TID-8530
REACTORS—POWER

EVALUATION AND DESIGN HEAVY WATER MODERATED POWER REACTOR PLANTS

April 28, 1960

Sargent and Lundy
Chicago, Illinois

UNITED STATES ATOMIC ENERGY COMMISSION • OFFICE OF TECHNICAL INFORMATION

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CONTRACT AT (38-1) 213
SAVANNAH RIVER OPERATIONS OFFICE
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SARGENT & LUNDY
ENGINEERS
CHICAGO

FOREWORD

The design and evaluation of heavy water moderated power reactor plants was undertaken by Sargent & Lundy in November, 1958, under Contract AT(38-1)193 with the Savannah River Operations Office of the U.S. Atomic Energy Commission. Nuclear Development Corporation of America was Nuclear Subcontractor to Sargent & Lundy on this contract. The purpose of the study was (1) the selection and recommendation of a conceptual design of the heavy water moderated power reactor plant offering optimum economics with slightly enriched fuel, but capable of operation with natural uranium, and (2) the preparation of preliminary design and cost estimates of a prototype of the recommended concept.

The studies under this contract culminated in the recommendation of a pressure tube reactor, cooled with boiling D_2O and utilizing the steam in a direct cycle, 200 MWe turbine-generator plant. The design and cost estimate for the prototype plant were based on a plant of minimum size consistent with operability on natural uranium fuel, and capable of direct extrapolation to the 200 MWe plant.

The prototype was therefore designed as a pressure tube, boiling D_2O cooled reactor providing steam in a direct cycle to a 70 MWe turbine-generator.

Subsequently, Sargent & Lundy was authorized by the Atomic Energy Commission, under Contract AT(38-1)213, to investigate the economics and performance of alternate cycles for heavy water moderated power reactors. These studies were conducted in conjunction with E. I. du Pont de Nemours & Company and Nuclear Development Corporation of America.

The work performed by Sargent & Lundy during this program consisted of the preparation of conceptual designs and cost estimates of reactor plants ranging in size from 70 MWe to 300 MWe, and including features that are representative of the current status of heavy water moderated reactors. A summary of the cost estimates developed in this study was presented in Report DP-480, "Heavy Water Moderated Power Reactors, A Status Report."

The detailed design descriptions and breakdowns of the cost estimates for these plants are presented in this report.

The results of other studies of heavy water moderated power reactor plants that have been performed by Sargent & Lundy and NDA are described in a series of reports as follows:

SL-1565, Design Study, Heavy Water Moderated Power Reactor Plants, Part I, Volumes I, II, and III, dated January 28, 1959, and Addendum No. 1, dated March 20, 1959.

SL-1581, Design Study, Heavy Water Moderated Power Reactor Plants, Part 2, Volumes I, II and III, dated February 28, 1959.

SL-1653, Design Study, Heavy Water Moderated Power Reactor Plants, Part 3, dated June 19, 1959.

REPORT SL-1773
EVALUATION AND DESIGN
HEAVY WATER MODERATED POWER REACTOR PLANTS

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1.0 INTRODUCTION

At the request of the Atomic Energy Commission, E. I. du Pont de Nemours & Company assisted by Sargent & Lundy and Nuclear Development Corporation of America submitted a report (DP-480) in March, 1960 which summarized the current economic and technological status of power reactors that are cooled and moderated by heavy water and fueled with natural uranium.

This report has been prepared to present the details of the Sargent & Lundy contribution to DP-480; namely, cost estimates, plant design studies and other work directly related to the current status of D_2O reactors.

The cost estimates and plant designs presented herein are for reactors moderated and cooled by heavy water and operating with either an indirect cycle or a direct cycle plant. The plant capacities considered range from 70 MWe, considered as prototypes, to 300 MWe and include reactors fueled with natural uranium metal and natural uranium oxide. These plants are basically similar to those previously reported by SL-NDA and du Pont independently and, with the exception of reactor design details, have been considered on a comparable design and estimating basis.

In addition to the cost estimates, the results of studies conducted by Sargent & Lundy under contract to the AEC, which have either a technological or economic effect on the current status of D_2O reactor plants are included. These studies are part of a continuing program to advance D_2O power reactor technology and many of the details of their execution have been and are being reported monthly by Sargent & Lundy in report series SL-1685.

2.0 SUMMARY

With the goal of establishing the current economic status of D_2O moderated and cooled power reactor plants, cost estimates were prepared for a series of full scale units using either boiling or pressurized D_2O as a coolant in direct or indirect cycles, respectively. The cases examined included the following 200 and 300 MWe plants fueled with either natural U-metal or natural UO_2:

1. Boiling D_2O cooled, pressure tube, direct cycle, cold moderator.
2. Pressurized D_2O cooled, pressure vessel, indirect cycle, hot moderator.
3. Pressurized D_2O cooled, pressure tube, indirect cycle, cold moderator.

The design of the metal fueled reactors was based on those prepared by du Pont in 1957 and 1958. The oxide fueled reactors are based on the designs previously reported by Sargent & Lundy and NDA. The use of both oxide and metal fuels was examined because they are currently being developed in parallel for use in D_2O power reactors.

All of the power costs presented are based on the following:

Plant Load Factor	80%
Fixed Charges for Depreciating Items	14%/yr.
Fixed Charges for D_2O Inventory	12.5%/yr.
Fixed Charges for Fuel Fabrication	12%/yr. of inventory value
Uranium Use Charge	4%/yr. of inventory value
D_2O Cost	\$28/lb.
Fuel Fabrication Costs (exclusive of uranium)	\$25/kg-U for uranium metal \$64/kg-U for uranium oxide

In accordance with these economic bases, Table 2.0-I summarizes the estimated power costs for the 200 and 300 MWe plants fueled with either natural uranium metal or oxide.

Fuel cycle costs for the metal-fueled reactors are on the basis of 100% batch refueling. Although higher average exposures and lower fuel costs could be obtained in these reactors by multizone refueling, the metallurgical limits on uranium metal are not known well enough for a

TABLE 2.0-I
SUMMARY OF CAPITAL AND OPERATING COSTS FOR 200 AND 300 MWe,
HEAVY WATER MODERATED AND COOLED REACTOR PLANTS

Reactor Power Plant	Plant Capital Cost mills/kwh	D_2O Inventory Cost mills/kwh	Total Fuel Cost mills/kwh	Operation, Maint. and Insurance mills/kwh	Total Power Cost mills/kwh
Boiling D_2O Cooled, pressure tube, direct cycle, cold moderator					
200 MWe, Oxide Fuel	5.7	1.5	2.2	1.3	10.7
200 MWe, Metal Fuel	5.7	1.1	1.7	1.3	9.8
300 MWe, Oxide Fuel	5.0	1.4	2.0	1.1	9.5
300 MWe, Metal Fuel	5.0	1.1	1.7	1.1	8.9
Liquid D_2O Cooled, pressure vessel, indirect cycle, hot moderator					
200 MWe, Oxide Fuel	6.3	1.6	2.5	1.3	11.7
200 MWe, Metal Fuel	5.8	1.1	2.7	1.2	10.8
300 MWe, Oxide Fuel	5.7	1.5	2.1	1.2	10.5 *
300 MWe, Metal Fuel	5.1	1.1	2.4	1.1	9.7
Liquid D_2O Cooled, pressure tube, indirect cycle, cold moderator					
200 MWe, Oxide Fuel	6.2	1.7	2.5	1.4	11.8
200 MWe, Metal Fuel	5.9	1.4	2.4	1.3	11.0
300 MWe, Oxide Fuel	5.7	1.5	2.3	1.1	10.6
300 MWe, Metal Fuel	5.4	1.2	2.1	1.1	9.8

*For illustrative purposes only. Design changes to satisfy reactivity requirements would increase this cost. Vessel size may be a feasibility problem.

realistic appraisal of such schemes. Fuel cycle costs for the oxide-fueled reactors are predicated on the use of multizone, off-power refueling schemes.

The cost data reported confirm the previous conclusion reached by du Pont and S&L-NDA independently: namely, that of the various D_2O moderated power reactors, the boiling D_2O, direct cycle plant yields the lowest power cost for units of large capacity; i.e., 200 to 300 MWe.

The costs for the boiling D_2O plant are still somewhat higher than power costs associated with a comparable coal-fired plant. Current estimates for a 300 MWe, conventionally-fired plant are about 7.5 mills/kwh with fuel at $0.35 per million Btu.

A review of the cost estimates for the 200 MWe, boiling D_2O, pressure tube, direct cycle reactor plant using uranium oxide fuel has been made since they were reported in SL-1565, Addendum 1. As a result, two changes were made: (1) the estimated cost of the two steam drums was reduced from $1,800,000 to $600,000 and (2) the net fuel cost was reduced from 2.7 mills/kwh to 2.3 mills/kwh. The first of these changes was effected through additional work and consultation with manufacturers of steam separating equipment; the second includes an improved estimate of the Pu^{239} content in the spent fuel and the inclusion of a credit for Pu^{240} and Pu^{241} that was omitted earlier. The revised estimates are:

	mills/kwh
Plant Capital Investment	6.1
Heavy Water Inventory	1.5
Total Capital Costs	7.6
Fuel Cost	2.3
Operation, Maintenance, and Insurance	1.4
TOTAL	11.3

These costs apply for a net thermal efficiency of 26.2%, which corresponds to a condenser pressure of 3.5 in. HgA; they are therefore comparable to the cost data reported previously. All other cost data, unless otherwise noted in this report are for operation at 1.5 in. HgA.

The results of other studies of various D_2O reactor plant cycles and prototype designs reported herein are summarized below.

2.1 70 MWe BOILING D_2O PROTOTYPE PLANT

The original design of the boiling D_2O prototype plant, as presented in SL-1581, has been analyzed in some detail to achieve economies in capital and operating costs through rearrangement of the reactor equipment, and analysis of the arrangement of equipment in the plant, as well as via an investigation of the need and adequacy of devices in the plant.

