APAE-42(Vol. I)

REACTORS—POWER

DESIGN ANALYSIS OF A PREPACKAGED NUCLEAR POWER PLANT (1000 eKW). VOLUME I. PRIMARY AND SECONDARY SYSTEM DESIGN

February 1, 1959

Alco Products, Inc.
Schenectady, New York

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APAE-42

DESIGN ANALYSIS

OF A

PREPACKAGED NUCLEAR POWER PLANT

(1000 eKW)

VOLUME I

PRIMARY AND SECONDARY SYSTEM DESIGN

ISSUED FEBRUARY 1, 1959

Work performed under Contract No. DA-44-009-Eng-3638

Alco Products, Inc.
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Schenectady, N. Y.

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I BASIS OF DESIGN ANALYSIS

1.0 CONTRACT REQUIREMENTS

The major guideline for this design analysis of a prepackaged nuclear power plant are:

System reliability with minimum down time for refueling.
Minimum installed capital cost at a remote site.
Utilization of proven technology.
Minimum personnel requirements for operation and maintenance.
Minimum of one year between refueling when operating at full power.
Ease and simplicity of operation and maintenance.

The power level of interest is 820 KW net electrical output and 5×10^6 BTU/hr heat load for space heating.

The overall scheduling require the entire plant to be suitable for fabrication, installation and acceptance testing within 21 months. Within this period, only one construction season of approximately three months will be available for installation at a site. Foundations will be constructed during the preceding construction period. Scheduling must be based upon a maximum of 15 months available after contract award and prior to installation, for fabrication and test at the contractor's plant and shipment to a site.

It is required that the skid mounted packages be air transportable.

It is assumed that condenser cooling water is not available; however it shall be indicated what equipment is in excess and the expected increase in plant performance if condenser cooling water were available.

1.1 Basic Assumptions for the Design Analysis

The design analysis is based on a permafrost installation at a remote site, using concrete as a secondary shielding medium and it is assumed that aggregate is available at the site. It is also assumed that service water and plant makeup water is available for plant usage.

The design of buildings and structures is not included as a part of this design analysis and only the general requirements for such are indicated.

The ambient air temperatures to be encountered range from a -70°F to $+70^\circ$F. and it is assumed that the maximum temperatures to be encountered occur for only very few hours during the day for only several days during the warmer months of the year.

It is assumed that standby power and heating facilities are available in the form of diesel generators which furnish 100% standby. The standby facilities are not included in this design analysis but an area has been indicated on the overall station arrangement drawings for the location of this standby power.

1.2 Selection of Primary and Secondary System Conditions

On the basis of earlier studies carried out for APAE-33, 2000 KW Skid Mounted Power Plant, the primary and secondary conditions of 2000 psia and 465 psia were selected.

For these studies, a range of primary coolant inlet temperatures were studied to determine the primary system pressures required to meet the basic design criteria of no boiling in the core at steady state full power operation.

The Alco code for the IBM 650 computer which determines maximum fuel element plate surface temperature was used for this study. Curves of maximum surface temperature versus flow rate at various inlet temperatures were plotted.

Core heat transfer studies permitted the association of a primary system pressure with a required coolant flow rate and reactor inlet temperature. With a selection of range of steam generator tube sizes and coolant velocity in the tubes plus a range of secondary system steam pressures, a group of steam generators each capable of the duty imposed could be formulated. A program was written for the IBM 650 to do the calculations. For a given set of input parameters, this code calculated the number of tubes required, and heat transfer area required.

Along with the running of primary system programs, an IBM 650 program on the effect of pressure, feedwater heating and condenser back pressure on turbine performance was run. This was to study the effect of secondary steam pressures, use of various numbers of feedwater heaters and effect of condenser back pressure on turbine output.

During the overall analysis many combinations of parameter values could be eliminated because of practical reasons such as physical size, weight, etc. Even with this weeding out process, a number of possible systems could be used.

The task was then to select a system to best meet the criteria of portability. This selection could not be based on one clear cut set of conditions, due to the number of interrelated factors involved. Such factors as accessibility, physical size of components, vapor containment, problem of bolting and gasketing high pressure flanges, control rod drive seals, and overall reliability had to be considered in making the final selection operating conditions.

The final selection of a primary pressure at 1750 psia and a secondary pressure of 465 psia at full load results in a plant having good operating efficiency, low weight and conservative operating pressures.

II GENERAL DESIGN FEATURES OF THE PLANT

1.0 TYPE OF PLANT

It is a nuclear power pressurized water steam-electric generating plant which is air transportable skid mounted and suitable for a remote site installation. The plant design incorporates the maximum degree of reliability, simplicity, minimum maintenance and cost, within the scope of the design requirements stated heretofore.

1.1 Air Transportability

In order to meet the limitations imposed by the air transportability and reliability requirements the plant components are preassembled and pretested prior to shipment to a remote site.

The weight and dimensional limitations are based on the use of C-130 aircraft. All transportable packages do not exceed 30 ft. in length, 9 ft width, and 9 ft. height and 30,000 lbs. in weight.

All packages are designed to meet the permissible floor loading and center of gravity location of the C-130 aircraft and structurally able to provide proper tie down connections to meet external forces encountered in flight.

1.2 Generating Requirements and Heating Load

The plant is capable of producing a gross electrical output of 1000 KW and a net electrical output of 800 KW and 5×10^6 BTU/Hr for space heating.

The primary system generates a total of 6.5 MW of heat in order to supply the required electrical and heating load.

1.3 Plant Packages

The total number of packages involved for the plant to meet air shipment requirements are as follows: -

Package	Number Required
Reactor Vessel Skid	1
Primary Shield Rings	1
Steam Generator Skid	1
Vapor container with upper shield tank	3
Turbine Generator	1
Condenser	1
Feedwater	1
Heat Exchanger	1
Air Blast Cooler	1

Switchgear	1
Waste Storage Tank and Spent Fuel Pit Lining and Lab Equipment	1
Shipping Casks	7
Interconnecting Piping, Interconnecting Wiring	2

1.3.1 Primary Skid

The primary system as shown on Drawing R9-42-1001 is shipped in three sections. One section being the steam generator skid on which is mounted the steam generator, pressurizer and blowdown cooler. The other section carries the reactor vessel and core support structure, the control rod drives and the primary coolant pump. The primary shield rings are shipped separately in order to keep all shipping weights below the allowable 30,000 lbs air shipment limitations. The primary piping is flanged and skid bases are flanged and doweled for ease of alignment when assembling the system in the field.

1.3.2 Vapor Container

This design incorporates the use of a cylindrical vapor container which will contain either the primary and secondary systems in the case of a remote possibility of a system rupture.

In the event vapor containment is not required modifications can be made to the general primary system arrangement as indicated on Dwg.R9-43-1005.

1.3.3 Instrumentation

Due to site conditions assumed and in order to minimize maintenance requirements the use of air for any purpose where instruments are concerned is determined undesirable. Therefore, all instrumentation is either mechanical or electrical.

To permit minimum operating personnel all plant parameters directly affecting plant operation are indicated on the control console which is located on the switchgear skid. The controls for such items as pumps and rod drives are also located on the console. Variables which affect plant safety are annunciated.

All other instrumentation and controls are local in order to insure visual inspection of equipment when instrumentation information is required or control functions are to be performed.

Operations at APPR-1 have indicated the need for complete isolation of instrument power from any plant voltage transients. The use of solid state components has reduced the power required by the instrumentation and permitted the use of one isolated supply for all of the instrumentation.

The use of this type of design will provide maximum plant reliability, minimize maintenance and greatly improve overall plant performance.

Operations at APPR-1 indicate that tubes and relays contribute significantly to unreliability and maintenance problems of nuclear instruments. Therefore, a nuclear instrumentation system containing only transistors and magnetic amplifiers for sending and control is being developed for APPR-1A in which some amplifiers are card mounted and interchangeable. Relays are utilized only to accomplish a function requiring a high current rating. Components of this transistorized system will be fully tested at APPR-1 prior to the fabrication of this plant.

Recorders and controllers specified for this plant are of the latest commercial design and require no vacuum tubes. This equipment has been thoroughly field tested by the manufacturer at isolated stations. It can also be tested under plant conditions at APPR-1 and APPR-1a before this proposed plant is fabricated.

1.3.4 Turbine Generator

The turbine generator is a 1000 KW machine rated for operation at 8 in. Hg. exhaust pressure with 425 psig steam delivered to the throttle which allows a 25 lb pressure drop in the main steam line between the steam generator and turbine.

The generator is rated at 1250 KVA, 1000 KW at .8 power factor and wound for 480 volts "Wye" connected, grounded neutral, 3 phase, 60 cycles and operates at 1200 RPM.

The total weight of the turbine generator is 32,000 lbs. To meet air transportability requirements, the turbine, gear and generator is shipped as a unit on the base weighing a total of 30,000 lbs and auxiliaries such as lube oil cooler, pump etc. are shipped as a separate package weighing 2,000 lbs.

1.3.5 Heating System

Due to the high quality of water desired in the secondary system, supplying of bleed steam for heating load directly from the cycle would require considerable water treatment of the heating system return drains. To eliminate the necessity of this water treatment and its high cost the use of a closed hot water heating system was selected.

1.3.6 Condenser System

Due to lack of cooling water available for condenser cooling, a closed cycle using an air blast cooler is utilized with an ethylene glycol solution as the cooling medium.

Consideration was given to the use of a direct air cooled condenser to remove the latent heat from the turbine exhaust steam and as an alternative the use of an intermediate glycol loop between a surface condenser and an air blast cooler.

Investigation into the two types of cooling systems indicated that the direct air cooled surface condenser has three major problem areas.

(a) Minimum experience to date
(b) Experience shows that tempering of air to prevent freezing of the condensate in the tubes is an unreliable method.
(c) In the case of plant shutdown the unit should be immediately drained to prevent freezing.

On the basis of the Site conditions for this plant and anticipating a continual rotation of personnel on approximately a nine month basis, it was determined that the glycol intermediate loop arrangement would provide the highest degree of reliability, although it would result in a lower overall station thermal efficiency. With the continual changing of personnel it is rather obvious that the possibility of the direct air blast cooler being neglected during an emergency shutdown could freeze and damage the condenser. The result of this would prevent the startup of the plant until repairs could be made. Should such an emergency exist with the glycol intermediate loop arrangement no trouble would be anticipated since draining the system will not be necessary.

1.4 Reliability

The plant design incorporates the maximum degree of reliability, simplicity, minimum maintenance and cost within the scope of the design requirements.

The primary system design is an improved design based on the successful APPR-1 unit. As a result, the systems and components utilize proven techniques and in addition will reflect the high degree of reliability of the APPR-1.

The reactor vessel, steam generator and pressurizer are of the same type of design and materials which have been used in PWR programs with complete success. Each component will be tested in accordance with design requirements.

The primary coolant pump is a "canned rotor" type pump which has been successfully used and proven in numerous applications for several years. This type of pump is widely used in the PWR field and its reliable performance record is evident.

The auxiliary systems are similar to those utilized and proven in APPR-1 and designed for APPR-1a. All equipment will be of the commercial type which has been proven in service.

The secondary system is designed to incorporate commercially available items which have been completely proven in service.

All auxiliary cooling systems throughout the plant are closed systems.

Successful operation of the APPR-1 fuel elements and control rods permits the use of a proven core for this design. Development work is not required for this core thereby making it possible to attain a high degree of operating reliability and meet the overall fabrication, erection and testing schedule.

The steam generator design is of the horizontal evaporator type to comply with shipping dimensional limitations on the primary skid. The design takes into consideration maintenance features such that the tubes can be plugged if necessary and is readily accessible to do this. This design will produce steam of 90% purity delivering dry and saturated steam to the turbine generator through a moisture separator just before the turbine generator.

This type of steam generator presents no difficult fabrication problems and can be manufactured in a minimum of time.

A natural convection cooling loop has been provided in the primary system for the removal of heat generated in the core following complete loss of electrical power.

The plant is basically designed to meet acceptable hazards requirements of pressurized water nuclear power plants and all necessary radiation monitoring devices for safety of performance are incorporated.

In order to maintain the continuity of operation, all pumps in the secondary system whose failure would cause shutdown are duplicated. This permits reliable performance of the plant while repairs are made.

1.5 Operating Data, Weight and Dimensional Data

1.5.1 Plant Performance

Thermal power developed in reactor	6.5 MW
Reactor Life	8 MW years
Gross Electrical power generated	1000 KW
Electrical power required for auxiliaries	200 KW
Net electrical power delivered with 8"Hg back pressure at turbine generator.	800 KW
Net electrical power delivered with 3"Hg back pressure at turbine generator	910 KW
Net electrical power using 40° well water and operating at 3-1/2" Hg back pressure at the turbine generator.	960 KW

Steam supplied for outside heating purposes	5×10^6 BTU/hr

1.5.2 Thermal Data of Reactor at Full Power

Operating Pressure	1750 psia
Design Pressure	2000 psia
Coolant flow	2505 gpm
Coolant inlet temperature	500°F
Coolant outlet temperature	519.1°F

1.5.3 Steam Generator

Tube Side

Operating Pressure	1750 psia
Design Pressure	2000 psia
Flow	2505 gpm
Inlet Temperature	518°F
Outlet Temperature	519.1°F

Shell Side

Operating Pressure	465 psia
Outlet Temperature	463°F
Inlet Temperature	306°F
Flow	24000 #/hr
Blowdown	170 #/hr

1.5.4 Pressurizer

Operating Pressure	1750 psia
Design Pressure	2000 psia
Design Temperature	650°F
Number of Heaters	20
Total heat output	30 KW
Steam volume (cu.ft.)	12.1
Water volume (cu.ft.)	5.9

1.5.5 Primary Coolant Pump

Type	Canned Rotor
Rated Flow	2505 gpm
Operating Head	24 ft.
Suction temperature	500°F

1.5.6 Primary Coolant Piping

Type	304 Stainless steel, schedule 120
Size	10" Nom.

1.5.7 Vapor Container

Design Pressure	240 psi
Material	Carbon steel GR-212 to SA-300
Operating Temperature	120°F

1.5.8 Core Design

Configuration	7 x 7 array-3 elements in each corner missing
Equivalent diameter-in	20.16
Active core height-in	22
Material content of core:	
U^{235} -Kg	18.49
B^{10} -gm	16.66
SS -kg	172.10
H_2O(68°F) -kg	91.54

Stationary Fuel Element

Type	APPR-1, Core II
Number of Elements	32
Plates/element	18
Active length-in	22
Clad thickness-in	0.005
Meat thickness	0.020
Meat Width	2.500
wt. U^{235}/element - gm	515.16
wt. B^{10}/element - gm	0.464

Control Rod Fuel Elements

Type	APPR-1, Core II
Number of Elements	5
Plates/element	16
Active length-in	21-1/8
Internal Flux Suppressor	
Material	Europium Oxide
Wt. of Eu/suppressor-gm	1
Length-in	7/8
thickness-in	0.020
width-in	2.281
Clad thickness-in	0.005
Meat thickness-in	0.020
Meat width-in	2.281
wt U^{235}/element-gm	401.12
wt B^{10}/element -gm	0.362

Control Rod Absorbers	
Type	APPR-1, Core I: Low CoSS
B^{10} - gm	56.4
Absorber plates/Rod	4
Travel - in	22
Initial Reactivities -%	
Cold (68°F) - no xenon	14.11
Hot (512°F) - no xenon	7.65
Hot (512°F) - Equilibrium xenon	5.15
Initial Bank Position - inches from bottom	
Cold (68°F) - no xenon	5.0
Hot (512°F) - no xenon	9.7
Hot (512°F) - equilibrium xenon	11.6
Power - Peak to Average	
Hot (512°F) - no xenon	
C-MWYR	
Radial (center)	1.46
Axial (center)	1.65
8-MWYR	
Radial (center)	1.55
Axial (center)	1.47
Average Thermal Flux-neutrons/cm^2sec	
0 MWYR	1.67×10^{13}
8 MWYR	2.33×10^{13}
Expected Total Energy Release-MWYR	
Burnup: 10 MWYR	
Average Fuel - %	26
Maximum Fuel - %	49
Maximum Control Rod -%	27
Temperature Coefficient	
Cold (68°F) - °F-1	-0.22×10^{-4}
Hot (512°F) - °F-1	-3.4×10^{-4}
Pressure Coefficient	
Hot (512°F, 1750 psia)-psi^{-1}	$+3.1 \times 10^{-6}$
Control Rod Worth	
Five Rod Bank	
Cold (68°F)-%	19.9
Hot (512°F)-%	19.5
Center Rod	
Cold (68°F)-%	4.5
Hot (512°F)-%	4.0

1.5.9 Shielding Design

Design Basis	
Access after shutdown - hr	2.5
Dose in Control Console and Turbine Generator - mr/hr	1.19
Primary Shield	
Type	Similar to APPR-1 (Concentric annuli of H_2O and steel. Steel ring clad on both sides with Boral. Inner surface of shield tank and outer surface of Pressure Vessel support ring clad with Boral)
Number of Steel Rings	4
Thickness - in	3-1/4
Boral clad; thickness-in	1/8
Water annuli; thickness-in	1-1/4
Dose rate 2.5 hr. after shutdown-mr/hr	33 mr/hr
Dose rate during operation - R/hr	161
Secondary Shield	
Type	Concrete
Thickness - Ft.	2-4
Dose Rate on Surface; mr/hr	2-30
Core Shielding	
Type	Water
Shutdown - days	1
Thickness - Ft.	11
Spent Fuel Shipping Cask	
Elements/cask	6
Weight-Tons	10
Thickness - in	10.5
Dose Rate one meter from source-mr/hr	2.81
Demineralizer Shielding	
Type	APPR-1
Shielding Material	Lead
Thickness (Radial) -in	3-11/16
Thickness (Axial) -in	3-3/16
Dose Rate	
Surface of Shield - mr/hr	58
One meter from source - mr/hr	8.7

Waste Tank

Active Source	Primary coolant and Normal Plant Waste
Shield Thickness - Ft.	
Concrete (= 2.4)	2.0
Dose rate on surface of shield - mr/hr	0.5
Dose Rate on surface of APPR-1 (waste tank with normal plant waste only-mr/hr=20)	

1.5.10 Thermal Design

Type of flow	Uniform
Inlet Temperature - °F	500°
Outlet Temperature -°F	519.1
Maximum plate surface temperature -°F	610.
Flow per fixed fuel element - gpm	58.5
Flow per control rod fuel element - gpm	56.0
Lattice flow - gpm	353
Total core flow - gpm	2505
Fixed Fuel Element -	
Maximum operating heat flux Btu/hr-Ft^2	1.149×10^5
Burnout heat flux Btu/hr-Ft^2	9.984×10^5
Maximum ratio of operating to burnout heat	0.1222
Control rod fuel element	
Maximum operating heat flux Btu/hr-Ft^2	1.154×10^5
Burnout heat flux	1.015×10^6
Maximum ratio of operating to burnout heat flux	0.1208
Maximum internal plate temperature °F	627
Ratio of peak to average power	2.46
Maximum stress in fuel elements -psi	14,530
Temperature difference across reactor vessel wall-°F	30.5
Thermal stress in reactor vessel - psi	4420
Thermal stress in thermal shield - psi	40,300
Thermal stress in vessel flange - psi	4,860
Thermal stress in outlet integral nozzle psi	3,500
Allowable thermal stress in vessel, flange, and nozzle - psi	8,750
Total core pressure drops = control rod pressure drop - Ft of H_2O	2.12
Pressure drop through fixed elements - Ft of H_2O	0.86
Required fixed element orificing - Ft of H_2O	1.26

Maximum pressure differential between fuel plates and lattice - psi	0.01
Maximum allowable pressure differential between fuel plates and lattice - psi	3.0

1.5.11 Weight and Dimensional Data of Major Items

Turbine Generator	
Dimensions	16'-4" x 7'-0" x 6'-2" high
Total weight	32,000 lbs.
Shipping Sections:	
Turbine, Gear, Generator and base	
Dimensions	16'-4" x 7'-0" x 6'-2" high
Weight	29,000 lbs.
Auxiliary Section	4,000 lbs.
Condenser Package	
Dimensions	27'-0" x 6'-6" x 9'-0" high
Overall Shipping Weight	29,070 lbs.
Feedwater Packages	
Dimensions	25'-9" x 9'-0" x 9'-0" high
Overall Shipping Weight	29,480 lbs.
Heat Exchanger Package	
Dimensions	19'-1½" x 9'-0" x 6'-6" high
Overall shipping Weight	14,310 lbs.
Air Blast Cooler	
Number of Sections Required	1
Dimensions	30'-0" x 9'0" x 9'-0" high
Overall Weight	25,200 lbs.
Switchgear Package	
Dimensions	26'-5" x 9'-0" x 8'-10" high
Weight	24,190 lbs.
Interconnecting Piping and Spare Parts	
Total weight - Pipe and Specialties	40,000 lbs.
Total weight of Spare Parts	4,000 lbs.
No. of shipping Sections Required	2
Interconnecting Wiring and Miscellaneous Equipment	
Total Weight of Wiring and Raceways	10,000 lbs.
Total Weight of Miscellaneous	14,400 lbs.
No. of Shipping Sections Required	1

Primary Package	
Reactor Skid Section	
Dimensions	11'-8½" x 9'-0" x 9'-0" high
Weight	28,388 lbs.
Steam Generator Skid Sections	
Dimensions	13'-10½" x 9'-0" x 9'-0" high
Weight	23,311 lbs.
Primary Shield Rings	29,000 lbs.
Vapor Container	
Total weight installed	60,000 lbs.
Dimensions installed	13'-0" Dia. x 38'-2"
As shipped condition	
Shell	8 pcs.
Heads	4 pcs.
Upper Shield tank	1 pc.
Waste Storage Tank	
Dimensions	7'-0" Dia. x 18'-0"
Weight	7,100 lbs.
Spent Fuel Cask	
7 Shipping casks ea.	17,800 lbs.
Chemistry and Health Physics Packaged Lab.	one package
Total Estimated Number of Packages (Excluding Spent Fuel Casks)	approx. 15

2.0 RANGES OF PLANT OUTPUT

The plant as described in this design analysis is rated at 6.5 MW of heat output at the reactor and 5 x 10^6 Btu/hr for space heating purposes with 1000 KW gross electrical output at the turbine generator.

At the design conditions of 8" Hg back pressure at the turbine generator, the net electrical output will be 800 KW. The auxiliary power at full load under design conditions including station lighting will be approximately 200 KW.

Under the same conditions, with the condenser back pressure at 3-1/2" Hg. the net electrical output will be 910 KW.

If condenser cooling water were available at 40°F and eliminating the air blast coolers and heat exchanger circulating pumps and operating at 3-1/2 inches Hg. back pressure at the condenser, the net electrical output would then be 960 KW.

2.1 System Modifications for Higher Power Requirements

2.1.1 Primary System

The primary system is capable of producing a maximum of 10 MW heat and this may be obtained by modifications to the steam generator and primary coolant pump.

The same reactor vessel and core may be used at the 10MW output as at the 6.5 MW.

For both power requirements, the same steam generator shell and nozzle size and configuration can be utilized. The only change required will be a modification in the number of tubes required.

The primary coolant flow requirements will be increased from 2505 gpm for the 6.5 MW to approximately 4240 gpm for the 10 MW, maintaining the same primary pipe size of 10" inches for each case.

The primary coolant pump will require modifications in going from one power level to the other. For 2505 gpm, a 30 HP, 3 phase, 60 cycle, 1200 RPM motor is required while for the 4240 gpm flow at the 10 MW power level a 65 HP 3 phase, 60 cycle, 1800 RPM motor is required. The impeller will necessitate slight revisions in going from one power level to the other.

2.1.2 Secondary System

The secondary system will require more extensive modifications than that required for the primary since a major increase in power output requirements would affect all secondary system components from the turbine generator back through the cycle.

Depending on the power level requirements, a 1500 KW or 2000 KW turbine generator can be used to obtain a net electrical output of approximately 1200 KW and 1700 KW respectively.

2.1.3 Procurement Schedule

The overall time schedule as indicated in Section II, subsection 5.0 would not be radically affected by the modifications required to obtain higher plant power outputs, and the overall period of 21 months can be met.

3.0 STATION ARRANGEMENT (DRAWING MO1M15)

3.1 Description

The plant is designed for the placement of all component packages and interconnecting wiring and piping on a flat slab in a building enclosure. The secondary system packages, office, and laboratories are all located in a single building 59 feet by 65 feet. Piping and wiring connecting the packages is run on the floor and decked over with grating at the elevation of the component skid beams.

The primary system and vapor container provided with secondary shielding in the form of concrete along with a concrete spent fuel pit and chute for transfer and storage of spent fuel elements.

Thickness of concrete required for shielding of primary system, spent fuel pit and waste tank are detailed in the Reactor Analysis Section.

An enclosure is provided above the upper shield tank and spent fuel pit with space provided for the installation of an overhead crane to be used in conjunction with fuel handling equipment.

A bridge type crane runs over the principal secondary equipment skids to facilitate maintenance and inspection of equipment. Space is provided for lay-down of turbine parts during inspections as well as other maintenance and storage of spare parts.

3.2 Alternate Arrangement

In the event that the air blast coolers are replaced by the deep well pumps, the heat exchanger skid would be eliminated and this bay of the building would be eliminated. The building would then be lengthened to accommodate the rearrangement of laboratory space. The building would then be approximately 45 ft. by 70 ft.

The secondary system mechanical and electrical equipment is included in the following six packages: the turbine generator package; the condenser package; the heat exchanger package; the air blast cooler package; the feedwater package; and the switchgear package.

4.0 TESTING OF PLANT

The following tests are proposed to be performed by Alco Products Inc., and/or other manufacturer's supplying equipment to Alco for the Plant.

1. Individual item test.
2. Components and Assemblies Test
3. Plant Factory System Test
4. Low and High Power Performance Test
5. Plant Performance Test

Tests 1, 2 and 3 will be performed directly after manufacture and assembly and prior to shipment to a Site.

Tests 4 and 5 will be performed under Alco Products, Inc. supervision, after installation of the plant at a Site.

The following outline basically covers the testing to be made since the specific details covering the testing requirements and procedures to be followed, and how the testing is to be accomplished, will be developed by Alco Products, Inc. during plant fabrication.

4.1 Individual Item Tests

Alco Products, Inc. will be responsible and provide to the Government for Alco fabricated items and where required from other suppliers to Alco Products, as follows:

ASME certificates for pressure vessels and code stamps.
Calibration curves for instruments, gauges and meters.
Performance curves and test results on pumps.
Rating curves and test results on the turbine generator.
Test results of cladding material.
Core flow and orificing test results.
Performance Test on Control Rod Drives.
Fuel Element Tests.

The testing of components will be performed as required by Alco Products for Alco fabricated components and by other manufacturer's for components purchased by Alco, prior to assembly on modules to demonstrate their functional integrity.

4.2 Components and Assemblies Test

Following fabrication and individual item testing, these items will be assembled on the plant modules and subjected to subassembly tests outlined as follows:

(1) Inspection of mountings and supports for equipment on the modules to preclude damage due to vibration and insure proper securement.

(2) Valves and shutoff controls associated with pressure vessels and their piping will be tested for functional operation and leakage.

(3) Primary system will be helium leak tested.

(4) Hydrostatic test will be performed on the assembled primary system module in accordance with applicable codes to insure integrity of the primary system piping and connections.

(5) Leakage of fluid from the primary system will be checked for excessive amounts beyond design conditions.

(6) Rotating machinery, pumps, motors will be tested for proper rotation, operation and excessive vibration.

4.3 Plant Factory System Test

Prior to preparation for shipment, the secondary system modules will be tested in the assembled configuration at Alco Products, Inc. The primary system will be checked and tested separately.

The plant modules will be assembled in the overall configuration as shown on drawing M01M15. The piping between the primary and secondary system will be assembled and checked for fit up and coding.

It is proposed to test the primary and secondary system separately. The secondary system will be supplied with steam from an external source and checked for integrity, operation and performance.

The secondary system modules including the air blast coolers and piping will be placed as shown in Dwg. M01M15 and all prefabricated interconnecting piping and wiring installed to check proper fitup, coding and integrity.

The primary steam generator skid and reactor skid sections will be assembled and bolted together and tested for integrity and operation using a dummy core.

An external steam source will be utilized to supply steam to the secondary system, at the design flow and pressure.

The physical integrity of the piping and vessels will be checked when simulating operating temperature pressure and flow conditions on the primary system and to check instruments, controls pumps and pressurizer heating elements, control rod drives and insure that all modules are stable and free from excessive vibration.

The capability of the system to deliver the required amount of electrical power within the required quality limits shall be checked.

Readings on all necessary flows, temperatures and other instruments will be made to record operating conditions such that a heat balance can be calculated.

4.4 Low and High Power Performance Test at the Site

Prior to pressurizing the primary system, the vapor container shall be tested for leakage rates with a helium mass spectrometer to insure that leakage rates are not exceeded.

Core loading and unloading procedures and transfer of fuel elements in transfer casks shall be test demonstrated.

The low and high power testing will include the following:

1. Each control rod shall be calibrated over its entire length with various settings of other control rods utilizing sufficient combinations of rod settings to determine all significant control rod effects.

2. Individual rod scram will be checked with coolant flow in the core at the design conditions.

3. Rod calibration shall be performed at temperatures from ambient to design level.

4. The temperature and pressure coefficients of reactivity will be measured at several points ranging from room temperature to design operating temperature while the primary coolant temperature is raised at approximately 30°F per hour.

5. Safe plant shutdown shall be tested according to the approved stuck rod criteria.

6. Tests and calibrations of process control instruments and radiation monitors will be made to insure proper operation and accuracy for safe plant operation.

7. Control mechanisms and circuits will be checked and tested for reliable operation.

All instrumentation will be inspected and tested for proper installation and connection. Check lists will be furnished to the government covering instrumentation calibration and performance check out indicating that each instrument and instrumentation system has met performance test recommended by the manufacturer.

Instrument calibration shall include the following:

a) Continuity and signal test of all detecting components, recording circuit and control circuits will be made after installation.
b) Signals simulating high flux levels and short periods will be applied to trip circuits to insure approved design response.
c) Module radiation detectors will be tested and calibrated by means of standard radiation sources.

d) All failures that relate to safety of the operating system will be induced and response checked against design requirements.
e) All control rod elements shall be loaded into the reactor vessel and filled with water at design temperature and pressure and the action of all control rod elements shall be initiated singly and in bank to indicate freedom from binding.

4.5 Plant Performance Test at the Site

The plant performance test will include the following items:

1. The ability of the plant to deliver a minimum of 1500 KW electrical power (depending on existing camp loads at the time) at the design conditions.

   a) The procedures for shifting and dividing of electrical and steam loads between the nuclear plant and the camp standby power shall be demonstrated.

2. Demonstration test of the radiation monitoring system will be made for proper operation during full load operation of the reactor. Three radiation surveys of the entire camp will be made.

3. Leakage rates of the primary and secondary systems shall be made to insure limitations within the design conditions.

4. Chemical analysis of the primary and secondary system water will be made to check impurity content within the design conditions.

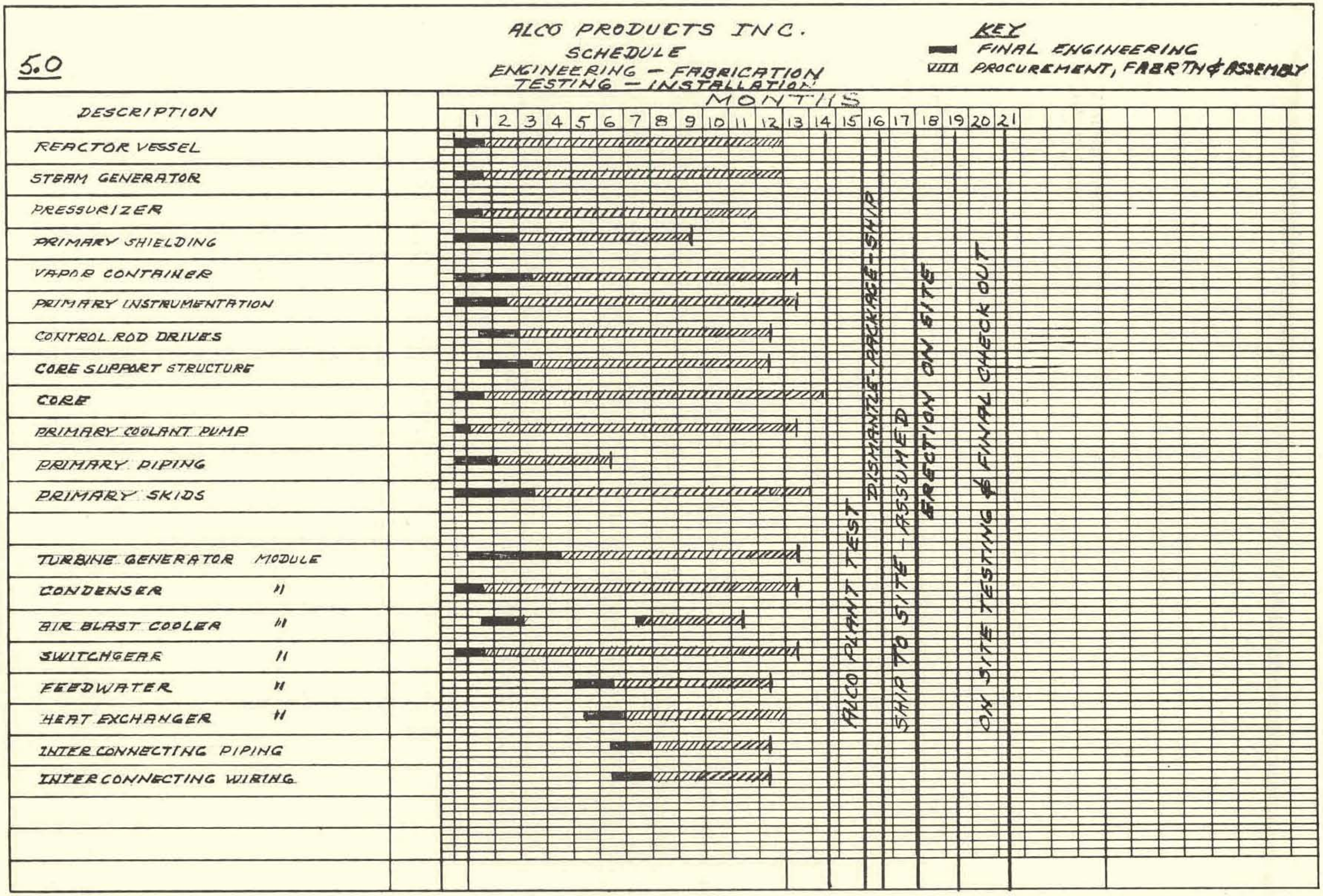
5. Decay heat removal from the primary system following loss of power without bulk boiling of the primary system coolant will be checked.

6. An endurance test shall be performed for 400 hours with less than 24 hours total planned and unplanned downtime and will include one 96 hour uninterrupted run with existing camp loads.

The construction progress schedule on the following page indicates manpower requirements and time requirements for erection and testing at the site.

5.0 OVERALL FABRICATION, TESTING AND INSTALLATION SCHEDULE

The bar graph schedule on the following page shows the overall scheduling of major plant components including items requiring the longest lead times. This schedule indicates the final engineering, procurement, fabrication, and assembly, testing, shipment to a site and final performance test all within a 21 month period.


5.0
ALCO PRODUCTS INC.
SCHEDULE
ENGINEERING – FABRICATION
TESTING – INSTALLATION
KEY
FINAL ENGINEERING
PROCUREMENT, FABR'TN & ASSEMBLY
DESCRIPTION
MONTHS
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
REACTOR VESSEL
STEAM GENERATOR
PRESSURIZER
PRIMARY SHIELDING
VAPOR CONTAINER
PRIMARY INSTRUMENTATION
CONTROL ROD DRIVES
CORE SUPPORT STRUCTURE
CORE
PRIMARY COOLANT PUMP
PRIMARY PIPING
PRIMARY SKIDS
TURBINE GENERATOR MODULE
CONDENSER "
AIR BLAST COOLER "
SWITCHGEAR "
FEEDWATER "
HEAT EXCHANGER "
INTERCONNECTING PIPING
INTERCONNECTING WIRING
ALCO PLANT TEST
DISMANTLE-PACKAGE-SHIP
SHIP TO SITE - ASSUMED
ERECTION ON SITE
ON SITE TESTING & FINAL CHECK OUT

6.0 PLAN FOR INSTALLATION OF THE PLANT AT A SITE

The installation plan which is herein outlined assumes that the building supporting piers and foundations for modules are installed by the government.

In order to erect the vapor container it will be necessary to install the top of the concrete shield after vapor container errection or install the complete concrete shield after vapor container installation.

6.1 Vapor Container Erection Procedure (Refer to AES-267)

a. Piece #1 will be rolled or placed by mobile crane.

b. Piece #2 will be placed and butted to Piece #1.

c. The above pieces will be aligned, bolted, secured to base and welded together.

d. So that there will be no holdup on the other module installations the primary skid will be skidded onto the vapor container bottom segment, aligned and secured. The reactor section with shielding will be skidded on segment first, then steam generator section will be skidded into place. The bases of each section will be aligned, doweled, bolted and the piping assembled at the flanged joints.

e. Pieces #3 and #4 opposite side will be installed using guide clips for fitting and aligning and the angle supports bolted to retain pieces in place. Use supports as shown or where there is clearance.

f. Pieces #5 and #6 opposite side will be installed using same procedure as in item (e). Use supports as shown, or where there is clearance.

g. The two parts of the access head will be welded together before installation and the same will be done with the rear elliptical head.

h. The top 90^{o} segment of V.C. will be installed and secured for welding.

i. Rear elliptical head will be installed, fitted and secured for welding.

j. Access head will be installed, fitted, secured and welded. The upper shield tank will be installed completing the vapor container structure.

k. Vessel shall be welded in accordance with ASME code for unfired pressure vessels.

l. All welds shall be 100% radiographed.

m. A helium leak test will be placed on vessel in accordance with test procedures.

6.2 Package Installation

During the V.C. assembly the main building modules will be installed in the following order.

1. Feedwater module will be skidded straight in from the side of building, the siding being left off until the module is installed.

2. The front panels of building will be left off or removed so that the remaining building modules can be skidded straight into building. The office, laboratory, and lavatory equipment and partitions will be installed after modules erected.

3. The air blast coolers will be installed on foundations upon arrival at site.

4. Interconnecting piping and wiring will be started as soon as modules are installed.

After completing the assembly of the vapor container the rigging crew will install the waste storage tank.

6.3 Erection Man Hours, Time, Equipment and Materials Required

It is estimated that approximately 8036 man hours will be required for the installation of the plant. On the basis of using 24 men as a minimum for the installation crew, 334 hours will be required for plant erection. Assuming a 10-hour day, 6-day work week for the installation of this plant, the total installation time will be approximately 5.5 weeks.

A breakdown of equipment and materials required for installation of the plant is as follows:

Description	Time
4 - 300 amp welding machines	Full period
1 - Air Compressor 315 CFM	Full period
1 - Air hoist	Full period
1 - 15 KW portable light plant	Full period
1 - 1/2" to 2" pipe cutting and threading machine	Full period
1 - D-4 Cat/w/winch and doser	Full period
2 - 2-ton chain hoists	
1 - 1-ton chain hoists	
Misc. tools, jacks	

Description	Time
Misc lumber (cribbing)	
Cat crane 15 ton capacity	1 month
Misc. angle iron 2", 3", 4" random to 20'-0"	
Torches and burning equipment	

A breakdown by trades and hours that will be required for installation is tabulated on the following page.

7.0 NUMBER AND QUALIFICATIONS OF OPERATING PERSONNEL

The following personnel are estimated as being required for the operation of the installed plant.

1. Plant superintendent	1 each
2. Shift engineers (Plant super. will handle day shift)	3 each
3. Operator (reactor console)	4 each
4. Mechanic	1 each
5. Instrument Technician	1 each
6. Process Control (HP & Chem)	1 each
7. Power Plant Electrician	1 each

The above will comprise the complete operating crew and should be set up by shifts as tabulated below:

Shift #1	Shift #2	Shift #3	Shift #4-Relief
Plant Super-Shift Engineer	Shift Engineer	Shift Engineer	Shift Engineer
Operator (reactor)	Operator	Operator	Operator
Turbine operator	Turbine Operator	Turbine Operator	Turbine Operator
Instrument Tech.			
Process Control			
(Health Physics & Chem.)			
Power Plant Elect.			
Mechanic			

The duties of each of the members of the operating crew are tabulated below:

Personnel	Duties
Plant Superintendent	Overall plant responsibility
Shift Engineers	Supervision of shift personnel and plant operations
Operators (reactor)	Console operator--under shift engineer
Turbine Operator	Responsible for turbine and misc. Turbine equipment operation
Instrument Technician	Responsible for Instru. control and on-call status
Process Control	Responsible for H.P. & Water Chemistry and on-call status
Power Plant Electrician	Responsible for all power plant electrical equipment and on-call status

While it is possible for two men to operate the plant under normal conditions which would prevail most of the time, we would recommend that three men be on duty at all times, namely; shift engineer, console operator, and a roving operator. The shift supervisor would be able to relieve either of the others and be available to act and assist during periods of emergency operations.

During the day shift when trained maintenance men and the plant superintendent are around, this third man may not be necessary.

The shift supervisor should be more experienced than the console operator but both should be well trained in the operation of the equipment involved. Both should be capable of rapid interpretation of data and capable of making decisions in an emergency.

The roving operator need not be so highly skilled but should understand and carry out such tasks as regeneration and checking of demineralizer, operate the oil purifier and operate the valves and equipment. He should be capable of being trained for console operator.

7.1 Qualifications of Operating Personnel

The qualifications of the operating personnel are listed as follows:

Personnel	Qualifications
Plant Superintendent	Mech. and Nuclear Engineering
Shift Engineers	Power Plant and Nuclear Plant Training
Electrical Supervisor	Electrical engineering

Personnel	Qualifications
Instrument Supervisor	Elect., Electronic or Mech. Engineering
Electrical Technician	Elect. and Electronic Training
Instrument Technician	Elect. and Electronic Training
Process Control	Health Physics and Chem. Engineering

8.0 PLANT RELOCATION FOLLOWING EXTENDED POWER OPERATION

The relocation of the plant can be accomplished without severe difficulty as far as the secondary system is concerned. The primary system will require special equipment and handling procedures for the relocation, depending on whether it will be a short haul or a long haul.

In order to relocate the reactor section of the primary module a special truck will be required to carry this section which will include the shield rings with a total weight of approximately 60,000#. It is necessary to include shield rings with reactor section due to possible high radiation level of the equipment.

On a short haul, this module can be relocated satisfactorily with the special truck. On a long distance relocation it may be more economical and practical to replace the reactor section of skid and vapor container.

Plans for relocation of the plant to a short haul site (within 1 mile) will require about the same numbers in manpower, vehicles, equipment, etc. as were required for the initial installation as described previously in section 6.

The procedure for handling modules and relocating to a new site will be the installation procedure in reverse with the exception of the primary system module which will require special attention and will be clearly explained later as a separate item.

The new site buildings and module foundations shall be completed before disassembly of plant. Hauling vehicles, transport equipment, hoisting equipment, manpower and other miscellaneous materials and equipment shall be at the disassembly site.

Disassembly and transporting of secondary system modules to a new location will take place simultaneously. Three pipefitting crews of two men each will start disassembly of interconnecting piping and clearly index same for re-erection. Two rigging crews of two men each plus two sled crews will remove packages as they are disconnected. The packages will be moved in the proper sequence of erection as explained in the initial installation procedure.

In order to relocate the primary module the fuel elements will be unloaded and stored in spent fuel tank.

The steam generator section of skid will be parted at flanged joints and unbolted at skid partition point, skidded out of vapor container onto sled and hauled to new location.

If the special sled is available to carry the reactor section of skid totaling 60,000#, it will be skidded onto sled and moved to new site. Personnel will avoid working around the back end which will have a dose rate somewhat higher than tolerance or about 2R. If the special sled capable of carrying 60,000# is not available it is recommended that a replacement reactor section and vapor container be manufactured and shipped to the new site for installation.

For relocating the plant in excess of 25 miles the same procedure will be required as used in the short haul with the following exception:

1. This plan will require sufficient hauling vehicles to handle all packages so that lags will be prevented in case of an exceptionally long haul.

2. Packages will be securely tied down on hauling vehicles and equipment protected from the elements by using tarpaulins or other covering.

The breakdown of men, materials, vehicles, equipment, and time required in each case are as follows:

Personnel	No.	Time Required
Riggers	4	6
Pipefitters (4 welders)	8	6
Electricians	4	6
Mechanics	4	6
Hoisting Engineers	2	5 weeks
Millrights	2	6 weeks

Equipment	Time Required
1 - 15-ton capacity cat. crane & crew	6 weeks
3 - 30,000# capacity hauling vehicles	5 weeks
1 - 60,000# capacity hauling vehicles	depends on distance to be hauled
4 - 10-ton hydraulic jacks	depends on distance to be hauled
Misc. lumber (cribbing)	-

Equipment	Time Required
2 - 300 amp. gas driven welding machines	6 weeks
D-4 cat. w/winch, doser & F.E.L. for utility	6 weeks
Air compressor 300 CFM gas driven	6 weeks
Air tugger (hoist)	6 weeks
1 - 15 KW portable lighting plant	6 weeks

Erection of Plant Modules - Manpower Breakdown

	Riggers M.H.	Pipe-Fitters	Elect.	Insul. Lab.	Hoisting Engrs.	Millright	Total M.H.
2 Airblast coolers	320	330	64	128	84	108	1034
Turbo Gen. Module	280	320	192	128	42	150	1112
Condenser Module	160	310	192	128	22	42	854
Heat Exch. Module	160	320	192	128	22	42	864
Feedwater Module	160	410	212	128	22	42	974
Switch gear Module	180		256	128	42	65	671
Primary System & V.C. Module	700	425	350	128	84	108	1795
Spent Fuel Pit, H.Waste Module	110	110	50	128	42	42	482
Misc.							250
	2070	2225	1508	1024	360	599	8036

Trades and Hours Required for Erection of Plant at the Site

	M.H.
2 - Millrights	599
4 - Riggers	2070
8 - Pipefitters (4 Pipefitter Welders)	2225
4 - Electricians	1508
4 - Laborers or Mechanics	1024
2 - Hoisting Engineers	360
24	7786
Misc	250
	8036

9.0 ESTIMATED COSTS

As per contract requirements DA-44-009-ENG-3638 the estimated cost of complete plant and packages excluding cost of shipment to a site, cost of site preparation, foundation and building costs, erection and installation labor or cost of overhead cranes and hoists, plant facilities such as lighting etc. is $1,955,000 F.O.B. Alco Plant, Schenectady, N.Y.

The above cost includes the cost of vapor containment and air blast coolers. It is estimated that deletion of the vapor container will deduct $25,800 from the above total estimated cost.

Comparative costs for condenser cooling systems using air blast coolers and cost of condenser cooling system using 40°F well water is given in Section IV of this volume.

III PRIMARY SYSTEM MECHANICAL AND INSTRUMENTATION DESIGN

1.0 REACTOR VESSEL (DRAWING NO. AEL 389)

1.1 Description

The reactor vessel drawing AEL 389 has been designed in accordance with Case 1234 of the ASME Unfired Pressure Vessel Code which refers to vessels subject to gamma radiation. The cover flange, shell flange, shell and nozzles are low alloy steel forgings overlaid with stainless steel. Dished stainless clad heads provide the end closures. A removable cover at the top provides access to the vessel core. The lower portion of the vessel contains penetrations and mounting provisions for the five control rod drive mechanisms.

The coolant nozzles are located below the active core of the reactor. The mounting flange for the core structure is located between the nozzles and, with the core structure, becomes the flow divider between the inlet and outlet chambers of the vessel. The coolant enters the vessel through the lower nozzle, flows upward through the core, down between the thermal shield and the vessel wall and out of the vessel through the upper nozzle. A certain portion is by-passed between the core and the thermal shield to provide adequate cooling of the thermal shield. The core support plate is mounted on brackets attached to the vessel wall. Provision is made by dowels and bolting to properly secure the support plate, still leaving freedom for differential thermal expansion between the vessel and support plate.

Low alloy carbon steel, clad with type 304 stainless steel, has been selected for the vessel material.

1.2 Design Data

Design Pressure	2000 psi
Design Temperature	600°F
Design Stress	17500 psi
Wall Thickness	2-3/8 in.
Overall Length of Vessel	125-5/16 in.
Overall Length of Vessel without Head	102-5/16 in.
Inside diameter of Vessel	37-3/4 in.
Insulation Thickness	2 in.

1.3 Thermal Shield Requirements

A single two inch thick thermal shield has been added to keep the thermal stress at the vessel wall to a level consistent with Code Case 1234 which allows thermal stress to be up to 50% of the pressure stress.

1.4 Closure Design

The reactor cover is secured in place by 18 - 2-3/4 diameter studs and nuts. The pressure seal is made by use of an octagonal dead soft stainless steel ring. This type of closure has been used on APPR-1 and has given excellent service.

1.5 Control Rod Drive Penetration

To provide penetration of the control rod drive tubes through the shield tank a water jacket is provided. This jacket consists of 5 inch diameter tubes surrounding the drive tubes with flanges at each end. These flanges are welded to the shield tank inner and outer walls at assembly of the reactor vessel in the shield tank. This method of construction eliminates the need for a separate water box as used in APPR-1.

1.6 Insulation and Jacket

The entire vessel and cover are encased in a stainless steel jacket to minimize heat losses from the vessel. The two inch space between the vessel and jacket is filled with glass wool insulation.

2.0 DESCRIPTION OF THE SKID MOUNTED CORE

2.1 Core Description

The skid mounted core is composed of 32 fixed fuel elements of APPR-1 Core II Specifications, 5 control rod fuel elements of APPR-1 Core II Specifications, and 5 boron absorber sections of APPR Core I Specification. These elements are arranged in the basic 7 x 7 element array of APPR-1 with three elements missing in each corner. This results in a core which has an equivalent diameter of 20.16 inches and an active height of 22 inches. The arrangement of the 37 elements in the core support structure and control rod baskets is very similar to that of the APPR-1 which has proven itself from all viewpoints.

2.1.1 Fuel Element Description

Each stationary fuel element consists of 18 fuel plates 0.020" x 2.50" x 22" with 0.005" thick stainless steel cladding on each side of the plate. The water gap between plates is 0.133". The control rod fuel element plates are 0.020" x 2.281" x 21.125" with 0.005" steel cladding. There are only 16 plates to a control rod fuel element. The water gap is also 0.133". A flux suppressor 0.020" x 2.281" x 0.875" is above the control rod fuel element meat. It consists of 1 gm of europium in the form of Eu_2O_3 dispersed in a low cobalt stainless steel.

2.2 Material and Nuclear Parameters

The material composition of the core includes 18.5 kg of U-235, 16.7 gm of B^{10}, 172.1 kg of S.S., and 91.5 kg of H_2O. The core will provide 10th MW of power for one year at 0.8 load factor. There is a negative temperature coefficient of reactivity at all temperatures which keeps the core stable during changes in the power level (-3.4×10^{-4} °F $°F^{-1}$ at 512°F). The maximum reactivity occurs at the beginning of operation and decreases with core lifetime.

More extensive nuclear parameter data is given in the previous section of the report. From the wealth of experimental data on the APPR-1, the characteristics and core performance of the skid mounted reactor can be accurately determined.

2.3 Startup Neutron Source

The startup neutron sources incorporated in the skid mounted core are:

1. a 15 curie Po-Be source
2. a 0.5" x 3" x 12" Beryllium block, a "photoneutron" source utilizing gamma radiation from fission products.

The combination of these neutron sources will insure a sufficiently large count rate at the neutron counters. In order to insure a safe startup, the sources are designed to achieve 10 counts per second at all times. The Po-Be source gives 32 counts per second at the start of core life. This falls off during core lifetime, and therefore a photoneutron source consisting of a beryllium block was added. The count rate at 1000 hours of operation and 10 days shutdown from the photoneutron source is 85 counts per second. At the end of core life, the photoneutron source gives a count rate of 28 counts per second.

A new Po-Be source must be used everytime a new core is inserted into the reactor.

2.4 Spent Fuel Pit Criticality

Calculations were performed to determine the criticality of a spent core in the spent fuel pit. The reactivity in the spent fuel pit criticality must at no time be greater than 0.70.

To insure subcriticality of the spent fuel pit, the stored fuel element should be placed in individual cells of a lattice possessing the following characteristics.

1. Minimum height of lattice is equal to that of the active fuel element height with element in stored position.
2. Lattice material consists of 1% boron steel in 1/4" plates.
3. Center to center dimension of an individual cell is 3.5".
4. For shielding and cooling purposes the entire pit is filled with water.

The reactivity of such a spent fuel pit loaded to maximum capacity (52 elements) with fresh APPR-1 type elements will not exceed 0.70 and hence pose no criticality problem.

3.0 CONTROL ROD DRIVES (DRAWING NO. R9-11-1018)

The control rod drive mechanisms are identical with minor modifications to those used so successfully in APPR-1 and being built for APPR-1a. They are of similar type to the Alco built drives now in operation in ALPR and the back up prototype for EBWR which has been thoroughly tested at ANL. Alco is now building similar drives for ACF for the Elk River Boiling Water Reactor.

Basically the drive consists of a rack and pinion with associated shafting inside the primary system, a mechanical seal to control leakage of primary water where the drive shaft penetrates the reactor vessel wall, and the external assembly comprising the position indication mechanism, emergency scram clutch, an accelerating spring and drive motor. The torque capacity of the clutch exceeds that necessary to raise the control rods by a factor of nearly 3. A shear element is provided at the motor to protect the mechanism from excessive torques resulting from possible malfunction of the limit switches, improper installations, etc. Torque capacity of nearly ten times that necessary to raise the rods is provided at this point and all other component stresses have safety factors well above this.

Driving speed of the rods, both up and down, is 3" per minute. Release time of the scram clutch is approximately 50 milliseconds and acceleration of the rods in the downward direction is ample to insert negative reactivity at a rate sufficient to shutdown the reactor on an emergency basis under both steady and transient power conditions.

An accelerating spring has been added to the basic APPR-1 drive to provide an additional downward force on the control rod during scram. While the overall control rod weight has been reduced from the 72 lbs of APPR-1 to 45.5 lbs. there has also been a considerable reduction in the pressure drop across the core which acts against the rod in scramming. The net result shows a slight decrease in scram time (.4 g for APPR-1 vs. .37 g) for a free falling rod. It was therefore deemed prudent to incorporate the accelerating spring mechanism of APPR-1a but using a lighter spring of approximately 20 lbs. to give a resultant rod acceleration of approximately .7 g. This type spring mechanism has been installed with good results on the Alco built ALPR rod drives now in operation at Arco.

Rod position indication is by means of 2 synchros which are gear driven on the rod side of the scram clutch. Thus, position indication is positive for both normal operation and after a scram. Rod position can be read within less than 0.050". Limit switches are provided to prevent overtravel in both the full up and full down positions.

The seal is an all-metallic unit of the floating ring labyrinth type. Leakage under operating conditions is approximately 3 lbs. per hour per seal and has remained essentially constant over long operating periods in APPR-1 without maintenance. Makeup water is provided under pressure to the reactor side of the seals so that leakage from the seals is essentially pure makeup water which is returned to the demineralizers for reuse in the system.

All elements of the drive system external to the reactor vessel, including the seal, can be removed for maintenance or replacement without draining or depressurizing the primary system. All adjustment of the limit switches, synchros, etc., can be made on the bench prior to installation to minimize the time required for replacement of drive components in the pit. Drive motor is conventional, commercially available three phase unit with integral spur gear reduction.

Bearings, motor, tear box and other components external to the reactor vessel employ conventional lubricants and insulation. Structural parts external to the reactor vessel are made of stainless steel or other corrosion resistant material to permit operation in high humidity atmospheres without experiencing damaging corrosion. All parts and components are interchangeable without shimming or fitting or installation.

4.0 STEAM GENERATOR

4.1 Description

As shown in the accompanying drawings, the steam generator is a kettle type unit, a U-bend, double pass, tube-in-shell, heat exchanger, horizontally mounted. Overall dimensions are 11' - 7½" long and 4'-2-5/8" wide (exclusive of side nozzles and support attachments). Dry weight is 17,600 lbs. and flooded weight is 22,850 lbs.

4.2 Selection of Horizontal

The kettle type design has been selected because it employs fully understood technology and poses no difficult or unanticipated stress concentration problems, such as occur with risers when a separating drum is used. Also, fabrication is more economical and quicker. The only other type worth considering is the vertical type, and for this particular installation, the 9' dimension limitation does not make it practical. Similarly, final field welding under Arctic conditions did not seem practical.

4.3 Operating and Design Conditions

Steam purity from the steam generator is 98%. This readily accomplished in the kettle type and is allowable here because of the line dryer being installed immediately before the turbine throttle valve. The separator built into the generator is the simplest type of dry pipe.

Tube side operating conditions are 1750 psig, 518°F. in and 500°F out. Shell side operating conditions are 465 psia, 306°F. in and 463°F out. Vapor generation rate is 24,000 lbs. per hour with a continuous blowdown of about 170 lbs. per hour.

Tube side design conditions are 2000 psig and 600°F. Shell side design conditions are 800 psig and 600°F. Test pressures are at 50% above design ratings.

In general, for the steam generator the following additional operating requirements hold:

Heat Load	23,000,000	Btu/hr
Primary Flow	2500	GPM
Pressure Drop	13	Ft.(Tube side)

4.4 Construction and Maintenance Features

Material specifications are shown on Drawing No. H47210-3-2. A bolted cover is used on the channel end and the primary fluid is retained within a permanently welded gasket, assuring full integrity of the system. The advantage of this bolted head over a welded one is better access to tubes for inspection and repair, since working through the small openings is impractical both for fabrication and field servicing.

Finally, further economy is possible by fabricating the channels, tube sheet and primary fluid nozzles of carbon steel overlayed with Type 304 S.S. Welding the tube sheet to the shell, and the tubes to the overlay, is then possible without encountering any bi-metallic weld problem.

4.5 Revisions for 10 MW Operation

The same steam generator can be used for 10 MW operation by modifying the number of tubes in the steam generator, but maintaining the same nozzle configuration and size.

For the 10 MW requirements which are listed below, 263 tubes are required while for the 6.5 MW 176 tubes are required. The tube lengths are the same for each case.

This results in a weight of approximately 11600 lbs. for the 6.5 MW steam generator and 17,600 lbs. for the 10 MW steam generator.

Conditions for the 10 MW steam generator are:

Heat Load	35,000,000	Btu/hr
Primary Flow	4240	GPM
Pressure Drop	13	Ft. (Tube Side)

5.0 PRIMARY LOOP PRESSURE DROP

The following calculations have been made for the total pressure drop in the primary coolant loop. Pressure drops for the active core and steam generator tube section have been determined elsewhere and the results only are presented here.

Pressure drops through the various fittings and restrictions of the loop were determined by obtaining velocity head loss coefficients to apply to the local velocity head. Sources used for these coefficients were "The Reactor Handbook", Volume Two and J. K. Vennard "Elementary Fluid Mechanics".

The primary loop can be divided into three major sections: piping, reactor vessel, and steam generator. A summary of the loop pressure losses is presented in Table 5-1.

5.1 Piping

Flow of 4240 gpm in 10 inch schedule 120 pipe develops a velocity head of 6.90 feet of fluid. Piping losses were subdivided into the friction loss. Fittings included:

1 - 90 deg. L.R. ell, 1 - 90 deg. S.R. ell, 2 - 45 deg. L.R. ells and 1 - 45 deg. S.R. ell.

5.2 Steam Generator

Pressure drop through this steam generator was divided into entrance and exit losses and tube friction loss. The tube friction loss has been determined elsewhere. Entrance and exit losses were based on abrupt expansion and contraction losses respectively.

5.3 Reactor Vessel and Core Pressure Drop

Entrance: the entrance loss to the reactor vessel was examined in two parts; the conical diffuser section and the abrupt expansion into the lower plenum chamber. The abrupt expansion loss was assumed to be the total velocity head at that point.

Core: See Reactor Analysis Thermal and Hydraulic Section.

Annulus: The contraction outside the top of the thermal shield was treated as an abrupt entrance and a gradual enlargement with the pressure drop based on the local velocity head.

Exit: The reactor vessel exit loss was considered due to an abrupt contraction from an infinite area with a correction for the rounded edges.

5.4 Total Drop in Primary Loop

Table 5-1 indicates a total loop head loss of 23.96 feet. This result is slightly conservative since no correction was made for the close proximity of various fittings. Also the assumption of total velocity head loss at the reactor vessel entrance may be slightly conservative since some velocity will be maintained in the plenum chamber.

TABLE 5-1

Pressure Loss in Primary Coolant Loop

LOCATION	HEAD LOSS (Ft. H_2O)
Pipe Friction	.56
Pipe Fittings	1.84
Reactor Entrance Nozzle Cone	.44
Reactor Entrance Abrupt Expansion	.93
Reactor Core	2.12
Thermal Shield Annulus	.90
Reactor Vessel Exit	.92
Steam Generator Entrance	1.81
Steam Generator Exit	.94
Steam Generator Tubes	13.5
Loop Total	23.96

6.0 PRIMARY COOLANT PUMP

6.1 Description

Flow of the primary coolant is powered through an hermetically sealed, integral liner - motor pump*, engineered and manufactured for zero leakage

*Centrifugal Type

in nuclear power service. This unit is equipped with a double thrust bearing assembly in the top of the motor, the unit being vertically mounted. All parts in contact with the fluid are fabricated of Type 304 stainless steel. The canned motor is a 30 HP, 1200 RPM, 440 volt, 3 phase, 60 cycle unit. Total weight of this equipment is 3700 lbs.

6.2 Design and Operating Data

Primary coolant pump operation for 6.5 MW primary system operation is as follows:

Capacity 2505 GPM
Fluid Temperature 500°F
Pumping Head 24 ft. water
Formal System Pressure 1750 psi

The pump is to be capable of pumping the liquid at a temperature of 100°F and the motor drive is sized accordingly.

6.3 Revision for 10 MW Operation

The primary coolant pump volute with inlet and outlet nozzle size and configuration can be used for 10 MW operating conditions which are listed below.

The horsepower requirements are increased to 65 HP for the 10 MW condition. The same motor frame size is used for both cases except that the RPM required is 1800 for the 10 MW and 1200 for the 6.5 MW.

Conditions for the 10 MW primary pump are:

4240 GPM	-	Capacity
500°F	-	Fluid Temperature
43 Ft. Water	-	Pumping Head
1750 psi	-	System Pressure

7.0 PRESSURIZER - AEL-348

The pressurizer is mounted in a vertical position in the primary loop and has the function of maintaining a constant system pressure, and to absorb the pressure variations caused by the changes in load on the system.

7.1 Description

The pressurizer is a cylindrical pressure vessel with hemispherical heads. It is designed in accordance with the ASME Unfired Pressure Vessel Code, using a material of stainless steel type 304. It has an inside diameter of 25-1/2 inches with a nominal wall thickness of 2-1/8 inches in the cylindrical portion and a nominal thickness of 1-1/4" in the hemispherical heads. The design pressure is 2000 psi at 650°F. The overall vessel length is 6'-0".

Steam saturation temperature and pressure is maintained by commercial type electric heaters mounted in individual heater wells located in the lower section of the pressurizer. The heater wells are sealed against system water making replacement of heaters possible without having to drain the primary systems. Twenty heaters, are arranged in two banks of 10 heaters each, having a total output of 30 KW, each heater producing 1.5 KW. Clearance between heater element and the wall of the heater well is held to a minimum to obtain a maximum heat transfer efficiency. The heaters are seated in the heater wells by weatherhead end connectors designed to withstand full system pressure should a leak occur in the heater well.

Normal operating pressure of the pressurizer is 1750 psi and operating temperature is approximately 620°F (saturation temperature).

7.2 Volume Requirements

The steam volume of the pressurizer is 7.6 cubic feet, and the liquid volume is 3.6 cubic feet under normal operating conditions, at full load. The normal liquid water level is approximately twelve (12) inches above the centerline of the lower row of heater well tubes. The variations in steam and liquid volumes, and transient conditions are covered in detail in the Reactor Analysis Section.

8.0 PRIMARY PIPING

8.1 Description

The components of the primary system are connected by 304 stainless steel pipe. Pipe runs and elbows are standard pipe with a nominal outside diameter of 10.75 inches and a nominal inside diameter of 9.064.

All pipe flanges are standard ASA weld neck type, made of 304 stainless steel. All welded connections are made in the shop using the consumable insert method. Ends of the pipe are machined and beveled on outside to permit full penetration welds. Reactor vessel nozzles are made of carbon steel with a type 304 stainless steel overlay. At the point of pipe and nozzle weld connection, the nozzle has an extra heavy overlay so that all weld connections in the primary loop involve similar materials.

The pressurizer connection to the primary loop is made at the steam generator. This connection is a 2-1/2 inch schedule 80 304 stainless steel pipe.

The primary pump is connected into the primary loop using standard ASA weld neck type 304 stainless steel flanges. All breaks in the primary piping for skid shipment will take place only at the flanged connections at the steam generator. This involves two flange connections, one at the primary pump and one in the primary piping. Flange connections will eliminate all field welding of the relatively large primary piping.

8.2 Operating Conditions and Design Data

The primary piping design pressure is 2000 psi at 600°F and has been designed in accordance with the ASA code standards. The test pressure for the primary piping and flanging 2275 psi. The coolant flow rate through the primary loop is 2500 gpm. The actual operating pressure is 1750 psi and the core outlet temperature is 518°F.

8.3 Flanging and Gasket Description

The three weld neck flange bolted connections use 12 - 1-7/8 inch bolts. The gasket mean diameter is 12 3/4 inches and is of the octagonal type. It has a width of 5/8 inch and is made of dead soft type 304 stainless steel. This type gasket has been used with good success for the top vessel closure of APPR-1.

9.0 SHIELDING

The following sections contain a detailed description of shielding which has been designed for the skid mounted reactor.

9.1 Primary Shielding

The primary shielding of the skid mounted reactor is made up of concentric annuli of steel and water with the steel being covered with Boral. Boral is a dispersion of B_4C in aluminum; the boron absorbs thermal neutrons and therefore reduces activation and n-γ reactions of the steel. In the shield tank there are four 3-1/4 inch steel rings sandwiched between 1/8 inch Boral sheets. The Boral steel sandwiches are separated by 1-1/4 inches of water. The outer surface of the pressure vessel support ring and the inner surface of the shield tank wall are also covered with Boral. Drawing No. R9-46-1039 shows the primary shielding. Table 9-2 contains a complete description of the primary shielding.

9.1.1 Shutdown Dose Rate

All shutdown dose rates were calculated on the basis of infinite operation at 6.5 MW. In addition to the dose rate from the core and shield tank activation, activated corrosion products distributed throughout the primary loop contribute to the dose rate in the vapor container after shutdown.

Further details and calculations covering primary shielding are covered in the Reactor Analysis Section.

9.2 Secondary Shielding

Secondary shielding is provided in form of concrete around the vapor container as indicated on Drawing AEL-414. Further details and requirements are worked out in the Reactor Analysis Shielding Design Section.

9.3 Spent Fuel Shielding

Provisions are made for removing a spent core and storing until shipment for reprocessing.

Shielding is provided to protect personnel from the complete core whether in the pressure vessel or in the spent fuel pit and protect personnel while single elements are transferred from the pressure vessel to the spent fuel pit through a transfer chute.

9.3.1 Water Tank Above Core

The water tank above the core performs the function of shielding personnel transferring spent fuel elements from the pressure vessel to the spent fuel pit and also provides a medium for removing decay heat from the spent core in the pressure vessel. The actual height of water above the core is determined from shielding considerations.

The water tank height above the core has been sized so that during element transfer a minimum of seven feet of water is always above the fuel element. Through seven feet of water the dose rate one foot above the surface of the water is 54.6 mr/hr. This calculation was made for an average fuel element removal 24 hours after shutdown after infinite operation at 6.5 MW.

9.3.2 Shielding Spent Fuel Pit

At end of life, the spent fuel elements are transferred to a storage area where the elements are cooled down before being shipped for reprocessing. While the elements are in the spent fuel pit, shielding must be provided so that personnel working above the pit do not receive excessive radiation. The shielding is in the form of water placed above the spent core.

The dose rate was calculated for 11, 12 and 13 feet of shield water. For 11 feet of shield water, the dose rate was 11.6 mr/hr on top of the spent fuel pit. With 12 and 13 feet of shield water, the dose rates are 2.59 and 0.59 mr/hr respectively. The results of the calculation are given in Fig. 4-1 of the shielding design analysis. For a dose rate not higher than 5 mr/hr on the top of the spent fuel pit 24 hrs. after shutdown, approximately 11.5 ft of shield water is required above the center of the core.

9.3.3 Shipping Cask

After the core burns out, the spent elements are shipped for reprocessing. The shipment of radioactive sources is controlled by I.C.C. regulation. The required shielding for the spent fuel cask is based on the regulation that the dose rate one meter from the radioactive source be no more than 10 mr/hr.

The shipping cask was designed to hold six (6) spent fuel elements 90 days after shutdown as shown in Dwg. Nos. R9-48-2036 and D9-48-2035.

The required thickness of lead shielding to limit the dose rate one meter from the source to 10 mr/hr is 9.5 inches.

9.4 Demineralizer Shielding

Although the N^{16} activity in the primary system has a 7.4 sec half-life and therefore quickly dies after reactor shutdown, corrosion products are activated and distributed throughout the primary system constituting a source of radioactivity after shutdown. In order to remove the corrosion products, a resin-filled demineralizer is placed in the primary coolant blowdown line.

Since the demineralizer removes the activated corrosion products from the primary water and concentrates them, shielding must be provided around the demineralizer. Therefore, the skid mounted demineralizer will be operated in its own shipping cask which is shown in Fig. 6-1 in the shielding design analysis.

The demineralizer shipping cask as shown has 3 - 11/16 inches of lead around the sides of the demineralizer and 3 - 3/16 inches of lead on the top and bottom. In addition, the lead is contained between two 5/8 inch steel plates. This shielding will reduce the dose rate on the surface of the cask to 58 mr/hr during extended normal full power operation. I.C.C. regulations will be met at all times.

9.5 Waste Tank Shielding

The shielding of the waste tank is based on normal expected activity in the tank. This radioactive source consists of activity present in the normal waste of the plant. The measured activity on the surface of the APPR-1 waste tank containing normal plant waste is 20 mr/hr. From this, it can be concluded that there is no need of extra integral shielding on the waste tank.

Two feet of concrete is provided as shielding for the waste tank for normal corrosion product activity in the primary coolant, when the primary coolant is diverted to the waste tank. This results in a dose rate of 1/2 mr/hr on the outside surface of the concrete shielding.

9.6 Cooling Provisions in Reactor Lower Shield Tank

During normal operation, gamma and thermal energy released by the reactor vessel to the lower shield tank must be dissipated by an internal cooling coil.

The gamma heat loss has been evaluated as 71,000 Btu/hr maximum. The thermal heat loss ordinarily is through the air space between the reactor and lower shield tank to the vapor container space. For the purpose under consideration, however, complete stagnation of this air space is assumed and on this basis the maximum possible thermal flow to the shield tank by conduction is 8700 Btu/hr. (See calculations this section) The total design load of the cooling coil is therefore 79,700 Btu/hr. Other design criteria are:

1. Cooling coil water temperature rise = 100 - 130^{o}F
2. Shield tank water temperature = 150^{o}F
3. Overall heat transfer coefficient = 100 Btu/hr/ft^{2}/^{o}F
4. Coil pipe size = 1" type 304 S.S.

