide adequate suction head on the lube oil pumps.

The lube oil sump tank is continuously vented to the atmosphere to prevent a pressure buildup in the tank. Connections to and from the lube oil purifier are provided. The oil level in the tank is measured by a dip stick which is marked to indicate high, normal and low oil levels.

Main Lube Oil Pump (LO-PU-01) - The main lube oil pump is a positive displacement gear type pump with submerged suction. It is located in the reduction gear casing and is driven by helical gears from the turbine shaft at a normal speed of 618 RPM with a flow of 59 GPM at a discharge pressure of 55 psig.

Auxiliary Lube Oil Pump (LO-PU-02) - The auxiliary lube oil pump is a gear type positive displacement pump of all steel flanged construction with mechanical shaft seals. It is installed on the turbine generator skid. The pump normally starts automatically by a pressure switch signal when the system oil pressure drops to 35 psig and stops automatically when the system oil pressure rises to 45 psig.

Design Data

Rated Capacity	- 60 gpm
Discharge Pressure at Rated Capacity	- 45 psig
Motor H.P.	- 5 H.P.
Motor Speed	- 1740 RPM
Power Supply	- 440 Volts, 60 cps, 3 Phase

Hand Oil Pump (LO-PU-05) - The hand oil pump is a gear type pump for emergency use in the event that the motor drive auxiliary oil pump is not available. It is capable of supplying sufficient lubricating and governing oil to allow the turbine to be started and brought up to a speed at which the main oil pump can take over the normal requirements. The hand oil pump is integral with the reduction gear casing.

Lube Oil Coolers (LO-HX-01, LO-HX-02) - Twin horizontally mounted lube oil coolers are provided on the turbine generator skid. The coolers reduce the temperature of the lube oil supplied to the turbine, gear, and generator bearings.

Each cooler is a shell and tube type single pass heat exchanger with one fixed and one floating tube sheet. Lube oil circulates around a series of baffles in the cooler shell.

A duplex three-way Kraissl transfer valve and interconnecting piping connect the shell side of the two coolers. The transfer valve is arranged such that lube oil flow to the bearings cannot be completely shut off at any position of the valve, and permits transfer from one lube oil cooler to the other without interruption of oil flow to the turbine generator.

Design Data

	Shell Side	Tube Side
Design Pressure	150 psi	150 psi
Design Temperature	300°F	300°F
Normal Operating Pressure	8-10 psig	19 psig
Inlet Temperature	155°F	115°F
Outlet Temperature	130°F	140°F
Flow Rate	32 gpm	15 gpm
Heat Transferred	167,000 Btu/Hr.	

Duplex Oil Strainer (LO-ST-01) - A duplex oil strainer is installed in the bearing lube oil header between the main lube oil pump and the lube oil coolers. A plug type transfer valve is provided in the strainer to direct the flow of oil through either strainer. Each strainer may be cleaned while the other is in service. Permanent magnets are supplied in each basket to attract and hold ferrous particles which may be present.

Bearing Oil Pressure Reducing Valve (LO-6) - A pressure reducing valve is located in the manifold between the main oil pump and the strainer to regulate the oil pressure to the bearings at 8 - 10 psig. This valve is orificed sothat oil to the bearings cannot be completely shut off.

Pump Pressure Relief Valves (LO-9, LO-16) - A pressure relief valve is provided at the discharge of the main and auxiliary oil pumps. These valves regulate the oil discharge pressure from their respective pumps by passing excess oil to the lube oil sump tank. The main oil pump pressure relief valve is set at 55 psig. The auxiliary oil pump pressure relief valve is set at 33 psig.

High Oil Temperature Alarm (LO-TX-01) - A high oil temperature alarm switch is installed on the lube oil header to the bearings. This switch is designed to close a set of contacts when the temperature reaches 140°F and sound an alarm at the plant control station. The switch operates on 115 Volt, 60 cps, power supply.

Low Oil Pressure Alarm Switch (LO-PX-02) - A low pressure alarm switch is installed in the oil supply header to the bearings. This switch is designed to operate from 115 Volt, 60 cps power supply and to sound an alarm at the plant control station by closing a set of contacts at 7 psig decreasing lube oil pressure. At 9 psig increasing lube oil pressure the contacts will reopen and de-energize the alarm circuit.

Low Oil Pressure Trip Switch (LO-PX-04) - A low pressure trip switch is installed in the lube oil supply line to the turbine low pressure bearing, the most remote bearing from the lube oil pump. At 5 psig decreasing lube oil pressure, this switch closes a set of contacts which energizes the low oil pressure trip solenoid valve. This switch is on 64 Volts DC power supply.

Low Oil Pressure Solenoid Trip Valve (LO-41) - The low oil pressure solenoid trip valve is installed on the trip throttle valve cylinder oil supply header. The valve is actuated by the low oil pressure trip switch or by a momentary contact push-button. Energizing the solenoid causes the valve to open, releasing the oil beneath the turbine trip throttle valve, thus securing the flow of steam to the turbine. The solenoid valve is a normally closed valve which is suitable for operation on 64 Volts DC power supply.

Overspeed Trip - A centrifugal bolt type overspeed trip mechanism is attached to the low pressure end of the turbine shaft. When the turbine speed reached approximately 10 per cent above normal, the overspeed bolt strikes the emergency tripping mechanism which in turn drains the oil from the trip throttle valve cylinder. Loss of oil pressure causes the trip throttle valve to close and stop the flow of steam to the turbine.

High Back Pressure Trip Valve (LO-42) - The turbine is protected against high exhaust pressure by means of a hydraulic back pressure trip. On an increasing exhaust pressure of 5 psig, the trip operates a three-way valve so as to release oil pressure from the trip throttle valve cylinder causing it to close and shutting off steam to the turbine.

Sight Flow Indicators - Sight flow fittings are provided at each bearing to permit visual check of the return oil flow from each bearing.

Thermometers - Bi-metallic type thermometers are installed in the drain line from each bearing to monitor the bearing oil temperature. Each thermometer has a 3/4 inch head, a type 304 stainless steel stem with Naval brass separable socket and a scale range of 30 to 240°F with 5° subdivisions.

Lube Oil Purifier (LO-PR-01) - A deLaval Model 30-23 lube oil purifier is provided on the turbine generator skid to maintain the purity of the turbine oil. The purifier will have a corrosion resistant bowl, and integrally mounted discharge pumps driven by a single 1/2 H.P. splashproof motor for operation on 440 Volts, 3 Phase, 60 cps current.

Lube Oil Cooling Pumps (LO-PU-03, LO-PU-04) - Two lube oil cooling pumps to circulate cooling water through the lube oil coolers are provided on the turbine generator skid.

Design Data

Type	- Close Coupled Centrifugal
Rated Capacity	- 15 gpm
Rated Head	- 45 Feet
Motor H.P.	- 1-1/2 H.P.
Motor Speed	- 3450 RPM
Power Requirements	- 440 Volts, 3 Phase, 60 cps

c. System Operation

Normal Operation - During normal operation of the turbine generator, the main lube oil pump, gear driven from the reduction gear, supplies lube oil for the governor valve, trip throttle valve, and lubrication of the bearings and gears. The oil flow from the pump divides into two branches. One branch supplies the lube oil header to the governor system and the trip throttle valve cylinder. The other branch supplies the lube oil header to the bearings and gear mesh.

Oil to the governor system and the trip throttle valve cylinder passes from the main oil pump through a check valve into a distribution header. From the distribution header a branch connection supplies oil to the governor pilot valve and operating cylinder for the governor are mounted on the gear casing and drain directly back to the sump through the gear casing. A second branch from the distribution header supplies oil through an orifice to the trip throttle valve cylinder. The high pressure trip, low oil pressure trip, and overspeed trip, dump valves are connected to the trip throttle valve supply line. Control oil to the steam seal regulator is also supplied from this distribution header. A pressure gage is connected to the distribution header through an orifice to indicate main oil pump discharge pressure.

Lube oil to the bearings pass from the main oil pump through a pressure reducing valve through the duplex strainer, through either of the lube oil coolers to a distribution header. Branch lines from this header supply oil to each bearing in the turbine, reduction gear, and generator and to the gear mesh. A bearing oil pressure gage, the low oil pressure trip, and low oil pressure alarm are connected to the header through orifice connections. Oil drains back to the sump from each bearing by gravity. Sight flow indicators installed adjacent to the turbine gear are provided in the return line from each bearing.

A relief valve in the discharge line from the main oil pump maintains the pump discharge pressure between 50 and 60 psig by bleeding excess oil back to the sump tank.

One of the lube oil cooling pumps is normally operated to circulate water through the lube oil cooler in service and the lube oil intercooler.

<u>Startup</u> - The auxiliary oil pump is normally used to supply oil for the governor system, trip throttle valve and lubrication to the bearings and gear mesh during startup. The pump takes suction from the lube oil sump and passes the oil through a check valve and a stop valve to the discharge header from the main lube oil pump. A pressure switch is installed in the line between the auxiliary oil pump and the main oil pump discharge header to monitor the main oil pump discharge pressure. This switch will automatically stop the auxiliary oil pump when the main lube oil pump discharge pressure reaches 45 psig. A relief valve installed between the auxiliary oil pump discharge and the check valve regulates the pump discharge pressure at 30 to 35 psig by bleeding excess oil back to the oil sump tank.

Shutdown - During shutdown the main oil pump will supply the lubrication requirements until such time as the turbine coastdown speed is reduced to the point that the oil pump discharge pressure drops below 35 psig. At this point the pressure switch will automatically start the auxiliary oil pump which will continue to supply oil to the lube oil system until manually stopped.

The design of the lube oil system is such that if the auxiliary lube oil pump fails to start and the hand pump cannot be manned during shutdown, the turbine generator set will coastdown to rest without damage to the bearings or gears.

After the lube oil system has been completely secured, the lube oil cooling pump is manually stopped.

Abnormal or Infrequent Operation - In the event the auxiliary oil pump is inoperative for any reason, the turbine generator set may be started using the hand pump to supply oil for the governor system, the trip throttle valve and lubrication of the bearings and gear mesh.

Failure of the operating lube oil cooling pump to deliver normal discharge pressure will cause the automatic transfer switch to start the standby pump and operate an alarm at the plant control station.

10. Service Water System (D)

Service Water System Diagram - Project No. 2110 (Fig. 185)

Process Instrumentation Service Water System - Project No. 2110-11 (Fig. 186)

a. Introduction

System Function - The Service Water System collects and processes reactor plant water to meet the permissible disposal activity level of 1×10^{-8} $\mu c/cc$ and stores cleaned up reactor grade water for reuse in the plant.

Brief Description - The Service Water System consists of the following major components:

Evaporator and demineralizer for radioactive cleanup of plant water.

Waste tank and drain tank for water storage.

Spent fuel tank for storage of spent fuel elements and control rods.

Waste tank pump and drain tank pump.

The waste tank (D-TK-02) stores all plant waste water prior to processing in the evaporator. Waste tank water is processed in the evaporator (D-EV-01). The evaporator is designed to yield an overhead product which meets the maximum permissible activity limit for disposal (1×10^{-8} $\mu c/cc$). The overhead product will flow by gravity to the drain tank for holdup prior to disposal. The impurities in the evaporator feed will concentrate in the evaporator bottoms to a 30-70% solid-water concentration. When this concentration is reached the product is packaged in a shipping container for shipment to a disposal area.

The drain tank (D-TK-01) serves as storage for the evaporator overhead. Makeup water for the reactor plant can be provided from this source. A drain tank sample is taken through sample line P-29 to insure that the water meets permissible dumping limits before dumping to the plant sewer. The drain tank is sized to store a volume of water equal to the free volume of the reactor vessel plus the water volume of the reserve feed tank. These are the maximum anticipated volumes which will be pumped from the plant at any one time. Drain tank water can be pumped to the waste tank for evaporation and cleanup.

A demineralizer (D-IX-01) identical to the unit described in the Coolant Purification System is provided to purify radioactive water from the spent fuel tank (D-TK-03). Spent fuel tank water is recirculated by the drain tank pump (D-PU-02) through the demineralizer and back to the spent fuel tank. Makeup water from the drain tank can be given additional cleanup in this demineralizer prior to delivery to the makeup tank in the Raw Water Purification System. Conductivity cell (D-C-01) and sample line P-29 located downstream of the demineralizer are provided to insure that reactor plant makeup water specification is met.

The spent fuel tank is utilized to store shipping casks containing the spent fuel elements and control rods. The casks are covered with water to provide a biological shield and to remove decay heat generated by the fuel elements.

The drain pump may be used for the following intermittent service:

Pump drain tank water to the plant sewer when it is desired to discharge water from the plant.

Pump makeup water from the drain tank to the makeup water tank in the Raw Water Purification System.

Circulate spent fuel tank water thru the demineralizer.

Pump drain tank water to the waste tank.

The waste tank pump is utilized to pump waste tank water to the evaporator.

All the system components except the spent fuel tank are located on the purification skid in the power plant building. The waste tank is hung from support members below the purification skid base in a recessed opening in the building floor. This allows gravity drainage to the tank from the various plant drains. The spent fuel tank is located adjacent to the containment vessel in the reactor complex.

System Design Data

Laboratory drains (from sampling and laboratory equipment)	70 Gal/week
Plant leakage	35 Gal/week
Radioactive laundry wastes	75 Gal/week
Maximum permissible activity level for disposal of water	1×10^{-8} μc/cc
Reactor grade water requirements	
Conductivity	2 μ mhos, max.
pH	6.5 - 7.5
Evaporator capacity	150 GPD
Evaporator bottoms activity level after six months	2.9×10^{-1} μc/cc

b. Component Description

Evaporator Description (D-EV-01) - The evaporator operates on an intermittent basis. When operating, it is fed at a rate of 150 GPD. The impurities in the feed will be concentrated in the bottoms to a 30%-70% solid-water mixture. The overhead from the evaporator is designed to yield a product whose activity meets a disposal tolerance specification of 1×10^{-8} μc/cc. After 8 months of operation the bottoms activity at this concentration will be about 2.9×10^{-1} μc/cc. The bottoms disposal volume per discharge is about 25 gal. Heating medium to the evaporator is 150 psig steam from the Main Steam System.

Evaporator Design Data

Fluid	Radioactive water
Rated Capacity	150 GPD
Feed Characteristics	
Total feed	180 Gal/week
Impurities in feed	10-3150 ppm (primarily detergents from laundry)
Activity in feed	$1x10^{-6}$ - $2.8x10^{-1}$ $\mu c/cc$
Evaporator btms. conc.	30% solids
Allowable carryover	0.03 ppm

Demineralizer Description (D-IX-01) - This unit is identical to the demineralizer shield cask unit in the Coolant Purification System. Refer to demineralizer description in Coolant Purification System.

Waste Tank Description (D-TK-02) - The waste tank is a cylindrical stainless steel tank of all welded construction. It is mounted in a veritcal position in a recessed opening under the purification skid in the power plant building. The tank is supported by steel members extending from the skid. The tank is sized to contain the following volumes.

	Gal.
Laundry waste water	75
Radioactive shower water	60
Lab. drain	10
Plant leakage	5
	150

Waste Tank Design Data

Design pressure	15 psig & 30 in. Hg Vac
Design temperature	$200^{\circ}F$

Material	304 stainless steel
Shell diameter	42 inches
Internal capacity	30 cu. ft.

Drain Tank Description (D-TK-01) - The drain tank is a cylindrical stainless steel tank with all welded construction. It is supported on the purification skid in a horizontal position.

Drain Tank Design Data

Design pressure	15 psig & 30 in. Hg Vac
Design temperature	200°F
Material	304 stainless steel
Shell diameter	7 feet
Internal capacity	320 cu. ft.

Drain Tank Pump Description (D-PU-02) - The drain tank pump is a close coupled, motor driven, self priming, centrifugal pump. It is mounted in a horizontal position on the purification skid.

Drain Tank Pump Design Data

Fluid	water
Capacity	5 GPM
Discharge pressure	39.6 psig
Suction pressure	11.5 psia
Total head	65 ft.
NPSH Available	9 ft.
Pumping temperature	120°F
Motor data	
Enclosure	open drip-proof
Type	induction
Voltage	440
Phase	3
Cycle	60

Waste Tank Pump Description (D-PU-01) - The waste tank pump is a sump type motor driven centrifugal pump. The pump is mounted on the head of the waste tank.

Waste Tank Pump Design Data

Fluid	Waste water
Capacity	2 GPM
Discharge pressure	16.6 psia
Suction pressure	11.8 psia
Total head	11.0 feet
NPSH Available	10.1 feet
Pumping temperature	60°F
Motor Data	
Enclosure	totally enclosed
Type	induction motor
Voltage	440
Phase	3
Cycle	60

Spent Fuel Tank Description (D-TK-03) - The spent fuel tank is a reactangular tank whose dimensions are $7\frac{1}{4}$ x $7\frac{1}{4}$ x 18 ft. It is mounted in a vertical position adjacent to the reactor. The tank is fabricated of carbon steel and its top is open to the reactor building.

c. System Operation

Normal Operation - The evaporator is put into service when the waste tank water volume rises to 75 gal. Main steam valve MS-45 and valve D-35 in the Service Water System are opened to supply 150 lb steam to the evaporator. The waste tank pump (D-PU-01) is started to supply feed. The condensed evaporator overhead flows by gravity to storage in the drain tank. When it is desired to supply makeup water to the primary plant, a take-down connection is made up to the Raw Water Purification System. The drain tank pump is started and drain tank water is recirculated through conductivity cell (D-C-01) and back to the drain tank. After several minutes of recirculation, a representative sample is drawn through sample line P-29. The conductivity and pH of the fluid is checked to insure that it meets reactor specifications. If the sample does not meet specifications, the fluid is recirculated through the ion exchange demineralizer until specifications are met. Excess water in the drain tank may be discharged to the sewer after checking a sample for the discharge requirement.

Startup and Shutdown - The Service Water System is operated intermittently as required. Startup of the system involves valve lineups for the particular operation to be performed. Shutdown is treated in the same manner.

Infrequent Operation - Spent fuel tank water is recirculated through the ion exchange demineralizer to reduce the activity in the spent fuel tank water. Suction is taken from the spent fuel tank with the drain tank pump and water is circulated thru the demineralizer. Samples are taken to check activity before and after cleanup. Because the drain tank pump operates with contaminated water, it is necessary to purge the pump after this operation. To purge the pump,suction is taken from the drain tank and water is pumped to the waste tank for a period of several minutes. A final cleanup is made by circulating drain tank water to the demineralizer and back to the drain tank.

11. Plant Heating System (PH)

Plant heating system diagram project No. 2111 (Fig. 188)

Process instrumentation - Plant Heating System - Project No. 2111-11 (Fig. 189)

a. Introduction

System Function - The plant heating system performs the following functions:

(1) Supplies the thermal equivalent of 400 KW net for a site heating.

(2) Supplies additional heat as necessary to maintain $60^{\circ}F$ in all plant buildings.

Brief Description - The plant heating system consists of units heaters in the Service Building, fin tube wall mounted convectors in the Reactor Complex, Condenser, Power Plant and Personnel Buildings, space heat exchanger, an oil-fired auxiliary boiler, two plant heating pumps, a surge tank and associated piping and valves.

The auxiliary boiler (PH-HX-02) and the space heat exchanger (PH-HX-01) are connected in parallel to common inlet and outlet headers so that either unit can supply the required heating loads. During normal operation of the reactor plant, the space heat exchanger is used to supply the heating requirements.

During shutdown of the reactor, the auxiliary boiler is operated. Water from the plant heaters and the site heating system are supplied to either the space heat exchanger or the auxiliary boiler through the inlet header. The water is heated to 220°F and distributed by the outlet header to the plant heating system and the site heating system. The equipment and piping necessary for site distribution is not a part of this system.

The plant heating system consists of three parallel loops, one loop supplies the Condenser Building, another loop supplies the Reactor Complex Building and the third loop supplies the power plant Personnel and Service Buildings. An orifice connects the supply and return legs of each loop and ensures a minimum flow of approximately 1 gpm through each loop to prevent freezing.

Each building has an independent heating loop connected across the supply and return mains. A thermostatically controlled valve installed in the return line from each loop and operated by a self-contained temperature pilot regulates the flow through the wall-fin convectors to maintain 60°F in each building. The hot water flow through unit heaters in the Service Building is not regulated. The temperature in this building is controlled by wall mounted thermostats which start and stop the unit heater fan.

System Design Data

Pressure	
@ Plant Heating Pump Suction	30 psig
@ Plant Heating Pump Discharge	56 psig
Temperature	
From Plant Heating System	190°F
To Plant Heating System	220°F
Flow	
Through Heat Sources	131 gpm (max)
To Site Heating System	91 gpm (max)
To Plant Heating System	38 gpm (max)
Heat Transferred - During normal steam plant operation:	
Total	1,715,000 Btu/hr.
Site Heating	1,365,000 Btu/hr.

Plant Heating	350,000 Btu/hr.

During Steam Plant Shutdown:

Total	1,913,000 Btu/hr.
Site Heating	1,365,000 Btu/hr.
Plant Heating	548,000 Btu/hr.

b. Component Description

Space Heat Exchanger (PH-HX-01) - The space heat exchanger is a steam to water heat exchanger located on the feed and condensate skid.

The heat exchanger is a helical-coil, shell and tube type unit. Water from the plant heating system makes one pass through the tube side of the heat exchanger. Steam from the auxiliary steam system is supplied to the shell side.

Design Data

	Shell Side	Tube Side
Design pressure	180 psig & 30"HgVac	250 psig
Design temperature	400°F	500°F
Operating pressure	30 psig	55 psig
Operating temperatures:		
Inlet	294°F	190°F
Outlet	250°F	220°F
Fluid	Steam	Water
Flow rate	1743 lbs/hr	131 gpm
Heat exchanged		1,715,000 Btu/hr

Auxiliary Boiler (PH-HX-02) - The auxiliary boiler is a packaged fire-tube boiler complete with fuel oil pump, blower and necessary controls and safety devices used to heat hot water for plant and site heating during plant shutdown, or whenever reactor steam is not available.

The auxiliary boiler is located in the Service Building and will use arctic grade diesel oil as fuel. Air for combustion is taken from the tunnel through the floor of the Service Building by a forced draft blower. Combustion gases are exhausted above grade by a 12" stack. This stack is insulated where it passes through the tunnel and the tunnel roof to reduce heat losses and minimize snow melting. Operating of the boiler fuel pump and forced draft blower is controlled automatically to maintain an outlet water temperature from the boiler of 220°F. The front and rear headers on the boiler are hinged to permit access to the fire tubes and fire box for inspection, cleaning and repair.

Design Data

Shell design pressure	75 psig
Design temperature	250°F
Rated heat output	2,000,000 Btu/hr.
Outlet water temperature	220°F
Inlet water temperature	190°F
Water flow rate	131 gpm

Plant Heating Pumps (PH-PU-01, PH-PU-02) - The plant heating pumps are used to circulate water from that part of the plant heating system used for heating the plant machinery and associated spaces to the space heat exchanger or the auxiliary boiler. Duplicate pumps are provided for reliability. One pump is normally operated, the other is maintained in standby condition.

Design Data

Type	Close-coupled centrifugal
Capacity	38 gpm
Discharge pressure	56 psig
Suction pressure	30 psig
Total head	62 feet
Fluid Pumped	water
Pumping temperature (normal)	190°F

Expansion Tank (PH-TK-01) - The expansion tank is hung from the roof trusses in the power plant building above the feed and condensate skid and is designed to absorb the volume changes in the plant heating system. The expansion tank is a cylindrical pressure vessel installed with its axis horizontal and connected to the plant heat pump suction header on the feed and condensate skid.

Design Data

Design pressure	75 psig
Design temperature	250°F
Outside diameter	30"
Over-all length	4'
Operating pressure	10 - 30 psig
Operating temperature	40 - 220°F

Convectors - Finned tube type convectors will be installed along the walls of the Reactor Complex, Condenser, Power Plant and Personnel Buildings to supply comfort heating. The convectors will consist of fin tube heating elements and a suitable sheet metal enclosures.

Heating elements are made from seamless copper tubing with aluminum fins firmly bonded to the tube by mechanical expansion of the tube. The heating elements are furnished with half of a union fitting swetted to each end of the element, such that field installation is simplified. The heating elements are installed on hangers which permit unrestricted axial movement during expansion and contraction of the element. Sheet metal enclosures are provided for the heating elements to provide mechanical protection and to direct the flow of air.

Design Data

Pressure	75 psig
Temperature	250°F
Inlet Water temperature to loop	220°F
Temperature drop through loop	30°F

Unit Heaters (PH-HX-10, PH-HX-11) - The Service Building is heated by two unit heaters, one installed in the boiler room, the other in the Machine Shop. These heaters are of the horizontal discharge, fin-fan type. Each heater is mounted in a duct (part of the plant ventilating system) which connects to louvered wall openings through the end of the Service Building and is fitted with an air recirculation control damper inside the building. Air from the tunnel is brought in through the louvered wall opening and mixed with recirculated air in the duct to raise the temperature to approximately 50°F. This mixed air flows across the heating coil and is discharged into the space served to provide comfort heating and ventilation. The water passing through the heating coil is not throttled. The space temperature is controlled by a wall thermostat which starts and stops the fan.

Each unit heater consists of a heat exchange coil installed in a casing and a propeller type fan. Each coil consists of finned copper tubes expanded into cast iron headers. The headers have center supply and return connections. The unit heaters are suspended by hanger rods fastened to the casing.

Design Data

Pressure	75 psig
Temperature	250°F
Rated output (each)	20,400 Btu/hr. (min.)
Inlet water temperature	220°F
Water temperature drop	30°F
Entering air temperature	60°F max.