An overall decrease in capital investment of about $3,800,000 was achieved as a result of these studies. The modifications leading to this reduction are summarized below:

Reactor Arrangement

a) The reactor inlet header arrangement in the lower header room was modified to replace the previous pigtail and riser system with a cross core headering system.

b) The feed water from the main condenser was returned to the steam drums instead of mixing with the reactor recirculating coolant at the lower header. This arrangement subcools the recirculating coolant on the suction side of the recirculating pumps 17F, thereby alleviating the NPSH requirements of the pumps. Cost reductions result from (1) the use of pumps with higher NPSH and (2) from the use of a higher fluid velocity in the downcomer, with attendant reduction in D_2O inventory. In addition, an improvement in the arrangement of the concrete structure was effected by being able to place the recirculating pumps at a higher elevation relative to the steam drums.

c) By replacing the vertical direct connected pumps originally specified for the prototype with horizontal, fluid drive coupled pumps, a reduction in pump horsepower was achieved. This follows from elimination of the control valves in the recirculation system. The use of horizontal pumps also allows a more economical arrangement of the recirculating piping and a decrease in D_2O inventory in this piping.

Plant Arrangements

The major modifications to the plant are summarized as follows:

a) The reactor building was reduced to a cylinder 108 ft. in diameter by 166 ft. high, with an internal design pressure of 27 psia.

b) The lower pigtail header arrangement of the reactor was replaced by a box header system, reducing the overall height of the reactor system and the reactor coolant inventory.

c) The dimensions of the turbine building were reduced in length and width by 5 ft. to 105 ft. by 95 ft. overall. The length of the office building was reduced by 5 ft. The height of the turbine building was reduced by reducing the height of the basement by 5 ft.

d) The crib house enclosure was removed and the equipment was rearranged to reduce the overall dimensions of the crib house to 30 ft. by 43 ft.

e) The waste disposal building was modified to improve the arrangement of shielding and equipment, with a resultant reduction in overall length of about 10 ft.

Systems Analysis

Various modifications in the flow diagrams were made to eliminate non-essential sources of D_2O leakage and inventory. These are summarized below:

a) Level and control devices were modified to provide top mounting on various tanks and vessels.

b) The two full-capacity condensate filters were replaced by three half-capacity filters to reduce D_2O inventory.

c) The condensate system was rearranged to bypass the air ejector and gland steam condenser, reducing D_2O holdup. These devices are now cooled with service water.

d) Rearrangement of piping and deletion of miscellaneous non-essential valves in the system.

D_2O Inventory

The D_2O inventory was reduced from 191 metric tons to 166 metric tons. The reduction is attributed primarily to reductions in the D_2O in the coolant recirculation loop, including the steam drums.

A summary of the estimated investment and the annual capital and operating costs of the oxide fueled plant is presented in Table 2.1-I. The total investment for construction includes 10% for contingencies, 12% for escalation, and $7,900,000 for top charges. On this basis, an investment of $35,900,000 is required for the plant and equipment. In addition, an investment of $10,200,000 is required for the heavy water inventory, which is estimated to amount to 166 metric tons. The total investment is estimated to be $46,100,000.

A comparison of the foregoing figures with the original cost estimate for the prototype plant, as reported in SL-1581, Volume I,

TABLE 2.1-I

CAPITAL AND OPERATING COSTS FOR 70 MWe, BOILING D_2O, PROTOTYPE PLANT
ANNUAL GENERATION: 484 x 10^6 KWH AT 0.8 L.F.

Fuel Material	Natural UO_2	
Design Burnup, MWD/metric ton-U	6100	
Refueling Scheme	5-Zone Outward Radial Shift with Inversion	
	Invest. $\$10^6$	Annual Cost $\$10^6$/yr.
Investment		
Reactor plant	21.3	3.0
Turbine plant	14.1	1.9
Miscellaneous buildings and equipment	0.5	0.1
Subtotal	35.9	5.0
D_2O inventory	10.2	1.3
Total investment	46.1	6.3
Operation and Maintenance		
Fuel		
Inventory		0.1
Non-nuclear inventory		0.2
Replacement		1.3
Total fuel costs		1.6
Heavy water make-up		0.2
Operating payroll		0.4
Maintenance labor and material		0.2
Supplies		0.1
Insurance		0.2
Total operation and maintenance		2.7
Total Capital and Operating Costs		9.0

indicates a reduction in both capital and operating costs. The cost estimates for both cases are summarized in Table 2.1-II. The design modifications developed in the study have resulted in a reduction of approximately $1,510,000 in direct construction costs. This reduction with attendant decreases in indirect costs and a reduction in D_2O inventory of about $1,600,000, results in an overall decrease in capital investment of about $3,800,000.

2.2 BOILING D_2O DIRECT CYCLE PLANT USING REHEAT

Studies of five alternate methods of using reactor steam and turbine extraction steam in a reheat cycle have shown that, for the 200 MWe boiling D_2O, direct cycle plant, four of the five arrangements result in an increase in the estimated cost per kilowatt-hour. These increases are attributed to various combinations of increased capital cost and decreased efficiency.

Two of the five cycles approach the power cost associated with the non-reheat cycle. These are:

a) Two stage reheat, with a moisture removal stage preceding the first stage, and a TCDF-38 in., 1800 rpm turbine.

b) Two stage reheat, with a moisture removal stage preceding the first stage, with a TC4F-23 in., 3600 rpm turbine.

Economic analyses of these cycles, with the nonreheat cycle as a base, indicate that cycle (a) would yield an increased power cost of about 0.1 mill/kwh. Cycle (b) is estimated to give a net reduction in estimated power cost of about 0.042 mills/kwh.

2.3 ALTERNATE HEAT DISSIPATION

A study was conducted to evaluate the economy of using a dual energy dissipating system in the boiling direct cycle prototype plant. The design would provide for the generation of 25 MWe net in lieu of the 70 MWe as presently envisaged, with the excess reactor power dissipated through a circulating water cooled heat sink.

If it is assumed that a credit of 6 mills/kwh is applied to the net electric power produced when the plant is operated at an 0.8 load factor, then the two plants may be compared, on the basis of net annual expenditure, as follows:

	70 MWe Prototype	25 MWe-Heat Sink Prototype
Ann. Plant Capital & Operating Cost, $\$10^6$ /yr.	8.955	7.951
Ann. Generation at 0.8 L.F., kwh	484×10^6	187×10^6
Ann. Income from Sale of Power at 6 mills/kwh, $\$10^6$/yr.	2.904	1.122
Net Ann. Cost of Plant, $\$10^6$/yr.	6.051	6.829

TABLE 2.1-II

COMPARISON OF ESTIMATED CAPITAL COSTS
PROTOTYPE BOILING D_2O PRESSURE TUBE DIRECT CYCLE PLANT

Item	Estimated Capital Costs	
	Original Prototype	Improved Prototype
Direct Construction	$23,164,235	$21,653,990
Indirect Costs	14,872,765	14,225,010
Total Construction Cost	$38,037,000	$35,879,000
D_2O Inventory	11,802,000	10,200,000
Total Capital Investment	$49,839,000	$46,079,000

2.4 PRESSURIZED D_2O COOLED PROTOTYPE PLANTS

Based upon reactor designs prepared by du Pont, 70 MWe prototype plants were designed and estimated for the pressurized D_2O cooled, pressure vessel and pressure tube concept. The reactors are both fueled with metallic natural uranium and, as such, do not necessarily represent a minimum size plant for operation on this fuel. The 70 MWe size was selected to make the cost estimates for the liquid cooled plants comparable to the building D_2O prototype. A summary of the estimated costs for both pressurized D_2O cooled prototype plants is presented in Table 2.4-I.

TABLE 2.4-I
SUMMARY OF CAPITAL AND OPERATING COSTS FOR
70 MWe PRESSURIZED D_2O COOLED PROTOTYPE PLANTS

Plant and Fuel	Pressure Vessel, Metal Fuel		Pressure Tube, Metal Fuel	
Avg. Design Fuel Burnup, MWD/MTU	3600		3800	
Refueling Scheme	100% Batch		100% Batch	
	Invest. $\$10^6$	Annual Cost $\$10^6$/yr.	Invest. $\$10^6$	Annual Cost $\$10^6$/yr.
Investment				
Reactor Plant	19.6	2.7	20.7	2.9
Turbine Plant	14.6	2.1	14.1	2.0
Misc. Buildings & Equipment	0.5	0.1	0.5	0.1
D_2O Inventory	7.6	0.9	7.5	0.9
TOTAL	42.3	5.8	42.8	5.9
Operating Costs				
Fuel Cost		1.5		1.4
D_2O Make-up		0.1		0.1
Operating, Maint. & Insurance		0.9		0.9
TOTAL		2.5		2.4
TOTAL OPERATING & MAINTENANCE		8.3		8.3

3.0 EVALUATION OF D_2O MODERATED POWER REACTOR CYCLES

The principal aim of the studies presented in this report is two-fold: first, to bring the power cost estimates for the family of D_2O cooled and moderated power reactor plants to a common basis representative of their current economic status, and second, to report the results of current studies which have a direct influence on these costs through plant design variation. Two major classes of reactors, boiling D_2O cooled, direct cycle and liquid cooled,indirect cycle, were considered for sizes of 70 MWe, 200 MWe and 300 MWe. In addition, cost estimates for each of these plants were prepared based on operation using either natural uranium metal or natural uranium oxide fuel.

Du Pont, Sargent & Lundy and Nuclear Development Corp. of America have prepared, over the past several years, a number of cost estimates for D_2O moderated and cooled power reactor plants covering a spectrum of capacities from 70 MWe to 460 MWe. The du Pont estimates centered principally on plants using metallic uranium fuels, while those of Sargent & Lundy were for plants fueled with natural UO_2.

The cost estimates reported below include effects resulting from studies currently being conducted and are therefore complimentary to the economic data reported in References (1), (2), (3) and (7).

3.1 BASIS OF COST ESTIMATES

Cost estimates for both metal fueled and oxide fueled plants have been prepared in order to place all cost data on a common base. Except for reactor operating pressures and coolant temperatures, which were adjusted to correspond to those used by SL-NDA for the oxide fueled plants, the reactor arrangements and design parameters for the metal fueled plants agree with those prepared by du Pont. The estimates for the UO_2 fueled plants, except for capacity, are based on designs that are similar to those reported previously by Sargent & Lundy.