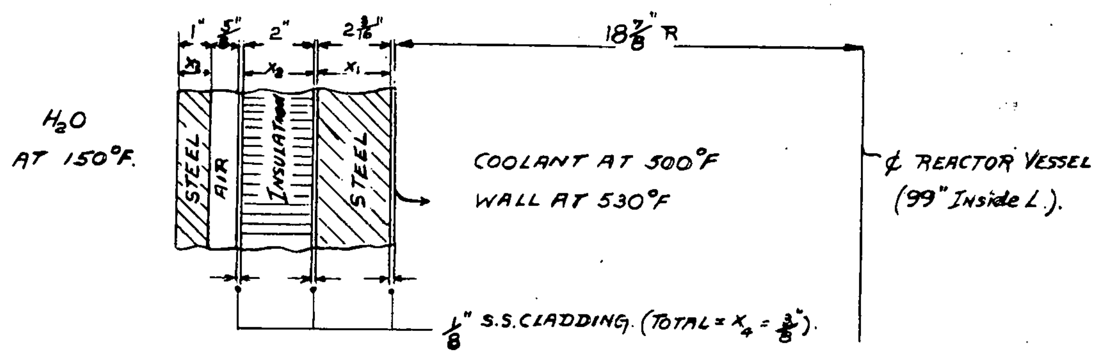
CALCULATIONS

OBJECTIVE : DISSIPATION OF GAMMA AND THERMAL HEATING AT REACTOR VESSEL

DESIGN BASIS:

1. GAMMA HEAT LOSS – 71,000 Btu/hr.
   (Verbal Comm. by T. Lence, Reactor Science Group. 1/12/59)

2. THERMAL HEAT LOSS.
   (To be calculated from sketch below)



A. THERMAL HEAT LOAD. (APPROXIMATION).
Loss computed on basis of conduction only and assumes airspace to be static.

$K_{CLADDING}$ = 16 Btu/hr/Ft/°F.

K_{STEEL} = 25 "

$K_{INSULATION}$ = 0.05 "

a_{air} = 1.3 Conductance Btu/hr/sq.ft/°F.

$$U = \frac{1}{\frac{1}{a_{air}} + \frac{x_1 + x_3}{K_{Steel}} + \frac{x_2}{K_{INSUL.}} + \frac{x_4}{K_{CLAD}}}$$

ALCO PRODUCTS INC.

BY W.R.Z DATE 1/13/59 SUBJECT Lower Shield Tank SHEET NO. 2 OF 3
CHKD. BY .... DATE .... Cooling Coils – 6.5 M.W. UNIT JOB NO. ....
Section 9.4

$$U = \frac{1}{\frac{1}{1.3} + \frac{0.265}{25} + \frac{0.167}{0.05} + \frac{0.031}{16}}$$

$$= \frac{1}{0.77 + 0.0106 + 3.34 + 0.0019} = \frac{1}{4.12} = 0.24$$

$$Q = U 2\pi R_{av} L \Delta t = 0.24 \times 6.28 \times \frac{22}{12} \times \frac{99}{12} \times 380$$

$$= 8700 \text{ Btu/hr.}$$

B. TOTAL HEAT LOSS

Gamma Loss	=	71,000 Btu/hr
Thermal "	=	8,700 "
TOTAL	=	79700 "

C. Cooling Coil AREA

1. DESIGN CRITERIA:

Coil water temp	=	100°F to 130°F (115°F Av)
TANK water temp	=	150°F
L.M.T.D	=	33°F

2. CALCULATION :

a). WATER FLOW lbs/hr $= \frac{79700}{30} = 2657 = 5.3$ g.p.m.

b). Velocity of flow. Ft/sec.

(ASSUME 1" S.S. PIPE: ID = 1.049" OD = 1.315"
INSIDE AREA = 0.006 Ft^2
SURFACE AREA PER LINEAL FT.
= 0.344 Ft^2).

$$v \text{ Ft/sec} = \frac{2657}{3600 \times 61.8 \times 0.006} = 2$$

3. Coil area:

$$A = \frac{79700}{100 \times 33} = 24.1 \text{ Ft}^2$$

(Coefficient U = 100 see Amer Soc. Htg & A.C. Engrs "GUIDE". 1958 Edition. p.1213.)

4. Cooling Coil Length:

$$L = \frac{24.1}{0.344} = 70 \text{ Ft.}$$

D. HEAD LOSS.

Use Fanning Formula for turbulent flow.

$$\Delta P_{100} = \frac{0.129 f \rho v^2}{d}$$

ΔP_{100} = Pressure drop per 100 Ft. pipe in p.s.i.
f = Friction factor.
ρ = Density of fluid flowing lbs/Ft^3.
v = Mean velocity of flow Ft/sec.
d = Internal diameter of pipe in inches.

$$\Delta P_{100} = \frac{0.129 \times 0.03 \times 61.8 \times 4}{1.049} = 0.91 \text{ p.s.i.}$$

Pressure Drop Through Coil = 0.64 p.s.i

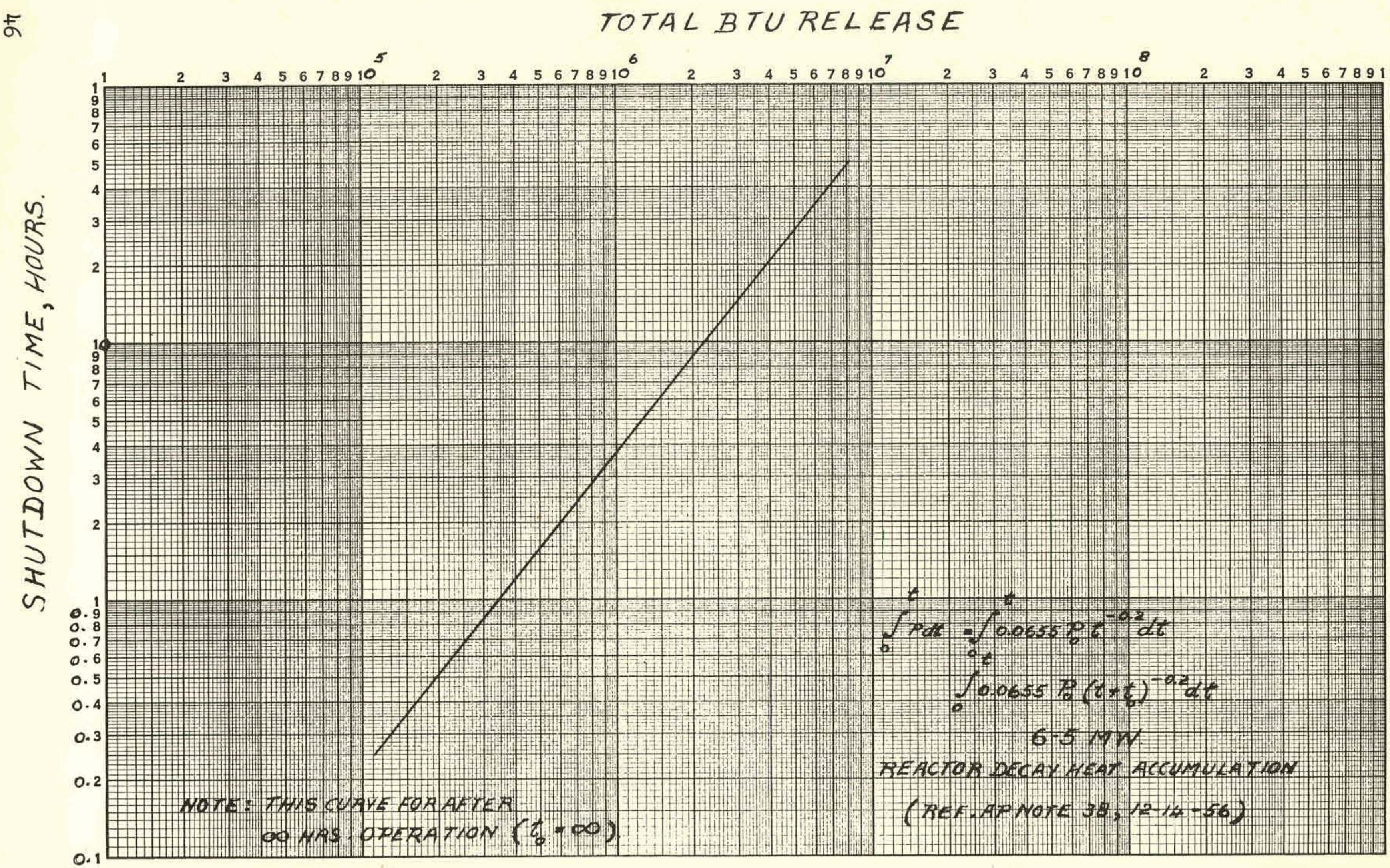


FIG. II

SECTION – 11.10

Cooling coil calculation indicates:

1.	Total cooling water flow	= 5.39 gpm
2.	Velocity of flow	= 2.0 ft/sec
3.	Required coil area	= 24.1 ft^2
4.	Cooling coil length	= 70 ft
5.	Loss of Circulating head	= 0.64 psi

10.0 PRIMARY SKID DESIGN

The primary skid carries the reactor vessel primary shielding, primary pump, pressurizer, steam generator, blowdown cooler and their necessary piping. In order to meet air shipment requirements the skid must be made on two halves.

10.1 Components on Primary Skid

The shield tank, shield rings, reactor vessel and primary pump are the main components on the reactor end of the skid. The seal leakage pump, and seal leakage tank are also located on this end of the skid. Because of shipping weight limitations the primary pump and the removable sections of the shielding will be shipped as a separate package. The reactor vessel cover will be removed for shipping to keep within the height limitations and a thin cover plate installed.

The steam generator, pressurizer, and blowdown cooler are the main components located on the steam generator end of the skid. The reactor vessel cover is carried on this skid during shipping.

10.2 Design Features

The main requirements of the design are to meet the size and weight requirements for air transportation, but yet be strong enough to withstand forces of 8 times gravity during shipment. Proper placing of the components on the skids to insure accessibility for erection and maintenance are also necessary.

10.2.1 Provisions for Air Transportability

In order to meet the size and weight requirements for air shipment, the skid is made in two halves. The parting line is directly under the flanges of the pump and primary coolant line near the center of the skid. The two halves of the skid are bolted together. Provision for lifting each half of the skid separately or as an assembly has been made. By using six points of suspension after bolting the deflection will be kept to an acceptable minimum.

10.2.2 Total Weights and Size of Complete Skid and Sections

The overall dimensions of the primary skid are, 23 ft. 11 in. long, 9 ft. 0 in. wide and 9 ft. 0 in. high. The total weight of the skid with the equipment in place is 91251 lbs. This does not include shielding water.

The reactor end of the skid with all its equipment in place weighs 64,619 lbs. and is 11 ft. 8.5 in. long, 9 ft. 0 in. wide and 9 ft. 0 in. high. This weight does not include primary or shielding water. With the shielding, cover and pump removed the reactor end of the skid weighs 28,388 lbs. The steam generator end of the skid with all its equipment in place weighs 20,600 lbs. and is 13 ft. 10.5 in. long, 9 ft. 0 in. wide and 9 ft. 0 in. high. With the reactor vessel cover on this skid for shipping the total weight is 23,311 lbs.

10.2.3 Description of Skid Bases

The basic construction of the skid drawing R9-42-1001 includes two 18 x 8-3/4 x 64 lb. "H" beams at the sides joined by cross ties and partial top deck. The weight requirement makes it necessary to build the skid in two halves. The parting plane is at the center of the skid and directly under the flanges at the steam generator. Fitted plates between the sections of the skids insure good field alignment. The halves of the skid are held together with bolting plates and ream bolts. Jacking screws are provided for leveling after installation of the skid in the vapor container.

11.0 VAPOR CONTAINER (DWG. NO. AEL-414)

11.1 General Description

The vapor container is a shop fabricated, cylindrical vessel made up of 3 segments and two heads which are welded together in the field. The size and weight requirements for air transportability make this construction necessary. Welding of the rear dished head of the vapor container is done after installation of the primary skid. Stress relieving of the field welds is not necessary to meet the code requirements for a welded vessel of this size and wall thickness. All welds are readily accessible for field X-ray.

An access hatch is located in the head at the steam generator end of the skid which is large enough to remove the primary pump or the steam generator bundle, if necessary. Most of the penetrations to the vapor container are also made in this head.

11.2 Normal Operating Temperatures

The operating temperature inside the vapor container is expected to be 120°F and 95% relative humidity. The temperature of the water in both upper and lower shield tanks is expected to be 150°F.

11.3 Vapor Container Design Conditions

A vapor container 13 feet in diameter by 38 feet long is necessary to contain the primary package and provide proper access for servicing. Subtraction of the primary component and shielding volumes leaves a new volume of approximately 4200 ft^3 of air space available for expansion of released coolant in case of rupture.

The vessel has been designed according to the ASME Unfired Pressure Vessel Code for failure of either the primary or secondary system. It has also been so designed that in case of the remote possibility of both a primary and secondary system rupture that the stresses in the vessel are well below both the yield and ultimate strength of the materials. A design stress of 25,000 psi which is approximately one third the ultimate and two-thirds the yield for Grade 212-B material was selected. This results in a vessel wall thickness of 3/4 inch. Release of either the primary or secondary coolant results in a stress in the vessel of approximately 80% of the code allowable.

11.4 Fabrication Features and Materials

To meet the shipping requirements, the vapor container will have to be sectioned and assembled on the site. Each head will be in two pieces and the cylindrical portion in 8 pieces. Erecting lugs will be installed at the factory and the sections prefit to insure proper installation in the field. The materials of construction are carbon steel SA 212 for the main cylinder and heads. The shield tank will be carbon steel clad with 304 stainless steel on the inside.

The wiring for the motors and instrumentation will be carried in a trough along the top of the vapor container and dropped down at the appropriate locations for connection to the primary components.

11.5 Upper Shield Tank

The upper shield tank is a cylindrical pressure vessel having an inside diameter of 9'-10" and an overall length of 14'-6". The primary function of this tank is to shield personnel while refueling the reactor core.

11.5.1 Description and Material

The upper shield tank is designed in accordance with the ASME Unfired Pressure Vessel Code using a design pressure of 150 psi at 500°F. The material for the tank walls and cover is SA-212 carbon steel with a 304 stainless clad. All flange connections are made of SA-212 carbon steel with a 1/8 in. thick 304 stainless steel overlay. All flange bolting material is SA-193-B7 carbon steel.

The tank walls have a nominal overall clad plate thickness of 3/8 inches, and the 2:1 elliptical cover also has a nominal overall clad plate thickness of 3/8 inches.

Cooling and decay heat removal coils are located in the shield tank and pertinent data pertaining to them is given as follows:

Upper Shield Tank:

1.	Coil design based upon load	=	150,000 Btu/hr
2.	Cooling coil water temperature range	=	100-130°F
3.	Shield water temperature	=	150°F
4.	Overall heat transfer coefficient	=	108 Btu/ft²/hr/°F

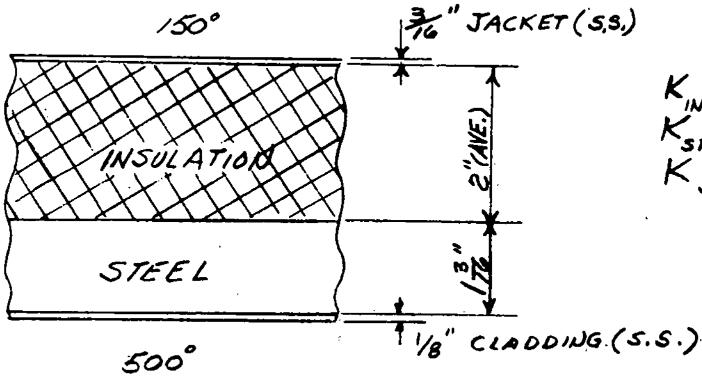
UPPER SHIELD TANK
COOLING COIL
SECTION 11.5.4

CALCULATIONS

OBJECTIVE: DISSIPATION OF THERMAL LOSS FROM REACTOR HEAD DURING OPERATION

DESIGN BASIS:

1. AMBIENT TEMPERATURES – 500°F FOR PRIMARY COOLANT INSIDE REACTOR HEAD AND 150°F FOR WATER RESERVOIR IN UPPER SHIELD TANK. CONVECTION IS NEGLECTED.
2. CAP INSULATION – FIBERGLAS
3. AVERAGE THICKNESSES USED TO OBTAIN REASONABLE APPROXIMATIONS (CF. DWG. AEL389)
   APPROXIMATE HEAD DIA. FOR CALCN. = 24"



$K_{INSULATION} = 0.05$
$K_{STEEL} = 25.$
$K_{S.S.} = 16.$

1. HEAT LOSS THROUGH INSULATED CAP

$$Q = UA\,\Delta T$$

WHERE
$$U = \frac{1}{\frac{X_{SS}}{K_{SS}} + \frac{X_{INSUL.}}{K_{INSUL.}} + \frac{X_{STEEL}}{K_{STEEL}}}$$

$$A = 1.09D^2 \quad \text{(ELLIPSOIDAL HEAD AREA)}$$

$$\Delta T = 500 - 150 = 350°F.$$

$$X_{INSUL.} = 0.167'$$

$$X_{S.S.} = 5/16 \times 1/12 = 0.026'$$

$$X_{STEEL} = 0.1'$$

THUS
$$Q = \frac{1.09(2)^2(350)}{\frac{0.167}{0.05} + \frac{0.1}{25} + \frac{0.026}{16}} = \frac{1530}{3.34 + 0.004 + 0.0016}$$

$$= 457 \text{ BTU./HR.}$$

UPPER SHIELD TANK
COOLING COIL
SECTION IV 11.5.4

2. HEAT LOSS THROUGH FLANGE (NEGLECTING CLADDING AND LIQUID FILM RESISTANCES).

BY GRAPHIC ANALYSIS THE FLANGE SHAPE FACTOR HAS BEEN FOUND TO BE

$$S = \frac{N \text{ (No. OF LANES)}}{I \text{ (No. OF ISOTHERMS)}} = \frac{12}{6} = 2.$$

$$Q = KL\frac{N}{I}\Delta T$$ (CF. P.16, HEAT TRANSMISSION BY McADAMS, 2ND ED.)

WHERE $K = 25$

$$L = \pi D_{AVE.} = 3.14 \times \frac{28}{12} = 7.32'$$

$$\Delta T = 500 - 150 = 350°F.$$

THEN $Q = 25(7.32)2(350)$

$= 128{,}000$ BTU./HR.

THEREFORE, COIL DESIGN CRITERIA WITH ALLOWANCES IS TAKEN AS 150,000 BTU./HR.

3. COOLING COIL AREA

USING THE SAME BASIS AS IN THE LOWER SHIELD TANK COIL FOR 1" S.S. PIPE, SCHED. 40, AND DISREGARDING VELOCITY INCREASES

$$A = \frac{150{,}000}{108\ (33)} = 42 \text{ FT.}^2$$

4. COOLING COIL LENGTH AND CONFIGURATION

WITH 1" PIPE, AREA PER FT. = 0.34 FT.^{2}
AND REQUIRED LENGTH IS

$$L = 42/0.34 = 124 \text{ FT.}$$

WITH A TANK DIAMETER OF 60", A COIL ℄ DIA. OF 56" CAN BE USED FOR EACH TURN, KEEPING THE COIL 1" AWAY FROM THE INSIDE WALL.

LENGTH OF EACH TURN = 14.6 FT.
No. OF TURNS REQ'D. = 124/14.6 = 8.5

UPPER SHIELD TANK
COOLING COIL
SECTION 11.5.4

5. FLANGE SURFACE TEMPERATURE (BY EVALUATING THERMAL DROP ACROSS FREE CONVECTION FILM)

BASIS: FLANGE DEPTH = 7.375"
FLANGE O.D. = 40.25"
FLANGE I.D. (AT SHOULDER) = 28"
STUD NUTS – No. = 18
THICKNESS = 3.5" } OVERALL
WIDTH = 5.0" }

$$\text{STUD AREA} = \frac{18\pi \times 5 \times 3.5}{144} = 6.86 \text{ FT}^2 \text{ (VERT. SIDES)}$$

FLANGE AREA (VERTICAL)

$$= \frac{\pi(40.25)(7.38)}{144} = 6.45 \text{ FT}^2$$

FLANGE AREA (HORIZONTAL)

$$= \frac{\pi}{4}\frac{(\overline{40.25}^2 - \overline{28}^2)}{144} = 4.55 \text{ FT}^2$$

TOTAL 17.86 FT^2 (CALL 18).

$Q_{CONDUCTION} = 25(7.32)(2)(500 - t_s)$ (CF. P. 2)
WHERE t_s = SURFACE TEMP.

$Q_{CONVECTION} = 18\, h_c\, (t_s - 150)$ (CF. FOR h_c, FIG. 128, P. 246, McADAMS HEAT TRANSMISSION)

BY TRIAL AND ERROR COMPUTATION, t_s IS FOUND TO BE 219-220°F., AT WHICH POINT THE HEAT FLOWS ARE 103,000 B.T.U. / HR.

WITH A 15 FT. HYDRAULIC HEAD, GIVING A 21.2 P.S.I.A. PRESSURE AT THE CAP, THE BOILING POINT IS 230°F. AND t_s IS APPROX. 10°F. BELOW THIS.

Upper Shield Tank (Cont'd):

5.	Coil pipe size	=	1" Sched 40 S.S. pipe
6.	External coil area	=	42 ft^2
7.	Required cooling coil length	=	124 ft.

Decay Heat Removal Coils:

1.	Coil design based upon load	=	351,000 Btu/hr
2.	Cooling coil water Temperature range	=	300-500°F
3.	Tank water temperature upper shield	=	212°F
4.	Overall heat transfer coefficient	=	150 Btu/hr/ft^2/°F
5.	Water flow	=	4.1 gpm
6.	Coil surface area	=	13.9 ft^2
7.	Coil length	=	32.0 ft.
8.	Coil pipe size	=	1 1/4" Sch. 40 S.S. pipe
9.	Loss of circulating head	=	0.21 ft of 62°F water

11.5.2 Reactor Vessel Cover Storage Provisions

Provision has been made to permit reactor vessel cover storage in the upper shield tank.

11.5.3 Shielding Water Depth Requirements

A minimum of 7 feet of water is required above the uppermost part of the fuel element during any fuel handling operation. The normal depth of the shielding water is 18'-6" above the core center line which will allow the necessary water above the fuel element while being transferred from the core to the transfer cask.

11.5.4 Provisions for Cooling

An upper shield tank cooling coil is required during normal operation to dissipate the heat losses from the reactor vessel head and flange.

The top head of the reactor is an elliptical, dished head which is covered with a fiberglas insulation inside a 4/16" stainless steel jacket. Average thickness of this covering is two inches.

Based on ambient temperatures of 500°F for the primary coolant inside the reactor head and 150°F for the water reservoir in the upper shield tank, and using the vessel dimensions shown in Dwg. No. 389, thermal conduction losses through the insulated section of the reactor head are found to be negligible (457 Btu/hr).

DESIGN BASIS:

RATE OF HEAT RELEASE AFTER 36 HRS = 86000 Btuh
HEAT TO BE REMOVED – DESIGN BASIS = 100,000 Btuh

A. COOLING COIL AREA:

1. Design Criteria:

Coil Water Temperatures = 100° – 130°F (Av. 115°).
Tank Water Temperature = 150°F
L.M.T.D = 33°F

2. Calculation:

a. Waterflow, lbs/hr = $\frac{100000}{30}$ = 3330 or 6.7 g.p.m.

b. Velocity of flow, Ft/sec = v

(Assume ¾" S.S. Pipe: ID = 0.824" OD = 1.050". Inside area = 0.0037 Ft². Surface area per lineal ft = 0.275 Ft²).

$$v = \frac{3330}{3600 \times 61.8 \times 0.0037} = 4 \text{ Ft/sec.}$$

3. COIL AREA:

$$A = \frac{100000}{100 \times 33} = 30.3 \text{ Ft}^2$$

(Coefficient U = 100 – see Amer. Soc. Htg & A.C. Engr's "Guide 1958" p. 1213).

4. COOLING COIL LENGTH:

$$L = \frac{30.3}{0.275} = 110 \text{ Ft.}$$

B: HEAD LOSS:

Fanning Formula - turbulent flow.

$$\Delta P_{100} = \frac{0.129 f \rho v^2}{d} = \text{p.s.i}/100 \text{ Ft.}$$

$$= \frac{0.129 \times 0.03 \times 61.8 \times 16}{0.824} = 4.7 \text{ p.s.i}/100 \text{ Ft.}$$

PRESSURE DROP THROUGH COIL = 5.2 p.s.i

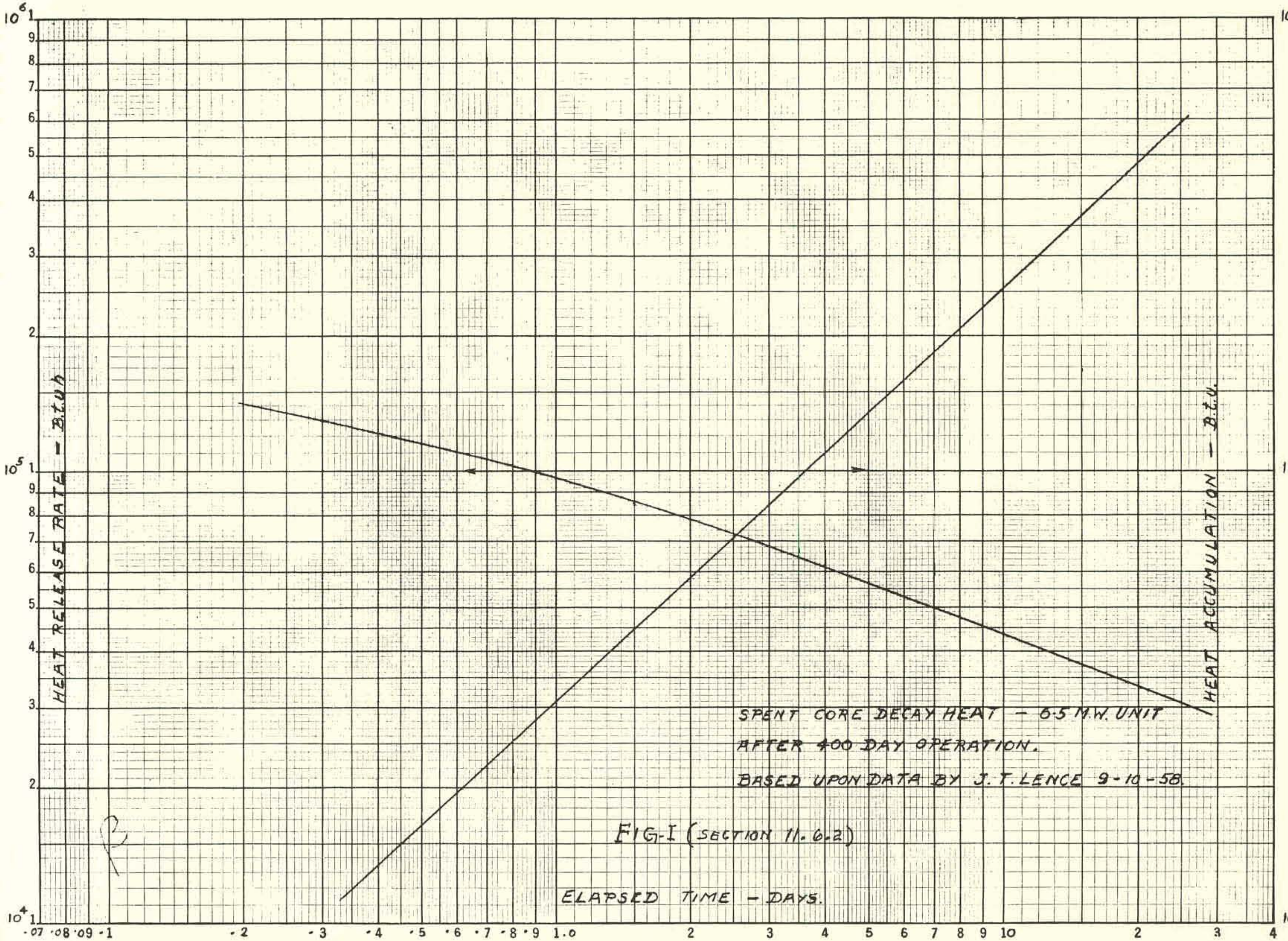


FIG-I (SECTION 11.6.2)

Consideration of the losses from the uninsulated flange, bolts, and nuts, reveals a much greater thermal flow through these portions of the vessel to the water reservoir. By graphic analysis the flange shape factor is found to be 2, and from the heat flow equation (p. 16, Heat Transmission by W. H. McAdams), the heat loss is found to be 128,000 Btu/hr. Allowing a 20% safety factor, so that the design criterion is 150,000 Btu/hr; the required cooling coil area is found to be 42 sq. ft., with a 1" schedule 40, S.S. pipe. The required minimum coil length is 124 ft.

Finally, evaluation of the thermal drop across the free convection film on the outside of the flange, by taking the total exposed metal area as 18 sq. ft. and balancing the conductive flow against the convective flow, yields a surface temperature of 219°F. With a 16½' hydraulic head, giving a 21.9 psia pressure at the cap, the boiling point is 233°F, considerably above the calculated metal temperature.

11.6 Spent Fuel Tank

11.6.1 Description and Materials

The spent fuel tank is located adjacent to the vapor container, but separated from it by concrete. The tank is approximately 18 ft. high, 9 ft. in diameter and is made of 1/4" thick stainless steel. A storage rack of 1/4% boron steel is provided to store a complete core. Space is provided for under water loading of two shipping casks.

11.6.2 Cooling Provisions

Cooling in the spent fuel tank is required continuously during normal operation to remove the decay heat from stored elements. The maximum condition assumed here is an entire spent core in the tank 36 hrs. after shutdown. At this time, the heat release rate is 86,000 Btu/hr (Cf. Fig. 1, Section 11.6.2), and a design basis of 100,000 Btu/hr has been selected.

Final design calculations yield a coil of 3/4 inch schedule 40 stainless steel pipe, 110 feet long. Circulation rate is 6.7 gpm with a 5.2 psi pressure drop.

11.6.3 Transfer of Spent Fuel Elements

The transfer of spent fuel elements to the spent fuel tank is accomplished by means of a spent fuel chute from the upper shield tank using a fuel handling system very similar to APPR-1.

Detail procedures and equipment requirements are given in Section 12 on Page 80.

11.7 Vapor Container Penetrations

The penetrations to the vapor container are made through the head at the steam generator end. There are, in this head, 12 water lines, 4 drain lines, one 4 inch steam line, and 11 electrical penetrations. The drain water and steam lines will be of varying size, but all require the same type of penetration. A nipple will be welded through the head and will be flanged on each end. The inside and outside prefabricated piping is attached to these flanged nipples with appropriate gaskets and bolts.

The electrical penetrations will also be a nipple welded through the head. A double ended cannon type plug will be used to make quick connections on both the inside and outside of the vapor container.

11.8 Space Cooler Requirements

Thermal heat losses from the reactor vessel, the pressurizer, the steam generator, the primary loop piping, and the lower shield tank necessitate the installation of a space cooler inside the vapor container. To the above losses must be added gamma heat generation during operation outside the lower shield tank.

For this evaluation of the heat accumulation in the vapor container, radiation losses have been taken into account, a temperature basis of 120°F in the space has been assumed, and no heat loss from the vapor container to the outside is considered, all heat removal to be through a finned, unit cooler circulating 100°F water.

Calculations show that the following heat buildup will exist in the vapor container:

Source	Flow
Gamma	3000 Btu/hr
Steam Generator	6700
Pressurizer	3020
Reactor Vessel	9100
Primary Piping	5430
Lower Shield Tank (Uninsulated)	12560
Total	39810 Btu/hr

To handle this load a self-contained unit cooler with integral fan has been selected.

11.9 Insulation Requirements

The vapor container is insulated to prevent excessive heat losses to the snow (ambient temperature - 15°F) and to keep the metal walls at a temperature (100-120°F) which will definitely be above the transition point, thus insuring maximum strength for a max crax condition.

ALCO PRODUCTS INC.

BY W.R.Z DATE 1/21/59 SUBJECT DECAY HEAT COOLING COIL — UNIT 6.5 MW SHEET NO. 1 OF 3
CHKD. BY .... DATE .... JOB NO. ....

A. DESIGN CRITERIA:

1. HEAT TO BE REMOVED PER HOUR = 351000 Btuh
   (For The 10 MW unit heat removed 540000 Btuh. For 6.5 MW unit heat removed in proportion.)
2. WATER TEMP. ENTERING COIL = 500 °F
3. WATER TEMP. LEAVING COIL = 300 °F
4. TANK WATER TEMP. UPPER SHIELD = 212 °F
5. L.M.T.D = 168 °F
6. COIL OPERATING PRESSURE = 1750 p.s.i.g
7. HEIGHT OF WATER COLUMN FOR CIRC. HEAD. = 9 ft.

B. COOLING COIL AREA and LENGTH:

(Assume $1\frac{1}{4}$" Sch. 40. SS pipe: OD = 1.66" ID = 1.38"
Internal area = 0.0104 ft^2. Surface area/Lineal ft = 0.434 ft^2).

1. Water flow in lbs/hr $= \frac{351000}{200}$ = 1755

   " " " g.p.m $= \frac{1755}{60 \times 7.17}$ = 4.1

2. Heat Transfer Coefficient:

$$U = \frac{1}{\frac{1}{h_o} + \frac{1}{h_i} + \frac{W}{K} + \frac{1}{f}} \quad \text{in which}$$

U = Overall coefficient. Btu/ft^2/hr/°F.

h_o = Film coefficient exterior pipe surface = 330 Btu/hr/ft^2/°F
(see p. 309 Mc Adams 2nd. Edition).

h_i = Film coefficient interior pipe surface = 600 Btu/hr/ft^2/°F
(see p. 183 Mc Adams 2nd Edition).

W = Pipe wall Thickness in ft = 0.012 ft.

K = Conductivity for type 304 S.S. = 16.2 Btu/hr/ft^2/ft/°F

f = Fouling resistance = 1000

$$U = \frac{1}{\frac{1}{330} + \frac{1}{600} + \frac{0.012}{16.2} + \frac{1}{1000}} = 150$$

3. COIL AREA "A" and COIL LENGTH "L".

$$A = \frac{351000}{150 \times 168} = 13.9\ ft^2$$

$$L = \frac{13.9}{0.434} = 32\ ft.$$

C. CIRCULATING HEAD:

$$H = \frac{(d_{300} - d_{500}) \times L}{144} = p.s.i$$

d_{300} = Density, water @ 300°F = 57.31 lbs/ft³
d_{500} = " " @ 500°F = 49.02 "
L = 9 ft.

$$H = \frac{(57.31 - 49.02) \times 9}{144} = 0.52\ psi$$

$$= \frac{0.52}{0.433} = 1.2\ ft,\ 62° \text{ water}$$

D. PRESSURE DROP "Δp" – Pipe and Fitting Resistance

1. PURPOSE OF "Δp" DETERMINATION
The circulating head must be equal to or greater than pipe and fitting resistance. Average coil water temperature is 400°F. By using "FRICTION CHART" p. 589 Amer Soc. HTG and A C ENGR'S "GUIDE" WHICH IS BASED ON 300°F THE ERROR MADE WILL BE ON THE CONSERVATIVE SIDE AND IS NOT OF MOMENT.

2. THE FRICTION CHART, FOR 1¼" PIPE AND A FLOW OF 1755 lbs/hr, INDICATES:

$$\Delta p = 0.175\ ft\ 62° \text{ water} / 100\ ft \text{ pipe length.}$$

3. EQUIVALENT LENGTH OF PIPE:

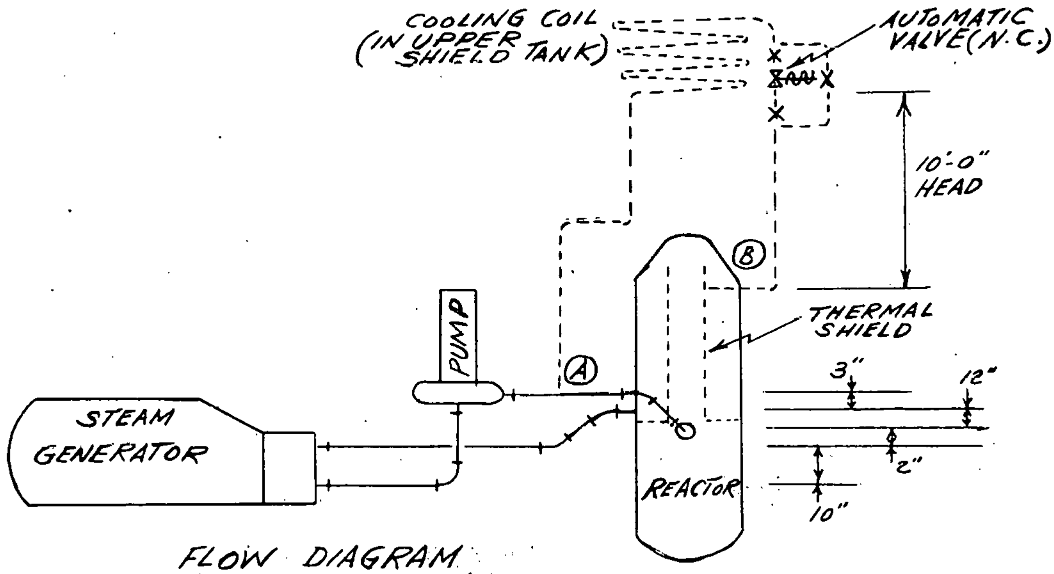
COIL = 32 ft
PIPERUN = 20 ft
FITTINGS AND VALVES
= 65 ft

TOTAL = 117 ft assume 120 ft.

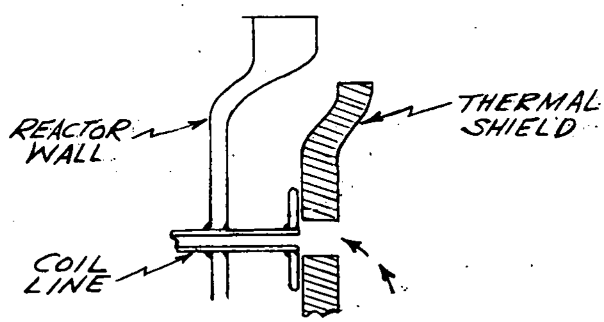
4. PRESSURE DROP:

$\Delta p = 1.2 \times 0.175 = 0.21$ ft against 1.2 ft available.

DECAY HEAT COOLING



FLOW DIAGRAM



REACTOR COIL TAP DETAIL

FIGURE 1
(SECTION 11.10)

11.10 Decay Heat Removal Analysis

11.10.1 Decay Heat Removal Provisions

In the event of power failure or primary pump breakdown, the reactor is scrammed automatically as soon as the primary coolant flow reaches 94% of full flow value. However, heat generation due to fission product decay constitutes a significant source of heat that must be removed from the core to prevent overheating. This decay heat accumulation is to be dissipated in the water reservoir of the upper shield tank. Transfer of the heat is accomplished by a cooling coil circuit that utilizes natural convection induced by the thermal head resulting from the decay heat. This separate system is necessary since the location of the horizontal steam generator below the reactor core level prevents adequate natural convection in the primary loop alone. The system is shown in Figure 1.

The automatic valve as shown in Fig. 1 prevents primary coolant from heating the upper shield tank during normal operation. In the event of pump failure, this valve is actuated at the time of reactor scramming; i.e., when the primary coolant has dropped to 94% of full flow value. The cooling coil will then be in operation when the primary flow due to inertia has decayed to a negligible value.

The cooling coil connections are as shown in Fig. 1 giving a 9 ft. height in order to obtain the needed circulating head.

After infinite hours operation, upon shutdown, the reactor decay heat accumulation during the first hour is 351,000 btu (Cf. Fig. II Section 11.10). Therefore, to accommodate this maximum condition a design load basis of 351,000 btu/hr was used. This assumes that the body of water is already at 212°F (boiling point) with the upper shield tank vented to the atmosphere. This is a condition that could exist and during this emergency period it will be necessary to maintain a water feed to the upper shield tank so that the boiled off water is replaced and the decay heat cooling coil is kept submerged at all times. In what follows the sizing of the cooling coil has been based upon the requirements of the 6.5 MW unit. For this unit, it was thought unnecessary to conduct an analysis with the analog computer similar to that performed in the case of the 10 MW unit.

11.10.2 Sizing of Cooling Coil

Preliminary design calculations yield a minimum coil length requirement of 32 ft. with 1 1/4", schedule 40, S.S. pipe. The thermal head attainable under the specified conditions is 0.52 psi at a flow of 4.1 gpm. Calculation of the decay heat cooling coil are included in this subsection.

11.10.3 Analysis of the Decay Heat Removal System

The sequence of events following failure of the primary coolant pump were investigated assuming the pump impeller becomes frozen. Initially, the reactor power is constant while the coolant flow rate decreases.

It was assumed that the coolant entering the reactor remained at its steady state value during this period and that the reactor power decreased only due to the effect of the negative temperature coefficient of reactivity. The reactor kinetic equations were solved for these circumstances yielding values of the average fuel surface temperature and the average coolant temperatures as a function of time. The design of this system provides for a low coolant flow scram initiated when coolant flow decreases to 94% of its steady state value. It was found that boiling did not take place before reactor scram.

By conservatively assuming a 1.55 second delay between pump failure and initiation of reactor scram, temperatures in the core were established.

TABLE I - NOMENCLATURE

Symbols:

A	Heat Transfer Surface Area, ft^2
C	Specific Heat , Btu/lb°F.
g	Acceleration due to Gravity, ft/sec^2
L	Length of Component, Ft.
P	Power Output of Core, Btu/sec
ρ	Density of Liquid, lbs/ft^3
R	Rate of Primary Coolant Flow, lb/sec
t	Time, sec
T	Temperature, °F
U	Overall Heat Transfer Coefficient, $Btu/ft^2/°F/Sec$
W	Weight, lb
x	Distance along tube, ft
z	Vertical distance, ft

Subscripts:

c	Mean Core Coolant Condition
D	Design Condition, Steady State
E	Mean Exchanger Coolant Condition
f	Friction Loss Term
F	Mean Fuel Plate Surface Condition
i	The i^{th} Increment
s	Mean Heat Sink Condition

Power was assumed to decrease linearly during the next 1.45 seconds to that level predicted as a result of decay heat only. The following equations were numerically integrated from 1.55 seconds after the accident:

$$W_F \, C_F \, \frac{dT_F(t)}{dt} = P\,(t) - A_F \, U_F \, (T_F\,(t) - T_c\,(t)\,) \quad (1)$$

$$W_c C_c \frac{dT_c}{dt}(t) = A_F U_F (T_F(t) - T_c(t)) - 2RC_c (T_c(t) - T_{inlet}) \qquad (2)$$

The rate of decay heat generation is given by: (8)

$$P(t) = P(o) \left(0.05225\, t^{-0.2} - 0.05225\, (t' + t)^{-0.2}\right) \qquad (3)$$

where: $P(o)$ = Normal power generation rate, Btu/sec.

= 9486 Btu/sec.

t' = reactor operating time, sec.

At the end of 23 seconds after pump failure the average fuel surface temperature (T_F) was found to be 600°F. The average coolant temperature (Tc) was 570°F. These temperatures established the initial conditions for the analog study of the heat removal system.

11.10.3.1 Analysis of the Heat Removal System

The performance of the heat removal system was analyzed by analog computer methods. It was assumed that the system did not make appreciable contributions until 23 seconds after the pump accident. This assumption is very conservative in light of the analysis in section 11.10.4 in which the cooling loop is shown to operate almost immediately after pump failure.

11.10.3.1.1 Analog Kinetic Model

A lumped kinetic model was used in which time lags in piping were neglected. (9) This is possible because the intervals investigated were long compared to these delays. Equations representing the temperature distributions in the system as well as the coolant flow rate through the heat removal coils were solved subject to the initial conditions existing at 23 seconds after the pump accident.

The rate of change of momentum of the fluid circulating in the heat removal loop was equated to the sum of forces acting on it. This yields a differential equation representing the coolant mass flow rate in the cooling loop.

$$\sum_i \frac{\Delta x_i}{A_i g} \frac{dR}{dt} + \sum_i (\Delta p_f)_i - \sum_i \rho_i \, \Delta z_i = 0 \qquad (4)$$

Evaluating the existing thermal head due to the position of the heat removal coils equation (4) becomes:

$$\frac{dR}{dt} = \frac{\gamma D}{\sum_i \frac{L_i}{A_i g}} (T_c - T_e - \frac{(\Delta p_f)_o}{\sum_i \frac{L_i}{A_i g}} \left(\frac{R}{R_o}\right)^{1.8} \tag{5}$$

The frictional pressure drop in equation (4) has been written as:

$$\sum_i (\Delta p_f)_i = (\Delta p_f)_o \left(\frac{R}{R_o}\right)^{1.8} \tag{6}$$

Here $(\Delta p_f)_o$ represents the calculated frictional pressure drop in the circuit at an assumed flow rate (R_o). The exponent 1.8 stems from a combination of basic turbulent flow relations. By choosing R_o larger than that expected to exist in the loop the exponent 1.8 can be conservatively replaced by 2. This function is simpler to generate on the analog computer.

Performing a heat balance on the fuel elements the lumped equation is:

$$W_F C_F \frac{dT_F}{dt} = P(t) - (U_F A_F)_o \left(\frac{R}{R_o}\right)^{0.8} (T_F - T_c) \tag{7}$$

The 0.8 power dependence of the heat transfer coefficient is in accord with the usual heat transfer equation of Nusselt:

$$N_N = \frac{h D}{K} = 0.023 \, (N_{Re})^{0.8} \, (N_{Pr})^{0.4} \tag{8}$$

By evaluating the heat transfer coefficient at an arbitrary flow rate (R_o) larger than that expected we may replace the exponent 0.8 by 1.

Similarly the equations for the other temperatures in the system become:

<u>Average Coolant Temperature</u>

$$W_c C_c \frac{dT_c}{dt} = (U_F A_F)_o \left(\frac{R}{R_o}\right) (T_F - T_c) - R C_c (T_c - T_E) \tag{9}$$

<u>Average Temperature of Coolant in the Heat Removal Coils</u>

$$W_E C_E \frac{dT_E}{dt} = R C_c (T_c - T_E) - (U_E A_E)_o \left(\frac{R}{R_o}\right) (T_E - T_s) \tag{10}$$

Average Temperature of Water in the Upper Shield Tank

$$W_s C_s \frac{d T_s}{dt} = (U_E A_E)_o \left(\frac{R}{R_o}\right) (T_E - T_s) - U_s A_s (T_s - 120) \quad (11)$$

11.10.3.1.2 Plant Operating Constants

$C_c = 1.27$

$C_E = 1.084$

$C_s = 1.004$

$C_F = 0.121$

$D = 8.70$

$R_o = 1.2$

$R_D = 466.8$ (at 4238 gpm)

$(U_E) = 0.0397$

$A_E = 22.6$

$U_s = 1.2916 \times 10^{-4}$

$A_s = 2447$

$\gamma = 4.62 \times 10^{-2}$

$$\sum_i \frac{L_i}{A_i g} = 216$$

$W_F = 429.7$

$W_c = 157.8$

$W_E = 28.7$

$W_s = 1.7689 \times 10^4$

$(\Delta P_f)_o = 21.191$ ft.

11.10.3.1.2 Time and Amplitude Scaling Factors

In order to keep the length of computing time at a minimum a time scale was chosen such that one computer second would be equivalent to ten real seconds. Thus the problem was solved in a time scale ten times faster that it actually takes place.

It was found that results could be more easily interpreted if a scaling factor of unity was chosen for problem amplitudes (one volt is equivalent to one physical unit). The resulting amplitudes were generated in sub-multiples to prevent them from exceeding $\pm$ 100 volts. A reference level for temperatures was established at 500°F. Temperatures were then generated above and below this reference level.

11.10.3.1.3 Potentiometer Settings

Servo set coefficient potentiometer values are listed in Table 2. Both the absolute magnitude of the setting and the physical symbols are listed.

Table 2

POTENTIOMETER SETTINGS

Number	Value	Physical Quantity
7	0.0970	10C/100
12	0.2604	$4U_E A_E 10^3/W_s C_s R_o$
18	0.0200	1/50
19	0.7000	70/100
38	0.3500	35/100
40	0.6337	$100/W_c$
41	0.5000	50/100
42	0.9617	$50/W_F C_F$
43	0.1465	$2U_F A_F/W_c C_c R_o$
45	0.4082	$10\ C_c/W_E C_E$
47	0.1857	$100\gamma\ D/\sum_i \frac{L_i}{A_i g}$
48	0.1857	$100\gamma\ D/\sum_i \frac{L_i}{A_i g}$
49	0.1626	$(\Delta P_f)_o R^2_o \frac{L_i}{A_i g}$
54	0.3880	38.8/100

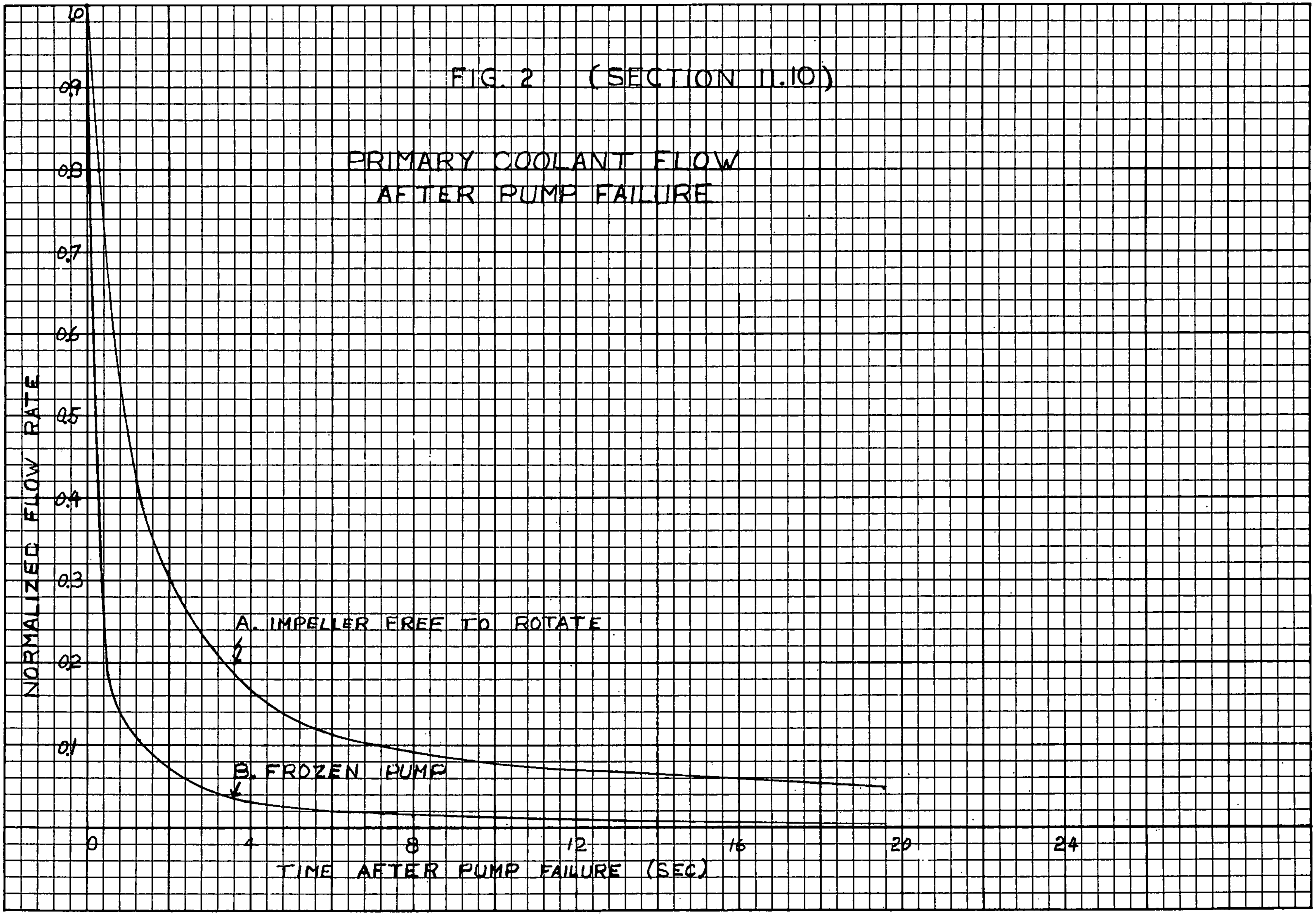


FIG. 2 (SECTION II.10)
PRIMARY COOLANT FLOW
AFTER PUMP FAILURE
NORMALIZED FLOW RATE
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
A. IMPELLER FREE TO ROTATE
B. FROZEN PUMP
0
4
8
12
16
20
24
TIME AFTER PUMP FAILURE (SEC)

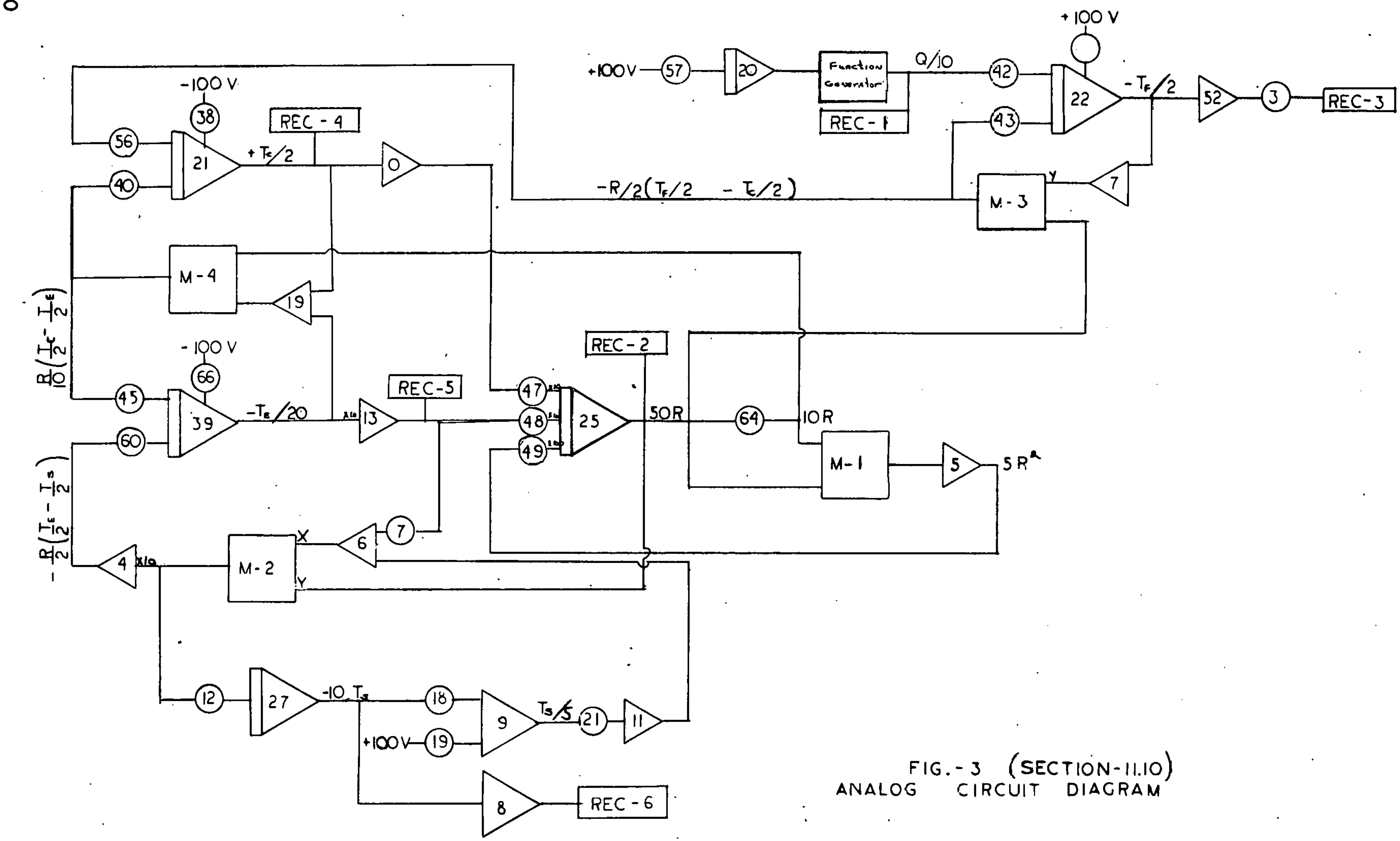
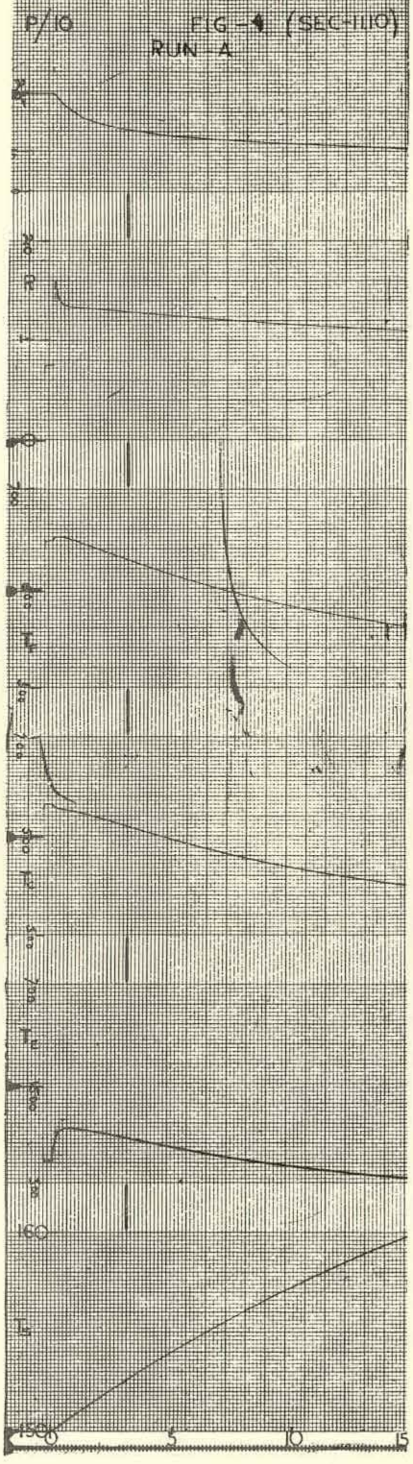
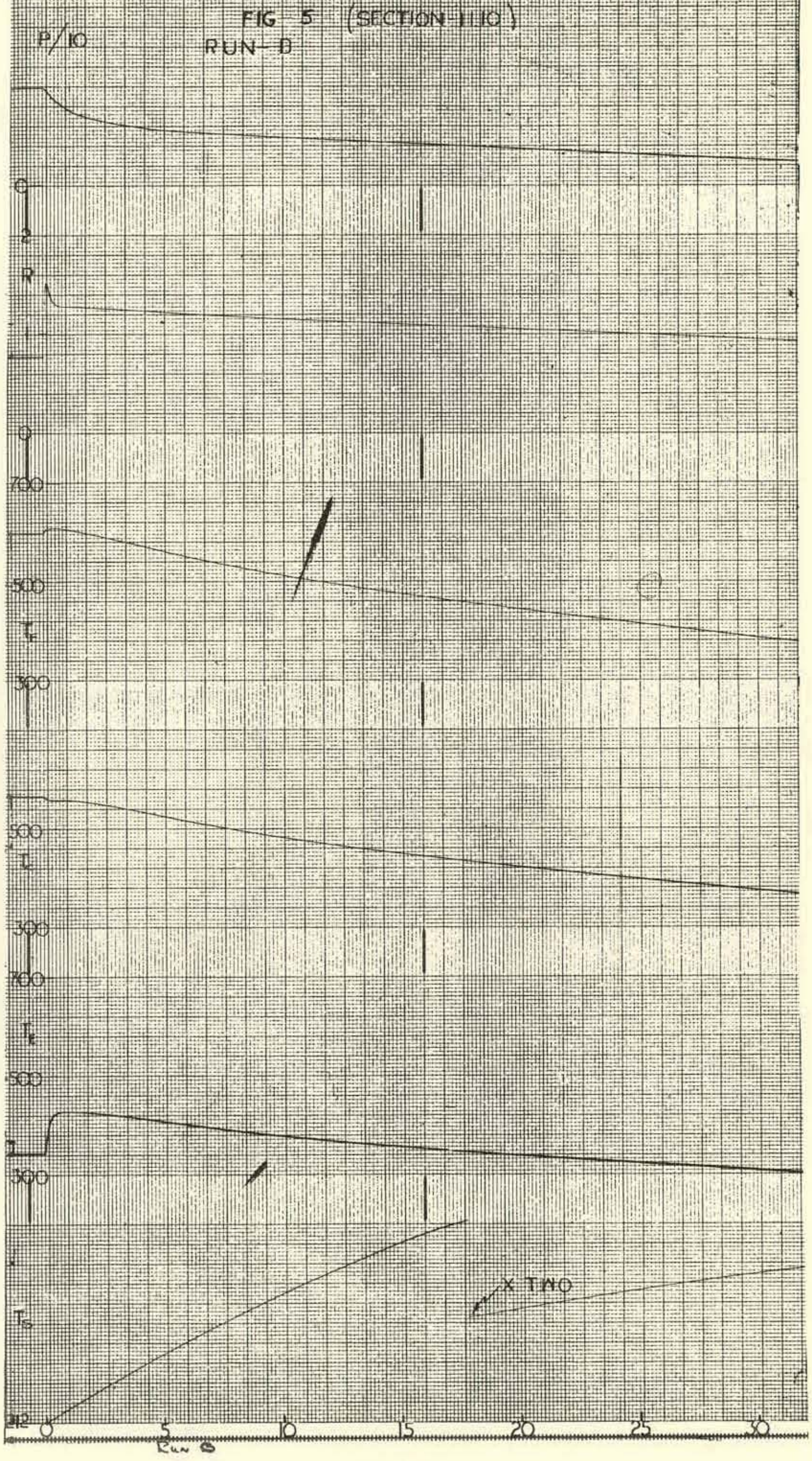


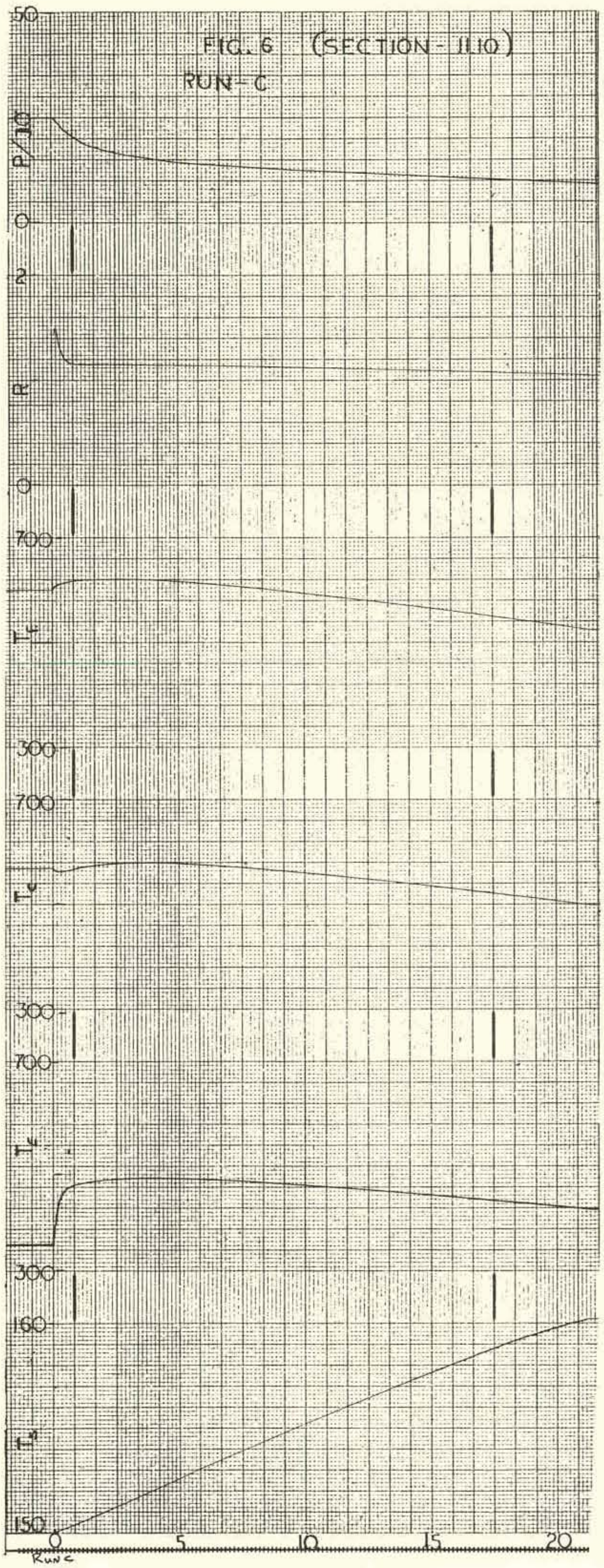
FIG.-3 (SECTION-11.10)
ANALOG CIRCUIT DIAGRAM



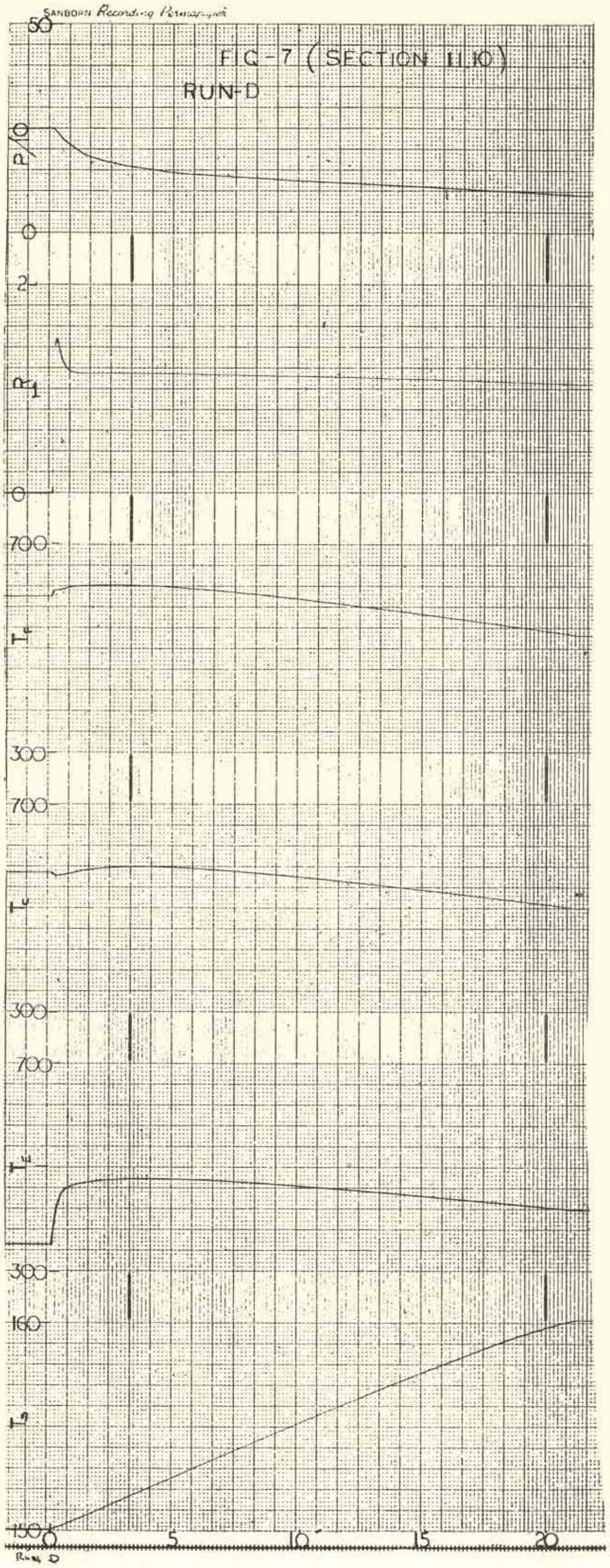
TIME (MIN)



TIME (MIN)



TIME (MIN)



TIME (MIN)

Table 2 (Cont)

Number	Value	Physical Quantity
56	0.3801	$20\ (U_F A_F)_o\ /W_c C_c R_o$
57	0.0100	1/100
60	0.0743	$2(U_E A_E)_o\ /W_E C_E R_o$
64	0.2000	1/5
66	0.8100	81/100

11.10.3.1.4 Analog Circuit Diagram

The analog circuit used in this study is shown in Fig. 3. The notation is the same as used in APAE-38. Feed-back connections have been shown in order to indicate the coupled nature of the problem.

11.10.3.2 Results of the Analog Analysis

Figures 4 through 7 indicate analog solutions under different initial conditions and plant parameters.

Run A most closely approximates the design parameters envisioned. It is seen from Fig. 4 that the average fuel surface temperature increases by 10°F after the decay heat removal system takes over. After a period of 30 seconds this temperature begins to decrease reaching 420°F approximately 15 minutes after pump failure. Since the hot channel temperature is considerably higher than the average fuel surface temperature, local nucleate boiling will exist there. The average coolant temperature never exceeds saturation. General boiling will not take place after pump failure.

The analog results were checked for consistancy by performing a heat balance on the entire system. This accounted for all heat generated within the limits of error of the problem.

11.10.4 Reverse Flow Analysis

During normal operation the automatic valve in the cooling coil circuit is closed. In the event of pump failure the valve opens when the primary coolant flow has dropped to 94% of full flow value. Valve is actuated by same signal that scrams reactor. At this instant some water at steam generator exit temperatures (500°F) will be forced into the cooling coil. Such flow is in the opposite direction of that intended for the cooling coil circuit; also, the presence of 500° F. water in the cold leg of the cooling coil circuit will reduce the thermal head intended for the decay heat removal.

However, analysis will show that if the valve is opened as early as the instant of pump failure, the undesirable flow will quickly reverse its direction and the original thermal head will re-establish itself. These conditions will be reached while there is still considerable flow due to primary coolant inertia. Hence, opening of the automatic valve as designated above will not interfere with the proper operation of the cooling coil.

Analysis upon which this conclusion is based follows.

The automatic valve will be assumed to open at the instant of pump failure. The amount of 500°F water pushed into the cooling coil loop will depend on how fast the primary pump driving head decreases. To be conservative in this computation it will be assumed that the impeller is free to rotate with coastdown following the curve A of Fig. 2*. Also, the force tending to drive the water into the cooling coil will be taken as that due to friction pressure drop of the primary coolant between points A and B of Fig. 1. This friction head at any given time will be based on the flow at the given time.