Temperature Regulating Valves (PH-34, PH-37, PH-38, PH-41 - Self-contained temperature pilot operated valves are installed in each convector loop to control the temperature in each building by throttling the water flow through the convector loop. The valves are installed between the convectors and the return water main.

The valves are one inch ASA Class 125 or 250 lb. globe pattern with screwed union ends and a screwed union bonnet with a packless bellow seal. The adjustment unit is designed for wall mounting and is connected to the valve by approximately 8 feet of capillary tubing. The adjustment unit provides manual setting over a 20°F range from 50°F to 70°F. The design temperature differential for full valve travel is 6°F. A locking device is provided whereby the temperature adjustment may be locked to retain the desired temperature setting. The temperature regulating valve is designed to control the set temperature within plus or minus 3°F.

Design Data

Flow rate

Reactor Complex	4.2 gpm
Condenser Building	13.3 gpm
Power Plant Building	11.3 gpm
Personnel Building	2.2 gpm

Water inlet temperature - all Buildings - 220°F

Inlet pressure:

Reactor Complex	37.4 psig
Condenser Building	33.4 psig
Power Plant Building	36.6 psig
Personnel Building	41.0 psig

Pressure drop:

Reactor Complex	11.5 psi
Condenser Building	6.8 psi
Power Plant Building	6.0 psi
Personnel Building	11.7 psi

Automatic Air Eliminators - Automatic air eliminators are installed in the high points of each convector loop to automatically vent air and non-condensible gases from the system. The automatic air eliminator is a float type valve designed to pass air but restrict the passage of water. Air and other non-condensibles accumulate in the body of the air eliminator displacing water and causing the float to drop. This opens a valve in the top of the eliminator body and system pressure forces the air and non-condensibles out of the valve.

Design Data

Pressure	75 psig
Temperature	250°F

Pipe connections	1/2" Female NPT
Orifice size	3/32" (minimum)

c. System Operation

Normal operation - During normal operation of the steam plant, the space heat exchanger supplies the heat load for plant heating and for site heating. Water from the plant heating pumps and from the return connection from the site heating load is supplied to the inlet header common to the space heat exchanger and auxiliary boiler. The inlet and outlet valves to the auxiliary boiler are shut when this unit is not operating. From the inlet header the water passes through the space heat exchanger to the outlet header and is distributed to the plant and site heating systems. The temperature of each building is controlled by the temperature regulating valves or the wall thermostats in the case of the Service Building. One plant heating pump is normally operated while the other is maintained in standy condition. Stop check valves in the discharge lines from each plant heating pump prevents back-flow through the idle pump. Under normal conditions the system is entirely self-regulating and operator action is not required, except to monitor the instrumentation provided to check the proper functioning of the system.

When the reactor steam plant is shut down or whenever reactor steam is not available the auxiliary boiler supplies the heating load. Operation and valve positions of the system is the same as during steam plant operation, except the inlet and outlet valves to the auxiliary boiler will be opened and the inlet and outlet valves to space heat exchanger will be closed.

Startup - The plant heating system is normally in continuous operation and the only operator action that will normally be required is transferring the heat load from the space heat exchanger to the auxiliary boiler or vice versa. However, for initial startup after the system has been filled and tested or in the event the system has been secured for some reason, the following procedure should be followed:

(1) Position all valves in their normal operating position.

(2) Open the surge tank drain valve and add water until a flow is observed from the drain.

(3) Shut the drain valve and continue adding water to the system until the pressure gauge (PH-GA-04) in the surge tank line reads 10 psig.

(4) If steam is available, open the steam valves to the space heat exchanger and the drain and vent lines from the space heat exchanger and close the inlet and outlet valves to the auxiliary boiler. If steam is not available startup the auxiliary boiler and close the isolation valves to the space heat exchanger.

(5) Start one plant heating pump.

Shutdown - The plant heating system is not normally shut down at any time. If it is necessary, the system may be shut down by securing the space heat exchanger or the auxiliary boiler whichever is in operation and stopping the plant heating pumps. It is not necessary to close any valves.

Abnormal or Infrequent Operation - Transfer of plant heating pumps may be accomplished by stopping the operating pump and starting the standby pump. Removal of the standby pump for maintenance or repair may be accomplished by closing the suction and discharge valves and removing the pump from the system by breaking the flange suction and discharge connections.

Each individual building heating loop is provided with isolation valves which, when closed, will permit removal or replacement of any component in the system for maintenance or repair.

12. Plant Ventilation System (PV)

Plant Ventilation System Diagram - Project No. 2112 (Fig.188)

Process Instrumentation - Plant Ventilation System - Project No. 2112-11 (Fig. 189)

a. Introduction

System Function - The function of the plant ventilation system is to provide normal ventilation for the reactor complex, generator, personnel, and service buildings and emergency ventilation for the reactor complex and generator building to purge any radioactive gas inadvertently released which may accumulate in these spaces.

Brief Description - In all buildings, other than the service building, duct type fans are installed in the exhaust duct from each building. Circulation air is induced from the tunnel through wall louvers located below the wall fin convectors in the plant heating system. The air mixes with the building air normally circulating through the wall-fin convectors and is heated.

In the service building the unit heaters in the plant heating system are used to induce air from the tunnel through wall louvers in the end of the building. The air is mixed with warm air recirculated from the building in the inlet duct to the heater to avoid freezing in the heating coils. After passing through the heating coils the air is discharged into the auxiliary boiler room and the machine shop. The ventilation air is exhausted to the ambient above grade through the auxiliary boiler stack. A louver is provided in the wall between the machine shop and the boiler room for passage of air from the machine shop to the boiler stack. The boiler stack is provided with a weighted damper in a branch connection to permit passage of air from the boiler room into the stack.

In the reactor complex building, the ventilation air is exhausted through a hood over the spent fuel tank. This hood may be removed during fuel transfer operations. A blanked branch connection is provided in the duct ahead of the fan to accomodate a flexible duct for ventilating the containment vessel before entry for maintenance or inspection.

The exhaust fan in the power plant building is located high in the end of the building away from the plant control station to insure air flow away from the control station. This is done to minimize the spread of contaminants to the control station in the event of an activity release. The fan has a free inlet and the outlet is connected to a duct that extends through the building and tunnel roofs and exhausts above grade. A two speed fan is provided to permit accelerated purging when necessary.

The exhaust fan in the personnel building takes suction from the laboratory and toilet areas and discharges above grade through a duct which penetrates the building and tunnel roofs. Air will enter the laboratory and toilet areas from the office and hall space through louvers in the doors.

The ventilation system is designed to normally provide approximately two air changes per hour. With the fans in high speed, the system will provide three to four air changes per hour in the reactor complex and generator buildings. Dampers are provided in the discharge duct from each fan and arranged for automatic closure by the fire protection system in the event of fire. The inlet wall louvers are adjustable and normally held open against spring tension. Fusible links are provided in the chain holding the wall louvers open to provide automatic closure in the event of fire.

<u>System Design Data</u>

Flow Rate (Normal Operation)

Reactor Complex Building	780 CFM

Power Plant Building	1140 CFM
Personnel Building	180 CFM
Service Building	240 CFM

b. Component Description

Fans (PV-FN-01, 02, 03)

Description - Axial type duct fans are used in the reactor complex, generator, and personnel buildings. Each fan consists of a four bladed fan, direct-connected to the motor shaft, mounted in a short cylindrical section of flanged duct which is bolted into the system ducting. A removable access plate is provided in the duct section for access to the motor and fan for maintenance.

Design Data

Building Served	Capacity	Speed	H.P.
Reactor Complex	780/1450 CFM	1750/3450 RPM	1/4
Power Plant	1140/1800 CFM	850/1725 RPM	1/6
Personnel	180 CFM	1140 RPM	1/8

c. System Operation

Normal Operation - During normal operation, the fans in the reactor complex and power plant buildings are operated at low speed. The fan in the personnel building is normally operated continuously. The fans for the unit heaters in the service building are controlled by independent wall thermostats to maintain the set temperature in the spaces served. The wall louvers are normally wide open, but may be manually adjusted, if desired, to reduce the amount of ventilation. Operator action is not normally required.

Startup - The fans are started manually by push buttons located in the space served. A remote control button is provided at the plant control station for the reactor complex fan. The exhaust dampers and wall louvers should be manually positioned prior to starting the fans.

Shutdown - Shutdown of the system is accomplished manually by pressing the fan stop button and closing the fan damper and wall louvers, if desired. In the event of fire, the system will be automatically shut down as previously described.

Abnormal or Infrequent Operation - The fans in the reactor complex and generator buildings are normally operated at slow speed. High speed operation of these fans may be accomplished by pressing the high speed pushbutton at the control console.

13. Fire Protection System (FP)

Fire Protection System Diagram - Project No. 2113 (Fig. 191)

Process Instrumentation - Fire Protection System - Project No. 2113-11 (Fig. 192)

a. Introduction

Function - The fire protection system is a total flooding low pressure CO_2 system designed to provide fire protection for the Reactor Complex, Power Plant, Condenser, Personnel and Service Buildings. The system provides the following functions:

(1) Detects fire in any of the buildings protected.

(2) Sounds an alarm at the plant control station and in the building affected in the event of a fire.

(3) Automatically extinguishes the fire by flooding the affected building with CO_2.

Description - Carbon dioxide is stored in a centrally located storage unit between the Power Plant and Condenser Buildings. A main header is attached to the storage unit by a normally locked-open shut-off valve and master valve. Branch headers extend to the various buildings protected. A selector valve is located in each branch header.

Actuation of the master and selector valves is normally accomplished by temperature detectors located in each building and spaced in accordance with Underwriters' recommendations and good engineering practice.

When fire occurs, the temperature detectors will close the control circuit. Visual and audible alarms are actuated at the plant control station and in the building where the fire is located. A light at the plant control station will indicate the location of the fire. Ventilation fans in the building where the fire is located will be stopped. The master valve and the selector valve for the building concerned will be opened after a pre-set time delay. The master and selector valves will close after releasing a pre-determined amount of carbon dioxide.

Pushbuttons located adjacent to the entrances and exits to each building are connected in parallel with the temperature detectors and the system may be actuated by means of the pushbuttons. Portable hand-operated extinguishers are also provided at strategic locations throughout the buildings for handling small fires.

The detection, alarm and control circuits are supplied from the emergency A-C power supply to ensure a reliable power supply. However, in the event of a power failure, the system is also provided with manual operated pilot valves.

The storage unit is designed to store sufficient carbon dioxide to provide at least two (2) complete discharges for the largest single hazard protected. The entire storage capacity of the system is available at all times for the protection of all hazards covered, but each discharge releases only the amount of carbon dioxide required by the particular hazard involved.

A dry ice conversion unit is provided for filling the storage unit with liquid carbon dioxide. This unit converts dry ice into liquid carbon dioxide which is drained to the storage unit through a dryer. Refilling the system will not require any dismantling of the system or interruption to protection provided by the system.

System Design Data

CO_2 Storage Pressure	- 300 psig
CO_2 Storage Temperature	- $0^{o}F$
CO_2 Storage Capacity	- 8000 Lbs.

Application Requirements:

Building	CO_2 Released/Disch.	Release Rate
Reactor Complex	1920 Lbs.	1450 Lbs./Min.
Condenser	1700 Lbs.	1650 Lbs./Min.
Power Plant	3000 Lbs.	3000 Lbs./Min.
Personnel	870 Lbs.	125 Lbs./Min.
Service	450 Lbs.	450 Lbs./Min.

Power Supply:

A-C Components	440 Volts, 3 Phase, 60 cps
D-C Components	64 Volts
Instrumentation and Controls	115 Volts, 1 Phase, 60 cps

b. Component Description

Storage Unit - The storage unit is essentially an insulated, refrigerated pressure vessel, equipped with necessary automatic controls and safety devices.

The pressure vessel is a cylindrical steel tank, manufactured and tested in accordance with the ASME code for unfired pressure vessels. It is of all welded construction. The storage vessel is insulated with not less than two layers of 4 inch blanket type insulation.

The entire storage unit is enclosed in a welded, sheet steel housing, mounted on a channel iron base. The housing is heremetically sealed.

Low temperature storage is provided by a compressor and refrigeration coil running lengthwise through the pressure vessel near the top. During the refrigeration cycle, carbon dioxide vapor coming in contact with these coils is condensed back into liquid carbon dioxide. A pressure switch starts the compressor whenever carbon dioxide pressure reaches approximately 305 PSIG and stops it whenever the pressure has been reduced to approximately 295 PSIG.

The storage unit is installed in the snow tunnel where ambient temperatures may be less than the carbon dioxide storage temperature for long periods of time. An electric immersion heater is provided to maintain pressure within the design range. A pressure switch energizes the heater whenever the carbon dioxide pressure reaches approximately 285 PSIG and de-energizes when the pressure is increased to approximately 295 PSIG.

The storage tank is provided with relief valve protection in the event that an extended outage of the refrigeration system causes pressure to increase in the tank.

The valve arrangement consists of: (1) a two-way switching valve, (2) bleeder relief valve, and (3) two pop type safety valves.

The two-way switching valve makes it impossible to shut off both pop safety valves at the same time.

The bleeder relief valve opens to relieve pressure when the pressure rises to 341 PSIG. If the pressure continues to rise beyond the capacity of the bleeder relief valve, the pop safety valve in service will open at 357 psig. The second pop safety valve will open at 357 psig and is placed in operation by the two-way switching valve during periods of service or replacement of the bleeder relief valve and pop safety valve normally in service.

In addition to the above safety devices, an alarm sounds automatically if the pressure rises to approximately 325 psig or falls below 275 psig.

Liquid level and pressure gages are located on the front of the storage unit to indicate quantity and pressure of carbon dioxide in the unit.

Design Data

Design Pressure	363 psig
Operating Pressure	285 to 305 psig
Operating Temperature	$0^{o}F$, nominal
CO_2 Storage Capacity	8,000 Lbs.
Power Supply:	
Compressor and Header	440 Volts, 60 cps, 3 Phase
Alarm Circuit	115 Volts, 60 cps, 1 Phase

Master and Selector Valves - The master and selector valves are practically identical in construction and design. There is one master valve and several selector valves. The master valve controls the flow of carbon dioxide from the storage unit, and is located in the area of the storage unit. The selector valves control the discharge of carbon dioxide to the fire area and are located adjacent to the particular hazard.

When the valve is in the closed position, carbon dioxide pressure is against the disc and keeps the disc tightly seated against the valve seat. When the pilot valve is operated, carbon dioxide pressure from valve inlet is admitted into the piston chamber through an orifice through the top cover. This forces the piston down and opens the valve. A spring under the disc closes the valve when the pressure above the piston is removed by closing of the pilot valve.

Pushbutton Stations - Pushbutton stations are provided outside the hazard protected. They normally require no maintenance other than routine semi-annual inspection or the replacement of the indicating light should it burn out.

The operation of a pushbutton station has the same effect as system actuation by the heat detectors. An auxiliary relay in the pushbutton station locks out the heat detectors to prevent recycling of the system until these devices can be inspected after the fire has been extinguished. The auxiliary relay also keeps the alarm sounding until the system has been reset.

The indicating light on the pushbutton station is normally on. The light goes out when the pushbutton has actuated the system.

Design Data

Power Supply	115 Volts, 1 Phase, 60 cps

Electro-Manual Pilot Valves - Two types of electro-manual pilot valves are used, the normally energized and the normally de-energized. Both types are identical in exterior appearance but differ in their interior construction to suite the application for which each is designed.

Both types are actuated electrically by the heat detectors or pushbutton stations through a relay. Manual operation is accomplished by breaking the glass in the front of the pilot valve enclosure cabinet and moving the actuator handle one-half turn. In manual operation, the handle must be returned to its original position to stop the discharge. In electric operation, the entire sequence is automatic.

Normally de-energized type electro-manual pilot valves are used for the selector valves. A normally energized electro-manual pilot valve is used for the master valve. This provides an extra safety factor. In the event of a power failure, de-energizing of the solenoid in the pilot control cabinet will cause the master valve to open and allow carbon dioxide to flow to the selector valves; thus, manual piloting of the master valve is not necessary.

Design Data

Power Requirements	64 Volts D.C.

Heat Detectors - The heat detectors are located near the roof in each building. They continuously monitor the air temperature in the building and automatically actuate the system whenever the air reaches a pre-set temperature.

Each temperature detector consists of two fine silver contacts mounted on curved struts that have a low expansion coefficient. This assembly is mounted under compression in a tubular stainless steel shell having a high coefficient of expansion. A temperature rise causes the shell to expand, which closes the contacts when the surrounding air reaches the set temperature. The temperature setting is adjustable up to 725°F. Unless actually damaged by the fire, the unit is automatically reset and need not be replaced.

Design Data

Set Point Temperature	140°F
Power Supply	115 Volts, 1 Phase, 60 cps

Dry Ice Converter - A dry ice converter is provided for refilling the storage unit. The converter unit consists of an electrically heated pressure vessel to vaporize the dry ice, a throwaway cartridge type dryer, and necessary controls, valves and other devices necessary for connecting the converter to the storage unit.

Design Data

Pressure Vessel Capacity	1000 Lbs./of Dry Ice
Dryer Capacity, Min.	8000 Lbs.
Power Supply	115 Volts, 1 Phase, 60 cps

c. System Operation

Normal Operation - During normal operation the master and selector valves are closed. The heater and refrigeration system in the storage unit are automatically controlled to maintain carbon dioxide storage pressure in the normal operating range.

In the event of a fire, one or more of the fixed temperature detectors will close the control circuit and actuate the appropriate alarms, cutouts, and pilot valves to release carbon dioxide to flood the building affected. Liquid carbon dioxide will pass from the storage unit through the system piping to the discharge nozzles installed in the building affected by the fire. The carbon dioxide will flash across the discharge nozzle orifices into vapor and snow. The carbon dioxide vapor reduces the oxygen content of the atmosphere below that required for combustion and the carbon dioxide snow tends to cool combustibles below ignition temperature.

WARNING: Personnel entering a building after release of carbon dioxide must wear some type of oxygen breathing apparatus to avoid asphyxiation until the carbon dioxide is purged from the building.

Startup and Shutdown - The fire protection system operation is normally completely automatic and does not require any operator action. Manual pushbutton stations and manual pilot valve actuation levers are provided to permit manual operation.

After operation of the fire protection system, the system will automatically return to normal operating positions. Ventilating fans, dampers, and other equipment which the system has actuated should be returned to normal operation manually.

Abnormal or Infrequent Operation - Refilling the storage unit after a discharge is accomplished by using the dry-ice converter. Dry ice blocks are loaded into the converter and vaporized using the electric heating jacket. As the dry ice vaporizes and builds up enough pressure to overcome the storage unit pressure, the carbon dioxide vapor and liquid is transferred to the storage unit through a cartridge type dryer. No interruption of the protection is experienced during recharge.

14. Plant Heat Balance

The Plant Heat Balance Diagram (Figure 114) shows that in order to generate a gross electrical output of 1250 KW plus a gross heating load of 502 KWTh (1.715×10^6 BTU/hr) a reactor thermal release rate of 7.48 MW is required. The net electrical output is 1000 KW at 0.8 power factor and the net heating load is 400 KWTh (1.365×10^6 BTU/hr). The actual plant electrical load is approximately 220 KW, however, 250 KW was used for the purposes of these calculations.

At full design plant load the steam flow from the reactor is 23,143 lbs/hr. of saturated steam at 600 psig. Feedwater is returned to the reactor at a temperature of 159°F. The heat loss to the air from the reactor is 110,000 BTU/hr. The steam flow to the turbine is 20,920 lbs/hr giving a turbine steam rate of 16.74 lbs/hr and a turbine engine efficiency of 61.6%. Steam flow to the reducing station is 2,173 lbs/hr and 50 lbs/hr of steam condensation represent the heat losses from the steam piping.

The heat load on the condenser and subcooler is 19.4×10^6 BTU/hr which is rejected to the air through the condenser stacks. The total fluid flow rate through the subcooler is 23,262 lbs/hr of which 3,472 lbs/hr is recirculation flow to provide the required capacity for auxiliary cooling.

For this heat balance air leakage into the system is assumed to be at 60°F and friction heating in the pumps is neglected.

It should be observed that all auxiliary heat exchangers are of the regenerative type and their heat contribution is used to heat reactor feedwater. The main condenser and subcooler are the only system heat sinks.

The condenser back pressure was established at 8" Hg.A and the loop flows and energies were calculated. Condenser performance as shown on the heat balance diagram has been verified by data reported in "PL Condenser Evaluation Report", (IDO-19031). This report shows that the operating conditions of 8" Hg.A with 50°F inlet air used in calculating the heat balance are conservative. According to the available data the condenser can be expected to maintain 8" Hg.A with cooling air inlet temperatures as high as 58°F.

By reducing the controlled inlet air temperature to the condenser, lower full power condenser pressure can be obtained. To avoid flashing of the water recirculated to the subcooler the condenser pressure cannot be reduced beyond the saturation pressure of the returning condensate. The lowest practical condenser pressure is approximately 6.5" Hg.A which corresponds to a cooling air inlet temperature of 55°F. If this air temperature is utilized the reactor power required is reduced from 7.48 MW to 7.20 MW.

C. ELECTRIC POWER GENERATION AND DISTRIBUTION

Electric Power One Line Diagram - Fig. 200

The primary purpose of the PL-2 plant is the generation and distribution of electrical power to a station load. In addition, the system must supply the electrical requirements for plant operation.

Electrical Power generation is accomplished by a single synchronous generator which is powered by a steam turbine prime-mover. The generated power is fed through switchgear to a station bus and a plant bus. An auxiliary power function is provided by a diesel generator which is capable of supplying the necessary plant requirements during plant start up and shut down. An emergency power system is provided to ensure that critical plant equipment is supplied at all times.

1. Main Generating System

a. Introduction

The main generating system is intended to act as a primary source of AC power for the station and for the plant. It is capable of operating as an independent power source and in parallel with other sources at the site.

The system consists of a single synchronous generator and a set of low voltage switchgear with associated relaying and monitoring. The main generator is a turbine-gear-driven unit mounted on an equipment skid in the Power Plant Building. The switchgear is housed in a cabinet assembly mounted on the electrical skid in the Power Plant Building.

<u>System Design Data</u>

Gross generator output	-	1250 KW(e) at 480 volts, 60 cycle, three-phase, 0.8 power factor.
Station Output	-	1000 kw(e) at 480 volts, 60 cycle, three phase, 0.8 power factor
Available for Plant	-	250 kw(e) - Actual plant requirements during normal operation are approximately 220 kw(e).

Distribution System	-	Three-phase, four-wire with full capacity ground.

b. System Components

1) Main Generator (MS-TG-01)

Outline, 1250 kw Synchronous Generator - Fig. 147

Assembly, 1250 kw Synchronous Generator - Fig. 148

Description - The generator is used to convert the mechanical power from the turbine to A.C. electrical power.

The generator is an A.C. synchronous machine operated at 1200 RPM and equipped with a static excitation system. Generator construction is of the open, dripproof, protected type with a single (outboard) bearing. (See section Ald for detailed description)

Time Constant of the Field: with the Armature Open Circuited	-	T_{do} ' -3.0 seconds
with the Armature Short Circuited	-	T_d ' -0.56 seconds
Time Constant of the Direct Axis Amortisser Winding with the Armature Short Circuited	-	T_d "-0.014 seconds
Normal Ventilation Rate Cubic Feet of Air/Minute	-	5100
Temperature Rise °C not to exceed:		
a. Armature Coils: by temperature detector	-	60° C
by thermometer	-	50° C
b. Collector by Thermometer	-	85° C
c. Field Coils by Resistance	-	80° C

Excitation - Max. Required		
KW	-	10.0
Volts		125
Frequency Regulation	-	±0.25%
Transient frequency variations	-	±2% maximum when subjected to an instantaneous load change of 240 KW at 0.8 P.F.
Recovery time to steady state frequency	-	5.0 sec.for max. variation
Unbalance, line to line, from no load to balanced full load	-	5% maximum.
RMS value of all harmonics, no load	-	5% max.
RMS value of any one harmonic, no load	-	2% max.

2) Exciter - Voltage Regulator

Static Exciter and Regulator, Sheet 1. - Fig.No. 208

Static Exciter and Regulator, Sheet 2. - Fig.No. 209

Static Exciter and Regulator, Sheet 3. - Fig.No. 210

Description - The exciter - voltage regulator system supplies field current to the generator and regulates this field current to maintain the generator output voltage constant. The system also provides a drooping characteristic of generator voltage for reactive current so that proper load division is made with generators operating in parallel.

The exciter consists of three saturable, current-potential transformers (SCPT'S),three linear reactors, and a three phase bridge rectifier. The SCPT'S sense the current and voltage in the generator output leads and supply current through the three-phase rectifier to the generator field.

The voltage regulator consists of passive elements and Zener diodes which are fed from current and potential transformers on the generator output. The generator output is compared to a reference voltage and signals proportional to the difference are fed to the control windings of the SCPT'S to adjust the field (and the output) voltage. A rheostat is provided in the regulator circuit to permit adjustment of the output voltage.

A passive, stabilizing, network is provided to increase system response during load changes. A current transformer resistor network is used to provide a reactive current droop characteristic.

The advantages of a static exciter regulator system include:

Low maintenance cost because of absence of moving parts, bearings and commutator.

Greater reliability.

A reduced length turbine-generator.

Better voltage regulation because of built-in compensation.

Faster voltage recovery during load changes due to the rapid response of the system components.

A switch (with the necessary connections) is provided to energize the field from an external source during generator startup.