All of the power costs presented are based on the following:

1. Plant Load Factor, 0.8
2. Fixed Charges for Depreciating Items, 14%/Yr
3. Fixed Charges for D_2O Inventory, 12.5%/Yr
4. Fixed Charges for Fuel Fabrication, 12%/Yr
5. Uranium Use Charge, 4%/Yr
6. D_2O Cost, $28/Lb

The oxide fueled plant estimates were prepared on the basis of designs similar, except for capacity, to those reported previously in Reports SL-1565 and SL-1565, Addendum 1, as Concepts 1, 2 and 3A. The metallic fueled reactor designs are similar to those prepared by du Pont in 1957 and 1958 and have been reported in DP-385.

Those plant designs for which cost estimates were prepared, but which had not been reported previously; e.g., the 300 MWe oxide and metal fueled plants, are described below. Appropriate references are made to those designs which have been reported previously by SL-NDA. For brevity, general arrangement drawings for the latter plants have been omitted; however, any changes in the original designs resulting from current work are discussed and appropriate adjustments in the cost estimates have been included.

In each case, the reactor designs are those of NDA and du Pont for the oxide fueled and metal fueled units respectively. Accordingly, the costs for these reactors are those estimated by NDA and du Pont. All other costs were prepared according to Sargent & Lundy's estimating practices.

Some of the important design differences between the metal fueled pressure tube reactors and the oxide fueled pressure tube reactors, as designed by du Pont and NDA respectively, are the design stresses for Zr-2 and the pressure tube arrangements. The metal fueled reactors employ insulated pressure tubes which pass through a stainless steel tank while the oxide fueled units use an aluminum calandria with air gap insulation between the moderator and coolant D_2O.

One exception to the above is that the design of the 70 MWe, pressurized D_2O cooled, pressure tube prototype reactor includes a calandria with air gap insulation. Accordingly, the cost estimate for this reactor was developed on the same basis as the oxide fueled boiling D_2O cooled unit.

3.2 FUEL CYCLES

Two fuel materials are considered for each of the full scale plant designs: natural uranium metal and natural uranium oxide. Each of these are being developed as fuel materials for power producing D_2O reactors, and each are characterized by specific advantages and uncertainties which merit their consideration. The current status of each of the fuel materials is discussed in DP-480, and is summarized below:

1. UO_2 is an acceptable power reactor fuel as demonstrated by its successful use in PWR and elsewhere; however, it is currently associated with high fabrication costs. UO_2 has good dimensional stability under irradiation and is resistant to attack by D_2O.

2. U-metal reacts with D_2O but has a potentially lower fabrication cost and provides higher nuclear reactivity. It is unknown at present whether or not uranium metal fuels can attain burnups at power reactor conditions which yield low fuel costs.

The form of the fuels considered for the designs reported here are:

1. UO_2 - 0.5 in O.D. pellets loaded in 0.025 in. thick Zr-2 tubes. These rods are assembled in 37-rod clusters and each final fuel element is composed of two pieces loaded in tandem. This permits axial inversion of the two elements and enhances the reactivity limited exposure of UO_2. For each of the UO_2 fueled, full scale plants, a 4-zone radial shift with axial inversion fuel cycling scheme has been considered. The boiling prototype uses a 5 radial zone scheme to increase the average available reactivity in the minimum size unit for natural UO_2 operation.

2. Metallic-U or U-2 w/o Zr coextruded with Zr-2 cladding in the shape of tubes. The liquid cooled reactors have a concentric fuel tubes at each lattice position with coolant flowing inside and outside the tube. Each of the metal fueled reactor fuel costs have been computed on the basis of burnups corresponding to a 100% batch reloading scheme. At present, the maximum burnup attainable with U-metal fuels is unknown; the maximum experienced to date being about 1200 MWD/Metric Ton-U under power reactor conditions. The burnups calculated for each design could be increased by employing fuel management schemes similar to those used with UO_2 and would be accompanied by significant decreases in fuel cost.

   The basis upon which the fuel costs were computed are given in Table 3.2-I.

TABLE 3.2-I

BASIS FOR NATURAL U-METAL
AND NATURAL UO_2 FUEL COSTS

	UO_2	U-Metal
1. Fuel Cost, $/kg-U	40.50	40.50
2. Spent Fuel Value	AEC Price Schedule	
3. Reprocessing Cost	$15,300/day for plant with 1 ton/day capacity	
4. Total Spent Fuel Shipping Cost, $/kg-U	5.00	5.00
5. Pu Credit, $/gm total Pu	12.00	12.00
6. Conversion of $PuNO_3$ to Metal, $/gm	1.50	1.50
7. Fuel Fabrication Cost, $/kg-U exclusive of Fuel, incl. losses	64.05	25.00
8. Fuel Inventory Lease Charge, %/Yr	4	4
9. Non-Nuclear; i.e. Fabrication, Inventory Charge, %/Yr	12	12
10. Fuel Management Scheme	Multizone	100% Batch

4.0 BOILING D_2O COOLED REACTOR PLANTS

Since last reported in SL-1581, the 70 MWe, boiling D_2O cooled, direct cycle prototype plant design has undergone substantial revision which has resulted in capital cost reductions. In addition, alternate cycles, for both the full scale and prototype plants, have been investigated with the purpose of evaluating their economic merit. The results of these studies together with the back up data for the full scale plant cost estimates presented in DP-480 are given in this section.

4.1 PROTOTYPE 70 MWe PLANT

The boiling D_2O, direct cycle plant, considered in this analysis is basically similar to the plant described in SL-1581, dated February 28, 1959. It includes a pressure tube reactor, with a cold moderator, and uses natural uranium oxide as fuel. The D_2O steam generated in the core is utilized in a direct cycle to drive a 70 MWe turbine generator.

Since the publication of SL-1581 studies of the prototype plant have been conducted for purposes of reducing the investment and operating costs of the plant. These studies were concerned with analysis of the systems to reduce equipment and D_2O inventory costs, and rearrangement of equipment in the buildings to simplify construction and reduce construction costs. The changes have been incorporated in the plant design presented herein, and the modifications are reflected in the cost estimates.

4.1.1 PLANT DESCRIPTION

The performance characteristics of the plant are summarized in Table 4.1.1-I. The reactor generates D_2O steam at 795 psia 515 F, which is separated from the coolant in a pair of steam drums and flows directly to the turbine at a rate of 1.06×10^6 lb/hr. to produce a net output of 69.1 MWe. A diagram of the plant cycle and its major auxiliaries is shown on the composite flow diagram, Dwg. NP-302.

REACTOR

The reactor consists of a low pressure aluminum calandria which contains cold D_2O moderator. The calandria is pierced by vertical aluminum calandria tubes arranged in an equilateral triangular lattice array with a pitch of 11.1 in. Zr-2 pressure tubes, passing through the calandria tubes, contain the boiling D_2O coolant and fuel elements.
The coolant and moderator are separated in order to provide insulation for the low temperature moderator. A separate moderator cooling system is provided, and the air filled annulus between each pressure tube and the corresponding calandria tube provides thermal insulation between the coolant and the moderator in the reactor. Approximately 7% of the reactor power is deposited in the moderator. The moderator cooling system is designed to remove this heat and maintain an average moderator temperature of 120 F.

TABLE 4.1.1-I
SUMMARY OF PROTOTYPE REACTOR CHARACTERISTICS

	Prototype
Cycle Performance	
Total thermal power, MW	255
Net plant output, MWe	69.1
Net plant efficiency, %	27.0
Turbine Conditions	
Throttle temperature, F	510
Throttle pressure, psia	765
Steam flow at throttle, lb/hr.	1.059×10^6
Steam flow from steam drum, lb/hr.	1.06×10^6
Condenser pressure, in. Hg. A.	1.5
Reactor Description	
Core geometry	
Active diameter, ft.	12.0
Active height, ft.	11.1
Lattice arrangement	equilaterial triangular
Lattice pitch spacing, in.	11.1
Total number of lattice positions	152
Fuel elements	
Type of element	cluster of rods
Fuel material	natural UO_2
Number of fuel elements	266
Number of fuel elements per fueled lattice position	2
Clad-material	Zr-2
Fuel rod OD, in.	0.552
Clad thickness, nominal, in.	0.025
Fuel element length, nominal, ft.	5.55
Control rods	
Number of safety rods	19
Number of shim rods	17
Number of regulating rods	2
Calandria	
ID, ft.	16
Overall height, basic tank, ft.	16'-1-1/4"
Number of tubes, total	171
Tubes, OD, in.	
Fuel	5.875
Control	4.875
Safety rods	2.5
Tube sheet thickness, in.	3
Material	5052-0 Al

TABLE 4.1.1-I (Cont.)

	Prototype
Reflector	
Material	D_2O
D_2O volume in reflector, $ft.^3$	1655
Pressure tubes	
OD, in.	4.974
Wall thickness, in.	0.162
Material	Zr-2
Annulus between calandria tube and pressure tube	
Material	air
Thickness, in.	3/8 nominal
Material inventories	
UO_2, metric tons	19.7
Uranium, metric tons	17.3
Reactor D_2O metric tons	95.7
External coolant system D_2O, metric tons	51.4
External moderator system D_2O, metric tons	13.9
Other plant D_2O, metric tons	5.0
Plant D_2O, metric tons	166.0

Thermal Characteristics of Reactor

Limiting condition	4000 F at center of UO_2 pellet
Maximum heat flux, Btu/hr.-$ft.^2$	2.4×10^5
Maximum clad temperature (inside surface), F	606
Power to coolant, MWt	237
Coolant flow rate through core, lb/hr.	7.54×10^6
Coolant inlet temperature, F	499
Coolant outlet temperature, F	516
Coolant inlet pressure, psia	820
Steam quality at core outlet, %	14
Liquid velocity at core inlet, max., ft/sec.	8
Power to moderator, MWt	18
Average moderator temperature, F	120

Nuclear Characteristics of Reactor

Effective multiplication factor, k_{eff} (equilibrium Xe and Sm - hot)	1.01
Xe and Sm poisoning, $\Delta k/k$	0.03
Initial conversion ratio (ICR)	0.85
Lattice properties (hot)	
a. Infinite multiplication factor, k_∞	1.067
b. Migration area, M^2, cm^2	342
c. Material buckling, Bm^2, cm^{-2}	1.8×10^{-4}

TABLE 4.1.1-I (Cont).