The force tending to prevent 500°F water from entering the cooling coil is due to the associated thermal head. At the instant of valve opening, this thermal head consists of a 13 foot cold leg (150°F) opposing a 13 foot hot leg 530°F. However, as soon as hot water (500°F) from the steam generator begins to push its way into the cold leg (with an equal amount of 150°F. water forced into the hot leg) the thermal head is reduced correspondingly. A parameter of this effect is the distance beyond point A of Fig. 1 that 500°F. slug of water has been forced into the cooling coil. Fig. 8 gives thermal pressure as a function of this distance.

A force opposing flow in either direction is the friction of the coil circuit itself. This force is negligible in this analysis until flow velocity in the coil has reached approximately 1.6 ft/sec. At this point, it is taken into account.

Newton's second law is applied to the mass of water in the cooling coil between points A and B of Fig. 1. "Up" is taken as the positive direction. Pipe size is 1-1/4 inches.

$$F_T = ma \qquad (1)$$

F_T is the sum of the three forces previously discussed.

---

* This curve was based on methods given in reference (10). Coastdown parameters incorporated follows:

Normal flow rate = 466 lb/sec

Total loop pressure drop = 39.31 ft.

Rated pump speed = 91.8 rad/sec

Moment of inertia, pump = 55 lb - ft^2

Rated efficiency = 65%

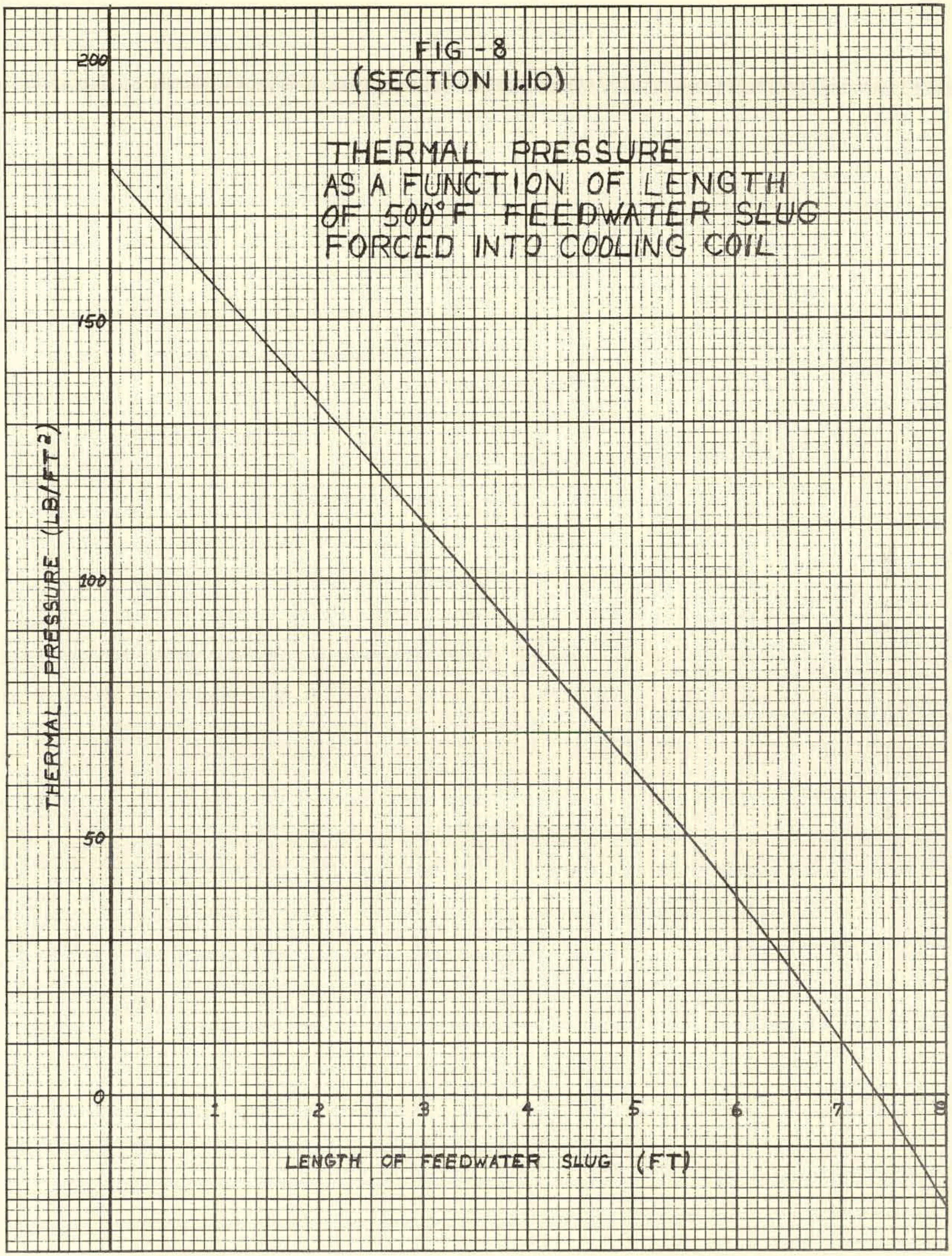
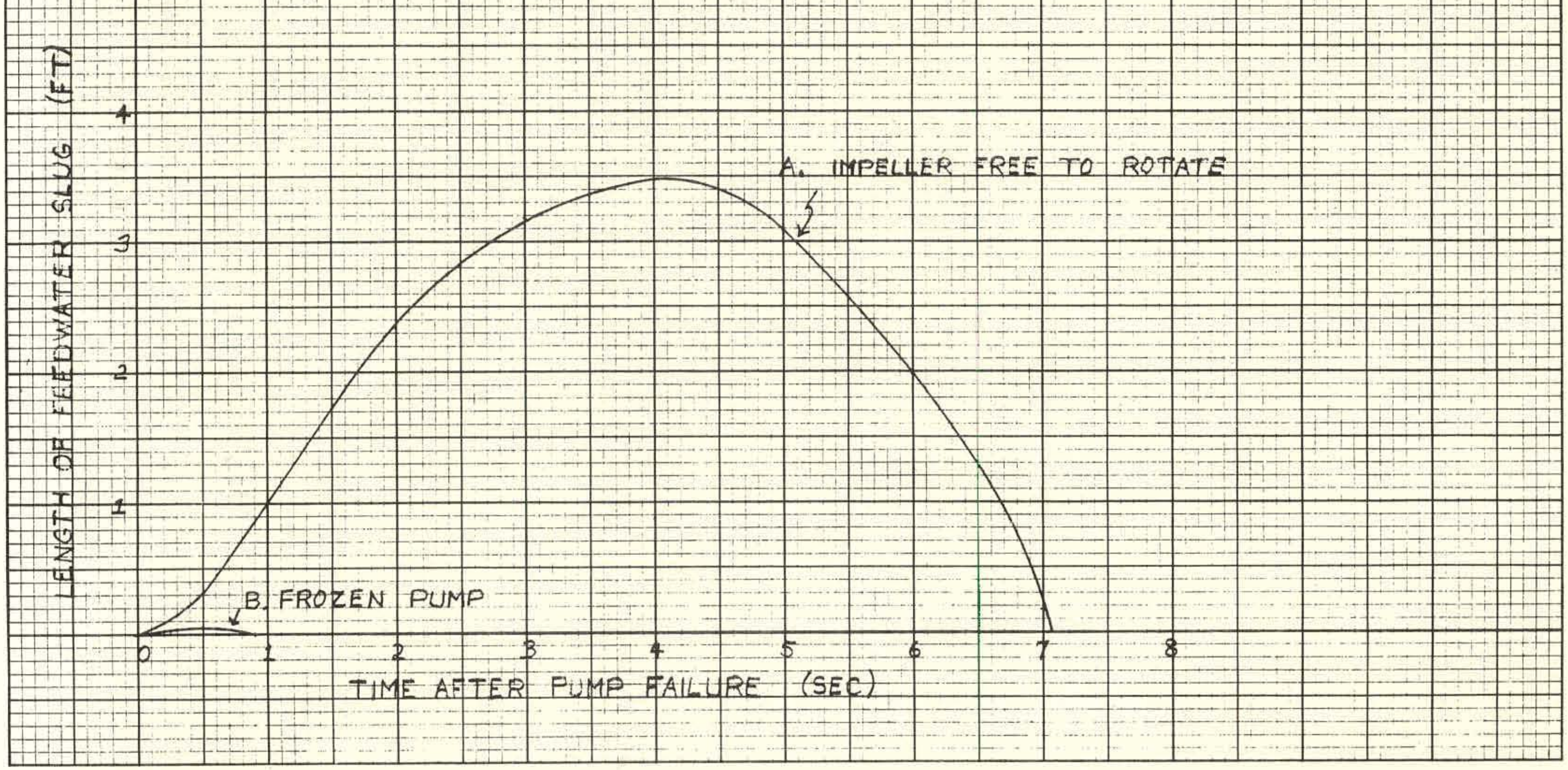


FIG - 8
(SECTION II.10)
THERMAL PRESSURE
AS A FUNCTION OF LENGTH
OF 500°F FEEDWATER SLUG
FORCED INTO COOLING COIL
200
150
100
50
0
1
2
3
4
5
6
7
8
THERMAL PRESSURE (LB/FT²)
LENGTH OF FEEDWATER SLUG (FT)

FIG. 9
(SECTION 11.10)

LENGTH OF 500°F FEEDWATER SLUG FORCED INTO COOLING COIL AFTER PUMP FAILURE



$F_T = F_f + F_{th} + F_\ell$

F_f = driving force due to friction drop of primary coolant between points A and B of Fig. 1 .

= $5.58\ G^{1.8}$ lbs (always positive)
Based on 10.6 ft. head at full flow

F_{th} = driving force due to thermal head

= values given in Figure 8 (always negative)

F_ℓ = friction force due to motion of cooling coil fluid

(assumed zero until v = 1.6 ft/sec)

$= 25 \left(\frac{v}{1.42}\right)^{1.8}$

G = normalized flow rate of primary coolant. Values as a function of time after pump failure are given by Curve A Figure 2.

v = velocity of flow in cooling coil pipe (ft/sec).

m = mass of water in cooling coil from point A to point B of Fig. 1.

= 1.19 slugs (assumed constant for this analysis)

a = acceleration of mass m. (ft/sec^2)

Once an average acceleration "a" has been established for a time interval, t, the corresponding velocity achieved (v) and distance traversed (s) during this interval may be determined from the following formulas.

$$v = v_o + a \Delta t \qquad (2)$$

$$= v_o \Delta t + 1/2\ a\ (\Delta t)^2 \qquad (3)$$

where v_o = velocity at beginning of time interval.

By solving equations (1), (2), and (3) for such discrete time intervals*, the motion of water mass m was established. Results are given in the form of a graph (Fig. 9, Curve A) showing the distance that the slug of 500°F. feedwater has moved into the cooling coil as a function of time after the pump failure and simultaneous valve opening. It can be seen that this water enters, reaches zero velocity, and is driven back out by the thermal head in about 7 seconds.

* Time interval was taken to be 0.5 seconds.

Comparison with Curve A of Fig. 2, indicates that at this time there is still approximately 10% of full flow through the main primary coolant loop.

An identical type analysis performed for the case of a frozen pump (flow coast down given by Curve B of Fig. 2) shows that is a negligible amount of steam generator exit water entering the cooling coil pipe. See Curve B of Fig. 9.

11.10.5 Results and Conclusions

In the event of primary pump failure the decay heat removal system is sufficiently adequate to prevent generalized boiling of the coolant within the core. The analysis is conservative in that it neglects heat lost through the pressure vessel cap.

The investigation was conducted both for the case of a frozen pump impeller and for the instance where normal electrical power is not available for the pump.

11.10.6 References:

(1) Table V, p. 315, Heat Transmission, 2nd Ed., by W.H. McAdams, McGraw - Hill, N.Y., 1942

(2) p. 86, Fan Engineering, Buffalo Forge Co. 1949
p.251, Proc. Eng'g. Calculations Manual, by L. Clarke, McGraw - Hill, N.Y., 1947

(3) Catalogs TT 330, 640, and 724, by Tube Turns, Louisville, Ky.

(4) p. 93, Cameron Hydraulic Handbook, Ingersoll-Rand, 1951
p.1610, Mark's Handbook, Fifth Edition

(5) Crane Co. Flow of Fluids Handbook, 1957

(6) AP Note 38 - "Reactor Power and Integrated Heat After Shutdown" by R.C. DeYoung.

(7) This Report - Part B - Kinetic Analysis Section 2.0 - "Reactor Behavior Following Pump Failure."

(8) Second United Nations Conference on the Peaceful Uses of Atomic Energy - Paper 1070 - J.R. Stehn and E.F. Clancy - "Fission Product Radioactivity and Heat Generation."

(9) APAE Memo 144 - Notes on Decay Heating After Power Failure by R.L. Murray.

(10) KAPL - M - TWT - 1 "Hydraulic Flow Transients" by T.W. Trout

11.11 Air Filtering

A ventilating system for the vapor container air space is provided for the primary section of the plant.

An external centrifugal fan and filter are installed with duct connections to and from the vapor container. A fresh air intake, a vent stack outlet and a filter by-pass are also provided with suitable manual valving for the various operations involved.

The "empty" volume of the vapor container is 5184 cu. ft. With a design air change of 100% every 15 mins., a fan capacity of 345 c.f.m. is required.

The filter housing, installed on the discharge side of the fan, holds two Cambridge 1D-1250 Absolute Filters in series. D type filters are selected because they are built to operate in 100% relative humidity air at temperatures up to 250°F. Their efficiency is 99.95% on 0.3 micron diameter particles. A specification set by the AEC for whom they are originally designed.

The filters are only used before the vapor container is to be entered, to bring the internal atmosphere down to a safe radiation level. Under this condition, the filters rarely become saturated according to APPR-1 experience.

12.0 FUEL HANDLING TECHNIQUE

12.1 Shield Tank Cover Removal

Assuming that the working area is clear the fuel handling technique covers the operations of opening the shield tank removing the spent fuel tube seal, opening the reactor vessel and changing fuel.

The first operation is to remove and store the shield tank cover. The cover is held in place by bolts and can be removed with an ordinary box wrench or power wrench. The cover is lifted with the overhead hoist and stored on the tilting rack provided on the outside rail of the working area.

The railings around the shield tank are set into the sockets provided and a drop light lowered into the tank.

12.2 Removal and Installation of Spent Fuel Tube Seal

The spent fuel tube seal will be removed next. Attach the upper end of the seal handling rod to the balancer and lower it into the spent fuel tube. When the operator can reach the upper end conveniently attach the tee handle to the seal handling rod. Slide the tool down the tube until the seal is contacted. Rotate the tool until the cross bar enters the first slot in the seal. Rotate the tool 90° until the tool enters the second slot in the seal. Rotate the tool further until the cross bar and the locking stud plate are engaged. Rotate the tool counter clockwise approximately 9 turns. Pull the tool out of engagement with the locking stud plate and rotate tool until it slides through first slot in seal. Rotate the tool clockwise and lift out of bayonet lock. Lift tool and seal up tube until tee handle can be disengaged. Continue lifting tool and seal out of the spent fuel tube. Store the tool and seal on the inside of the shield tank, in the socket provided. To reinstall the seal reverse the above procedure. The spent fuel tube seal must be removed before the vessel cover is opened and put back in place after the vessel cover is in place so that no damage will be done to the core if it is dropped.

12.3 Removal and Storage of Vessel Nuts and Cover

Next the Sweeney wrench will be used to loosen the vessel cover nuts. Before lowering the wrench into the tank check the direction of rotation of the wrench. When removing the nuts the socket turns counterclockwise, and for tightening, clockwise. To change direction of rotation the wrench portion of the tool must be turned over. The following method is used to accomplish this: Loosen the two socket head cap screws that hold the wrench to the bottom plate; remove the snap ring that holds the socket in the wrench; raise the input shaft clear of the wrench; lift the wrench, turn it over and set it back into the sockets on the bottom plate; tighten the two socket head cap screws; slip the socket in place and reinstall the snap ring; lower the input shaft into its socket.

With the aid of the over head crane start to lower the bottom half of the tool into the tank. When the operator has sufficient clearance to the crane rails the top half of the tool can be slipped into its sockets and the tool can be lowered to the vessel cover. Position the tool across the vessel cover so that the two anchors fit on two of the nuts and the socket is on the nut being loosened. If the socket does not line up with the nut the input shaft should be rotated until it does. Approximately 75 half turns of the work handle will be required to loosen the nut. The work handle should be used at all times, except for final tightening of the nuts.

When tightening nuts with this type of wrench the socket tends to become locked on the nut, so a release pawl is provided. A "T" handle fits into the socket of the release pawl. To release the socket, rotate the input drive clockwise until the "T" handle can be rotated counterclockwise. While holding the "T" handle engaged rotate the input drive counterclockwise to the end of its travel.

In the case of loosening nuts no specific pattern must be used, but in tightening the pattern should be as follows. Tighten two diametrically opposite nuts to about 100 ft. lbs on the tension indicator. Then tighten two nuts at right angles to the first pair to full torque or 175 ft. lbs. Retighten the first pair to full torque. From this point on no specific pattern has to be followed.

After all the nuts have been tightened the Sweeney tool can be removed from the tank and stored in the corner of the floor extension.

The nuts must now be removed from the vessel studs and stored on the dummy studs. A 16 foot Tee handle with a universal joint and a socket on the lower end is used to perform this operation. This tool has a bail on top and <u>must</u> be suspended from the over head balancer at all times. The socket has two detents in it which line up with holes in the faces of the nut. After engaging the socket on the nut a slight downward push will engage the detent balls. The universal has been provided to reduce the bending moment imposed on the threads by the long handle. The tool is merely turned until the threads disengage and the nut lifted and moved to the dummy stud. The nut need only be turned on the dummy stud 3 or 4 turns. A slight upward "tug" will release the socket from the nut. As the nuts are being stored the 3 stud caps must be installed on 3 studs approximately 120° apart. One should be placed near each of the lifting lugs.

After storage of the nuts is complete the vessel cover must be broken loose from the gasket. Using the same long Tee handle, as the previous operation, but without the universal joint, and the small socket provided turn the 4 jack-screws to lift the cover slightly off its seat. Back off the jack screws so the cover can be reseated on the gasket when it is put back.

Now the sling can be attached and the cover stored. With the sling attached to the overhead crane lower the hooks to the cover, making sure the safety locks on the hooks are open. By grabbing the cable the hooks can be swung into the pin and hooked in place. Apply slight upward pressure with the overhead crane, enough to put slight tension in the cables. With the stud cap runner on the tee handle engage the square on the end of the locking pin of the hook and close the lock. The leg of the sling with the "tugit" hoist must be engaged with the pin which lies on the radial centerline of the vessel cover. After all 3 hooks are installed center the overhead crane over the center of the vessel. Lift the cover straight up about 3 feet. Flip the lever on the tugit hoist to the up position and raise the cover to a vertical position. Raise the cover, with the overhead crane until it clears the rack and move the cover over the rack. Lower the cover into the rack. Release the sling from the overhead hoist and attach to the rail.

The rotating platform is used to allow the operator to get closer to the center of the core when installing or removing caps, control rod absorbers and elements, and stationary fuel elements. The platform is placed over the tank extension and lined up with the edge of the main tank. The flange of the shield tank and the flange on the bottom of the platform interlock when the platform is rotated from this installing position. The operator can rotate the platform to any position he desires for loading or unloading the core.

12.4 Control Rod Elements

The control rod caps will now be removed and stored. The control rod cap tool is fitted to the tee handle and lowered into the tank. The corner caps must be removed first to avoid tool interference with the other caps. The tool fits over the cap. A slight downward pressure and 45° rotation, counterclockwise, unlocks the cap. Then by lifting the cap will come out of its seat, to be stored in the dummy tubes on the wall of the tank. Excessive "horsing" or jerking of this tool is not at all necessary. To re-apply the cap to the dummy tube or control rod reverse the above procedure. Note - Always have the core cover doors down when removing or replacing caps to prevent damage to the lower parts of the rod or drive mechanism.

The control rod element tool is used for installing and removing the control rod fuel elements and absorbers. To install a new fuel element the tool is lowered down a wooden chute, which runs from the top of the outside shield tank railing to the top of the cement shielding. A fuel element is attached and the tool is locked from the top. This tool must be suspended from the balancer at all times. The tool is raised until the element clears the railing. The tool and element are inspected for cleanliness and proper marking. The funnel is placed over the desired control rod so that the element will not be damaged during installation. The tool and element are lowered into the tank and inserted into the control rod. The element is so designed that the plates will be properly orientated in the core. If the element is 90° out of phase, if two elements are used or if 2 absorbers are used the control rod cap will not lock in place. After the element is seated in the control rod, release the locking jaw on the tool by applying a slight downward pressure to the handle. Lift the tool up and repeat the above operation.

12.5 Removal of Fuel Elements

The removal of fuel elements and absorbers is accomplished with the same tool. Lower the tool into the desired control rod, keeping the tool against the side of the control rod. Release the locking pin and lower the tool until contact is made with the pin. Push the tool down easy until it will move no further. Move the tool towards the center of the control rod and lift up slightly.

If the tool cannot be rotated then successful engagement with the pin has been made. Lock the locking pin and raise the element vertically to clear the spent fuel tube.

Move the element over the spent fuel tube and gently lower into the tube. Tip the tool over to line up the axis of the tool with the axis of the tube. Keep the opening of the hook towards the top, so the tool will fall away when releasing the element. Lower tool until element bottoms in the hopper. The operator at the spent fuel pit can notify the inside operator of this. Also the ears for the bail will be close to the mouth of the spent fuel tube. Release the locking pin, apply a slight downward pressure. Withdraw the tool and repeat this operation. When picking up an element in the spent fuel tube the procedure will be the same, except that the open side of the hook should be down, so that the tapered nose will lead itself on to the element. The above procedures will be exactly the same for the absorber sections.

Two tools are required to open the core cover doors. A hook tool that fits on the tee handle and a bolt clearance socket that fits on the universal joint and tee handle. The socket tool is to loosen or tighten the hold down nuts. For easier operation the two nuts holding the top doors should be loosened first. The hook tool engages the U bolt on the door and the door is lifted to the open position. In the case of closing the doors the lower doors are lowered in place first and the hook tool is used to hold the door down while the hold down nut is turned into place.

12.5 Stationary Fuel Elements

The stationary fuel elements can be handled over the top of the tank, in the case of new fuel, or thru the spent fuel tube, in the case of reclaimed fuel. The tool is lowered over the side of the shield tank and down the chute. This tool must always be suspended from the balancer. The man on the lower deck inserts the tool into the fuel element and the man above locks the tool in place. The tool and element are then raised to clear the outside railing. The tool and element are then checked for cleanliness and proper marking. The element is lowered into the tank and gently placed into the specified spot of the core. The lower end of the fuel element has a pin and the socket of the bottom plate has a groove. The pin must fit into the groove or the element will not seat and the doors will not close. This precaution is necessary to insure that the fuel plates are properly orientated in the core. After seating the element the tool is unlocked by turning the T handle on top of the tool approximately 11-1/2 turns counterclockwise. The tool is then lifted out of the core and the procedure is repeated.

When unloading the core the tool is lowered into the tank vertically and entered into the desired fuel element. The tool is locked to the element. The operator should try and rotate the tool before lifting the element out of the core to make sure the tool is securely locked. The tool and element are lifted vertically to clear the top of the reactor vessel. Move the element over the spent fuel tube and gently insert the element into the tube. The tool is then tipped at an angle until the axis of the tube and the axis of the tool are lined up. Lower the tool until the element bottoms in the hopper. The operator has two indications that the element is bottomed; the tool will go no further and the ears for the bail will be very close to the upper end of the transfer tube. Also the operator at the spent fuel tank can see the top of the element and notify the inside operator when the element is bottomed. The tool can be released and withdrawn.

The tool used in the spent fuel pit is exactly the same as the tool used inside the vapor container. The reason the two tools are the same is in the event of one tool failure, inside the vapor container, a replacement is readily available. The hopper is lifted to a vertical position and hooked in place. The stationary tool is entered into the fuel element and locked as previously explained. The element is lifted out and placed into the storage rack for a predetermined length of time. After this period the fuel element is transferred from the storage rack to the fuel cask, with the same tool.

12.6 Retrieving Tool

A special retrieving tool was built to pick up anything that may be accidently dropped into the tank. The tool has clam shell type jaws on the lower end and 3 handles at the top. By moving any one of the handles along the axis of the tool the jaws can be opened or closed. The 3 handles are for working at different levels in the tank. This tool was used to install the radiation test specimens. Also the "pill" was installed with this tool. The wire on the "pill" was gripped with the jaws of the tool lowered into the tank, swung over the tube, and lowered into the tube.

12.7 Time Schedule

The following time table shows the operations as if the core would be completely re-loaded.

Remove Spent Fuel Tube Seal		10 Min.
Loosen Vessel Nuts	72 Min.	
Remove & Store Nuts, Install Stud Caps	69 Min.	
Install Sling	34 Min.	
Store Cover	13 Min.	3 Hr. 8 Min.
Remove Control Rod Caps	14 Min.	
Unload & Load Control Rods	275 Min.	
Replace Control Rod Caps	14 Min.	5 Hr. 3 Min.
Open Core Structure Doors	12 Min.	
Unload Stationary Elements	309 Min.	
Load Stationary Elements	184 Min.	

Close Core Cover Doors	50 Min.	9 Hr. 15 Min.
Position Cover	16 Min.	
Remove Sling	32 Min.	
Place nuts & remove stud caps	56 Min.	
Tighten Nuts	190 Min.	4 Hr. 54 Min.
Replace Spent Fuel Tube Seal		10 Min.
Closing Shield Tank		1 Hr.
	TOTAL	23 Hr. 38 Min.

It is assumed that some preliminary work could be done during the cool down period. The shield tank covers could be removed, the lights and railings installed. It is assumed that 1 hour would be sufficient time to perform this particular operation. Therefore 1 hour has been added to the above total time to allow for closing the shield tank.

13.0 PRIMARY SYSTEM INSTRUMENTATION

13.1 Design Considerations

The controls and instrumentation for the plant incorporates a centralized control center to monitor and control the package power plant with a minimum of operating personnel but with maximum over-all control efficiency. The utilization of fully automatic and semi-automatic controls has been incorporated to eliminate any possible human inefficiencies in operation at a centralized control center. This console design; reflects all operating, maintenance, design problems, and experience incurred in APPR-1 and APPR-1A.

The control console carries the recorders and indicators necessary to keep the plant operator informed of pertinent plant parameters and the minimum controls necessary to operate the plant. The console is located on the skid with the instrument supply distribution panel, secondary switchgear and motor control centers so that all electrical controls are easily accessible to the operator. The nuclear channels, radiation monitoring, primary and secondary system recorders and indicators, rod-drive controls, primary system pump controls, pressurizer heater controls, scram and trip functions, trip valve controls and the annunciator are included on the control console.

Instrumentation and controls are provided for the complete nuclear powered steam source. They include instruments, controls and safety devices for the reactor, the primary coolant system, the steam boiler feedwater system and the radiation monitoring system. Pre-fabricated units are used to lower the installed cost of the equipment, whenever possible. The physical size of the units is small to minimize initial costs, space requirements, weight and transportation costs to afford convenience of operation. The central location of equipment and the use of maintenance aids keep maintenance costs to a minimum.

Locally mounted controls and indicators are utilized only in cases where plant operations are not affected. These instruments are monitored and any "off-normal" conditions are alarmed at the control center. Remote mounting of control, recording and indication instruments are used where radiation hazards, inaccessability for inspection and maintenance, and/or ease of plant operation are the deciding factor.

The electrical indicating, control and recording instruments are of the latest electrical design and minaturized instrument case dimensions. Instrument interchangeability of identical instruments has been incorporated for simplicity, economy, reliability and a maximum of plant operation. The use of transistorized, magnetic-amplifiers and/or printed circuitry and trip valves on lines from the vapor container are electric solenoid or electro-hydraulic type for maximum reliability and safety. Where components of questionable reliability cannot be eliminated military and industrial "ruggedized" long life types, hermetically sealed will be used. In the more critical applications, parallel and coincidence circuitry is used so that failure of a component cannot cause system failure.

Operation reliability is accomplished by the maximum use of "plug-in" components which are factory pre-tested for ease of maintenance and replacement.

Pneumatic instrumentation has been eliminated for signal transducing, transmission, air loading of valves, and low temperature and moisture problems. The elimination of pneumatic controls also eliminates the need for an air compressor to furnish instrument air.

A radiation monitoring system is provided as a permanent integrated part of the plant to detect, record and alarm the presence and level of potential radiation hazards. It serves to alert the operating personnel of any abnormal situations which may become hazardous to personnel and plant operation both on and/or off the site.

The Nuclear Instrumentation and controls consist of five nuclear channels, Safety #1, Safety #2, Log N and Period, Linear Power, and Startup (BF_3 and Period). All the nuclear instrumentation is located at the control center located on the skid so all controls are convenient to the operator.

The secondary instrumentation is composed primarily of local indicating instruments. Secondary controls are electrically monitored through the control console only where necessary for plant operations or plant safety. All the instruments used are of the latest proven design manufactured as standard equipment by companies regularly engaged in production of precision instruments. Instruments used in identical or similar applications are interchangeable where possible for ease of maintenance, reduction in spare parts requirements and maximum reliability of plant operation.

The reliability of plant operation is of importance second only to safety. Use of components of the highest reliability and components requiring frequent replacement avoided. Semi-conductors, magnetic amplifiers, solid diodes and other high reliability components shall be used in preference to relays and vacuum tubes unless such design is uneconomical.

Safety of plant and personnel are of utmost importance. Insofar as possible all failures shall occur in a safe direction.Those failures which are not in a safe direction shall be annunciated, if possible, by opening a normally closed relay when the failure occurs. Any failure which is neither safe nor conveniently annunciated shall have duplicate circuitry such that the possibility of simulataneous failure of both units is extremely remote.

13.2 Control Console

13.2.1 General

The control console is sized to provide uninterrupted one-man operation of the power plant. Recorders and controllers for the steam and feedwater parameters are included in the console. As indicated on the layout of the switchgear control skid, associated controls for operation of the power plant such as switchgear, turbine-generator controls, etc., are adjacent to the operator. A graphic panel is not used since this is packaged power plant.

The control console is functionally arranged for simplicity and ease of operation of the plant. The nuclear recorders and control rod drives necessary to control the primary system are on panels directly in front of the operator, with the controls mounted on an inclined panel at desk top level. The annunciator unit and associated test panel is directly above this instrumentation within reach of the operator to acknowledge alarms. Additional nuclear instrumentation and radiation monitoring equipment is at the operator's left. The instruments and controls for the primary system are to the right of the operator. All recorders and indicators of variables are mounted on vertical panels in the console at operating eye level; controls are on inclined panels at desk top level. Extensive use of the miniaturized type recorders with a 4 inch chart has been made in the primary, nuclear, and secondary instrumentation for space conservation and operational assistance to the operating personnel.

13.2.2 Annunciator

The annunciator will occupy the vertical panels of the console and will annunciate 96 variables. It is designed for 28 volt D. C. Operation with relays, lamps and horn mounted in the same section of the control unit. All external connections will be of the plug-in type. Relays shall be sealed, plug-in type used with circuits that are designed with normally closed initiating contacts. Two relays and two lights will be used for each annunciating station. The annunciator panel shall be hinged at the bottom to allow the panel to be rotated around a horizontal axis for any maintenance to components located on the rear of the panel. Wiring will be accomplished in a manner that will permit no stress or strain on cables or wires during opening and closing of the annunciator panel. The annunciator horn shall be provided with adjustable volume control and shall be audible a distance of 30 feet. Individual audible alarms are provided with radiation monitors in areas occupied by personnel. These audible alarms can be heard above the noise level of operating machinery. The operator is required to acknowledge both the off-normal and the return to normal conditions of both the local and control room annunciation.

The annunciator panel including the annunciator test panel have been arranged so that the panels can be bench wired and inserted into the console as pre-fabricated assemblies.

13.2.3 Primary System Instruments

The vertical eye-level panels of the console contain instruments which record and/or indicate all necessary system variables and are as follows:

1. Primary Coolant Mean Temperature

2. Primary Coolant Temperature
3. Primary Coolant Pressure
4. Primary Coolant Flow
5. Pressurizer Level and Temperature
6. Vapor Container Pressure
7. Primary System Temperature Monitor Indicator
8. Primary Coolant Pump Motor Ammeter
9. Spare Position for Additional Recorder

The right and left inclined control panels at desk top level contain switches and indicator lights used in the control of primary system pumps, pressurizer heaters and trip valves.

13.2.4 Secondary Instruments

The right panel contains the instruments necessary to record and control steam output of the plant to the secondary system and are as follows:

1. Main Steam Pressure Recorder
2. Main Steam Temperature Recorder
3. Main Steam Flow Recorder
4. Steam Generator Level Recorder-Controller
5. Feedwater Flow Recorder
6. Feedwater Pressure Recorder

13.2.5 Nuclear Instruments

The vertical panels contain all nuclear recorders and are as follows:

1. Safety Channel No. 1
2. Safety Channel No. 2
3. Period, 2-channel, high and low level
4. Log N
5. Log Count Rate BF_3
6. Linear Power
7. Spare position for additional recorder

Amplifiers used in conjunction with these instruments are mounted in these recorders. Any controls requiring attention of the operator will be included on a panel on the front of the unit.

The center panel contains controls and indication for the reactor rod drives. The indicators are dual synchro receivers using 60 cycle or 400 cycle power supply. The short needle is the "coarse" indicator or rod position making approximately one revolution for full rod travel. The longer needle is the "fine" indicator making one revolution for each 3 inches of rod travel. The combined indication of the two needles is the rod position within $\pm$ 0.020 of an inch.

Each of the five rods drive positions is indicated by a separate Syncro receiver. Upper and lower limits of travel are indicated by red and green lights, respectively. At these limits of travel the circuit to the rod drive motor starter is broken, preventing further motor rotation by either manual or automatic means. A double pole-double throw center off-switch, located near each indicator controls direction of individual rod travel. A ten-pole-double-throw-center off switch is used for gang control of the regulating and shim rods so that the rods may be moved in unison.

13.3 Radiation Monitoring

A radiation monitoring system is provided for the protection of personnel and plant operation. Radiation levels of 5 mr/hr will be alarmed both locally and in the control room to warn personnel in a particular area and the control room operator of a hazardous condition. The use of positioning detectors in designated areas and any malfunction which would result in the release of radioactive waste is detected and corrective action may be taken by the operator. Two analyzers, monitoring plant water and effluents are provided for the protection of off-site personnel and to double check the in-plant monitoring systems. These analyzers are also provided with suitable means of indication and alarm. The in-plant monitoring systems is gamma sensitive only since both primary and secondary reactor shielding contains all neutrons and the pipe walls are of sufficient thickness to contain beta radiation. Both the water and air effluent monitors are beta and gamma sensitive because the effluents are not contained.

13.4 Nuclear Instrumentation

The nuclear instrumentation system has been simplified by Alco with the experience gained on APPR-1 and APPR-1A nuclear instrumentation systems. Neutron detecting chambers used in startup operations and their connectors have been a major problem. Our design calls for withdrawal of this chamber when not in use for the protection of these chambers and their connectors. One startup channel is eliminated at the same time because this withdrawal will be made in calibrated steps providing the usual two decade overlap of the power channel. When the reactor is at power the chamber will be fully withdrawn to extend the life of the chamber and connector.

The safety level chambers are used in two out of two coincidence circuits requiring both chambers to initiate a scram at 120 percent of design level power. Failure of one of the fail safe safety channels will be annunciated without scramming the reactor and will allow time for a replacement of parts in the channel without a shutdown. But, if the other channel calls for a scram, (legitimate or not), before the defective channel is corrected, the reactor will be scrammed.

Five (5) nuclear channels will be provided using six recorders. High and low level periods are recorded on a dual channel instrument.

1. Startup - BF_3 counter with low level period
2. Log N and Period
3. Linear Power
4. Safety #1
5. Safety #2

The BF_3 proportional counter channel with a minimum sensitivity of 4 counts/mv will cover the neutron flux range from source level to the range where the Log N channel gives accurate indication. This startup range corresponds to a power level of from about 0.01 watt to about 100 watts. The Log N channel will cover the power range from about 10 watts to over 10 megawatts. Associated with the Log N channel is a period amplifier, and a period of 3 seconds will cause a scram. At a period of 10 seconds rod withdrawal is stopped.

A linear power channel with range selector switch is provided with the same operating range as the Log N.

The use of five nuclear channels, with a two out of three coincidence scram circuit to the two safety channel system with two out of two coincidence circuit is based on the following:

1. Usage of solid state systems and elimination of vacuum tubes, including solid state preamplifiers for the chambers which increases reliability and stability.

2. Usage of regulated and isolated power supplies reduces the chance of false scrams due to outside interference.

3. Usage of chamber wells extending to the outside of the vapor container with improved type connectors for the chamber leads.

4. Usage of a BF_3 - 28 V.D.C. motor-operated lifting mechanism to remove the BF_3 Counter tube from the region of high flux level during power operation. The BF_3 lifting mechanism will extend the usable life of the tube and reduce tube connector failure.

13.5 Startup Considerations

The flux mentioned at startup reflects the worst condition that possibly can be encountered. This condition can occur at the initial startup of the reactor system. After the initial startup, the problem is eased somewhat by a photoneutron source which yields neutrons from a reactor involving gamma radiation from fission products and induced activity. The source is in the form of Beryllium-containing slab placed near the core. The yield of neutrons from the photoneutron source is considerably greater than the yield from the Po-Be source, so the counting rate is well within the range of the BF_3-counter channel.

The neutron flux is well within the range of the BF_3 counter channel after reloading the reactor with fresh fuel elements. A new source of Po-Be will be required after refueling the reactor.

13.6 Rod Travel Limit Switches

The rod travel limit switches are the simplest interlocks preventing travel of rods beyond predetermined limits thereby protecting the rod drive starter, and motor from overheating and possible burnout.

13.7 Rod Automatic Drive Down

The contact in parallel with the "in" contact of the "gang" switch which is closed during an "scram" condition, energizing the rod drive motors "in". The main clutches are disengaged and the rod drive motors, when energized in this manner, operate through the overrunning clutches to break loose any rod that may "hang-up" during the "scram". Once broken loose the rod will again fall freely to complete the scram action.

13.8 Nuclear Interlocks and Scrams

In either the low-power level of the intermediate power level regions, a reactor period shorter than some predetermined value prevents rod withdrawal. Both period channels function continuously in the low power region with the low-level channel losing its value above 10 watts. This interlock accomplishes its function by making it impossible to apply power to the rod drive motor starters when any attempt is made to withdraw rods.

A rod minimum startup count rate interlock is used to guard against reactor runaway during startup because of lack of neutrons when achieving a critical mass.

A low-level protection by-pass in the log N channel by-passes both the short period and minimum count rate interlocks at some predetermined higher power level. This by-pass interlock protects against failure of either of the interlocks described above which would prevent rod withdrawal at high power levels. Actuation of this interlock will be annunciated by a momentary audible alarm and switching on of a yellow warning light on the annunciator panel. This procedure is reversed during shutdown of the reactor.

The period scram is automatically by-passed when the following conditions have been satisfied:

1. Primary Coolant Average Temperature 480°F
2. Power Level 80%

If either or both of these parameters drop below 480°F and 80% power, respectively, the period scram is automatically activated. Deactivation of the by-pass is clearly annunciated to alert the operator.

13.9 Reactor Rod Control and Indication

Individual rod position is indicated on a single indicator unit utilizing two independently mounted and geared synchro transmitters electrically connected to their respective receivers. The receivers are connected mechanically to two concentrically driven pointers and contained in the indicator unit. The coarse indicator pointer travels approximately 360° for the full rod travel. The short pointer and smaller dial is used for this indication. The fine indicator pointer, which is the longer of the two, travels 360° for each three inches of rod travel. Rod position may be read to at least within ± 0.02 of an inch. The receiver dials are mounted on the control console directly in front of the operator together with associated rod drive control levers and indicator lights. Rod position at either extreme of travel is indicated by lights mounted directly to the right of the synchro indicators. A green light for "down" or "in" position and a red light for "up" or "out" position. The lights are "push-to-test" lights allowing periodic testing of lights locally instead of remote control.

Each reactor rod is rack and pinion driven by a 3-phase, 440 volt, 60-cycle motor. The power is transmitted through a main clutch and a smaller over-running clutch when traveling in the "down" or "in" direction and through the main clutch only in the "out" or "up" direction. The overrunning clutch drives any rod "down" which may not fall freely after a "scram" has been initiated. The clutch actuation will continue until the full "down" or "in" position is reached.

All five rods may be controlled from the control unit individually through their respective three-position lever switches. The three-position switches have spring return to the neutral-off position. When either "in" or "out" contactor is energized by correctly positioning the three position lever switch, 3-phase power is supplied through the starter to the motor. The motor then drives the rod "up" or"down" through a gear box and rack and pinion assembly.

In order to speed up additions of negative or positive reactivity during startups, etc., all five rods may also be controlled in a group or "gang". A switch for controlling the "gang" of five rods is located below the panel of the console containing the individual rod drive controls. The handle of this switch is of distinctive color and shape to further decrease the chance of operator error and at an offset location.

The limits of rod travel are controlled by "in" and "out" limit switches located on the actual rod drive. These switches prevent travel beyond the normal rod travel limits. Upon actuation of either limit switch, the respective limit light is energized and all power through the individual and gang control switches to the motor contactor is cut off, preventing further rod travel.

The results of analog computer studies to date indicate that any rod withdrawal above the temperature and power conditions listed above will result in a power level scram before a period scram. The same studies also indicate that at other power levels of power and temperature it is possible to limit rod withdrawal in conjunction with a period scram by-pass. However, this has not been incorporated in our designs because normal operation of a plant is usually nearly design power. In a special case, however, circuitry to by-pass the period scram at lower levels may be incorporated in the design.

A primary coolant pump interlock prevents rod withdrawal when the pump is not operating. This prevents reactor startup and overheating of the primary system because of lack of primary coolant flow. The closure of this interlock on the pump motor starter allows withdrawal. Since there is a backup low flow scram action, starter actuation is considered satisfactory evidence that the pump is running.

Whenever conditions satisfy any or all of the rod withdrawal interlocks specified above, rod withdrawal is prohibited. It is then not possible to energize the rod withdrawal permissive relays. The operator is warned of this condition by the turning on of a rod (not permissive) light and the extinguishing of the green (permissive) light on the control console panel. The reverse is true when rod withdrawal is permitted.

The rod drive "In" contactor will always override the "out" contactor in the event that both of the contactors are energized simultaneously. This is a fail-safe interlock which would assist in shutting down the reactor.

The rod transfer lock switch requires initiation of reactor operations by a keyed switch. Also, if an attempt is made to start up in the "off" or "zero" positions, the reactor will scram.

During zero power operations very low limits must be maintained since the reactor pressure vessel cover may be off as in criticality tests. A scram contact is provided in the log N channel set at some predetermined level, such as 1 KW.

Routine power operation required by-passing the zero power scram through the transfer lock switch. However, the safety channels remain in the protective circuitry. A power level of 120% will initiate a scram action through the safety channels.

High rates of flux increase in the reactor coinciding with increased rate of heat production, are detrimental to the normal operation of the power plant and can cause serious damage. Therefore, the rate of flux increase is monitored and the reactor is scrammed if too high a period is reached. Two period channels with overlapping ranges are used as monitors and scrams are affected by opening contacts in their signal circuits to the final output stage of the safety channel. The low level period scram utilizing the BF_3 channel is only in effect at low-period levels and is by-passed by the same log N contacts specified above.

The intermediate level scram channel remains in the circuit to scram the reactor on a prescribed period below those encountered during normal system load transients.

There are seven scrams which do not depend upon nuclear channels for their scram signals. The three scrams which depend upon a pressure signal are made up of three pressure switches for each scram. The three pressure switches are connected in coincidence so that if any two of the three switches are actuated a scram is initiated. Alarms are also provided through the same pressure switches. The alarms will also detect a defective pressure switch when an erroneous alarm is made.

1. Low primary coolant pressure will first alarm and then scram the reactor.

2. High primary coolant pressure will first alarm and then scram the reactor. Together with this scram the power to the pressurized heaters is cut off since the condition of high pressure may be caused by the heaters rather than the reactor.

3. High pressure secondary steam will alarm and scram the reactor. This control implies a primary coolant breakthrough in the steam generator.

4. Low primary coolant flow is alarmed at approximately -3% and a scram occurs at approximately -6%. This control guards against boiling in the reactor.

During zero power operation there is no necessity for primary coolant flow and low pressure controls because (a) the low power developed, (b) the pressure vessel cover may be off. Because of this the low flow and low pressure alarm and scram specified above are by-passed by the transfer lock-switch located in the control unit.

5. High reactor outlet temperature of primary coolant is alarmed and scrammed. A high reactor outlet temperature indicates higher rate of heat generation than the steam generator and primary coolant system are capable of handling.

6. High temperature steam is alarmed and scrammed. High steam temperature exists when the secondary system is incapable of removing heat from the primary system.

7. High Primary coolant flow is also alarmed and scrammed.

13.10 Console Construction

The control console structural members will be steel channeling, using U-shaped channels welded in a manner so as to serve as both structural support for the control unit equipment and wiring duct for electrical leads from the main internal wiring ducts. Using the channel as wiring duct reduces the amount of harnessing necessary, speeding production, improves appearance and facilitates maintenance by allowing easy identification of cables, their routing and replacement.

The inclined panels containing equipment control will be mounted individually and hinged at the bottom so that they may be opened from the front for any maintenance or repair that is necessary. The upper or top sixteen inches of the three vertical panels of the control console containing the annunciator unit and test panel may be inclined forward to about 60° from the vertical to allow easier reach to the annunciator switches.

The instrument distribution panel will be built integral with the console and will also have structural channels to form wiring ducts similar to the construction described for the console. The unit shall be completely enclosed and provided with access doors. Power and control cables will be connected to vertical termination boards in the lower section of the distribution panel.

The annunciator panels will be treated the same as the equipment control panels. They will be hinged at the bottom so that the panel may be rotated exposing the circuitry for repair. The panel and associated equipment will be accessible from the rear for minor repairs and maintenance.

All cables and wires entering the control console from the vapor container, nuclear rack and other locations will be plugged into connectors wired to the termination boards in the distribution panel section of the control console. These cables shall enter the distribution panel via overhead raceway except for power supplies from the control skid or nuclear panel. The leads from the distribution terminal boards will enter the control console through three wire-ways in the rear base of the console, acessible from the rear of the console. The three section wireways will segregate signal, high power and low power cables for ease of trouble shooting and to insure no signal distortion due to pickup caused by proximity to unshielded power leads. Cables will be placed directly into the "channel" construction members from this wireway. Wires and cables from the controls and equipment in the console will be permanently wired to connectors mounted on the terminal boards.

13.11 Cables

All instrumentation cables used to connect the panels and units are cut to length at the factory and wired into plug-in type connectors at each end and completely coded. The resulting leads are tested at the factory and prior to installation for continuity and insulation resistance. The cables will be laid in wireways in which provisions are made for segregating signal and power leads and plugged into the correct receptacles at the plant site. All cables have waterproof jacketing to suit the required temperature and humidity conditions and shall be terminated in water resistant connectors.

13.12 External Wiring and Wireways

All instrumentation cables, wires, power and control cables external to the panels and units will be carried in standard wireways with hinged and gasketed areas. These will be bolted or screwed together to form wireways interconnecting the panels and units. The wireways will be run in two sections so that low-level and signal cables can be isolated from power and control cables.

13.13 Distribution Unit

The instrument distribution panel will be built integral to the console and will also have structural members of steel unistrut channel to form wiring ducts similar to the construction described for the console. The unit shall be completely enclosed and provided with access doors.

The distribution section will have openings in the base that will mount over and enclose the power cable conduit outlets in the top of the skid.

The power and control cables will be connected to vertical termination boards in the lower section of the distribution panel. The power supplies terminal board will contain circuit breakers not mounted in the switchgear section of the skid or in the control console.

All cables and wires entering the control console from the vapor container, nuclear rack and other locations will be plugged into the termination boards in the distribution panel section of the control console. These cables shall enter the distribution panel via overhead raceway except for power supplies from the control skid or nuclear panel. The leads from the distribution terminal boards will enter the control console through three wire-ways in the rear base of the console, accessible from the rear of the console. The three section wire-ways will segregate signal, high power and low power cables for ease of troubleshooting and to insure no signal distortion due to pickup caused by proximity to unshielded power leads. Cables will be placed directly into the "channel" construction memebers from this wireway. Placement of these channel struts will allow use as ducts alternately for signal end power leads. At a point laterally opposite the termination point of the cable, it will exit from the channel for connection.Cables and wires will be contained in the channel by using sections of a spring steel cover mounted at strategic points along the channel.

The distribution terminal boards will be mounted vertically in the lower section of the distribution unit. Wires and cables from the controls and equipment in the console will be permanently wired to connectors mounted on the terminal boards.

Conditions of temperature, humidity and air purity within and surrounding the control unit must be maintained at levels which insure operation of all equipment within their respective specified accuracies. Thermal emmission devices shall normally have their filament at operating voltages except during prolonged shutdowns.

13.14 Electro-Hydraulic Control Valves

Electro-Hydraulic control valves are used in the all electrical instrumentation system in lieu of air operated valves. An electrically operated valve is approximately two to three times the cost of an air control valve, therefore overall plant cost is less because fewer valves are needed and the complete instrument air system with its associated piping is eliminated. The elimination of air type control is also highly desirable for this plant to prevent the possibility of freezing of moisture in the air supply and control lines.

Self-contained electrically powered hydraulic piston type control valves position with a high order of accuracy and have excellent frequency response. The stability of positioning in this type valve is superior to a pneumatic diaphragm operator that is a resilient assembly moving in response to dynamic forces transmitted from the valve or plug proper on the fluid stream. The hydraulic piston is positioned by a non-compressible fluid that dampens vibration and prevents jumping of the inner valve with resultant rough control and wear inherent in the pneumatic operator.

The electro-hydraulic valves are self-contained requiring no inputs other than the electrical control signal and a.c. power from the distribution line.

Electro-hydraulic trip valves will "fail-safe" on loss of power and close. Control valves will lock in position and annunciate the condition, or close on loss of power.

14.0 PRIMARY PURIFICATION AND MAKE-UP SYSTEM

14.1 Functional Requirements

In conventional power and utility plants, the purity of the boiler water is controlled by a continuous schedule of blowdown and make-up. The same principle was followed in design of the purification system for the APPR-1, the APPR-1a, and this skid mounted nuclear power plant. The Fort Belvoir Plant was the first pressurized water reactor to utilize a low-pressure purification system; because of its many advantages and proven performance, this type of system has been used in most succeeding land-based plants, including Indian Point, Yankee, Savannah, etc. In the APPR-1 design, a small portion of water is continuously withdrawn from the main primary system, purified by mixed-bed demineralization, and reintroduced as make-up to the primary system and control rod seals. Advantages include simplicity of operation, minimum capital investment, and elimination of any waste disposal problems with normal operation.

The purification and make-up system is designed to perform the following functions:

1) Continuously remove dissolved and suspended impurities.

2) Control system pH.

3) Scavenge dissolved oxygen from the coolant by the addition of suitable chemicals (e.g. hydrogen during operation or hydrazine during start-up).

4) Prevent deposition on heat transfer surfaces.

5) Minimize possibility of fuel element failures.

6) Minimize corrosion.

7) Protect moving parts and small orifices from clogging or sticking.

8) Minimize radioactivity buildup on primary system components.

9) Attempt to eliminate radiological hazards to operating personnel and the environment.

14.2 Summary Description of System

The purification and make-up system contains five basic components: 1) a non-regenerative heat exchanger (blowdown cooler), 2) a pressure reducing-flow control station consisting of orifices, a self contained pressure reducing valve and an electro-hydraulic valve, 3) a non-regenerative disposable mixed-bed demineralizer, 4) a make-up tank, and 5) a positive displacement make-up pump.

In addition, the system contains valves, instruments, and auxiliary equipment required for operation and isolation. The blowdown cooler, as shown on R9-47-1013 - Primary System Skid Arrangement - is located on the steam generator skid. The other components are located on the feedwater skid as illustrated by drawing M02M3 - Feedwater Package General Arrangement.

The basic flow diagram for the purification and make-up system of this skid mounted nuclear power plant is diagramed on drawing R9-47-1014 - Primary System P.&I.D. Primary water enters the purification system at approximately 510°F and 1750 psia. The temperature is reduced to about 110°F in the blowdown cooler to protect the demineralizer resins from thermal damage. A pressure reducing flow control station consisting of orifices, one self-contained pressure reducing valve and one electro-hydraulic valve reduces the pressure to less than 100 psia before the water is processed through a mixed-bed demineralizer. Flow through the purification system is regulated at about 1 gpm, although instantaneous flow is controlled by pressurizer level. Demineralizer influent also includes a small amount of control rod seal leakage water, and as required, make-up condensate to replace system or sampling losses.

A radiation monitor located on the demineralizer constantly monitors radioactivity buildup in this unit. Should radiation levels exceed preset values - as would probably occur during fuel element failure - an alarm in the control room signals the plant operator to discontinue purification flow. When the source of activity is analyzed, flow may either be diverted to the hot waste tank or processed through the demineralizer.

The demineralizer functions both as a filter and an exchanger. Actual operating experience with the APPR-1 has proven that this demineralizer design effectively maintains primary coolant purity and, by removing radioactive nuclides from the water, minimizes radiation and maintenance problems throughout the plant. Since regeneration of radioactive resins is not feasible, and since removal of the resins introduces major handling, storage, and disposal problems, the demineralizer is designed as an inexpensive, low-pressure unit that can be quickly and easily discarded and replaced. The unit is equipped with quick-disconnect seals that completely seal in all radioactive water and resins. The discarded unit can be disposed of either by burial or dumping at sea.

After passing through a filter designed to remove any resin fines that might have entered the water, the purified water is collected and stored in a 60 gallon stainless steel tank. A positive hydrogen pressure is maintained over the water in the tank to prevent air in-leakage and to introduce hydrogen into the make-up water. This hydrogen is automatically supplied from cylinders through regulating valves. Under a gamma flux, hydrogen not only suppresses dissociation of primary coolant, but scavenges any dissolved oxygen that might enter the system. By excluding air from the system, corrosion problems are minimized and air-born radiation hazards, such as the formation of argon-41, are eliminated.

From the make-up tank, purified coolant is recirculated to the primary system and control rod seals by the primary make-up pump. Pump output can be manually adjusted from 0.17 to 1.7 gpm.

The make-up system provides means for adding a controlled, measured amount of hydrogen to the system during normal operation (through the hydrogen addition flask), hydrazine for oxygen scavenging prior to start-up, and, if necessary, a decontamination or soluble poison solution.

Since all primary water is collected and returned to the system, waste disposal problems are almost eliminated. No primary coolant is discharged to the environment. Thus, this design is suitable for even the most populated area and eliminates any possible public repercussions that might result from the discharge of radioactive water.

Design of this typical purification and make-up system is based on operating experience with the APPR-1. All components have been tested under conditions similar to those that will exist in this plant and have proven that the design is not only effective and reliable, but requires a minimum of operational manpower.

14.3 Design Requirements

The basic design requirements and conditions for the primary purification and make-up system are as follows:

a. The system shall maintain primary coolant purity to such a degree that radiation dose levels due to activated corrosion products, impurities, and deposited "crud" external to piping and components will not pose hazardous accessibility or maintenance problems. The effectiveness of the purification system in minimizing transport and deposition of activated corrosion products is as yet not fully known; however, this design utilizes the best information available from Task I - Activity Buildup Testing Program - of the research and development programs being performed by Alco under Contract AT(30-3)-326.

b. To minimize radiological hazards from gaseous impurities such as A^{41} and N^{16}, and to minimize corrosion due to oxygen or radiation synthesized products such as NH_3 and HNO_3, the make-up system must be designed to prevent introduction of air with the make-up water.

c. To minimize corrosion by scavenging oxygen and effecting a recombination of the H_2 and O_2 produced by dissociation of the coolant under a neutron flux, the system shall be designed to maintain in the coolant 15-30 cc of hydrogen per kg of water.

d. The required operating life of the demineralizer shall be the maximum consistent with arrangement and component removal considerations, but not less than 90 days.

e. Means shall be provided to protect the demineralizer resin from water exceeding 140° Fahr. to avoid thermal decomposition of the resin and the resultant loss of capacity.

f. To facilitate field modifications or insertions, connections between the major components of the system shall use tubing and compression fittings unless welding is required by the type of service.

g. Primary coolant inlet temperature during operation will vary from 509°F to 500°F.

h. System operating pressure shall be 1750 psig upstream of the pressure reducing-flow control station and less than 2000 psi downstream of the make-up pump. The remaining parts of the system shall be designed for operation at 50 to 100 psig, depending on location.

i. The design corrosion rate of Type 304 or 347 stainless steel under the thermal and hydraulic conditions existing in the primary system is 5 $mg/dm^2/mo$.

j. Plant radiation levels under normal operating conditions shall be such that the dose received by plant personnel working 84 hours per week shall not exceed 300 mr.

k. The equipment shall be designed or braced to withstand maximum shock loadings encountered in the C-130 aircraft.

l. Leakage from the five control rod seals will be less than 0.1 gpm.

m. Primary system volume control shall be based on adjustment of purification rate rather than make-up rate. Although no plant operating data is available on this control arrangement, discussions with manufacturers indicates that this will permit closer control of large transient variations than is possible with the APPR-1 setup.

n. Resin bed depth in the demineralizer shall be a minimum of 30 inches. In the absence of APPR-1 operating data on the effect of flow loadings on optimum demineralizer decontamination factors (gross D. F.'s as well as individual nuclides), flow loading specifications shall be based on conductivity data available from resin manufacturers. During normal operation, flow loadings shall be about 7.5 gpm per square foot of bed surface.

o. The primary coolant shall be maintained at essentially neutral pH. Although data from other installations indicates operation at high pH may be beneficial, the effect of high pH on APPR-1 operation (activity build-up, corrosion rates, corrosion product release rates, heat transfer, gas activity, fission product levels, etc.) has not been demonstrated.

p. Based on data obtained under Task I - Activity Buildup Studies under Contract AT(30-3)-326 and APPR-1 operating data, 25% of the total solids in the coolant are conservatively assumed to be soluble for design purposes. The average chemical combining weight of the corrosion products is assumed to be 50. Capacity of the resin is 10,000 $grains/ft^3$ as $CaCO_3$.

q. Based on APPR-1 operating results, system design will not include an in-line gamma radiation monitor to measure primary purification radiation levels. Experience indicates that crud bursts, activity deposition on the chamber surface, and other factors nullify attempts to use this type of monitor to detect failed fuel elements. The need for a failed fuel element detection system is presently being evaluated under Task III - Fission Product Study of Contract AT(30-3)-326. Area monitors are included for personnel protection.

r. A connection shall be provided on the suction of the primary make-up pump to introduce hydrazine for oxygen scavenging during initial startup, a decontaminating solution, and a soluble poison solution. Although the latter two are not required by plant design criteria, their inclusion is considered desirable emergency features. The decontamination solution would be used in the event of fuel element failure, excessive buildup of long-lived deposited activity on primary system surfaces, or to facilitate relocation of the plant. The soluble poison solution would be used to control hot-to-cold reactivity changes in the event a control rod becomes stuck in the "full out" position or two rods become stuck in the operating position during the first part of core life.

s. Mixed-bed resin specifications are as follows:

Mixture: mixture of strongly acidic cation resin in the hydrogen form and strongly basic anion exchange resin in the hydroxyl form in proportions of 1.0 equivalent of hydroxl ion to 1.0 equivalent of hydrogen ion.

Particle Size: both the cation and anion resins shall have a mean particle size of 16 to 50 mesh and a uniformity coefficient of less than two.

Capacity: the cation resin shall have a total finished capacity of not less than 47 milliequivalents per dry gram, of which not less than 95 equivalent percent shall be in the hydrogen form.

The anion resin shall have a total finished capacity of not less than 3.5 milliequivalents per dry gram, of which as great a proportion as is feasible, but not less than 80 equivalent percent shall be in the hydroxyl form.

Impurities: The resins shall be specially treated to remove any soluble organic contaminants which may be present. The resin shall not contain impurities of foreign cations greater than the following:

	Parts per million (of dry resin)
iron	200
copper	100
heavy metals (as lead)	100

The resin shall not contain impurities of foreign anions greater than the following:

	Percent (equivalent)
chloride	5
carbonate	15

14.4 System Design Data

Primary system piping and vessels will be fabricated of AISI type 304 stainless steel. All other system components exposed to the primary water will be of type 304 stainless steel with the following exceptions:

(1) Rod drive mechanism

Valve seat and pinion	type 410 stainless steel
Water seal shaft	Armco 17-4 pH stainless steel

(2) Instrumentation — type 441 stainless steel (where no flow exists)

Purification system flow rates are based on the design requirements outlined in 14.3. The primary system surface area and volume used for corrosion and activity buildup considerations were 2.48×10^6 cm^2 and 555 gallons, respectively. The calculated values for the individual components are as follows:

Primary System Surface Areas and Volumes

	Area, Ft^2	Volume, Ft^3
Thermal Shield	60.8	-
Core and Control Rod Drive Mechanism	1580.0	-
Reactor Vessel (net water)	91.2	42.8
Primary Piping	39.8	7.6
Primary Coolant Pump	2.5	3.0
Steam Generator	591.0	15.1
Pressurizer	-	6.0
Total	2365.3	74.5

Based on the above, and assuming that at equilibrium the soluble and insoluble corrosion products entering the coolant are equal to the corrosion rate of the material under consideration, the impurities added to the coolant by corrosion were calculated to be 3.79 x 10-4 lb/hr or 124 grams per month. Using various assumptions for demineralizer efficiency, purification system effectiveness in competing with system surfaces for circulating "crud", deposition rates on heat transfer and nonheat transfer surfaces, demineralizer decontamination factors, etc., the required purification flow rate was calculated to be 1.1 to 1.5 gpm, Evaluation of standard pump capacities and designs offered by manufacturers indicated that a positive displacement pump with a 1.7 gpm maximum output would be sufficient to meet system make-up and control rod drive seal requirements.

Assuming that all soluble corrosion products stay in solution and using 0.25 as the ratio of soluble to insoluble impurities (see 14.3, q), the volume of resin required per month can be calculated. The effect of filtered crud on the exchange capacity of the resin is unknown and is not factored into the calculations. For this prepackaged nuclear plant, a minimum of 0.12 Ft^3 of resin will be exhausted per month or 0.36 Ft^3 in 3 months of operation at system temperature. To account for unknown factors, the design value used was 1.5 times the minimum value or 0.54 Ft^3 of resin for 3 months operation.

For comparison, with improvements in influent distribution to prevent the channeling found under Task VI - Shielding Studies of Contract AT(30-3)-326, an APPR-1 type demineralizer would last about 9 months. This coincides reasonably well with APPR-1 operating experience.

Pressure drop data used to determine design pressure requirements of individual components in the purification system were a combination of manufacturers' data and measured values during APPR-1 operation. The head loss due to friction/100 ft. of 1/2" 16 BWG stainless steel tubing was calculated using the Fanning equation:

$$h = \frac{fLv^2}{2gd} \quad \text{or} \quad \frac{0.03112\ fLg^2}{d^5} \qquad (1)$$

where:

h = Head loss to friction, ft.
f = Friction factor, dimensionless
L = Length of pipe, ft. (100 ft.)
v = Velocity of flow, ft. sec.
g = Acceleration of gravity, ft/sec^2 (32.2)
q = Flow of liquid, gal/min
d = Internal Diameter of pipe, in (0.370 in.)

Substitution of known constants in equation

(1) yields:

$$h = 9.1 \times 10^7\ fg^2$$

The friction factor is determined as a function of Reynolds number by the equation

$$N_{Re} = \frac{DV_p}{u}$$

where:

D = Dia. of pipe, ft.
V = Velocity of fluid, ft/sec.
p = Density of fluid, lbs/ft^3 (assumed temperature of 120°F Ave.)
u = Viscosity, lbs-mass/ft-sec. or centipoises/1488

Assuming various flow rates in the purification system, the head loss per 100 ft. of 1/2" stainless steel tubing was calculated. The results are tabulated below:

Head Loss/100 ft. of 1/2" S. S. Tubing

q gal/min	g ft³/sec	g² ft⁶/sec²	D Ft.	V ft/sec	P # Mass/ft³
1	.0022	485×10^{-8}	.0309	3	61.5
2	.0044	1940×10^{-8}	.0309	6	61.5
5	.0110	$12,100 \times 10^{-8}$	.0309	15	61.5
10	.0220	485×10^{-6}	.0309	30	61.5
20	.0440	1940×10^{-6}	.0309	60	61.5

q gal/min	u Centipoises 1488 $\times 10^{-4}$	DVp/u Dimensionless	f $\times 10^3$	Head Loss Ft.	Head Loss Psig
1	4.05	14,100	6.25	2.76	1.2
2	4.05	28,200	6.0	10.6	4.6
5	4.05	70,500	4.5	49.5	21.5
10	4.05	141,000	4.0	177	76.5
20	4.05	282,000	3.5	618	268

The values used for pressure drop through valves, fittings, and other system components was as follows:

Pressure Drop Through Purification System Components Downstream of the Pressure Reducing - Flow Control Station

	Pressure Drop Psig	Equivalent ft. of 1/2" tubing
Demineralizer ("dirty")	10	
Filter	5	
Valves		23.75
Flow Indicator	2	
Tees, elbows, fittings	-	25.6
	17	49.35

For 50 equivalent feet of tubing in valves and fittings, the total pressure drop due to system components was calculated for various flow rates. Results are listed as follows:

Head Loss Due to System Components

gal/min	pressure drop for 50 eq. ft.	Total pressure drop
1	0.6	17.6
2	2.3	19.3
3	4.2	21.2
4	7.0	24
5	11.0	28
6	16.0	33

From the above calculations, it is apparent that designing the demineralizer to withstand 100 psig will be more than adequate with expected flow rates.

14.5 Detailed Description of Equipment and Components

14.5.1 Purification Heat Exchanger (blowdown cooler)

The purification heat exchanger consists of a spiral shaped series of coils held between two flat surfaces - a base plate and casing. These parts when bolted together form closed spiral shaped fluid circuits outside of the coils and in between the two surfaces previously referred to, running counterflow to the companion circuits inside of the coils. Coils are stacked on top of one another and held together by the base plate and casing. Each coil is attached to a manifold located at either end of the coil. These manifolds are then bolted to the base plate matching up with the piping connections to and from the coil side of the unit. The connection that admits cooling water to the outside of the coils is located on the base plate.

The heat exchanger will have the following characteristics:

a. Type: spiral tube, counterflow

b. Materials of Construction:

Coil:	3/8 x 18 BWG stainless type 304
Manifold:	bar stock stainless type 304
Base plate:	steel plate
Casing:	fabricated steel

c. Performance

	Conditions	
	Inside Coil	Outside Coil
1. Fluid Circulated	Primary Coolant	Cooling Water
2. Rate of Flow	104 g.p.h.	600 g.p.h.
3. Max. Entering Temp. °F	600	100
4. Max. Leaving Temp. °F	120	183
5. Max. press. drop, psig	-	less than 1

	Conditions	
	Inside Coil	Outside Coil
6. Operating Press. psig	1750	
7. Design Press., psig	2000	100
8. Hydrostatic Test Press., psig	2275	150
9. Total duty, BTU/hr	416,000	
10. Total Surface ft^2	11.6	

14.5.2 Pressure Reducing - Flow Control Station

Purification flow is controlled by use of; 1) a pressure reducing orifice, 2) a pressure control valve, and 3) a flow control valve. The pressure control valve is a self-contained control valve that senses the pressure downstream of itself and adjusts accordingly. The flow control valve is an electro-hydraulically actuated valve. The electrically operated valve actuator produces high performance without the use of electronic amplification, utilizing only a simple force motor to control the hydraulic pilot. The pilot system incorporates no close fitting parts, such as sliding plate or spool valves, using instead simple nozzle-flapper combinations to control hydraulic pressure. Although no operating experience is available with this setup in an APPR-1 type system, it is believed to offer a marked improvement over the motor-operated throttling valve installed in the Fort Belvoir plant.

The pressure reducing orifice is sized to reduce the pressure in the purification system from 1750 psig to approximately 450 psig. The pressure regulating valve downstream of the orifice controls effluent pressure at 100 psig (or other preset value). Since the flow control valve is not involved in pressure regulation, it can accurately control purification flow as required.

14.5.3 Demineralizer

The demineralizer is a vertically mounted cylinderical vessel constructed of Type 304 stainless steel with a design pressure of 100 psig. It serves simply as a container for the resin used to purify the primary coolant. The resin purifies the water by removing radioactive and non-radioactive corrosion product, serving both as a filter for insoluble material and exchanger for soluble ionic impurities. Since regeneration of radioactive resins is not feasible, the demineralizer is designed as an inexpensive unit that can be discarded and replaced. To facilitate replacement, minimize radiation exposures, and to prevent contamination of the shipping cask, inlet and outlet connections are provided with self-sealing quick disconnect couplings.

Influent water enters the top of the vessel through a distribution assembly which retains the resin in the unit and evenly distributes the water to minimize channeling. A similar assembly is also installed in the bottom of the demineralizer vessel to collect the purified water and prevent resin escaping into the outlet line. The distribution assembly chosen for the design consists of a number of slotted pipes radiating from the center inlet and outlet manifolds similar to spokes on a wheel.

To minimize radiation exposures to the operating crew, the demineralizer will be kept within the shipping cask which will be used to dispose of the unit when the resin is exhausted. Cask shielding design is covered in another section of this report.

14.5.4 Purification Filter

A cartridge type filter is included in the purification system to catch any resin fines leached from the demineralizer or, in the event of malfunction, any crud that might channel through the resin bed. Mean pore size of the filter is 5 microns, rated to remove any particles over 2 microns in diameter. Pressure drop across a clean unit is about 1 psi; however, entrapped material may increase this to over 5 psi. If pressure drops exceed the latter value, the housing is designed so that the cartridge can easily be replaced with a new unit.

14.5.5 Primary Make-up Tank

To provide a positive net suction head on the primary make-up pump and to provide an immediate supply of purified water for the primary system during possible emergencies, a 60 gallon make-up storage tank is included in the system. Assuming the maximum addition rate, the tank will hold a 30-minute supply of water. This time interval will permit the flow rate of make-up condensate from the secondary system to be increased to handle reasonable leakage rates.

A positive hydrogen blanket is maintained automatically over water in the tank to prevent in-leakage of air. The hydrogen is supplied from a cylinder with discharge pressure regulated by a pressure control valve. Since sufficient hydrogen may not be introduceable by this method to maintain 15-30 cc of hydrogen per kg. of coolant, particularly if appreciable air enters the primary system, a hydrogen addition system is included in the make-up system design.

14.5.6 Primary Make-up Pump

The primary make-up pump is a positive displacement, constant speed, controlled volume duplex pump rated at 1.7 gpm, maximum output under expected operating conditions. Discharge capacity can be adjusted from 0.17 gpm to 1.7 gpm by manually resetting the plunger stroke lengths while the pump is at rest. The pump motor is rated at 5 H.P., 440V, 3-phase, 60-cycles.