The exciter voltage regulator system is located in the switchgear cabinet on the electrical skid.

<u>Design Data</u>

D-C output, rated load	-	73 amperes
D-C voltage	-	125
Power	-	10 kw
Variation generator output voltage	-	3.0% no load to full load
Regulation, steady state voltage	-	±0.5% around any point in the N.L. to FL range
Transient voltage variation, maximum	-	±6% between 80 kw and 1250 KW when subjected to an instantaneous change of 240 KW at 0.8 P.F.
Recovery time	-	1.5 seconds, maximum, for above transient

3) Main System Switchgear

Switchgear Arrangement - Figure 95

Switchgear Arrangement Detail - Figure 96

Elementary System Wiring - Figures 201 through 207

Description - The switchgear is used to distribute and monitor the main generator output power and to protect the system components in the event of faults.

The power from the generator is fed overhead from the turbine generator skid (generator connections) thru a busway to low voltage switchgear cabinets on the electrical skid. The switchgear assembly contains the switch breakers, the monitoring instruments, the control relays, the voltage regulator, the static exciter and other items pertinent to the generating system. The cabinets are free-standing sheet metal cabinets designed for front and rear access and assembled in accordance with applicable standards of NEMA, AIEE, and ASA.

Within the switchgear cabinet the power is fed through a generator breaker, then is divided between the station breaker and the plant bus breaker. A second plant bus breaker in parallel with the first is provided for reliability. The breakers are mechanically interlocked so that only one can be closed at a time. The circuit breakers are low voltage draw out type air breakers containing removable breaker elements, stationary structure, bus connections, and associated equipment. The breakers with their interpole barriers, arc quenchers, racking mechanisms and other items are all mounted on removable draw out carriages. Stored energy mechanisms are provided on the breakers provide high speed closing of breaker contacts during closing of the breaker. The station breaker is equipped with dual magnetic, (instantaneous and time delay) over current tripping devices for each pole. The generator breaker is equipped with an overcurrent trip, a differential current trip and a trip input from the turbine trip mechanism. These trips are fed to a lock out relay which in turn trips the breaker. The breakers are operated electrically from switches on the switchgear panels or on the secondary control station in the plant control console.

Two sets of instruments are provided to monitor the system parameters. A complete set is located in the switchgear instrument compartment. A partial set is located on the secondary control station in the plant control sonsole. Operation of the electrical system can be accomplished from either point and sufficient information is provided at either point to permit coordination of the plant electrical functions. All system indicators except the watt-hour meters are 4-½" dial, switchboard instruments with a 1% accuracy and are designed to resist shock. The items which are monitored on the switchgear cabinet include generator exciter voltage, field current, voltage, output current, output watts, watt hours, power factor, and frequency; station bus voltage, current and watts. The meters provided on the secondary control station (plant control console) indicate: generator field voltage, field current, voltage, output current, output watts, power factor and frequency; station bus voltage, current and watts. The inputs to these meters are provided from potential transformers and current transformers mounted in the bus and breaker compartments. These potential and current transformers are arranged for easy access, inspection and maintenance. The potential transformers are equipped with primary current limiting fuses mounted on a hinged rear panel.

The generator and primary bus system is protected by suitable relaying. The generator itself is provided with differential relay protection, reverse power relay protection and overcurrent protection. These relays are supplied from current transformers on the primary bus work and function to trip the main generator breaker in the event of transients which exceed the values set on the trips. The station breaker is provided with overcurrent protection such that it will trip in the event that excessive current should occur. The relays are mounted on the face of the switchgear panels in the instrument compartment and are of the switchboard drawout type with built in testing facilities and fitted with targets to indicate operation. The contacts of the relays are self-aligning and visible to permit ready inspection. The outputs from the station breaker and the plant bus breakers are carried to terminations at the top of the switchgear cabinet from which the station bus may be fed to the desired point and a bus section connects to the plant bus duct along the wall of the Power Plant Building.

<u>Design Data</u>

Generator Breaker (MS-CB-01)

type	-	low voltage drawout
voltage	-	600(AC - 60 cycles)
current	-	2000 amperes
trip element	-	3 pole, electrically and mechanically trip free
operating mechanism	-	stored energy

accessories	-	shunt trip, auxiliary switch

Station Breaker (MS-CB-02)

type	-	low voltage drawout
voltage	-	600(AC - 60 cycles)
current	-	1600 amperes
trip element	-	3 pole, electrically and mechanically trip free
operating mechanism	-	stored energy
accessories	-	shunt trip, auxiliary switch
trips	-	dual magnetic overcurrent (instantaneous & long time delay)

Plant Breakers (MS-CB-03 and MS-CB-04)

type	-	low voltage drawout
voltage	-	600 (AC - 60 cycles)
current	-	600 amperes
trip element	-	3 pole, electrically and mechanically trip free
trips	-	dual magnetic overcurrent (instantaneous & long time delay)
accessories	-	shunt trip, auxiliary switch

Relays

control bus voltage	-	115 volts; 60 cycles AC

types - time- overcurrent; differential, time-overcurrent; reverse power; auxiliary, hand-reset.

overcurrent trip characteristics	-	long time delay and instantaneous
accessories	-	universal targets

Meters

type	-	long scale switch board units
size	-	approximately $4\frac{1}{4}$" square
scale rotation	-	250°
accuracy	-	$\pm 1\%$

meter inputs

frequency (AC meters)	-	60 cycles
current transformer ratio	-	2500:5
potential transformer ratio		480:120

kilowatt - hour register (watthour - meter)-
pointer type

Current Transformers

type	-	indoor
insulation class	-	600 volt, 60 cycles
current ratio	-	2000:5 amperes, 60 cycles 2500:5 amperes, 60 cycles
output to	-	meters and relays

Potential Transformers

type	-	indoor
insulation class	-	600 volt, 60 cycles
voltage ratio	-	480:120 volts, 60 cycles
fuses in primary	-	two
accuracy classification	-	0.3 at rated voltage

2. Auxiliary Generating System

a. Description

The auxiliary generating system is provided to supply the plant with A.C. power during critical periods of operation such as reactor startup, reactor shutdown and periods during which the main turbine generator may be tripped off the line. An automatic transfer system continuously monitors the plant bus voltage. In the event that such voltage drops below 70% of its rated value, the transfer system starts a diesel generator and after the generator has come up to rated speed, transfers the plant bus supply to the diesel generator.

The system consists of a four cycle diesel electric set and a generator control and automatic transfer cabinet. The diesel generator is mounted on a skid base and includes an air cleaner, lifting eyes, a lube oil cooler, an exhaust silencer, an engine gage panel, front mounted radiator and fan, an 11.5 gallon/lube oil system, a 32 volt automatic start-stop system with batteries and charging generator, and special tools. The generator control equipment is enclosed in a sheet-metal wall mounted cabinet and includes: metering, relaying, switchgear and the automatic transfer system.

The system is located in the Service Building and is supplied with fuel from the diesel oil day tank.

System Design Data

Output	200 KW(e) continuous 225 KW(e) intermittent
Fuel	arctic type
Dimensions (envelope) diesel electric set	107" long x 40" wide x 52" high (less silencer)
Shipping Weight	10,000 lbs.
Startup time, rated	25 seconds

b. Components

Diesel unit - The engine is a 6 cylinder, 4 cycle diesel which operates at 1800 RPM. It is designed to use an arctic type fuel meeting Federal Specification No. VVF-F-800 Grade DF-A. It is a general purpose, stationary, solid injection, internal combustion machine with a supercharger, compression ignition, and wet cylinder liners. Cooling is accomplished with a front mounted radiator and a built in gear driven pump. The engine is equipped with a silencer and an electric starting system. An instrument board is provided for temperature and pressure gages.

Design Data

Horsepower	360 @ 2000 RPM
Cycles	four
Cylinders	6
Bore and stroke	5.4" x 6.5"
Displacement	893 cubic inches
Fuel	arctic type
Fuel rate, approximate	$\frac{1}{4}$ load - 6.6 gal/hr.
	$\frac{1}{2}$ load - 9.6 gal/hr.
(19,500 BTU/lb., 7.12 lbs/gal Fuel,	$\frac{1}{4}$ load - 12.8 gal/hr.
sea level Barometric pressure, 60^{o}F ambient)	full load - 16.4 gal/hr.

Generator (AE-DG-01) - The generator is a revolving field AC unit of open dripproof protected construction. The generator is close coupled to the flywheel and has a single outboard bearing. Stator and rotor insulation are class B. The exciter and voltage regulator is a static system and is mounted in a separate enclosure on top of the generator. Compensation is provided for parallel operation.

Design Data

Rating	-	200 KW continuous
Voltage	-	480Y/277 volts
Phases	-	3
Frequency	-	60 cycles
Power Factor	-	0.8

Motor starting ability - starts (across the line) a 75 HP motor (5.5 KVA/HP) with a transient voltage dip not exceeding 35%.

Generator Control and Automatic Transfer - The control panel is a wall mounted enclosure and includes the following equipment: a generator output volt meter, a generator output ammeter (both of the 4-½" panel type with 2% accuracy), a frequency meter of the 3" reed type, meter switches and instrument transformers, one circuit breaker (molded case, 3 poles, 600 volt, 250 amperes, 35,000 amps interrupting capacity) for generator protection, and a transfer circuit. The automatic transfer system includes a JKL frame circuit interrupter with a motor operated mechanism interlocked with the plant bus circuit breaker and the diesel generator breaker, one set of voltage sensitive relays, two time delay devices, a set of plant potential transformers and a manual switch for plant operation. A synchronizing switch and meter are provided to permit the unit to be synchronized with the main turbine during startup functions.

c. System Operation

During normal plant condition the diesel generator operates as a standby unit, normally off the line except as run periodically for normal checkout and maintenance. Under these conditions the plant bus breaker from the main turbine generator set is closed, the diesel generator breaker is open, and the load is served through the closed circuit interrupter. If main power is lost for over 3 seconds (adjustable on a time delay device) a relay initiates starting of the diesel electric set. When the diesel generator reaches 90% of rated voltage, the circuit interrupter opens, isolating the load from the main turbine generator. The diesel generator breaker then closes supplying load from the standby generator. If the main power source is re-established but for less than one minute, (adjustable on time delay device) load continues to be supplied from standby. If main power source continues past the delay period, the diesel generator breaker opens and the circuit interrupter closes. The load is then supplied from the main generator.

d. Adjustments and Controls

Adjustments are provided in the static excitor and the static regulator to regulate the generator within its working limits. The adjustments on the time delay relays in the automatic transfer switch permit selection of the transfer times desired between the main generator and the diesel unit.

3. Emergency Power System

a. Description

In the event of simultaneous interruption of the turbine generator and the diesel generator power, an emergency power system is provided to ensure continuity of electrical service to critical instruments and equipment provided for the plant.

The emergency power system consists of two AC to DC converters, a DC bus, a nickel-cadmium battery, D.C. regulator and DC to AC convertors. During normal plant conditions, the converters supply the DC bus with power from the plant bus. The battery is floated on and receives a trickle charge from the DC bus. DC power is supplied through regulators to the process instrumentation, plant annunciator and plant communications and directly to the switchgear trip system. DC to AC inverters operating from the DC bus, supply process instrument alarms and controls, radiation monitoring, nuclear instrumentation and the rod control system.

System Design Data

Bus voltage - 84 volts (floating) to 68 volts (cutoff)

Connected Loads (approximate)

DC Regulated - 0.5 KW continuous

DC Unregulated - 0.6 KW momentary

AC Single Phase - 1.4 KW continuous

AC Three Phase - 3.4 KW intermittent

Emergency Service Duration - 4 hours

b. Components

AC to DC Converters The converters AE-CV-01 and AE-CV-02, are static devices with transformers, and solid state rectifiers and regulators. The units are housed in sheet metal cabinets, convection cooled and are mounted in enclosures adjacent to the switchgear on the electrical skid. A voltage surge suppressor and current limiting fuses are provided for short circuit protection. In addition, the units have a 3 pole AC breaker on the primary and a 2 pole DC breaker on the secondary side. Meters are provided on the face of the panel to indicate the output voltage and the output current. The voltage control is also located on the face of the front panel.

Design Data

Power rating - 5 KW

Input voltage - 440 volts, 3 phase, 60 cycle

Output voltage	-	DC, 65V nominal adjustable 60 - 90 volts
Regulation	-	1% for inputs from 400 to 480 volts, outputs from 0 to full load.
Protection	-	primary AC breaker secondary DC breaker surge suppressors & voltage limiting fuses.

Batteries (AE-B-01) The battery consists of 60 nickel cadmium cells with pocket plate construction. The cells are assembled in steel containers and are mounted in a rack between the converter units on the electrical skid.

Design Data

Type	-	nickel cadmium
No. of cells	-	60
Ampere hour rating/ cell	-	80
Plate construction	-	pocket plate
Floating voltage	-	1.4 volts
Discharge voltage (voltage at end of allowed discharge period)	-	1.14 volts
Case Material	-	nickel plated cold rolled steel

Inverters

Single phase units (AE-CV-03, AE-CV-04)

Input voltage	-	68 to 84 volts
Output voltage	-	117 volts, 60 cycle, AC
Output power	-	1.5 kw
Line Regulation	-	Better than 6% for stated input variation
Load Regulation	-	Better than 5% for stated no load to full demand load

Harmonic Content of Output	-	Less than 5%
Frequency Variation		±1%
Duty Cycle	-	Continuous
Ambient Temperature		30°C Max.
Cooling	-	Convection Cooled
Mounting	-	Rack Type
Enclosure	-	Sheet Steel equipped with front handles and with input and output voltage meters and ammeters, a frequency meter and a frequency adjustment

Features - The units are constructed of static components and are protected against overloads and transient variations.

3 Phase Units (AE-CV-05, AE-CV-06)

Input Voltage	-	68 to 84 Volts DC
Output Voltage	-	208 Volts, 3 Phase, 60 Cycle AC
Voltage Regulation		±5% for stated variations in input voltage ±5% for load variations of 0 to Full Load
Wave distortion	-	less than 10% Harmonics
Frequency Regulation		±5%
Enclosure	-	Steel, Convection Cooled and Rack Mounted. The Enclosure is provided with meters to indicate input and output voltages and currents. The unit is constructed of static components and is designed to operate continuously without exceeding 40°C (outside of case)

Series Regulators (AE-VR-01, AE-VR-02)

Input Voltage	-	68 to 84 Volts DC
Output Voltage	-	Adjustable from 61 to 69 volts
Current Capacity	-	10 amperes
Voltage Regulation	-	±.25 Volts for stated variations in input voltage; ±.25 Volts for load variations from 0 to Full Load
Ripple and Noise	-	Less than 1 millivolt RMS
Enclosure	-	Sheet steel enclosure designed for rack mounting and equipped with meters to indicate the output voltage and current, and the control to adjust the output voltage. The unit is equipped with internal protection to prevent damage to the components in the event of direct short circuit on the output terminals and is capable of continuous duty at full load with a maximum air intake temperature of 40°C. (Outside of case)

c. System Operation

General - The components of the emergency power system are mounted in a cabinet adjacent to the switchgear cabinet on the electrical skid. During normal plant conditions the converters receive power from the plant bus and supply DC power to the DC bus. From this point DC power is supplied through the series regulator to the power distribution panel(Fig. 217)in the plant control console, supplying the process instruments, the annunciator and the communications system. Power is also supplied directly from the DC bus to the breaker trip circuits in the switchgear cabinets. Power is supplied from the DC bus through a pair of single phase inverters, operating in parallel for reliability, through the AC distribution bus in the plant control console to process inst., radiation monitoring and nuclear instrumentation. Power is supplied from the DC bus through a pair of 3 phase inverters to the control rod drive supply circuits within the plant control console.

The nickel cadmium battery is floated on the DC bus at a full charge voltage of 84 volts with a trickle charging current of 60 milliamperes. In the event that AC power to the plant bus is interrupted for any reason, power continues to be supplied from the DC bus by the battery to the various loads. In the event that one of the series regulators or one of the inverters fail to operate as designed, the other unit continues to supply the required output until maintenance can be accomodated. Restoration of the plant AC supply through the plant bus is done by the converters which will pick up the DC loads and supply charging current to the batteries.

<u>Adjustments and Controls</u> - All converters, series regulators and inverters are supplied with voltage controls, frequency controls for the AC inverters and protective equipment; which may be adjusted to properly operate the mechanisms.

4. Plant Electrical Services

a. Introduction

The plant electrical service system is provided to receive power from the main turbine generator supply through the plant bus breakers and distribute this power throughout the plant to the required motor and utility loads. The system also provides utility panelboards to provide control and supply of the lighting circuits, the convenience outlets, the ventilation fans, and numerous other small utility loads.

The system consists of a low voltage bus duct emanating from the switchgear cabinets on the electrical skid and carried on the wall of the Power Plant Building, the Condenser Building, the Service Building and the Reactor Complex Building from which plug-in breakers on the duct supply flexible, metallic sheathed cables running to the individual utilization points. Two separate plugs and feeders are run from the bus duct to each equipment skid. Each feeder supplies one of a pair of motor loads which are used for the same purpose i.e. one operating, one standby. Transfer switches on the skids permit individual motor loads to be connected to either feeder. Figures 111, 112 and 113 show the wiring layouts on typical skids. Power for the utility panelboards is also taken from plug in breakers on the bus duct at various building locations and supplied to panelboards which are surface mounted on the wall of the buildings in which they are located.

<u>System</u> <u>Design</u> <u>Data</u>

Distribution Voltage	-	480 Volts
Power Capacity	-	400 Amperes
Type Conductors:		
(1) In Buildings	-	Plug-In Bus Duct, Aluminum Bus Bars.
(2) Between Buildings	-	4 Conductor 600 Volt, Silicone Insulated, Metallic Sheathed Cable

Branch Feeder Protectors

Bus Plug In Type Units with Pole Operated Circuit Breaker.

Panelboards - Combined Light and Power:

(1) 480Y/277, 3 Phase

(2) 208Y/120, 3 Phase

(3) Utility Transformer - 480-208Y/120

b. Components

Bus Duct (ES-BD-01)- The bus-way consists of 4 high tensile strength aluminum tube bus bars, silver plated and continuously enclosed in the insulation to prevent travelling arcs. Spacer blocks are provided at intervals of length and the insulated bus bars and spacer blocks are bound with steel strapping to withstand short circuit forces. The entire insulated bus bar and spacer block assembly is contained in a totally enclosed housing which is provided with external mounted flanges (drilled) for mounting the bus-way. The bus-way is furnished in standard 10 foot lengths with dead front type plug outlets provided, 12 per 10 foot length, half on each side of the bus-way, all useable simultaneously. Outlets are polarized and arranged so that plugs can be inserted or removed only when a plug is in the off position. The joints are of a high compression type to clamp all bus bars at one time. Joint covers are removable so a length or fitting can be removed from bus-way without disturbing adjacent elements.

Elbows, keys, crosses and switchboard stubs are of the rigid type with minimum length legs. Hangers suitable for attachment to the bus-way at any point along the run permit the bus-way to be hung from the building roof truss.

Design Data

1)	Voltage Rating	-	600 Volts
2)	Current Rating	-	400 Amperes Continuous
	Interrupting Rating	-	50,000 Amperes RMS a Symmetrical short circuit
3)	No. of Conductors	-	4 Wire, 3 Phase, Full Rated Neutral

Cable - The cable provided for conduction of plant power between the buildings consist of a 3 conductor cable with ground wires enclosed in a continuous corrugated steel sheath with the sheath covered by an insulated jacket. The cable ends shall be provided with plugs which are suitable for connection to the bus duct in an end cable tap box.

Design Data

1) Voltage Rating - 600 Volts

2) Current Rating - 400 Amperes Continuous

Conductor Insulation - Silicone Rubber

Jacket Material - Polyvinyl Chloride

Ground Conductor Capacity - Fully Rated

Bus-way Plugs - The bus-way plugs include a molded case circuit breaker for branch feeder protection. An external operated handle is provided for pole operation of the breaker from front or side.

The plugs are of the interchangeable base type so that they may be used in any of the available plug-in openings in the bus duct. The bases have stab shields and pressure reinforced stabs and are equipped with a padlocking type cover catch and a means for padlocking in the off position. The plugs are housed in sheet steel housings with a cover. Clamps are provided for quick attachment of the plug to the bus-way. Solderless and mechanical terminals are provided for the wire connection, including a ground terminal. All current carrying parts are silver plated.

Design Data

Voltage Rating - 600 Volts, 60 Cycle, AC

Poles - 3

Current Rating as follows:

10 Units (ES-CB-02, ES-CB-03, ES-CB-04, ES-CB-05, ES-CB-07, ES-CB-08, ES-CB-06, EM-CB-08, EM-CB-13, and EM-CB-15) - 15 Amperes Continuous

2 Units (EM-CB-10, EM-CB-11) - 30 Amperes Continuous

1 Unit (EM-CB-16) - 70 Amperes Continuous

4 Units (EM-CB-17, EM-CB-18, EM-CB-19, EM-CB-20)
175 Amperes Continuous

Feeders - From the bus duct plug-in units power is supplied to the points of utilization through feeder cables. These cables are 3 conductor fully rated ground which are enclosed in a continuous corrugated steel sheath and covered with a plastic jacket. One end of the cable is terminated in the plug-in unit in the bus duct in solderless connectors. The other end of the cable is terminated in a 4 pole quick disconnect power connector which fits into a mating receptacle on the points of utilization.

Design Data

Voltage Rating - 600 Volts

No. of Conductors (Power Circuit) - 3

No. of Ground Wires - 3 placed in interstices of the power conductors.

Conductor Insulation - silicone rubber

Jacket Material - Polyvinyl Chloride

Current Rating as follows:

12 Cables (ES-CA-01, ES-CA-02, ES-CA-03, ES-CA-04, ES-CA-05, ES-CA-06, ES-CA-07, ES-CA-08, ES-CA-09, ES-CA-10, ES-CA-11, and ES-CA-12) - to be 40 Amperes

1 Cable (ES-CA-17) - 70 Amperes

4 Cables (ES-CA-13, ES-CA-14, ES-CA-15, and ES-CA-16) - 155 Amperes

5. Motor Control

Description

Control and operation of the plant motors (AC induction type) is provided by individual starter units which are housed in general purpose NEMA 1 type enclosures and mounted in access or operating areas near the motors. The starters are all of the AC magnetic type using 120 volt control coils and are equipped with bi-metallic type thermal overload relays to provide overcurrent protection. Under voltage protection is obtained by using momentary contact pushbuttons and a hold-in contact on the contactor assembly. Short circuit protection is provided in the combination units by air circuit breakers (within the enclosure) which are sized according to NEC code requirements for the particular motors involved. On the combination units the circuit breaker is mechanically interlocked with the door to allow opening only when the handle is in the off position. In addition, the units are equipped with a means for padlocking the breaker in the off position. On the combination units, a current transformer is provided to supply a signal to an indicating light on the panel (plant control console) to indicate when the motor is being supplied with current. A control transformer is also provided in the combination units to supply control power from the 440 motor supply lines. Two starting stations are provided for the combination starters. One station consists of lighted on-off pushbuttons located in the door of the enclosure. The second station consists of lighted on-off pushbuttons mounted on the plant control console - motor control board. The reversing contactors are interlocked to prevent one picking up when one is energized. The plant motor starters are identified by component number with the corresponding type and data provided in Table I below.

MOTOR STARTER DATA

TABLE I

Component No.	Type	NEMA Size	Motor H.P.	Breaker Setting	Overload Trip Setting	Motor Device No.	Operator (in case)
EM-ST-01	Combination non-reversing	1	5	20	9.0	LO-PU-02	ON & OFF pushbuttons
-02	"	1	1-1/2	15	3.0	LO-PU-03	"
-03	"	1	1-1/2	15	3.0	LO-PU-04	"
-04	"	1	1/2	15	1.6	LO-PR-01	"
-05	"	1	5	20	9.0	C-PU-01	"
-07	"	1	3	15	5.0	PH-FN-01	"
-08	"	1	3/4	15	2.25	PH-PU-03	"

TABLE I (contd.)

Component No.	Type	NEMA Size	Motor H.P.	Breaker Setting	Overload Trip Setting	Motor Device No.	Operator (in case)
-09	Combination non-reversing	1	1/2	15	1.6	P-PU-01	ON & OFF Pushbuttons
-11	"	1	3/4	15	2.25	PH-PU-01	"
-12	"	1	1/2	15	1.6	D-PU-04	"
-13	Manual non-reversing	1	1/3		1.25	F-6	Toggle
-14	"	1	1/3		1.25	C-40	Toggle
-15	Combination non-reversing	1	1/2	15	1.6	RWP-PU-01	ON & OFF Pushbuttons
-16	"	1	3/4	15	2.25	PH-PU-02	"
-18	"	1	5	20	9.0	C-PU-02	"
-21	"	1	1-1/2	15	3.0	CP-PU-01	"
-23	"	1	1-1/2	15	3.0	CP-PU-02	"
-26	Reversing Contactor	1	3/4		2.25	C-LM-01A	"
-27	"	1	3/4		2.25	C-LM-01B	"
-28	"	1	3/4		2.25	C-LM-02A	"
-29	"	1	3/4		2.25	C-LM-02B	"
-30	Combination non-reversing	4	60	150	90.0	F-PU-01	"
-31	"	4	60	150	90.0	F-PU-02	"
-32	"	2	20	50	30.0	C-F-01A	"
-33	"	2	20	50	30.0	C-F-01B	"

TABLE I (contd.)