	Prototype
Geometric buckling, B^2, cm^{-2}	1.6×10^{-4}
Neutron leakage, (B^2M^2)	0.056
Average thermal neutron flux in fuel, n/cm^2-sec.	6.4×10^{13}
Maximum thermal neutron flux in fuel, n/cm^2-sec.	1.52×10^{14}

Coolant D_2O enters a header system below the reactor, passes up through the pressure tubes, where boiling occurs, and flows through a header system above the reactor to a pair of steam drums. Dry and saturated steam from the drums is delivered to the turbine, while the liquid D_2O is recirculated from the steam drums to the reactor inlet header.

Reactor control is effected by 17 shim and two regulating rods which are driven from below the reactor. Emergency shutdown is achieved by the release of 19 safety rods, which are latched above the core and fall by gravity into the core when released. As a backup for the safety rods, the moderator D_2O may be drained through quick opening valves to the moderator storage tanks.

Off power refuelling is accomplished from above the reactor, by a remotely operated fuel handling machine located in a shielded room. The machine removes plugs on the pressure tube extension to gain access to the fuel elements.

Fuel Elements

The fuel elements consist of natural UO_2 pellets in Zr-2 rods, arranged in clusters of 37 rods, with an overall length of 5.5 ft. Two fuel elements occupy each lattice position in tandem. This arrangement improves the reactivity limited burnup by making it possible to interchange the relative vertical positions of the two elements after partial burnup has occurred. A total of 266 fuel elements, with 17.3 metric tons of natural uranium, are required for the 133 fuel positions.

Turbine Plant

Dry and saturated D_2O steam generated in the reactor is utilized in a turbine located in a separate building. Under design conditions, the turbine-generator gross output is 73.6 MWe at a condenser pressure of 1.5 in. HgA. Four stages of feed water heating produce a final feed water temperature of 387 F. As shown on the composite flow diagram, the feed water returns to the steam drums, where it mixes with the recirculating reactor coolant, and the subcooled mixture is returned to the reactor inlet header. The net plant efficiency is 27%.
The turbine is a nominal 70 MWe, 3600 rpm, tandem compound, triple flow extraction steam turbine, equipped with special seals to minimize D_2O leakage losses.

A two-pass, double tube sheet design condenser is used. The tubes are fabricated of aluminum alloy.

The condensate and feed water pumps are fitted with special gland seals, designed to limit and collect any D_2O leakage.

Auxiliary Systems

The auxiliary systems, consisting of the moderator cooling system, moderator and coolant purification systems, shield cooling system, service and circulating water systems, waste disposal system, D_2O recovery system, D_2O distillation system, and the recombiner and off-gas systems, are described in detail in SL-1581, Vol. I.

Buildings

The reactor, steam drums and reactor auxiliaries are housed in a cylindrical steel containment building, as shown in Dwgs. NP-415 through NP-420. The turbine-generator, condenser, feed water auxiliaries and electrical auxiliaries are located in a conventional steel-frame building, adjacent to the reactor building and joined to the reactor building by a double-door airlock. The offices, control room, shops, locker rooms and laboratories are located in the office building, which adjoins the turbine building. The arrangement of these buildings is indicated on Dwg. NP-424.

Design Improvements

During the course of the studies, the design of the system and the arrangement of the equipment in the buildings was modified to reduce equipment and D_2O inventory costs, simplify construction and reduce building costs. The results of these investigations are summarized below.

Reactor Arrangement

a. The reactor inlet header arrangement in the lower header room was modified to replace the previous pigtail and riser system with a cross core headering system.
b. The feed water from the last feed water heater was returned to the steam drums instead of mixing with the reactor recirculating coolant at the lower header. This arrangement subcools the recirculating primary coolant on the suction side of the recirculating pumps by 17 F, thereby increasing the NPSH of the pumps. Cost reductions result from (1) the use of pumps with higher NPSH and (2) through the use of a higher fluid velocity in the downcomer, with attendant reduction in D_2O inventory. In addition, an improvement in the arrangement of the concrete structure was effected by being able to place the recirculating pumps at a higher elevation relative to the steam drums.
c. By replacing the vertical direct connected pumps originally specified for the prototype with horizontal, fluid drive coupled pumps, a reduction in pump horsepower was achieved. This follows from elimination of the control valves in the recirculation system. The use of horizontal pumps also allows a more economical arrangement of the recirculating piping and a decrease in D_2O inventory in this piping.

The revised arrangement of the reactor system is shown on the reactor building Dwgs. NP-415 through NP-420.

Containment Building

In addition to reducing D_2O inventory, pumping and piping costs, the rearrangement of the reactor recirculating system allowed reductions in the size of the containment building. Dwgs. NP-415 through NP-420 show the revised reactor building, which is 108 ft. in diameter and 166 ft. in height, and designed for an internal pressure of 25.8 psia. The original prototype building was 125 ft. in diameter, 178 ft. high, and designed for a pressure of 22.5 psia.

The principal access, emergency exit and freight doors are similar to the original prototype design. As in the previous design, the main floor is located 79 ft. above grade and provides access to the upper header room, as shown on Dwg. NP-415. A 50 ton crane with an auxiliary hook capacity of 5 tons serves the reactor and the area between equipment hatches. The reduction in overall height of the building was effected by raising the moderator circulating pumps and moderator cooler. The coolant storage tanks and moderator D_2O storage tanks were also raised to areas at the lower level of the building which were not crowded with equipment. In addition, the lower header room height was reduced as a result of redesign of the lower header and piping connections to the reactor coolant tubes as previously described. See Dwgs. NP-418 and NP-419.

The relocation of equipment also permitted a reduction in the length of large size piping, with a corresponding reduction in D_2O inventory.

The reduction in diameter of the containment vessel was effected partly by placing the reactor circulation pumps on opposite sides of the calandria as shown on Dwg. NP-416, and partly by placing the moderator cooler at nearly the same elevation as that of the reactor circulating pumps. Then by shifting the spaces for purification equipment and other auxiliary equipment it was possible to reduce the diameter of the containment vessel and still maintain the desired features of accessibility for operation, maintenance, and removal of equipment.

The elevation of the spent fuel transfer tunnel was raised 11 ft. from that shown on the original design as a result of reducing the depth of the reactor building below grade. The reactor recirculation pumps were relocated to an elevation 3 ft.-6 in. below the steam drum (from centerline to centerline) whereas the original prototype had the pumps 42 ft. below the drum centerline. This location is consistent with the studies reported on Recirculation System Economics in Report SL-1653, whereby the optimum location regarding total annual costs and operating considerations would be to place the pumps approximately 30 feet below the steam drums.

In addition, the pumps are now indicated as horizontal type driven by an electric motor through a fluid drive speed control mechanism. The original prototype had vertical pumps direct connected to a vertical motor with pump output controlled by a regulating valve at the discharge of each pump. Utilizing horizontal pumps with variable speed fluid drives, eliminates expensive high pressure control valves, eliminates high friction losses through the valve thereby reducing pumping power and motor size; and allows more economical piping arrangements to and from the pump. The pump location is shown on Dwgs. NP-416 and NP-420.

Turbine Building

The turbine building was reduced in size to 75 ft. by 105 ft. at the operating floor, as indicated on drawing NP-424, from 85 ft. by 110 ft. as indicated on drawings of the original design. A one story bay, 20 ft. wide, adjoins the turbine room, as in the original prototype design, to provide condenser tube pulling space, compressors, pumps, and water clarifying and demineralizing equipment.

The operating floor of the turbine room is 30 ft. above grade floor and is 5 ft. lower than that on the original prototype. The overall height of the building from grade floor to the top of the roof is 73 ft.-6 in., which is 9 ft. lower than on the original building.

The turbine room crane is 75 ft. long compared to an original length of 85 ft., and the capacity of the main hook has been reduced to 30 tons from an original capacity of 50 tons. The reduced capacity of the crane is still ample to handle the generator rotor and other auxiliaries such as feed water heaters and any heavy items entering the reactor plant from the turbine room.

All feed water heaters have been made vertical type; heater "A" was previously a horizontal type. With the main condenser placed considerably lower than that of the original design, a vertical low pressure heater is feasible, reducing space requirements and the length of piping. In addition, lowering the condenser to place the hotwell below the basement floor provides natural shielding for this portion of the equipment. Space is provided for concrete shielding as may be found desirable later.

The condenser hotwell pumps were placed at the side of the condenser hotwell instead of next to the condenser return water box as in the original design. The circulating water inlets and outlets at the condenser were revised from that previously shown.

The turbine oil precipitation tank and purifying equipment were located in a separate room in front of the turbine and just below the basement floor. This room, at the lowest level in the turbine room proper, also contains the miscellaneous D_2O drain tank and pump.

The turbine-generator is provided with a separate motor driven main exciter whereas the exciter was direct connected on the original prototype. This change enabled a reduction in the length of the turbine foundation by approximately 7 ft., thus permitting a reduction in the length of the turbine building.

Water clarifying equipment was located in the basement in the 20 ft. bay with its accompanying filters. The water storage tank for the effluent from this equipment has a capacity of 15,000 gals. and is located on the roof of the bay attached to the turbine room.

The studies of exhaust ventilation requirements to maintain minimum tritium concentrations indicate that two 8,000 cfm fans are adequate for the turbine room. These fans are located on the mezzanine floor at the end of the building to permit a short run of discharge duct to the stack.

The arrangement of the main, auxiliary, and reserve auxiliary transformers was revised to permit the extension of the railroad track directly into the turbine room basement. This facilitates erection of the plant, and simplifies the transfer of heavy equipment such as generator rotor or feed water heaters into and out of the building after the plant is in operation.