14.5.7 Hydrogen Addition Flask

A hydrogen addition flask is provided in the purification and make-up system design to permit addition of a controlled known volume of hydrogen to the primary coolant in excess of that introduced in the make-up tank. The addition assembly is illustrated on R9-47-1012 - Piping and Instrument Diagram, Primary Coolant System. Hydrogen is supplied to the addition flask from a cylinder of the gas and is used both to purge and pressurize the flask. When required, the flask is valved into the make-up line, the by-pass valve closed, and the make-up water sweeps the hydrogen into the primary system.

14.6 Boron Injection

In the event the reactor could not be brought to zero power because of a stuck rod condition, a secondary means of accomplishing this would be boron poisoning. One side rod stuck in the full up position is the most critical case and would require 9 grams of boron-10 dispersed within the core to effect zero power under these conditions. This could be accomplished by injecting 13.6 lbs. of boric acid in solution into the primary system.

14.6.1 Poison Tank

To prepare a 50% solution of boric acid at room temperature, 65 gals. of water are required, therefore a 75 gal. tank could serve as a mixing and storage tank and with the necessary piping to the suction side of the primary make-up pump the required injection force could be provided by this pump. The injection could be completed in 39 minutes.

14.7 Seal Leakage System

14.7.1 Seal Leakage Tank

A closed 20-gallon type 304 stainless steel tank is provided in the plant design to collect control rod seal leakage water. The tank is equipped with level control switches to automatically actuate the seal leakage pump. Pump effluent is discharged into the purification system upstream of the demineralizer. The tank is also provided with a high-pressure alarm, and a vent and relief valve connected to the stack through a flame arrestor.

14.7.2 Seal Leakage Pump

A canned rotor centrifugal pump is provided to empty the seal leakage collection tank as required. Pump output was sized so as to not adversely affect demineralizer efficiency due to high flow loadings. The level control switches which actuate the pump are designed to permit frequent operation of the pump to minimize seizure due to exposure in a moist atmosphere.

14.8 Spent Fuel Tank Recirculating Equipment

On the bottom of the spent fuel tank, inlet and outlet gate valves with 1/2" flanged connections are provided. A portable centrifugal pump is used to recirculate the water through a cartridge type filter whenever such action is dictated by excessive turbidity of the water. The use of a portable centrifugal pump has proved its usefulness at the APPR-1 installation at Fort Belvoir for such uses as recirculating, filling, draining and other general utility purposes.

14.9 Initial Fill

The primary system may be initially filled at a rate of 25 gpm from the secondary feedwater storage tank by utilizing one of the cooling water circulating pumps and the necessary piping and valves. The water will be pumped directly into the primary system and avoid the 1/2" primary blowdown line.

14.10 Activity Buildup Considerations

Radioactivity isodose levels around the primary system eight hours after shutdown from prolonged full power operation cannot be accurately predicted with present technology. Development work on this technology is presently proceeding under Task I of Contract AT-(30-3)-326. The following information on radioactivity levels in the primary system of the Army Package Power Reactor at Ft. Belvoir, Virginia is indicative of what can be expected in this similar skid mounted nuclear reactor. The data are based on least mean square values of dosage eight hours after shutdown following one year of extrapolated full power operation. Radiation measurements in pipe lines were taken on contact with the four inches of insulation surrounding the 12 inch outside diameter pipe.

	Location in System	Radiation Level Due to Deposition Activity on Primary System Surfaces (Mr/hr)
Crud	Piping Elbow below Steam Generator	850
Traps	Piping Elbow below Pressurizer	1900
	Reactor Inlet Pipe	270
	Side of Steam Generator	200

It should be noted that the piping elbows were crud traps and the activity could be reduced rapidly by flushing the crud from these points. The 200 mr/hr value in the steam generator appears to be the normal radiation level at points where crud does not concentrate.

The following table gives approximate radiation levels at given distances from the steam generator eight hours after shutdown.

Distance from Steam Generator	Radiation Level (mr/hr)
Contact with Steam Gen. Insulation	200
1 foot	112
2 feet	76
3 feet	40
4 feet	36
5 feet	24

15.0 WASTE DISPOSAL SYSTEM

15.1 Functional Requirements

The waste disposal system is sufficient to collect and process the entire liquid contents of the primary and secondary systems plus normal waste accumulation over a 2-month period. This is a total of 4400 gallons. However, the design capacity is based more realistically on the total volume of water in the primary system, the shield tank above the pressure vessel, and two months accumulation of normal radioactive plant wastes (hot laboratory wastes, active wastes from equipment and floor drains, and active wastes from sampling). In addition, sufficient extra capacity is included to accomodate decontamination and rinsing of the primary system.

15.2 Summary Description of System

The hot waste storage tank shown on R9-47-1014 - Piping and Instrument Diagram - Primary Coolant System - is the major facility for containment of radioactive liquids. Radioactive water will be added to the tank from a number of sources and for various reasons. During normal operation of the purification system, settings on the relief valves may be momentarily exceeded, dumping a small amount of water into the tank. If primary coolant or demineralizer effluent exceeds preset limits due to crud bursts or fuel element failure, the demineralizer influent or effluent can be manually diverted to the tank. In the event of a steam generator tube failure which would contaminate the steam generator blowdown, the blow-off tank can be dumped into the hot waste tank. Hot waste tank influent can also include shield tank water if the latter is contaminated by intermixing with the primary coolant when the pressure vessel cover is removed. Other fluids that may be added to the tank are condensate from the vent stack if the latter becomes contaminated; hot laboratory wastes; equipment and floor drains from certain skids; sampling wastes; contaminated laundry wastes; and solutions used to decontaminate, rinse, or flush equipment and system components.

Whatever the source or activity in the solutions added to the hot waste tank, the contents must be stored and/or processed. If storage and decay sufficiently reduce the activity and the water is not required for plant usage, the contents can be pumped into the ice cap for disposal. If purification is required, connections are provided on the discharge of the pump to process the tank contents through the purification system demineralizer. Demineralizer effluent from this operation can be returned to the plant via the make-up tank or can be returned to the hot waste tank for further processing or disposal.

15.3 Design Requirements

A 5000-gallon storage tank is used for the containment of radioactive liquid. This tank will provide for more than adequate collection of the entire primary coolant, one decontaminating flush, two rinses, and two months accumulation of normal plant wastes. The design capacity figures are listed below:

Volume of primary coolant	550 gal.
Volume of decontamination flush	550 gal.
Volume of two rinses	1100 gal.
Volume of two month's normal waste	350 gal.
	2550 gal.

Alternately, the tank is capable of holding the entire primary and secondary system volume plus two months normal waste. The total capacity required in this case amounts to 4400 gallons, including 600 gal. for primary coolant, 350 gal. for normal wastes, and 3500 gal. for the secondary system. The latter comprises the following:

Steam Generator	690 gal.
Condenser Hotwell	300 gal.
Pump and Piping	10 gal.
Condensate storage Tank	2500 gal.
	3500 gal.

Since all of these solutions, including any reducing-complexing solution used as a decontaminating reagent, can be processed through the demineralizer, the storage volume required will be less than that listed above. It is anticipated that the hot waste tank will normally only have to provide temporary storage of solutions pending treatment and disposal. A decontamination flush into this tank with subsequent disposal of radioactive crud will be necessary prior to plant relocation. However, due to insufficient technology on control of activated corrosion products, it is not known if the decontamination flush will have the desired effectiveness in reducing the radiation level of primary system components.

An evaporator will be provided for concentration of radioactive waste and reclaiming of waste water if directed by the government. it is anticipated that an evaporative capacity of 30 to 50 gallons per hour will be sufficient for this purpose. This would allow processing of a full tank of waste water in less than one week of continuous operation.

IV SECONDARY SYSTEM MECHANICAL AND ELECTRICAL DESIGN

A. Secondary System Description

1.0 Heat Balance and Flow Diagram for Design Conditions

The heat balance diagram for 1000 kilowatt gross load with 5×10^6 BTU per hour heating load is shown on drawing No. M01M5. A complete secondary station flow diagram of all systems is shown on drawing No. M01M1. The flow diagrams of each package is shown individually on drawings No. M01M2, No. M01M3, and No. M01M4.

1.1 Cycle Description

The steam generator delivers 24, 190 pounds per hour of dry saturated steam to the system. This steam is expanded from 425 p.s.i.g at the inlet of the turbine to 8 inches Hg. absolute at exhaust, which is condensed in a single-pass surface condenser.

Non-condensibles are removed from the condenser by means of a steam jet ejector which is cooled by a small surface condenser in the condensate stream.

Deaeration takes place in the condenser shell where special provision is made to produce oxygen-free water. The guaranteed maximum free oxygen remaining in the condensate is 0.03 c.c. per liter. Condensate is pumped from the condenser through the air ejector condenser and a feedwater heater to the suction of the boiler feed pumps. These pumps deliver the boiler feedwater to the boiler at a temperature of about 260°F. at full load. The feedwater heater receives steam from an uncontrolled extraction point on the turbine at approximately 45 p.s.i.a.

Drainage from the post heat exchanger is cascaded to the feedwater heater, which has an internal drain cooler through which the combined drains from the post heat exchanger and feedwater heater flows to the condenser.

Two, vertical centrifugal feedwater pumps are provided to return the feedwater to the steam generator, both being motor-driven. A three-element controller regulates and balances the steam flow in the main line and the feedwater flow to the steam generator by controlling the delivery of the centrifugal feedwater pumps through a feedwater regulating valve in the line to the boiler.

A packaged, manually-regenerated, single tower demineralizer delivers make-up to the 2500 gallon storage tank. It will also be used to supply the initial charge of water for both the primary and secondary systems. Make-up to the secondary system will be from the storage tank through response to level control in the condenser hotwell.

To control corrosion in the secondary system, the condensate will be continuously fed with morpholine solution to control pH and sulfite to scavenge oxygen. Morpholine will also be added to the storage tank to control corrosion in this tank and in the line to the condenser and cooling water system.

In the basic analysis it was assumed that cooling water as such would not be available in quantity, and it was decided to provide cooling services with an air blast cooler. This cooler is located on a single skid with maximum surface used.

The cooler delivers approximately 3000 g.p.m. of 60 percent by weight solution of ethylene glycol, which has a freezing point of minus 60°F., to the condenser; and a special section of the air blast cooler delivers 100 g.p.m. of glycol solution to the cooling water heat exchanger and the oil coolers of the turbine generator. These closed circulating water cooling systems supply all of the water required for cooling requirements. The cooling water heat exchanger cools approximately 28 g.p.m. of condensate, which in turn is used to cool the necessary items in the primary system. These include the primary coolant pump, primary shield tank cooling coils, spent fuel pit cooling coil, the primary blowdown heat exchanger, and primary space cooler.

Demands outside the station will require 130 g.p.m. of high temperature water for heating. This is produced by a heat exchanger using steam from the steam generator outlet. The drains will normally be returned to the feedwater heater, but may be returned to the condenser when the heater is out of service.

1.1.1 Alternate Cycle

In the alternate analysis, the cooling water at 40°F. is supplied from wells. In this case, the condenser and cooling water heat exchanger will be reduced in size, and the circulating water and heat exchanger circulating water pumps will be replaced by the deep well pumps. All other components remain the same.

1.2 Station Electrical Output

1.2.1 The auxiliary power requirements will, of course, vary somewhat with the outside temperature and load on the turbine, but the variation under all conditions will not be more than 20-25 percent. The auxiliary power, at full load under design conditions, including station lighting, will be approximately 200 kilowatts.

1.2.2 As shown on the heat balance diagram, drawing No. M01M5, the net electrical output of the station will be 800 kilowatts when the boiler output is 24, 190 pounds per hour, of which 5,490 pounds per hour is used for heating, and the condenser back pressure is 8 inches Hg. (outside air at 35oF.).

1.2.3 Under the same conditions, except that the condenser back pressure is 3-1/2 inches Hg., the net electrical output would be 910 kilowatts.

1.2.4 A graph No. M01 Figure 1, is attached hereto showing the net electrical output as it varies with condenser back pressure between 3-1/2 inches Hg. and 8 inches Hg.

1.2.5 When 40^{o}F. well water is used for cooling water, the auxiliary power requirements are reduced due to substitution of the well pumps for the condenser and heat exchanger circulating pumps and the air cooler fans. The net electrical output would then be 960 kilowatts. The back pressure should be constant at 3-1/2 inches Hg. under these conditions so the auxiliary power would be constant for a particular load.

2.0 SECONDARY SYSTEM INSTRUMENTATION AND CONTROLS

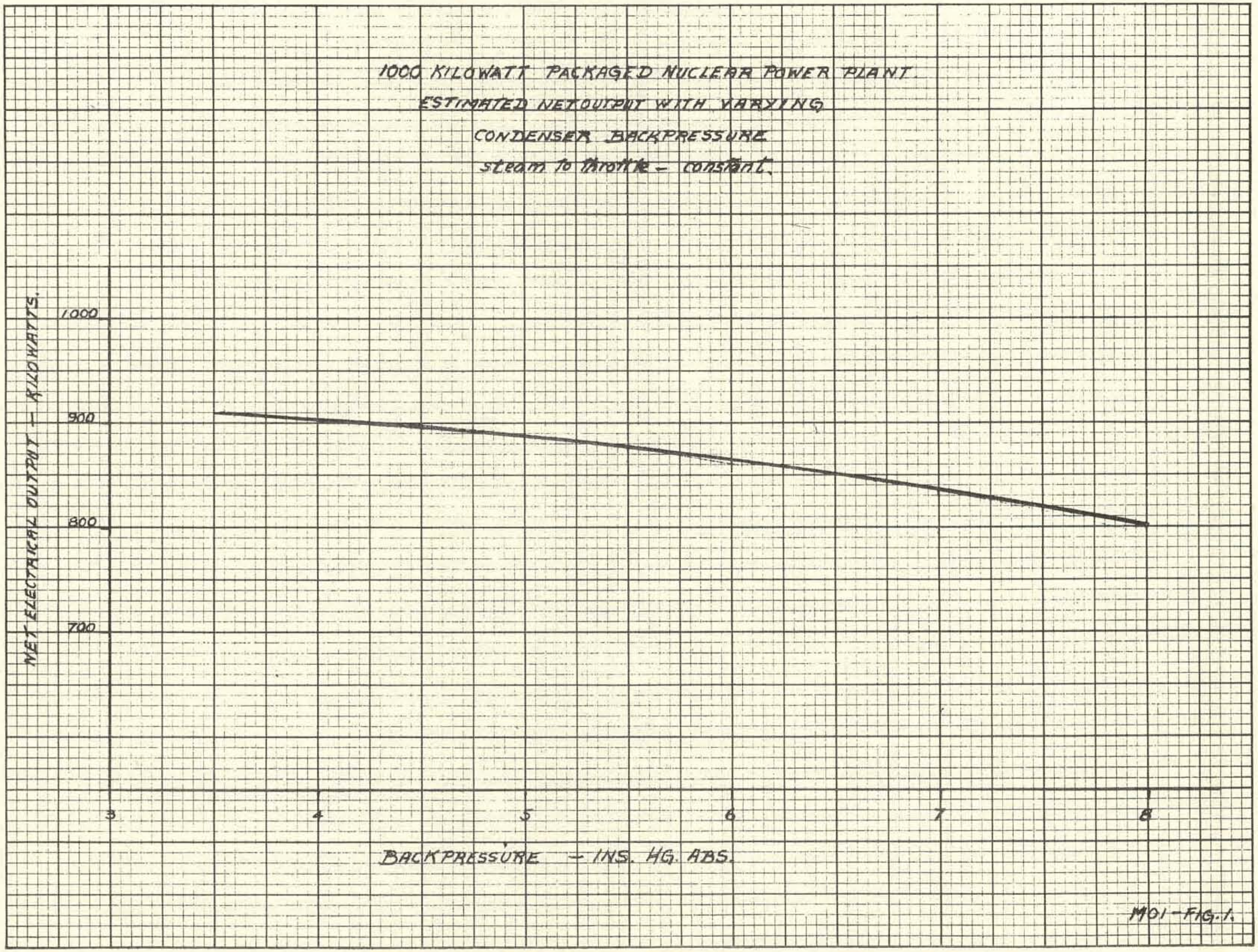
Since this plant is to be located in an area where temperatures are extremely low, it was felt that the use of air for any purpose where instruments were concerned was undesirable, due to the possibility of freezing the moisture in the air. Therefore, all of the instrumentation is either entirely mechanical or electrical. It is further basically decided that the plant would be operated with the minimum of personnel; hence, it is desirable to transmit to the main control board any indication of difficulty in the secondary side of the plant, and to use automatic start on any critical motors.

2.1 Specific Systems

All levels and tanks, condenser and heaters which are of any operating significance are provided with float-operated electrical switches which will annunciate on the main control board whether the level is high or low, as may be required. Such levels, if they are required to be controlled, are controlled by mechanically-linked, float-operated valves.

One of the most critical services to be found in the plant is the cooling water used to cool the primary coolant pump. Loss of this water would shut down the primary coolant pump in a few minutes. For this reason, the heat exchanger circulating pumps and the cooling water pumps are each provided with pressure switches on the discharge which will annunciate low discharge pressure, and will start the second pump in case of failure of the running pump.

One of the most critical services in the secondary system is the delivery of water to the boiler. Loss of pressure on the suction of the boiler feed pump could result in flashing of the liquid and consequent seizure of the boiler feed pump. For this reason, the boiler feed pump will


1000 KILOWATT PACKAGED NUCLEAR POWER PLANT.
ESTIMATED NET OUTPUT WITH VARYING
CONDENSER BACKPRESSURE
steam to throttle - constant.
NET ELECTRICAL OUTPUT - KILOWATTS.
1000
900
800
700
3
4
5
6
7
8
BACKPRESSURE - INS. HG. ABS.
M01-FIG. 1.

be protected by two pressure switches, one set slightly higher than the other. The tripping of one pressure switch will sound an alarm at the control room and automatically start the second condensate pump. Should both pressure switches trip, the boiler feed pump itself will be tripped out until such time as the operator may determine the cause and replace the system in operation.

3.0 STATION ARRANGEMENT

3.1 Description

The plant is designed for the placement of all component packages and interconnecting wiring and piping on a flat slab in enclosures. The secondary system packages, office, and laboratories are all located in a single building 59 feet by 65 feet. Piping and wiring connecting the packages is run on the floor and decked over with grating at the elevation of the component skid beams.

A bridge type crane runs over the principal equipment skids to facilitate maintenance and inspection of equipment. Space is provided for laydown of turbine parts during inspections as well as other maintenance and storage of spare parts.

3.2 Alternate Arrangement

In the event that the air blast coolers are replaced by the deep well pumps, the heat exchanger skid would be eliminated and this bay of the building would be eliminated. The building would then be lengthened to accommodate the rearrangement of laboratory space. The building would then be approximately 45 feet by 70 feet.

B GENERAL DESCRIPTION OF SECONDARY PACKAGES

The secondary system mechanical and electrical equipment is included in the following six packages: the turbine generator package; the condenser package; the heat exchanger package; the air blast cooler package; the feedwater package; and the switchgear package.

1.0 TURBINE GENERATOR PACKAGE

The general arrangement of the turbine generator is shown on appended drawing No. M01M14. The overall dimensions of the package are 16 feet 4 inches long by 7 feet wide by 6 feet 2 inches high. In order to meet the weight limitations imposed by aircraft transportation, several parts were removed and will be included with miscellaneous parts. This unit is a 1000 kilowatt, geared, turbine generator set, consisting of a multi-stage, multiple valve, condensing turbine with one uncontrolled extraction point, a single reduction herringbone gear, a 1200 r.p.m. air cooled generator, a direct connected 7.5

kilowatt exciter, lubricating oil cooler, oil purifier, and steam auxiliary lubricating oil pump, all mounted on structural steel base with an integral lubricating oil storage tank. The turbine is provided with an integral trip and throttle valve, speed control governor, and an overspeed governor.

1.1 Operating Characteristics of Machine and Auxiliaries

The turbine is designed to deliver 1000 kilowatts when supplied with steam at 425 p.s.i.g., dry and saturated, at the throttle and with 8 inches Hg. absolute condenser conditions. The turbine is also designed to receive steam at rising pressure from 425 p.s.i.g. at full load to 750 p.s.i.g. at no load. The turbine can be safely operated at condensing conditions down to approximately 3-1/2 inches Hg. absolute, without danger of excessive erosion in the last stage blading.

The turbine operates at 10,440 r.p.m. One extraction point at 45 p.s.i.a. is available for feedwater heating. Oil pressure for lubrication and operation of the hydraulic governor and control valves is supplied by a direct-connected gear pump, and an automatically controlled steam-driven auxiliary oil pump.

Lubricating oil cooling is accomplished by built-in heat exchanger which will be cooled with a glycol and water solution circulated through an auxiliary section of the air blast coolers.

1.2 Generator Characteristics and Operation at 1200 feet elevation

The generator is open-type, with two outboard bearings, and a direct-connected overhung exciter. It is rated at 1250 kilovolt amperes, 1000 kilowatts at 80 percent power factor, and wound for 480 volts "Wye" connected, grounded neutral, 3 phase, 60 cycles, and operates at 1200 r.p.m. The exciter is rated at 7.5 kilowatts, 125 volts, direct current, and is self-ventilated. The generator and exciter are designed to N.E.M.A. standards, and proportioned for continuous operation at full load with acceptable temperature rise for operation at full load with acceptable temperature rise for operation at an elevation of 1200 feet above sea level.

1.3 Total Weight and Weight Distribution

The total weight of the turbine generator unit is about 32,000 pounds. Since this exceeds the allowable shipping weight of 30,000 pounds, auxiliary equipment, including trip and throttle valve, and miscellaneous auxiliary devices weighing about 4,000 lbs., will be shipped separately.

1.4 Provisions for Air Transportability

To permit shipping this unit by air transportation, removable bracing and locking devices will be provided for the turbine and generator by the manufacturer, which will prevent axial movement of the rotating parts and resist the forces developed during air transit.

2.0 CONDENSER PACKAGE

The condenser package is shown on the appended drawings No. M01M6 and No. M01M7. This package is 27 feet 0 inch long, 6 feet 6 inches wide, and 9 feet high, and includes the condenser, two condensate pumps, and the steam air ejector. All piping and valving between components and the wiring and locally-mounted instrumentation are provided in the package with flanges provided for connection to other packages. All piping on the shell side of the condenser will be welded and flanged to prevent leakage of air into the condenser as completely as possible. As few connections as possible will be located below the water line to minimize this source of oxygen contamination.

Starters for the pump motors are located near the pumps. All electrical controls are run to one junction box from which connections will be made to the control center.

2.1 Condenser

One Alco Products, Incorporated's 3200 square foot, single-pass, horizontal surface condenser is being supplied. The condenser will be of the deaerating type with a steel hotwell of approximately four-minute storage attached. The unit is 19 feet 11 inches overall length and 51 inch diameter shell. The shell will contain 1040, 3/4 inch, 19 B.W.G., Admiralty metal tubes bowed between steel tube sheets. The condenser is elevated as high on the skid as possible to provide NPSH for the condensate pumps.

2.1.1 Design and Operating Data

The unit is designed to transfer 14.7 million B.T.U. per hour when supplied with 2980 g.p.m. of ethylene glycol solution 60 percent by weight at 130°F., and under these conditions will produce a vacuum at the steam inlet to the condenser of 8 inches of Hg. absolute. The pressure drop on the glycol side of the condenser will not exceed 4.9 feet of water.

The condenser is equipped with a float-operated level control which will admit water to the condenser from the feedwater storage tank. High and low level alarms will indicate difficulty with the control system to the operator.

2.1.2 Deaeration

The condenser is of the deaerating type and is guaranteed to produce condensate with 0 degree depression and with no more than 0.03 c.c. per liter oxygen content. This is the normal guarantee for any condenser, and since this condenser will be of the deaerating type it is expected that it will produce condensate of considerably better quality than guaranteed.

2.2 Air Ejectors

The air ejector selected is a steam jet ejector, with dual, single stage jets discharging into a 75 square foot surface condenser cooled by the condensate.

2.2.1 Design and Operating Data

The air ejector with one element operating is designed to remove at least 3 c.f.m. of free air from the condenser at absolute pressures greater than 3-1/2 inches of mercury when supplied with 350 pounds of 300 p.s.i.g. steam per hour. The jets require at least 25 g.p.m. of water for condensing the steam, and hence, it will be necessary to recirculate water back to the condenser at all loads under 500 kilowatts. The recirculation is done automatically by a Fulton Sylphon valve on the discharge side of the air ejector condenser, with the quantity of water recirculated being limited by a fixed orifice.

2.2.2 Advantages of Air Ejector Versus Vacuum Pump

Prior to the selction of the steam jet ejector, a study was made of the steam jet air ejector versus the rotary type vacuum pump. Conclusions indicated that the steam jet ejector was thermodynamically approximately as efficient as the rotary vacuum pump. In addition, its simplicity of operation and small amount of maintenance made it very attractive for the location in a remote area. Costwise, the dual element steam ejector with one spare element was approximately the same as the rotary vacuum pump with no spare capacity, hence, with these factors weighed, it was fairly obvious that the steam jet ejector was the proper selection.

2.3 Condensate Pumps

The two condensate pumps are vertical, volute, centrifugal pumps. They are driven by 20 horsepower, 1750 r.p.m., dripproof, vertically mounted, solid shaft, normal thrust, squirrel cage, induction motors.

2.3.1 Design and Operating Data

These pumps were selected for their low weight and ability to operate with low NPSH. Due to the head room limitation on the skid, approximately 1-1/2 feet of NPSH is available for the condensate pumps. Each pump will deliver 75 g.p.m. of condensate at 152°F. against a total dynamic head of 338 feet.

2.4 Skid Design

The structural steel skid, as shown on drawing No. M01S2, is made of United States Steel Company's "Tri-Ten", a high strength steel capable of withstanding shock at low temperatures. The skid is an all welded frame designed to support the weight of the equipment during transportation, including lifting, skidding etc. The skid is also designed to resist the inertial forces of the equipment while being transported by air; namely, 8 G's forward, 2 G's aft, 2 G's vertical, and 1.5 G's lateral.

2.4.1 Weight and Weight Distribution

The total weight of the condenser package, inclduing the structural skid, is 29,000 pounds. The skid has been proportioned to distribute the weight of the package in accordance with the allowable floor loading of the C-130 aircraft.

2.5 Condenser Cooling System

Two arrangements of the condenser cooling water system are considered. The air blast cooler is the basic design and well water cooling is the alternate.

2.5.1 Air Blast Cooler

The basic design uses an air blast cooler for cooling the fluid which serves to cool the plant auxiliaries. This design assumes that water is available in limited quantity.

2.5.1.1 Ethylene glycol solution containing 60 percent by weight of ethylene glycol is used as a coolant. While it has a low heat transfer coefficient, it will not freeze above minus 60°F. and, hence, should make operation much more dependable. If water were used it would necessitate draining quickly after shutdown and possible freezing of coils in the cooler during low loads.

2.5.1.2 The circulating water pumps required are low head centrifugal type located on the heat exchanger package, and are typical of the type of pump used in most power station service.

2.5.2 Well Water for Cooling

It is assumed that well water of suitable quality for direct, once-through cooling is available in quantities of about 600 g.p.m. Water is at a depth of 220 feet below grade approximately 300 feet from the condenser, and will be returned to a pool about 800 feet from the plant.

2.5.2.1 Equipment Required for Wells.

For reliability, two full capacity, multi-stage, deep well pumps complete with intake screen, suction pipe, shaft, discharge head, and 60 horsepower motor are supplied to deliver 600 g.p.m. of 40°F. water. 560 gallons per minute would be delivered to an 800 square foot, four-pass, condenser which would be adequate to produce the full capacity at 3-1/2 inches Hg. The remaining 40 g.p.m. would be used for miscellaneous cooling.

Since the water is so cool, the cooling water heat exchanger would be reduced in size and placed on the condenser skid which is now reduced in size. This system eliminates the need for the heat exchanger skid entirely.

2.5.2.2 Power Requirements

The deep well pumps will require 53 horsepower which is offset by 40 horsepower condenser circulating water pumps, 3 horsepower in heat exchanger circulating water pump, and 60 horsepower in cooling fans.

2.5.3 Comparison of Air Cooler Versus Well Water

2.5.3.1 Estimated Costs

The well pumps, condenser well water piping, and condenser for the well water installation would cost approximately $37,000.00. On the other hand, the equipment comparable to this with the air cooler would cost $74,000.00. This includes the 3200 square foot condenser, entire heat exchanger skid, air blast cooler, additional switchgear and controls. It should be pointed out that these figures do not include erection of equipment, foundations for equipment, drilling wells, reduction in building if wells are used, or enclosure for wells.

2.5.3.2 Power Requirements

The auxiliary power is reduced 50 horsepower (42 kilowatts) when using the well water at full load, and somewhat less as load decreases.

2.5.3.3 Plant Performance

The plant will operate at a constant 3-1/2 inches Hg. with well water and, hence, will effectively give a fixed higher station capacity and operate more efficiently at most load conditions.

3.0 HEAT EXCHANGER PACKAGE

This package is shown on appended drawings No. M01M12 and No. M01M13. This package is 9 feet 1-1/2 inches long by 9 feet 0 inch wide by 6 feet 6 inches high. The components included in this package are the cooling water heat exchanger, cooling water heat exchanger pumps, and the circulating water pumps. The cooling water heat exchanger has been held as close to the skid as possible. All piping has been held as close to the skid as practical for ease of supporting during shipment. All operating controls are accessible from the edge of the skid. The skid is entirely pre-wired with a minimum of connections necessary by the field to place in operation. This entire skid will be eliminated if well water is used for cooling.

3.1 Cooling Water Heat Exchanger

The cooling water heat exchanger manufactured by Alco Products, Incorporated, is a U-tube heat exchanger, 13 feet 6 inches in overall length with a 16 inch diameter shell.

3.1.1 Design and Operating Data

The heat exchanger is designed to transfer 380,000 BTU per hour from the cooling water entering at 127°F. and leaving at 100°F. to 63 g.p.m. of 60 percent by weight ethylene glycol. The ethylene glycol enters from the air blast cooler at 92°F. and leaves the exchanger at 107.5°F.

3.2 Circulating Water Pumps

The circulating water pumps delivering glycol to the condenser in a closed cycle are two, Worthington's type 6L-1, double suction, half capacity, horizontally split case pumps.

3.2.1 Design and Operating Data

Each circulating water pump has a rated capacity of 1500 g.p.m. against a total head of 38 feet. They operate at 1800 r.p.m., and require 20.0 brake horsepower when pumping the 60 percent glycol solution at 130°F. The pumps are the standard, cast iron, bronze fitted pumps with ball bearings, and are driven by two General Electric Company's induction motors rated at 20 horsepower, or equal.

3.3 Heat Exchanger Circulating Water Pumps

Two full capacity heat exchanger circulating water pumps deliver water to the cooling water heat exchanger and the air and lube oil coolers on the turbine generator. They are centrifugal pumps, mounted together with a 3 horsepower induction motor on a common structural steel baseplate.

3.3.1 Design and Operating Data

Each single stage pump operating at 3550 r.p.m. is designed to deliver 100g.p.m. of ethylene glycol solution against a total head of 40 ft. at a temperature of 92°F. The pump has a vertically split steel casing, with cast iron impeller and oil lubricated ball bearings. Only one pump will be operated at a time, and it will deliver approximately 63 g.p.m. to the heat exchanger, 37 g.p.m. to the turbine oil cooler.

3.4 Skid Design

The structural skid, as shown on drawing Number M01S4, is made of United States Steel Company's "Tri-Ten", a high strength steel capable of withstanding shock at low temperatures. The skid is an all-welded frame designed to support the weight of the equipment during transit, including lifting, skidding, etc. The skid is also designed to resist the inertial forces of the equipment while being transported by aircraft; namel, 8 G's forward, 2 G's aft, 2 G's vertical, and 1.5 G's lateral.

3.4.1 Weight and Weight Distribution

The total weight of the heat exchanger package including the structural skid is about 14,310 pounds. The skid has been proportioned to distribute the weight of the package in accordance with the allowable floor loading of the C-130 aircraft.

4.0 AIR BLAST COOLER PACKAGE

The general arrangement of the air blast cooler is shown on Alco drawing No. AES-288.

4.1 General Description

Due to the lack of cooling water at the site, closed circuit air blast coolers are used for condensing steam. An ethylene glycol and water solution is circulated in a closed circuit through the main condenser and air blast cooler. Auxiliary cooling is provided by a separate section of the air blast cooler, circulating a glycol solution through the auxiliary heat exchanger in a separate closed circuit. The air blast coolers are extended surface heat exchangers, liquid to air. The cooler is arranged with two banks of cooling sections placed vertically, one on each side of the unit. The liquid flow is horizontal through multiple tubes extending the full length of each bank. The tubes are connected into vertical headers at each end. Air flow is horizontal across the tube banks entering on the outside faces of the banks, flowing to the center. Air flow is produced by induced draft fans located between the tube banks, and placed at the top of the unit. The discharge from the fans is vertically up. The liquid flow in each main bank is two-pass entering and leaving the bank through flanged pipe connections on the headers at the same end. The main banks on each side of a cooler unit are arranged for parallel flow. The cooler is 30 feet 0 inch long by 9 feet wide by 9 feet high.

4.2 Performance and Design Data

Service - Glycol solution cooler
Draft Type - Induced
Number of units - One

	Units	Main Cooler	Auxiliary Cooler
Duty	Btu/hr	14,700,000	500,000
Extended Surface	Sq. Ft.	117,400	2,470
Air Temperature-In	°F	35	35
Air Temperature-Out	°F	109	76.8
Liquid Temperature-In	°F	142.2	106.3
Liquid Temperature-Out	°F	130	92
Total Fluid Entering	Lb/hr	1,500,000	44,800
Liquid Side Pressure Drop	p.s.i.	7	2.5

		Combined Cooler
Total Air Flow at Standard Conditions	c.f.m.	195,000
Total Static Pressure	In.-H_2O	0.55
Fans	Koppers	68 Inch Dia.
Number of Fans		4
Fan Speed	r.p.m.	675
Horsepower per Fan	h.p.	15
Total horsepower	h.p.	60

Materials:

Headers		Carbon Steel
Plugs		Brass
Tubes		Admiralty
Fins		Aluminum
Header Type		Welded Steel
Tube Type		Pressure Wrapped Fin
Tubes	1"O.D.x24'-0"	18 BWG

4.3 Weight Distribution

The air blast cooler has a weight of 25,200 pounds. The cooler is designed symmetrically about the longitudinal centerline and the weight of the coils and fans is uniformly distributed along the two side frames.

4.4 Skid Design

The skid is all-welded structural steel frame designed to support the weight of the equipment during transit, including lifting, skidding, etc. The skid is also designed to resist the inertial forces of the equipment while being transported by aircraft; namely, 8 G's forward, 2 G's aft, 2 G's vertical, and 1.5 G's lateral.

5.0 FEEDWATER PACKAGE

This package is shown on the appended drawings No. M01M8, No. M01M9, No. M01M10 and No. M01M11.

5.1 General Description and Components on the Package

This package is 25 feet 9 inches long by 9 feet 0 inch wide by 9 feet 0 inch high, and contains the feedwater heater, post heat exchanger, boiler feed pumps, feedwater storage tank, chemical feed system, cooling water pumps, secondary system demineralizer, and the following primary system auxiliaries: primary make-up pump, primary demineralizer, and the primary make-up tank. The two heat exchangers have been elevated in a horizontal position on the skid to allow the placing of smaller equipment underneath, and to assist in draining the heaters to the condenser. The constant speed, vertical boiler feed pumps and the heaters have all been grouped at one end of the skid to allow complete operation of this equipment within a small area. The feedwater storage tank has been located near the center of the skid so that its broad surfaces could be used for mounting the pump starters and controls, and the large amount of small piping from the primary system. The feedwater heater level controls are located between the feedwater heaters and are accessible for maintenance. The primary auxiliaries are all located at one end of the skid and on the outside of the package for ease of maintenance. In general, all of the piping, instrumentation, and electrical control on the panel are completely interconnected on the skid, requiring a minimum of connections being made to other skids.

5.2 Feed Water Heater

5.2.1 Description

The low pressure heater which is mounted along the edge of the skid is 17 feet 4 inches overall with a 14 inch outside diameter shell. The heater which is in the suction to the boiler feed pumps is valved for by-passing, U-tube design with the lower pass being shrouded for an integral drain cooler. It will have 26 U-tubes of 3/4 inch outside diameter arsenical copper, comprising a total gross surface of 138 square feet of which 69 square feet is in the sub-cooling zone. The heater will contain the required auxiliary equipment, including high level alarm, gauge glasses, level control, and tube and shell side safety valves.

5.2.2 Design and Operating Data

The extraction heater is designed to heat 24,000 pounds per hour of condensate after leaving the air ejector, to a total temperature of 258.7° F. at full load, operating normally at 41.0 p.s.i.a. It will receive drains from the post heat exchanger, which will be subcooled to approximately 177°F. or 10 degrees above the entering water. The drains from the heater will be returned to the condenser shell, and it is expected that the heater will have sufficient pressure differential to return these drains at all loads above 200 kilowatts.

5.3 Post Heat Exchanger

5.3.1 Description

The post heat exchanger is mounted parallel to the feedwater heater. It is 8 feet 9 inches in overall length with an 18 inch outside diameter shell. The exchanger will receive steam from the main steam line at reduced pressure to heat 130 g.p.m. of water for a high temperature water heating system. The exchanger is an Alco Products, Incorporated's four-pass, U-tube design. Temperature of the water will be maintained automatically by throttling of the inlet steam by a temperature actuated control valve. The exchanger will contain 90 U-tubes of 5/8 inch diameter, 18 gauge, 90-10 cupro nickel, comprising a total surface of 214 square feet. The exchanger will be equipped with the usual safety valves, level alarm, and drainer. Drains will normally cascade to the feed water heater, but may be routed direct to the condenser when the heater is out of service.

5.3.2 Design and Operating Data

The exchanger is designed to heat 130 g.p.m. of water from 190°F to 270°F continuously at all station loads, using saturated steam at 465-750 p.s.i.g. from the main steam line. A pressure regulator and safety valve is inserted in the incoming steam line to reduce the pressure to a constant 200 p.s.i.g. so that the exchanger and control valve would not need to be designed for the high pressure. Normal shell operating pressure will be 49.2 p.s.i.a.

5.4 Feedwater Pumps

The two feedwater pumps are vertical, 15 stage, double case, centrifugal pumps. Each pump is driven by a Louis Allis Company's 40 horsepower, 3550 r.p.m., dripproof, vertically mounted, solid shaft, squirrel cage induction motor. Either pump can supply the full load requirement of the boiler.

5.4.1 Performance and Design Data

The pumps are placed between the low pressure heater and the steam generator. Each pump will deliver 75 g.p.m. of feedwater at a temperature of 260°F. against a discharge pressure of 465 p.s.i.g. with a suction pressure of 100 p.s.i.g., and will deliver 10 g.p.m. against a discharge pressure of 750 p.s.i.g. The efficiency at 75 g.p.m. is 51 percent. The pumps are designed specifically for boiler feed service, the outer shell is of carbon steel, and the casings, impellers, wearing rings, shaft and shaft sleeves are constructed of 11-13 percent chrome steel.

5.4.2 Selection of Pumps

Due to the conditions of rising drum pressure with falling load, peculiar to the steam generator, a thorough investigation of various types of feed pumps was made before selecting vertical centrifugal pumps. Variable speed, multiple-cylinder, positive displacement pumps were considered because of the high discharge pressure required at low load; however, the high turn down range of 9 to 1 would require complicated speed control of the driver, and a gear speed reducer between the variable speed driver and the pump. Alternating current to direct current drives, hydraulic couplings, eddy-current couplings, and mechanical variable speed drives were considered. In each case, space requirement, weight, and first costs were higher than the centrifugal pumps. The centrifugal pumps operating at constant speed simplify the regulation of feedwater to the boiler drum. Whereas by variable speed drive the water level control would have to be translated by control mechanism to pump speed, with the centrifugal pumps the water level controller simply adjusts a throttling control valve in the discharge line between the pump and boiler.

5.4.3 Pump Mounting and Provisions for Air Shipment

The vertical feedwater pumps are supported by a mounting flange at the discharge head of the pump. This mounting flange is bolted to the structural supporting frame which forms a part of the complete feedwater package skid. The pump casing which contains the multi-stage pump is below the mounting flange, extending down to the bottom of the skid. This results in keeping the center of gravity of the pumps low on the skid, which is advantageous in shipping. The vertical motors which are mounted above the discharge head of the pumps will be removed for shipment for two reasons; one, to reduce the shipping weight of the package, and, two, to protect the pump shaft and impellers from damage during transit.

5.5 Chemical Feed System

5.5.1 General Description

The purpose of the chemical feed system in the secondary side of the plant is to treat the condensate, boiler feed, and steam in such a manner that the corrosion of all equipment will be held to a minimum. Practically all corrosion control systems in power plants accomplish this purpose by controlling the pH of the water in the boiler at a given alkalinity, and providing some means of oxygen scavenging. In this case, morpholine will be added to the condensate ahead of the low pressure heater which will in some degree control the pH of the feedwater in the cycle, as well as the pH of the water in the boiler. Since morpholine is carried through as a gas with the steam, it will protect the entire system from the boiler outlet back through the condenser.

Sodium sulphite will be added to the condensate stream at the same point prior to entering the low pressure heater. It will be fed continuously into the condensate stream and thereby protect the heaters and piping into the boiler, at which point the residual will be maintained to scavenge oxygen in the boiler. When the condenser is functioning properly, the amount of sulphite required to be pumped into the system will be rather small.

5.5.2 Performance and Design Data

Identical chemical feed pumps and tanks have been selected for both the morpholine and sulphite service since neither chemical is particularly corrosive. Each pump will be a proportioning pump with a single cylinder, having a capacity of 1.7 g.p.h. and being driven by a 1/3 horsepower, 1725 r.p.m., three phase, 440 volt, alternating current motor. The capacity of the pumps may be varied from zero to full rated maximum capacity by adjustment of the stroke. These pumps take their suction from a 15 gallon stainless steel tank set immediately above the pump. The suctions of the two tanks have been interconnected so that the pumps can be used for pumping either sulphite or morpholine in the event that one pump is out for service.

5.6 Secondary Water Treatment System

The secondary water treatment system consists of one mixed bed deionizer, which will receive raw water, and deliver water having a specific resistance of over 1,000,000 ohm centimeters. The unit having an overall height of 89-1/2 inches will be furnished on a baseplate approximately 47 inches wide by 33 inches deep, which will contain one deionizing tank 20 inches in diameter and 72 inches high, completely piped with 1 inch stainless steel Saunders type valves. The unit will contain 2.6 cubic feet of cation resin and 3.9 cubic feet of anion resin which will be manually regenerated.

5.6.1 Description and Performance Data

With the specified water containing no more than 180 p.p.m. total solids, the deionizer will have a flow rate of 1000 gallons per hour, and the capacity between regenerations of 5000 gallons. The unit will be regenerated manually, and should require between 2 and 2-1/2 hours to regenerate. During the regeneration period, the unit will require approximately 500 gallons of water at a rate not exceeding 17. g.p.m. Approximately 20 c.f.m. of air are required at 10 p.s.i. g. for mixing the beds after regeneration. A small softener will be supplied to soften the water for anion regeneration.

5.6.2 Supplementary Equipment

A blower, size 315, capable of producing 20 c.f.m. at 10 p.s.i.g. with accessories, and a 3 horsepower, dripproof motor will be furnished with the unit for operation during periods of regeneration to mix the resin.

This demineralizer package will be complete with an inlet integrating flow meter and Industrial Instrument Company's Solu Bridge indicating controller which will close a motor-operated water valve when the purity exceeds a present standards.

5.7 Feedwater Storage Tank

Forming a part of the skid will be a rectangular storage tank made of 1/4 inch steel plate. The tank will be covered and vented with an access manhole in the top. The tank is 6 feet 0 inch wide by 7 feet 3 inches long by 7 feet 11 inches high, and contains 2500 gallons of useable capacity. This rectangular shape tank utilizes the available space on the skid to the best degree. The tank will be complete with high and low level alarms and drain connection.

The 2500 gallon tank will have an expected storage capacity equivalent to 10 hours of operation. In case of emergency, the blowdown on the boiler could be cut off and the storage time extended to more than 24 hours.

The low level alarm on the tank has been set at approximately 2/3 capacity so that there will be sufficient time to regenerate the demineralizer in case of any difficulty after the alarm. Morpholine will be added to the tank to control pH of the water, and thereby reduce corrosion of this carbon steel tank and associated piping.

5.8 Cooling Water Pumps

The purpose of the cooling water pumps is to supply cooling water to the primary coolant pump, primary heat exchanger, space cooler, spent fuel pit cooling, and the shield tank coolers. This system is a closed circuit from the cooling water pumps through the various pieces of equipment to be cooled, back through the cooling water heat exchanger, and to the suction of the cooling water pumps. The feedwater storage tank is connected into the suction of the cooling water pumps, acting as a surge tank for the system.

5.8.1 Description and Design

The cooling water pumps which are provided in duplicate are centrifugal process pumps driven by 3 horsepower, 440 volt, dripproof motors at 3600 r.p.m. The pumps are rated at 35 g.p.m. and deliver 100°F. water against a total head of 50 p.s.i. The pumps are vertically split, with steel casing, cast iron impellers, and oil lubricated ball bearings. Although this is a heavy-duty, process type pump, a 100 percent spare has been provided which will automatically start in case of loss of discharge pressure.

5.9 Blowdown Flash Tank

A small flash tank is located on this skid together with the meter and control valves. The tank is sized to handle the maximum flow from the boiler through a 1/2 inch line, flashing the steam and retaining the water until cool.

5.10 Primary System Auxiliaries

While the primary system auxiliaries located on this package have no connection with the other equipment, it provides a convenient place for locating this equipment during shipment, and fits in quite well with the overall arrangement of the plant. Located on this skid are the primary coolant make-up tank, primary coolant make-up pump, and the primary coolant demineralizer, and cask together with the associated instrumentation and piping which are required to be accessible by the operators. The equipment is located around the edge of the skid for ease of maintenance and operation.

5.11 Shipment

Due to the limitation on height, it will be necessary to remove the safety valves on the heaters and ship separately. Due to the limitation on weight, it will be necessary to remove the primary and secondary demineralizers and ship them separately. For practical reasons and limitation on weight, it is desirable to remove the motors from the two vertical boiler feed pumps and to ship them separately, as will be detailed later. All other equipment will be shipped intact as assembled.

6.0 SWITCHGEAR PACKAGE

6.1 General Description

The switchgear package is as shown on drawing No. M01E3. The package is 26 feet 5 inches long by 9 feet wide by 8 feet 10 inches high.

6.1.1 Components

The switchgear package will contain the control console, the instrument distribution cabinet, the nculear rack, the motor control center, the switchgear, the battery rack and the rectifier,

6.1.2 Arrangement

The switchgear package has been arranged with the control console, the instrument distribution cabinet, and the nuclear rack mounted at the front of the skid. Due to its length the motor control center will occupy one side of the package and be separated by an aisle from the remaining components. Access space has been allowed at both sides of the control console. The switchgear front shall face the outside of the package to provide draw-out space for the breakers.

6.2 Switchgear Equipment

The switchgear will be one, indoor, draw-out type, unitized, 600 volt, 2000 ampere, 3 phase, 3 wire, metal - enclosed switchgear consisting of:

(a) One section for control of one, 1000 kilowatt, 480 volt, 3 phase, turbine generator.

(b) One section for control of one, 480 volt, 3 phase, incoming line.

(c) One section for control of one, 480 volt, 3 phase, auxiliary power circuit and two, 480 volt, 3 phase, outgoing feeder circuits.

6.3 Motor Control Center

The motor control center shall be an indoor, unitized, 600 volt, 600 ampere, 3 wire, 3 phase, motor control assembly, including motor starters, circuit breakers, etc., for the 480 volt circuits to the primary, feedwater condenser, heat exchanger, and air blast cooler package, and to the station services. The control center will also contain panel boards for the distribution of alternating current and direct current power for instrumentation.

6.4 Station Batteries.

The station battery will supply the direct current requirements of the control console and the tripping requirements of the switchgear circuit breakers. The battery will be the nickel cadmium type mounted in trays on a steel battery rack. The rating of 165 ampere hours is based on supplying the instrumentation load for approximately one hour after station power failure.

6.5 Electrical Equipment for Instrumentation

The rectifier unit will include both a power rectifier and an automatic battery charger mounted in the same unit. The unit will supply direct current control power which will be changed to a preferred alternating current supply for the control console, nuclear rack, and monitoring devices. The distribution of the control power is as shown on drawing No. M01E2.

6.5.1 Rectifier Unit

The rectifier unit will be a free standing, fully enclosed, ventilated, indoor unit of the solid state type. The power rectifier will be rated for the 100 ampere, 28 volt, direct current instrumentation load, and the floating charge of the battery. The automatic battery charger will be capable of recharging the battery from a fully discharged state, and shall automatically reconnect the battery at the end of the charging cycle or, in case of failure of normal power, at any time during the charging cycle. The charger will automatically set the charging cycle required by the state of discharge of the battery.

6.5.2 Inverter

The inverter will be a solid-state unit for inverting approximately 3000 watts, 28 volts, direct current to 115 volts, 60 cycle, alternating current. The inverter will be designed to mount in the motor control center.

6.6 Weight Distribution

The weight distribution is as follows:

Unit	Pounds
Motor Control Center	5,000
Control Console	2,700
Instrument distribution cabinet	750
Nuclear Rack	1,550
Battery	800

Rectifier	1,000
Switchgear	6,000
Conduit and wire	500
Skid	5,890
Total	24,190

C. INTERCONNECTING PIPING AND WIRING

Inasmuch as each package unit is completely piped and wired within itself at the factory, there remains only the necessity for interconnecting the various packages when they are in place. As each package is made up of functionally associated apparatus, the items involved in the interconnection of the packages are held to a minimum. It was possible, therefore, to design the interconnecting piping and wiring between packages to permit erection in the field with the expenditure of a minimum of time and labor. All piping is designed to be entirely prefabricated in the shop in the largest pieces consistent with shipping clearances.

Piping between skids of all lines where drainage is not a problem will be run and supported along the floor underneath the grating. Other piping will be supported from skids and building as required.

1.0 PROVISIONS FOR MINIMUM ERECTION TIME

In addition to use of Maximum lengths of prefabricated pipe, all connections will be designed to use the type of coupling requiring the least labor to install consistent with the service.

A building crane is specified which should facilitate handling of larger sections of pipe, and setting of the vertical motors and other pieces of equipment that were removed for shipment.

1.1 Flanged Connections

High pressure steam and boiler feedwater piping will be furnished with 600 pound, raised face, steel, welding type of flanges. Low pressure steam, condensate, and other miscellaneous piping, will be furnished with 150 pound, raised face, steel, welding type of fittings, except at points of connection to iron body flanges on pumps and valves. At these connections, the 150 pound, steel flanges will be flat faced to prevent the hazard of breaking the iron mating flanges. Flanges on the stainless steel piping will be stainless steel welding flanges of pressure ratings suitable for the particular lines, or stainless steel lap joints with carbon steel flanges.

1.1.1 Victaulic Connections

All low pressure lines below 180°F. will be connected wherever possible with victaulic couplings to reduce weight and labor of erection. These couplings also are capble of some misalignment and expansion.

1.2 Gasketing

Flanges on the high pressure steam and boiler feed lines will be made up with "Flexitallic", or equal, gaskets. Low pressure steam and all other lines over 150°F. will be made up with asbestos composition gaskets "Cranite", or equal. All flanged lines operating at 150°F. and lower will use red rubber gaskets.

Special silicone rubber gaskets will be used with victaulic couplings at very low temperatures.

1.3 Electrical Connections

Interconnecting power wiring between the motor control center and the separate packages, and instrument and control wiring between the various packages, are run in cable trays. The cables are arranged in a single tray with a barrier between the power and instrument wiring.

Main generator leads to the enclosed metal switchgear are in waterproof bus duct.

All power and instrument connections are made to centralized junction boxes by means of quick disconnect plug-in receptacles.

2.0 Estimated Interconnecting Piping and Wiring

The estimated weight of the interconnecting piping between the packages, including pipe, valves, fittings, insulation, and supports is approximately 40,000 pounds and will require two shipping packages. The estimated weight of the interconnecting wiring materials is 10,000 pounds which will require 1/2 package for shipment.

D. SUMMARY OF SECONDARY SYSTEM DESIGN DATA

1. Overall Summary

Total Number of Secondary Skids		6
Total Number of Secondary Shipping Packages		9
Total Weight of Secondary Packages	Lb.	218,650

2. Turbine Generator

Dimensions		16' 4" X 7' 0" X 6' 2" high
Total Weight	Lb.	32,000
Shipping Sections:		
Turbine, Gear, Generator and Base - Dimensions		16' 4" X 7' 0" X 6' 2" high
Weight	Lb.	29,000
Auxiliary Section	Lb.	4,000
Voltage:		
Main		480 V. AC, four wire
Exciter		125 V. DC

3. Condenser Skid

Dimensions		27' 0" X 6' 6" X 9' 0" high
Overall Shipping Weight	Lb.	29,070
Components and Weights:		
Condenser	Lb.	19,100
Air Ejector	Lb.	1,150
Condensate Pumps	Lb.	2,000
Condensate Pump Motors (Shipping separately)		
Skid Base	Lb.	4,820
Electrical Equipment	Lb.	200
Piping and Controls	Lb.	1,800

4. Feedwater Skid

Dimensions		25' 9" X 9' 0" X 9' 0" high
Overall Shipping Weight	Lb.	29,480
Components and Weights:		
Boiler Feed Pumps (less motors)	Lb.	5,600
Feedwater Heater	Lb.	2,800
Post Heat Exchanger	Lb.	2,900
Secondary Demineralizer (shipped separately)		
Air Pump and Motor	Lb.	300
Cooling Water Pumps and Motors	Lb.	750
Feedwater Storage Tank	Lb.	3,300
Blowdown Tank	Lb.	430
Chemical Feed Pumps and Tanks	Lb.	560
Make-up Pump	Lb.	1,000
Make-up Tank	Lb.	350
Controls and Instruments	Lb.	1,470
Electrical Starters and Wiring	Lb.	1,000
Piping	Lb.	1,820
Skid Base and Floor Plates	Lb.	6,300
Insulation	Lb.	900

5. Heat Exchanger Package

Dimensions		19' 1-1/2" X 9' 0" X 6' 6" high
Overall Shipping Weight	Lb.	14,310
Components and Weights:		
Cooling Water Heat Exchanger	Lb.	2,400
Circulating Water Pumps	Lb.	3,260
Heat Exchanger Circulating Water Pumps	Lb.	1,200
Electrical Equipment	Lb.	500
Piping	Lb.	3,190
Skid	Lb.	3,760

6. Air Blast Cooler

Number of Sections Required		1
Horsepower Requirements - Total		60
Dimensions		30' 0" X 9' 0" X 9' 0" high
Overall Weight	Lb.	25,200
Volume of Glycol Solution	Gal.	665

7. Switchgear Skid

Switchgear Skid - Dimensions		26' 5" X 9' 0" X 8' 10" high
Switchgear Skid - Total Weight	Lb.	24,190
Components and Weights:		
Primary Instrument Console	Lb.	2,700
Nuclear Panel	Lb.	1,550
Motor Control Center	Lb.	5,000
Battery	Lb.	800
Instrument Distribution Cabinet	Lb.	750
Switchgear	Lb.	6,000
Skid	Lb.	5,890
Conduit and Wire	Lb.	500

8. Interconnecting Piping and Spare Parts

Total Weight and Piping and Specialties	Lb.	40,000
Total Weight of Spare Parts	Lb.	4,000
Number of Shipping Sections Required		2

9. Interconnecting Wiring and Miscellaneous Equipment

Total Weight of Wiring and Raceways	Lb.	10,000
Total Weight of Miscellaneous Equipment	Lb.	14,400
Primary Demineralizer	Lb.	6,000
Condensate Pump Motors	Lb.	1,200
Boiler Feed Pump Motors	Lb.	600
Turbine Auxiliary Equipment	Lb.	4,000
Secondary Demineralizer and Softener	Lb.	2,600
Number of Shipping Sections Required		1

V. Appendix

This section contains comments and answers relative to comments previously received from Eastern Ocean District and ERDL, Army Corps of Engineers.

These comments pertained to Alco Products "APAE-39 Design Analysis of a Prepackaged Nuclear Power Plant for an Ice Cap Installation. Comments which are not directly applicable to this design analysis were not included in this section.

APPENDIX

Comments on Alco Proposal for Power Plant

R1.

1.08. What provisions will be made to prevent battery gasses and solutions from effecting controllers and sensitive instruments on the control package? What provisions will be made to reduce transformer and plant noise in the control room?

1.08-A. The battery can be enclosed and vented, the venting arrangement depending upon final enclosure arrangement. An enclosure can be provided around the switchgear skid to eliminate plant noise in the control room.

1.11. Can all lines be drained to prevent freezing in the event that heating is not available during prolonged shutdown?

1.11-A. Yes

R2.

Dwg. No. M01M2 does not show any means for bypassing steam around the turbine directly to the condenser. It is felt that this additional flexibility can be valuable in operations, i.e., starting the plant. Was it considered, and if so, why was it not included?

A.- Yes it was considered. It was not included since it is not necessary for plant operation and without going to additional weight and cost in piping, valves and a desuperheater not more than 25% by-pass could be achieved.

Dwg. No. M01E1 should show the size of all breakers in the motor control center. A synchronizing lamp should be provided for the synchronizing panel.

A.- For a final design the size of all breakers would be included. A synchronizing lamp can be provided for the synchronizing panel.

Dwg. No. R9-43-1004 shows the flanges on the primary coolant line between reactor vessel and steam generator to be below the level of the core in the reactor vessel. The inlet and outlet lines also join the reactor vessel below the level of the core. When it is necessary to disconnect the main flanges or remove the head of the steam generator to plug a tube, what is to prevent the water in the reactor vessel from draining to below the level of the core? Available space to pull the pressurizer or primary coolant pump is questionable.

A.- This has been considered. Although not indicated on the drawings, provisions for inserting an inflatable type ballon into the inlet and outlet primary coolant lines at the steam generator can be made. This approach will preclude the draining of the primary system coolant below the level of the core, when removing the steam generator head.

Space to pull the primary coolant pump or pressurizer is available.

Dwg. No. R9-47-1011. Some sort of a graphic panel for process control is desired. The steam pressure and feed water pressure should be recorded on the same chart since the boiler feed water excess pressure controller will be maintaining a constant differential between these two.

A.- It can be provided ($2000.00) but it is felt that the quality of operators would leave it unused. An excess pressure controller is not required as pressure load characteristic of steam generator and boiler feed pump are parallel.

Dwg. No. H47210-3-1 and H47210-3-2 show that if the liquid level in the steam generator varies between the liquid level control points shown, approximately 9 inches of the upper portion of the tube bundle will be alternately covered and exposed. This is the worst possible condition for occurrence of stress corrosion in the tubes and tube sheet joints. There seems to be no way to avoid this circumstance with the type of steam generator and liquid level controls which have been selected.

A.- The liquid level controller will hold the level within limits to prevent tube baring during normal operation. The level will not vary between the level control connection joints maximum limit.

R3.

3.8: If suitable specifications exist for Europium containing absorber sections for the control elements at the time the core is fabricated, will they be used in lieu of Boron containing absorbers? The Europium absorber sections have been designed to have the same worth as the present APPR-1 Boron rod. However, the fabricating technique is different so that the corners of the EU rod are filled with absorber, in contrast to the APPR-1 rods. If Alco assumed $(\Sigma \text{ a thickness})^{B} = (\Sigma \text{ a thickness})^{EU}$, the Europium rod will be worth more than the Boron rod. Unreported work in the original ORNL critical experiments for APPR-1 show that filling the corners with absorber makes a significant difference.

A.- Europium containing absorber sections for the control elements will not be used at this time. This depends on the results of rods taken out of the APPR-1.

No, the fabricating technique is the same.

3.9 What part of the 247 r/hr dose rate at the surface of the shield tank is due to neutrons and what part to gammas? Dose rate at the surface of the primary demineralizer shield cask is 70 mr/hr and is too high since it is located on the feed water package.

A.- For the 10 MW primary system the 247 r/hr was a conservative calculation for the dose rate at the surface of the shield due to gammas. The dose rate due to neutrons would be 30 r/hr and it was felt that the 247 r/hr dose rate would cover both.

For the 6.5 primary system the dose rate at the surface of the shield tank is 161 r/hr of which 20 r/hr is due to neutrons. It was assumed that personnel would not be on the feedwater skid for any appreciable time. The dose rate decreases with distance from the cook surface which is located at the far end of the skid. Therefore, the cash was designed that the dose rate would be about 58 mr/hr on the cash surface. If a lower dose rate is desired more lead would be needed. One inch of lead added will decrease the dose rate to about 20 mr/hr on the surface of the cash.

3.10: In calculating the maximum internal fuel plate temperature what allowance was made for scale on the plate surfaces? What thickness was assumed and what value of thermal conductivity was used?

A.- It was assumed that there was no scale formation. This is more realistic than assuming scale as a very high purity water is used in the primary system.

R4.

4.1. If a rupture of the primary blowdown line occurs downstream of the blowdown cooler and outside of the vapor container but upstream of the pressure reducing- flow control station, what will be the rate of loss of primary water? Where is the pressure reducing station located on the feedwater package (Dwgs M02M3, M02M4)? Are demineralizers and filters capable of handling the maximum blowdown rate which is controlled by pressurizer level?

A.- The rate of primary water loss would be extremely high. The pressure reducing station is located upper left of primary make-up tank when viewing the skid from the demineralizer end. The demineralizers and fillers are capable of handling the maximum blowdown rate.

4.1.3. A filter placed upstream from the demineralizer would prolong the demineralizer life. Could this be included?

A.- Judging by results from Task I - Activity Buildup Studies and Task VI- Shielding Studies of the APPR-1 Research and Development Program, Contract AT(30-3)-326, a filter upstream of the demineralizer would improve ion exchanger performance and reduce activity on the resin bed. However, of the commercially available filters, only porous stainless steel has been used in an operating pressurized water reactor plant. Naval reactor experience with this type of filter in the hydraulic service system has been one plugging and high pressure drops necessitating frequent back-flushing. Because of the potential advantages filters offer for coolant purification - compactness, weight reduction, cost, decreased cooling water requirements, etc.- the naval reactor program has been conducting development programs on several types of filters with encouraging results. Accordingly, as part of the APPR-1 research and development program, it has been proposed to test axial bed filters in the APPR-1 purification system upstream and downstream of the blowdown cooler. The object is to develop a filter capable of operating at system temperature and pressure, since one disadvantage of ion exchangers is the necessity of cooling influent water to prevent thermal damage. If successful, the purification system could combine filtration at a high flow rate plus demineralization at a low flow rate, appreciably reducing cooling water requirements and the size, weight, and cost of auxiliary system components.

Until the proposed development program is completed, however, inclusion of a filter upstream of the demineralizer is not recommended. Possible advantages could be negated by operational problems.

4.4.4 and 4.4.8: A conflict exists in the setting for the power level scram 120% and 150% are indicated.

A: 120% is correct.

4.4.8: A scram at minus 6% flow is listed. What type sensor will be used to eliminate false scrams from normal turbulent flow?

A: Turbulent flow is encountered at Ft. Belvoir with flow tube in outlet of pump. Present sensor is across steam generator. If power recorder is provided a Gentile' flow tube will be used. This is manufactured by Foster and is designed specifically for conditions encountered in our type of system.

4.4.8: Why are high primary flow and high steam temperature scrams included? The primary temperature scram should cover the function of the latter above mentioned scram.

A: High primary flow, this is essentially to give indication of steam generator tube pluggage and should be in the form of an alarm. The steam temperature scram would indicate a primary-secondary rupture.

4.4.9: At a site where 1-year tours are expected, all simplifications possible for the operators including a graphic panel are worthwhile. What is the difference in cost to be expected? The graphic layout obviously should not be as extensive as in APPR-1.

A: Graphic panel would take the form of small panel over console with lights. According to complexity cost will be in the range of $1-2000.

4.4.9.6: Annunciator for 96 variables has 2 relays per station. Could these be replaced with transitor and magnetic amplifier switches to reduce maintenance?

A: This is being considered together with selective annunciation of the first off-normal variable causing trouble. Redesign and delivery time is a problem.

R10:

How will the reactor skid section be pulled into the vapor container if only one end is open?

A: The reactor skid section can be pulled into the vapor container by use of winches at the end of the vapor container and cables which can be attached to the front of the skid.

R15:

What means are furnished to replace shield tank water which will boil away during emergency cooling?

A: Water will be replaced through tank filling connection.

17.3: What assurances, in the form of test procedures, will be available prior to start up at the site that cracks and potential failures have not been produced in critical primary system components during shipment?

A: Pressure testing is contemplated.

R19:

The plan for relocation of the primary system (reactor vessel, shield rings and shield tank) seem unrealistic. Has any economic comparison been made of cost of relocation of these components versus replacement with new, uncontaminated components?

A: If the outside surface bearing will not support a 60 ton load or if a 60 ton vehicle cannot be made available then the relocation scheme we reported will necessarily be changed.

As an alternate, if the above is "unrealistic" the following relocation procedure will be used:

1. Cut eliptical head from the steam generator end of vapor container and remove.

2. Part primary skid at dividing point.

3. Remove steam generator end of skid including pump which is within 30,000# and haul to new location.

4. Parting flange as primary shield tank will be disengaged to clamping device.

5. Reactor section of primary skid including shielding rings will be skidded out of vapor container. The weight of this package will be 60,000#.

6. The vapor container will be cut up into two sections to come within the 30,000# limitation. Three girth welds will be necessary after relocation of V.C. or about 120 ft. of welding.

7. To replace V.C. the cost is approximately $59,600.00 FOB Dunkirk. Replacement of major components would include, reactor vessel, shield rings, core support structure, half shield tank, inlet and outlet pipe to and including

two flanges, and the half skid. The cost of the items listed FOB Dunkirk is approximately $170,000.00 or approximately $230,000.00 with V.C.

2.0 Since the temperature coefficient becomes more negative at higher temperatures, further work is necessary to demonstrate the validity of the extrapolation from APPR-1 nuclear design in regard to loading, reactivity and anticipated control rod position as a function of life and temperature.

A: Further experimental work on the APPR-1 on effect of life and temperature upon loading, reactivity and control rod position must be performed. This data will enable us to determine the accuracy of our analytical technique and can be applied to the skid mounted analysis.

2.5 Thermal Parameters: The maximum steady state fuel plate surface temperature (610°F) is only 7°F below saturation temperature at design primary pressure (1750 p.s.i.) This is very close considering the inaccuracies in hot channel factors.

A: All hot channel factors were on the high side and were assumed to occur simultaneously. The answer is therefore conservative and the plate surface temperature a maximum value.

8.2 What consideration has been given to the stresses that will arise in major piping during the extremes of temperature that can be experienced between operating and shutdown conditions?

A: This has been properly investigated via piping stress analysis.

8.3 Will primary system flanged connections require seal welding?

A: It is not completed to do any seal welding at the primary system flanged connections.

11.10 How is water added to the upper shield tank to replace that which boils off following loss of coolant flow?

A: Water can be added to the primary shield tank to replace that which boils off following loss of coolant flow.

13.2.1.6.2 Period scram cust out at 80% of full power. Since the plant may be operating below this level quite a bit of the time, it is felt that this cut-out is set too high.

A: The 80% power cut out is conservative. It can be lowered. We request a more definate indication of power levels anticipated.

13.4 Are the chamber wells really thimbles in the vapor containers from which the detectors can be withdrawn without opening the vapor container? BF_3 has not proven to be sufficiently dependable to operate alone. How far from core region is it withdrawn? It should either be completely withdrawn from the vapor container or duplicated.

A: Detectors can be withdrawn without entering the vapor container. Removal device is to increase chamber life. It is only required for use during startup and shutdown. Calculations indicate that BF_3 does not have to be moved during startup.

The BF_3 is completely withdrawn from the shield tank after startup and it is proposed to withdraw the BF_3 from the shield tank into a shielded container directly above the shield tank.

13.6 It is difficult to calibrate safety detector tubes by location with respect to core. Either (1) provide better calibration than APPR-1, or (2) be sure that 120% of power is not critical.

A: Better calibration can be provided due to experience gained on APPR-1. Final calibration will be performed after full power is attained. Recalibration is necessary as fluxes increase.

Secondary System

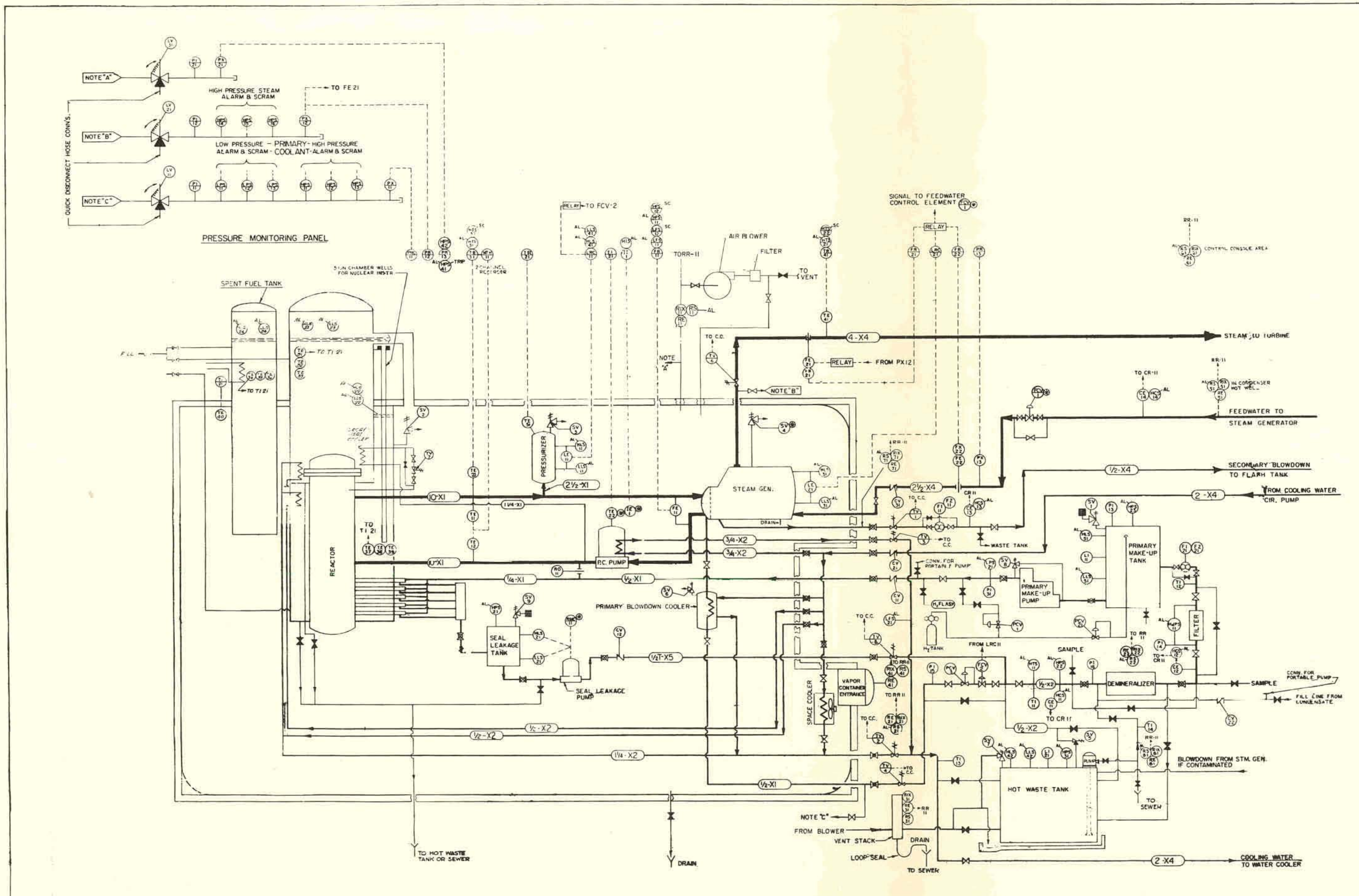
5.4.2 There should be added to the boiler feed system a differential pressure controller and a throttle control valve. The controller would sense the pressure differential between the steam generator steam outlet and the feed pump outlet and would provide the signal for the throttle control valve. The latter would be located in the line between the feedwater control valve and the feed pump outlet. The controller would be adjusted to provide a constant pressure drop across the feedwater control valve. This latter valve is actuated by signals from the three-element controller and would not operate properly when exposed to the large variation of differential pressure that would exist without the two additions described above.