Component No.	Type	NEMA Size	Motor H.P.	Breaker Setting	Overload Trip Setting	Motor Device No.	Operator (in case)
-34	Combination non-reversing	2	20	50	30.0	C-F-01C	ON & OFF Pushbuttons
-35	"	2	20	50	30.0	C-F-01D	"
-36	"	2	20	50	30.0	C-F-02A	"
-37	"	2	20	50	30.0	C-F-02B	"
-38	"	2	20	50	30.0	C-F-02C	"
-39	"	2	20	50	30.0	C-F-02D	"
-42	"		15	40	23.0	)-Reactor) Crane)	Pendant- "
-43	"	1	3	15	5.0	)	" "
RC-MS-01	Reversing Contactor	1	1/8			RC-DP-01	Horiz., Open Type
-02	"	1	1/8			-02	"
-03	"	1	1/8			-03	"
-04	"	1	1/8			-04	"
-05	"	1	1/8			-05	"
-06	"	1	1/8			-06	"
-07	"	1	1/8			-07	"
-08	"	1	1/8			-08	"
-09	"	1	1/8			-09	"

6. Transfer Switches

Critical pumping applications in the plant are provided with two pumps so that in the event one pump fails, an automatic transfer to the standby pump is initiated. To ensure continuity of the AC power supply to these pumps, one pump from each critical pair is fed from a separate AC feeder. The supply to pumps or motors which do not have a standby unit is achieved by the installation of a transfer switch to permit connection of the supply to these components from either feeder input line. The switch assemblies are multiple rotary units operated by a pistol grip handle and mounted in a general purpose NEMA 1 enclosure. They are mounted on the skids in a position near the motor starters in the access area so that the operator can manually transfer from one supply to the other.

Design Data

Voltage Rating - 600 Volts

No. of Poles - 4

No. of Throws - 2

Ampere Rating - 25

7. Wireways and Conduit

Electrical Wiring, Condenser Skid - Fig. 111

Electrical Wiring, Purification Skid - Fig. 112

Electrical Wiring, Feed and Condensate Skid - Fig. 113

The assembly of power and control wiring on the skids is accomplished by a configuration of wireway and conduit from the location of the motor starters and the motor control junction boxes to the various points of utilization. The wireways provided are of the rain tight type provided with front access for minimum possibility of moisture accumulation in the box. The conduits used are of the thick-wall type and are coated inside and out with an organic finish and surfaced on the outside with zinc plate. The organic finish on the inside of the conduit greatly reduces the resistance to wire pulling and facilitates the assembly. The conduit fittings used are also of steel and are provided with side, front or back access as required by the particular application to provide for easiest access. The conduit runs to the points of utilization are supported by structural material and are secured with conduit clamps. The fittings at all entries (starter box, junction box, and motor inlet housing) are provided with gaskets to minimize the danger of moisture leakage into the enclosures.

8. Panelboards (ES-DB-01 to 06)

The panelboards are used to supply and protect building lighting and utility circuits. They consist of two separate breaker sections and a transformer enclosed in a common housing of sheet metal and provided with an input power connector for connecting to a cable from the bus duct and with a latching type sheet metal door to provide front access. Wiring gutters are provided along the sides of the assembly to provide space for running the various circuit connections to the points of use. The units are provided with lugs on the back for mounting vertical unistrut members attached to the building wall. Knockouts are provided along the sides of the enclosures for the lighting and utility circuits which are run to the outlets or to the lighting fixtures.

Design Data

(a) Power Connector Rating

Voltage	- 600 Volts
Current	- 60 Amperes
No. of Poles	- 4
Top Protection	- Spring Door

(b) Breaker Section A

Main Breaker Rating	- 480 Volt, 3 Phase, 50 amperes
No. of Circuits	- 6, Single Phase
Ampere Rating of Circuits	- 15

(c) Transformer

Input Voltage	- 480 Volt, 3 Phase
Output Voltage	- 208/120, 3 Phase
Power Capacity	- 3 KVA

(d) Breaker Section B

Main Breaker Rating	- 208, 3 Phase, 50 amperes

No. of Branch Breakers (single phase)	- 12
Branch Breaker Setting	- 15 Amperes

(e) Neutral Bus

Type	- Copper Strip
Connection (Solderless Connector)	- Screw Type
No. of Connections	- 18
Termination	- From Ground Wire Input from Bus Duct

9. Fluorescent Lighting

The reactor complex, the condenser building, the power plant building, the personnel building and the service building are provided with lighting by means of fluorescent light fixtures. In the buildings the fluorescent fixtures are suspended between the roof trusses. In each building the number of fixtures provided is sufficient to supply the building with a lighting level suitable for the operations. The lighting levels required were established on the basis of Illuminating Engineering Society standards. The fixtures are all steel industrial type, 4 bulb fixtures of two different designs.Within the personnel, service and power plant buildings the fixture will be open, flanged fixture for maximum reflection and minimum interference. For the reactor complex and condenser buildings a 4 lamp fixture with a removable wire grid to protect the lamps from damage is supplied. The lights themselves are cold cathode 3500^{o} white units. The cold cathode unit was selected because of its long life, its adaptability to dimming, its low current consumption and its instant starting.

D. PLANT CONTROL

Primary control of the entire plant is consolidated at one point: the plant control console which is located on the electrical skid adjacent to the main switchgear. The control console is equipped with a secondary control station, a plant motor control board and is the focal point for the process instrumentation readouts and the reactor control. Plant control during startup is accomplished by two men, one of whom remains at the control console, the second of whom is performing duties at various points throughout the plant. During normal routine operation with the plant at power, control of the entire plant can be accomplished by a single man.

1. Plant Control Console

Isometric of Control Console Cabinet Plus Details - Fig. 211

a. Description

The plant control console houses the instrumentation and controls necessary for the control and operation of the plant. It also provides information about process, reactor, and area parameters so that the operators may keep a check on the condition of the plant at all times.

The control console is a U-shape unit, free standing on the skid base and is equipped with information panels, operating boards, a writing desk and turret sections. The unit is constructed of aluminum angle and aluminum sheet which are assembled by welding and riveting as shown on the referenced drawings. Access is provided to the rear of the right, left and front sections. The right section and the front section are equipped with full length doors which have a continuous hinge and a latch capable of being locked. The left section, since it is adjacent to the remainder of the equipment on the electrical skid and does not provide sufficient room for swinging open cabinet doors, is equipped with full length removable panels for access to the rear. Connections to the console components from the remainder of the equipment on the electrical skid is accomplished by wiring through channels in the skid into the bottom of the cabinet. Connections to off-skid equipment are provided through multipin connectors on the top of the center section of the console to multiconductor cables in an overhead cable tray. The meters, lights, switches, recorders, annunciators and other readout components are mounted on the face of the console arranged for optimum viewing by the operator. Power supplies, amplifiers, relays, terminal boards, alarm units, converters, and other items necessary for proper functioning of the systems are mounted within the console and are arranged for easy access.

b. Console Layout

Developed Layout of Plant Control Console Assembly - Fig. 216

The equipment on the console is laid out to place the readout and control equipment of primary importance directly in front of the operator. Parameters of lesser importance or those in separate groupings are placed at a greater height or at one side of the operator. The console face area is divided into three sections. Section A is at the operator's left as he sits facing the console. On the vertical panel in this section are the monitoring instrumentation and a graphic display of the power generation and distribution network. The meters provided on the face of this panel permit the operator to read voltages and currents from the plant emergency supply; current, voltage and watts from the auxiliary supply; voltages, current, watts, power factor and frequency from the turbine generator supply; voltages, currents and watts from the station supply;and,include two synchronizing meters to permit synchronizing of the turbine generator or the diesel generator with other available sources.

The switches which control the plant breakers are also located on this panel(these are a duplicate set of the switches provided on the switchgear cabinet for the operation of the switchgear there). Secondary starting stations for most of the motors throughout the plant are located below the secondary control station on the control board section. The motor symbols on this panel are grouped in an elementary graphic display to facilitate motor location by the operator. The pushbutton stations which operate these motors are lighted stations for indication of the condition of the motor controller. The light located within the motor symbol is fed, Fig. 218, from a current transformer on the motor windings. This provides a secondary independent method of indication that power is being supplied to the motors.

In the center section of the console (Section B) are located the alarm and scram annunciator, most of the process readouts and all of the nuclear instrumentation readouts. The process parameters which are presented on this panel are shown with their respective process connections in Fig. 199. Arrangement of these readout instruments is such as to provide ones of primary interest a central location on the console with those of decreasing interest being placed further out from the center. Nine (9) individual indicators are provided on this panel to indicate the position of the reactor control rods.

Below the process instrument panel in Section B of the console is the reactor control board. At the left of this board are key switches for switching the control power (AC and DC) to the console equipment, pushbutton stations for operation of the main steam and feedwater isolation valves at the reactor, by-pass switches for the reactor scram functions and operational buttons for the annunciator on the turret section at the top of Section B. Directly in front of the operator are three (3) pistol grip switches and two (2) selector switches for the operation of the rods and the by-pass steam valve around the turbine. Above these switches is a push-button with a mushroom head (provided with a guard ring) for initiating a manual scram of the reactor. At the operator's right on this board is the intercom station with its controls and its plug-in phone. Above the intercom station are ten (10) key type switches which provide for emergency operation of the control rods.

Section C of the console at the operator's right contains the self-checking drawer for nuclear instrumentation, the radiation monitoring stations, controls and indicators for the condenser louver mechanism, a digital clock, and indicators and switches for the plant temperature sensors. A horizontal surface thirteen inches wide and thirty three inches long is provided at the lower part of this section as a writing surface for the operator to facilitate note taking, data logging, etc. A drawer is supplied within this writing desk for plant log books, operating data sheets and other necessary materials.

c. Components

1) Meters

All meters provided for electrical and process indications are 4 1/2 inch square, 250° scale, 1% switchboard type indicating meters. The meter face is a white background with black markings: the scale and the pointer are black. All instruments are shielded from external magnetic fields. Cases are dust tight and moisture resistant and the movement is capable of withstanding shock.

2) Switches

<u>Selector and Control</u> - The selector switches for meter inputs and the control switches for breakers, control rods and a by-pass valve are rotary type switch assemblies designed for switchboard applications. These units are of a compact design and have cam operation for positive opening and closing of contacts.

<u>Pushbutton Type</u> - The switches used for motor control, isolation valve control, and the key switches used for panel power, scram by-pass and emergency rod control functions are of the industrial miniature oil tight type which feature compact design, pressure type terminations and illuminated buttons for the push-button assemblies.

<u>Toggle Switches for Temperature Selection</u> - The selector switches which are used to supply inputs to the temperature monitor from the process or area thermocouples are a panel assembly

of toggle type low resistant switches with a capacity up to 96 switching points.

3) Recorders

Five recorders are provided on the console to indicate and record the levels of plant parameters. These recorders are miniaturized strip chart units and are equipped with two pens. The chart provided is a sixteen day folding chart for convenience in checking and filing. The indicating scale is a horizontal scale with 4 inches of effective length. The second scale is provided on the tear bar. Both scales feature black figures on a white background. Internal,incandescent chart illumination is provided for greater readability.

4) Controllers

The controllers provided for plant and reactor parameters are universal electronic types featuring static components with plug-in assemblies for rapid changeability. The units are plug-in from the front of the chassis and are equipped on the face of the controller with a set point dial, a deviation meter, a manual operating knob, and an automatic to manual transfer switch. The control modes available include proportional plus reset, plus derivative.

5) Rod Position Indicators

Reactor control rod position is indicated by nine individual units located immediately above the reactor operating board. These units are dual pointer type indicators driven from a synchro follower which is actuated by the synchro transmitter geared to the control rod drive shaft. The dials feature dual scale with black markings on a white background with one scale indicating 0 to 40 inches and the second scale indicating from 0 to 4 inches.

6) Temperature Indicators

Two indicators are provided to give information on process temperatures and area temperatures(Fig. 221)at the plant control console. These units are miniaturized, servo-driven, potentiometers with line operated constant voltage sources (no batteries) and a plug-in chassis.

7) Annunciator

The plant annunciator which alerts the operator to abnormal conditions Fig. 219, is located in the center section of the console on the turret portion. The annunciator is assembled of static devices with solid state amplifiers on plug-in cards. The power supply for the annunciator is located within the console and is connected to the annunciation board on the front panel by a cable. The annunciator is equipped with one and one-eight inch by three inch windows, power failure and ground detection devices, a flasher, integral scram horn and pushbuttons. The unit is provided with three pushbuttons for silence, reset and test and with an audible volume control. The annunciation sequence provided is as follows:

Condition	Indication	Horn
Normal	Off	Off
Alarm	Flashing	On
Acknowledge	Steady	Off
Revert to Normal	Flashing	Off
Reset to Normal	Off	Off

8) Alarm Units

The alarm units monitor selected plant parameters and send signals to the annunciator in the event the parameters exceed preset values. The alarm units are assembled of solid state components housed in a rack mounted sheet steel enclosure.

2. Nuclear Instrumentation

Nuclear Instrument Block Diagram - Fig. 224

Nuclear Instrument Cable Diagram - Fig. 225

a. Description

The nuclear instrumentation is provided on the PL-2 plant to sense the neutron flux which emanates from, and is a function of, the neutron population in the reactor core from source levels to full power ranges. The instrumentation provides information at the plant control panel on the level of the neutron flux, the rate of change of the neutron flux and supplies interlocks, controls, and safety functions which are required for proper and safe operation of the plant.

The nuclear instrument system consists of seven neutron sensitive detectors located in instrument wells within the containment vessel and adjacent to the reactor core and a cabinet (NI-CE-01) containing operational modules which are capable of receiving, amplifying, computing, and performing operations with the signals received from the neutron detectors. In addition, several meters are provided for remote readout of the system parameters on the face of the plant control console. The neutron detector units consist of two sensitive

BF_3 chambers to monitor the neutron flux in the source range, two compensated ion chambers to monitor the flux in the intermediate range and three uncompensated ion chambers to monitor the flux in the power range. The three ranges overlap by a minimum of two decades so that adequate coverage is obtained through the entire operating range of neutron flux. The operational modules in the nuclear instrument cabinet are solid state units with transitorized circuits and are mounted on cards to afford the use of plug-in construction for system flexibility and easy maintenance.

Design Data

a.	Neutron Flux Range Monitored	2.5×10^{-1}NV to 2.5×10^{10}NV
b.	Power Required	120 Volts, 60 Cycles, 1 Phase, 640 Watts

b. Components

Source Range - The source range equipment consists of two identical channels of instrumentation including a sensitive BF-3 counter, a preamplifier, a log count rate amplifier, a pulse amplifier and descriminator, a log integrator, an amplifier, a period derivation circuit with a period amplifier, and output control equipment. All items for each channel except for the detector and preamplifier are located in a single drawer assembly in the nuclear equipment cabinet.

The detectors are located in instrument wells outside of the reactor pressure vessel and the lead shielding and within the shield tank. The detectors for the source range are spaced 90° apart and approximately 135° from the core source for good monitoring of the core flux in the source range. Within the well the detector is sandwiched between two plates of insulated material connected with tie rods. The cage serves to insulate the chamber from the sides of the instrument well.

The lead shielding around the reactor pressure vessel reduces the gamma level from the core to a level which is tolerable for the chamber without additional shielding. Since the chamber high voltage is removed during startup at a point in the intermediate range, the chamber need not be removed to a position of lesser neutron flux during operation. An attenuation of neutron level of approximately five decades exists between the core and the monitoring position in the shield tank, the neutron level at full power does not exceed the 10^{10} value for neutrons which is the maximum value tolerable for the chamber.

Design Data, Chambers (NI-PC-01, NI-PC-02)

Neutron Flux Range	$2.2x10^{-2}$ to $2.2x10^{4}$ NV
Maximum Gamma Flux	10^{5} R/Hr.
Maximum Neutron Flux	10^{10} NV
Neutron Sensitivity	45 Counts/Neutron/cm^2
Recommended Operating Voltage	2,000 Volts
Maximum Operating Temperature	300^{o}F
Pulse Aplitude	60 MV
Pulse Rise Time	10^{-7} Sec.

Design Data, Amplification and Readout Equipment

Range	6 Decades, 1 Count/Sec. to $1x10^{6}$ Counts/Sec.
Accuracy	± 5%
Drift	2% per 1000 Hrs. at Fixed Temperatures
Period Output Range	-100 Secs. to Infinity to + 10 Secs.
Control Functions	Low Count Interlock, Rod Withdrawal Stop On Fast Period, Outputs to Comparators between Drawers for Self-Checking System

Intermediate Range Channels - Two identical intermediate range channels are provided to monitor the neutron flux in the range from 2×10^{2} NV to approximately 3×10^{10} Nv. All components except the detector are housed in a drawer assembly which is located in the nuclear instrument cabinet. Since the channels are identical, a typical channel is discussed.

The detectors are located in instrument wells within the shield tank adjacent to the instrument wells containing the source range detectors. The two detectors are located 90^{o} apart and 135^{o} from the core source to provide good information on the neutron flux during start-up. The intermediate range chambers are also provided with an insulating cage to insulate them from the instrument well.

The drawer assembly components are modularized plug-in components for flexibility and ease of maintenance. The channel covers a range of approximately 8 decades which provides for an overlap of two decades on the source range channels and two decades with the power range channels. The equipment provided in the drawer includes the high voltage and compensating power supplies for the chamber, the log N amplifier, the differentiator and period amplifier and the bi-stable trip. Test and calibrate outputs to the components in the chambers are provided from auxiliary modules. Outputs from the log N amplifier and the period amplifier are provided to meters on the face of the drawer for indicating the log neutron level and the reactor period. Remote outputs are also provided to a log N indicator and a period indicator on the face of the control console for the operators use. The bi-stable trips operating from the period amplifier output supply inputs to the scram mixer driver and will initiate reactor scrams in the event of a short reactor period. A bi-stable trip output is also provided from one of the channels to remove the high voltage from the source range channels.

<u>Design Data, Chambers (NI-CIC-01, NI-CIC-02)</u>

Type	Compensate Ion Chamber
Range	2.5×10^2 to 2.5×10^{10} Neutrons/cm^2/sec.
Operating Voltage	300 to 800 Volts
Compensating Voltage	-10 to -80 Volts
Thermal Neutron Sensitivity	4×10^{-14} Amperes/NV
Temperature, Maximum	300°F

<u>Design Data, Readout Equipment</u>

Range	8 Decades
Accuracy (Log-In)	± .25 Decades
Accuracy (Period)	± 5% of Full Scale
Control Functions	Bi-Stable Outputs from Period Circuit to initiate reactor scram, Bi-Stable Output to Source Range to Cut Out High Voltage from Chambers

Power Range Equipment - Three identical power range channels are provided to monitor the neutron flux in the operating range. These chambers, neutron sensitive detectors, are uncompensated ion chambers which are located in the instrument wells spaced approximately 120° around the periphery of the reactor vessel within the shield tank. Spacing the detectors around the reactor vessel provides for better monitoring in that it minimizes the effect of flux tilts and rod shadowing. The detectors are mounted in insulated cages within the well as were the detectors for the intermediate and source range channels.

All of the equipment for a given channel except the detector is located in a drawer assembly which is mounted in a nuclear instrument cabinet. The components within the drawer are modularized pull-in units to provide flexibility and ease of maintenance. The readout system consists of linear amplifiers with outputs to percent rated power on meters on the face of the drawer and outputs a recorder on the face of the console. Output signals are also supplied to the comparison units to provide a self-checking feature and to the three bi-stable trips which provide scram functions in the event that a high percent power level signal should exist. A control function is also supplied from a bi-stable trip to cut out the intermediate range period scram when the reactor is operating in the power range.

Design Data, Chambers (NI-UIC-01, NI-UIC-02, NI-UIC-03)

Neutron Detector Type	Ion Chamber, Uncompensated
Neutron Flux Range	2.5×10^{3} to 2.5×10^{10} Neutrons/cc^2/ secs.
Thermal Neutron Sensitivity	4.4×10^{-14} Amperes per NV
Operating Voltage	200 to 1000 Volts
Temperature	300°F

Design Data, Readout Equipment

Range	1.5 to 150%
Accuracy	± 1% Full Scale Current
Control Functions	% Power Outputs to Local Meters and a Remote Recorder, Outputs to Comparators in the Self-Testing System, Outputs to 3 Bi-Stable Trips for Scram Functions, Period By-Pass in the Intermediate Range

Safety System - The outputs from the bi-stable units used to initiate rod control action are passed through switching components. The outputs from the period trips in the intermediate range are fed directly into a mixer unit which operates the solid state relays providing power to the control rod drive clutch mechanisms. In the power range the bi-stable trips are compared in"and"gates whose output is fed into the mixer. The output of the solid state relay unit (28 Volts DC) is fed through the rod control circuitry to operate the individual clutch mechanisms. Process scram initations and the manual scram switch output are also fed into the mixer to initiate scram action to the rods.

Design Data

(a)	Bi-Stable Trip - Output Signals	10 Volts Untripped 0 Volts Tripped
	Trip Point Adjustment	Continuously Adjustable from -3 to + 10 Volts
	Trip Time	Less than 0.2 micro-seconds
(b)	And Gates	
	Type	Passive Network Units
	Operation	All Inputs Must Be Present to Provide an Output
(c)	Mixer Unit	
	Type	Passive Networks
	No. of Inputs	24
	Function	Inputs of one from any input source are transmitted to the solid state relays
(d)	Solid State Relay	
	Type	Silicon Controlled Rectifiers
	Number	2
	Output Voltage	28 Volts

Output Current	5 Amperes
Action	Input of 1 causes Output to be supplied

(e) <u>Scrams</u> - The following conditions initiate scram action to the control rods.

High Neutron Flux (% power)

High Reactor Period (intermediate range)

High Reactor Steam Pressure

Low Reactor Steam Pressure

High Reactor Water Level

Low Reactor Water Level

Manual (push button on console)

In addition, a rod withdrawal"stop"control function is initiated on a high period signal from the source range.

<u>Self-Testing System</u> - The self-testing system consists of two parts, one using a pulsing technique, the other a comparison technique. The bi-stable units and the switching devices provided in the system are supplied from the self-testing system with test pulses provided by the test pulse generator. The outputs from the components are then compared in the testing system with delayed pulses that were supplied by the pulse generator and,in the event that the pulses do not properly correspond,a signal is sent to the indicting panel located on the C section of the plant control console to indicate the malfunction.

The comparison system receives output from similar channels and if these outputs do not properly correspond, indicates malfunction on the indicating panel. The testing system does not cause an output operation (e.g. a scram) or prevent such an operation due to a normal operational characteristic of the monitoring system. Failure of the testing system or any part of the system does not cause an output function or prevent one if one is desired. The testing system recognizes inoperative components or channels and does not determine drift of components.

System Operation

<u>Source Range</u> - When the console control (AC power) is switched to the "On" position, the nuclear instrumentation will be

energized and prior to reactor startup, the source range channels will indicate a neutron level from the subcritical core. These channels provide a startup interlock such that the reactor control rods cannot be withdrawn unless the control rods are all down and a neutron level reading of greater than 1 count per second is indicated. Since the reactor vessel is at ambient pressure the low pressure scram unit must be by-passed by operation of the corresponding key switch on the reactor control board. When the count rate and the by-pass conditions have been met, the rod withdrawal relay on the control rod drive is energized and control rods may be withdrawn.

As the core neutron flux increases, a period is indicated on the source range period indicator and the log count rate indicator provides indication of the increasing flux. In the event that the reactor period becomes too short, the bi-stable trip units in the source range initiates action of the rod withdrawal relay to prevent further movement of rods in the out direction. As the period increases toward infinity, the rod withdrawal relay is energized permitting the operator to continue his startup. When the count rate moves into the upper 2 decades of the source range, the intermediate range channels pick up the signal and provide a log N indication on the face of the control console and period protection in the form of scram actuation. Selector switches under the log N and period indicators on the face of the console permit the operator to select either of the source or the intermediate channels for presentation.

Intermediate Range - With continued startup the log N indication of reactor flux moves through the intermediate range and is indicated on the face of the console. The reactor period in the intermediate range is also indicated on the console and is supplied through trip units to the scram mixer so that in the event a short period occurs, a reactor scram is initiated. If startup proceeds routinely, a bi-stable unit initiates a switching function to remove the high voltage from the source range chambers and prevent damage to these chambers during power range operation. This by-pass function is indicated on the main annunciator on the face of the console.

Power Range - As the reactor flux moves above 1% of reactor full power, the power range channels pick up the signal and indicate the power level on the flux recorder on the face of the console. The three channels provided in the power range permit a coincidence technique for the overpower reactor scram. This insures that any two of the three channels provided must be indicating a high reactor flux before the reactor is shut down. In this way, spurious scrams in any one channel will not inadvertently scram the reactor and cause plant downtime. Since the components in these channels are monitored for proper operation and any malfunction is annunciated, this coincidence technique insures a high level of reliability and continuity of system operation. Coincidence techniques are not used in the source range or the intermediate range channels since, with power reactor type operation, a minimum time will be spent in these ranges and the use of individual channel scrams provides a greater degree of safety during the startup operation. When the reactor power level exceeds 20% power a bi-stable trip provides a switching operation to by-pass the intermediate range period scram and avoids spurious trips in the power range from the intermediate range period trips.

Operation During Reactor Scram - In the event of a reactor scram from an operating power condition the operation will be the same as previously noted except that the low reactor pressure scram does not have to be by-passed during the startup. During a reactor shutdown the reverse procedures will occur with the intermediate range period protection and the source range high voltage automatically being restored as the neutron flux drops below the preset values.

System Adjustments - Adjustments are provided on the trip points on all the bi-stable units, on the output of the solid state relay, and on the power supplies to the chambers. Switches on the front of each drawer assembly provide for the initiation of test signals through the circuitry contained within the drawer, permitting the operator to observe that the units are functioning properly.