The exterior walls of the turbine building are now of insulated aluminum panel instead of uninsulated corrugated cement asbestos panels. Considerable savings in heating requirements plus reduction in heating boiler capacity and fuel oil storage requirements are a result of this change. In addition, a tighter enclosure is provided as well as the elimination of the undesirable feature of occasional "sweating" of inside surfaces with uninsulated cement asbestos panel. The modified heating requirements are described in a later section.

Office Building

The office building adjoins the turbine building and is subdivided into a 26 ft. wide control room section and a 33'-6" wide office section as indicated on earlier prototype drawings. However, the overall length was reduced from 120 ft. to 115 ft. by reducing the length of the control room section from 56 ft. to 51 ft.

The office section has only one mezzanine floor as compared with two mezzanine floors on the original prototype. The operating superintendent's office was relocated to a corner in the turbine room adjacent to the control room. By eliminating the meeting room, relocating the laboratories, and reducing hallway space to a workable minimum, it was possible to provide for the remaining rooms even though one mezzanine floor was eliminated in the office section.

In the control room section, the 2400 volt switchgear was relocated to the basement floor from its previous location on the mezzanine. The mezzanine in this section is used for the 480 volt switchgear, batteries and charging equipment, and amplifying equipment associated with instruments in the control room above.

The 480 volt transformer was located outdoors at grade level and in line with the 2400 volt switchgear. The diesel driven generator was moved to the turbine room basement, adjacent to the room housing the 2400 volt switchgear.

The exterior walls of the office building have insulated aluminum panels instead of uninsulated corrugated cement asbestos panels. This panelling reduces the heating requirements during the heating season, and also reduces the air conditioning load during the summer season, thereby reducing costs of equipment and distribution ductwork as well as space requirements for both. Interior walls and partitions are unchanged from the original prototype.

Crib House

An outdoor type of crib house structure is provided as indicated on Dwgs. NP-426 and NP-428. The length is now roughly 43 ft. as compared to a length of 52 ft. on the original prototype design. The pump compartment is 29 ft. wide as compared to an original width of 35 ft. The seal well was relocated to the side of the pump compartment, providing a floor for the chlorination equipment. Additional floor space for small equipment was provided by cantilever floors.

The height of the main floor was reduced to 24 ft. from the bottom slab of the crib house, compared to an average of 33 ft. on the original prototype design. All pumps and equipment are located on the main floor reducing overall lengths of service water pumps and travelling screen by approximately 8 ft. In addition, some of the interior walls were eliminated as they are no longer required for strength and stability because of reducing the height of the structure.

To permit utilizing an outdoor crib house the motors for the various pumps are outdoor weather protected type. Piping which does not have continuous water flow is traced with electrical heating cable to avoid freezing of lines during periods of cold weather. The additional costs for weather protection are accounted for in the capital cost estimate.

Waste Disposal Building

The size of this building, as indicated on Dwg. NP-421, was reduced to 42 ft. 6 in. wide by 47 ft. long from 42 ft. wide by 57 ft. long. The reduction in size was made principally by moving the 5000 gal. acid storage tank and the alpha-cellulose fill tank from the basement to the main floor and re-arrangement of other equipment and stairways.

The arrangement of buried equipment adjacent to the building, such as the permanent resin storage tank, solid waste burial pit, and radioactive gas hold-up tanks, are unchanged from that in the original prototype design.

Fuel Handling Building

This building, as shown on Dwg. NP-421, is about 3 ft. shorter than that on the original prototype design, because the bottom of the reactor building was raised 11 ft. the spent fuel transfer tunnel has been raised by the same amount. The rest of the elevations were not changed, and the storage pool size and depth is unaffected.

Revised Heating Requirements

The provision of insulated aluminum panels in the turbine room as well as for the office building permits a reduction in the capacity of the heating boiler from 8600 lbs. per hour to 5200 lb/hr. The capacity of the boiler is based on heating the office building to 75 F and the turbine building to 65 F when the outdoor temperature is 20 F. The heating load for the buildings under these conditions is 892,000 Btu/hr. as compared to 1,952,000 Btu/hr. for buildings with corrugated cement asbestos walls as specified for the original prototype plant.

The total annual fuel oil consumption for the plant, including that required for steam used in the distillation plant, is estimated to be 84,380 gals. This can be handled adequately with only one 50,000 gal. capacity storage tank, consequently the second tank as indicated on the original prototype drawings has been omitted.

Control and Instrumentation

The evaluation of the control and instrumentation for the prototype heavy water moderated reactor has led to an alternate design incorporating recently developed components which are now available commercially. The following description covers the features of the alternate design which is shown on the nuclear instrument block diagram, Dwg. NP-495.

The start-up channels and the log N Channels have been integrated to give low period and high period signals which use a common period meter and recorder. This provides period information at one instrument.

Short period signals during reactor start up are introduced into time delay circuits which delay scramming if erratic signals are received. Scramming of the reactor on low level short period signals is varied with the time delay circuit so that the scram is practically instantaneous as the period approaches a positive value of one second.

High level short period scram signals derived from the log N channels do not have any time delay trip circuit and therefore scram instantaneously on short period signals.

Each of the above period scram circuits incorporates individual alarm signals and hand-reset relays. This arrangement gives the operator visual indication of a scram and control of the reset function after determining the cause of the scram.

To further insure reliability of the instrumentation channels, test circuits are incorporated in each of the channels so that a system of routine channel checking is available.

The integration of low and high level period tripping permits further consolidation of meters and recorders by the use of selector switches and the transferring of signals by relay to the recorders.

The start-up channels use boron lined proportional counters, filled with argon and carbon dioxide gas, for detectors. These detectors have been developed to resist radiation damage at powerflux levels. This type of proportional counter permits the motor operated detector positioners to be omitted. This arrangement simplifies the start-up channel detector installation and reduces potential outages due to failure of the motor operated positioners.

The development of transistorized circuits for many of the earlier electron tube circuits has reduced the space requirements for the reactor control and indicating circuits. Several manufacturers now have complete reactor instrumentation systems incorporated into a single cubicle. The circuits have been transistorized and developed in modulus systems, resulting in compact designs.

It is possible to place such a cubicle in the control room without any appreciable increase in space requirements. In addition, the extensive transistorization of the electronic circuits in the instrumentation cubicle minimizes heat removal problems.

This centralization of reactor instrumentation provides a means of monitoring the instruments and channels easily without leaving the control room. The use of drawout type modules facilitates removal and testing of malfunctioning components.

Safety Rod Position Indication

Various methods of determining the safety rod positions were reviewed. In general, a signal should be initiated as the safety rod reaches its extreme upper position. This signal is used to limit the upward travel, to give the operator visual indication of the rod's position, and to provide interlocks with other reactor functions.

The methods of obtaining a signal fall into four general groups:

1. Mechanically actuated switches

2. Magnetically actuated switches

3. Capacitive probes

4. Inductive probes

It has been concluded that the magnetically actuated switch is the most suitable for this application. This conclusion is supported by the following considerations:

a. Although the operation of the magnetic switch requires a movement of the actuator, it presents no problem since the number of operations required will be limited. This method of detection is consistently applied to important measurements in conventional power plants and is considered to be reliable. The direct translation of actuation into a usable signal is considered to be more advantageous than proximity probes, which develope minute signals that must be electronically amplified.

b. The magnetic switch is simple to install since it does not require penetration of the safety rod tube. Any penetration of the tube would be a potential source of D_2O leakage. Mechanically actuated switches are least desirable from this viewpoint. In comparing the magnetic switch with the proximity probe, it is evident that, although the probes are static devices which may be easily adapted to this particular application, they would be more costly to install because of the use of coaxial cables which require cable termination fittings.

c. The magnetic switch and the mechanically actuated switch provide the simplest overall system of position indication. The proximity probe signals would have to be amplified electronically, which would add considerably to the complexity of the system, and potentially reduce its reliability.

4.1.2 ESTIMATED COSTS

Estimates of the capital and operating costs were prepared for the revised prototype plant.

Heavy Water Costs

The revised inventory of heavy water for the prototype plant was determined for the reduced physical size of reactor and turbine plants and is treated as an investment cost as was done for the original prototype design.

The breakdown of this investment in the various sections of the plant as compared to the original plant is as follows:

	Original Prototype Metric Tons	Investment	Revised Prototype Metric Tons	Investments
Reactor	103.4	$6,369,000	95.7	$5,909,000
External Cooling System	63.2	3,893,000	51.4	3,173,000
External Moderator System	13.0	801,000	13.9	858,000
Other	12.0	739,000	5.0	309,000
Total	191.6	$11,802,000	166.0	$10,249,000

The difference in inventory in the reactor is attributed to a lower operating level established in the steam drums and to the change in design ofthe lower headers and pigtails. The reduction in volume of D_2O in the external cooling system is the result of a reduction in pipe sizes in the reactor recirculation system, the relocation of equipment and consequent reduction in piping length in both the reactor plant and turbine plant, and the revision of purification system equipment requirements. The reduction in the miscellaneous D_2O is the result of further study of the holdup in the distillation plant, off-gas system, and miscellaneous D_2O drains tanks in the reactor and turbine building.

Design and Construction Costs

The estimated costs of design and construction including material, labor, Contractors' overhead, contingency, escalation, and engineering design are summarized in Table 4.1.2-I. The estimated costs of the original prototype are also listed for comparison. As indicated, the estimate includes 10% contingency 12% escalation and $7,989,000 top charges. The total investment required, exclusive of D_2O inventory, is estimated to be $35,879,000.

In addition, an investment of $10,249,000 is required for the D_2O inventory, which is estimated to amount to 166 metric tons. Thus the total investment required is $46,128,000, and compares to a figure of $49,839,000 for the original prototype.

A summary of the estimated investment and the annual capital and operating costs of the plant is presented in Table 4.1.2 - II.