5.5.2 Are the chemical feed pumps standard industrial quality or are they laboratory type equipment?

A: They are of standard industrial quality.

VI Drawings

This section includes the drawings covering the plant components and packages and overall plant arrangement. Details of buildings and foundations are not included but are only indicated.



GENERAL IDENTIFICATIONS

		VALVES	CONTROLLERS			MEASURING DEVICES				TRANSMITRS		SWITCH
		REGULATING	RECORDING	INDICATING	BLIND	RECORDING	INDICATING	PRIMARY ELEMENTS	GLASS OBSERVATION	BLIND	INDICATING	HIGH, LOW
		CV	-RC	-IC	-C	-R	-I	-E	-G	-X	-IX	-S
TEMPERATURE	T-	TCV	TRC	TIC	TC	TR	TI	TE	—	TX	TIX	H-L-TS
FLOW	F-	FCV	FRC	FIC	FC	FR	FI	FE	FG	FX	FIX	H-L-FS
LEVEL	L-	LCV	LRC	LIC	LC	LR	LI	LE	LG	LX	LIX	H-L-LS
PRESSURE	P-	PCV	PRC	PIC	PC	PR	PI	PE	—	PX	PIX	H-L-PS
CONDUCTIVITY	C-	—	CRC	CIC	CC	CR	CI	CE	—	CX	CIX	H-L-CS
RADIATION	R-	—	RRC	RIC	RC	RR	RI	RE	—	RX	RIX	H-L-RS
DIFFERENT. TEMP	dT-	—	dTRC	dTIC	dTC	dTR	dTI	dTE	—	dTX	dTIX	H-L-dTS
" PRESS	dP	—	dPRC	dPIC	dPC	dPR	dPI	dPE	—	dPX	dPIX	H-L-dPS

Z = FLOW INTEGRATOR

LEGEND

LV LEVER OPERATED VALVE
LOCALLY MOUNTED INSTRUMENTS
BOARD OR PANEL MOUNTED INSTRUMENTS
CC CONTROL CONSOLE
SV SAFETY VALVES (SAFETY & RELIEF)
CV CHECK VALVE
TV TRIP OR SNAP-ACTING VALVE
FLOW INDICATOR
CHECK VALVE
GATE " NORMALLY OPEN
GLOBE " "
GATE " " CLOSED
GLOBE " " "
RELIEF VALVE
CONTROL VALVE
SOLENOID OPER. VALVE, NORMALLY OPEN
" " " CLOSED
RO RESTRICTING ORIFICE
CPS CONTROL PRESSURE SWITCH
AL ALARM
SC SCRAM
FURNISHED BY EQUIPMENT VENDOR
ORIFICE OR FLOW SENSING ELEMENT
RMC REMOTE MANUAL CONTROL
MO MOTOR OPERATOR

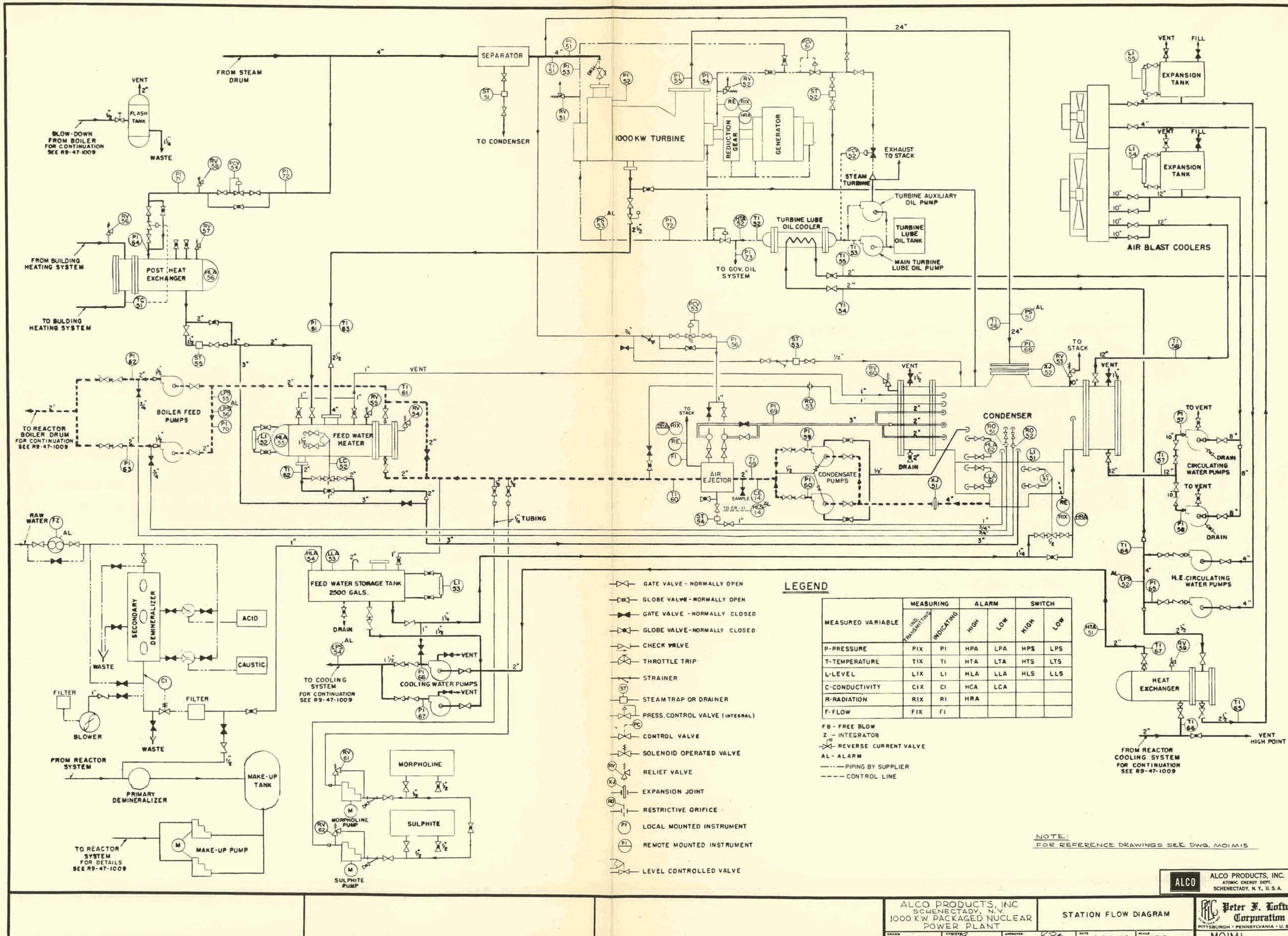
PIPING SPEC'S.

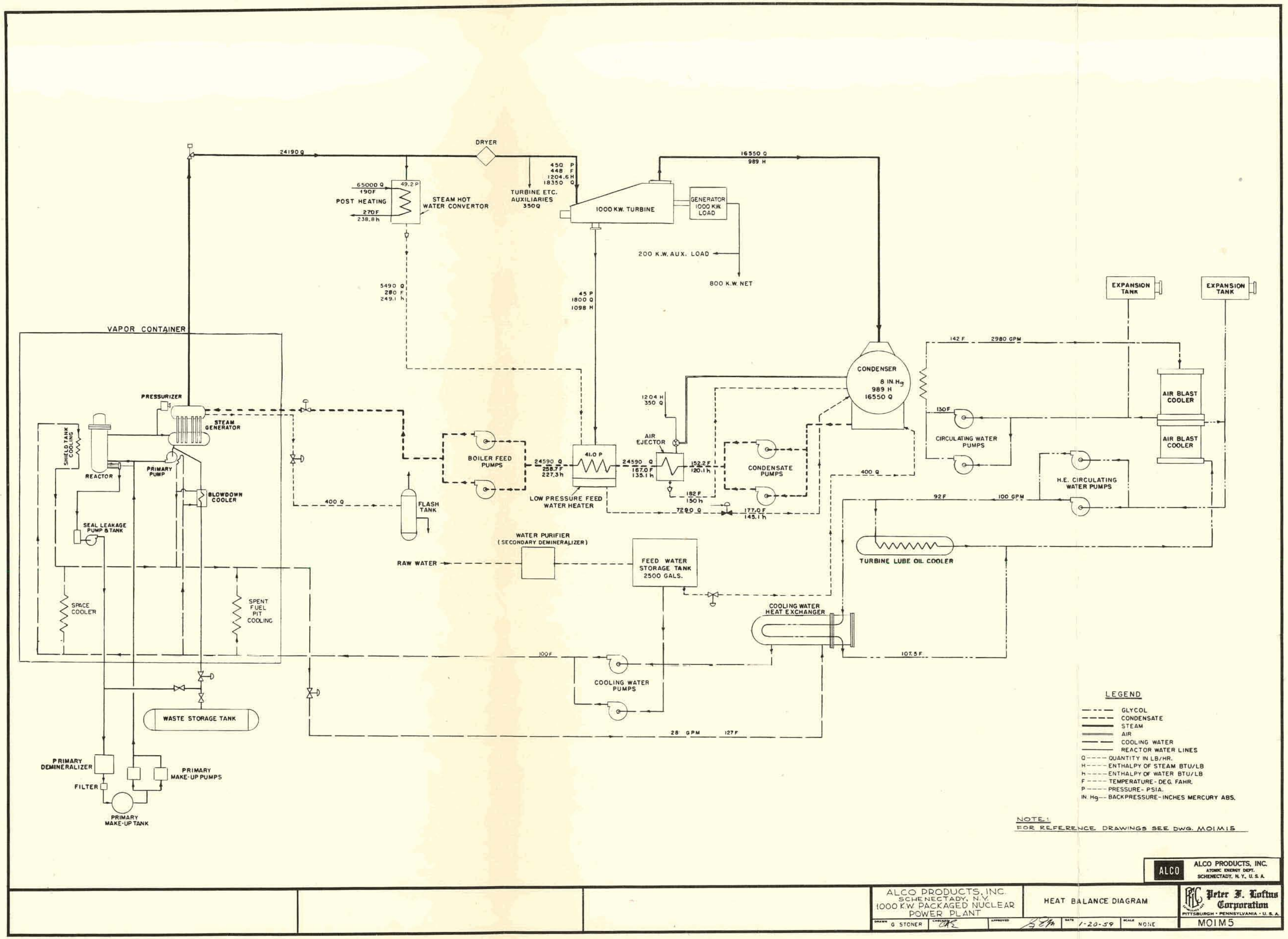
SPEC. SYMBOL	RATING		MATERIAL
	DESIGN	SERVICE	
X1	2000PSIA 600°F	1750PSIA 525°F	SEAMLESS ASTM A312 TP304
X2	150PSIA 500°F	50PSIA 110°F	SEAMLESS ASTM A312 TP304
X3	150PSIA 500°F	LOW PRESSURE-TEMP.	ELEC. RESISTANCE WELD A-135 ASA B11 SCHED. 80
X4	SECONDARY SYSTEM PIPING		
X5	150PSIA 500°F	50PSIA 110°F	SEAMLESS ASTM A312

NOTE "D": ALL VALVES VENTING H_2 WILL VENT THRU FLAME ARRESTORS.

ALCO PRODUCTS, INC.

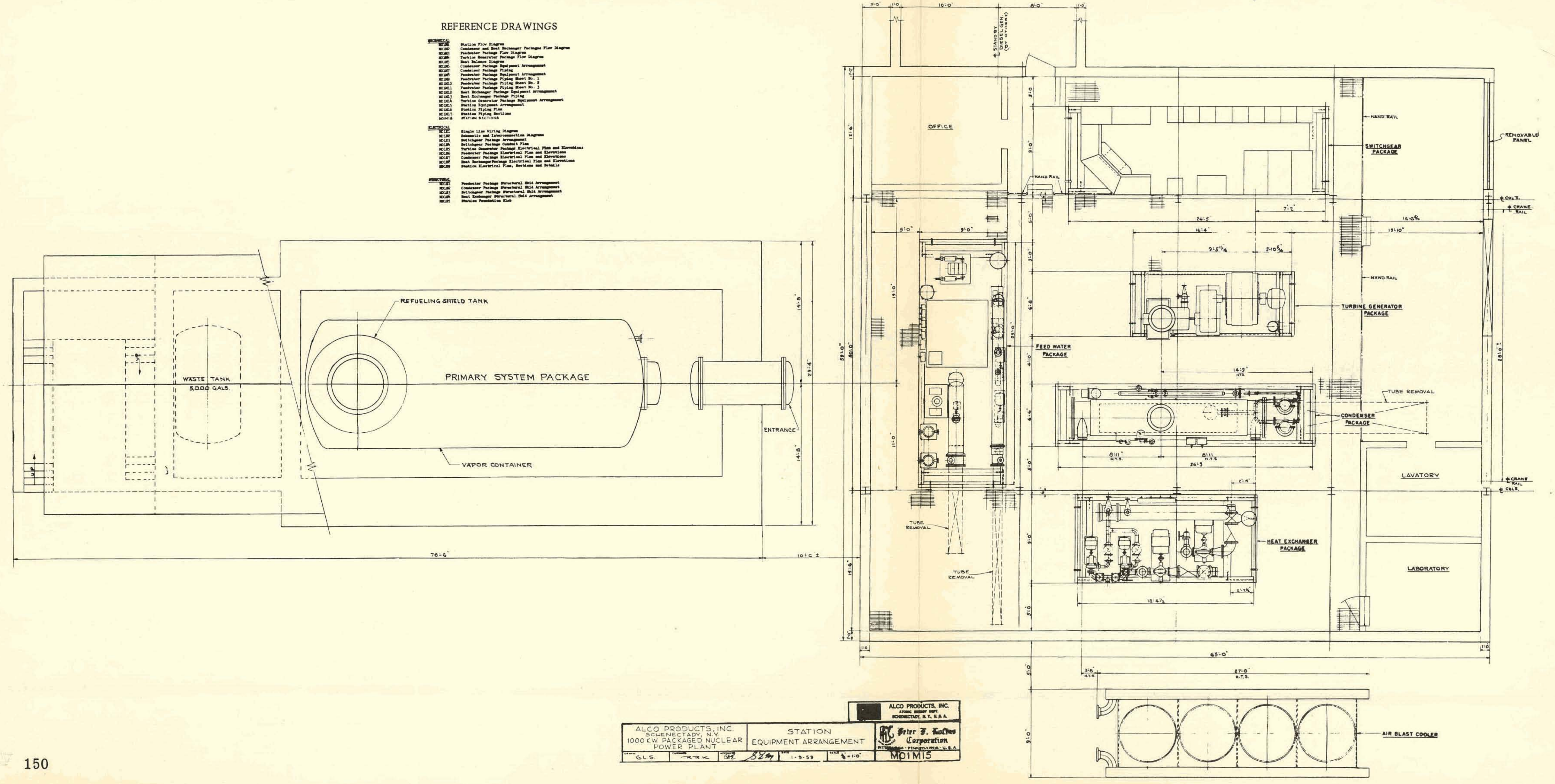
RS-47-1014

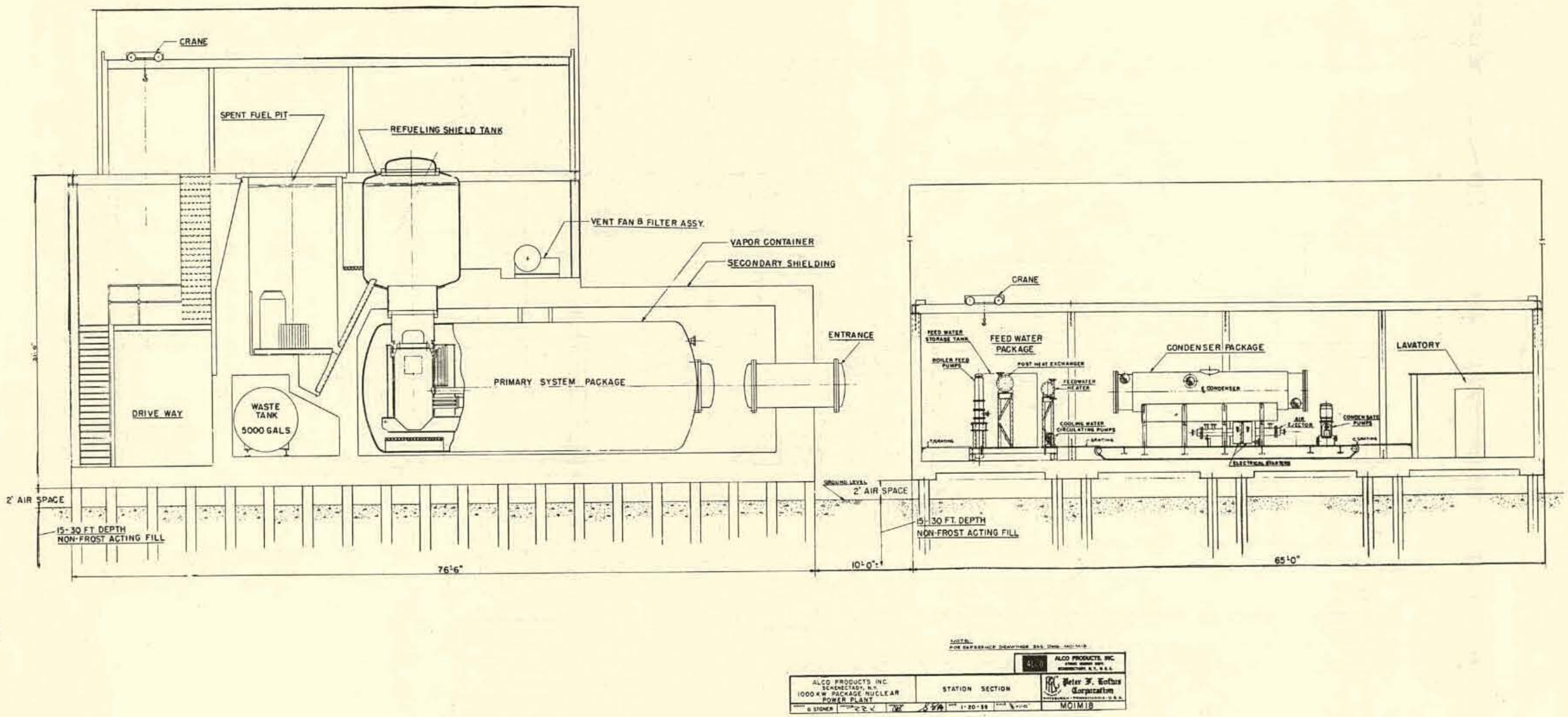

SEPARATOR
FROM STEAM DRUM
TO CONDENSER
1000 KW TURBINE
REDUCTION GEAR
GENERATOR
EXHAUST TO STACK
STEAM TURBINE
TURBINE AUXILIARY OIL PUMP
TURBINE LUBE OIL COOLER
TURBINE LUBE OIL TANK
MAIN TURBINE LUBE OIL PUMP
TO GOV. OIL SYSTEM
EXPANSION TANK
VENT
FILL
AIR BLAST COOLERS
FLASH TANK
BLOW-DOWN FROM BOILER FOR CONTINUATION SEE R9-47-1009
WASTE
FROM BUILDING HEATING SYSTEM
POST HEAT EXCHANGER
TO BUILDING HEATING SYSTEM
TO REACTOR BOILER DRUM FOR CONTINUATION SEE R9-47-1009
BOILER FEED PUMPS
FEED WATER HEATER
CONDENSER
AIR EJECTOR
CONDENSATE PUMPS
CIRCULATING WATER PUMPS
DRAIN
TO STACK
TUBING
RAW WATER
SECONDARY DEMINERALIZER
ACID
CAUSTIC
FILTER
BLOWER
FROM REACTOR SYSTEM
PRIMARY DEMINERALIZER
MAKE-UP TANK
TO REACTOR SYSTEM FOR DETAILS SEE R9-47-1009
MAKE-UP PUMP
FEED WATER STORAGE TANK 2500 GALS.
TO COOLING SYSTEM FOR CONTINUATION SEE R9-47-1009
COOLING WATER PUMPS
MORPHOLINE
MORPHOLINE PUMP
SULPHITE
SULPHITE PUMP
H.E. CIRCULATING WATER PUMPS
HEAT EXCHANGER
FROM REACTOR COOLING SYSTEM FOR CONTINUATION SEE R9-47-1009
VENT HIGH POINT
GATE VALVE - NORMALLY OPEN
GLOBE VALVE - NORMALLY OPEN
GATE VALVE - NORMALLY CLOSED
GLOBE VALVE - NORMALLY CLOSED
CHECK VALVE
THROTTLE TRIP
STRAINER
STEAM TRAP OR DRAINER
PRESS. CONTROL VALVE (INTEGRAL)
CONTROL VALVE
SOLENOID OPERATED VALVE
RELIEF VALVE
EXPANSION JOINT
RESTRICTIVE ORIFICE
LOCAL MOUNTED INSTRUMENT
REMOTE MOUNTED INSTRUMENT
LEVEL CONTROLLED VALVE
LEGEND
MEASURED VARIABLE | MEASURING: IND. TRANSMITTING, INDICATING | ALARM: HIGH, LOW | SWITCH: HIGH, LOW
P-PRESSURE | PIX | PI | HPA | LPA | HPS | LPS
T-TEMPERATURE | TIX | TI | HTA | LTA | HTS | LTS
L-LEVEL | LIX | LI | HLA | LLA | HLS | LLS
C-CONDUCTIVITY | CIX | CI | HCA | LCA
R-RADIATION | RIX | RI | HRA
F-FLOW | FIX | FI
FB - FREE BLOW
Z - INTEGRATOR
REVERSE CURRENT VALVE
AL - ALARM
PIPING BY SUPPLIER
CONTROL LINE
NOTE: FOR REFERENCE DRAWINGS SEE DWG. MOIMIS
ALCO PRODUCTS, INC. ATOMIC ENERGY DEPT. SCHENECTADY, N.Y. U.S.A.
ALCO PRODUCTS, INC SCHENECTADY, N.Y.
1000 KW PACKAGED NUCLEAR POWER PLANT
STATION FLOW DIAGRAM
Peter F. Loftus Corporation
PITTSBURGH - PENNSYLVANIA - U.S.A.
DRAWN G. STONER
DATE 1-20-59
SCALE NONE
MOIMI


DRYER
24190 Q
16550 Q
989 H
450 P
448 F
1204.6 H
18350 Q
65000 Q
190F
POST HEATING
270F
238.8 h
49.2 P
STEAM HOT WATER CONVERTOR
TURBINE ETC. AUXILIARIES 350 Q
1000 K.W. TURBINE
GENERATOR 1000 K.W. LOAD
200 K.W. AUX. LOAD
800 K.W. NET
5490 Q
280 F
249.1 h
45 P
1800 Q
1098 H
EXPANSION TANK
EXPANSION TANK
VAPOR CONTAINER
142 F
2980 GPM
CONDENSER
8 IN. Hg
989 H
16550 Q
AIR BLAST COOLER
AIR BLAST COOLER
130 F
CIRCULATING WATER PUMPS
H.E. CIRCULATING WATER PUMPS
PRESSURIZER
STEAM GENERATOR
SHIELD TANK COOLING
REACTOR
PRIMARY PUMP
BLOWDOWN COOLER
SEAL LEAKAGE PUMP & TANK
BOILER FEED PUMPS
24590 Q
258.7 F
227.3 h
41.0 P
LOW PRESSURE FEED WATER HEATER
1204 H
350 Q
AIR EJECTOR
24590 Q
167.0 F
135.1 h
152.2 F
120.1 h
182 F
150 h
7280 Q
177.0 F
145.1 h
CONDENSATE PUMPS
400 Q
92 F
100 GPM
400 Q
FLASH TANK
WATER PURIFIER (SECONDARY DEMINERALIZER)
RAW WATER
FEED WATER STORAGE TANK 2500 GALS.
TURBINE LUBE OIL COOLER
SPACE COOLER
SPENT FUEL PIT COOLING
COOLING WATER HEAT EXCHANGER
100 F
107.5 F
COOLING WATER PUMPS
WASTE STORAGE TANK
28 GPM
127 F
PRIMARY DEMINERALIZER
FILTER
PRIMARY MAKE-UP PUMPS
PRIMARY MAKE-UP TANK
LEGEND
GLYCOL
CONDENSATE
STEAM
AIR
COOLING WATER
REACTOR WATER LINES
Q ---- QUANTITY IN LB/HR.
H ---- ENTHALPY OF STEAM BTU/LB
h ---- ENTHALPY OF WATER BTU/LB
F ---- TEMPERATURE - DEG. FAHR.
P ---- PRESSURE - PSIA.
IN. Hg --- BACKPRESSURE - INCHES MERCURY ABS.
NOTE:
FOR REFERENCE DRAWINGS SEE DWG. MO1M15
ALCO
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.
ALCO PRODUCTS, INC.
SCHENECTADY, N.Y.
1000 K.W. PACKAGED NUCLEAR POWER PLANT
HEAT BALANCE DIAGRAM
Peter F. Loftus Corporation
PITTSBURGH • PENNSYLVANIA • U.S.A.
G. STONER
1-20-59
NONE
MO1M5

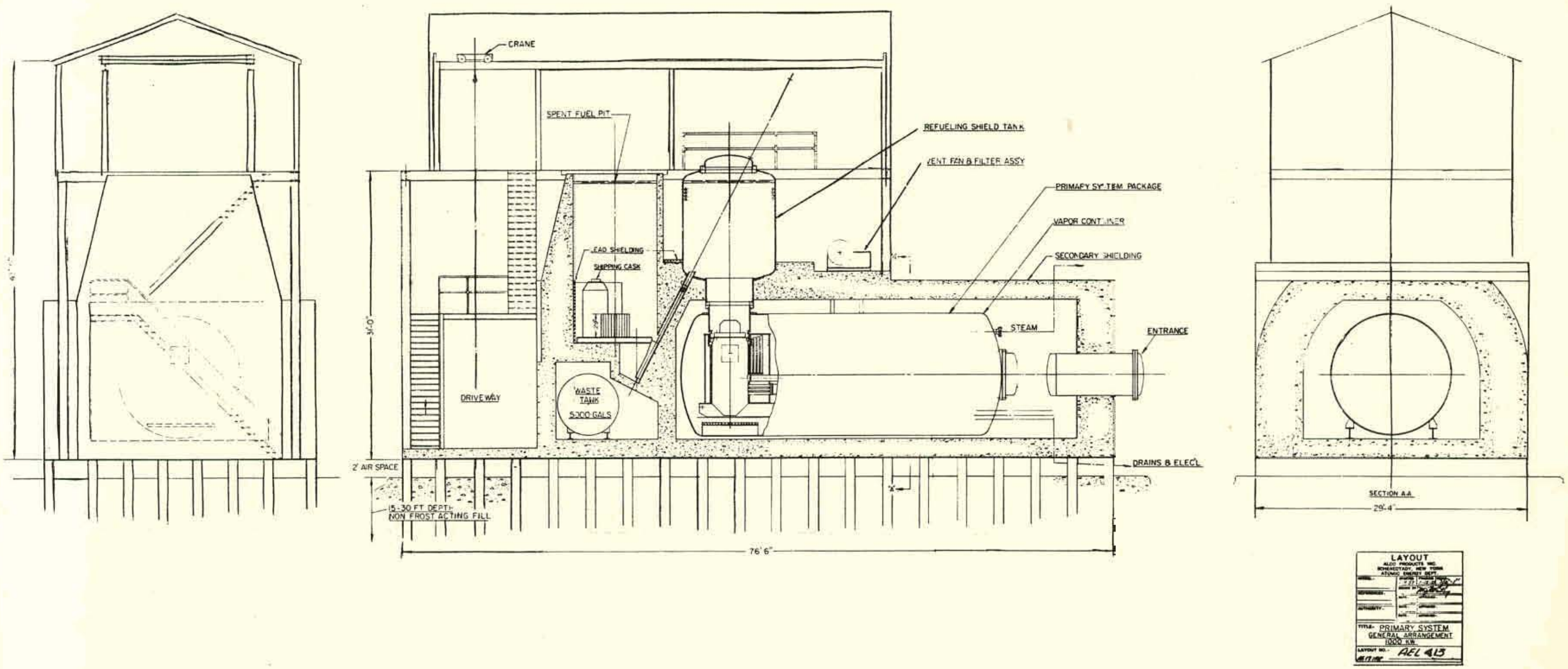
REFERENCE DRAWINGS

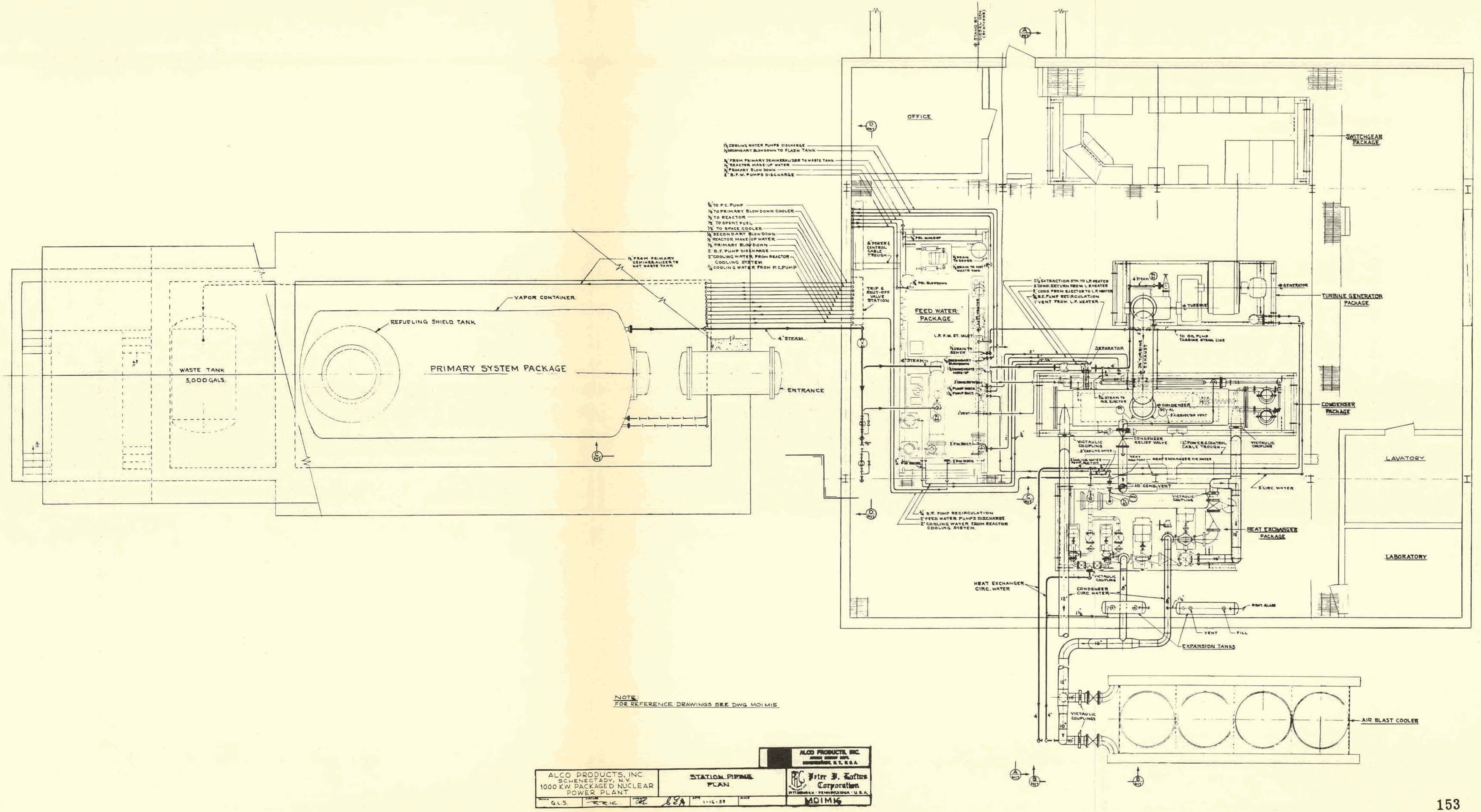
MECHANICAL	
MD1M1	Station Flow Diagram
MD1M2	Condenser and Heat Exchanger Packages Flow Diagram
MD1M3	Feedwater Package Flow Diagram
MD1M4	Turbine Generator Package Flow Diagram
MD1M5	Heat Balance Diagram
MD1M6	Condenser Package Equipment Arrangement
MD1M7	Condenser Package Piping
MD1M8	Feedwater Package Equipment Arrangement
MD1M9	Feedwater Package Piping Sheet No. 1
MD1M10	Feedwater Package Piping Sheet No. 2
MD1M11	Feedwater Package Piping Sheet No. 3
MD1M12	Heat Exchanger Package Equipment Arrangement
MD1M13	Heat Exchanger Package Piping
MD1M14	Turbine Generator Package Equipment Arrangement
MD1M15	Station Equipment Arrangement
MD1M16	Station Piping Plan
MD1M17	Station Piping Sections
MD1M18	STATION SECTIONS
ELECTRICAL	
MD1E1	Single Line Wiring Diagram
MD1E2	Schematic and Interconnection Diagrams
MD1E3	Switchgear Package Arrangement
MD1E4	Switchgear Package Conduit Plan
MD1E5	Turbine Generator Package Electrical Plan and Elevations
MD1E6	Feedwater Package Electrical Plan and Elevations
MD1E7	Condenser Package Electrical Plan and Elevations
MD1E8	Heat Exchanger Package Electrical Plan and Elevations
MD1E9	Station Electrical Plan, Sections and Details
STRUCTURAL	
MD1S1	Feedwater Package Structural Skid Arrangement
MD1S2	Condenser Package Structural Skid Arrangement
MD1S3	Switchgear Package Structural Skid Arrangement
MD1S4	Heat Exchanger Structural Skid Arrangement
MD1S5	Station Foundation Slab

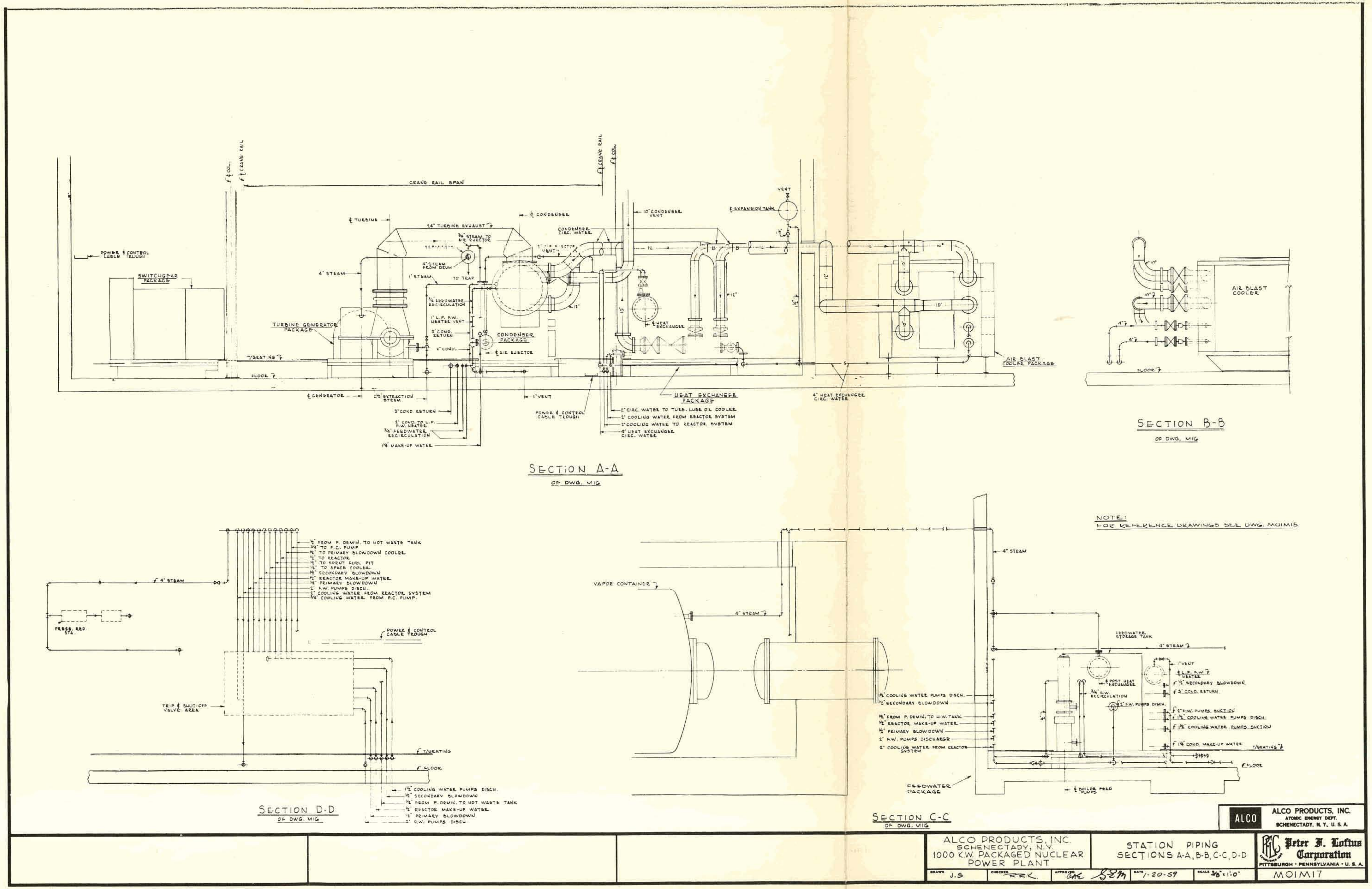


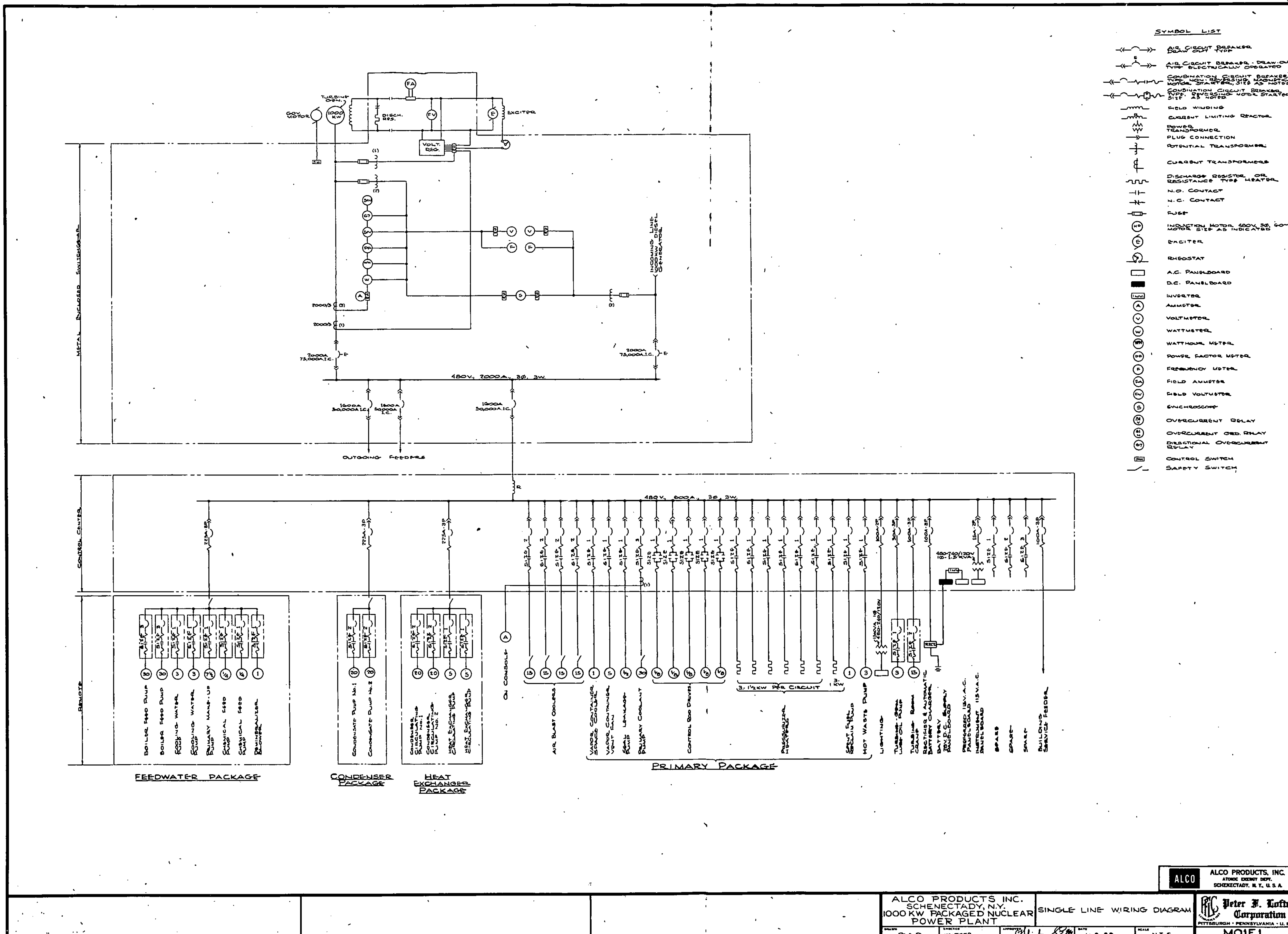

CRANE
SPENT FUEL PIT
REFUELING SHIELD TANK
VENT FAN & FILTER ASSY.
VAPOR CONTAINER
SECONDARY SHIELDING
ENTRANCE
PRIMARY SYSTEM PACKAGE
DRIVE WAY
WASTE TANK 5000 GALS
2' AIR SPACE
15-30 FT DEPTH
NON-FROST ACTING FILL
76'-6"
10'-0"±
GROUND LEVEL
2' AIR SPACE
15-30 FT. DEPTH
NON-FROST ACTING FILL
65'-0"
CRANE
FEED WATER STORAGE TANK
FEED WATER PACKAGE
BOILER FEED PUMPS
POST HEAT EXCHANGER
FEEDWATER HEATER
COOLING WATER CIRCULATING PUMPS
GRATING
CONDENSER PACKAGE
℄ CONDENSER
AIR EJECTOR
CONDENSATE PUMPS
ELECTRICAL STARTERS
LAVATORY
ALCO PRODUCTS, INC.
ALCO PRODUCTS INC.
SCHENECTADY, N.Y.
1000 KW PACKAGE NUCLEAR
POWER PLANT
STATION SECTION
Peter F. Loftus Corporation
G STONER
1-20-59
M01M18

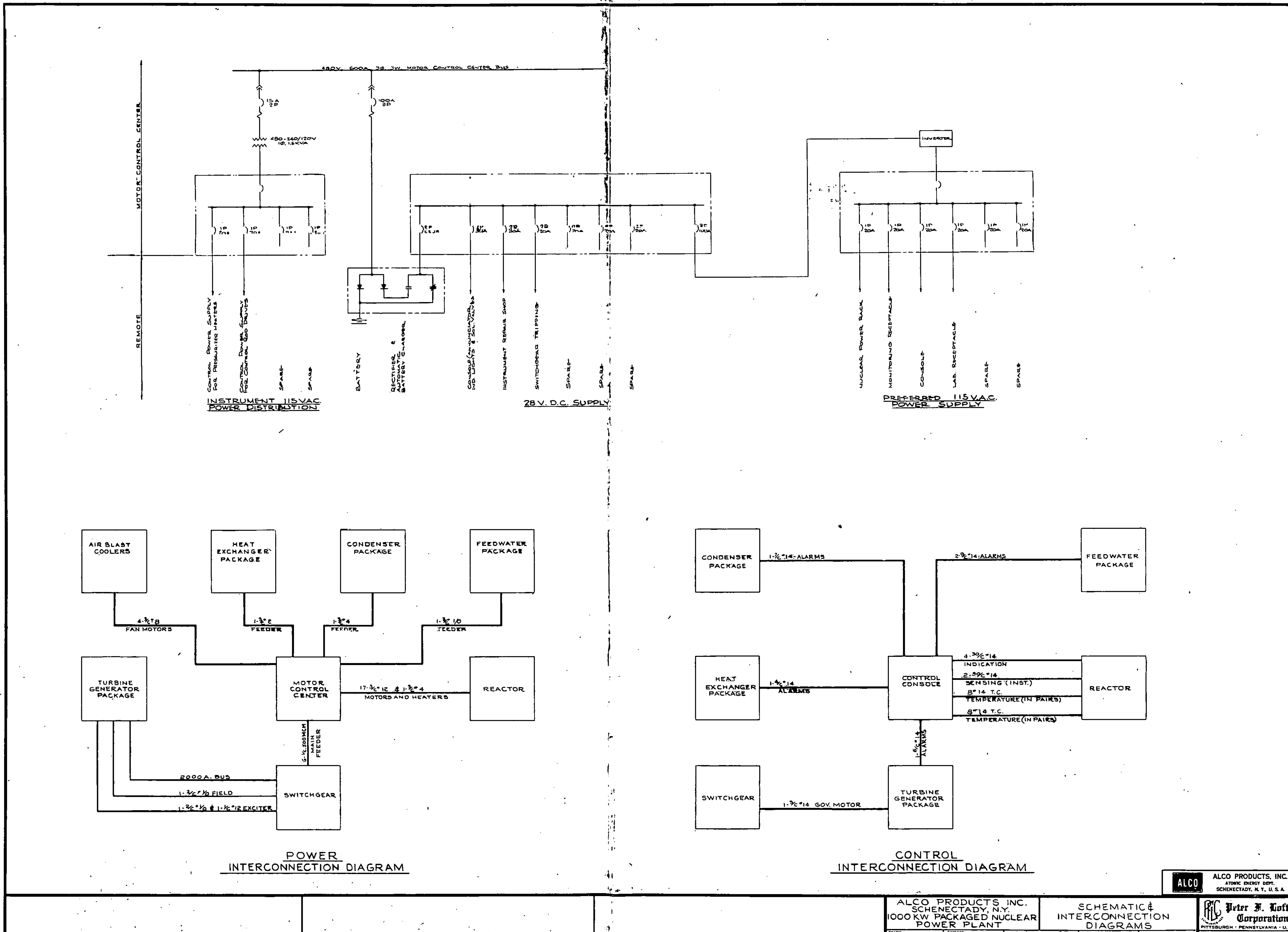
151


CRANE
SPENT FUEL PIT
REFUELING SHIELD TANK
VENT FAN & FILTER ASSY
PRIMARY SYSTEM PACKAGE
VAPOR CONTAINER
SECONDARY SHIELDING
LEAD SHIELDING
SHIPPING CASK
STEAM
ENTRANCE
DRIVEWAY
WASTE TANK
5000 GALS
31'-0"
2' AIR SPACE
15-30 FT DEPTH
NON FROST ACTING FILL
DRAINS & ELEC'L
76' 6"
SECTION A-A
29'-4"
LAYOUT
ALCO PRODUCTS INC.
SCHENECTADY, NEW YORK
ATOMIC ENERGY DEPT.
TITLE- PRIMARY SYSTEM
GENERAL ARRANGEMENT
1000 KW
LAYOUT NO.- AEL 415

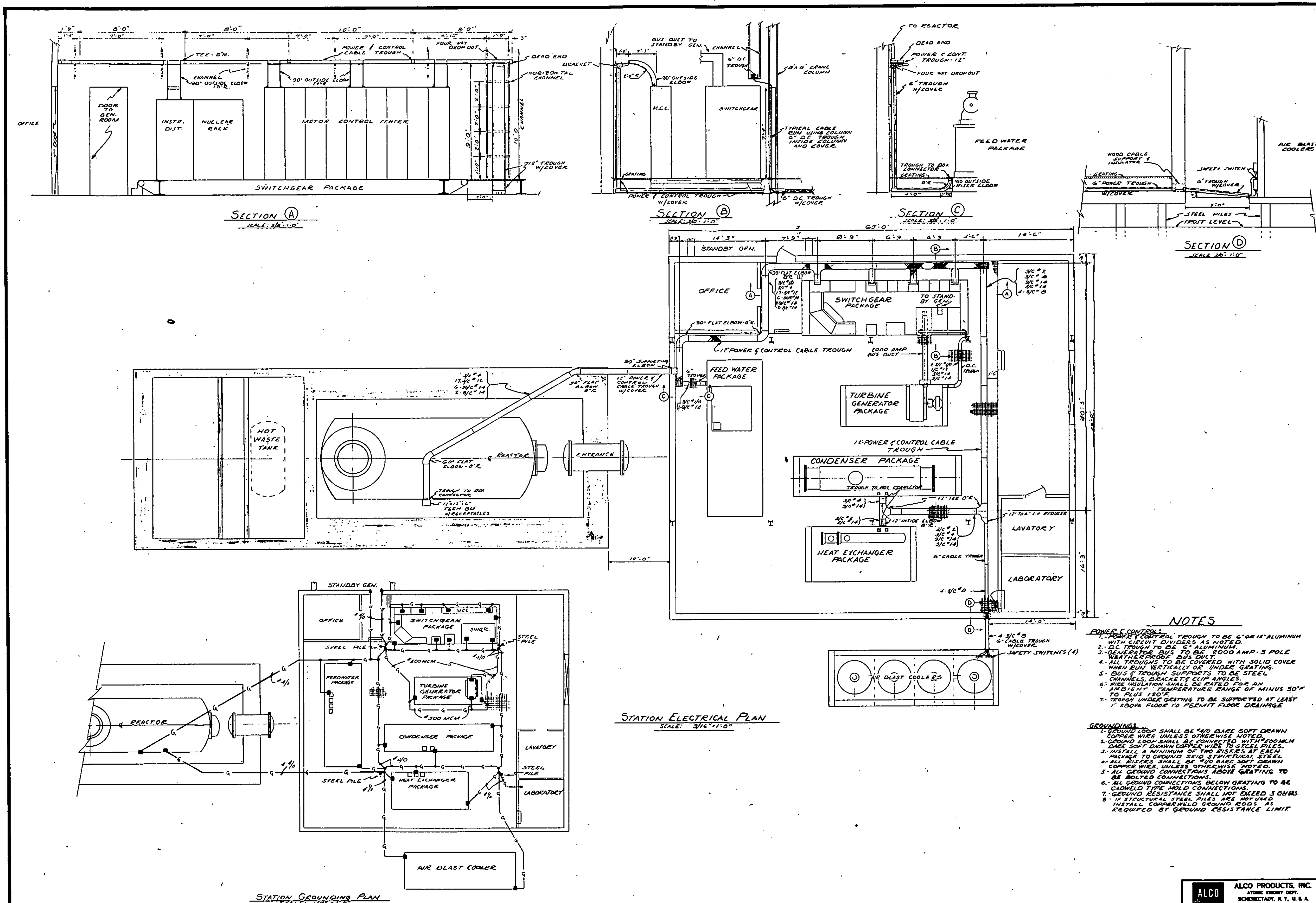

OFFICE
SWITCHGEAR PACKAGE
1½" COOLING WATER PUMPS DISCHARGE
½" SECONDARY BLOWDOWN TO FLASH TANK
½" FROM PRIMARY DEMINERALIZER TO WASTE TANK
½" REACTOR MAKE-UP WATER
½" PRIMARY BLOW DOWN
2" B.F.W. PUMPS DISCHARGE
¾" TO P.C. PUMP
½" TO PRIMARY BLOWDOWN COOLER
½" TO REACTOR
½" TO SPENT FUEL
½" TO SPACE COOLER
½" SECONDARY BLOWDOWN
½" REACTOR MAKE-UP WATER
½" PRIMARY BLOWDOWN
2" B.F. PUMP DISCHARGE
2" COOLING WATER FROM REACTOR COOLING SYSTEM
¾" COOLING WATER FROM P.C. PUMP
½" FROM PRIMARY DEMINERALIZER TO HOT WASTE TANK
6" POWER & CONTROL CABLE TROUGH
TRIP & SHUT-OFF VALVE STATION
VAPOR CONTAINER
REFUELING SHIELD TANK
WASTE TANK 5,000 GALS.
PRIMARY SYSTEM PACKAGE
4" STEAM
ENTRANCE
FEED WATER PACKAGE
2½" EXTRACTION STM. TO L.P. HEATER
3" COND. RETURN FROM L.P. HEATER
2" COND. FROM EJECTOR TO L.P. HEATER
¾" B.F. PUMP RECIRCULATION
1" VENT FROM L.P. HEATER
4" STEAM
TURBINE
GENERATOR
TURBINE GENERATOR PACKAGE
TO OIL PUMP TURBINE STEAM LINE
SEPARATOR
24" TURBINE EXHAUST
¾" STEAM TO AIR EJECTOR
CONDENSER
2" AIR EJECTOR VENT
CONDENSER PACKAGE
VICTAULIC COUPLING
CONDENSER RELIEF VALVE
12" POWER & CONTROL CABLE TROUGH
2" COOLING WATER
VENT
HEAT EXCHANGER CIR. WATER
10" COND. VENT
2" CIRC. WATER
LAVATORY
LABORATORY
¾" B.F. PUMP RECIRCULATION
2" FEED WATER PUMPS DISCHARGE
2" COOLING WATER FROM REACTOR COOLING SYSTEM
HEAT EXCHANGER PACKAGE
HEAT EXCHANGER CIRC. WATER
CONDENSER CIRC. WATER
VENT
FILL
EXPANSION TANKS
VICTAULIC COUPLINGS
AIR BLAST COOLER
NOTE:
FOR REFERENCE DRAWINGS SEE DWG MO1M15
ALCO PRODUCTS, INC.
SCHENECTADY, N.Y.
1000 K.W. PACKAGED NUCLEAR
POWER PLANT
STATION PIPING
PLAN
G.L.S.
1-16-59
ALCO PRODUCTS, INC.
Peter F. Loftus Corporation
PITTSBURGH · PENNSYLVANIA · U.S.A.
MO1M16


SECTION A-A
OF DWG. M1G
SECTION B-B
OF DWG. M1G
SECTION C-C
OF DWG. M1G
SECTION D-D
OF DWG. M1G
NOTE:
FOR REFERENCE DRAWINGS SEE DWG. M01M15
CRANE RAIL SPAN
SWITCHGEAR PACKAGE
TURBINE GENERATOR PACKAGE
CONDENSER PACKAGE
HEAT EXCHANGER PACKAGE
AIR BLAST COOLER PACKAGE
AIR BLAST COOLER
VAPOR CONTAINER
FEEDWATER PACKAGE
FEEDWATER STORAGE TANK
TRIP & SHUT-OFF VALVE AREA
ALCO
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.
ALCO PRODUCTS, INC.
SCHENECTADY, N.Y.
1000 K.W. PACKAGED NUCLEAR POWER PLANT
STATION PIPING
SECTIONS A-A, B-B, C-C, D-D
Peter F. Loftus Corporation
PITTSBURGH • PENNSYLVANIA • U.S.A.
J.S.
1-20-59
3/8" = 1'-0"
M01M17


SYMBOL LIST
AIR CIRCUIT BREAKER DRAW OUT TYPE
AIR CIRCUIT BREAKER - DRAW-OUT TYPE ELECTRICALLY OPERATED
FIELD WINDING
CURRENT LIMITING REACTOR
POWER TRANSFORMER
PLUG CONNECTION
POTENTIAL TRANSFORMER
CURRENT TRANSFORMERS
N.O. CONTACT
N.C. CONTACT
FUSE
EXCITER
RHEOSTAT
A.C. PANELBOARD
D.C. PANELBOARD
INVERTER
AMMETER
VOLTMETER
WATTMETER
WATTHOUR METER
POWER FACTOR METER
FREQUENCY METER
FIELD AMMETER
FIELD VOLTMETER
SYNCHROSCOPE
OVERCURRENT RELAY
CONTROL SWITCH
SAFETY SWITCH
TURBINE GEN.
GOV. MOTOR
1000 KW
DISCH. RES.
EXCITER
VOLT. REG.
INCOMING LINE FROM DIESEL GENERATOR
480V, 2000A, 3Ø, 3W
OUTGOING FEEDERS
METAL ENCLOSED SWITCHGEAR
CONTROL CENTER
REMOTE
480V, 600A, 3Ø, 3W
ON CONSOLE
AIR BLAST COOLERS
CONTROL ROD DRIVES
3-1½KW PER CIRCUIT
PRESSURIZER HEATERS
HOT WASTE PUMP
LIGHTING
SPARE
SPARE
SPARE
BUILDING SERVICE FEEDER
PRIMARY PACKAGE
FEEDWATER PACKAGE
CONDENSER PACKAGE
HEAT EXCHANGER PACKAGE
BOILER FEED PUMP
BOILER FEED PUMP
CONDENSATE PUMP No. 1
CONDENSATE PUMP No. 2
ALCO PRODUCTS INC.
SCHENECTADY, N.Y.
1000 KW PACKAGED NUCLEAR POWER PLANT
SINGLE LINE WIRING DIAGRAM
N.T.S.
M01E1
ALCO
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y. U.S.A.
Peter F. Loftus Corporation
PITTSBURGH • PENNSYLVANIA • U.S.A.



480V, 600A, 3Ø, 3W, MOTOR CONTROL CENTER BUS
MOTOR CONTROL CENTER
REMOTE
INVERTER
CONTROL POWER SUPPLY FOR PRESSURIZER HEATERS
CONTROL POWER SUPPLY FOR CONTROL ROD DRIVES
SPARE
SPARE
BATTERY
RECTIFIER & AUTOMATIC BATTERY CHARGER
CONSOLE/ANNUNCIATOR, IND LIGHTS & SOL. VALVES
INSTRUMENT REPAIR SHOP
SWITCHGEAR TRIPPING
SPARE
SPARE
SPARE
NUCLEAR POWER RACK
MONITORING RECEPTACLE
CONSOLE
LAB. RECEPTACLE
SPARE
SPARE
INSTRUMENT 115 VAC. POWER DISTRIBUTION
28 V. D.C. SUPPLY
PREFERRED 115 V.A.C. POWER SUPPLY
AIR BLAST COOLERS
HEAT EXCHANGER PACKAGE
CONDENSER PACKAGE
FEEDWATER PACKAGE
FAN MOTORS
FEEDER
FEEDER
FEEDER
TURBINE GENERATOR PACKAGE
MOTOR CONTROL CENTER
REACTOR
MOTORS AND HEATERS
MAIN FEEDER
2000 A. BUS
FIELD
EXCITER
SWITCHGEAR
POWER INTERCONNECTION DIAGRAM
CONDENSER PACKAGE
ALARMS
FEEDWATER PACKAGE
ALARMS
HEAT EXCHANGER PACKAGE
ALARMS
CONTROL CONSOLE
INDICATION
SENSING (INST.)
TEMPERATURE (IN PAIRS)
TEMPERATURE (IN PAIRS)
REACTOR
ALARMS
SWITCHGEAR
GOV. MOTOR
TURBINE GENERATOR PACKAGE
CONTROL INTERCONNECTION DIAGRAM
ALCO
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y. U.S.A.
ALCO PRODUCTS INC.
SCHENECTADY, N.Y.
1000 KW PACKAGED NUCLEAR
POWER PLANT
SCHEMATIC & INTERCONNECTION DIAGRAMS
Peter F. Loftus Corporation
PITTSBURGH · PENNSYLVANIA · U.S.A.
N.T.S.
MO1E2



NOTES

POWER & CONTROL:

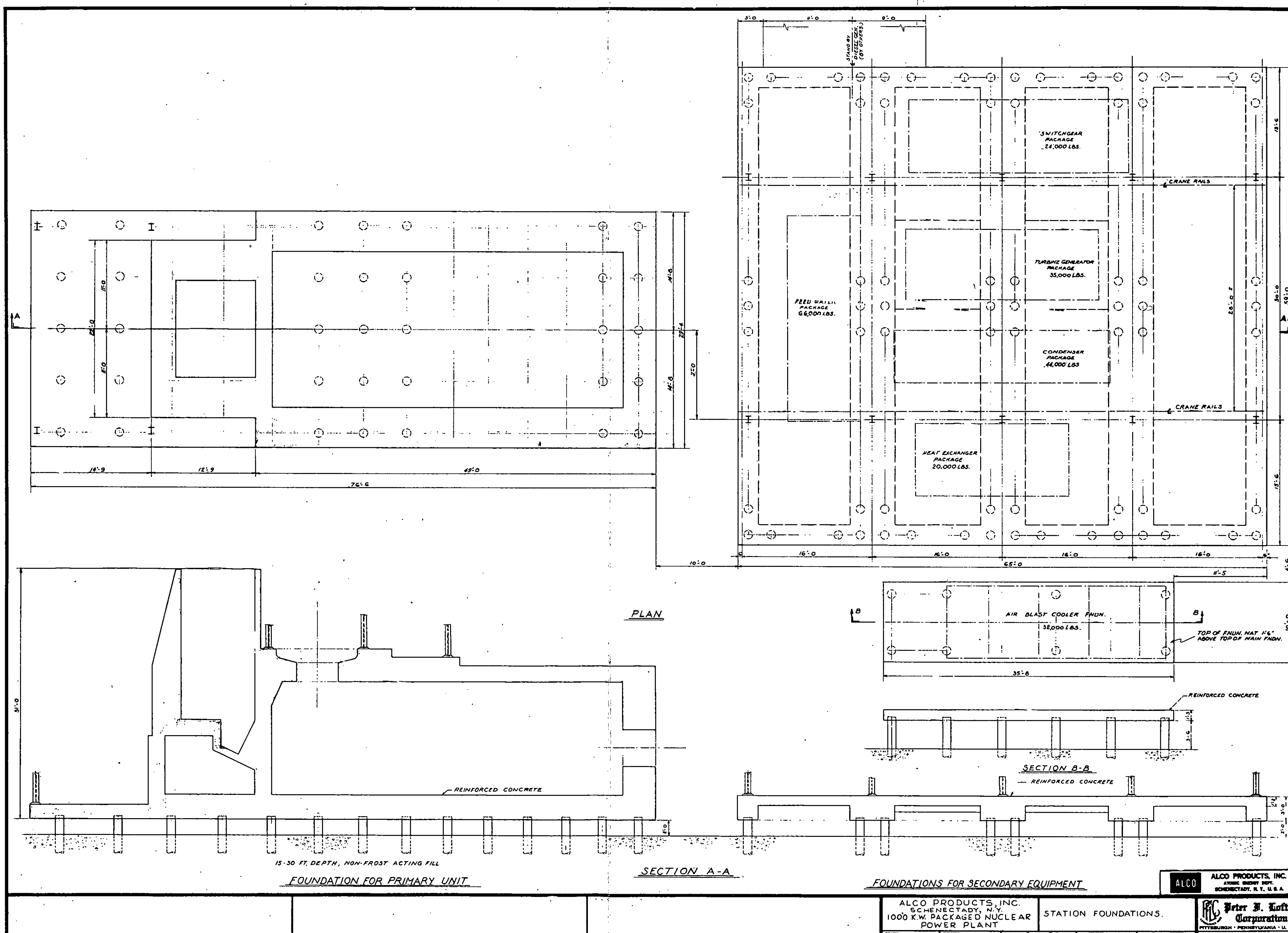
1. - POWER & CONTROL TROUGH TO BE 6" OR 12" ALUMINUM WITH CIRCUIT DIVIDERS AS NOTED.
2. - D.C. TROUGH TO BE 6" ALUMINUM.
3. - GENERATOR BUS TO BE 2000 AMP - 3 POLE WEATHERPROOF BUS DUCT.
4. - ALL TROUGHS TO BE COVERED WITH SOLID COVER WHEN RUN VERTICALLY OR UNDER GRATING.
5. - BUS & TROUGH SUPPORTS TO BE STEEL CHANNELS, BRACKET & CLIP ANGLES.
6. - WIRE INSULATION SHALL BE RATED FOR AN AMBIENT TEMPERATURE RANGE OF MINUS 50°F TO PLUS 120°F.
7. - TROUGH UNDER GRATING TO BE SUPPORTED AT LEAST 1" ABOVE FLOOR TO PERMIT FLOOR DRAINAGE

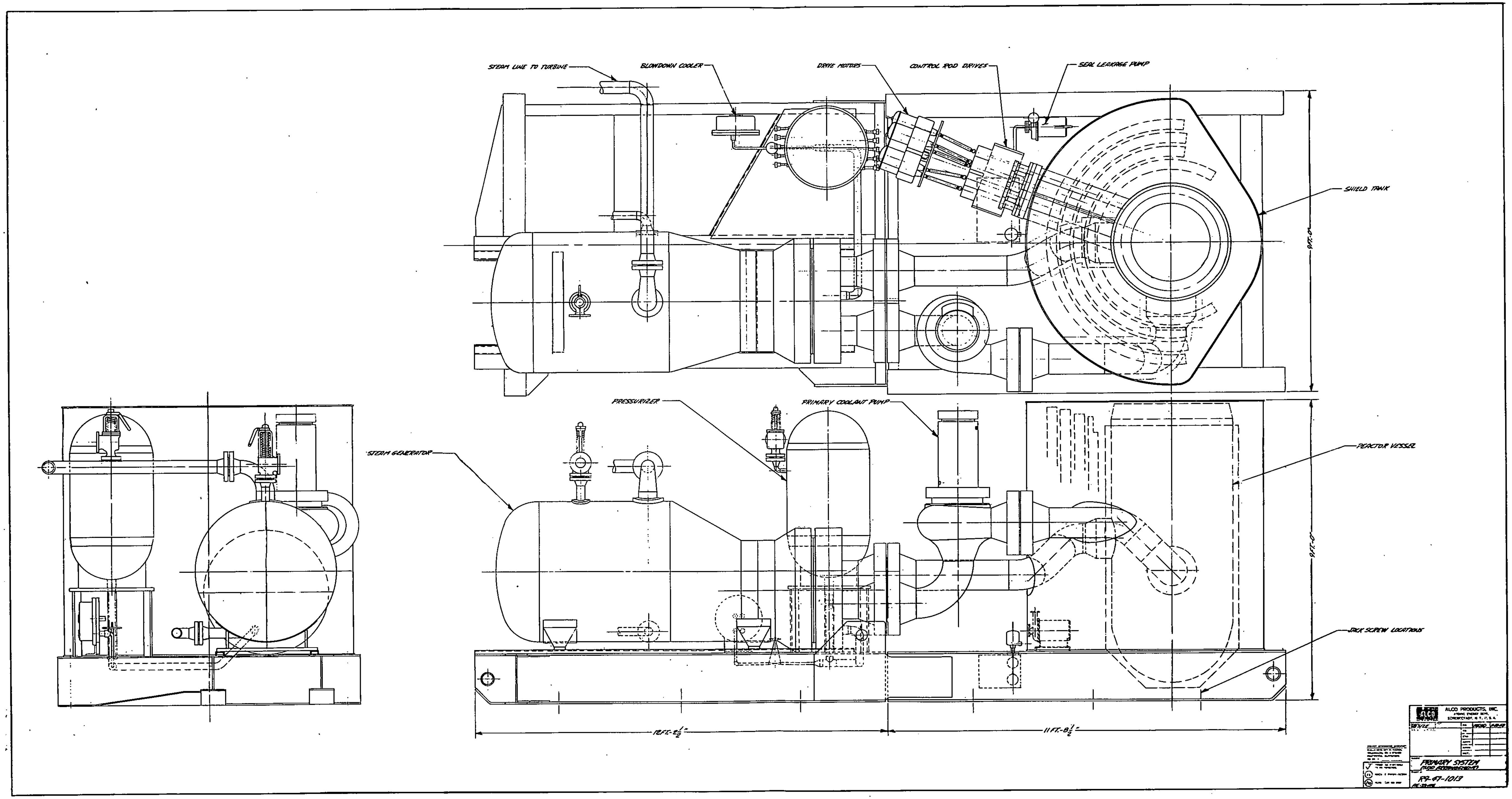
GROUNDINGS:

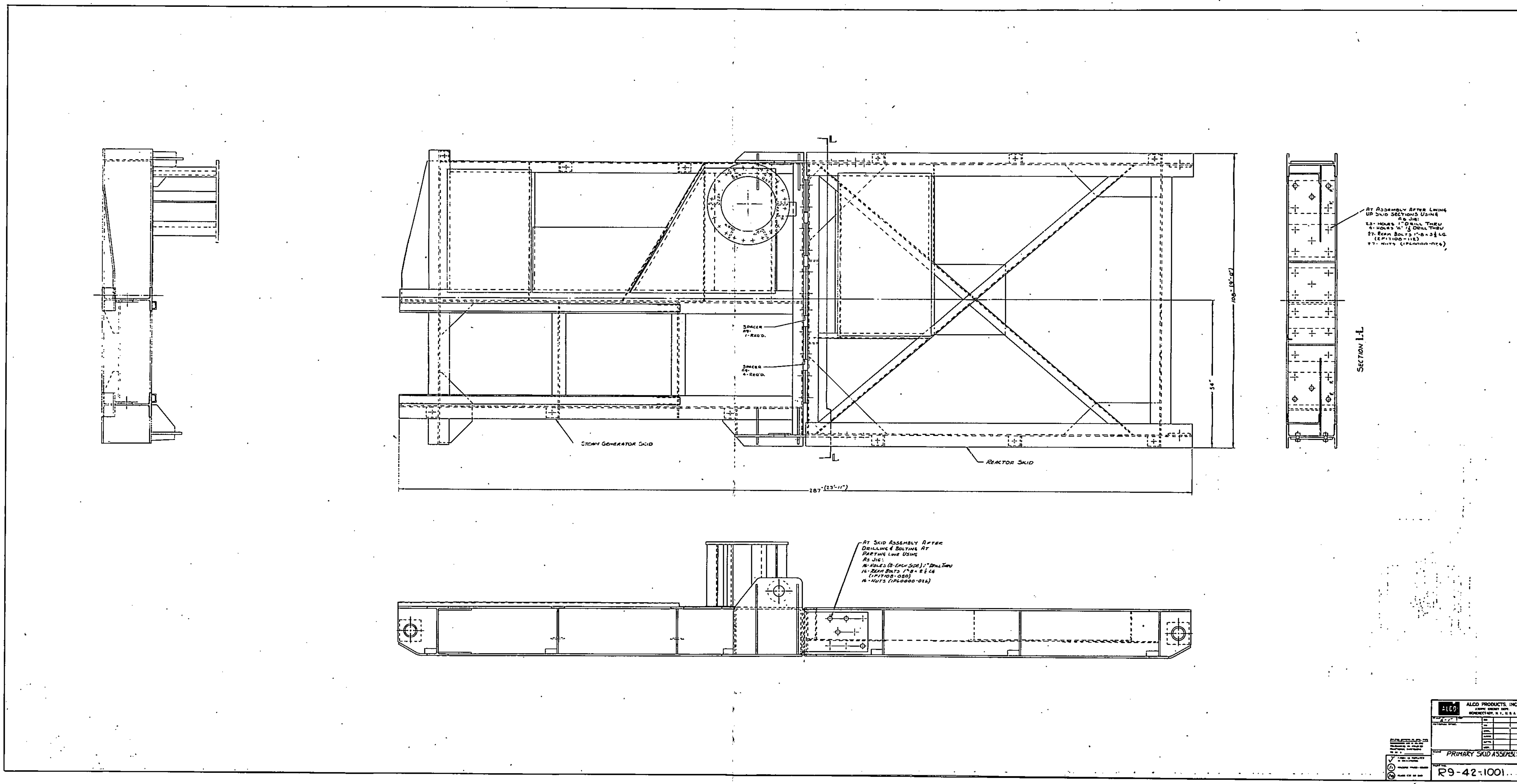
1. - GROUND LOOP SHALL BE #4/0 BARE SOFT DRAWN COPPER WIRE UNLESS OTHERWISE NOTED.
2. - GROUND LOOP SHALL BE CONNECTED WITH #500 MCM BARE SOFT DRAWN COPPER WIRE TO STEEL PILES.
3. - INSTALL A MINIMUM OF TWO RISERS AT EACH PACKAGE TO GROUND SKID STRUCTURAL STEEL
4. - ALL RISERS SHALL BE #1/0 BARE SOFT DRAWN COPPER WIRE, UNLESS OTHERWISE NOTED.
5. - ALL GROUND CONNECTIONS ABOVE GRATING TO BE BOLTED CONNECTIONS.
6. - ALL GROUND CONNECTIONS BELOW GRATING TO BE CADWELD TYPE MOLD CONNECTIONS.
7. - GROUND RESISTANCE SHALL NOT EXCEED 5 OHMS.
8. - IF STRUCTURAL STEEL PILES ARE NOT USED INSTALL COPPERWELD GROUND RODS AS REQUIRED BY GROUND RESISTANCE LIMIT.