3. Reactor Control System

Rod Drive and Safety System - Fig. 220

Reactor Rod Control Block Diagram - Fig. 226

a. Description

The reactor control system is provided to permit the reactor control rods to be withdrawn or inserted manually or automatically from the plant control console and to automatically insert the rods in the event that an undesirable reactor or plant conditions exist.

The rod control system consists of the manual operating and selector switches and the scram button on the reactor control board, the control relays, the nine reversing starters, the automatic control unit, the rod position indicators, and the supply to the equipment in the rod drive package.

System Design Data

Manually Operated Rods	Individually 1 to 8 or banked 1 thru 8
Automatically Controlled Rods	1 which also has a manual control for individual manual operation.

Position Indication	Individual
Indication Accuracy	± .1 inches

b. Components

<u>Control Panel Equipment</u> - The switches, controller and position indicators in the rod control system have been described in the section on the control console.

<u>Starters (RC-MS-01 thru 09)</u> - The nine starters provided for operation of the control rod motors are identical units and are mounted within the reactor control console in the area under the secondary control station.

<u>Design Data</u>

Type	Magnetic Reversing
Arrangement	Horizontal
Interlock	Mechanical
No. of Poles	3
NEMA Size	1
Input Voltage	208 Volts, 60 Cycle, 3 Phase
Thermal Overload Rating	1 Ampere

c. System Operation

<u>Normal Operation</u> - With the plant shut down the rods are all down and the down limit lights (green lights directly above the individual position indicators) on all rods are indicating the rods down condition. If a reading greater than 1 count per second exists on the source range meter, the rod withdrawal relay is energized which permits the control rods to be withdrawn. The selector switch on the reactor control board enables the operator to select any one of the manually controlled eight rods for withdrawal. Actuation of the pistol-grip switch operating the manual rod on the reactor control board actuates the starter corresponding to that particular rod which in turn supplies drive power to the motor in the control rod drive package and causes the rod to withdraw. A high period signal occurring in the source range would cause the rod withdrawal relay to drop out, preventing further withdrawal of any of the rods. Control rods would be withdrawn to an approximate bank position in turn by individually selecting and withdrawing until the desired position is reached. Adjustment of the entire bank of rods is permitted by a position on the selector switch which

permits all rods except the center one to be actuated simultaneously by the manual rod drive switch.

The center rod in the reactor core is operated individually through a selector switch which permits a manual mode or an automatic mode to be selected. Selection of the manual control mode permits the rod to be operated from the pistol-grip drive switch on the reactor control board. Selection of the automatic mode permits the rod to be operated from the controller which senses steam pressure and adjusts the control rod in response to variations in reactor pressure. Lights are provided above the motor selector switch to indicate whether the manual or the automatic mode has been selected.

A synchro transmitter in the control rod drive package feeds back a signal proportional to rod position which is indicated by the corresponding position indicators on the face of the console.

Emergency Operation - In the event a high period exists in the source range, the rod withdrawal relay is de-energized by the nuclear instrumentation which prevents further rod withdrawal until the period drops to a safe value. In the event that a high period in the intermediate range or a high power condition exists in the power range, the down drive relay is energized which causes the starters to be picked up and the rods to be driven in a down direction. The control rods themselves will previously have been inserted under spring and gravity action into the core at the time the clutch power was removed by the clutch power relay. Driving the control rod units in the down direction will pick up any of the control rod blades which may have stuck during the scram action and will drive them into the core.

Individual key operated switches are provided on the reactor control board on the console so that in the event the selector switches or the drive switches do not function properly, the operator may individually actuate selected starters to drive the corresponding rods in a desired direction.

4. Steam Pressure Control

Main Steam System Instrumentation - Fig. 116

a. Description

The reactor in the PL-2 plant is designed to operate at a constant reactor pressure of 600 psig. Load changes on the generator, for given settings of the control rods, will act to change the reactor pressure. A system is provided to sense the reactor pressure and to adjust the reactor control rods which adjusts the reactor power and brings the reactor pressure back to the set point.

The system consists of a pressure detector (MS-PT-04), mounted on the main steam line in the reactor complex, which supplies pressure signals to a pressure recorder and a controller mounted on the face of the plant control console. The output of the control unit is fed into the rod control system through the mode selector switch to operate the center control rod whenever the value of pressure exceeds the control band.

Design Data

Range	550 to 650 psig
Control Band	± 25 psig, centered at 600 psig
Dead Band	± 5 psig around 6000 psig
Mode of Control	Proportional plus Reset plus Rate

b. Components

Pressure Transmitter - The pressure transmitter is a force balance type with a solid state amplifier and a DC output.

Design Data

Range	550 to 650 psig
Body Material	Steel
Bellows Capsule	316 Stainless Steel
Accuracy	± 5% of Span

Controller and Recorder - These units have been described in the section in the plant control console.

c. System Operation

When the reactor plant has been pressurized and raised to its operating power level the automatic manual selector switch on the controller may be moved to the automatic position. With the reactor pressure adjusted to 600 ± 5 psi the mode selector switch on the reactor control system may be moved to the automatic position. At that time, control of the center rod in the reactor core will be transferred to the pressure control system and the system will accommodate load changes by moving the center rod to maintain the pressure constant.

The turbine by-pass steam valve provides an alternate means of reactor control if the pressure control system has to be deactivated for maintenance. Since the reactor pressure does not change (disregarding long term effects) if the steam flow is maintained constant, the operator adjusts the by-pass valve position , if load changes occur. This compensates for the change in steam flow to the turbine and maintains the steam flow constant.

5. Reactor Water Level Control

Main Steam System Process Instrumentation - Fig. 116

a. Description

The amount of water in the reactor vessel under operating conditions is subject to change because of differences in steam flow (output) and feedwater flow (input). A control system is provided to sense the amount of water in the reactor vessel, indicate this value, and adjust the feedwater flow valve to maintain the level of water in the reactor within prescribed limits. Alarms are provided to annunciate conditions of unfavorable water levels and scram action is provided to shut down the reactor if the levels exceed the alarm limits.

The system consists of three water level sensors mounted on the reactor head, and three identical channels of read out and control equipment. Each channel consists of a meter, a high and low alarm unit, a high and low scram unit and a controller. The high and low scram outputs are fed to the nuclear instrument system and are incorporated in the scram circuit. Outputs from the controllers are supplied through a selector switch to the feedwater regulating valve. All system components except the sensors are located in the plant control console.

System Design Data

Range of Measurement	0-150 inches (from the bottom of the active core to a point just below the reactor vessel flange)
Control Point	58-1/2 inches above the top of the active core
Control Band	± 6" around control point
Alarm Points	± 9" around control point
Scram Points	± 12" around control point

b. Components

Sensors (MS-LS-01, MS-LS-02, MS-LS-03) - The three water level sensors are displacement-float units, flange- mounted on the reactor vessel head. A buoyant tube extends downward from the head assembly into a still well attached to the vessel wall. The force of the water on the submerged portion of the buoyant tube is transmitted through the hanger rod and a crank arm to a torque rod. The torque rod moves slightly under the action of increasing or decreasing forces and adjusts the spacing on a pair of capacitor plates. An amplifier senses the changes in capacitance and transmits a current signal proportional to this capacitance to the readout system. The signals from two of the channels are presented on a dual pen recorder on the face of the console.

Design Data

Pressure Design	600 psig
Material	316 Stainless Steel
Mounting	Raised Face Flange
Measurement Span	0 to 150"
Sensitivity	0.02% of Span
Linearity	1% of Span

Meters (MS-IM-04, MS-IM-05, MS-IM-08) - The signals from the sensors are indicated on meters located inside the console.

Design Data

Type	Long Scale Switchboard
Size	Approximately 4 1/2" square
Scale Rotation	250°F
Accuracy	± 1%

Alarm Units (MS-AU-05, MS-Au-06, MS-Au-08, MS-Au-09, MS-AU-11, MS-AU-12) - The signal from each channel is fed through two identical alarm units. The outputs from one unit are fed to the annunciator for high and low water level alarms. The outputs from the second unit are fed to the annunciator and the nuclear instrumentation for high and low water level scrams. The alarm units use solid state amplifiers and regulators. All components are mounted in a sheet metal enclosure suitable for rack mounting. Connections and adjustments are made at the front of the unit.

Design Data

Case	Steel, Rack Mounting
Construction	General Purpose, NEMA I
Amplifiers	Multi-stage, Transistorized
Contact Arrangement	SPDT
Set Point Accuracy	± 2% of Span
Repeatability	± 0.1% of Span

Controllers (MS-C-02, MS-C-03, MS-C-04) - The signal from each channel is fed through a controller which is capable of operating the feedwater control valve. The controllers are process type flow controllers using solid state amplifiers and plug in modules. All components are housed in a sheet steel enclosure equipped for panel mounting. The front of the controller is equipped with a set point dial, a deviation indicator, a valve position indicator, a manual operator and a manual to automatic transfer switch.

Design Data

Case	Steel, Panel Mounting
Construction	General Purpose, NEMA I
Amplifiers	Transistorized
Control Modes	Proportional Plus Reset
Accuracy	±0.5% of Span
Repeatability	± 0.1% of Span

Selector Switch (MS-SW-01) - The controller outputs are fed to a selector switch so that any one of the controllers may be selected to operate the feedwater control valve, F-6. These switches are compact, rotary type, switchboard units with cam operated contacts.

Recorders (MS-R-02) - Two of the three water level signals are presented on the face of the console on a recorder. The recorder is a miniaturized, dual pen, folding 4" strip chart unit, with replaceable ink packs and an internal light. The recording unit is removable from the housing; electrical connections are made through a plug in connector.

Design Data

Case	Steel, Panel Mounting, NEMA I
Pens	2
Chart Drive	Synchronous Electric
Accuracy	$\pm$ 0.5% of Full Scale
Repeatability	0.5% of Full Scale
Internal Illumination	Incandescent

c. System Operation

The sensor-transmitters continuously monitor the water in the reactor vessel and send signals proportional to the water level to their respective readout circuits.

In normal operation, the controller in one channel is selected to operate the feedwater valve, F-6, to adjust the mass of water in the reactor vessel to the set point. Alarms and scrams are in the energized condition.

If the water level exceeds the alarm or scram points, the corresponding alarm units drop out initiating annunciation and control action in the case of the scram units. Coincidence is provided on the scram outputs so that scrams are initiated only on signals from two out of three channels.

6. Condenser Air Temperature Control

Condensate System Process Instrumentation - Fig. 155

a. Description

The air condensers in the condenser building are the means by which the heat is rejected from the turbine exhaust steam to the atmosphere. These units are designed to operate with an input air temperature of $50 \pm 20^{\circ}$ and are provided with a control system to hold the inlet air temperature at the desired value.

The system consists of two of the temperature detectors on each side of each condenser which output through a converter to a temperature controller. The output from the controller unit is fed to the motor starters which actuate the bypass louvers. The louvers operate to adjust the ratio of bypass and exhaust air to cause bypass air to be mixed with the tunnel inlet air. This mixture of hot and cold air passes over the temperature sensors and into the fan inlets.

System Design Data

Air Temperature Range	20 to 120°
Set Point	50°F
Control Span	30 to 70°F
Dead Band	± 3°F about 50°

b. Components

Resistance Bulbs (C-RT-01B, C-RT-01C, C-RT-02B, C-RT-02C, C-RT-03B, C-RT-03C, C-RT-04B, C-RT-04C)
The resistance bulb units used for sensing the average air temperature entering the condensers are 500 ohm units which are housed inside a 27 ft., 1/8 in. diameter copper tube. These tubes are mounted on the sides of the condenser unit as shown in Fig. 111.

Design Data

Measurement Span	0 - 100°F
Resistance, Nominal at 68°F	500 ohms

Converter (C-RI-01 thru 08) - The output from the resistance bulb units is fed into a resistance-to-current converter which provides a current output proportional to the change in resistance of the bulb due to temperature.

Design Data

Type	Static (transistor and magnetic amplifier)
Mounting	Rack
Accuracy	± .5% of Span
Span	30 to 70°

Controllers (C-CL-03 thru 06) - The controllers receive signals proportional to temperature and, if the temperature deviates from the set point, send actuating signals to the louver motor starters. The controllers are process type controllers using solid state amplifiers and plug in modules. All components are housed in a sheet steel enclosure equipped for panel mounting. The front of the controller is equipped with a set point dial, a deviation indicator, a manual operator and a manual to automatic transfer switch.

Design Data

Case	Steel, Panel Mounting, NEMA I
Construction	General Purpose
Amplifiers	Transistorized
Control Modes	Proportional plus Reset
Accuracy	± 0.5% of Span
Repeatability	± 0.1% of Span

Starters (EM-ST-26 thru 29)- The output from the controller is supplied to a motor starter which feeds power which operates the actuator that moves the louvers.

Design Data

Type	Magnetic Reversing Contactor
Number of Poles	3
Input Voltage	440, at 60 Cycles, 3 Phase

c. System Operation

During normal operation of the condenser control system, the incoming air from the tunnel and the recirculated air from the bypass louvers is mixed in the building area adjacent to the side of the condenser and is drawn, by the action of the fans, across the resistance bulb units. These resistance bulbs provide an average temperature of the incoming air and feed this temperature through converters to a temperature controller. The control unit supplies signals to the motor controllers which supply power to the actuator operating the louvers. Should the input temperature signal differ from the set point of 50 degrees by more than 3 degrees the motor controllers are actuated and the actuators are moved to cause more or less bypass air to feed into the input air stream and adjust the temperature back toward the set point.

The manual to automatic transfer switch on the controller permits the operator to switch from the automatic control and operate the louvers manually with the knob on the controller. Louver position is fed back from the actuator and is indicated on meters above the control units for the operators information. Separate channels are provided for the temperature monitoring. These channels use the same type of resistance bulb sensor and provide independent channels of information with standby inputs for the controller.

This system is a duplicate of the system which was installed and tested on a PL- prototype condenser at the SL-1 plant (NRTS).

E. PLANT RADIATION MONITORING

Radiation Monitoring Block Diagram - Fig. 227

Radiation Monitoring Conduit & Cable - Fig. 228

1. Area Monitoring System

a. Description

The area monitoring system senses ambient radioactivity levels in various areas of the plant and initiates alarms if these levels become too high.

The system consists of 11 identical channels of equipment. A typical channel consists of a detector and pre-amplifier with annunciator and readout meter located on the plant control console. The 11 channels are powered by a single power supply which is fed from the plant emergency bus to insure continuity of operation during all conditions existing in the plant. One sensing unit is located at each of the following points: the electrical skid, adjacent to the turbine, adjacent to the hotwell, at the feedwater strainer, near the waste tanks, near the purification demineralizers, in the condenser area, on the main steam line, on the reactor complex exhaust stack, on the power plant exhaust stack and adjacent to the spent fuel tank.

Monitoring range - 1 to 1000 mr/hr

b. Components

Detectors (RM - DA - 01 thru 11) - The sensing elements are ionization chambers which are housed in watertight cylindrical containers and include a strontium 90 calibration source and an electrometer tube to provide a logarithmic output.

Design Data

Type - ion chamber

Sensitivity - beta gamma

Mounting - bracket mounted

Housing - watertight, vapor tight

Operating voltage - 100 volts

Readout Station (RM - AP - 01 thru 11) - Individual stations are provided from the chamber output to indicate an alarm when the indication exceeds a preset value. The units include remote calibration controls, an alarm reset button, and a source shutter control. Indication of the radiation level being monitored is provided on the front of the station on a 2 1/2" meter with a 3 decade scale.

All stations are supplied with power from a common power supply with built-in regulation.

c. System Operation

During normal system operation the individual channels will indicate the radiation level being monitored in their corresponding area. In the event that the radiation level in any of the areas exceeds the value preset on the meter dial, this condition will be annunciated by an alarm from the alarm unit in the plug-in station and visually by a red light at the station. The alarm annunciation will continue until the condition is manually reset by the operator.

2. Gaseous Effluent Monitoring

a. Description

Gaseous disassociation products produced in the reactor plant are removed from the system through the air ejectors which take the non-condensible gases from the condenser header. These gases are passed through a charcoal bed filter and vented to the atmosphere through the condenser discharge ducts. A radiation monitoring system in provided to monitor the line from the charcoal beds to the exhaust stack, to indicate the level of the radiation, and to alarm if the radiation becomes excessive.

The system consists of a radiation detector mounted adjacent to a gas chamber through which a selected portion of the effluent gases are passed. Valving and a bypass line with a sight flow indicator in the bypass and in the monitoring lines enable the operator to set a flow ratio and monitor a portion of that ratio from which the activity in the total effluent passes can be computed. The signal from the detector is fed to a logarithmic rate meter which in turn supplies a recorder and an alarm. Power is supplied to the effluent monitoring system from the emergency power supply to insure continuity of service under all plant conditions.

System Design Data

Monitoring range 10 - 10^6 CPM

Alarm set point - 10^3 CPM

b. Components

Detector (RM - DA - 12)

Type - gamma scintillation

Operating voltage - 750 to 1800 volts

Amplifier - photo multiplier (with mu-metal shield)

Housing - cylinder, watertight at connector and crystal ends

Gas Monitoring Chamber (RM - GC - 01)

Material - stainless steel

Dimensions - 6 and 5/8 inches diam. x 7" long

Inlet and outlet connections - 1" OD

Features - removal lid for decontamination

Readout Assembly RM - AP - 12 - Continuous indication of the radioactivity monitored is provided by a log rate meter which is mounted in the plant control console. Outputs from this rate meter circuit are fed to a strip-chart recorder on the face of the control console and to an alarm circuit mounted inside the console.

Design Data

Type - transistorized log ratemeter

Mounting - rack

Meter - 4 1/2" square

Scale - 5 decades (10 to 10^6 CPM)

Features - front panel controls, recorder output, alarm output.

c. System Operation

The effluent monitoring system detects, indicates, and records the level of radioactivity fed through the gas chamber and, in the event that the monitored level is excessive, initiates an alarm to alert the operator to this condition.

3. Air Particulate Monitoring (RM - DU - 01)

a. Description

The air particulate monitoring system measures the airborne radioactivity at a desired point in the Power Plant Building. The unit consists of a detector and amplifier unit which outputs to an indicating meter. The detector monitors the activity build-up on a filter assembly which includes a pumping system, a filter paper advance mechanism and suitable shielding to eliminate background and previously monitored activity. An alarm system and a recorder are provided on the unit to give a continuous record and an annunciation in the event of unfavorable conditions. The entire assembly is mounted on a mobile cart so that it may be positioned at any desired location within the power plant building.

System Design Data

Detector type - GM

System sensitivity (Beta Gamma) - 2.5×10^{-9} uc/ml per hour.

Indication single scale 3 cycle logarithmic 50 to 50,000 CPM

Recorder chart size - 4" width

Annunciation - 2 levels

Alert - Bell rings for 10 seconds, amber light flashes

Alarm - Bell rings continuously, red light flashes

b. System Operation

The system is moved to a designated spot in the plant building and put in operation. The compressor unit causes air to be drawn through the filterpaper adjacent to the detector and particulate matter in the air builds up on the paper. As the paper moves underneath the detector, radioactive particles are detected and counted. The activity is indicated on a recorder. In the event that the activity exceeds the alarm value, corresponding annunciation occurs.

F. PLANT COMMUNICATIONS

1. Description

An intercom system is provided within the plant to enable plant personnel at various locations to communicate with one another and to permit a public address type of operation for announcements from the console or warnings from the fire protection and radiation monitoring system.

The communication system consists of a master station at the plant control console with a power supply (fed from the plant emergency bus to insure continuity of operation under all plant conditions) and remote stations located in the reactor complex, the condenser building, the service building and the personnel building. The remote stations are equipped so that any station can talk to any other station or group of stations. The speaker at the console area is a cone type unit inset within the console while the speakers at the remote stations are horn type units designed for greater volume and audibility above the background noise level. The speakers serve a dual function and are used as microphone inputs in the event of transmission from that station.

Auxiliary inputs are provided through hand sets with plug in cord sets to the various stations. The hand sets are equipped with sufficient cord so that personnel can move around to inspect various equipments while they are talking. The system is adjusted so that radiation level warnings and fire signals are transmitted by tone generators thru the plant intercom systems regardless of the operation of various stations or of the volume control settings at these stations.

G. SHIELD DESIGN

1. Introduction

a. Objectives

The PL shield design has been developed to ensure that the exposure of the operating crew does not exceed 1.25 rem per quarter for all routine operation and maintenance including refueling; that there is safe access to the reactor complex and tunnel for maintenance and refueling; and, that activation of components does not interfere with operation and maintenance. These objectives have been met.

b. Methods

Determination of fast neutron dose rates and thermal neutron fluxes was accomplished by means of SPIC-1, an IBM-704 computer code[1]. Uncollided gamma fluxes were computed using the SPAN-2 code[2]. Applicable buildup factors were calculated by use of polynomial expressions found in APEX-510[3].

Variation in fission-product gamma energy after shutdown was determined from NDA curves[4] and equations developed by Obenshain and Foderaro[5].

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(1) WAPD-TM-196, "SPIC-1, An IBM-704 Code to Calculate the Neutron Distribution Outside a Right-Circular Cylindrical Source", P. Gillis, Nov. 1959.

(2) WAPD-TM-176, "SPAN-2, An IBM-704 Code to Calculate Uncollided Flux Outside a Circular Cylinder", P. A. Gillis, T. J. Lawton, K. W. Brand, August 1959.

(3) APEX-510, "Polynomial Approximation of Gamma Ray Buildup Factors for a Point Isotopic Source", M. A. Capo, November 1958.

(4) NDA-27-39, "Decay of Fission Product Gammas", F. H. Clark, December 30, 1954.

(5) WAPD-P-652, "Energy from Fission Product Decay", F. E. Obenshain and A. Foderaro, May 1955.

Air scattering of radiation was estimated from work done by Spielberg[1], with the additional help of equations found in the Reactor Shielding Design Manual[2].

The detailed aspects of the shielding design shall be presented in Volume VI.

2. Criteria

To reach the objectives mentioned, certain criteria have been established. The effectiveness of the shielding is to be measured by the following:

The radiation at living quarters must be undetectable.

At one mile from the reactor, the neutron flux must be equal to or less than one neutron per square meter per minute.

The power plant controlled perimeter is to be at the isodose line of 0.06 mr per hour, which is less than specified in 10CFR-20[3].

A man working an 84 hour week must not accumulate more than 1250 mr in a period of 13 weeks, as required in 10CFR-20.

The temperature rise in the snow base, because of heat generation, is a minimum in order to maintain foundation stability.

The spent fuel cask and the demineralizer unit must meet ICC shipping regulations. These state that the maximum dose rate on any surface of the component, during shipment, must not exceed 200 mr per hour and that at a distance of one meter, the dose rate shall be 10 mr per hour, maximum.

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(1) WKNL-89 (Vol. 1), "Shielding Characteristics of Air, Soil, Water, Wood and Other Common Materials. Volume 1. Air Scattering of Gamma Rays and Neutrons", D. Spielberg, February 28, 1957.

(2) TID-7004 "Reactor Shielding Design Manual, T. Rockwell (Editor), 1956.

(3) Atomic Energy Commission regulation 10CFR Part 20, "Standards for Protection Against Radiation", effective January 1, 1961.

3. Primary Shield Design

a. Operation at Power

Radiation Sources - The principal sources of radiation considered in the shield calculations are:

Thermal neutrons.

Fission fast neutrons.

Fission gammas.

Fission product gammas.

The principal secondary sources considered are:

Neutron-capture gammas.

Activation gammas.

Plant Dose Rates and Power Plant Control Perimeter - The radiation present in the plant area can be depicted by means of constant dose rate (isodose) lines. A value of 0.06 mr per hour is used to determine the outer perimeter of supervised movement. The Atomic Energy Commission's regulation 10 CFR Part 20 states that no licensee shall create in any unrestricted area from radioactive material and other sources of radiation in his possession radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of 100 millirems in any seven consecutive days. This is an allowable rate of 0.6 mr per hour. The selected perimeter is at a value that is one-tenth of allowable. Curve 1 shows the isodose perimeter on the surface of the snow above the power plant. The region encompasses mainly the reactor complex tunnel and its access tunnel. Outside of this region, no control of personnel is required. The power plant outline is depicted in dashed lines.

Curve No. 2, shows the 500, 20, 1 and 0.06 mr per hour isodose lines for a cross-section taken at the base of the power plant snow tunnel. The lines in the reactor complex tunnel show the effect of the spent fuel tank which acts as a shadow shield. Isodose lines in the access tunnel are estimates of scattering produced by the air. It is pertinent to note that the reactor and the spent fuel tank are both below the level of the access tunnel and no direct radiation reaches it except through the underlying snow. In addition, the reactor is offset from the tunnel as shown in Curve No. 2.

Sufficient information is not available at the moment to indicate with comparative firmness the location of the 1 and .06 isodose lines outside of the reactor complex area. Effects of piping and plant components are not included in the figure.

Neutron Flux - Thermal and fast neutron fluxes inside the containment vessel are depicted graphically in Curves 3 and 4. The cross-section shown is at a height corresponding to the maximum power peak in the reactor. Variation of the fluxes was determined for an operating power level of 8.5 MW. A criterion for the fast neutron flux is that the value at the pressure vessel wall when integrated over the lifetime of the unit must not exceed 10^{21} neutrons per square centimeter. For 20 full power years the maximum integrated flux is 1.4×10^{20} NVT.