TABLE 4.1.2-I

SUMMARY OF ESTIMATED ENGINEERING AND CONSTRUCTION COSTS
PROTOTYPE 70 MWe BOILING D_2O PRESSURE TUBE DIRECT CYCLE PLANT

	Original Prototype Total	Revised Prototype Total
L - LAND	$ 20,000	$ 20,000
A - STRUCTURES		
Ground Improvements	544,500	544,500
Reactor Plant	2,522,000	2,009,900
Turbine-Generator Building	794,500	720,000
Waste Disposal Building	210,500	210,500
Fuel Handling Building	305,000	215,000
D_2O Distillation Structures	15,000	15,000
Circulating Water System Structures	233,800	187,000
Miscellaneous Other Buildings	148,300	148,300
TOTAL STRUCTURES - "A"	$4,763,600	$4,050,200
B - EQUIPMENT		
Reactor Plant		
1. Reactor Equipment	6,735,500	6,667,000
2. Auxiliaries	595,375	358,750
3. Piping	672,500	586,500
4. Instrumentation	101,000	200,000
TOTAL B-I	$8,104,375	$7,812,250
Turbine-Generator Plant	6,108,100	5,903,120
Crib House	292,460	255,500
D_2O Distillation Plant	164,680	136,680
Waste Disposal System	206,480	206,480
Fuel Handling Plant	1,241,110	1,241,110
TOTAL EQUIPMENT - "B"	$16,117,205	$15,555,140
C - ELECTRICAL		
Reactor Plant	701,580	646,100
Turbine-Generator Plant	1,323,800	1,145,800
Crib House	11,000	11,000
D_2O Distillation Plant	5,600	Incl. C-VI
Waste Disposal System	11,100	11,100
Fuel Handling Plant	7,400	11,700
TOTAL ELECTRICAL - "C"	$ 2,060,480	$ 1,825,700

TABLE 4.1.2-I (Cont.)

	Original Prototype Total	Revised Prototype Total
D - MISCELLANEOUS EQUIPMENT		
Health	127,250	127,250
Offices and Locker Rooms	10,000	10,000
Machine Shop and Store Room	64,500	64,500
Fire Protection	1,200	1,200
TOTAL MISCELLANEOUS EQUIPMENT -"D"	$ 202,950	$ 202,950
Sub-Total (L Plus A to D Inclusive)	$23,164,235	$21,653,990
E - CONTRACTOR'S OVERHEAD AND PROFIT	$ 1,140,104	$ 1,056,000
Sub-Total (L Plus A to E Inclusive)	24,304,339	22,709,990
F - CONTINGENCY - 10%	2,430,661	2,271,010
Sub-Total (L Plus A to F Inclusive)	26,735,000	24,981,000
G - ALLOWANCE FOR ESCALATION (3 Years - 4% Per Year) - 12%	3,208,000	3,000,000
Sub-Total (L Plus A to G Inclusive)	29,943,000	27,981,000
H - TOP CHARGES		
Professional Services		
1. Reactor Design	3,350,000	3,350,000
2. Reactor and Turbine Systems and Plant	1,750,000	1,750,000
Other Charges (Purchasing, Field Supervision, Interest During Construction, Etc.) - 10%	2,994,000	2,798,000
TOTAL TOP CHARGES - "H"	$ 8,094,000	$ 7,898,000
TOTAL ESTIMATED COST	$38,037,000	$35,879,000

NOTES:

1. Personnel training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

TABLE 4.1.2-II

CAPITAL AND OPERATING COSTS FOR 70 MWe,
BOILING-D_2O, PROTOTYPE PLANT
ANNUAL GENERATION: 484 x 10^6kwh at 0.8 L.F.

Fuel Material	Natural UO_2	
Design Burnup, MWD/metric ton-U	6100	
Refueling Scheme	5-Zone Outward Radial Shift with Inversion	

	Invest. $\$10^6$	Annual Cost $\$10^6$/yr.
Investment		
Reactor plant	21.3	3.0
Turbine plant	14.1	1.9
Miscellaneous buildings and equipment	0.5	0.1
Subtotal	35.9	5.0
D_2O inventory	10.2	1.3
Total investment	46.1	6.3
Operation and Maintenance		
Fuel		
Inventory		0.1
Nonnuclear inventory		0.2
Replacement		1.3
Total fuel costs		1.6
Heavy water make-up		0.2
Operating payroll		0.4
Maintenance labor and material		0.2
Supplies		0.1
Insurance		0.2
Total operation and maintenance		2.7
Total Capital and Operating Costs		9.0

The annual costs were calculated on the following basis:

Plant Load Factor	80%
Annual Fixed Charges on Plant	14%
Annual Fixed Charges on D_2O	12.5%
Annual Fixed Charges on Uranium	4.0%
Annual D_2O Loss	2%
Fuel Burnup, MWD/metric ton-U	6100
Fuel Inventory in Core, metric tons-U	17.3

On the foregoing basis, an estimated total annual cost of \$9,000,000 is indicated, which, with an annual generation of 484×10^6 kwh, amounts to 18.6 mills per kwh.

4.2 FULL SCALE, BOILING D_2O, DIRECT CYCLE PLANTS

The full scale, boiling D_2O, pressure tube, direct cycle reactor plant designs considered are basically similar to the 200 MWe unit reported as Concept 3A in SL-1565, Addendum 1, dated March 20, 1959. Both the metal and oxide fueled boiling plants are characterized by similar plant general arrangements and, except for the reactors, have identical facilities for units of the same capacity. The oxide fueled reactor design is that referenced above. The metal fueled reactor design corresponds to that prepared by du Pont and has been reported as the 1-K Series in DP-385.

4.2.1 PLANT DESIGN DESCRIPTIONS

Specific design characteristics for the 200 and 300 MWe boiling plants fueled with natural uranium metal or natural uranium oxide are given in table 4.2-I. General arrangement drawings for each of the boiling D_2O direct cycle plants appear as follows:

Drawing No.	Plant
NS-700	200 MWe, Metal Fueled
NS-710	300 MWe, Metal Fueled
NS-720	300 MWe, Oxide Fueled

For general arrangements and more specific discussion of the concept, reference is made to SL-1565 and Addendum 1 to SL-1565.

REACTOR

Each of the full scale reactors is similar in design and construction; i.e.,they are natural uranium fueled, boiling D_2O cooled, pressure tube, cold moderator type. Specific design details for the 200 and 300 MWe oxide and metal fueled units are given in Table 4.2-I.

The core consists of a calandria, containing cold D_2O moderator, which is penetrated by a number of tubes fastened to upper and lower tube sheets. Zr-2 pressure tubes pass through the calandria tubes and are used to house the fuel and contain the primary system pressure. Coolant D_2O enters the core at 498 F through a pigtail arrangement beneath the reactor and passes up past the fuel where boiling occurs. Coolant leaves the core at 515 F as a steam-water mixture at 14% quality and flows to two steam drums through a headering system. In the drums, saturated D_2O steam at 795 psia is separated and sent to the turbine; the remaining water is force-recirculated back to the lower header room where it is mixed with 387 F turbine plant feed water before re-entering the core.

TABLE 4.2-I

PLANT DESIGN CHARACTERISTICS FOR 200 and 300 MWe
BOILING D_2O, PRESSURE TUBE, DIRECT CYCLE REACTORS

Reactor Type	Boiling-D_2O, Direct Cycle, Pressure Tube			
Nominal Plant Capacity, MWe		200		300
Fuel Material	UO_2	U-Metal	UO_2	U-Metal
Total Thermal Power, MW	790.0	790.0	1075	1075
Net Plant Power, MWe	218.5	218.5	300	300
Net Plant Efficiency, %	27.7	27.7	27.9	27.9
Turbine Throttle Temperature, F	510	510	510	510
Turbine Throttle Pressure, psig	750	750	750	750
Condenser Pressure, in. Hg A	1.5	1.5	1.5	1.5
Reactor Core				
Active diameter, ft.	16.4	13.1	18.6	15.5
Active height, ft.	17.7	15.0	20.0	15.0
Lattice geometry	Triang.	Square	Triang.	Square
Lattice pitch, in.	11.1	8.5	11.1	8.5
Number of fueled lattice positions	268	257	344	362
Number of control rods	19	31	25	43
Number of safety rods	19	31	25	43
Reactor Vessel	Calandria		Calandria	
Material	Al	SS	Al	SS
I.D., ft.	18.4	15.1	20.6	17.5
Height, ft.	20.7	22.8	23.1	22.8
Reflector	D_2O	D_2O	D_2O	D_2O
Radial and axial thickness, ft.	1.0	1.0	1.0	1.0
Pressure Tube Material	Zr-2	Zr-2	Zr-2	Zr-2
I.D., in.	4.65	3.54	4.65	3.54
Wall thickness, in.	0.162	0.150	0.162	0.150
Primary Coolant				
Outlet temperature, F	515	515	515	515
Inlet temperature, F	499	499	499	499
Primary system pressure, psia	800	830	800	830
Maximum Core Heat Flux, Btu/hr-ft^2 (nom.)	318,000	360,000	318,000	360,000
Fuel				
Core loading, metric ton-U	58.4	41.0	85.7	58.0
Average design burnup, MWD/metric ton-U	7500	4800	8500	5100
Total D_2O Inventory, metric tons	290	218	375	310

The fueled lattice positions are assembled on a square and equilateral triangular pitch of 8.5 and 11.1 inches for the metal and oxide fueled reactors respectively. Control is effected by means of rods located in lattice positions and entering from the bottom of the core. Separate safety rods, located at off-lattice positions, provide negative reactivity for reactor scram. In addition, each reactor has a backup scram provision in the form of fast drain of the cold D_2O moderator.

Moderator System

Heavy water moderator is maintained at an average temperature of 155 F in the core of the full scale reactors by circulating the D_2O through an all-aluminum external moderator cooling system made up of a circulating pump, service water cooled heat exchanger, and a bypass purification system. The moderator fluid enters the calandria at 110 F and flows down through a one foot thick reflector region. It then passes up through the core and exits at 200 F. No attempt is made in any of the present designs to recover the heat deposited in the moderator.

Primary and Reactor Auxiliary Systems

Saturated D_2O steam at 515 F is passed from the steam drums directly to the turbine. Since all of the direct cycle turbines are supplied with radioactive D_2O steam, they are of special construction. An allowance for decontamination facilities in the turbine has been made and special seals are provided at the shaft ends. The main condensers are constructed of aluminum tubes and carbon steel shells and are designed with double tube sheets to permit leakage detection of either D_2O out or H_2O in at the tube sheets. The condensate system uses three one-half capacity condensate pumps and three one-half capacity feed water pumps connected in parallel to pump the feed water through a series of extraction feed water heaters. Each of the feed water heaters are connected such that the extraction steam is cascaded to the main condenser for deaeration. All of the feed water cycles are closed. Full flow feed water filters have been incorporated to remove particulate impurities down to 2-micron size.