ALCO — ALCO PRODUCTS, INC. ATOMIC ENERGY DEPT. SCHENECTADY, N.Y., U.S.A.

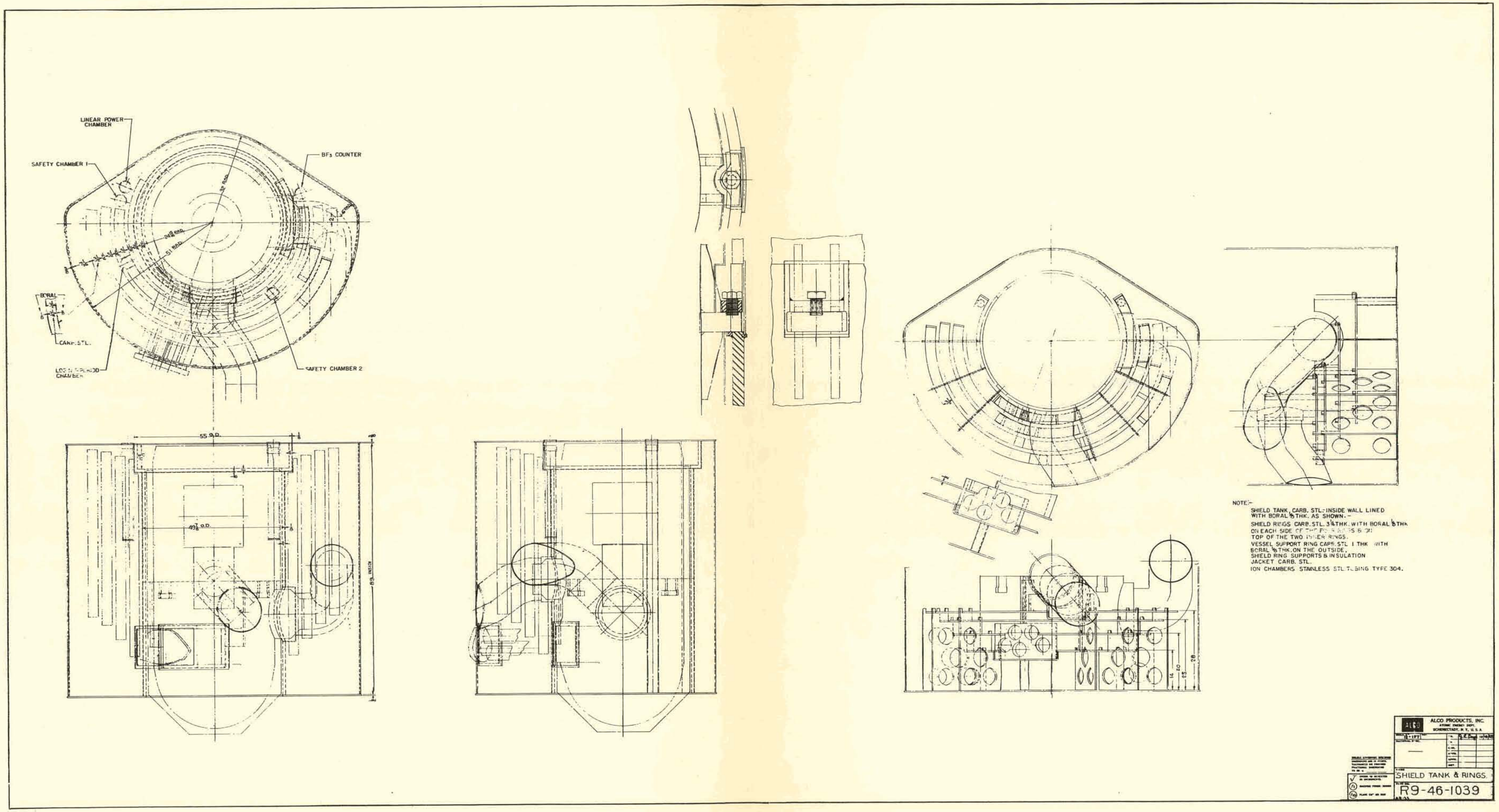
ALCO PRODUCTS INC. SCHENECTADY, N.Y. 1000 KW PACKAGED NUCLEAR POWER PLANT	STATION ELECTRICAL PLAN SECTIONS & DETAILS	Peter F. Loftus Corporation PITTSBURGH · PENNSYLVANIA · U.S.A.
DRAWN R.C. BINZ · CHECKED HEITZER · APPROVED [signatures]	DATE 1-16-59 · SCALE AS NOTED	M01 E9


PLAN
SECTION A-A
FOUNDATION FOR PRIMARY UNIT
15-30 FT. DEPTH, NON-FROST ACTING FILL
REINFORCED CONCRETE
SWITCHGEAR PACKAGE 24,000 LBS.
TURBINE GENERATOR PACKAGE 35,000 LBS.
FEED WATER PACKAGE 66,000 LBS.
CONDENSER PACKAGE 44,000 LBS.
HEAT EXCHANGER PACKAGE 20,000 LBS.
CRANE RAILS
AIR BLAST COOLER FNDN. 32,000 LBS.
TOP OF FNDN. MAT 1'-6" ABOVE TOP OF MAIN FNDN.
SECTION B-B
FOUNDATIONS FOR SECONDARY EQUIPMENT
ALCO PRODUCTS, INC.
ALCO PRODUCTS, INC. SCHENECTADY, N.Y. 1000 K.W. PACKAGED NUCLEAR POWER PLANT
STATION FOUNDATIONS.
Peter F. Loftus Corporation
PITTSBURGH · PENNSYLVANIA · U. S. A.
KALENEN
J. A. X.
1-21-59
1/8" = 1'-0
M0155

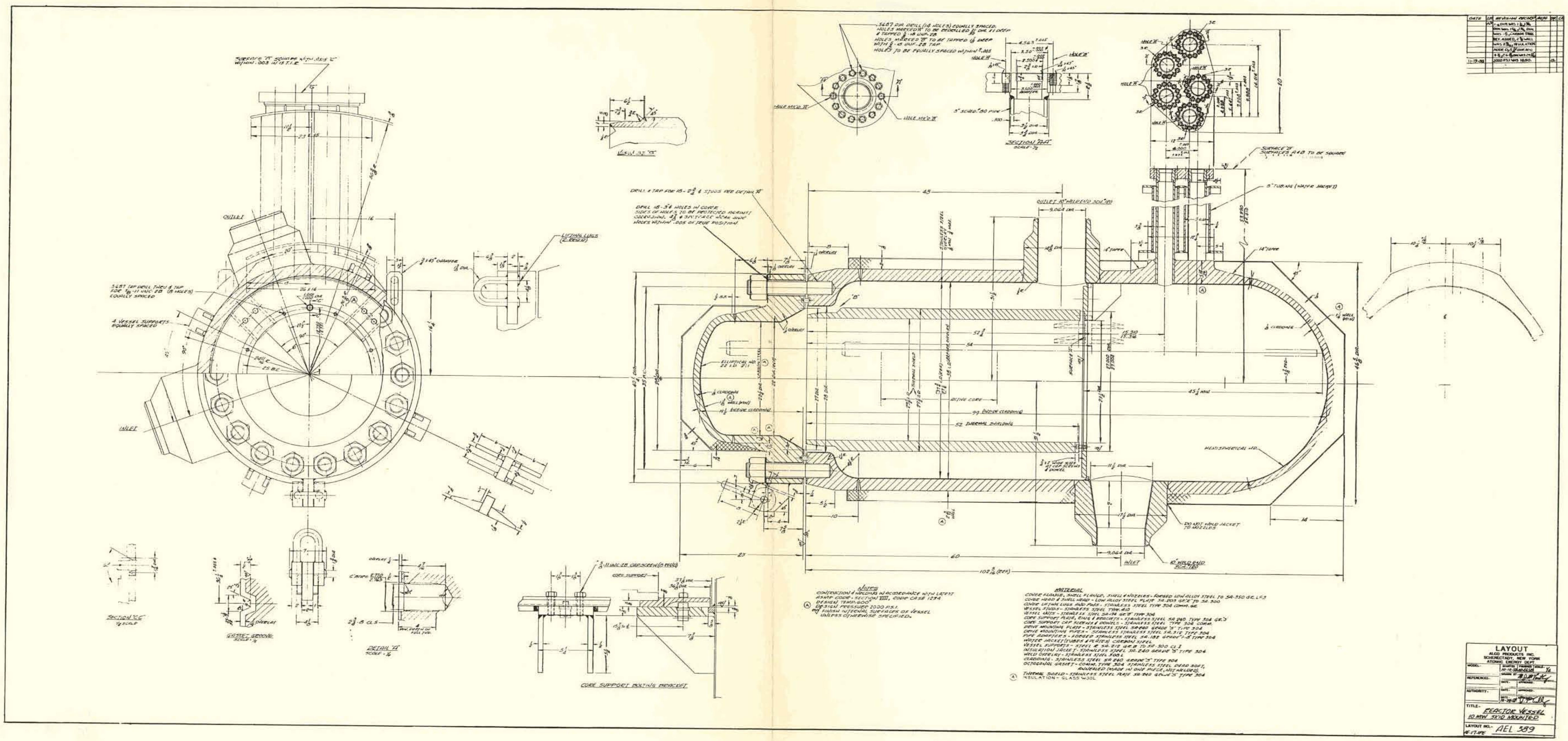

STEAM LINE TO TURBINE
BLOWDOWN COOLER
DRIVE MOTORS
CONTROL ROD DRIVES
SEAL LEAKAGE PUMP
SHIELD TANK
PRESSURIZER
PRIMARY COOLANT PUMP
STEAM GENERATOR
REACTOR VESSEL
JACK SCREW LOCATIONS
ALCO PRODUCTS, INC.
SCHENECTADY, N. Y., U. S. A.
PRIMARY SYSTEM
R9-47-1013

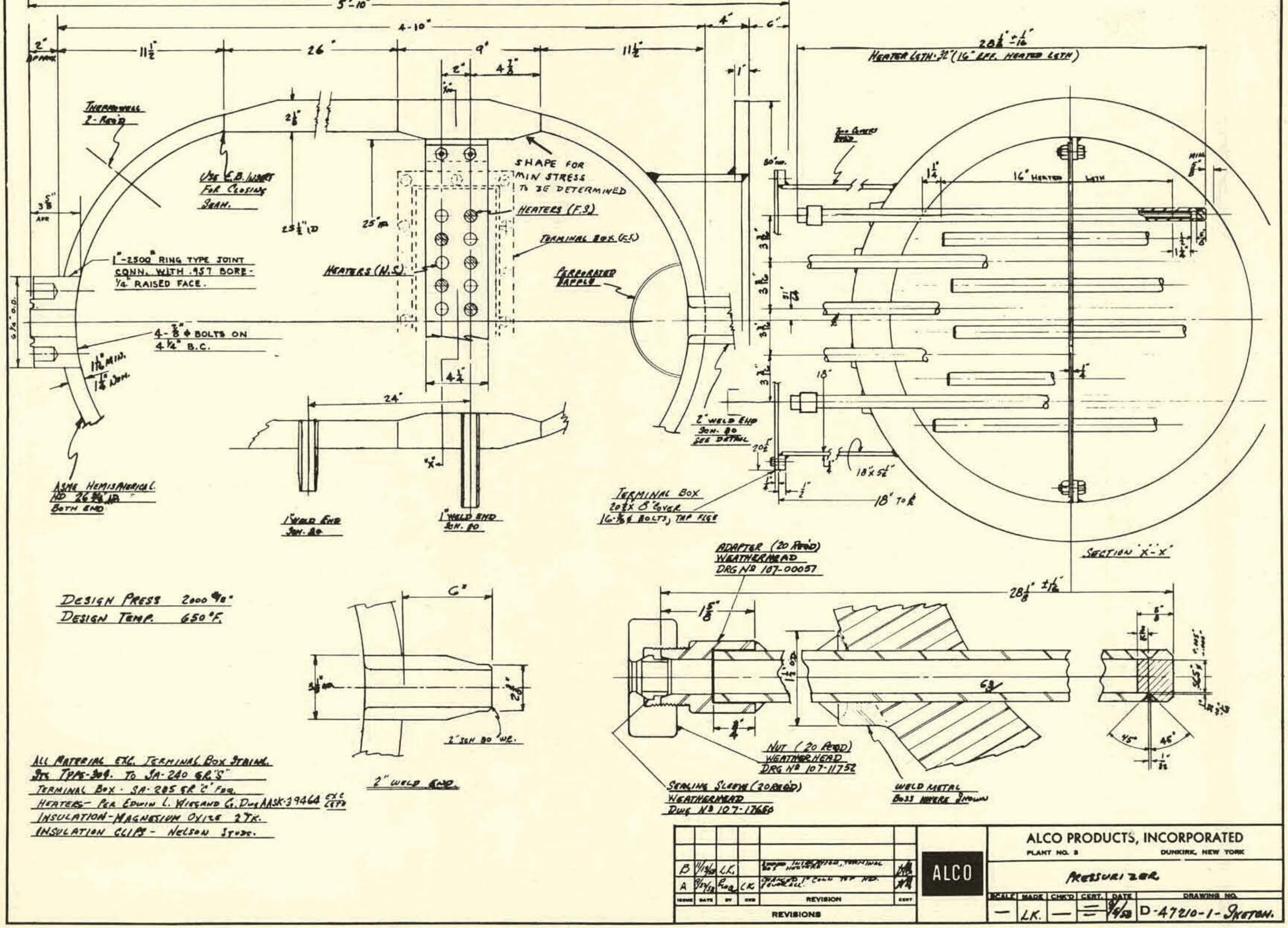


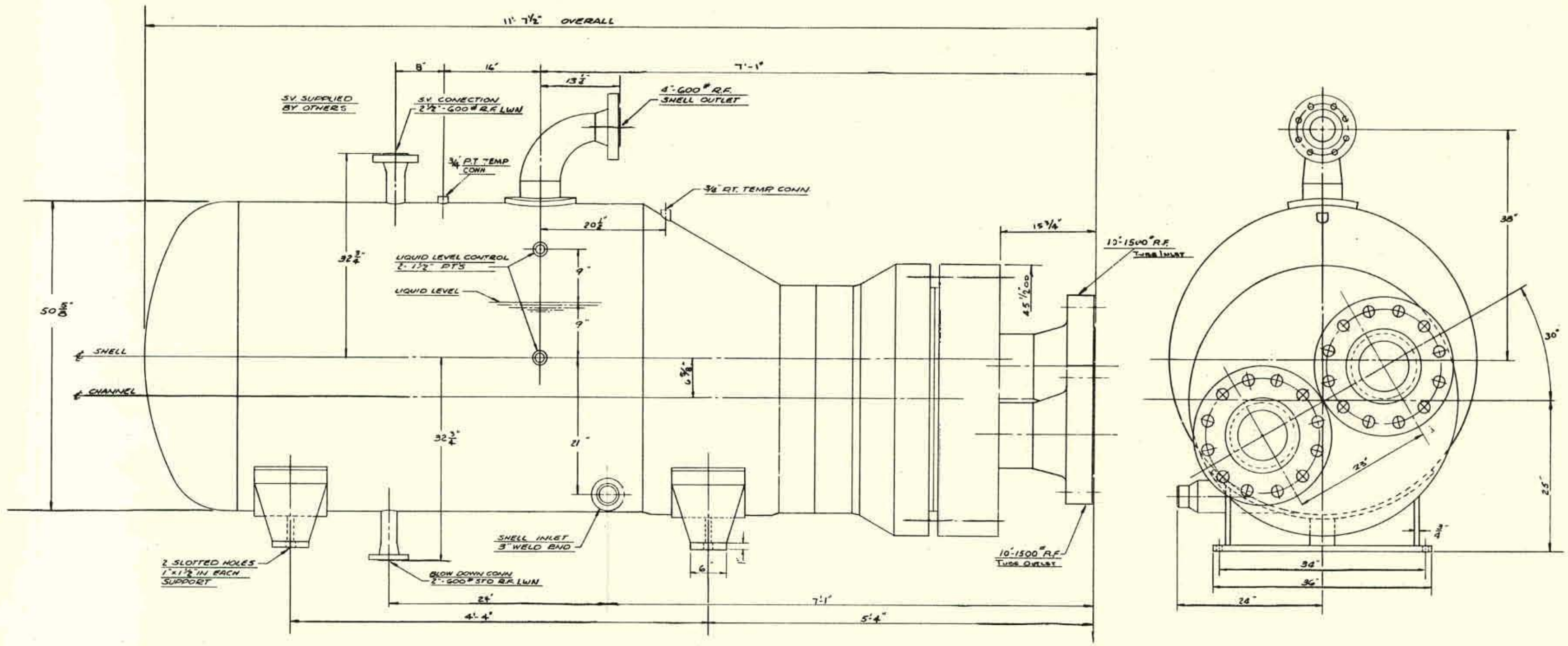
L
SPACER
STEAM GENERATOR SKID
REACTOR SKID
287" (23'-11")
SECTION L-L
At Assembly After Lining Up Skid Sections Using As Jig:
At Skid Assembly After Drilling & Bolting At Parting Line Using As Jig:
16-Holes (8-Each Side) 1" Drill Thru
(1P17108-080)
16-Nuts (1P60000-026)
ALCO PRODUCTS, INC.
PRIMARY SKID ASSEMBLY
R9-42-1001



LINEAR POWER CHAMBER
SAFETY CHAMBER 1
BF3 COUNTER
BORAL
CARB. STL.
SAFETY CHAMBER 2
55 O.D.
NOTE:-
SHIELD TANK, CARB. STL.-INSIDE WALL LINED WITH BORAL 1/8 THK. AS SHOWN.-
SHIELD RINGS CARB. STL. 3 1/4 THK. WITH BORAL 1/8 THK ON EACH SIDE
TOP OF THE TWO
VESSEL SUPPORT RING CARB. STL 1 THK WITH BORAL 1/8 THK. ON THE OUTSIDE.
SHIELD RING SUPPORTS & INSULATION JACKET CARB. STL.
ION CHAMBERS STAINLESS STL.
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N. Y., U. S. A.
SHIELD TANK & RINGS.
R9-46-1039


LAYOUT
ALCO PRODUCTS INC.
SCHENECTADY, NEW YORK
ATOMIC ENERGY DEPT.
MODEL-
REFERENCES-
AUTHORITY-
TITLE-
REACTOR VESSEL
10 MW SKID MOUNTED
LAYOUT NO.-
AEL 389


5'-10"
4-10"
2"
11½"
26"
9"
11½"
4"
6"
2"
4⅞"
28⅛" ±1/16"
HEATER LGTH. 32" (16" EFF. HEATED LGTH)
THERMOWELL 2-REQ'D
USE E.B. INSERT FOR CLOSING SEAM.
SHAPE FOR MIN STRESS TO BE DETERMINED
HEATERS (F.S)
TERMINAL BOX (F.S)
HEATERS (N.S)
PERFORATED BAFFLE
1"-2500# RING TYPE JOINT CONN. WITH .957 BORE - 1/4" RAISED FACE.
4-⅝" ϕ BOLTS ON 4½" B.C.
24"
4½"
"X"
2" WELD END SCH. 80 SEE DETAIL
ASME HEMISPHERICAL HD 26⅜" ID BOTH END
1" WELD END SCH. 80
1" WELD END SCH. 80
TERMINAL BOX 20⅞ x 8" COVER 16-⅝" ϕ BOLTS, TAP FLGE
18" TO ℄
16" HEATED LGTH
SECTION "X-X"
DESIGN PRESS 2000 #/□"
DESIGN TEMP. 650°F.
6"
2" SCH 80 WE.
2" WELD END.
ADAPTER (20 REQ'D) WEATHERHEAD DRG Nº 107-00057
NUT (20 REQ'D) WEATHERHEAD DRG Nº 107-11752
SEALING SLEEVE (20 REQ'D) WEATHERHEAD DWG Nº 107-17656
WELD METAL BOSS WHERE SHOWN
45°
45°
ALL MATERIAL EXC. TERMINAL BOX STAINL. STL. TYPE-304. TO SA-240 GR. "S"
TERMINAL BOX - SA-285 GR "C" FBQ.
HEATERS - PER EDWIN L. WIEGAND CO. DWG ASK-39464 EXC LGTH
INSULATION - MAGNESIUM OXIDE 2 THK.
INSULATION CLIPS - NELSON STUDS.
ALCO PRODUCTS, INCORPORATED
PLANT NO. 3
DUNKIRK, NEW YORK
ALCO
PRESSURIZER
REVISION
REVISIONS
SCALE
MADE
CHK'D
CERT.
DATE
DRAWING NO.
LK.
D-47210-1-SKETCH.



	DESIGN PRESS	TEST PRESS	DESIGN TEMP
SHELL	800 P.S.I.	1200 P.S.I.	600°F
TUBES	2000 P.S.I.	3000 P.S.I.	600°F

EST WT PER UNIT	
DRY	17,600#
FLOODED	22,850#

PRELIMINARY H 47210-3-1

ISSUE	DATE	BY	CHK	REVISION	COST
A	11-18	RL		General	

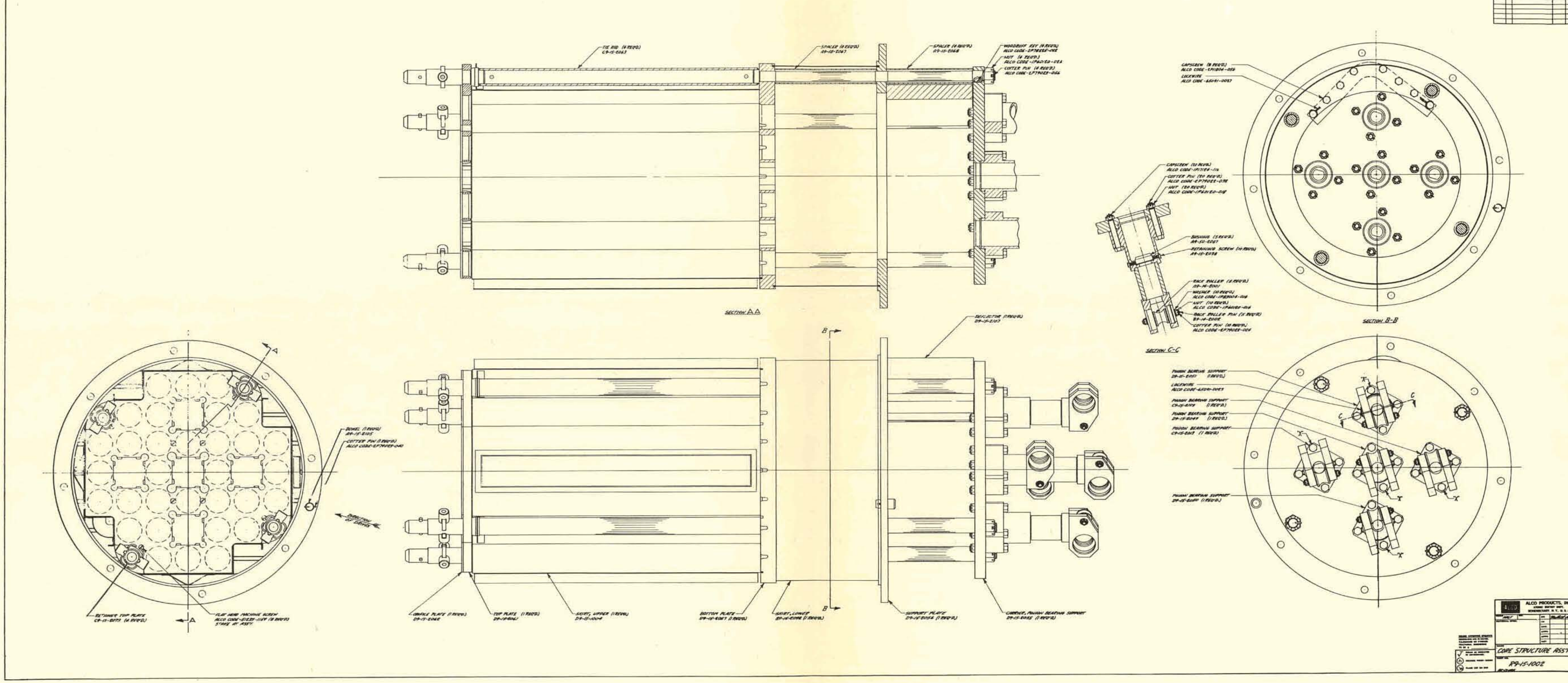
REVISIONS

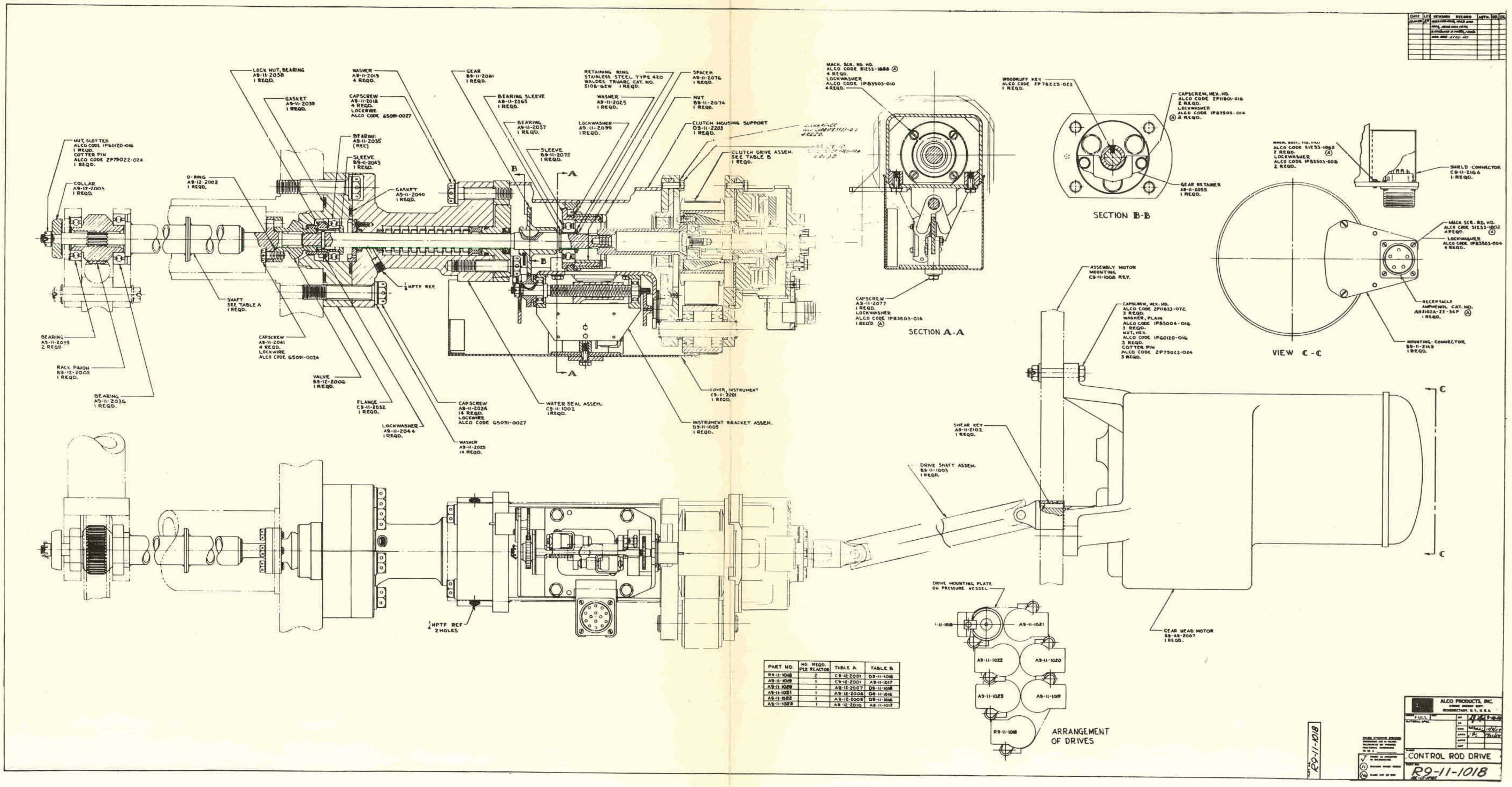
ALCO

ALCO PRODUCTS, INCORPORATED
PLANT NO. 3 DUNKIRK, NEW YORK

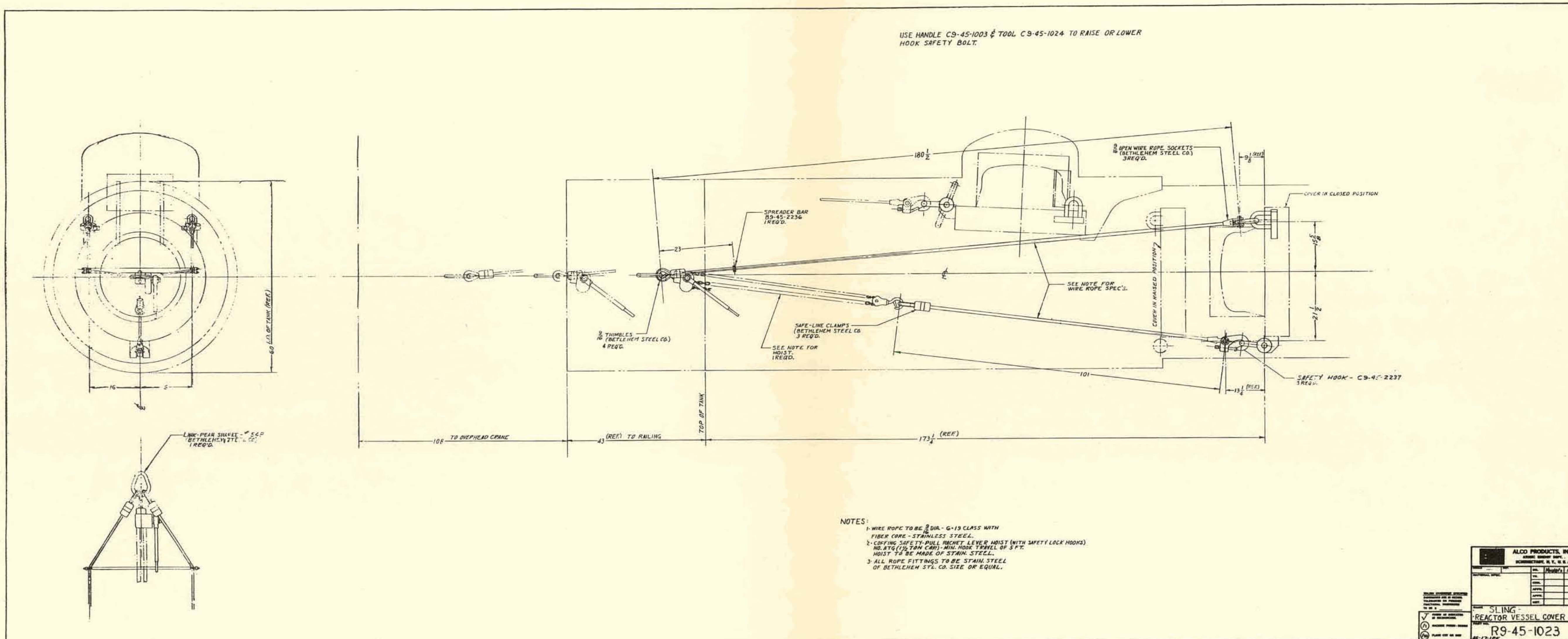
STEAM GENERATOR
SIZE 48-35-84 TYPE W-10-42-78-H

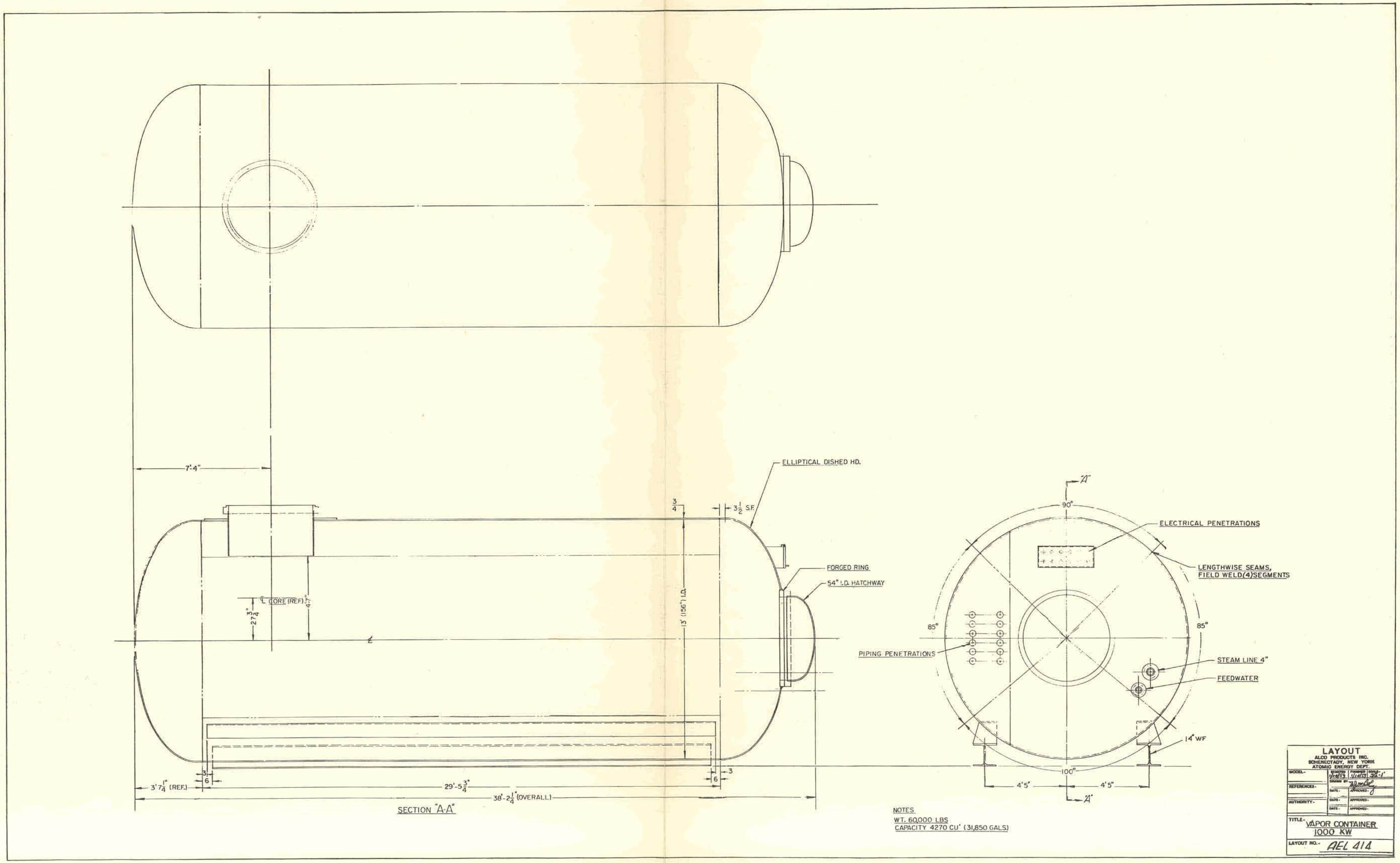
SCALE	MADE	CHK'D	CERT.	DATE	DRAWING NO.
½"	RL			10/23/58	H 47210-3-1

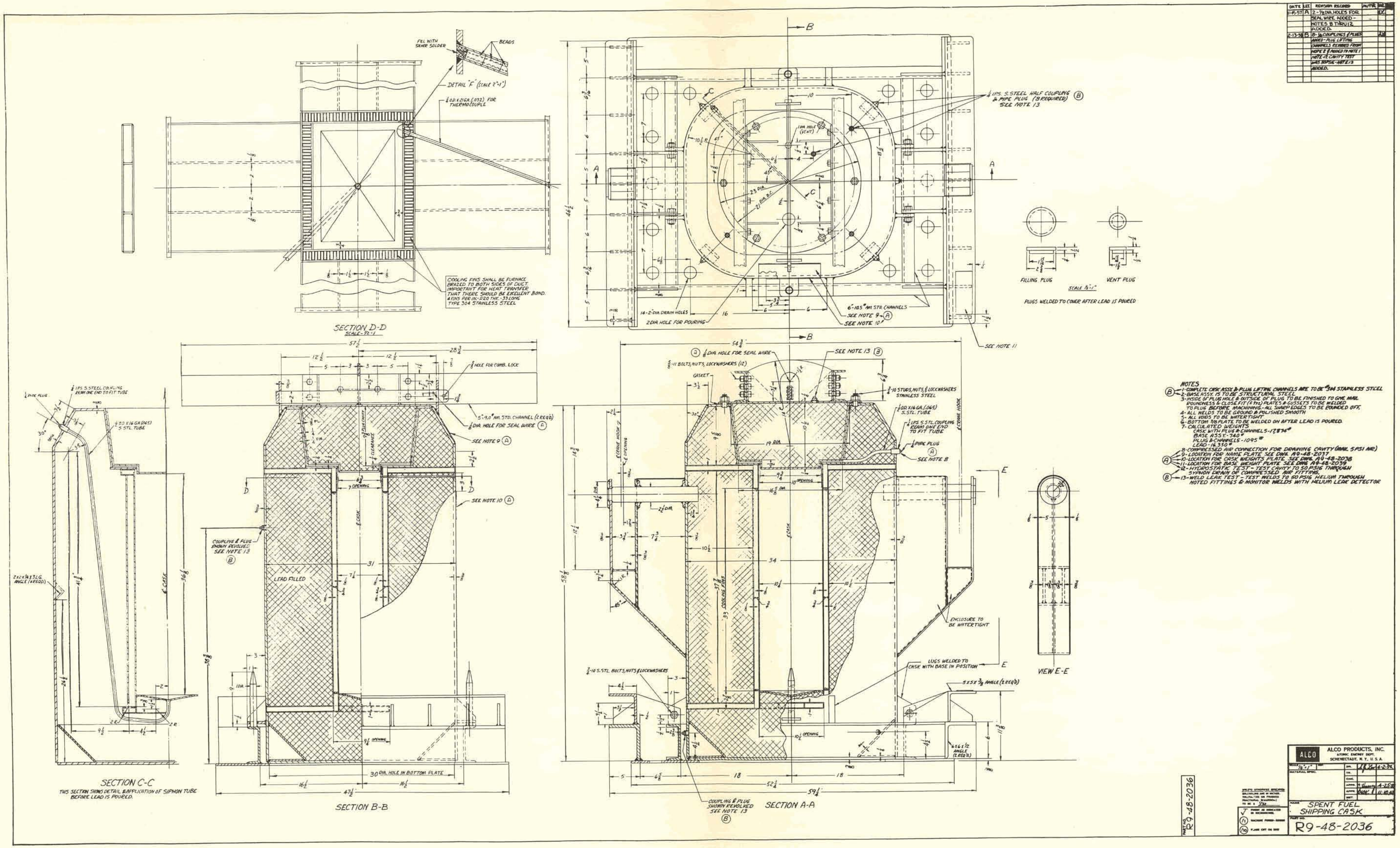

SECTION A-A
SECTION B-B
SECTION C-C
ALCO PRODUCTS, INC.
CORE STRUCTURE ASSY.
R9-15-1002

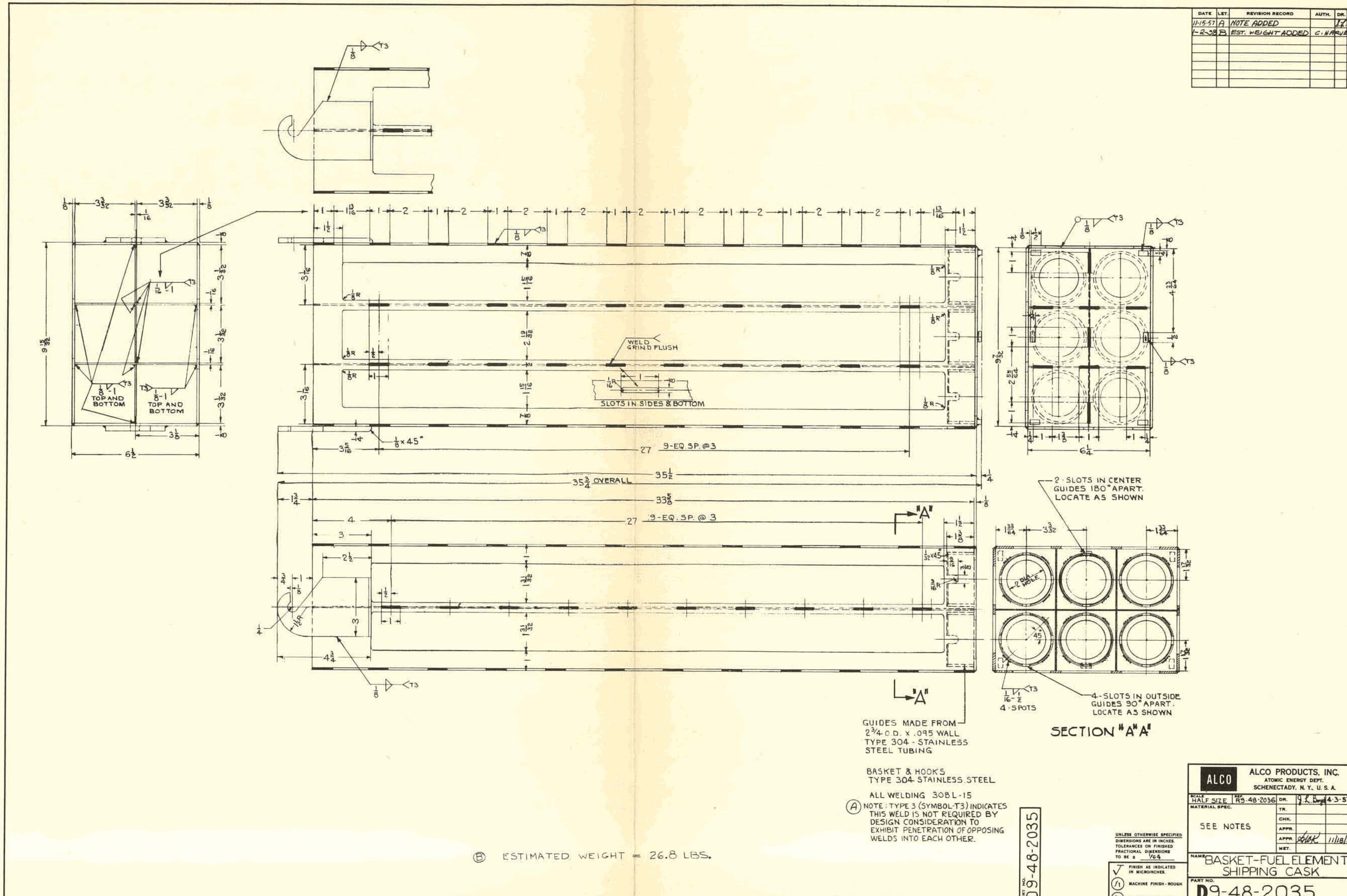


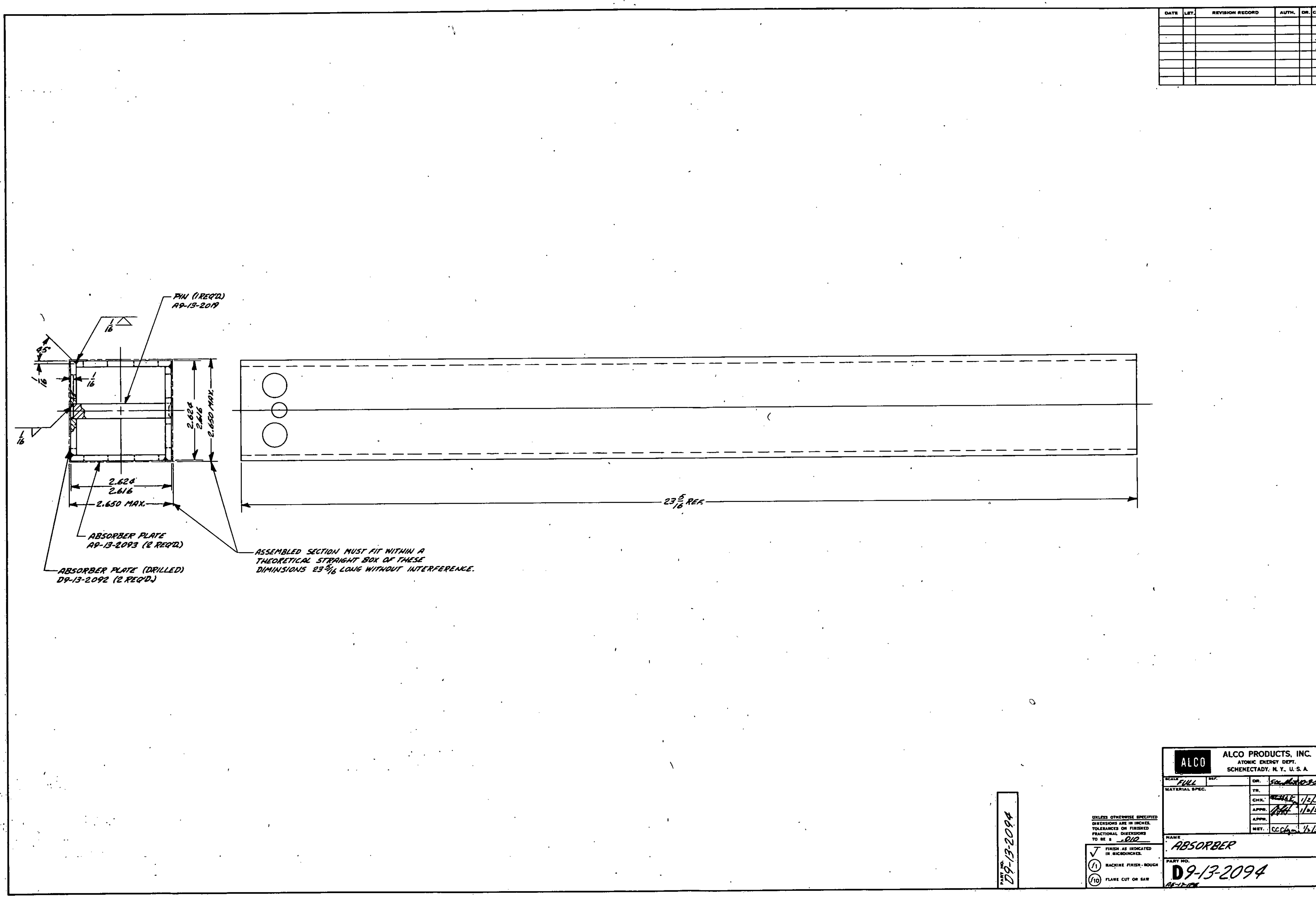
PART NO.	NO. REQD. PER REACTOR	TABLE A	TABLE B
R9-11-1018	2	C9-12-2001	D9-11-1016
A9-11-1019	1	C9-12-2001	A9-11-1017
A9-11-1020	1	A9-12-2007	D9-11-1016
A9-11-1021	1	A9-12-2008	D9-11-1016
A9-11-1022	1	A9-12-2009	D9-11-1016
A9-11-1023	1	A9-12-2010	A9-11-1017

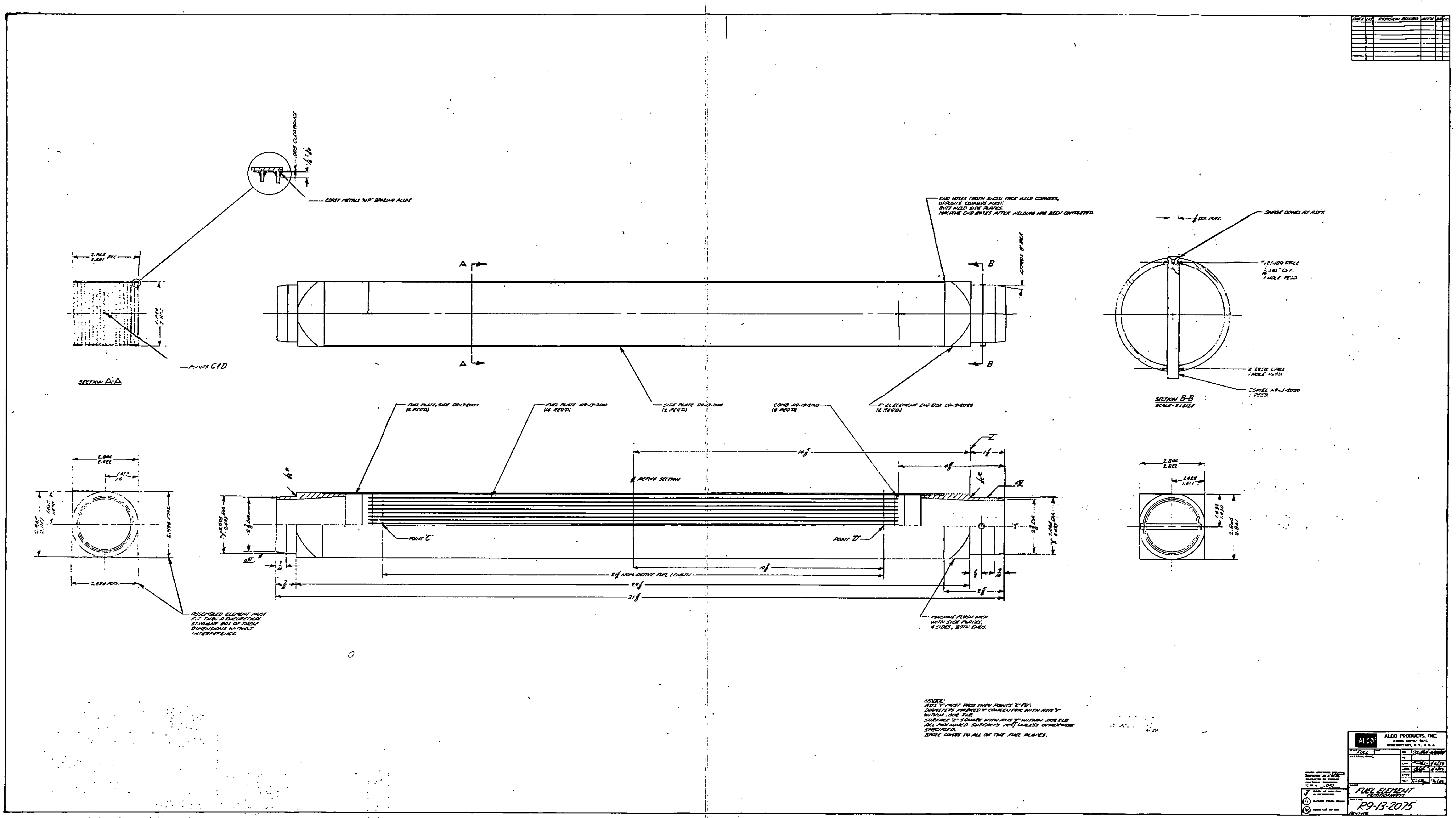

USE HANDLE C9-45-1003 & TOOL C9-45-1024 TO RAISE OR LOWER HOOK SAFETY BOLT.
OPEN WIRE ROPE SOCKETS (BETHLEHEM STEEL CO.) 3 REQ'D.
COVER IN CLOSED POSITION
SPREADER BAR B9-45-2236 1 REQ'D.
SEE NOTE FOR WIRE ROPE SPEC'S.
COVER IN RAISED POSITION
THIMBLES (BETHLEHEM STEEL CO.) 4 REQ'D.
SAFE-LINE CLAMPS (BETHLEHEM STEEL CO. 3 REQ'D.
SEE NOTE FOR HOIST. 1 REQ'D.
SAFETY HOOK - C9-45-2237 3 REQ'D.
60 I.D. OF TANK (REF.)
TO OVERHEAD CRANE
(REF.) TO RAILING
TOP OF TANK
NOTES:
1- WIRE ROPE TO BE 9/16 DIA. - 6-19 CLASS WITH FIBER CORE - STAINLESS STEEL.
2- COFFING SAFETY-PULL RACHET LEVER HOIST (WITH SAFETY LOCK HOOKS) NO. ATG (1½ TON CAP.) - MIN. HOOK TRAVEL OF 5 FT. HOIST TO BE MADE OF STAIN. STEEL.
3- ALL ROPE FITTINGS TO BE STAIN. STEEL OF BETHLEHEM STL. CO. SIZE OR EQUAL.
ALCO PRODUCTS, INC.
SLING - REACTOR VESSEL COVER
R9-45-1023


ELLIPTICAL DISHED HD.
7'-4"
$3\frac{1}{2}$ S.F.
FORGED RING
54" I.D. HATCHWAY
℄ CORE (REF.)
$27\frac{3}{4}$"
4'-7"
13' (156") I.D.
$3'-7\frac{1}{4}$" (REF.)
$29'-5\frac{3}{4}$"
$38'-2\frac{1}{4}$" (OVERALL)
SECTION "A-A"
"A"
90°
ELECTRICAL PENETRATIONS
LENGTHWISE SEAMS, FIELD WELD (4) SEGMENTS
85°
85°
PIPING PENETRATIONS
STEAM LINE 4"
FEEDWATER
14" WF
100°
4'5"
4'5"
"A"
NOTES
WT. 60,000 LBS
CAPACITY 4270 CU' (31,850 GALS)
LAYOUT
ALCO PRODUCTS INC.
SCHENECTADY, NEW YORK
ATOMIC ENERGY DEPT.
MODEL-
STARTED
FINISHED
SCALE-
DRAWN BY
REFERENCES-
DATE-
APPROVED-
AUTHORITY-
DATE-
APPROVED-
DATE-
APPROVED-
TITLE- VAPOR CONTAINER
1000 KW
LAYOUT NO.- AEL 414


SECTION D-D
SECTION C-C
THIS SECTION SHOWS DETAIL & APPLICATION OF SIPHON TUBE BEFORE LEAD IS POURED.
SECTION B-B
SECTION A-A
VIEW E-E
FILLING PLUG
VENT PLUG
PLUGS WELDED TO COVER AFTER LEAD IS POURED
LEAD FILLED
ENCLOSURE TO BE WATERTIGHT
LUGS WELDED TO CASK WITH BASE IN POSITION
NOTES
1-COMPLETE CASK ASSY & PLUG LIFTING CHANNELS ARE TO BE #304 STAINLESS STEEL
2-BASE ASSY. IS TO BE STRUCTURAL STEEL
3-INSIDE OF PLUG HOLE & OUTSIDE OF PLUG TO BE FINISHED TO GIVE MAX. ROUNDNESS & CLOSE FIT (±1/32) PLATES & GUSSETS TO BE WELDED TO PLUG BEFORE MACHINING.-ALL SHARP EDGES TO BE ROUNDED OFF.
4-ALL WELDS TO BE GROUND & POLISHED SMOOTH
5-ALL VOIDS TO BE WATERTIGHT
6-BOTTOM 3/8 PLATE TO BE WELDED ON AFTER LEAD IS POURED.
7-CALCULATED WEIGHTS
CASK WITH PLUG & CHANNELS-17,874#
BASE ASSY.-740#
PLUG & CHANNELS-1095#
LEAD-16,350#
8-COMPRESSED AIR CONNECTION FOR DRAINING CAVITY (MAX. 5 PSI AIR)
9-LOCATION FOR NAME PLATE SEE DWG A9-48-2037
10-LOCATION FOR CASK WEIGHTS PLATE SEE DWG A9-48-2038
11-LOCATION FOR BASE WEIGHT PLATE SEE DWG A9-48-2039
12-HYDROSTATIC TEST-TEST CAVITY TO 50 PSIG THROUGH SYPHON DRAIN OR COMPRESSED AIR FITTING.
13-WELD LEAK TEST-TEST WELDS TO 50 PSIG HELIUM THROUGH NOTED FITTINGS & MONITOR WELDS WITH HELIUM LEAK DETECTOR
ALCO
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.
SPENT FUEL SHIPPING CASK
R9-48-2036

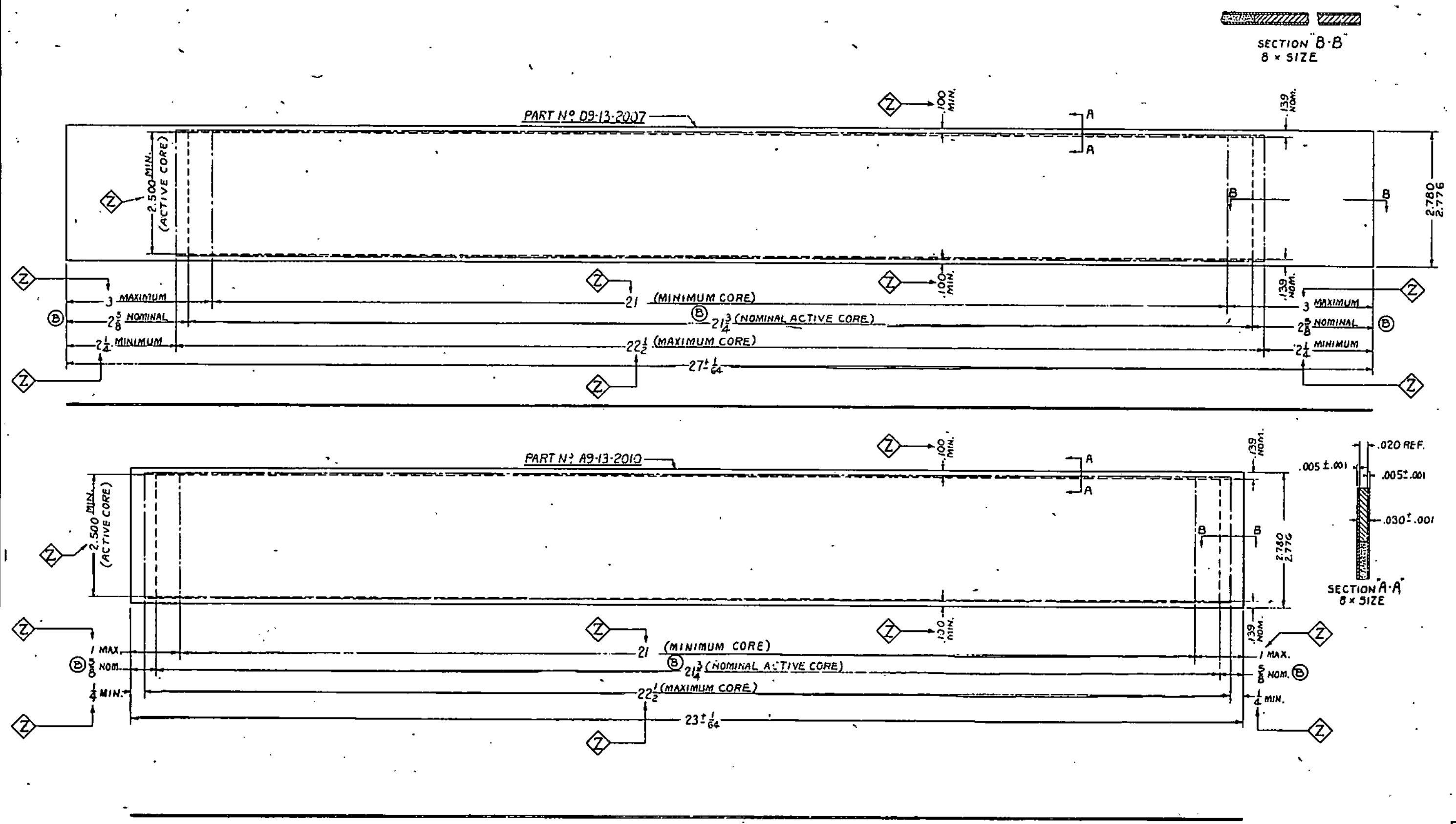

DATE | LET. | REVISION RECORD | AUTH. | DR. | CHK.
11-15-57 A NOTE ADDED
1-2-58 B EST. WEIGHT ADDED C. HARVEY
WELD GRIND FLUSH
SLOTS IN SIDES & BOTTOM
TOP AND BOTTOM
35¾ OVERALL
9-EQ. SP. @ 3
2-SLOTS IN CENTER GUIDES 180° APART. LOCATE AS SHOWN
4-SLOTS IN OUTSIDE GUIDES 90° APART. LOCATE AS SHOWN
4-SPOTS
SECTION "A" "A"
GUIDES MADE FROM 2¾ O.D. x .095 WALL TYPE 304-STAINLESS STEEL TUBING
BASKET & HOOKS TYPE 304 STAINLESS STEEL
ALL WELDING 308L-15
(A) NOTE: TYPE 3 (SYMBOL-T3) INDICATES THIS WELD IS NOT REQUIRED BY DESIGN CONSIDERATION TO EXHIBIT PENETRATION OF OPPOSING WELDS INTO EACH OTHER.
(B) ESTIMATED WEIGHT = 26.8 LBS.
D9-48-2035
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON FINISHED FRACTIONAL DIMENSIONS TO BE ± 1/64
FINISH AS INDICATED IN MICROINCHES.
MACHINE FINISH-ROUGH
FLAME CUT OR SAW
ALCO
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N. Y., U. S. A.
HALF SIZE
R9-48-2036
4-3-57
11/18/57
MATERIAL SPEC.
SEE NOTES
BASKET-FUEL ELEMENT-SHIPPING CASK
PART NO.
D9-48-2035


PIN (1 REQ'D.)
A9-13-2019
45°
2.624
2.616
2.650 MAX.
23 5/16 REF.
ABSORBER PLATE
A9-13-2093 (2 REQ'D.)
ABSORBER PLATE (DRILLED)
D9-13-2092 (2 REQ'D.)
ASSEMBLED SECTION MUST FIT WITHIN A THEORETICAL STRAIGHT BOX OF THESE DIMINSIONS 23 5/16 LONG WITHOUT INTERFERENCE.
DATE
LET.
REVISION RECORD
AUTH.
DR.
CKD.
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N. Y., U. S. A.
SCALE FULL
REF.
MATERIAL SPEC.
DR.
TR.
CHK. 1/2/59
APPR. 1/2/59
APPR.
MET. 1/2/59
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON FINISHED FRACTIONAL DIMENSIONS TO BE ± .010
FINISH AS INDICATED IN MICROINCHES.
MACHINE FINISH - ROUGH
FLAME CUT OR SAW
NAME
ABSORBER
PART NO.
D9-13-2094



SECTION A-A
SECTION B-B
POINT "C"
POINT "D"
ALCO PRODUCTS, INC.
SCHENECTADY, N. Y., U. S. A.
FULL
FUEL ELEMENT
R9-13-2075

DATE	LTR	REVISION RECORD	AUTH.	CK.
12-27-55	A	REVISED		
6-27-58	B	DIM. 21 3/4 WAS 22, 2 5/8 WAS 2 1/2, 5/8 WAS 1/2		



NOTE:–
ACTIVE CORE MUST FALL WITHIN DIMENSIONS MARKED ⟨Z⟩

PART Nº	NAME
D9-13-2007	FUEL PLATE-SIDE
A9-13-2010	FUEL PLATE

D9-13-2007

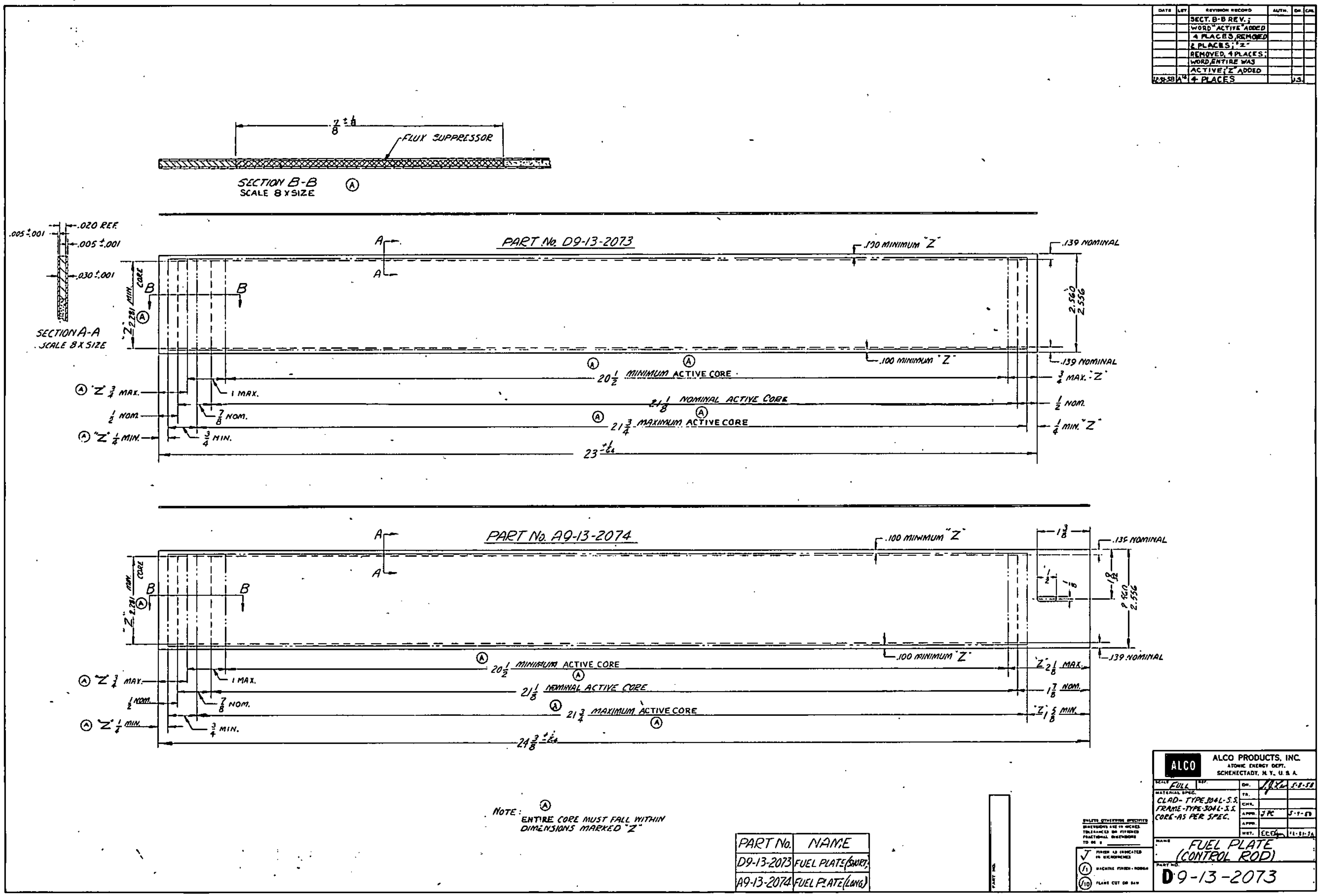
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.