Foundation Heating - Curve sheet 5, represents the model used to determine snow foundation temperature in the reactor complex. A snow tunnel temperature of 0°F is used together with a heat sink temperature of -15°F. The heat generation is of variable magnitude, depending on the location with respect to the radiation source. Curve sheet 6 shows the resulting temperature profile obtained by machine computation for a maximum heat generation of 1.64 BTU per hour per cubic foot. A maximum of about 5 degrees above tunnel temperature is shown.

Since the computation, the heat generation in the snow has been lowered to 0.017 BTU per hour per cubic foot because of the increase of lead shielding about the lower section of the reactor vessel and also because the lead has been relocated to a more advantageous position. The heat generation is now such that it does not significantly affect foundation stability.

b. Shutdown

Radiation Sources - After shutdown the production of fission neutrons and gammas ceases. Neutron capture gammas are no longer present. The main sources of shutdown radiation are:

a. Fission product decay gammas
b. Core activation product gammas

Of the two, the fission product gammas are preponderant until months after shutdown.

Containment Vessel - The criterion for shutdown is that the surface of the containment vessel shall be not more than 100 MR per hour at 120 minutes after shutdown. Computations show that the maximum dose rate on the containment vessel is experienced directly below the reactor. From this point the dose rate decreases as one proceeds up to the operating floor. Table II lists the maximum dose rate at various times after shutdown:

TABLE II

MAXIMUM DOSE RATES AT SURFACE OF CONTAINMENT VESSEL

Time After Shutdown, hrs.	2	6	12	24
Maximum Dose Rate, MR/hr.	45	29	23	20

4. Refueling and Spent Fuel Handling

a. Refueling Operation

Two hours after shutdown, personnel will have access to the operating floor and preparations for refueling may begin. The containment vessel head will be removed, the control rods dropped and the pressure vessel head taken off. At this time, the water level in the pressure vessel will have been raised to 10 feet. The dose rate at the 10 foot water level with the head removed 2 hours after shutdown is calculated to be about 6 MR per hour. When the 6 inch refueling steel plate is in position, the dose rate is much less than 1 MR per hour.

When refueling operations begin, one fuel assembly at a time (1/24 of the active core) is raised and placed in the transfer cask. Assuming that a maximum-power assembly is transferred 12 hours after shutdown, the resulting dose rate at the refueling position is shown in Curve 7. As the assembly is raised, the dose rate increases to 40 MR per hour. This is achieved when the fuel is about 2 feet under water. Movement beyond this point causes the dose rate to decrease because the transfer cask begins to act as a shadow shield. A low point of about 28 MR per hour is reached as the fuel continues to enter the transfer cask. When the fuel is fully contained and in position, the dose rate on the surface of the cask is 66 MR per hour. Three feet away it is 20 MR per hour.

Taking one half hour as the time to position the fuel, the integrated dose is 10 MR. This represents a maximum since it is expected that the low-power density assemblies will be handled first and allow more time for the high-power density assemblies to cool off.

b. Spent Fuel Tank

The spent fuel is transferred to a tank where it is placed in lead lined containers with internal provisions for maintaining subcriticality under all environmental conditions. Dose rates to be expected on the operating floor with a full core in place are shown in Curve 8. With 10 feet of water over the core, the dose rate on the operating floor twenty-four hours after shutdown, is about 3 MR per hour.

c. Transfer Cask

Ten inches of lead plus one-half inch of steel comprise the shielding of the transfer cask. Curve sheet 9 depicts the dose rates encountered on the surface of the cask and also within one meter of it with a spent fuel assembly in position. The values depend upon the time after shutdown. Representative dose rates are tabulated in Table III for a fuel assembly that has been operated at 8.5 MW continuously for 2 years before removal:

TABLE III

FUEL ASSEMBLY DOSE RATES AFTER 2 YEARS AT 8.5 MW CONTINUOUS OPERATION

Time/Shutdown (hours)	Cask Surface (MR/hr.)	One Meter from Cask (MR/hr.)
6	94	28
8	79	23
12	66	19
24	55	16
48	50	15

During the refueling operation, it is expected that the fuel pulling mechanism will be remotely operated and thus the dose level at the operator's position will not exceed that tabulated for one meter.

d. Shipping Cask

Eight fuel assemblies are accommodated in one shipping cask for shipment to reprocessing plants. The number is equivalent to one-third of the active core. Shielding of the assemblies consists of seven inches of lead and one inch of steel plus the internal containment structure. All of the spent fuel will not have been operated at the same power density and therefore variations in emission will exist. Curve sheet 10 shows representative dose rates met on the surface of the container and at one meter from it for various times after shutdown. It is assumed that the spent fuel has been two years at 8.5 MW before containment.

Table IV tabulates selected values of dose rates at different times after reactor shutdown. ICC shipping regulations specify that the surface dose rate shall not exceed 200 MR per hour and that at one meter, the rate shall be 10 MR per hour, maximum.

TABLE IV

SHIPPING CASK DOSE RATE

Time/Shutdown (days)	Surface of Cask (MR/hr.)	One Meter from Cask (MR/hr.)
10	5906	1644
20	2910	810
30	1580	440
60	344	96
120	75	21
180	51	14
240	40	11

H. QUARTER SCALE MODELS

Quarter scale models of the reactor complex, one condenser skid, and the power plant building were developed to:

(1) Assist in developing equipment and piping arrangements.

(2) Check accessibility and pull space requirements for operation, maintenance and repair of equipment, valves and instrumentation.

(3) Provide a training aid for training plant operators.

Photos 1 through 10 are photographs of the quarter scale models.

Photo 1 shows the Reactor Complex Assembly. The structural steel, spent fuel tank, and reactor and containment vessel.

The Reactor and Containment Vessel are shown in Photo 2. The Containment Vessel has been cut away to show the reactor vessel, control rod drives, and lead shielding. The lower section of the reactor vessel has been cut away to show the thermal shield, core supports, core shroud, and a section of the fuel elements.

Photos 3 through 7 show the Air Cooled Condenser, Purification Skid, Feed and Condensate Skid, Turbine-Generator Skid, and Electrical Skid, respectively.

The interconnecting piping and pipe racks in the power plant building are shown in Photo 8. Photos 9 and 10 show the general arrangement of the equipment in the power plant building.

The quarter scale models were particularly helpful in developing the equipment and piping arrangement on the Purification and Feed and Condensate Skids. They permitted arrangement of the equipment, piping, and associated instrumentation and controls in the most convenient and compact manner possible within the size, weight and accessibility limitations. The models were also of great value in minimizing the number of interconnections between skids and arranging the pipe bank in a simple and compact manner.

I. SHIPPING SUMMARY

The PL-2 plant equipment, foundations, structures and enclosures can be shipped by three C130 aircraft in a total of 37 loads transporting a total of 541 tons within a one month period.

The plant equipment weighs 329 tons and requires 23 C130 aircraft loads. The plant foundations, structures and enclosures weigh 212 tons and require a total of 14 C130 aircraft loads.

The Shipping Summary shown in Section II, the Plant Data Sheet lists the shipping requirements for the PL-2 installed in a snow tunnel, at Byrd Station, Antarctica. The column "was", shows the comparable shipping requirements for the PL-2 as reported in IDO 19021 - ABWR Design Report.

Two additional aircraft loads are required to transport the containment vessel. One additional load is required to transport the equipment required for radioactive gas handling. Two additional loads are required as result of an increase in the shielding. With the increased shielding,access after shutdown is no longer restricted to the operating floor level. This increased access has permitted considerable simplification of the reactor building structure which results in a reduction in shipping requirements of one load when the building is designed using structural steel shapes. The major equipment is now carried directly on the timber foundation mat; the structure is no longer required to support this large weight, and it has been possible to redesign the reactor building using built up aluminum members. The aluminum structure results in a net reduction of two aircraft loads.

In summary; an increase in three aircraft loads is required to transport the PL-2 plant foundations and enclosures as compared with the requirements reported in IDO-19021.