A bypass demineralization loop is connected to the reactor recirculation piping for normal primary water cleanup. This loop is sized to be capable of processing four times its normal flow capacity to provide rapid emergency cleanup in the event of a fission product release from ruptured fuel.

The circulating water systems for the plants consist of the requisite number of vertical circulating water pumps located in an insulated metal panel crib house. Conventional intake screens and screen washing equipment are provided in all plants. All circulating water piping and discharge flumes are of a conventional power plant construction.

The plants are provided with a D_2O distillation facility used to remove H_2O contaminant from the moderator or coolant.

On site, radioactive waste disposal facilities for solid, liquid and gaseous wastes have been provided for the plants. High activity solid and liquid wastes are permanently disposed of in on-site underground storage containers. Low level liquid wastes are held up as necessary for decay and diluted into the circulating water discharge stream. Gaseous wastes can be compressed and held up for decay and then discharged into a waste disposal stack where they are diluted to tolerable levels by building ventilation or dilution air discharging out the stack.

Conventional auxiliary plant power supply equipment has been provided. Heating, air conditioning, ventilation and plumbing services have also been provided with special consideration given to the possible presence of airborne H^3. Service water for component cooling is supplied to the plants by service water pumps located in the crib house. Also located in the crib house are the normal electric and diesel powered fire pumps for normal and emergency conditions respectively. A diesel powered motor generator located in the crib house supplies emergency power in the event of normal power supply failure. Compressed air is supplied by a normal station air compressor and a control air compressor connected such that, should instrument air supply fail, it can be backed up by station compressed air.

Buildings and Site

Features common to all the boiling D_2O direct cycle plants are the turbine, office and service buildings, the crib house and circulating water systems, switchyard equipment and waste disposal facilities. In addition, because a similar site was used for all the full scale plant designs, it was possible to generalize on the yard features, such as fencing, outdoor fire protection equipment, gate house, parking facilities and oil storage tanks.

The reactor building is a cylindrical vapor tight containment vessel which houses the reactor and its auxiliaries. All primary system equipment within the reactor building is housed in sealed compartments with controlled air flow so that any leakage D_2O can be recovered and tritium contamination of the building minimized.

The turbine buildings are of conventional insulated metal panel construction. Adjacent to, and an integral part of the turbine building, is a similarily constructed office building containing the plant control room, general offices, machine shop, maintenance area, switchgear, locker rooms and storage areas.

Fuel, which is removed from the core remotely in the upper header room by an off-power refueling machine, is transferred out of the reactor building through a vertical chute, into a transfer tunnel beneath the reactor building, and finally into a separate fuel handling building. This building is used to receive and store fresh fuel and to hold up and process spent fuel for shipping.

4.2.2 COST ESTIMATES

Estimates for the capital and operating costs associated with each of the boiling D_2O direct cycle plants using natural uranium metal and natural UO_2 fuel have been prepared and are presented as follows:

Table No.	Plant
	Capital Costs
4.2-II	200 MWe, Metal Fueled
4.2-III	200 MWe, Oxide Fueled
4.2-IV	300 MWe, Metal Fueled
4.2-V	300 MWe, Oxide Fueled
	Capital and Operating Costs
4.2-VI	200 & 300 MWe, Metal & Oxide Fueled

Each of these estimates was prepared using the bases given in Section 3.1 above and constitute the detailed breakdowns of the summary costs reported in DP-480.

The costs for the oxide fueled 200 MWe plant given in Tables 4.2-III and 4.2-VII are based on the full scale plant design previously reported in Reference (2). Since publication of these data, a review of the cost estimate has been made. As a result, two changes were made: the estimated cost of the two steam drums was reduced from $1,800,000 to $600,000, and the net annual fuel cost was reduced from $3,938,000/yr. to $3,336,000/yr. The first of these changes was effected through additional work and consultation by NDA with manufacturers of steam separating equipment; the second includes an improved estimate of the Pu-239 content in the spent fuel and the inclusion of a credit for Pu-240 and Pu-241 which was omitted earlier.

All power costs for the full scale plants are based on the annual generation when operating with a condenser back pressure of 1.5 in. HgA.

TABLE 4.2-II

200 MWe BOILING D_2O PRESSURE TUBE
DIRECT CYCLE POWER REACTOR PLANT
NATURAL U-METAL FUEL

ESTIMATED ENGINEERING AND CONSTRUCTION COSTS

L-Land	$10,000
A-Structures	
I. Ground Improvements	636,000
II. Reactor Plant	4,107,000
III. Turbine-Generator Building	1,276,000
IV. Waste Disposal Building	246,000
V. Fuel Handling Building	312,000
VI. D_2O Distillation Structures	15,000
VII. Circulating Water System Structures	364,000
VIII. Miscellaneous Other Buildings	174,000
Total Structures - "A"	$7,130,000
B-Equipment	
I. Reactor Plant	
1. Reactor Equipment	$11,751,000
2. Auxiliaries	1,105,200
3. Piping	1,302,000
4. Instrumentation	115,000
Total B-I	$14,273,200

Table 4.2-II (Cont.)

II. Turbine-Generator Plant	$14,450,100
III. Crib House	692,700
IV. D_2O Distillation Plant	164,700
V. Waste Disposal System	275,500
VI. Fuel Handling Plant	1,892,800
Total Equipment - "B"	$31,749,000
C-Electrical	
I. Reactor Plant	$853,500
II. Turbine-Generator Plant	2,130,100
III. Crib House	11,000
IV. D_2O Distillation Plant	5,600
V. Waste Disposal System	12,500
VI. Fuel Handling System	9,800
Total Electrical - "C"	$3,022,500
D-Miscellaneous Equipment	
I. Health	$158,300
II. Offices and Locker Rooms	13,000
III. Machine Shop and Store Room	90,000
IV. Fire Protection	1,500
Total Miscellaneous Equipment - "D"	$262,800

Table 4.2-II (Cont.)

Sub-Total (L Plus A to D Inclusive)	$42,174,300
E-Contractor's Overhead and Profit	1,958,900
Sub-Total (L Plus A to E Inclusive)	$44,133,200
F-Contingency - 10%	4,413,300
Sub-Total (L Plus A to F Inclusive)	$ 48,546,500
G-Allowance For Escaltion (3 Years - 4% Per Year) - 12%	5,825,600
Sub-Total (L Plus A to G Inclusive)	$ 54,372,100
H-Top Charges (Engineering, Field Supervision, Interest During Construction, Etc.) - 15%	8,155,800
Total Estimated Cost	$62,527,900

Notes:

1. Personnel training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

TABLE 4.2-III

200 MWe BOILING D_2O PRESSURE TUBE
DIRECT CYCLE POWER REACTOR PLANT
NATURAL UO_2 FUEL

ESTIMATED ENGINEERING AND CONSTRUCTION COSTS

L-Land	$10,000
A-Structures	
I. Ground Improvements	636,000
II. Reactor Plant	4,372,000
III. Turbine-Generator Building	1,276,000
IV. Waste Disposal Building	246,000
V. Fuel Handling Building	312,000
VI. D_2O Distillation Structures	15,000
VII. Circulating Water System Structures	364,000
VIII. Miscellaneous Other Buildings	174,000
Total Structures - "A"	$7,395,000
B-Equipment	
I. Reactor Plant	
1. Reactor Equipment	$11,530,000
2. Auxiliaries	1,105,200
3. Piping	1,302,000
4. Instrumentation	115,000
Total B-I	$14,052,200

Table 4.2-III (Cont.)

II. Turbine-Generator Plant	\$14,450,100
III. Crib House	692,700
IV. D_2O Distillation Plant	164,700
V. Waste Disposal System	275,500
VI. Fuel Handling Plant	1,892,800
Total Equipment - "B"	\$31,528,000
C-Electrical	
I. Reactor Plant	\$853,500
II. Turbine-Generator Plant	2,130,100
III. Crib House	11,000
IV. D_2O Distillation Plant	5,600
V. Waste Disposal System	12,500
VI. Fuel Handling System	9,800
Total Electrical - "C"	\$3,022,500
D-Miscellaneous Equipment	
I. Health	\$158,300
II. Offices and Locker Rooms	13,000
III. Machine Shop and Store Room	90,000
IV. Fire Protection	1,500
Total Miscellaneous Equipment - "D"	\$262,800

Table 4.2-III (Cont.)

Sub-Total (L Plus A to D Inclusive)	$42,218,300
E-Contractor's Overhead and Profit	1,961,500
Sub-Total (L Plus A to E Inclusive)	$44,179,800
F-Contingency - 10%	4,418,000
Sub-Total (L Plus A to F Inclusive)	$48,597,800
G-Allowance for Escalation (3 Years - 4% Per Year) - 12%	5,831,700
Sub-Total (L Plus A to G Inclusive)	$54,429,500
H-Top Charges (Engineering, Field Supervision, Interest During Construction, Etc.) - 15%	8,164,400
Total Estimated Cost	$62,593,900

Notes:

1. Personnel training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

TABLE 4-2-IV

300 MWe BOILING D_2O PRESSURE TUBE
DIRECT CYCLE POWER REACTOR PLANT
NATURAL U-METAL FUEL

ESTIMATED ENGINEERING AND CONSTRUCTION COSTS

L-Land	$10,000
A-Structures	
I. Ground Improvements	636,000
II. Reactor Plant	4,642,000
III. Turbine-Generator Building	1,450,000
IV. Waste Disposal Building	276,000
V. Fuel Handling Building	312,000
VI. D_2O Distillation Structures	15,000
VII. Circulating Water System Structures	414,000
VIII. Miscellaneous Other Buildings	174,000
Total Structures - "A"	$7,919,000
B-Equipment	
I. Reactor Plant	
1. Reactor Equipment	$14,153,000
2. Auxiliaries	1,305,700
3. Piping	1,519,000
4. Instrumentation	115,000
B-I	$17,092,700

Table 4.2-IV (Cont.)