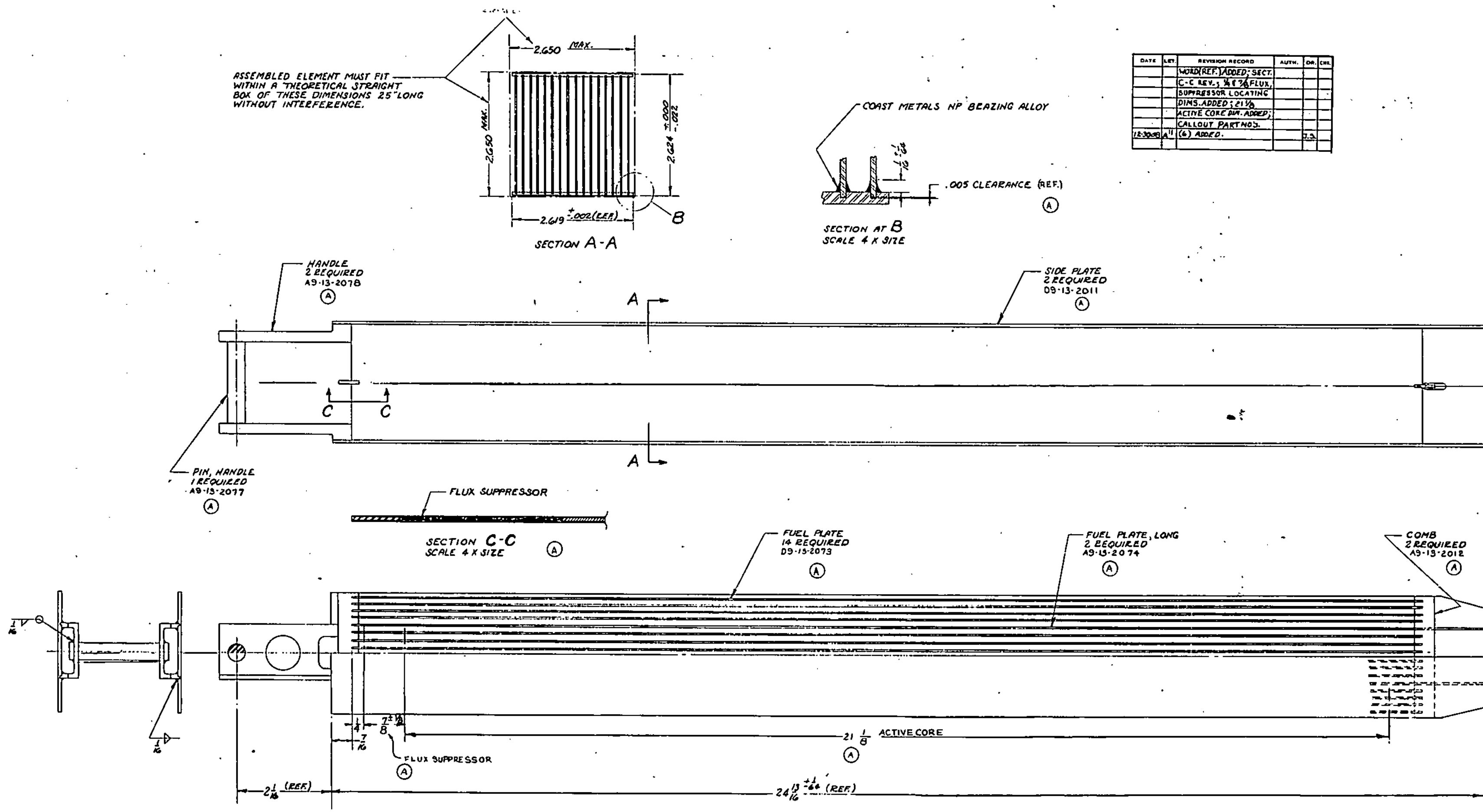
SCALE: FULL SIZE
MATERIAL SPEC.: CLAD - TYPE 304 L SS; FRAME - TYPE 304 L SS; CORE - AS SPECIFIED

NAME: FUEL PLATES (STATIONARY)

PART NO. D9-13-2007

174


SECT. B-B REV.; WORD "ACTIVE" ADDED 4 PLACES, REMOVED 2 PLACES; "Z" REMOVED, 4 PLACES; WORD ENTIRE WAS ACTIVE; "Z" ADDED 4 PLACES
FLUX SUPPRESSOR
SECTION B-B
SCALE 8 X SIZE
SECTION A-A
SCALE 8 X SIZE
PART No. D9-13-2073
PART No. A9-13-2074
.100 MINIMUM "Z"
.139 NOMINAL
20 1/2 MINIMUM ACTIVE CORE
21 1/8 NOMINAL ACTIVE CORE
21 3/4 MAXIMUM ACTIVE CORE
NOTE: ENTIRE CORE MUST FALL WITHIN DIMENSIONS MARKED "Z"
PART No. | NAME
D9-13-2073 | FUEL PLATE (SHORT)
A9-13-2074 | FUEL PLATE (LONG)
ALCO
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.
CLAD - TYPE 304L-S.S.
FRAME - TYPE 304L-S.S.
CORE - AS PER SPEC.
FUEL PLATE (CONTROL ROD)
D9-13-2073



DATE	LET.	REVISION RECORD	AUTH.	DR.	CHK.
		WORD (REF.) ADDED; SECT.			
		C-C REV.; 1/4 & 7/8 FLUX			
		SUPPRESSOR LOCATING			
		DIMS. ADDED; 21 1/8			
		ACTIVE CORE DIM. ADDED;			
		CALLOUT PART NOS.			
12-30-58	A	(6) ADDED.		J.S.	

METHOD OF ASSEMBLY

1. HELI-ARC HANDLES TO SIDE PLATES AS SHOWN.
2. ASSEMBLE SIDE PLATES (WITH HANDLES), FUEL PLATES AND COMBS.
3. FURNACE BRAZE FUEL PLATES TO SIDE PLATES AND COMBS TO FUEL PLATES.
4. HELI-ARC PIN TO HANDLES.
5. BREAK SHARP EDGES AND REMOVE ALL BURRS.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FINISHED FRACTIONAL DIMENSIONS TO BE ± 1/64

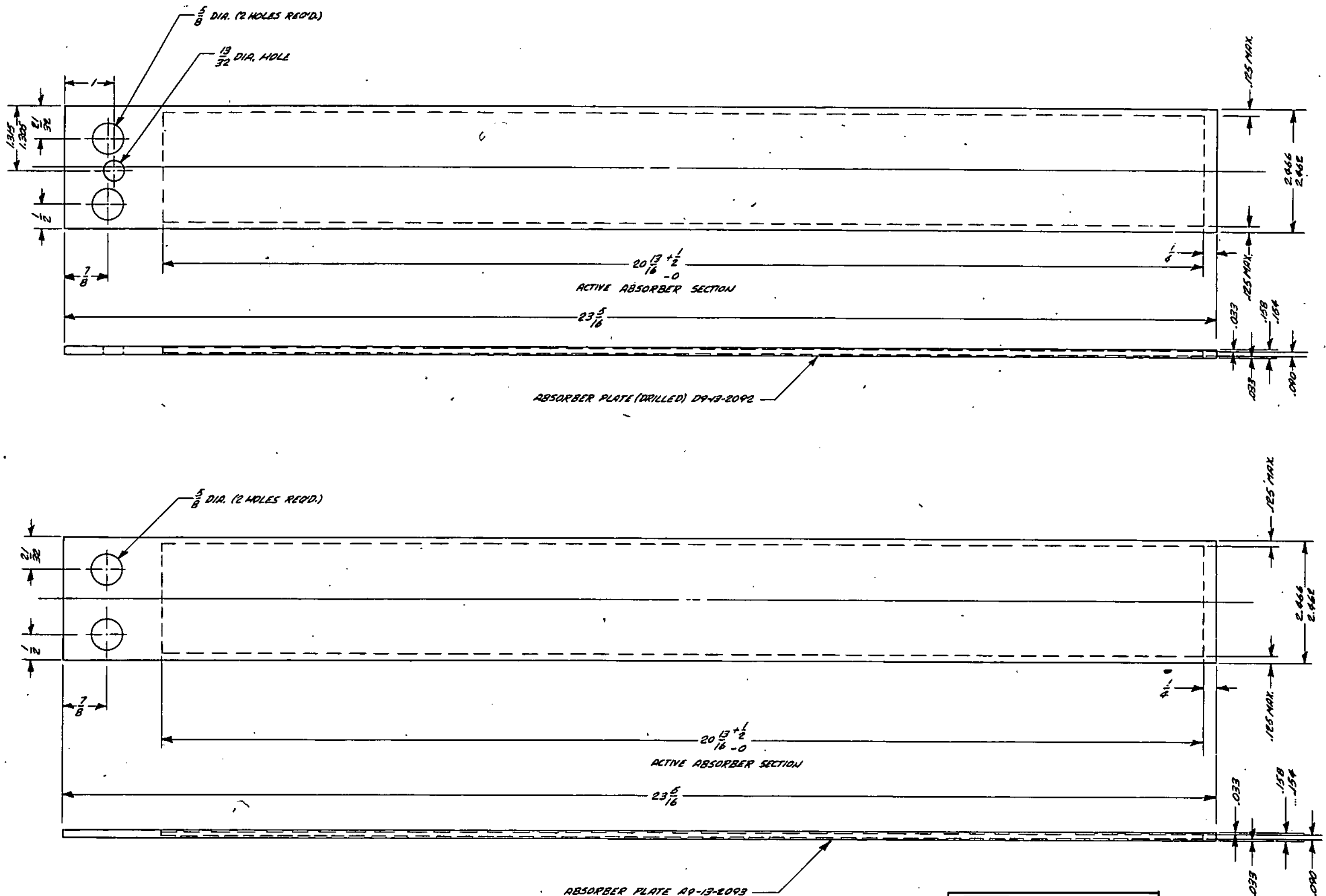
√ FINISH AS INDICATED IN MICROINCHES
(/1) MACHINE FINISH - ROUGH
(/10) FLAME CUT OR SAW

ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.

SCALE: FULL	REF. D9-13-1004	DR.	[illegible]	2-13-59
MATERIAL SPEC.		TR.		
		CHK.		
		APPR.		
		APPR.	[illegible]	1-14-59
		MET.	CCS	12-31-58

NAME: FUEL ELEMENT (CONTROL ROD)

PART NO.: D 9-13-1011



PART NO.	PART NAME
D9-13-2092	ABSORBER PLATE (DRILLED)
A9-13-2093	ABSORBER PLATE

ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N. Y., U. S. A.

SCALE FULL

MATERIAL SPEC. SEE MATERIAL SPECIFICATION.

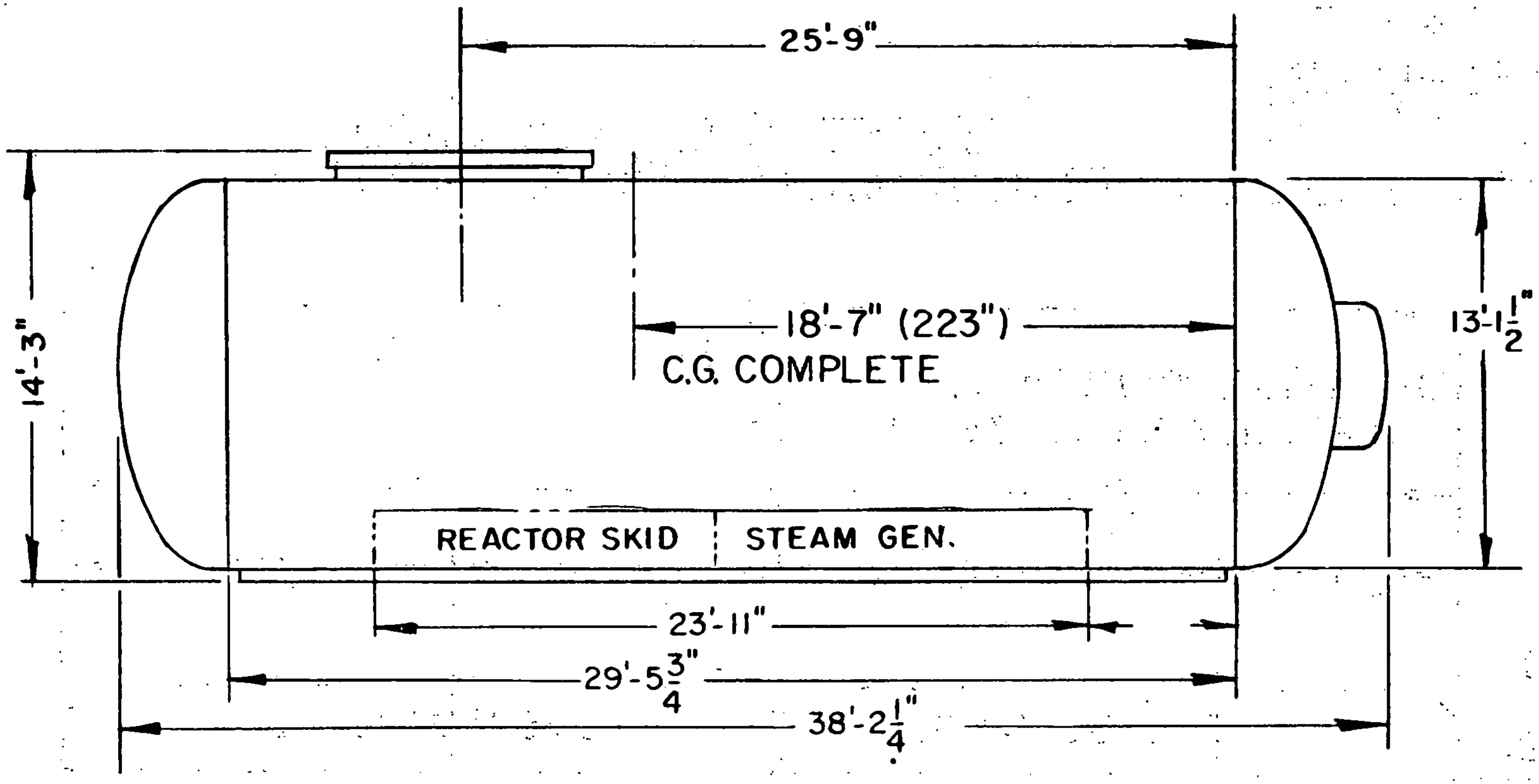
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON FINISHED FRACTIONAL DIMENSIONS TO BE ± .010

FINISH AS INDICATED IN MICROINCHES.
MACHINE FINISH - ROUGH
PLANE CUT OR SAW

DR. 10-9-58
TR.
CHK. 1/2/59
APPD. 1/2/59
APPD.
MET. 1/2/59

NAME: ABSORBER PLATE (DRILLED)

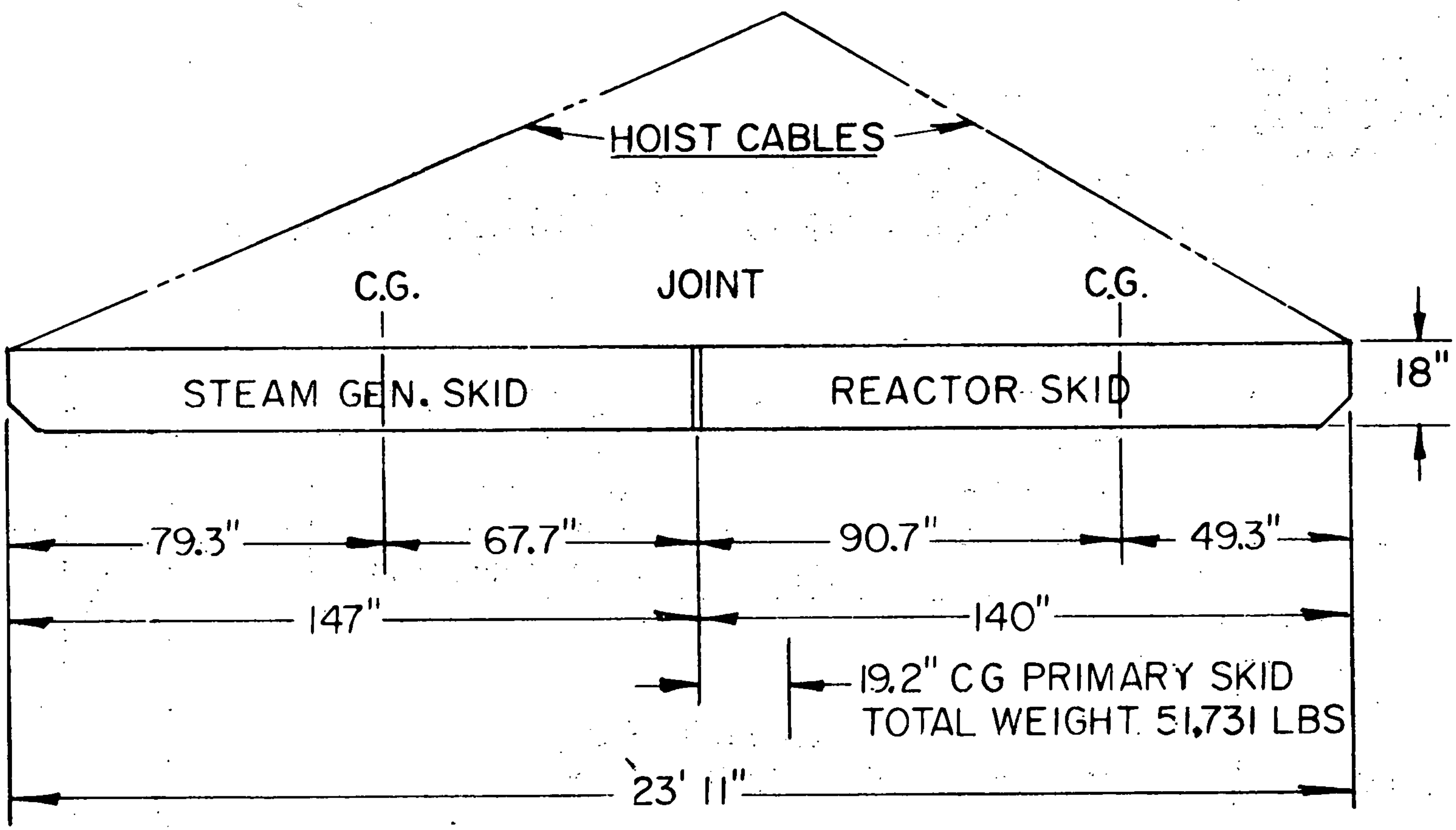
PART NO. D9-13-2092



WEIGHT DISTRIBUTION AND CENTER OF GRAVITY OF VAPOR CONTAINER WITH ALL COMPONENTS

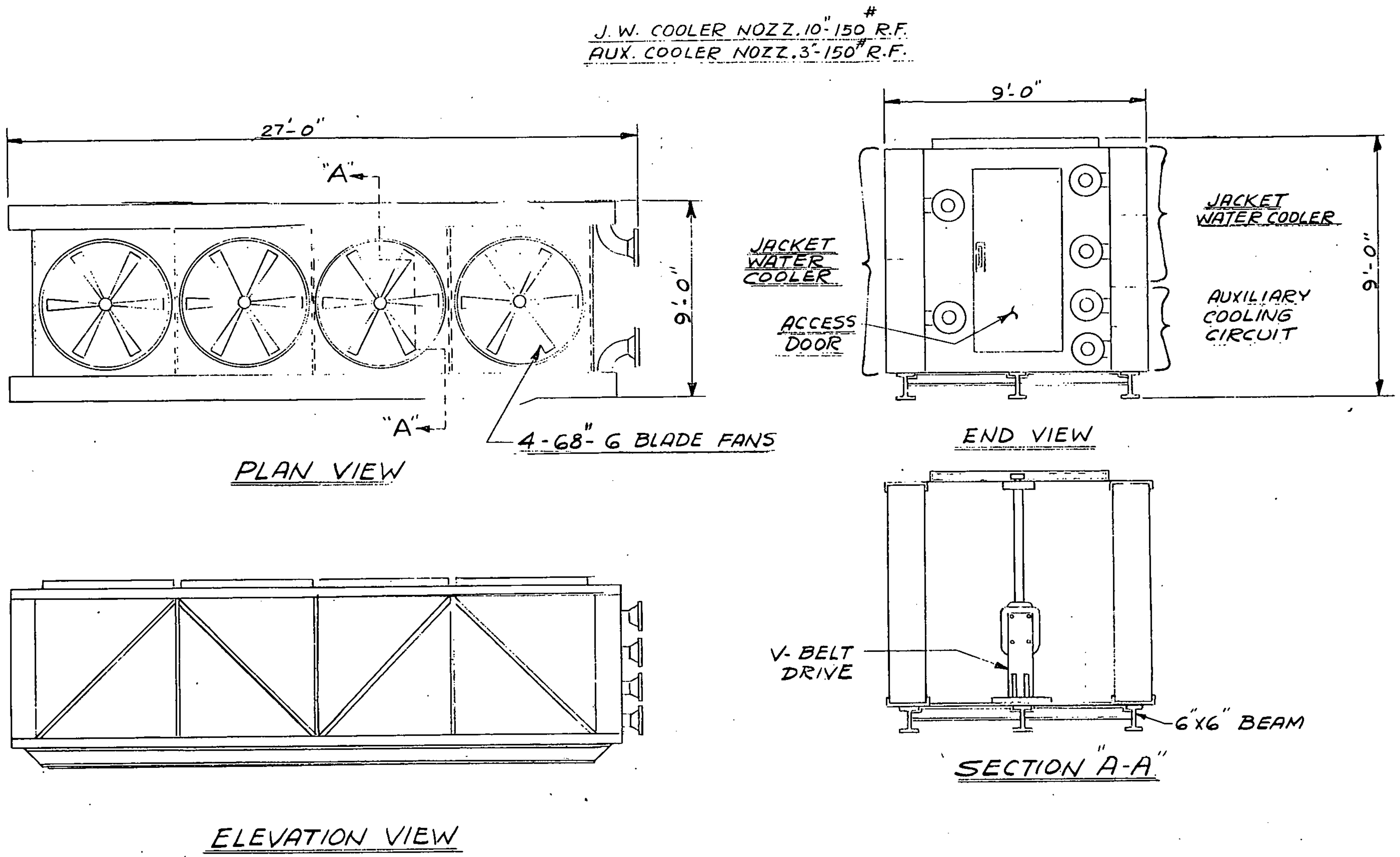
ALCO PRODUCTS INC.
SCHENECTADY, N.Y.
JAN. 14, 1959

AES 283



PRIMARY SKID WEIGHT DISTRIBUTION & CENTERS OF GRAVITY
WITH STEAM GEN. & REACTOR

AES 285
ALCO PRODUCTS
1-21-59



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON FINISHED FRACTIONAL DIMENSIONS TO BE ±

√ FINISH AS INDICATED IN MICROINCHES.

ƒ1 MACHINE FINISH - ROUGH

ƒ10 FLAME CUT OR SAW

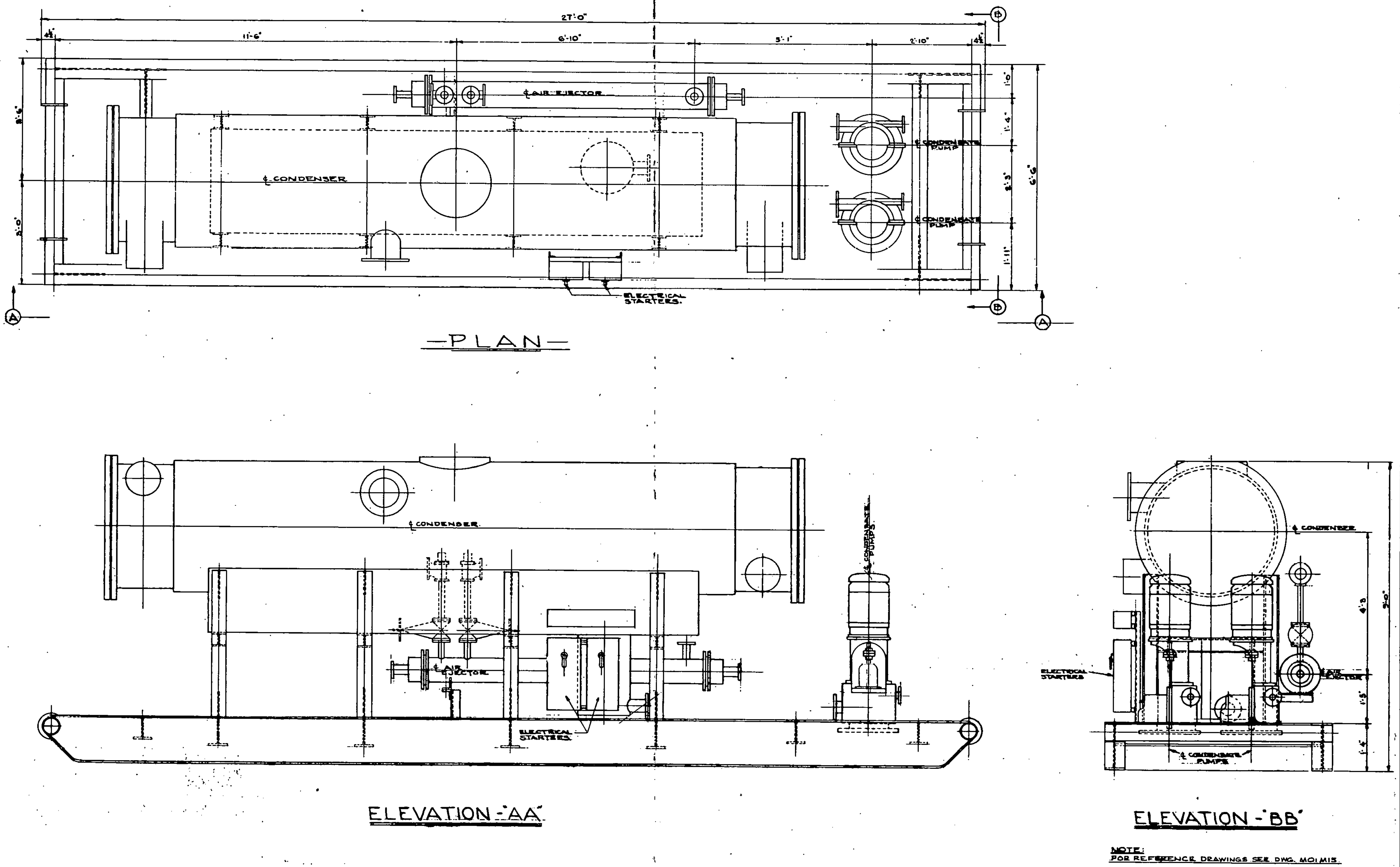
ALCO

ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N. Y., U. S. A.

SCALE NONE	REF. B-133760	DR.	E Beyer	1-28-59
MATERIAL SPEC.		TR.		
		CHK.		
		APPR.		
		APPR.		
		MET.		

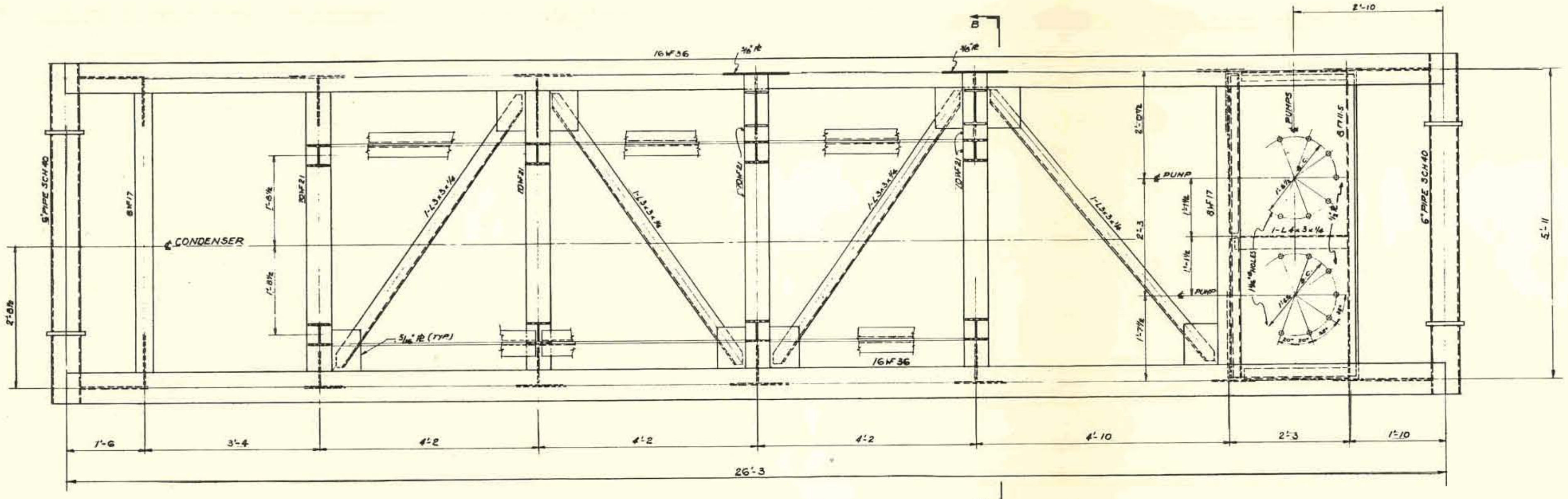
NAME: AIR BLAST COOLER

PART NO.: C A.E.S.- 288

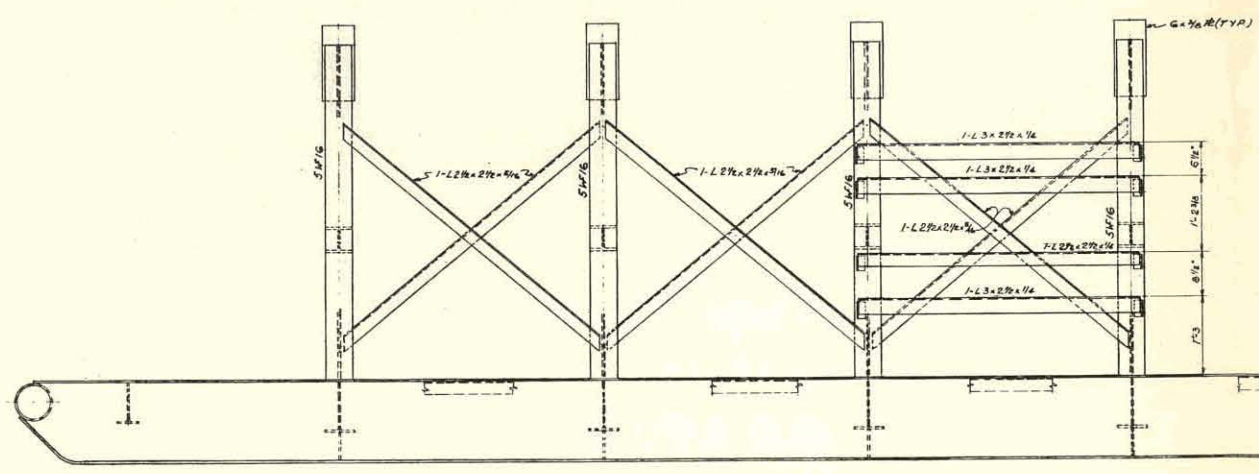


ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N. Y., U. S. A.

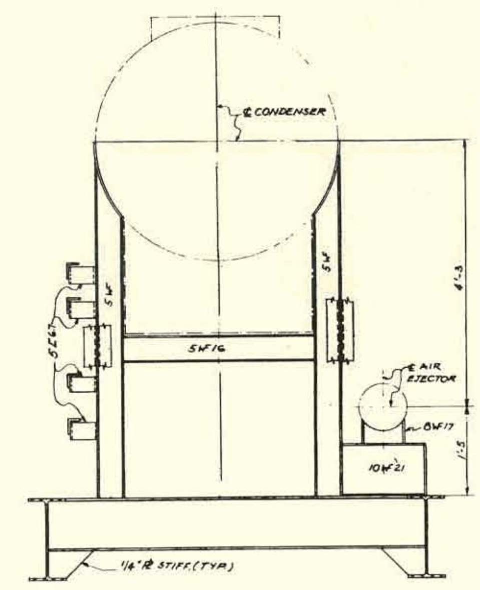
ALCO PRODUCTS, INC. SCHENECTADY, N.Y. 1000 K.W. PACKAGED NUCLEAR POWER PLANT	CONDENSER PACKAGE EQUIPMENT ARRANGEMENT	Peter F. Loftus Corporation PITTSBURGH · PENNSYLVANIA · U. S. A.
DRAWN R.J.K · CHECKED J.S · APPROVED	DATE 1-20-59 · SCALE 1"=1'-0"	M01M6



PLAN



ELEVATION



SECTION B-B

NOTES

STEEL TO BE U.S. STEEL CORP. "TRI-TEN." MAXIMUM ALLOWABLE TENSILE STRESS TO BE 24,000 P.S.I. FOR STATIC LOADING WITH AN ALLOWABLE INCREASE OF ONE-THIRD FOR COMBINED STATIC AND DYNAMIC LOADING. COMPRESSION STRESSES TO CORRESPOND.

THE FRAME AND ITS COMPONENT MEMBERS SHALL BE CAPABLE OF RESISTING THE FOLLOWING DYNAMIC FORCES.

THRUST FORWARD 8 G.
" AFT 2 G.
" VERTICALLY 2 G.
" LATERALLY 1½ G.

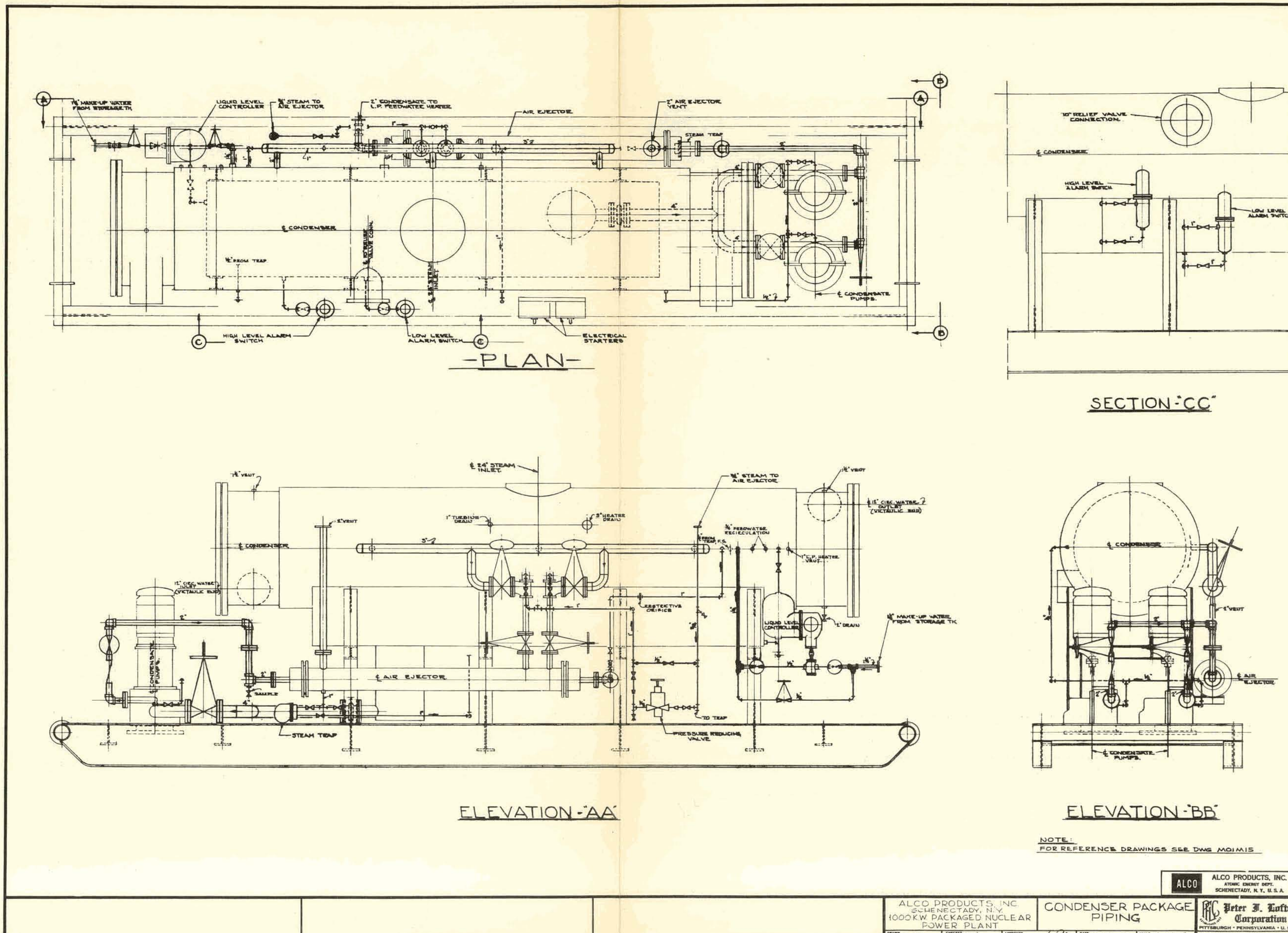
FABRICATION - THE FRAME SHALL BE FULLY WELDED AS INDICATED, AND IN COMPLIANCE WITH SPECIFICATIONS OF THE AMERICAN WELDING SOCIETY. WELDS SHALL BE CONTINUOUS UNLESS NOTED.

ESTIMATED WEIGHT OF SKID - 4,820#

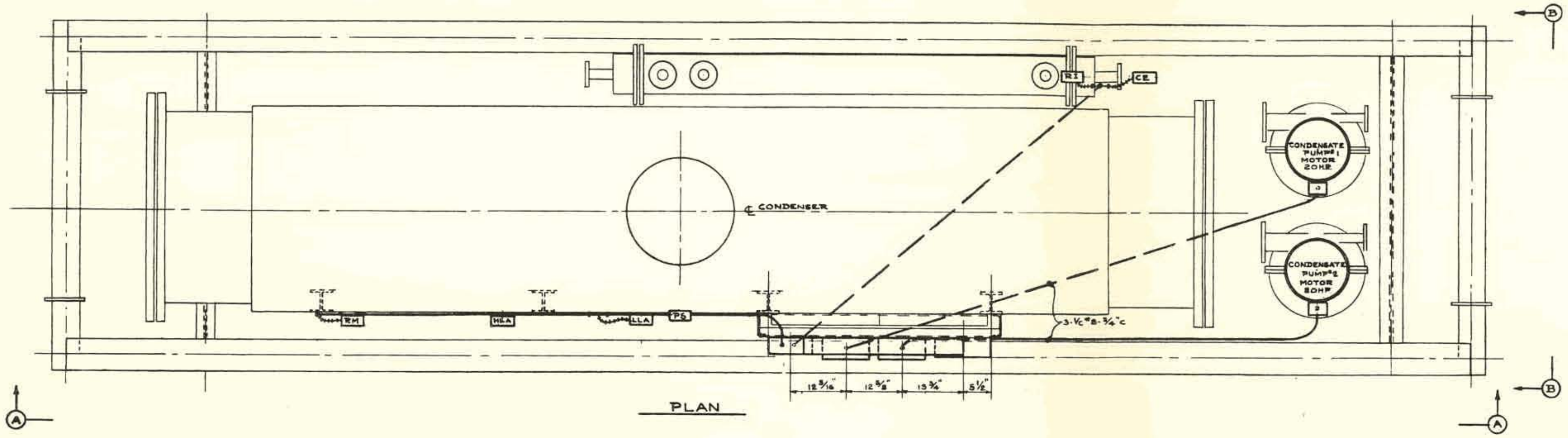
FOR REFERENCE DRAWINGS SEE DWG. MO1M15

ALCO | ALCO PRODUCTS, INC. ATOMIC ENERGY DEPT. SCHENECTADY, N. Y., U. S. A.

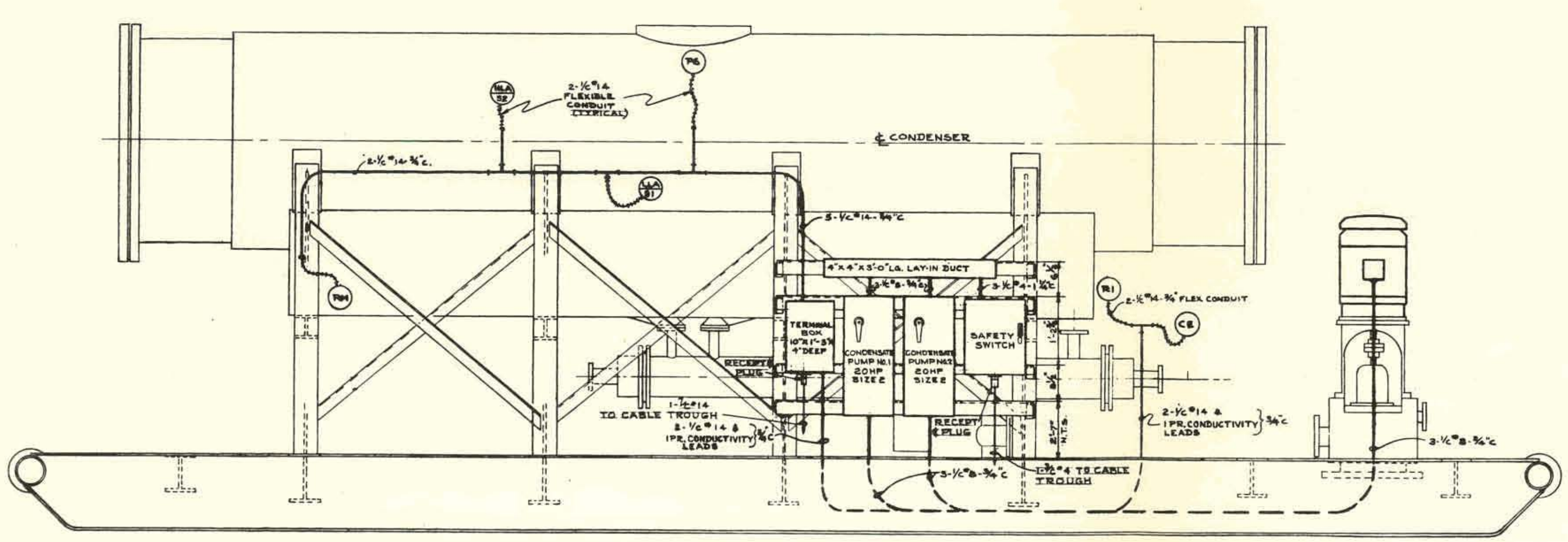
ALCO PRODUCTS, INC. SCHENECTADY, N.Y. 1000 K.W. PACKAGED NUCLEAR POWER PLANT	CONDENSER PACKAGE STRUCTURAL SKID ARRANGEMENT PLAN & SECTIONS	Peter F. Loftus Corporation PITTSBURGH • PENNSYLVANIA • U. S. A.
DRAWN KELEMEN · CHECKED J.A.K. · APPROVED CAE SEM	DATE 1-14-59 · SCALE 1" = 1'-0	MO1S2



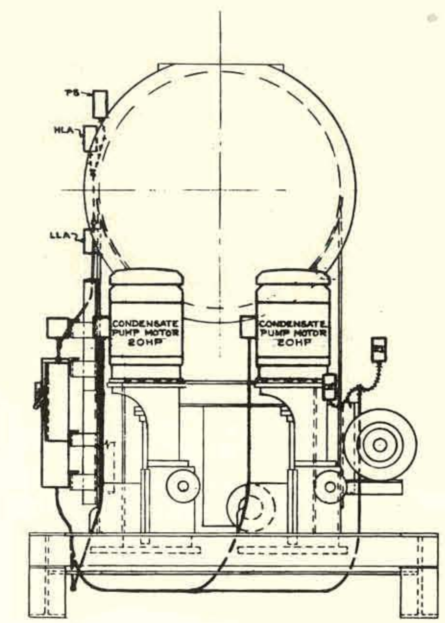
-PLAN-
SECTION "CC"
ELEVATION "AA"
ELEVATION "BB"
NOTE:
FOR REFERENCE DRAWINGS SEE DWG MOIMIS
ALCO
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.
ALCO PRODUCTS, INC.
SCHENECTADY, N.Y.
1000 KW PACKAGED NUCLEAR
POWER PLANT
CONDENSER PACKAGE
PIPING
Peter F. Loftus
Corporation
PITTSBURGH • PENNSYLVANIA • U.S.A.
R.J.K.
11-26-58
1" = 1'-0"
MOIM7



PLAN



ELEVATION (A)



ELEVATION (B)

ALCO

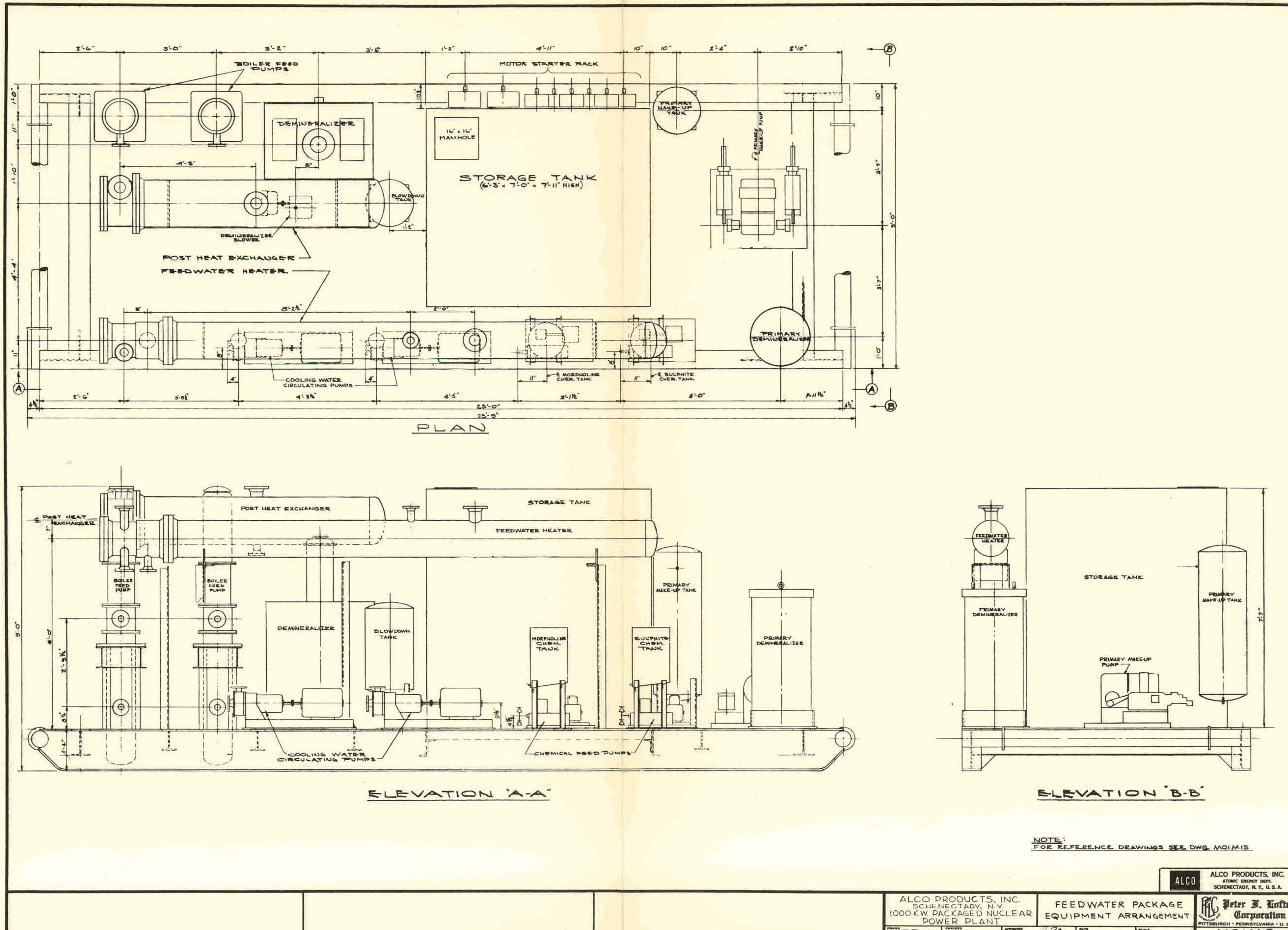
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.

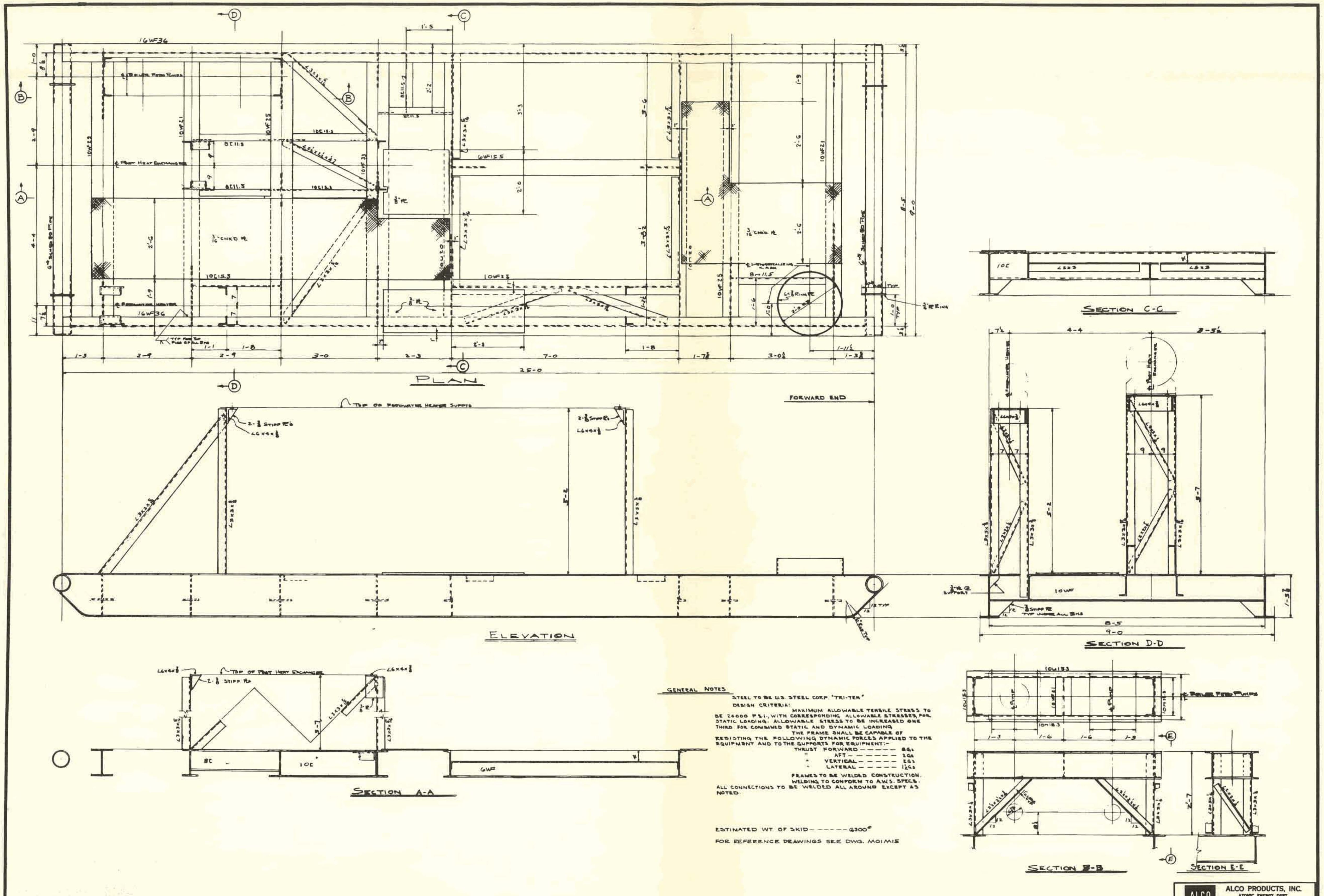
ALCO PRODUCTS INC.
SCHENECTADY, N.Y.
1000 KW PACKAGED NUCLEAR POWER PLANT

CONDENSER PACKAGE
ELECTRICAL
PLAN & ELEVATIONS

Peter F. Loftus Corporation
PITTSBURGH • PENNSYLVANIA • U.S.A.

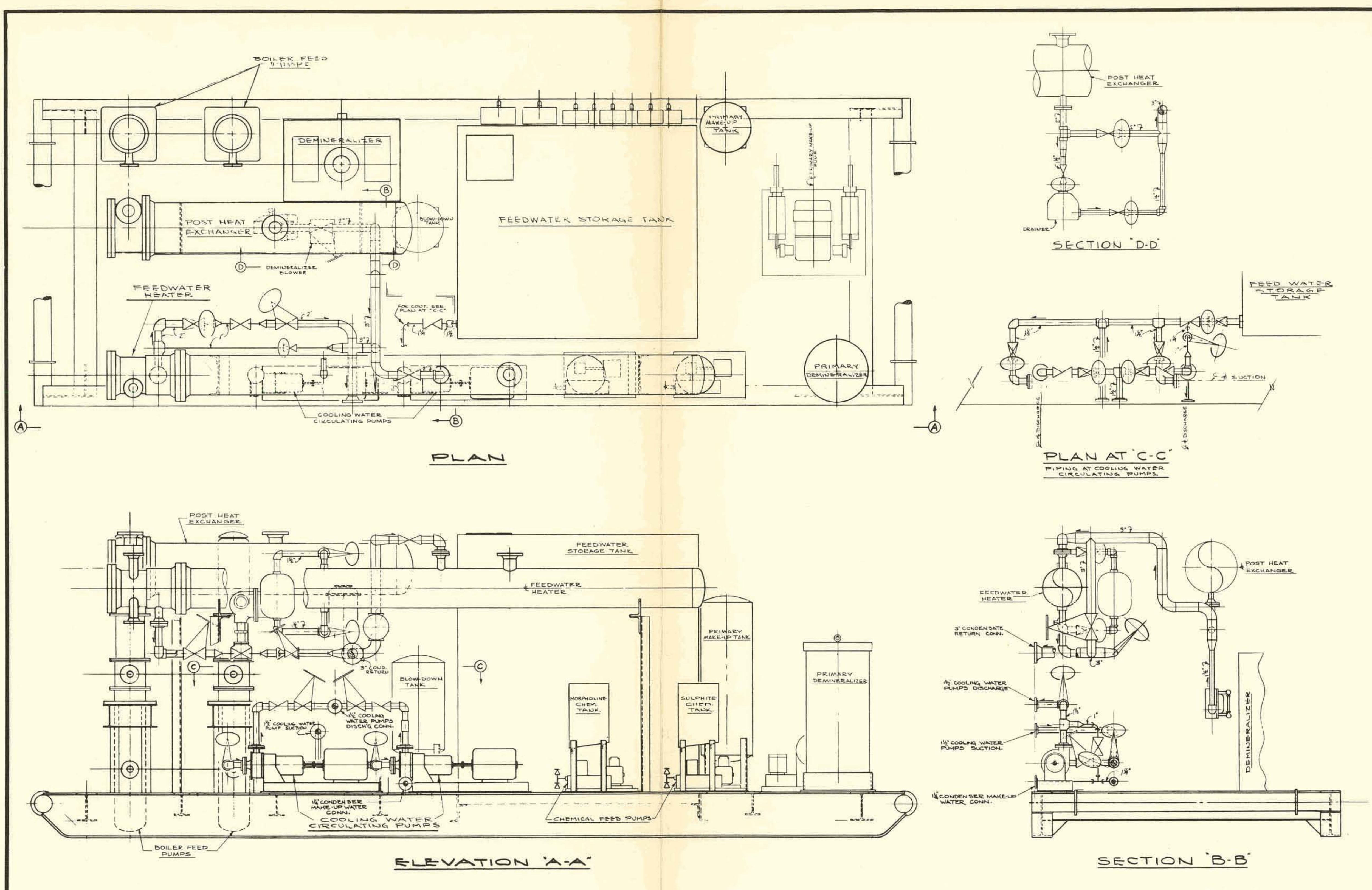
DRAWN	CHECKED	APPROVED	DATE	SCALE	
F.A.L.	HEITZER		1-5-55	1" = 1'-0"	M01E7


BOILER FEED PUMPS
MOTOR STARTER RACK
DEMINERALIZER
16" x 16" MANHOLE
STORAGE TANK (6'-3" x 7'-0" x 7'-11" HIGH)
PRIMARY MAKE-UP TANK
PRIMARY MAKE-UP PUMP
BLOWDOWN TANK
DEMINERALIZER BLOWER
POST HEAT EXCHANGER
FEEDWATER HEATER
PRIMARY DEMINERALIZER
COOLING WATER CIRCULATING PUMPS
℄ MORPHOLINE CHEM. TANK
℄ SULPHITE CHEM. TANK
25'-0"
25'-9"
PLAN
POST HEAT EXCHANGER
STORAGE TANK
FEEDWATER HEATER
BOILER FEED PUMP
DEMINERALIZER
BLOWDOWN TANK
MORPHOLINE CHEM. TANK
SULPHITE CHEM. TANK
PRIMARY MAKE-UP TANK
PRIMARY DEMINERALIZER
COOLING WATER CIRCULATING PUMPS
CHEMICAL FEED PUMPS
ELEVATION "A-A"
FEEDWATER HEATER
STORAGE TANK
PRIMARY DEMINERALIZER
PRIMARY MAKE-UP TANK
PRIMARY MAKE-UP PUMP
ELEVATION "B-B"
NOTE: FOR REFERENCE DRAWINGS SEE DWG. MO1M15
ALCO
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.
ALCO PRODUCTS, INC.
SCHENECTADY, N.Y.
1000 K.W. PACKAGED NUCLEAR POWER PLANT
FEEDWATER PACKAGE
EQUIPMENT ARRANGEMENT
Peter F. Loftus Corporation
PITTSBURGH - PENNSYLVANIA - U.S.A.
DRAWN R.R.K.
CHECKED J.S.
DATE 10-7-58
SCALE 1" = 1'-0"
MO1M8



ALCO ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.

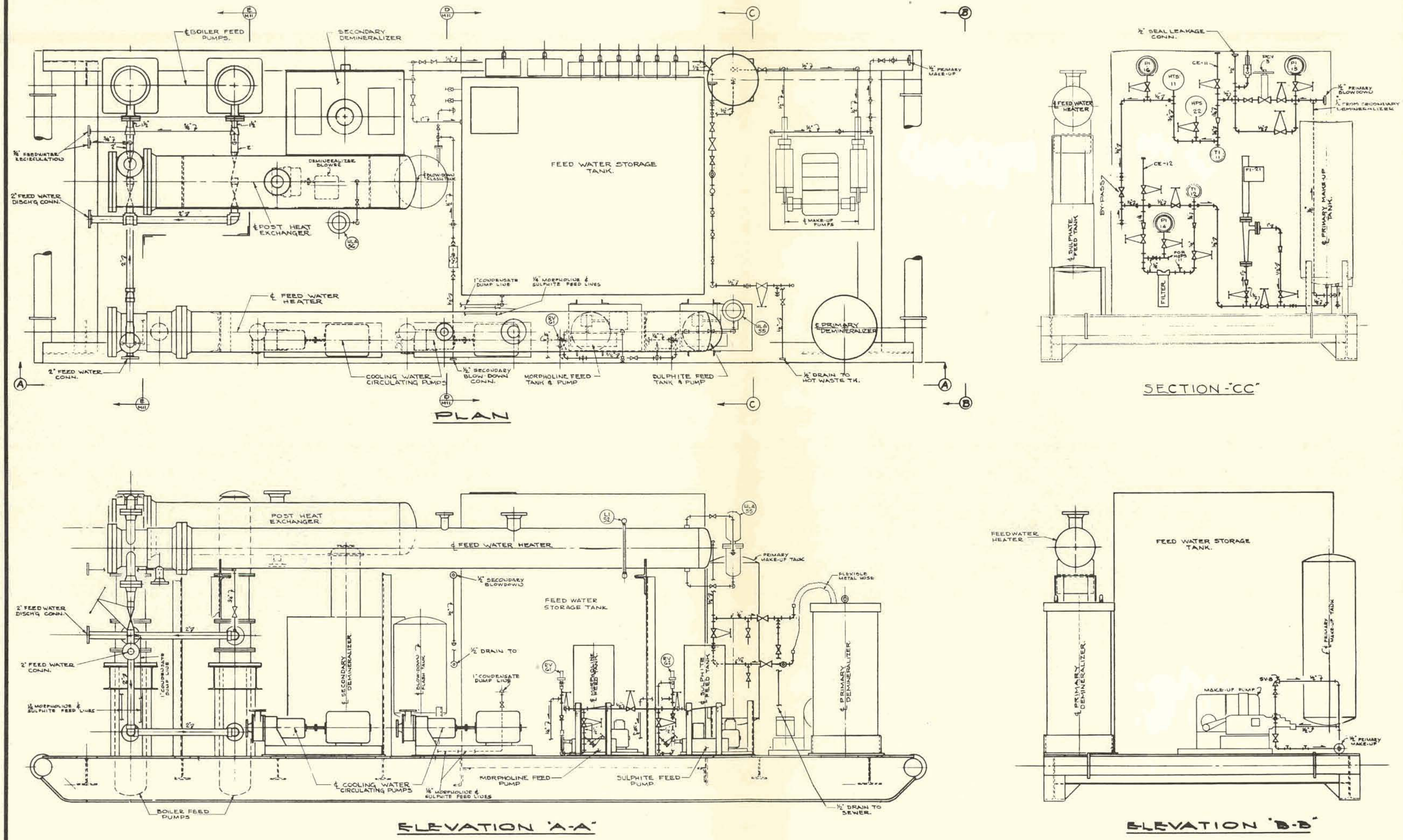
ALCO PRODUCTS, INC. SCHENECTADY, N.Y. 1000 K.W. PACKAGED NUCLEAR POWER PLANT	FEEDWATER PACKAGE STRUCTURAL SKID ARRANGEMENT	Peter F. Loftus Corporation PITTSBURGH • PENNSYLVANIA • U.S.A.
DRAWN WHC / CHECKED JAK / APPROVED CAE / DATE 1-20-59	SCALE 1" = 1'-0	M01S1



NOTE:
FOR REFERENCE DRAWINGS SEE DWG. MO1M15.

ALCO | ALCO PRODUCTS, INC. ATOMIC ENERGY DEPT. SCHENECTADY, N.Y. U.S.A.

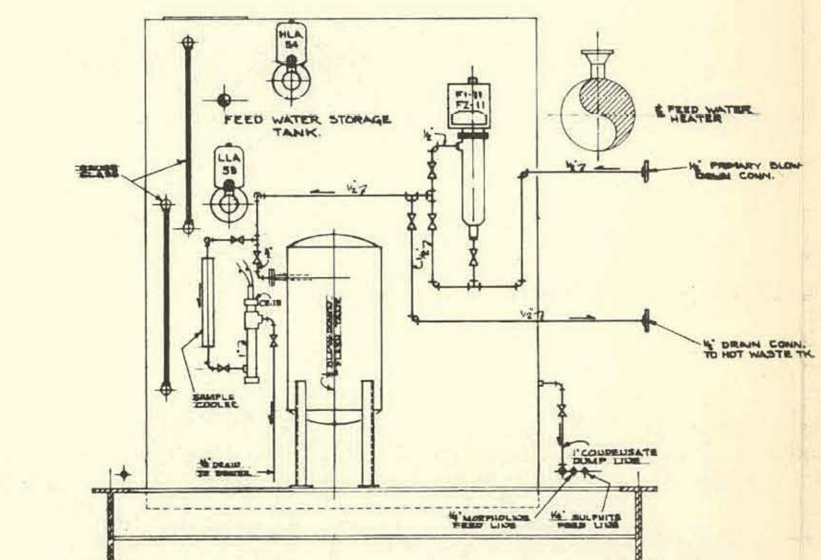
ALCO PRODUCTS, INC. SCHENECTADY, N.Y. 1000 K.W. PACKAGED NUCLEAR POWER PLANT		FEEDWATER PACKAGE PIPING SHEET #1		Peter F. Loftus Corporation PITTSBURGH • PENNSYLVANIA • U.S.A.	
DRAWN R.R.K.	CHECKED J.S.	APPROVED CAZ	DATE 1-20-59	SCALE 1"=1'-0"	MO1M9



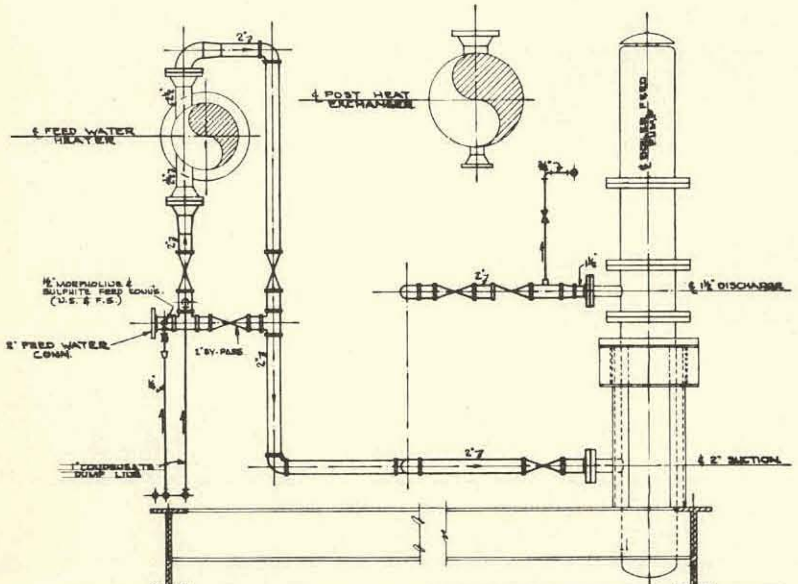
NOTE:
FOR REFERENCE DRAWINGS SEE DWG. MO1M15

ALCO
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.

ALCO PRODUCTS, INC. SCHENECTADY, N.Y. 1000 K.W. PACKAGED NUCLEAR POWER PLANT	FEEDWATER PACKAGE PIPING SHEET #2	Peter F. Loftus Corporation PITTSBURGH • PENNSYLVANIA • U.S.A.
R.J. KOFMEHL · C.S. · CAE · GEM · 10-10-58	1"=1'-0"	MO1M10



SECTION - DD

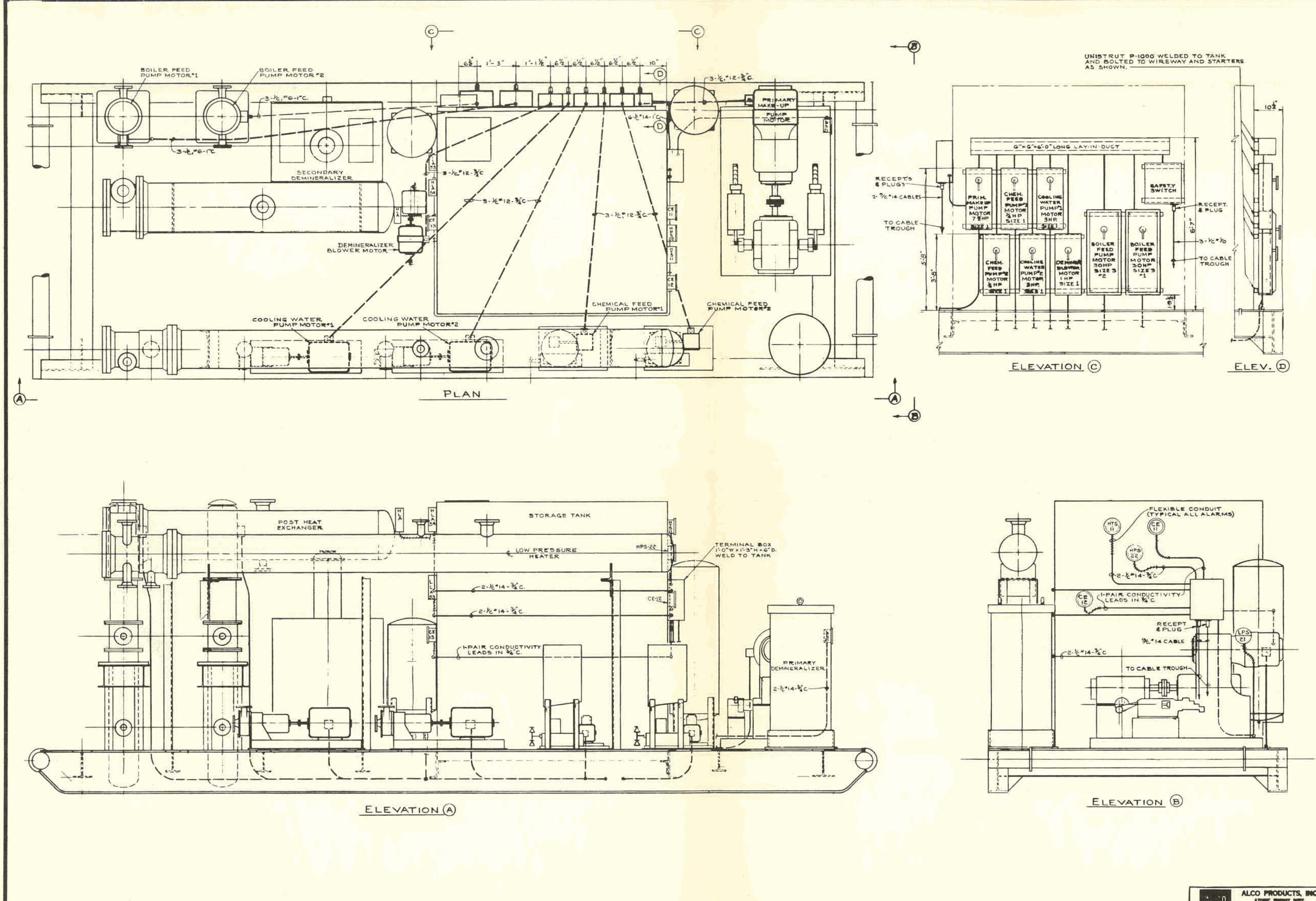


SECTION - EE

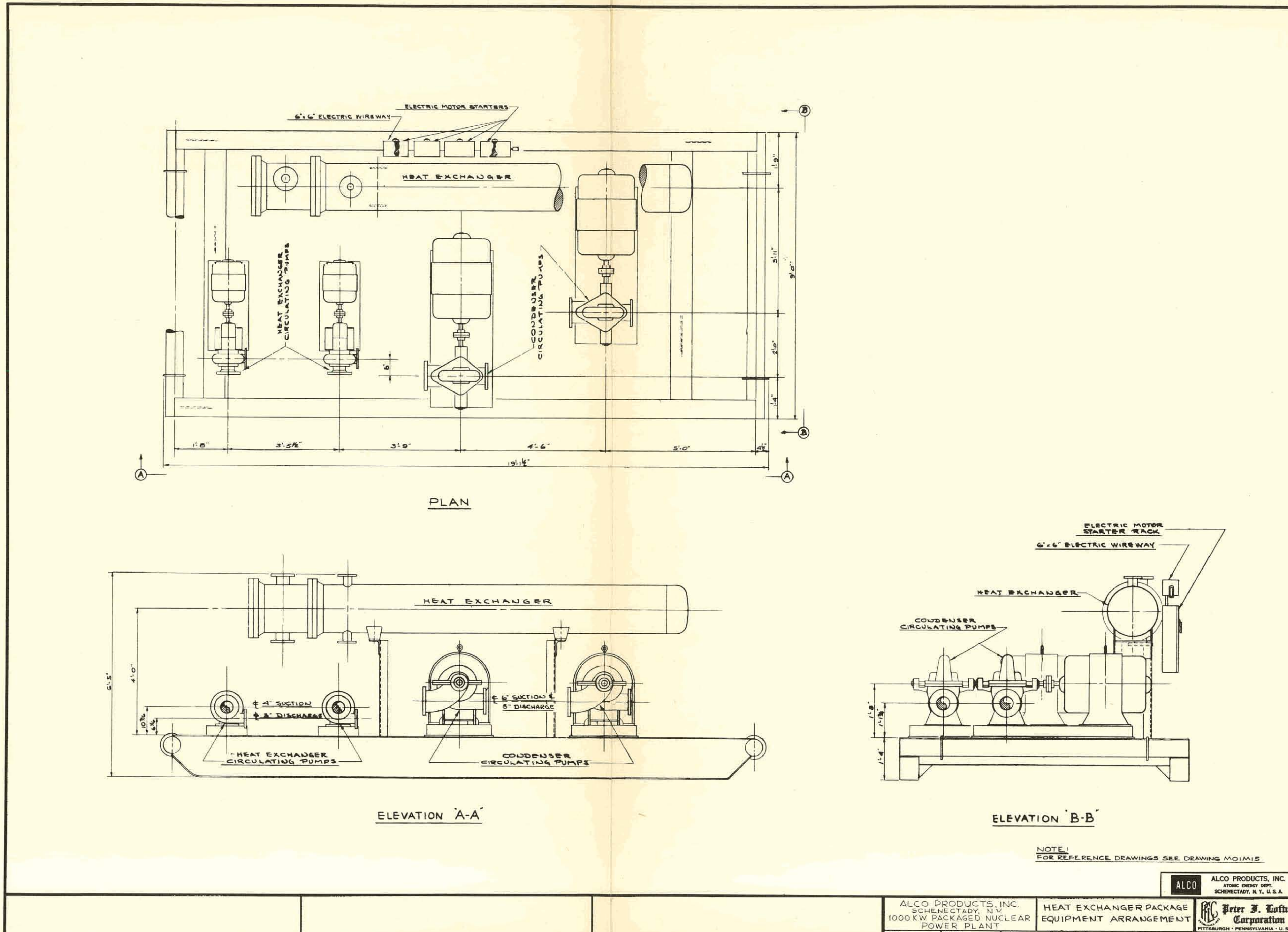
NOTE:
FOR REFERENCE DRAWINGS SEE DWG. MOIMI5

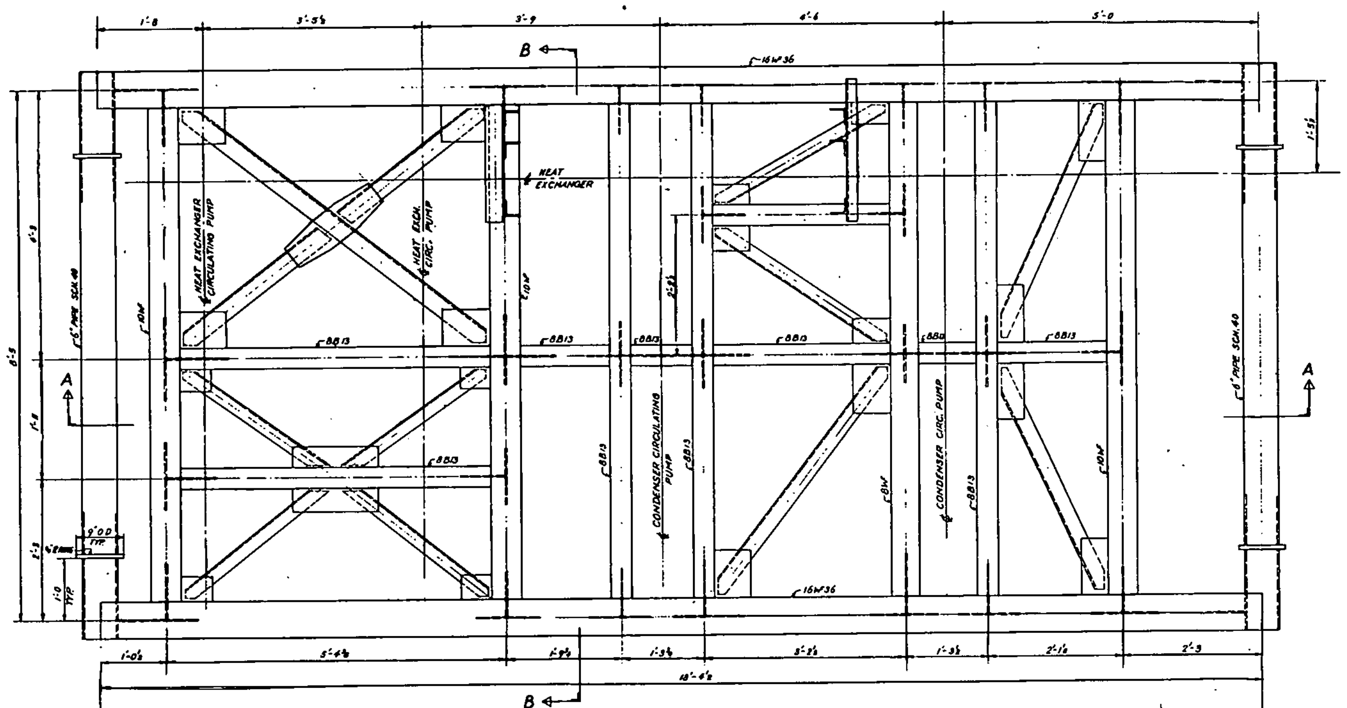
ALCO PRODUCTS, INC. SCHENECTADY, N.Y. 1000 KW PACKAGED NUCLEAR POWER PLANT	FEEDWATER PACKAGE PIPING SHEET No.-3	Peter F. Loftus Corporation PITTSBURGH · PENNSYLVANIA · U.S.A.
DRAWN D.C.M. CHECKED J.S.	APPROVED	DATE 10-13-58 SCALE 1" = 1'-0"
		MOIMI1

ALCO PRODUCTS, INC. ATOMIC ENERGY DEPT. SCHENECTADY, N.Y., U.S.A.