PHOTOS

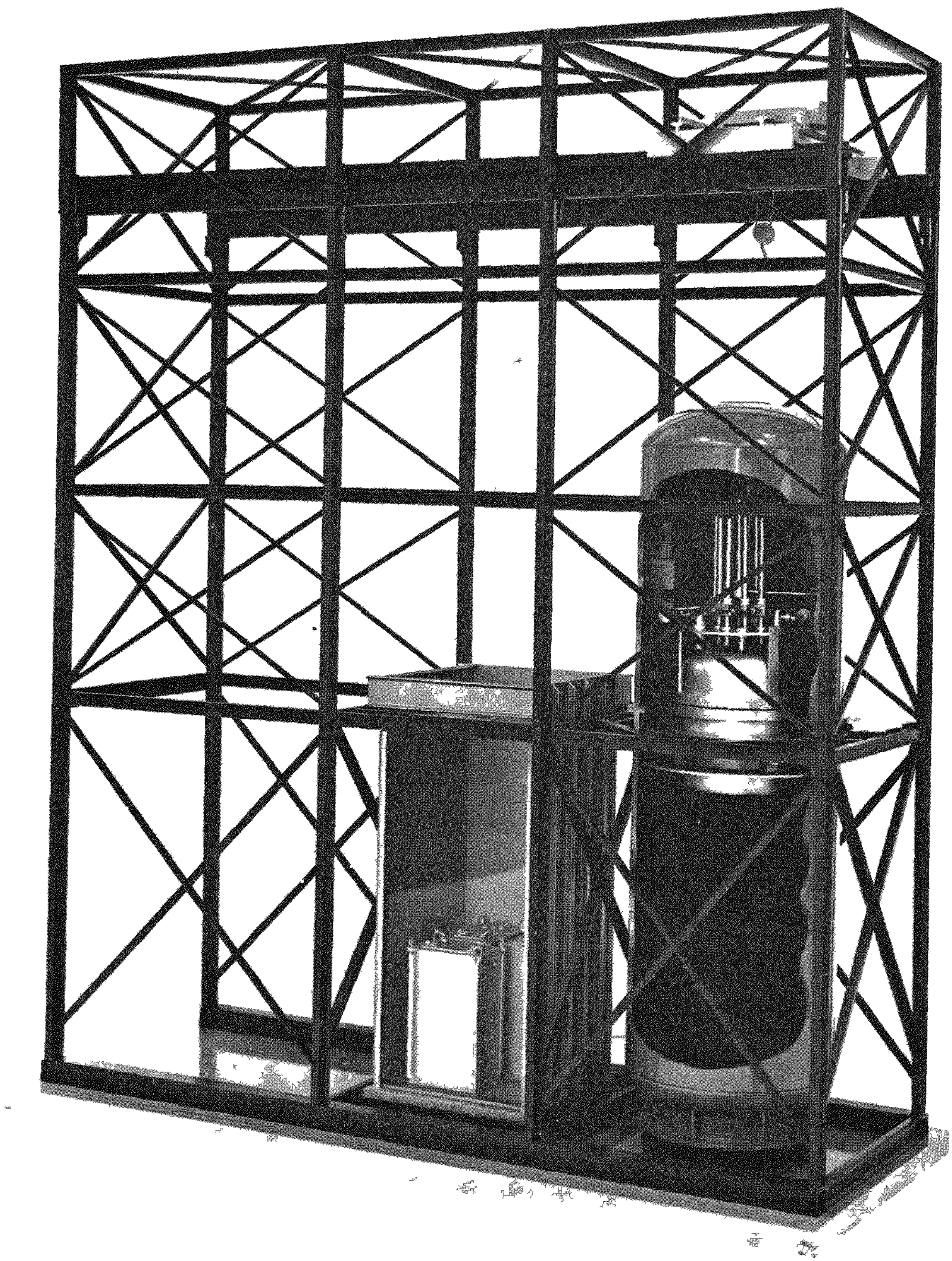


PHOTO 1   REACTOR COMPLEX ASSEMBLY

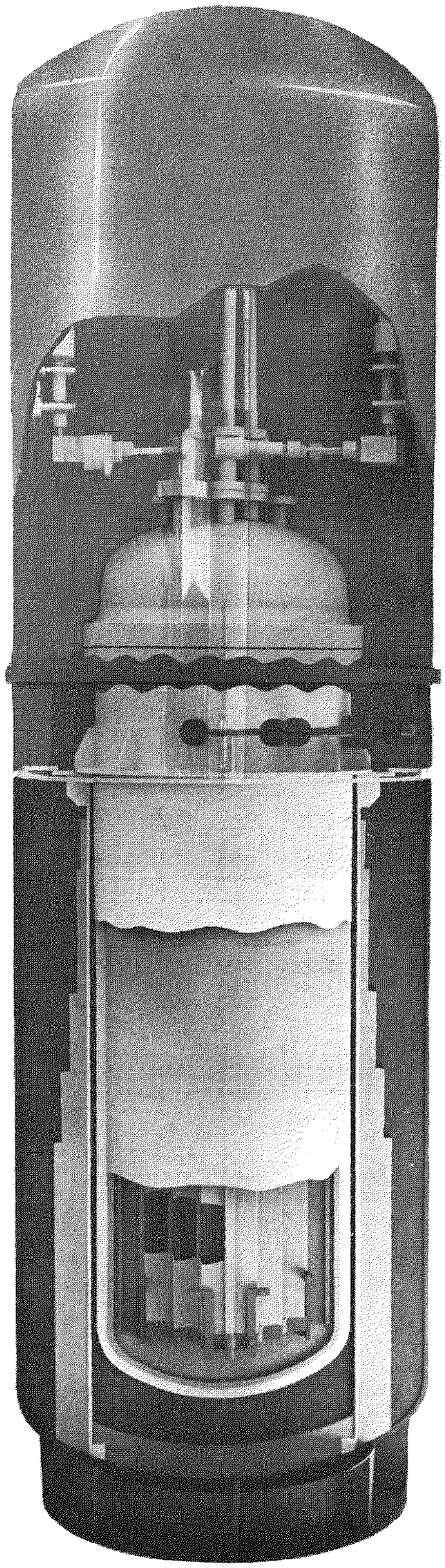


PHOTO 2 REACTOR AND CONTAINMENT VESSEL

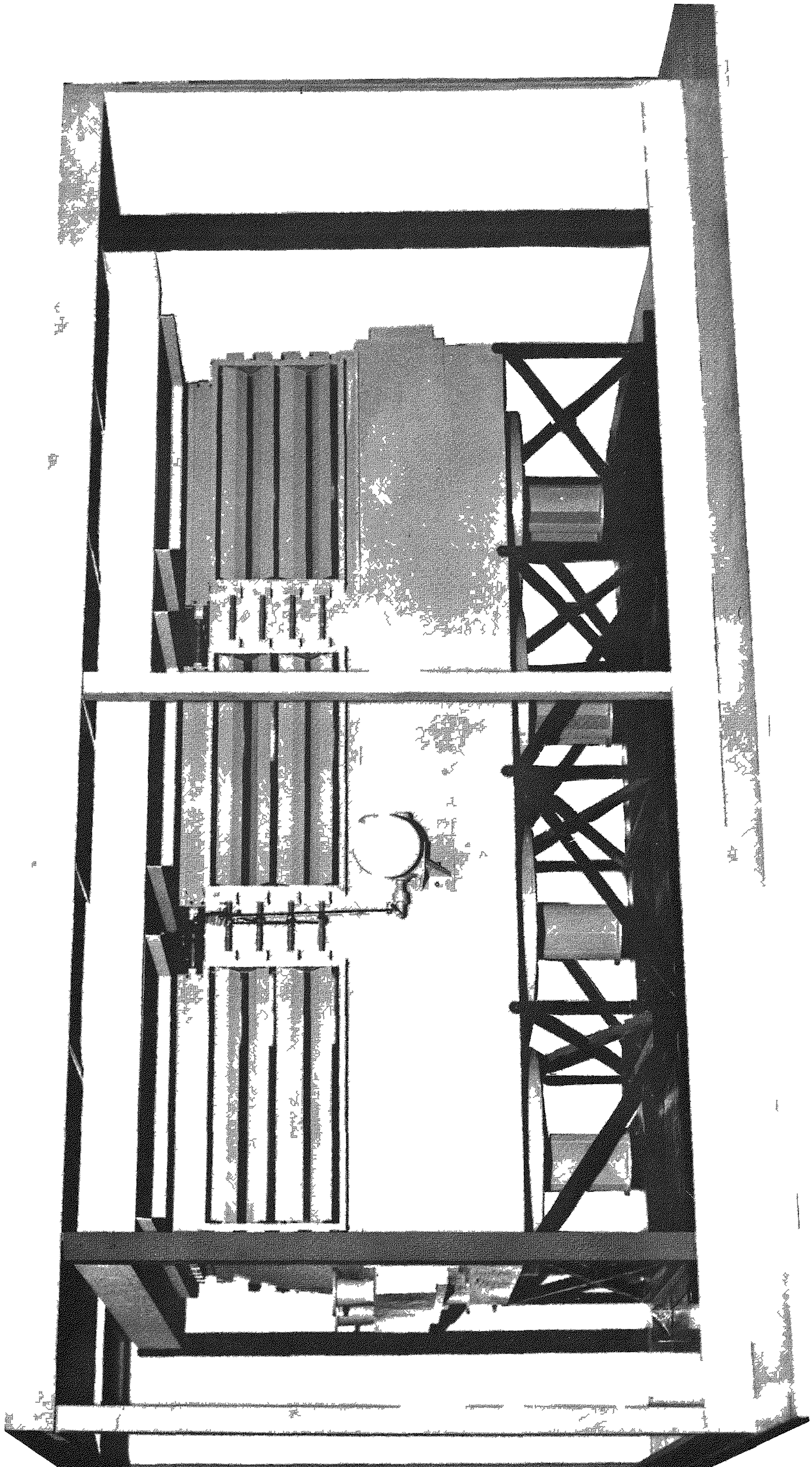


PHOTO 3 AIR COOLED CONDENSER

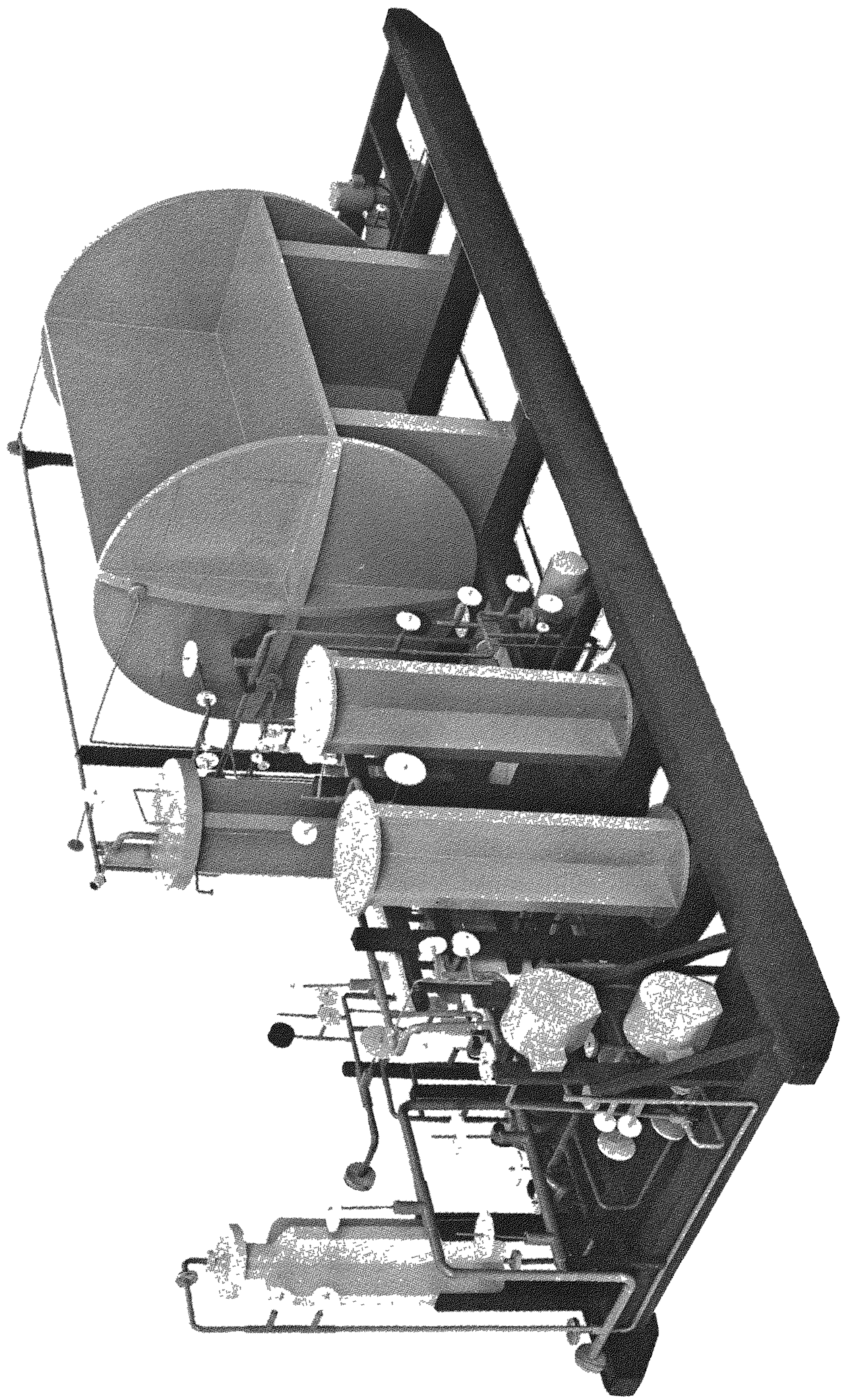


PHOTO 4 PURIFICATION SKID

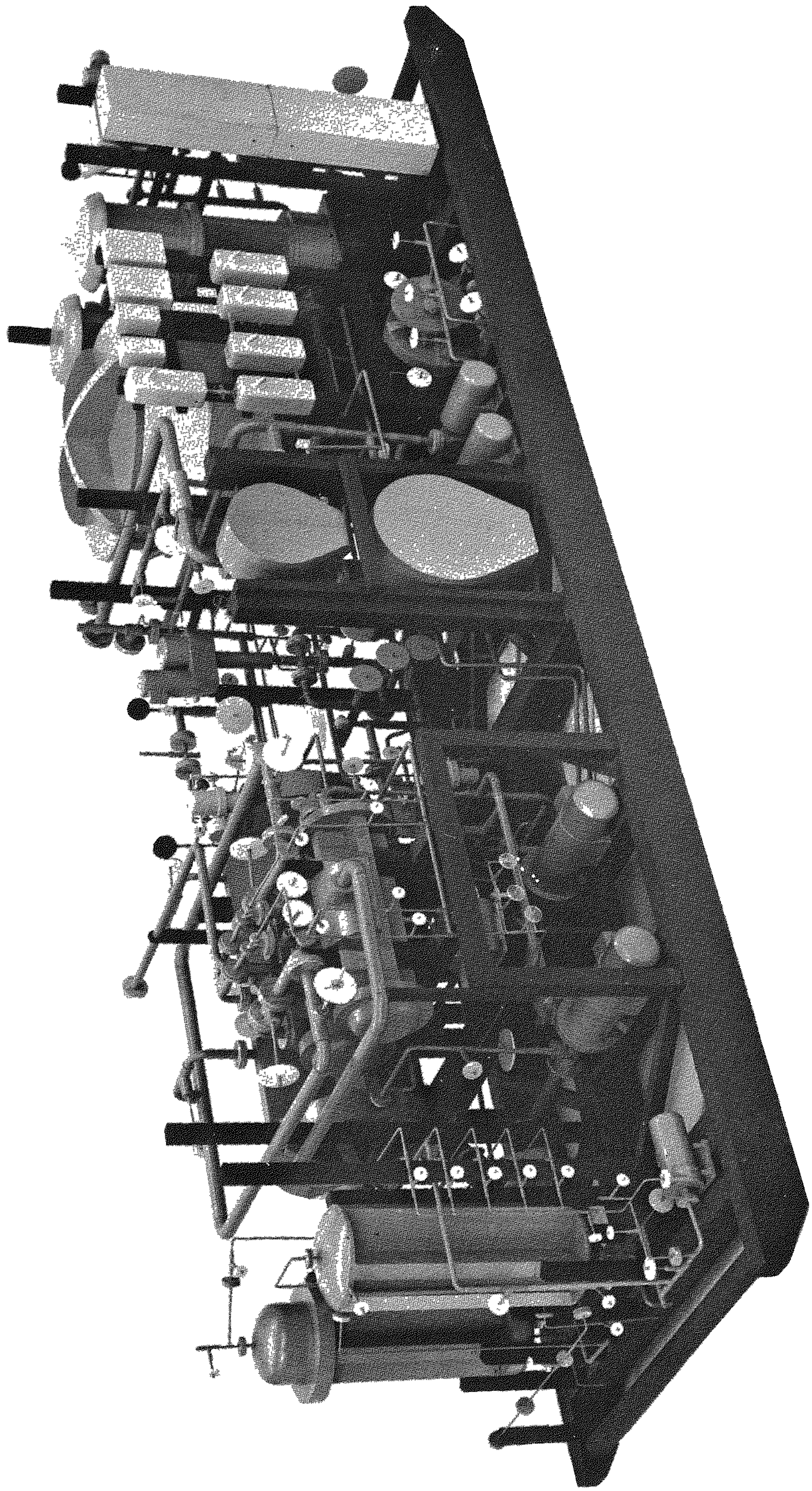


PHOTO 5 FEED AND CONDENSATE SKID

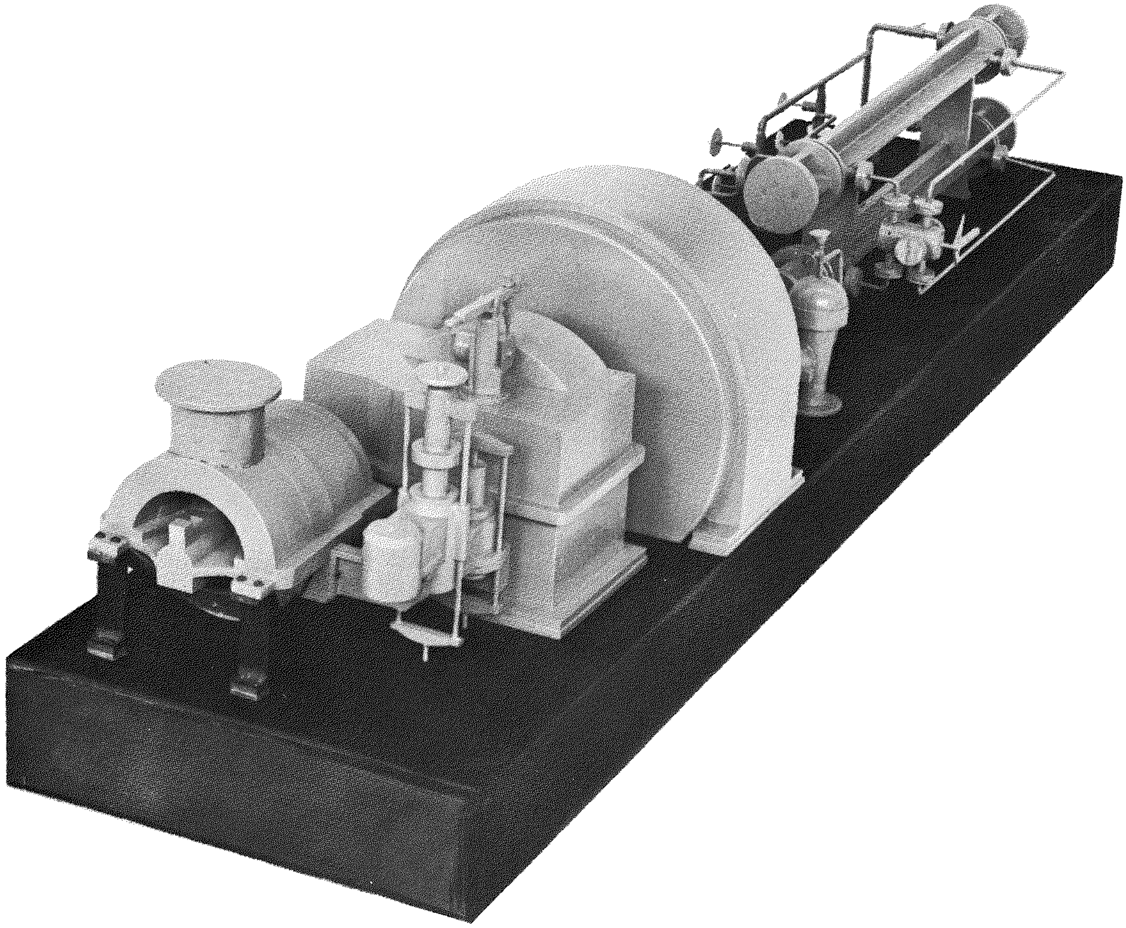


PHOTO 6 TURBINE - GENERATOR SKID

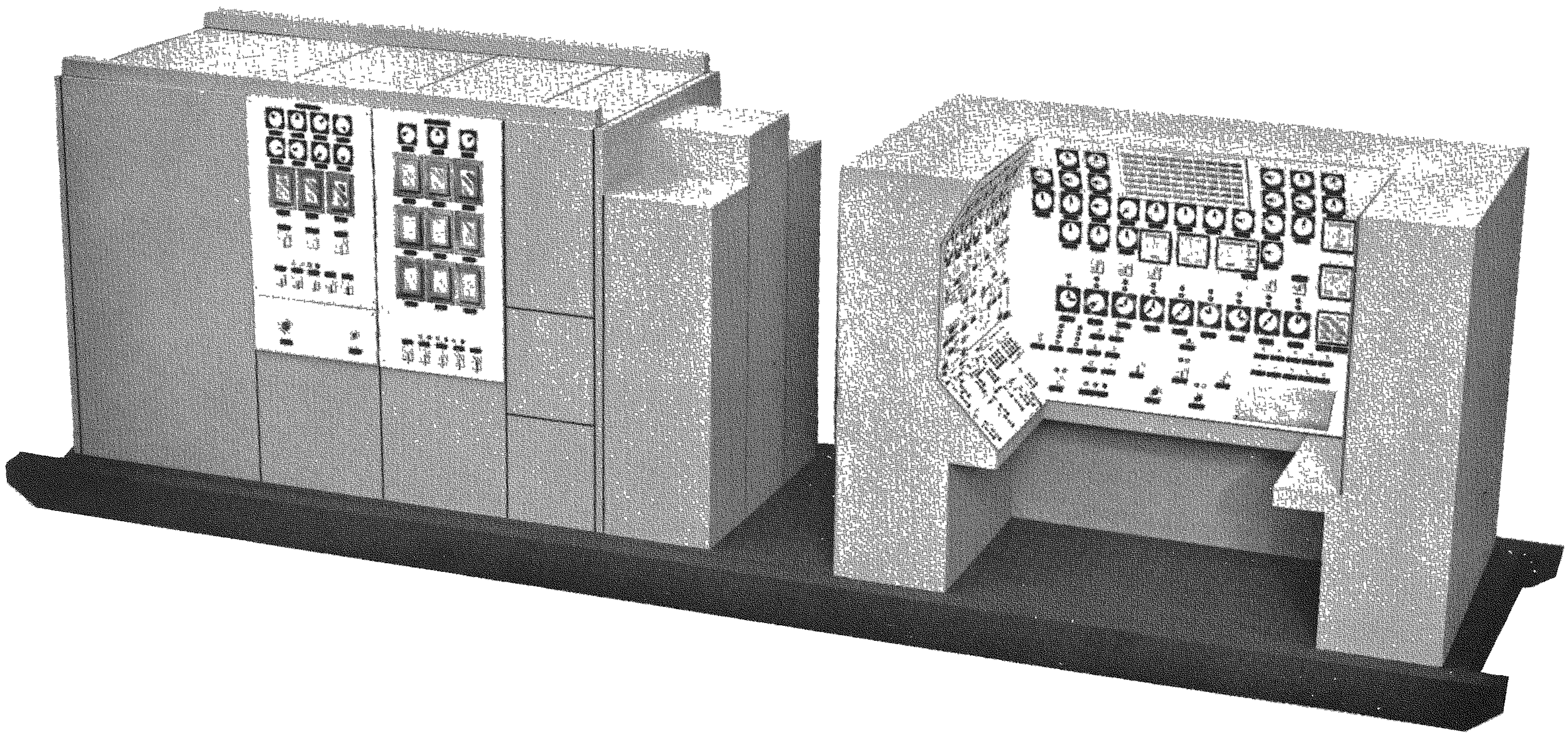


PHOTO 7 ELECTRICAL SKID

PHOTO 8 PIPE BANK — POWER PLANT BUILDING

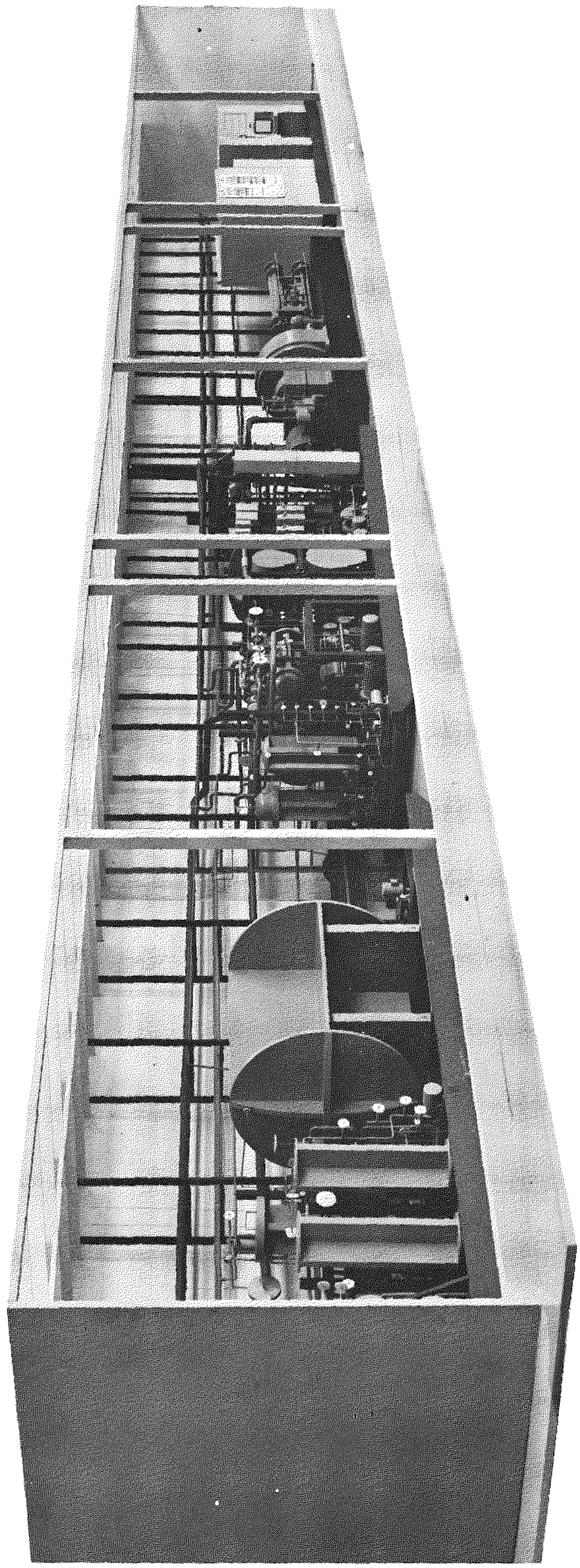


PHOTO 9 POWER PLANT BUILDING ARRANGEMENT

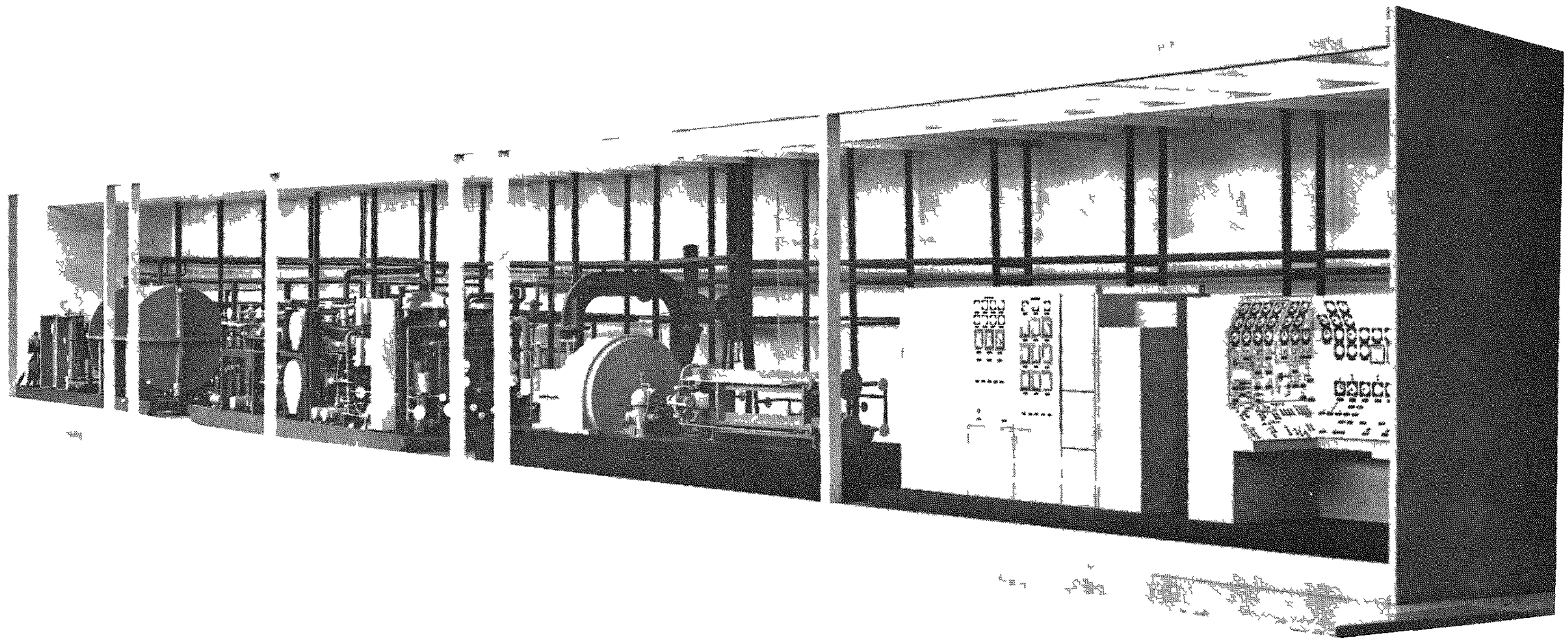
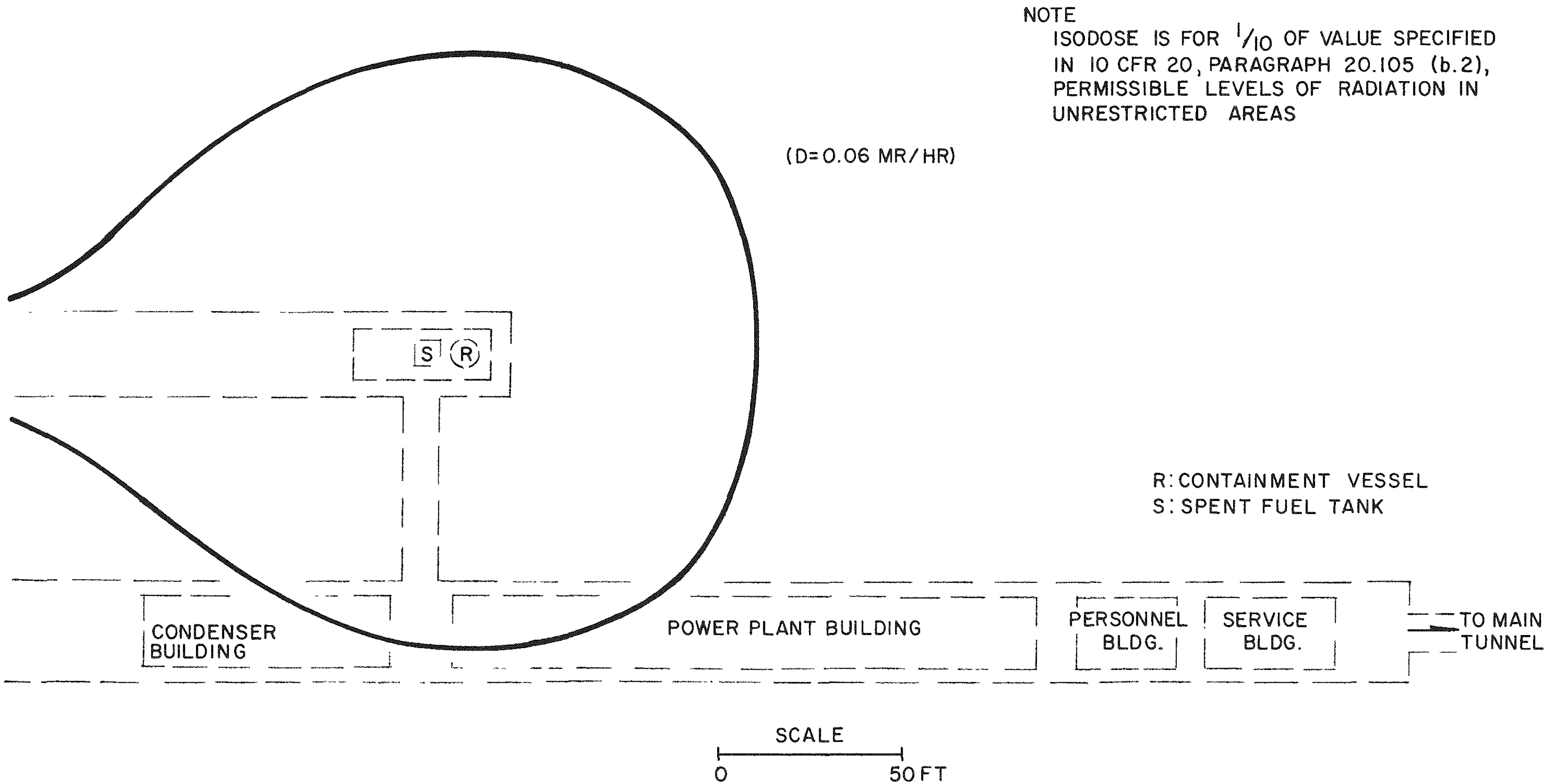


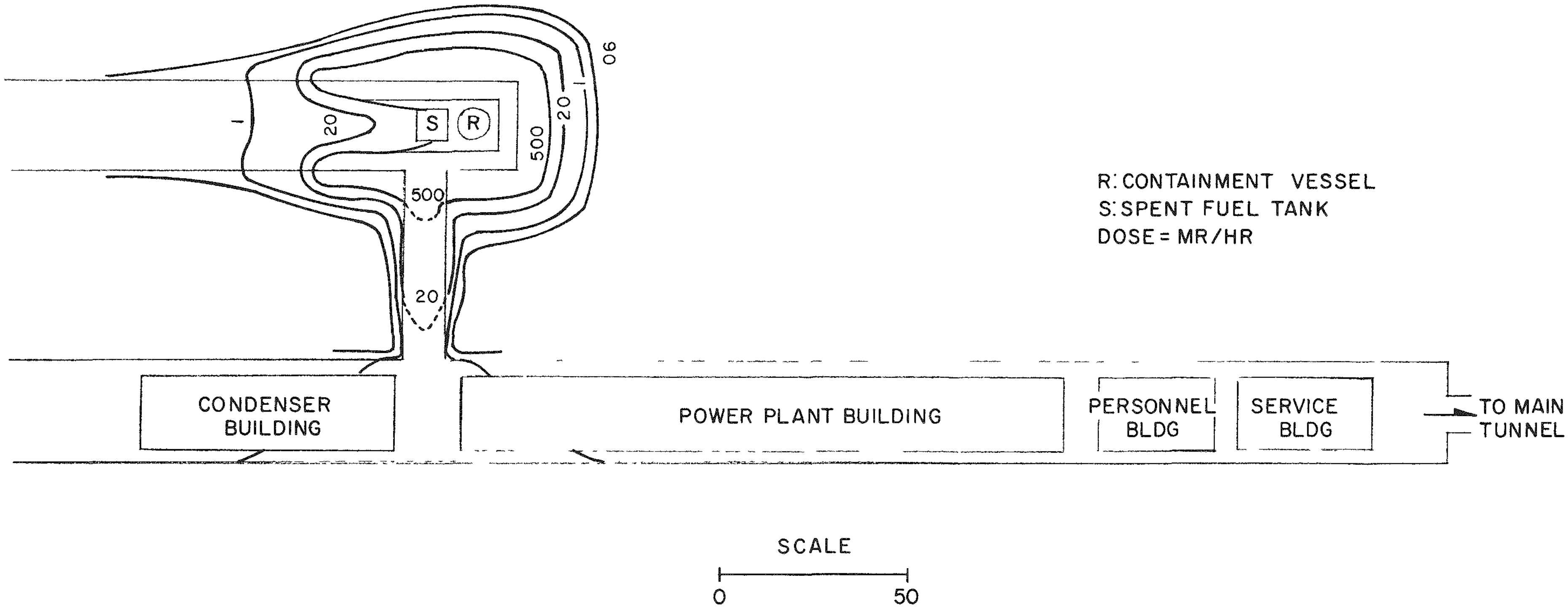
PHOTO 10 POWER PLANT BUILDING ARRANGEMENT

CURVES



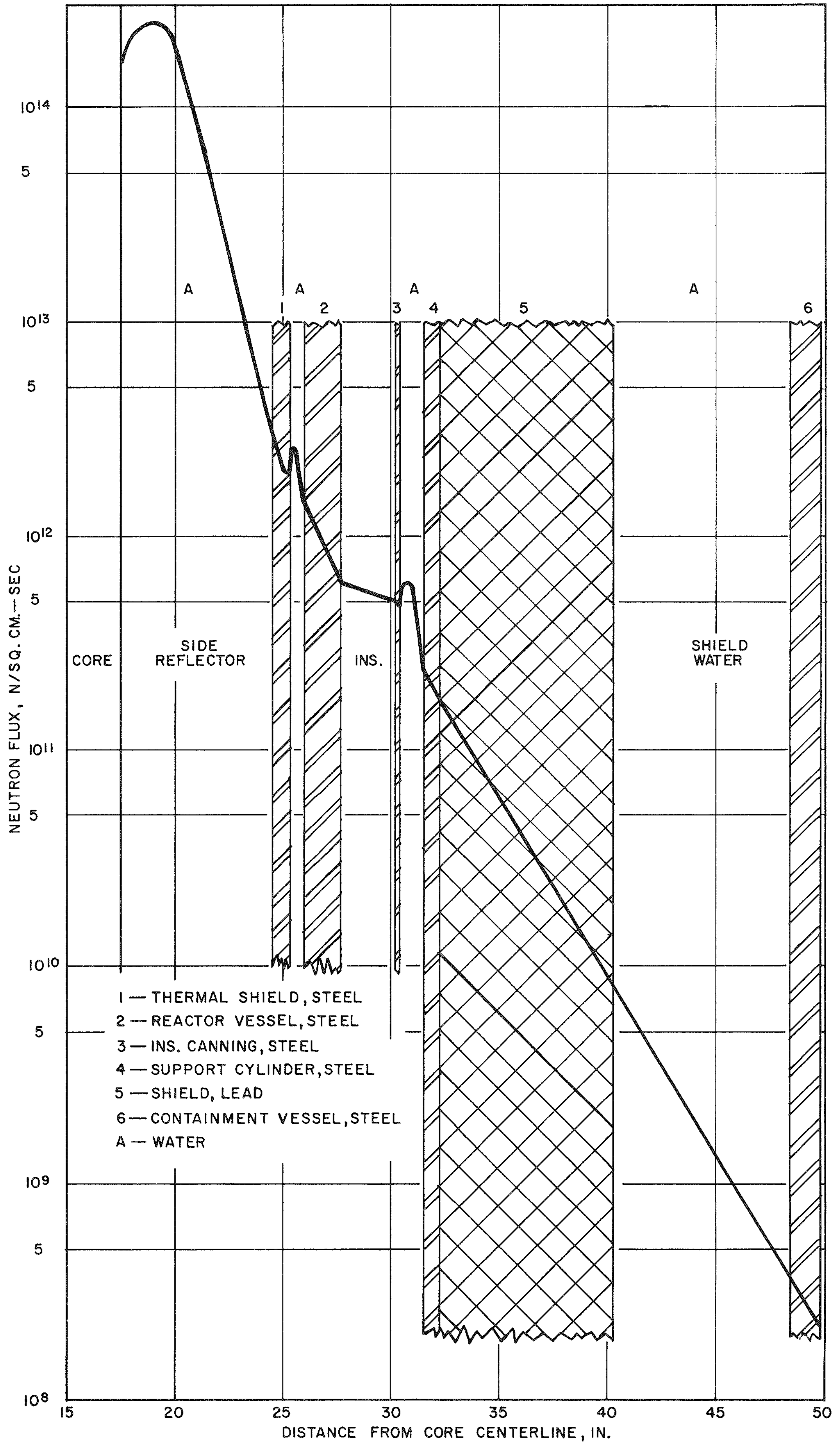
Curve 1

ISODOSE, SNOW SURFACE ELEVATION 100 FT



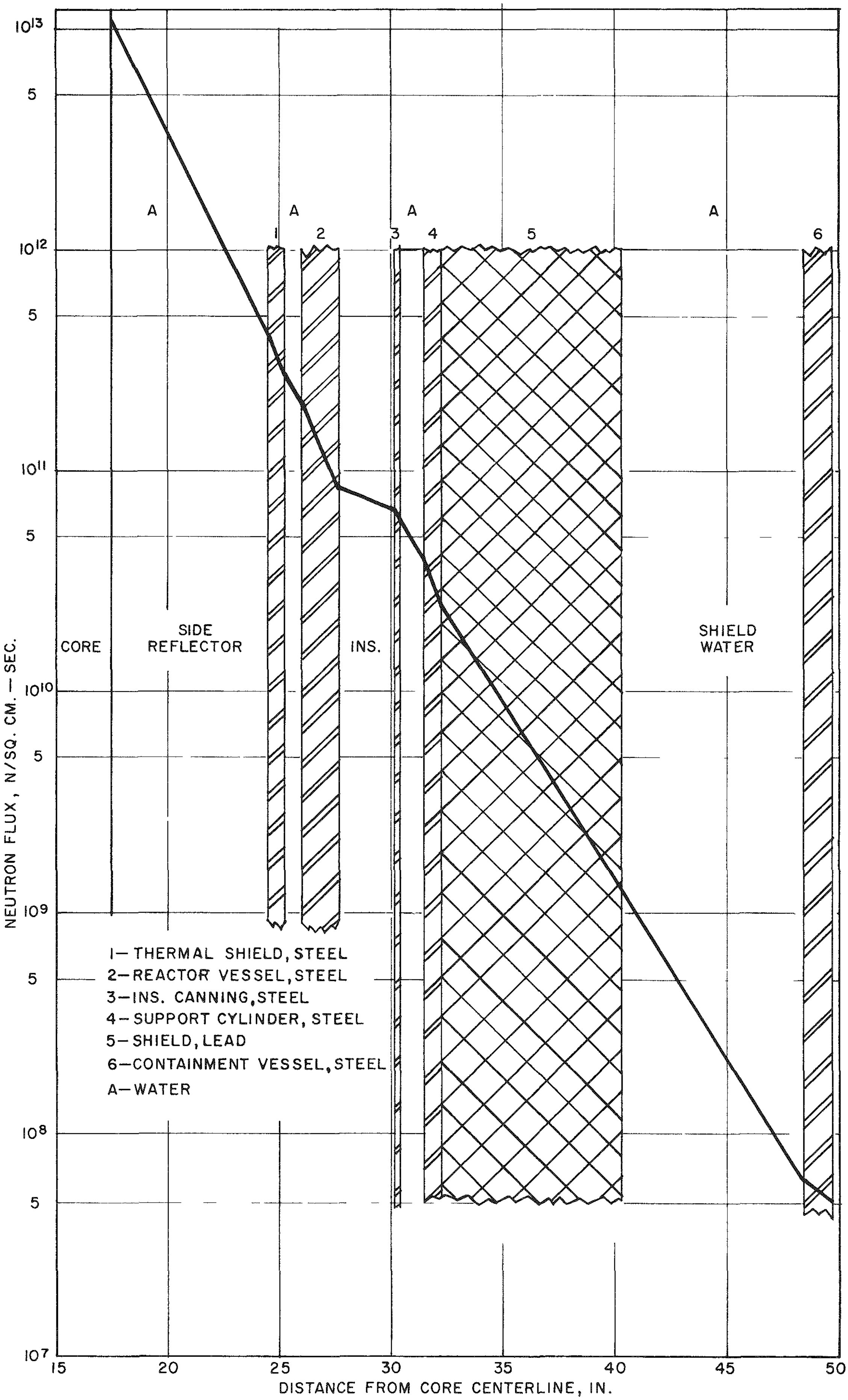
Curve 2

ISODOSE LINES, TUNNEL FLOOR SECTION (ELEVATION 69 FT)