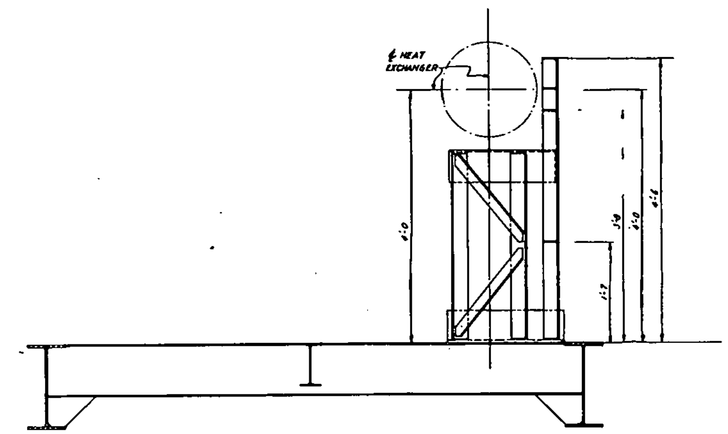


ALCO PRODUCTS INC. SCHENECTADY, N.Y. 1000 KW PACKAGED NUCLEAR POWER PLANT	FEED WATER PACKAGE ELECTRICAL PLAN & ELEVATIONS	Peter F. Loftus Corporation PITTSBURGH · PENNSYLVANIA · U.S.A.
HAWN · HEITZER · [signature]	1-5-59 · 1" = 1'-0"	M01E6

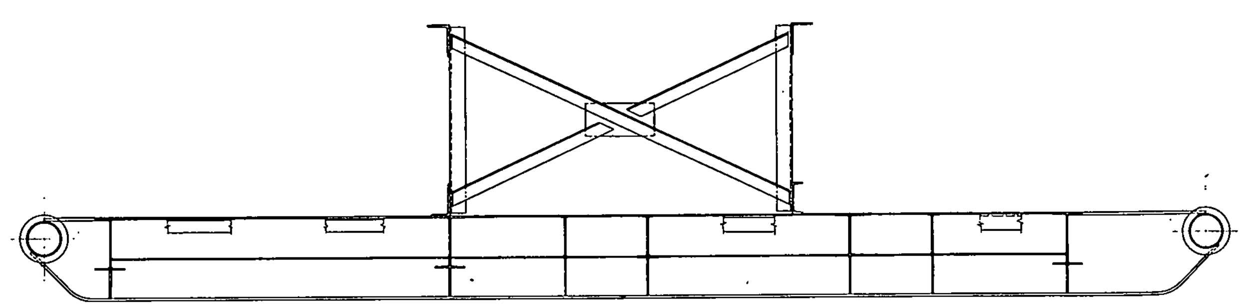

ELECTRIC MOTOR STARTERS
6"x6" ELECTRIC WIREWAY
HEAT EXCHANGER
HEAT EXCHANGER CIRCULATING PUMPS
CONDENSER CIRCULATING PUMPS
1'-8"
3'-5½"
3'-9"
4'-6"
5'-0"
19'-1½"
1'-9"
3'-11"
9'-0"
2'-0"
1'-4"
6"
PLAN
HEAT EXCHANGER
℄ 4" SUCTION
℄ 3" DISCHARGE
℄ 6" SUCTION ℄
5" DISCHARGE
HEAT EXCHANGER CIRCULATING PUMPS
CONDENSER CIRCULATING PUMPS
6'-5"
4'-0"
ELEVATION "A-A"
ELECTRIC MOTOR STARTER RACK
6"x6" ELECTRIC WIREWAY
HEAT EXCHANGER
CONDENSER CIRCULATING PUMPS
1'-8"
1'-4"
ELEVATION "B-B"
NOTE:
FOR REFERENCE DRAWINGS SEE DRAWING MO1M15
ALCO
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.
ALCO PRODUCTS, INC.
SCHENECTADY, N.Y.
1000 KW PACKAGED NUCLEAR
POWER PLANT
HEAT EXCHANGER PACKAGE
EQUIPMENT ARRANGEMENT
Peter F. Loftus Corporation
PITTSBURGH • PENNSYLVANIA • U.S.A.
R.R.K.
J.S.
1-20-59
1" = 1'-0"
MO1M12



PLAN



SECTION B-B



SECTION A-A

NOTES:

STEEL TO BE U.S. STEEL CORP. "TRI TEN."

DESIGN CRITERIA:

MAXIMUM ALLOWABLE TENSILE STRESS TO BE 24,000 P.S.I., WITH CORRESPONDING ALLOWABLE COMPRESSIVE STRESSES, FOR STATIC LOADING. ALLOWABLE STRESSES TO BE INCREASED ONE-THIRD FOR COMBINED STATIC AND DYNAMIC LOADING.

THE FRAME SHALL BE CAPABLE OF RESISTING THE FOLLOWING DYNAMIC FORCES APPLIED TO FRAME AND EQUIPMENT SUPPORTED ON FRAME:

THRUST	FORWARD	- 8 G's
"	AFT	- 2 G's
"	VERTICAL	- 2 G's
"	LATERAL	- 1.5G's

FRAME TO BE WELDED CONSTRUCTION.

WELDING TO CONFORM TO A.W.S. SPECIFICATIONS - ALL CONNECTIONS TO BE WELDED ALL AROUND.

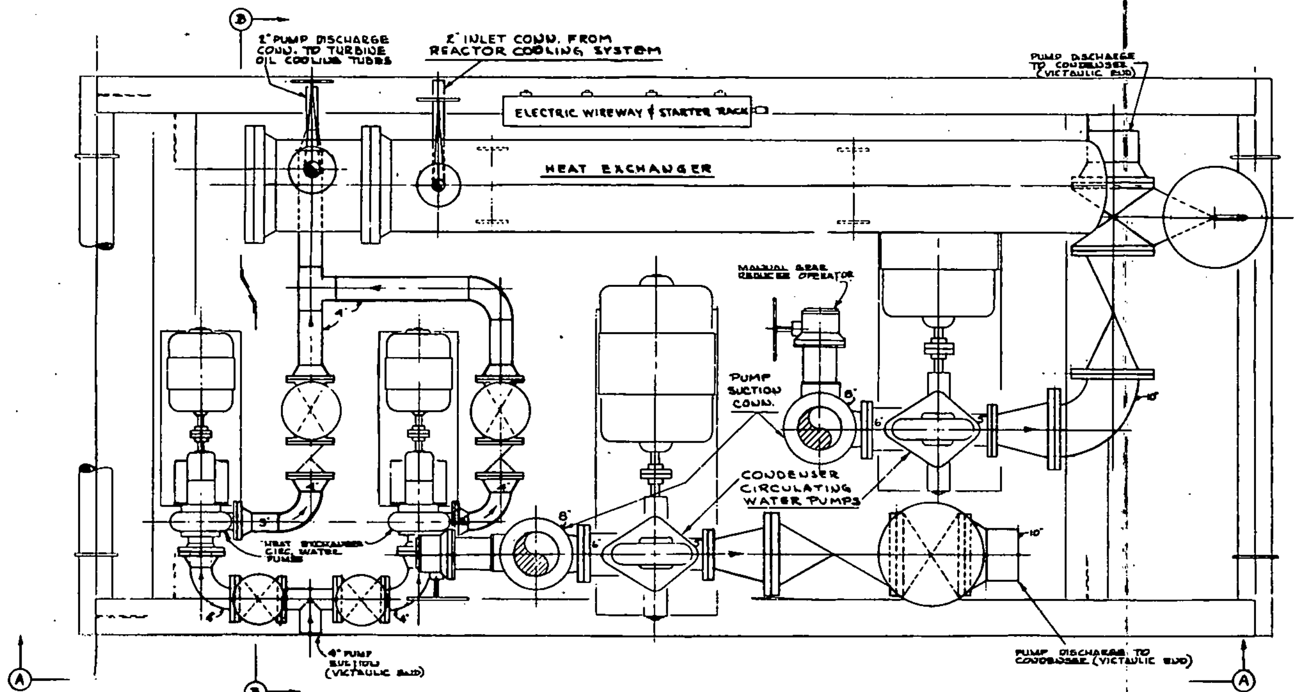
ESTIMATED WEIGHT OF SKID - 3,760#

FOR REFERENCE DRAWINGS SEE DWG. MOIM15

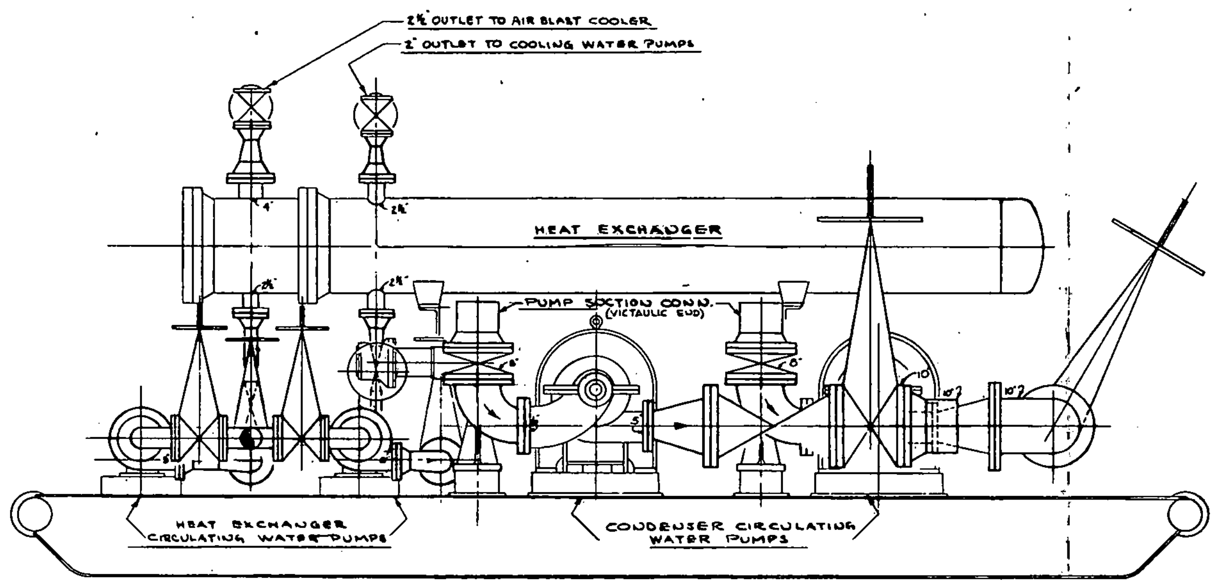
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.

ALCO PRODUCTS, INC. SCHENECTADY, N.Y. 1000 K.W. PACKAGED NUCLEAR POWER PLANT		HEAT EXCHANGER PACKAGE STRUCTURAL SKID ARRANGEMENT		Peter F. Loftus Corporation PITTSBURGH • PENNSYLVANIA • U.S.A.
DRAWN A. NAGY	CHECKED I.A.K.	APPROVED CAE SEM	DATE 1-14-59. SCALE 1"-1'-0	MO1S4

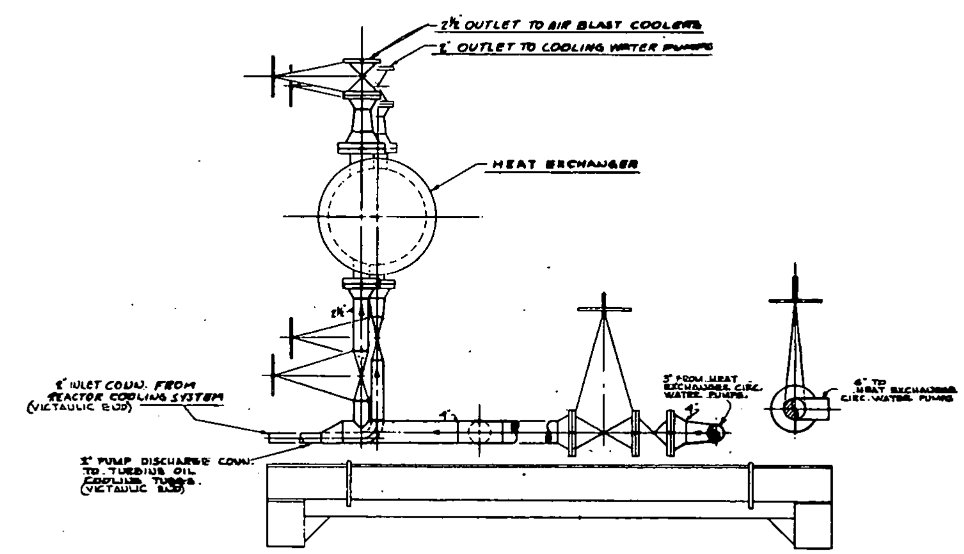
191



PLAN



ELEVATION "A-A"

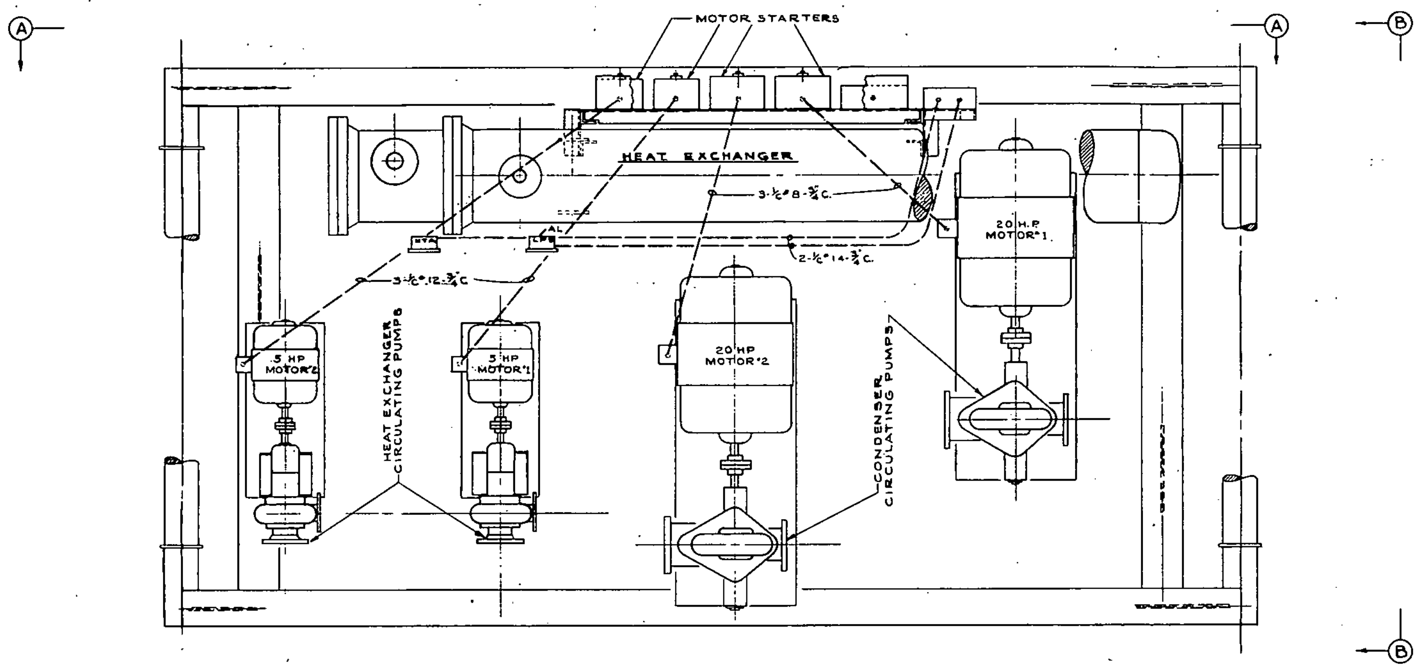


SECTION "B-B"

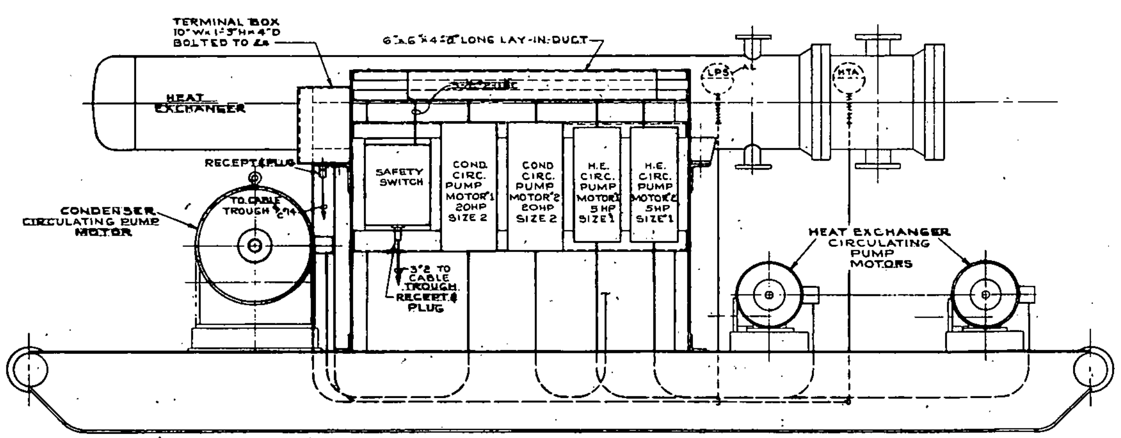
NOTE:
FOR REFERENCE DRAWINGS SEE DWG. MO1M15

ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y. U.S.A.

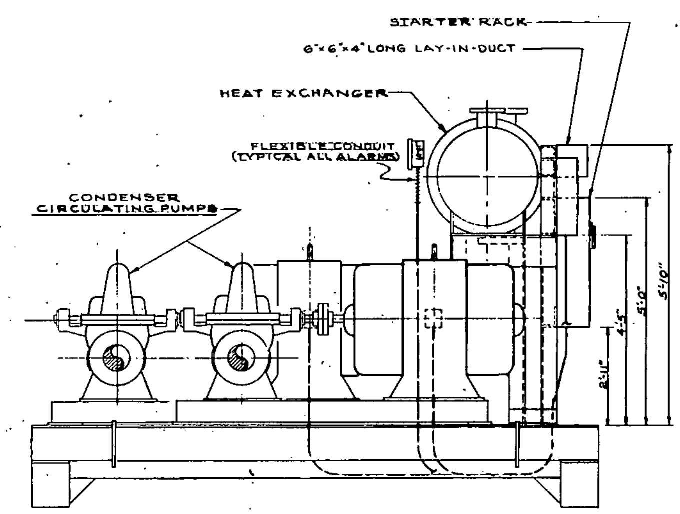
ALCO PRODUCTS, INC. SCHENECTADY, N.Y. 1000 K.W. PACKAGED NUCLEAR POWER PLANT	HEAT EXCHANGER PACKAGE PIPING	Peter F. Loftus Corporation PITTSBURGH · PENNSYLVANIA · U.S.A.
DRAWN F.R.K. CHECKED R.J.K.	DATE 1-20-59 SCALE 1"=1'-0"	MO1M13



PLAN



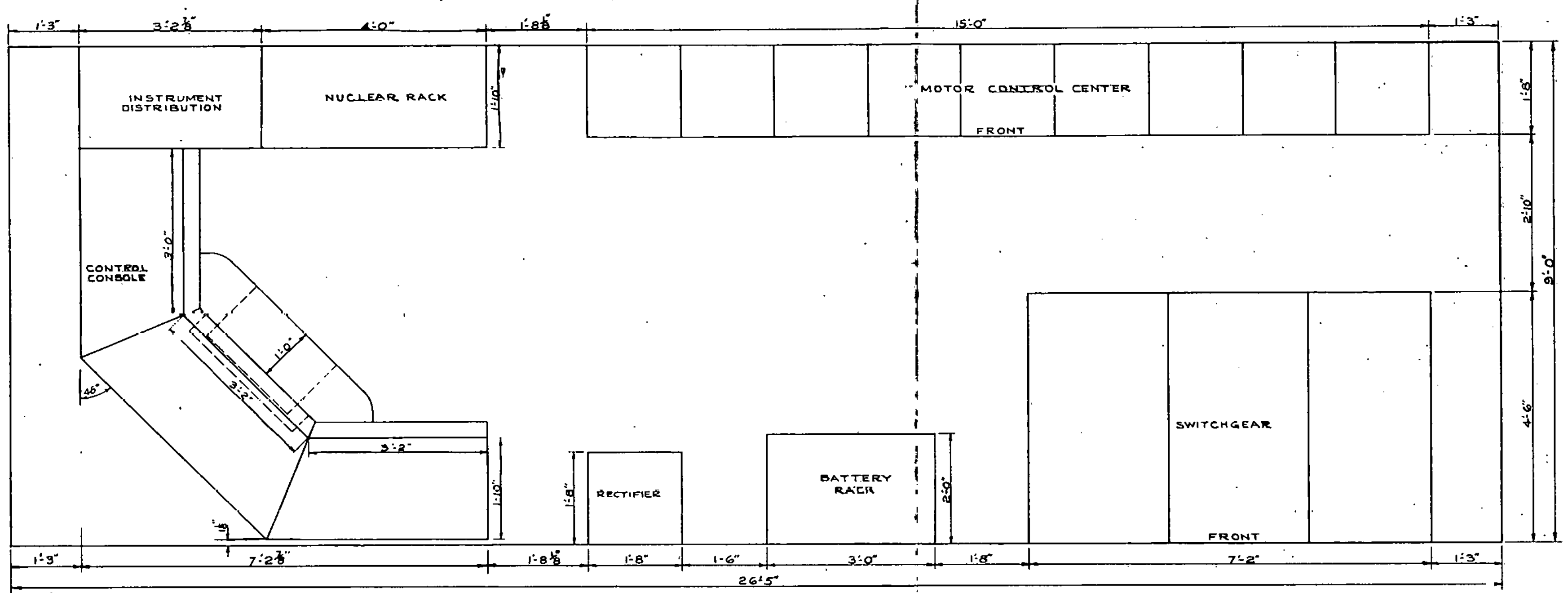
ELEVATION (A)



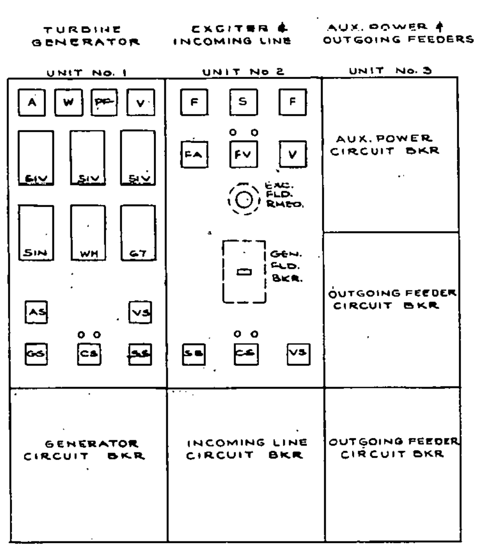
ELEVATION (B)

ALCO PRODUCTS INC. SCHENECTADY N.Y. 1000 KW PACKAGED NUCLEAR POWER PLANT	HEAT EXCHANGER PACKAGE ELECTRICAL PLAN & ELEVATIONS	Peter F. Loftus Corporation, PITTSBURGH - PENNSYLVANIA - U.S.A.	ALCO — ALCO PRODUCTS, INC. ATOMIC ENERGY DEPT. SCHENECTADY, N.Y., U.S.A.
DRAWN HAWN; CHECKED HEITZER	DATE 1-3-59; SCALE 1"=1'-0"	MO1E8	

EST. WEIGHT	
MOTOR CONTROL CENTER	5000 LBS
SWITCHGEAR	6000
CONTROL CONSOLE	2700
INSTRUMENT DISTRIBUTION	750
NUCLEAR RACK	1530
BATTERY	800
RECTIFIER	1,000
CONDUIT & WIRE	500
SKID	2,000
TOTAL	20,300 LBS



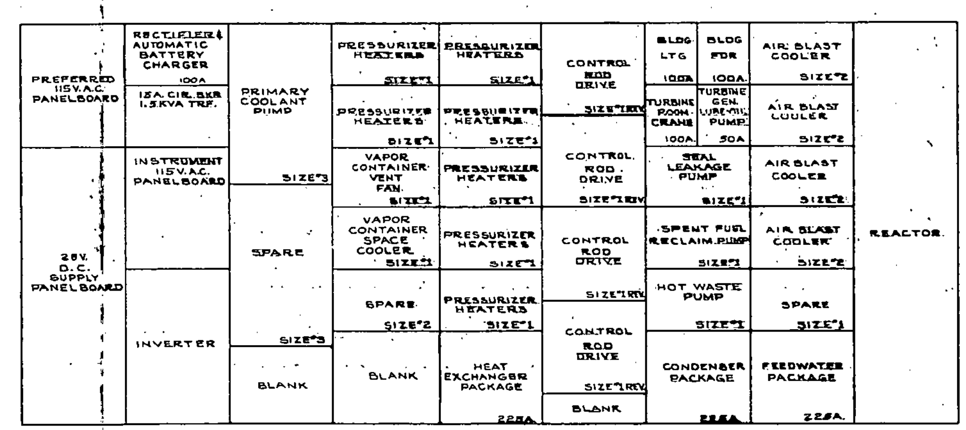
PLAN



600 VOLT METAL-ENCLOSED SWITCHGEAR UNIT
FRONT VIEW

LEGEND

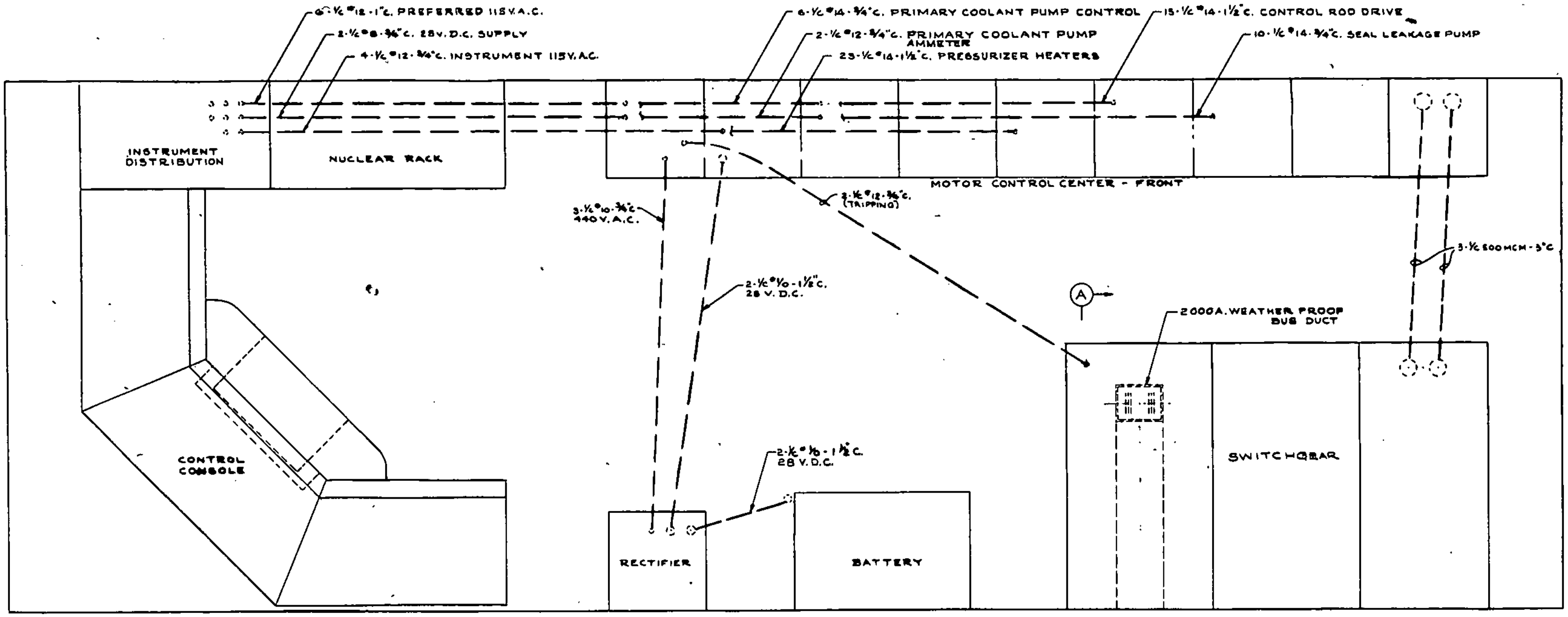
A	AMMETER
V	VOLTMETER
PF	POWER FACTOR METER
W	WATTMETER
WH	WATTHOUR METER
F	FREQUENCY METER
FA	FIELD AMMETER
FV	FIELD VOLTMETER
S	SYNCHROSCOPE
51V	OVERCURRENT RELAY
51N	OVERCURRENT GRD RELAY
67	DIRECTIONAL OVERCURRENT RELAY
AS	AMMETER SWITCH
VS	VOLTMETER SWITCH
GS	GOVERNOR SWITCH
SS	SYNCHRONIZING SWITCH
CS	BREAKER CONTROL SWITCH



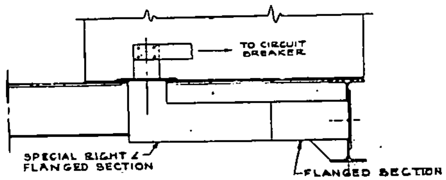
MOTOR CONTROL CENTER
FRONT VIEW

ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.

ALCO PRODUCTS INC. SCHENECTADY, N.Y. 1000KW PACKAGE NUCLEAR POWER PLANT		SWITCHGEAR PACKAGE ARRANGEMENT		Peter F. Loftus Corporation PITTSBURGH · PENNSYLVANIA · U.S.A.
DRAWN HAWN	CHECKED HEITZER	APPROVED [signature]	DATE 1-5-55	SCALE 1"=1'-0"
				MO1E3



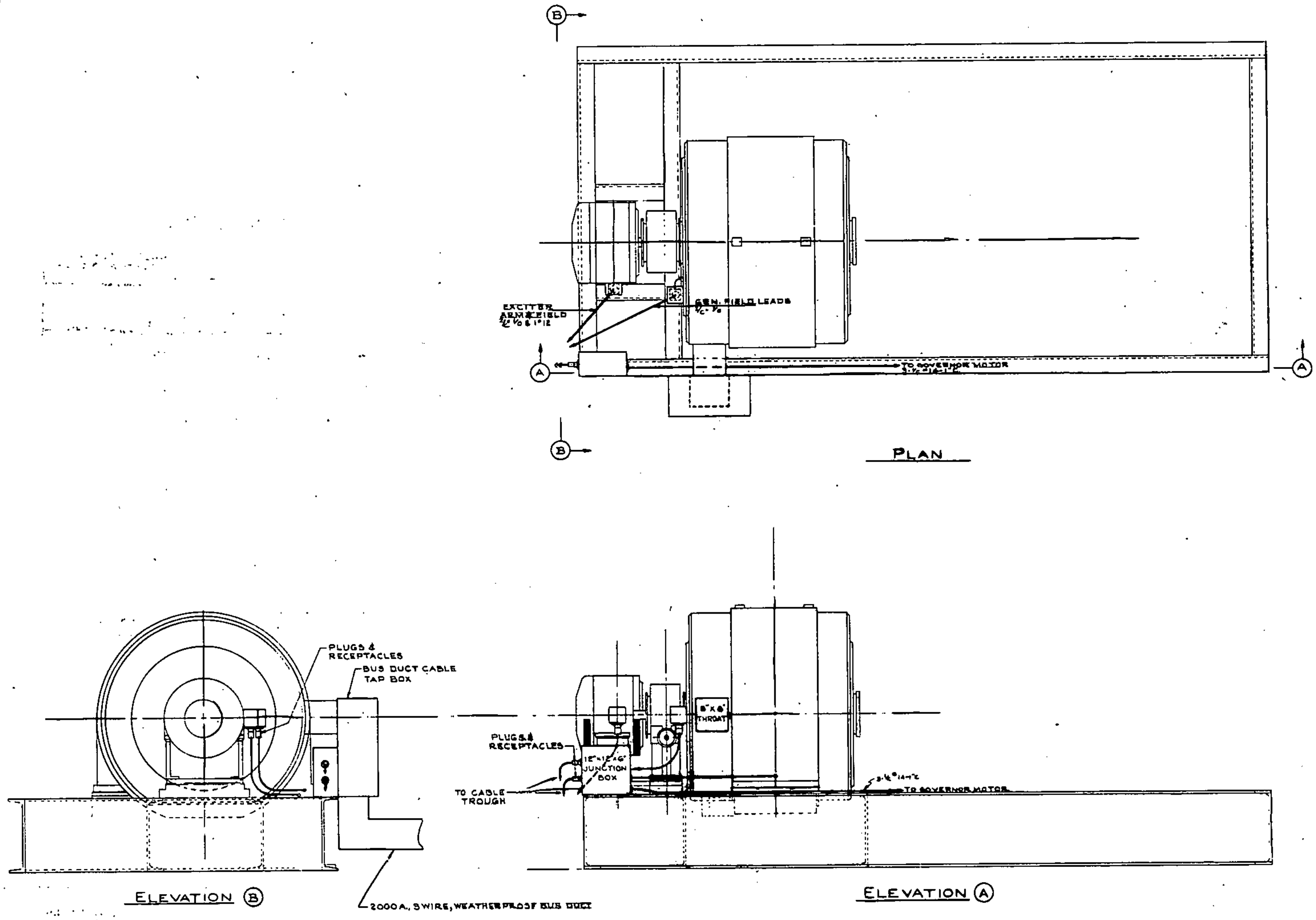
PLAN



SECTION (A)

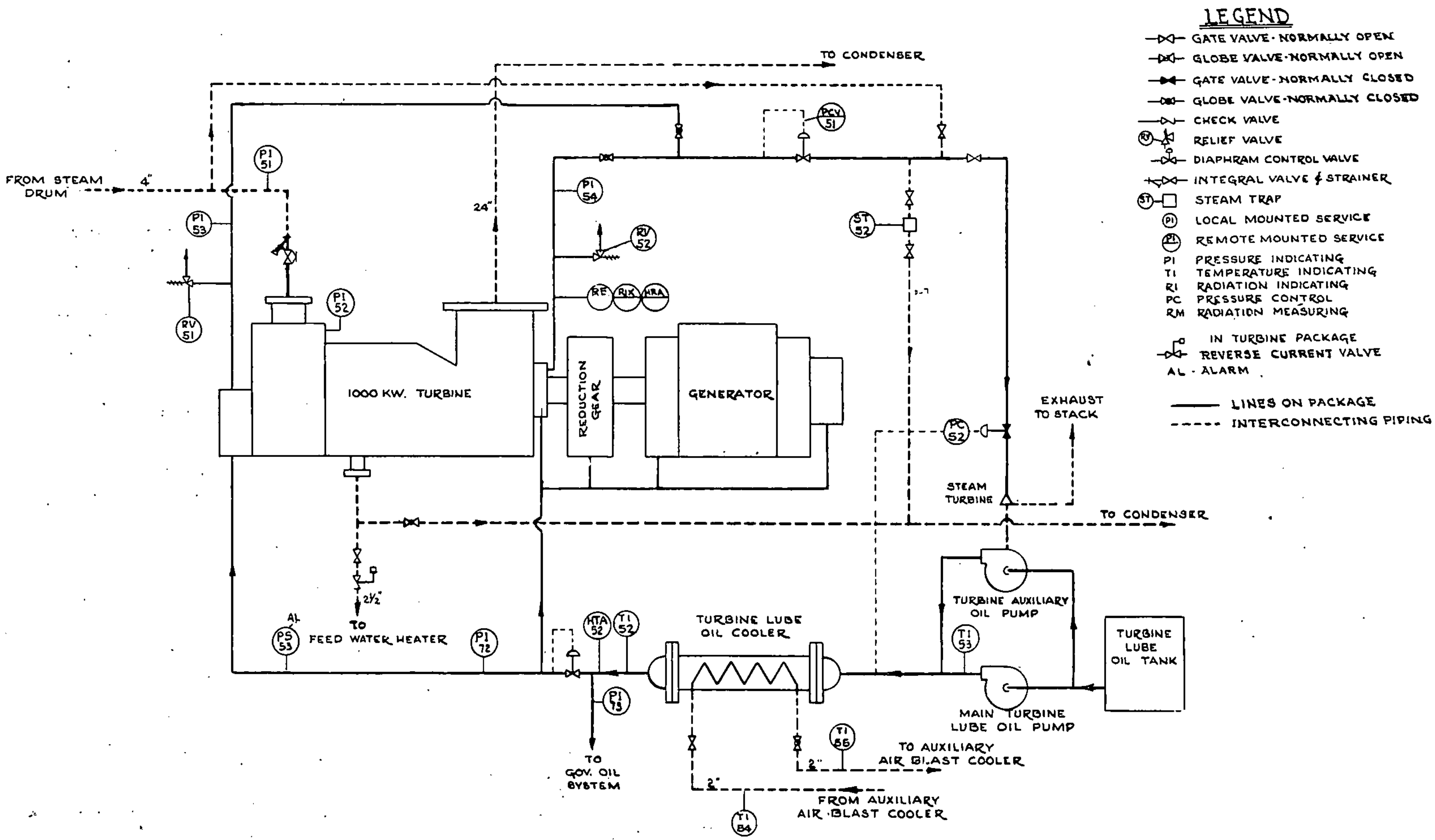
ALCO | ALCO PRODUCTS, INC. ATOMIC ENERGY DEPT. SCHENECTADY, N. Y. U. S. A.

ALCO PRODUCTS INC. SCHENECTADY, N.Y. 1000 KW PACKAGED NUCLEAR POWER PLANT	SWITCHGEAR PACKAGE PLAN & ELEVATIONS	Peter F. Loftus Corporation PITTSBURGH - PENNSYLVANIA - U. S. A.
DRAWN HAWN / CHECKED HEITZER / APPROVED [signature]	DATE 1-5-59 / SCALE 1"=1'-0"	M01 E4



ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N. Y., U. S. A.

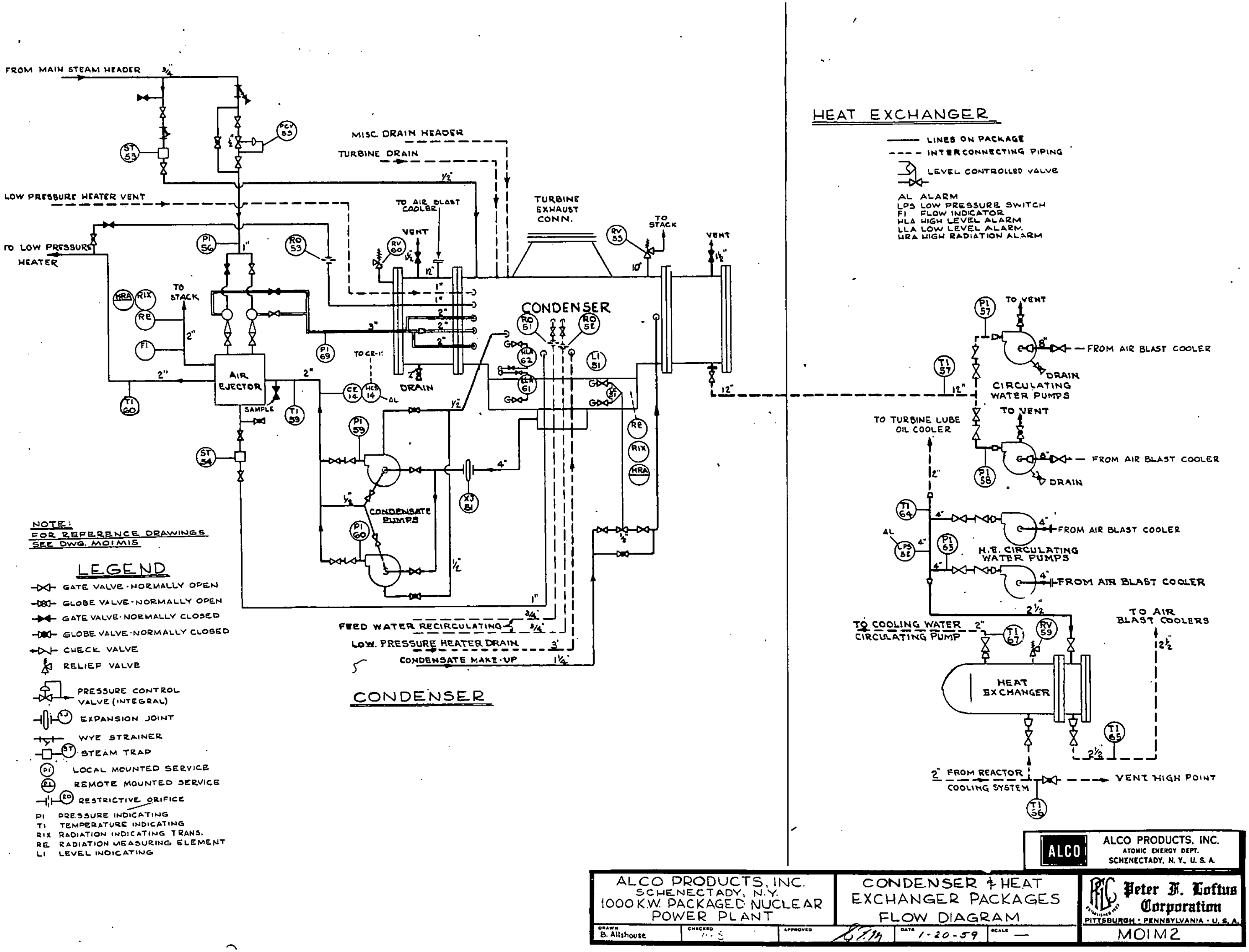
ALCO PRODUCTS INC. SCHENECTADY, N.Y. 1000 KW PACKAGED NUCLEAR POWER PLANT	TURBINE GENERATOR PACKAGE - ELECTRICAL PLANS & ELEVATIONS	Peter F. Loftus Corporation PITTSBURGH - PENNSYLVANIA - U. S. A.
DRAWN HAWN / CHECKED HEITZER	APPROVED [signature] / DATE 1-8-59 / SCALE 1" = 1'-0"	M01E5

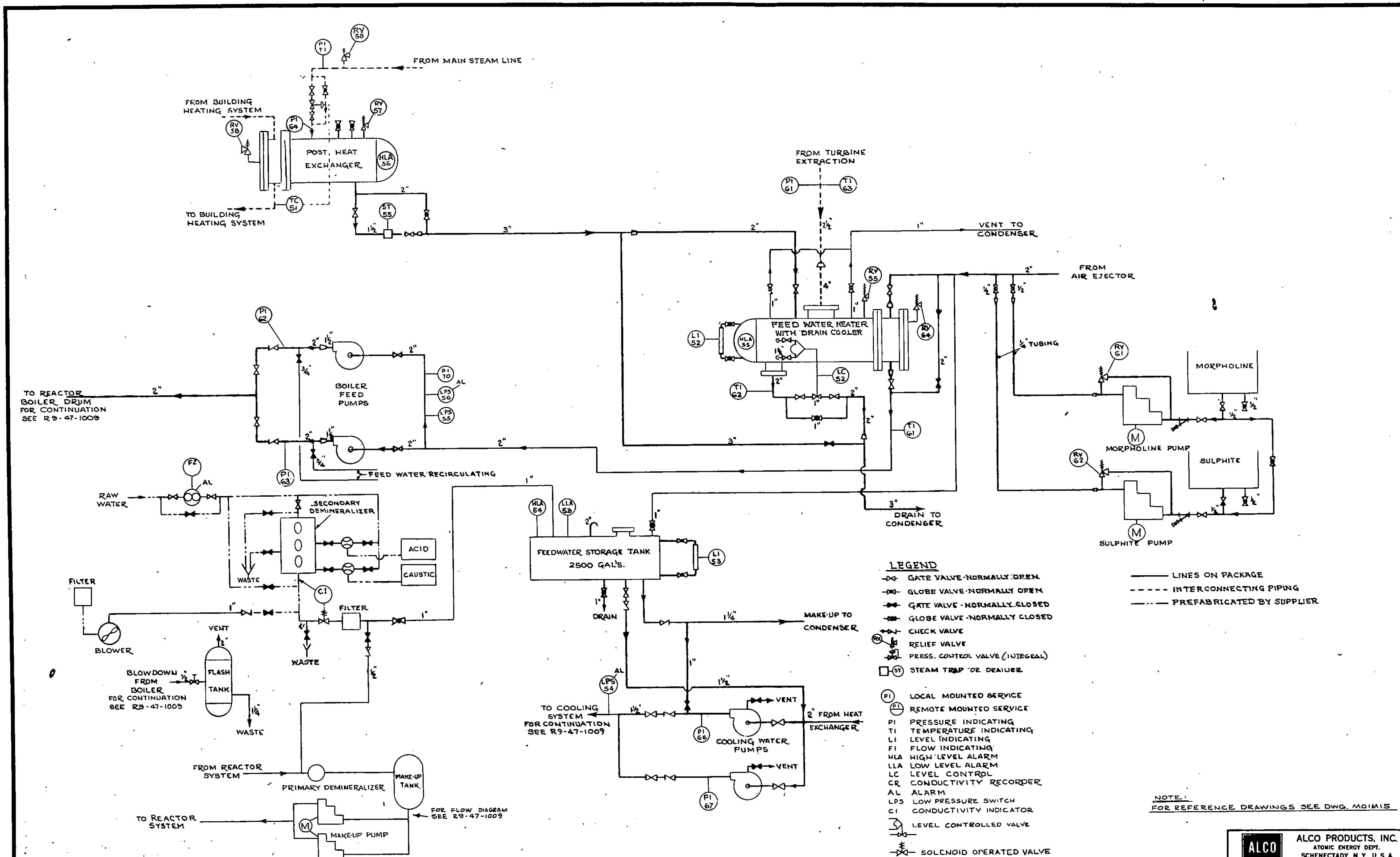


NOTE:
FOR REFERENCE DRAWINGS SEE DWG. M01M15

ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N. Y., U. S. A.

ALCO PRODUCTS, INC. SCHENECTADY, N.Y. 1000 K.W. PACKAGED NUCLEAR POWER PLANT	TURBINE GENERATOR PACKAGE FLOW DIAGRAM	Peter F. Loftus Corporation, PITTSBURGH · PENNSYLVANIA · U. S. A.
DRAWN B. Allshouse / CHECKED / APPROVED	DATE 7-20-59 / SCALE —	M01M4


FROM MAIN STEAM HEADER
LOW PRESSURE HEATER VENT
TO LOW PRESSURE HEATER
MISC. DRAIN HEADER
TURBINE DRAIN
TO AIR BLAST COOLER
VENT
TURBINE EXHAUST CONN.
TO STACK
CONDENSER
AIR EJECTOR
SAMPLE
DRAIN
TO CR-11
CONDENSATE PUMPS
FEED WATER RECIRCULATING
LOW PRESSURE HEATER DRAIN
CONDENSATE MAKE-UP
NOTE: FOR REFERENCE DRAWINGS SEE DWG. MO1M1S
LEGEND
GATE VALVE - NORMALLY OPEN
GLOBE VALVE - NORMALLY OPEN
GATE VALVE - NORMALLY CLOSED
GLOBE VALVE - NORMALLY CLOSED
CHECK VALVE
RELIEF VALVE
PRESSURE CONTROL VALVE (INTEGRAL)
EXPANSION JOINT
WYE STRAINER
STEAM TRAP
LOCAL MOUNTED SERVICE
REMOTE MOUNTED SERVICE
RESTRICTIVE ORIFICE
PI PRESSURE INDICATING
TI TEMPERATURE INDICATING
RIX RADIATION INDICATING TRANS.
RE RADIATION MEASURING ELEMENT
LI LEVEL INDICATING
CONDENSER
HEAT EXCHANGER
LINES ON PACKAGE
INTERCONNECTING PIPING
LEVEL CONTROLLED VALVE
AL ALARM
LPS LOW PRESSURE SWITCH
FI FLOW INDICATOR
HLA HIGH LEVEL ALARM
LLA LOW LEVEL ALARM
HRA HIGH RADIATION ALARM
TO VENT
FROM AIR BLAST COOLER
DRAIN
CIRCULATING WATER PUMPS
TO TURBINE LUBE OIL COOLER
H.E. CIRCULATING WATER PUMPS
TO COOLING WATER CIRCULATING PUMP
TO AIR BLAST COOLERS
HEAT EXCHANGER
FROM REACTOR COOLING SYSTEM
VENT HIGH POINT
ALCO PRODUCTS, INC. ATOMIC ENERGY DEPT. SCHENECTADY, N.Y. U.S.A.
ALCO PRODUCTS, INC. SCHENECTADY, N.Y.
1000 K.W. PACKAGED NUCLEAR POWER PLANT
CONDENSER & HEAT EXCHANGER PACKAGES FLOW DIAGRAM
Peter F. Loftus Corporation
PITTSBURGH · PENNSYLVANIA · U.S.A.
DRAWN B. Allshouse
DATE 1-20-59
MO1M2



ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N. Y., U. S. A.

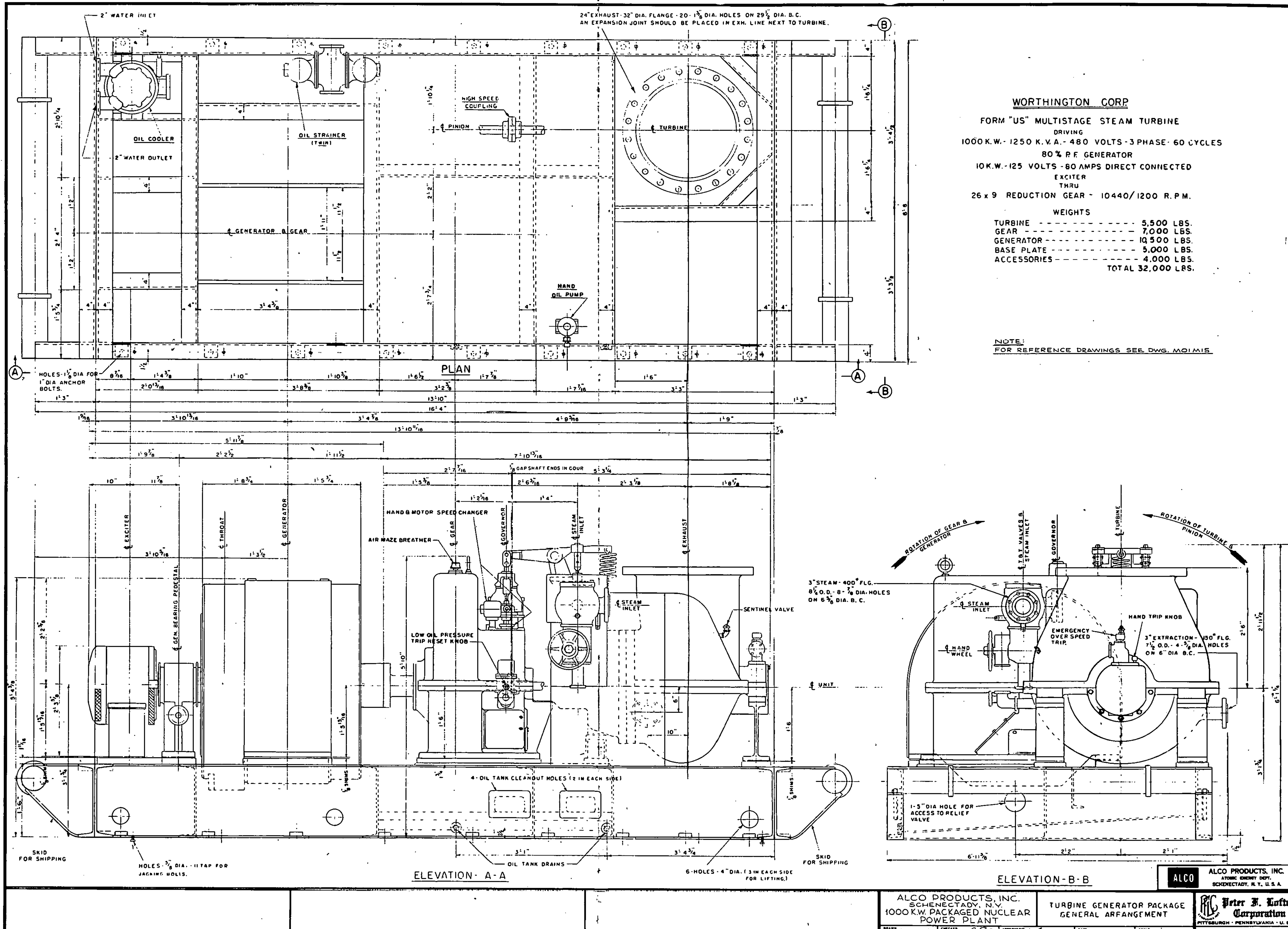
ALCO PRODUCTS, INC.
SCHENECTADY, N.Y.
1000 K.W. PACKAGED NUCLEAR POWER PLANT

FEEDWATER PACKAGE
FLOW DIAGRAM

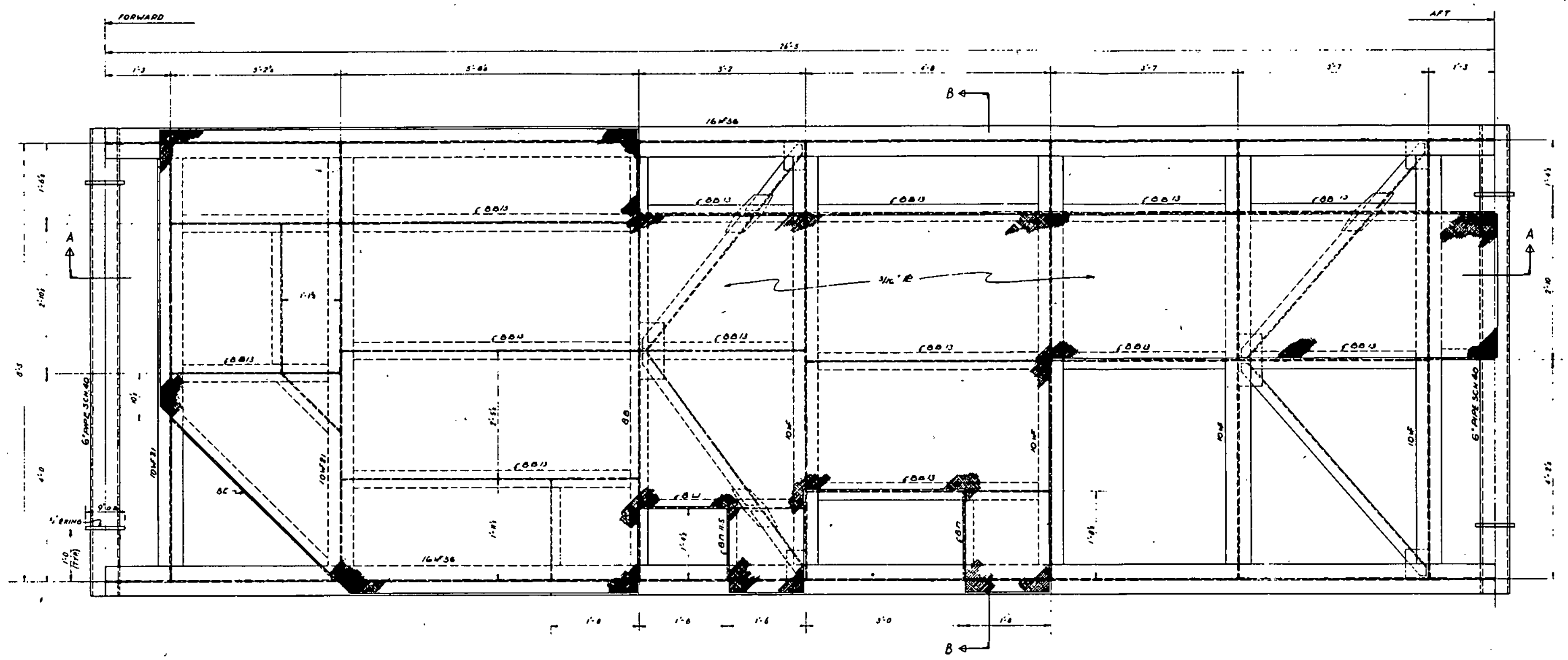
Peter F. Loftus Corporation
PITTSBURGH · PENNSYLVANIA · U. S. A.

DRAWN	CHECKED	APPROVED	DATE	SCALE
B. Allshouse			1-20-59	—

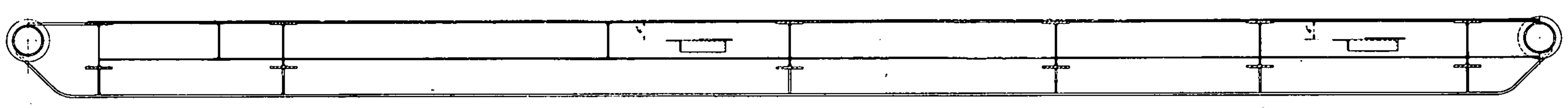
M01M3



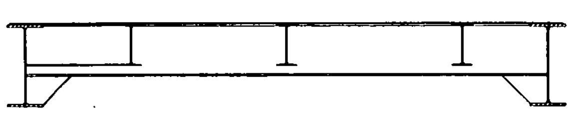
2" WATER INLET
24" EXHAUST - 32" DIA. FLANGE - 20 - 1 1/8 DIA. HOLES ON 29 1/2 DIA. B.C.
AN EXPANSION JOINT SHOULD BE PLACED IN EXH. LINE NEXT TO TURBINE.
OIL COOLER
2" WATER OUTLET
OIL STRAINER (TWIN)
HIGH SPEED COUPLING
℄ PINION
℄ TURBINE
℄ GENERATOR & GEAR
HAND OIL PUMP
HOLES - 1 1/8 DIA FOR 1" DIA ANCHOR BOLTS.
PLAN
WORTHINGTON CORP
FORM "US" MULTISTAGE STEAM TURBINE
DRIVING
1000 K.W. - 1250 K.V.A. - 480 VOLTS - 3 PHASE - 60 CYCLES
80 % P.F. GENERATOR
10 K.W. - 125 VOLTS - 80 AMPS DIRECT CONNECTED
EXCITER
THRU
26 x 9 REDUCTION GEAR - 10440/1200 R.P.M.
WEIGHTS
TURBINE - - - - - - 5,500 LBS.
GEAR - - - - - - 7,000 LBS.
GENERATOR - - - - - - 10,500 LBS.
BASE PLATE - - - - - - 5,000 LBS.
ACCESSORIES - - - - - - 4,000 LBS.
TOTAL 32,000 LBS.
NOTE:
FOR REFERENCE DRAWINGS SEE DWG. MO1M15
HAND & MOTOR SPEED CHANGER
AIR MAZE BREATHER
LOW OIL PRESSURE TRIP RESET KNOB
℄ EXCITER
℄ THROAT
℄ GENERATOR
℄ GEN. BEARING PEDESTAL
℄ GEAR
℄ GOVERNOR
℄ STEAM INLET
℄ EXHAUST
℄ STEAM INLET
SENTINEL VALVE
℄ UNIT
4 - OIL TANK CLEANOUT HOLES (2 IN EACH SIDE)
SKID FOR SHIPPING
HOLES - 5/8 DIA. - 11 TAP FOR JACKING BOLTS.
OIL TANK DRAINS
6 - HOLES - 4" DIA. (3 IN EACH SIDE FOR LIFTING.)
ELEVATION - A - A
ROTATION OF GEAR & GENERATOR
ROTATION OF TURBINE PINION
℄ T.&T. VALVES & STEAM INLET
℄ GOVERNOR
℄ TURBINE
3" STEAM - 400# FLG. 8 1/4 O.D. - 8 - 7/8 DIA. HOLES ON 6 5/8 DIA. B.C.
℄ STEAM INLET
℄ HAND WHEEL
EMERGENCY OVER SPEED TRIP.
HAND TRIP KNOB
3" EXTRACTION - 150# FLG. 7 1/2 O.D. - 4 - 3/4 DIA. HOLES ON 6" DIA. B.C.
1 - 5" DIA HOLE FOR ACCESS TO RELIEF VALVE
ELEVATION - B - B
ALCO
ALCO PRODUCTS, INC.
ATOMIC ENERGY DEPT.
SCHENECTADY, N.Y., U.S.A.
ALCO PRODUCTS, INC.
SCHENECTADY, N.Y.
1000 K.W. PACKAGED NUCLEAR POWER PLANT
TURBINE GENERATOR PACKAGE
GENERAL ARRANGEMENT
Peter F. Loftus Corporation
PITTSBURGH · PENNSYLVANIA · U.S.A.
DRAWN G. STONER
CHECKED
APPROVED
DATE 1-13-59
SCALE 1 1/2 = 1'-0"
MO1M14



PLAN



SECTION A-A



SECTION B-B

GENERAL NOTES:

STEEL TO BE U.S STEEL CORP. "TRI TEN"

DESIGN CRITERIA.

MAXIMUM ALLOWABLE TENSILE STRESS TO BE 24,000 P.S.I., WITH CORRESPONDING ALLOWABLE COMPRESSIVE STRESSES, FOR STATIC LOADING. ALLOWABLE STRESSES TO BE INCREASED ONE-THIRD FOR COMBINED STATIC AND DYNAMIC LOADING.

THE FRAME SHALL BE CAPABLE OF RESISTING THE FOLLOWING DYNAMIC FORCES APPLIED TO FRAME AND EQUIPMENT SUPPORTED ON FRAME:

THRUST FORWARD - 8 G's
" AFT - 2 G's
" VERTICAL - 2 G's
" LATERAL - 1.5 G's

FRAME TO BE WELDED CONSTRUCTION.
WELDING TO CONFORM TO A.W.S SPECIFICATIONS - ALL CONNECTIONS, EXCEPT FOR FLOOR ℞s, TO BE WELDED ALL AROUND.

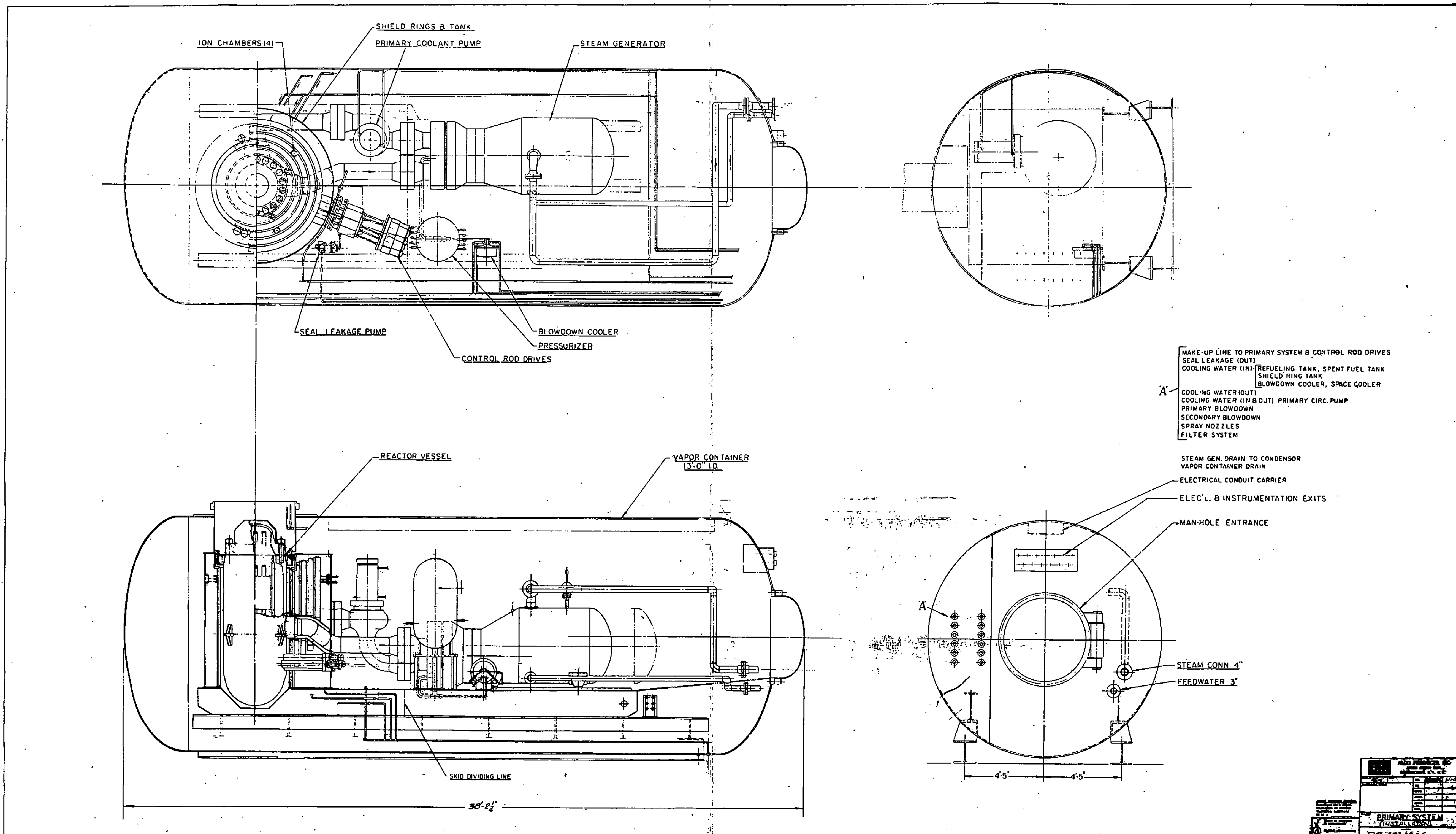
ESTIMATED WEIGHT: 5890#

FOR REFERENCE DRAWINGS SEE DWG. M01M16

ALCO | ALCO PRODUCTS, INC. ATOMIC ENERGY DEPT. SCHENECTADY, N. Y., U. S. A.

ALCO PRODUCTS INC SCHENECTADY, N.Y. 1000 K.W. PACKAGED NUCLEAR POWER PLANT	SWITCHGEAR PACKAGE STRUCTURAL SKID ARRANGEMENT	Peter F. Loftus Corporation PITTSBURGH · PENNSYLVANIA · U. S. A.

DRAWN	CHECKED	APPROVED	DATE	SCALE	
A NAGY	J A K.	CAE SSM	11-14-58	1"-1'-0	M01S3


ION CHAMBERS (4)
SHIELD RINGS & TANK
PRIMARY COOLANT PUMP
STEAM GENERATOR
SEAL LEAKAGE PUMP
BLOWDOWN COOLER
PRESSURIZER
CONTROL ROD DRIVES
MAKE-UP LINE TO PRIMARY SYSTEM & CONTROL ROD DRIVES
SEAL LEAKAGE (OUT)
COOLING WATER (IN) REFUELING TANK, SPENT FUEL TANK
SHIELD RING TANK
BLOWDOWN COOLER, SPACE COOLER
"A"
COOLING WATER (OUT)
COOLING WATER (IN & OUT) PRIMARY CIRC. PUMP
PRIMARY BLOWDOWN
SECONDARY BLOWDOWN
SPRAY NOZZLES
FILTER SYSTEM
STEAM GEN. DRAIN TO CONDENSOR
VAPOR CONTAINER DRAIN
ELECTRICAL CONDUIT CARRIER
ELEC'L. & INSTRUMENTATION EXITS
MAN-HOLE ENTRANCE
REACTOR VESSEL
VAPOR CONTAINER
13'-0" I.D.
"A"
STEAM CONN 4"
FEEDWATER 3"
SKID DIVIDING LINE
38'-2¼"
4'-5"
4'-5"
PRIMARY SYSTEM
(INSTALLATION)
R9-45-1006