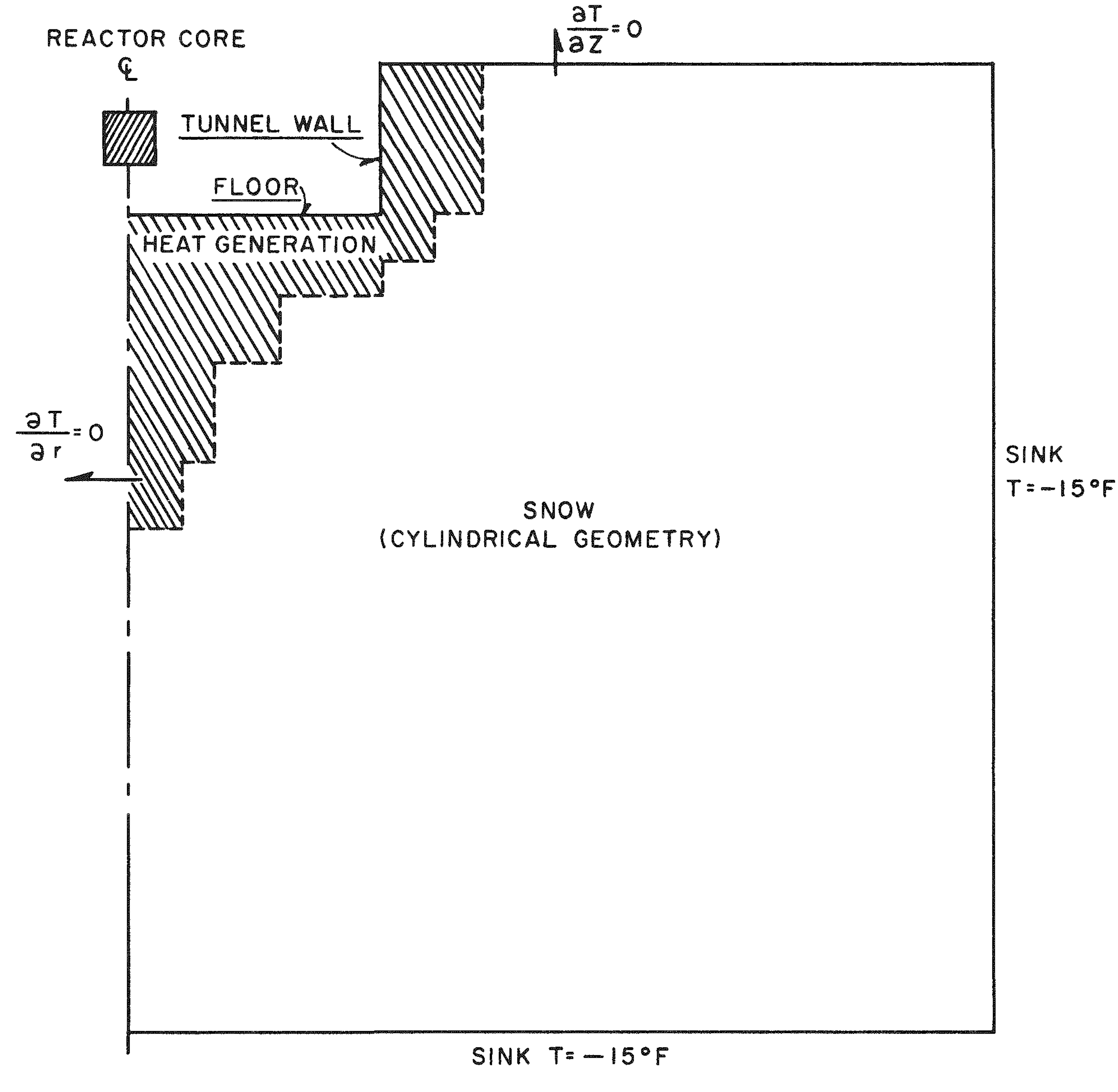
THERMAL NEUTRON FLUX vs RADIAL DISTANCE

Curve 3



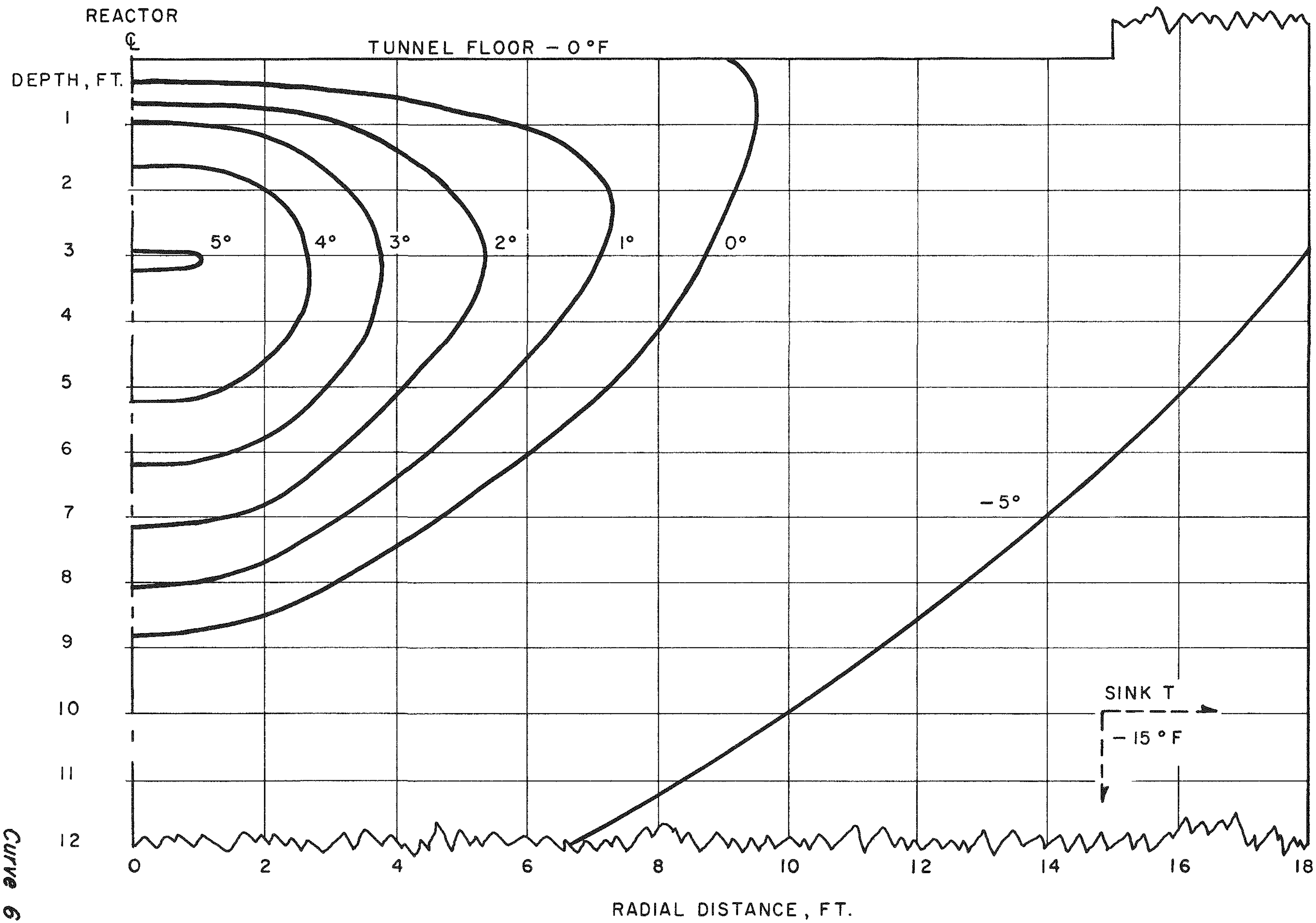
FAST NEUTRON FLUX vs RADIAL DISTANCE

Curve 4



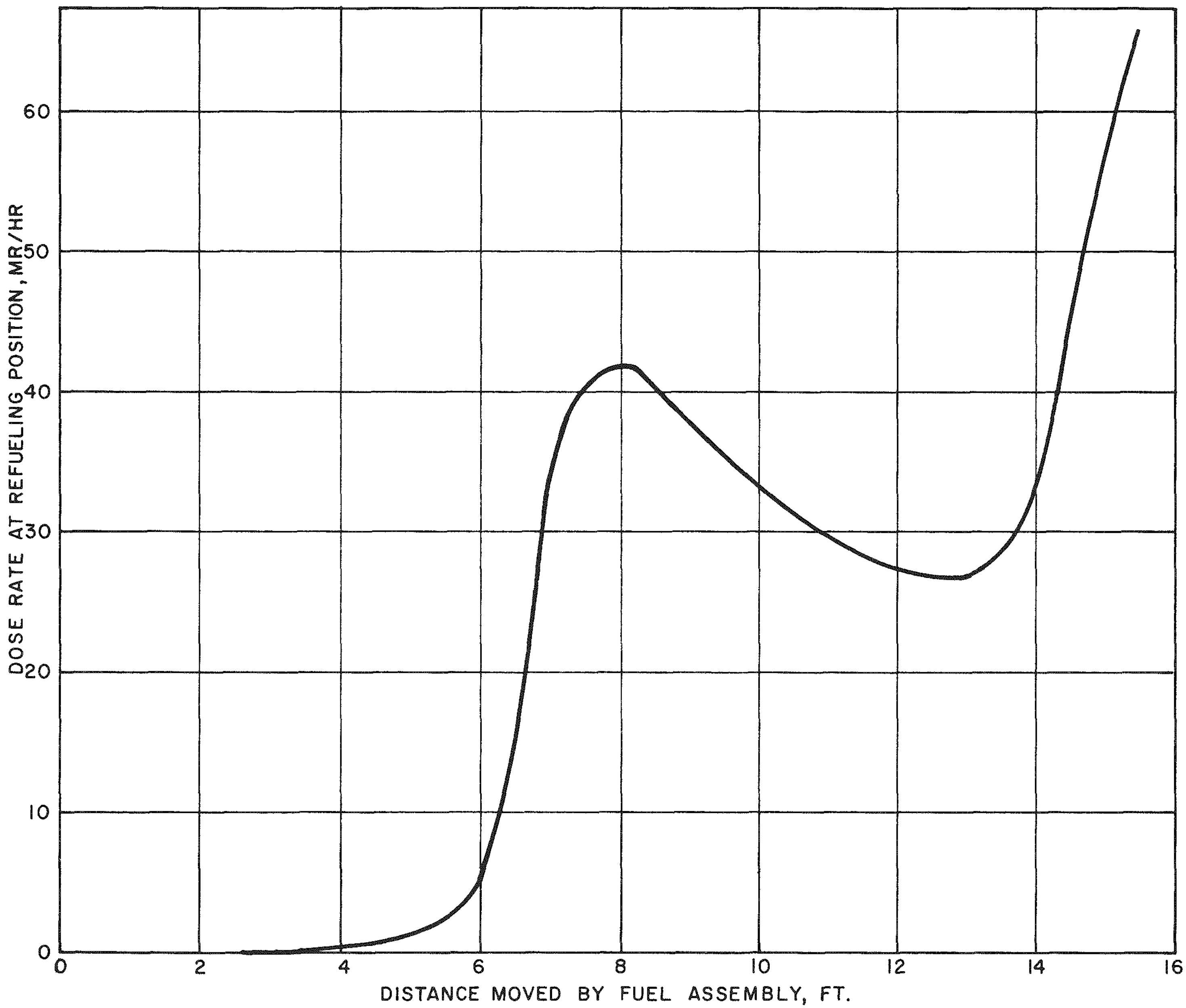
SNOW TUNNEL ISOTHERM CALCULATION MODEL

Curve 5



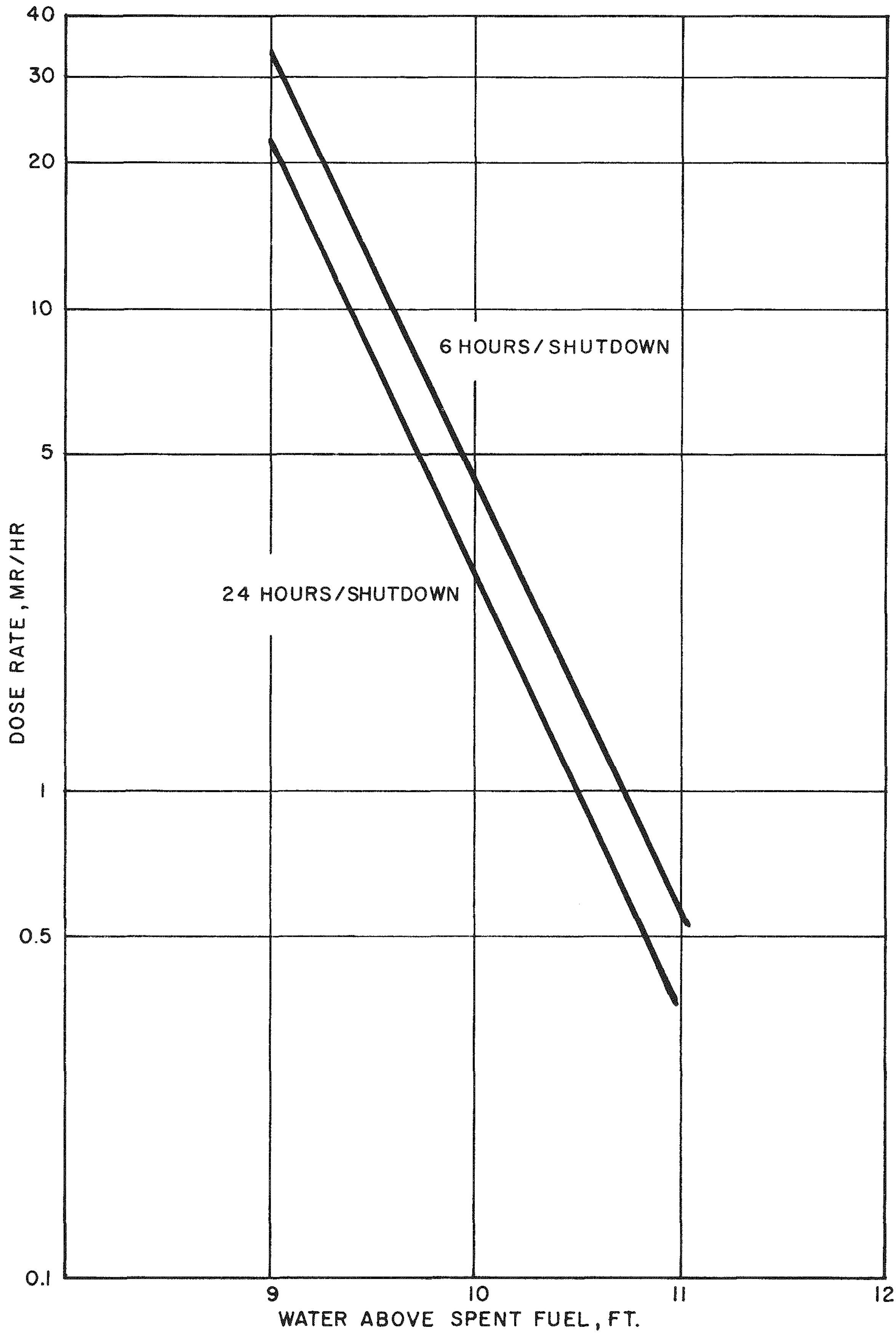
SNOW TUNNEL ISOTHERMS, TUNNEL TEMPERATURE 0°F

Curve 6



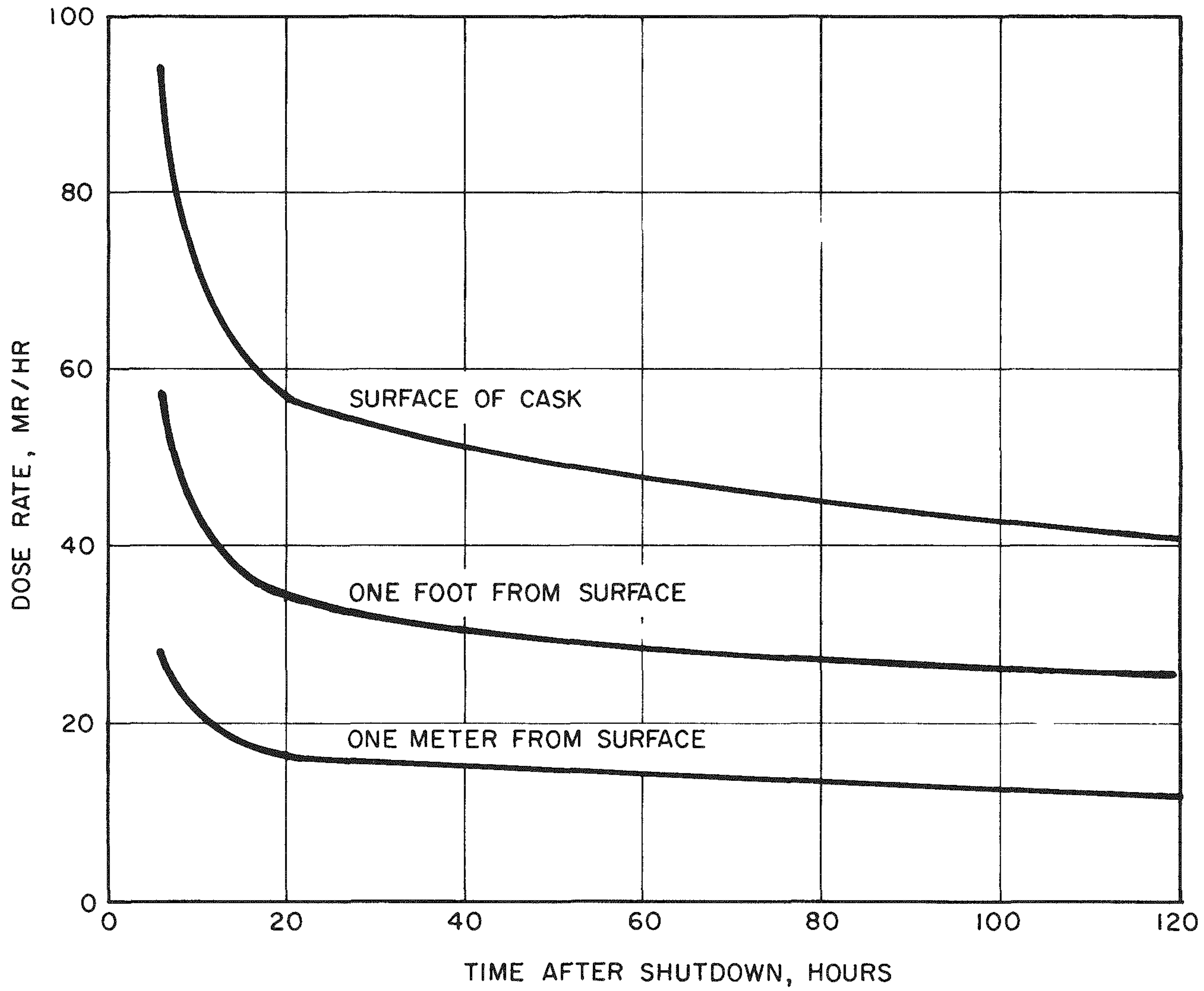
DOSE RATE, MAX. POWER ASSEMBLY
12 HRS/SHUTDOWN REFUELING OPERATION

Curve 7



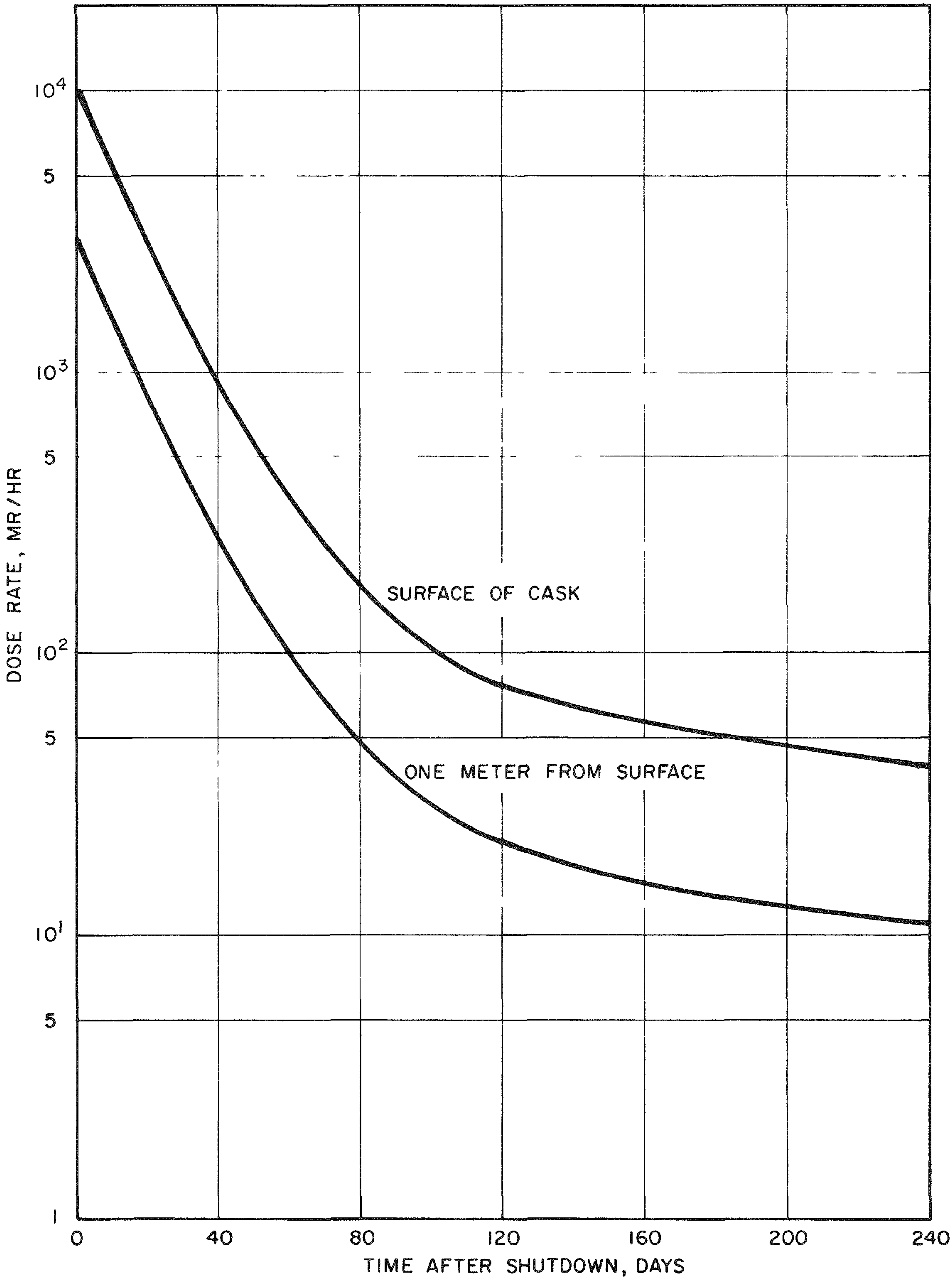
SPENT FUEL TANK, WATER SURFACE DOSE RATE vs HEIGHT OF WATER

Curve 8



TRANSFER CASK, DOSE RATE vs TIME AFTER SHUTDOWN
TIME AT POWER: 2 YEARS

Curve 9



SHIPPING CASK, DOSE RATE vs. TIME AFTER SHUTDOWN
TIME AT POWER: 2 YEARS

Curve 10