II. Turbine-Generator Plant	$18,639,600
III. Crib House	875,000
IV. D_2O Distillation Plant	164,700
V. Waste Disposal System	319,900
VI. Fuel Handling Plant	2,116,600
Total Equipment - "B"	$39,208,500
C-Electrical	
I. Reactor Plant	$934,500
II. Turbine-Generator Plant	2,485,100
III. Crib House	13,000
IV. D_2O Distillation Plant	5,600
V. Waste Disposal System	12,500
VI. Fuel Handling System	10,500
Total Electrical -"C"	$3,461,200
D-Miscellaneous Equipment	
I. Health	$173,600
II. Offices and Locker Rooms	15,600
III. Machine Shop and Store Room	99,300
IV. Fire Protection	1,800
Total Miscellaneous Equipment - "D"	$290,300

Table 4.2-IV (Cont.)

Sub-Total (L Plus A to D Inclusive)	$50,889,000
E- Contractor's Overhead and Profit	2,262,500
Sub-Total (L Plus A to E Inclusive)	$53,151,500
F-Contingency - 10%	5,315,200
Sub-Total (L Plus A to F Inclusive)	$58,466,700
G-Allowance for Escalation (3 Years - 4% Per Year) - 12%	7,016,000
Sub-Total (L Plus A to G Inclusive)	$65,482,700
H-Top Charges (Engineering, Field Supervision, Interest During Construction, Etc.) - 15%	9,822,400
Total Estimated Cost	$75,305,100

Notes:

1. Personnel training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

TABLE 4.2-V

300 MWe BOILING D_2O PRESSURE TUBE
DIRECT CYCLE POWER REACTOR PLANT
NATURAL UO_2 FUEL

ESTIMATED ENGINEERING AND CONSTRUCTION COSTS

L-Land	$10,000
A-Structures	
I. Ground Improvements	636,000
II. Reactor Plant	4,870,000
III. Turbine-Generator Building	1,450,000
IV. Waste Disposal Building	276,000
V. Fuel Handling Building	312,000
VI. D_2O Distillation Structures	15,000
VII. Circulating Water System Structures	414,000
VIII. Miscellaneous Other Buildings	174,000
Total Structures - "A"	$8,147,000
B-Equipment	
I. Reactor Plant	
1. Reactor Equipment	$13,973,000
2. Auxiliaries	1,305,700
3. Piping	1,519,000
4. Instrumentation	115,000
Total B-1	$16,912,700

Table 4.2-V (Cont.)

II. Turbine-Generator Plant	\$18,639,600
III. Crib House	875,000
IV. D_2O Distillation Plant	164,700
V. Waste Disposal System	319,900
VI. Fuel Handling Plant	2,116,600
Total Equipment - "B"	\$39,028,500
C-Electrical	
I. Reactor Plant	\$934,500
II. Turbine-Generator Plant	2,485,100
III. Crib House	13,000
IV. D_2O Distillation Plant	5,600
V. Waste Disposal System	12,500
VI. Fuel Handling System	10,500
Total Electrical - "C"	\$3,461,200
D-Miscellaneous Equipment	
I. Health	173,600
II. Offices and Locker Rooms	15,600
III. Machine Shop and Store Room	99,300
IV. Fire Protection	1,800
Total Miscellaneous Equipment - "D"	\$290,300

Table 4.2-V (Cont.)

Sub-Total (L Plus A to D Inclusive)	$50,937,000
E-Contractor's Overhead and Profit	2,263,900
Sub-Total (L Plus A to E Inclusive)	$53,200,900
F-Contingency - 10%	5,320,100
Sub-Total (L Plus A to F Inclusive)	$58,521,000
G-Allowance for Escalation (3 Years - 4% Per Year) - 12%	7,022,500
Sub-Total (L Plus A to G Inclusive)	$65,543,500
H-Top Charges (Engineering, Field Supervision, Interest During Construction, Etc.) - 15%	9,831,500
Total Estimated Cost	$75,375,000

Notes:

1. Personnel training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

TABLE 4.2-VI
CAPITAL AND OPERATING COSTS FOR 200 AND 300 MWe BOILING-D_2O
DIRECT CYCLE, PRESSURE TUBE REACTOR PLANTS

Nominal Plant Capacity	200 MWe (Annual Generating Capacity 1530 x 10^6 kwh)						300 MWe (Annual Generating Capacity 2103 x 10^6 kwh)					
Fuel Material	Natural U-Metal			Natural UO_2			Natural U-Metal			Natural UO_2		
Design Burnup MWD/metric ton-U	4800			7500			5100			8500		
Refueling Scheme	100% batch			4-zone			100% batch			4-zone		
	Invest. $\$10^6$	Ann. Cost, $\$10^6$/yr.	Power Cost, mills/kwh	Invest. $\$10^6$	Ann. Cost, $\$10^6$/yr.	Power Cost, mills/kwh	Invest. $\$10^6$	Ann. Cost, $\$10^6$/yr.	Power Cost, mills/kwh	Invest. $\$10^6$	Ann. Cost $\$10^6$/yr.	Power Cost mills/kwh
Investment												
Reactor plant	33.827	4.781	3.125	33.893	4.784	3.125	42.616	5.945	2.732	42.686	5.955	2.735
Turbine plant	28.040	3.886	2.539	28.040	3.886	2.539	31.865	4.460	2.220	31.865	4.460	2.220
Miscellaneous buildings and equipment	0.661	0.093	0.061	0.661	0.093	0.061	0.824	0.125	0.055	0.824	0.125	0.055
Sub-total	62 528	8.760	5.725	62.594	8.763	5.725	75.305	10.530	5.007	75.375	10.540	5.010
D_2O inventory	13.460	1.680	1.100	17.843	2.230	1.460	19.150	2.390	1.140	23.150	2.890	1.377
Total investment	75.988	10.440	6.825	80.437	10.993	7.185	94.455	12.920	6.147	98.525	13.430	6.387
Operation and Maintenance												
Fuel												
Inventory		0.106	0.069		0.134	0.088		0.151	0.072		0.184	0.087
Non-nuclear inventory		0.197	0.129		0.636	0.416		0.279	0.133		0.873	0.420
Replacement		2.279	1.490		2.566	1.675		3.088	1.471		3.140	1.490
Total fuel costs		2.582	1.688		3.336	2.179		3.518	1.676		4.197	1.997
Heavy water												
Losses		0.270	0.176		0.356	0.233		0.384	0.183		0.463	0.220
Dist. plant operation		0.006	0.004		0.006	0.004		0.008	0.004		0.008	0.004
Total D_2O costs		0.276	0.180		0.362	0.237		0.392	0.187		0.471	0.224
Operating payroll		0.610	0.399		0.610	0.399		0.715	0.339		0.715	0.339
Maintenance labor and material		0.406	0.265		0.406	0.265		0.510	0.243		0.510	0.243
Supplies		0.140	0.092		0.140	0.092		0.175	0.083		0.175	0.083
Insurance		0.490	0.320		0.490	0.320		0.570	0.271		0.570	0.271
Total Operation and Maintenance		4.504	2.944		5.344	3 492		5.880	2.799		6.638	3.157
Total Capital and Operating Costs		14.944	9.769		16.337	10.677		18.800	8.946		20.068	9.544

4.3 REHEAT CYCLE

The turbine steam conditions for the 200 MWe boiling D_2O direct cycle plant (750 psig, saturated) are such that a large exhaust area is required in the turbine to handle the exhaust flow. The size of the turbine exhaust blading restricts the choice of turbines to low speed machines. An 1800 rpm unit was selected for the direct cycle plant for this reason.

If the steam is reheated prior to entering the low pressure turbine, the removal of moisture and the increase in internal energy of the steam makes it possible to use a turbine with a smaller exhaust area, and a 3600 rpm turbine becomes feasible. In addition, the cycle efficiency may be improved.

Potentially, economic benefits of the reheat cycle arise from three considerations:

a) A lower plant heat rate.

b) The capital investment for a 3600 rpm turbine-generator is less than for an 1800 rpm turbine of equal rating.

c) The elimination of moisture in the low pressure steam makes it feasible to eliminate moisture removal stages in the low pressure cylinder, effecting a further reduction in capital investment for the turbine.

The foregoing benefits must be compared to the additional investment required for the steam reheaters, drain pumps, piping, additional D_2O inventory, and decreased efficiency of the 3600 rpm turbine. Therefore, a study was conducted to evaluate the economics of several possible arrangements of reheaters and turbines. The study included analysis of the cycles, development of plant arrangement drawings, and preparation of cost estimates to determine the difference in costs between this plant and the direct cycle, non-reheat plant.

4.3.1 SELECTION OF OPERATING CONDITIONS

For purposes of comparison with the non-reheat cycle, identical design operating conditions of the reactor were used in each of the cycles evaluated. Thus, the power input to the coolant was assumed to be 2.506×10^9 Btu/hr., and the reactor steam conditions were 750 psig, saturated. Steam flow and reactor inlet temperature were adjusted to accommodate the differences in turbine cycle performance.

Other conditions that were assumed are as follows:

a. The temperature of the reheated steam was set at 480 F in all cases.

b) The feed water heating cycles each consisted of four heaters, with the same temperature rises and pressures in corresponding heaters. Final feed water temperatures of 387 F were used in all cases.

c) Reheat was introduced between the high and low pressure cylinders of the turbine in each case.

d) A turbine condenser pressure of 3.5 in. HgA was assumed.

4.3.2 ALTERNATE REHEAT CYCLES

The analysis was conducted for five reheat cycles, each of which was compared to the 200 MWe non-reheat cycle plant described elsewhere in this report. For purposes of comparison, then, a total of six cycles was evaluated, as shown in simplified form in Figure 4.3.2-1:

a) Direct cycle, non-reheat plant, with a TCDF-38 in., 1800 rpm turbine of nominal 200 MWe capacity, which served as the base cycle.

b) Single stage reheat utilizing reactor steam as the source of heat, with a TC4F-23 in., 3600 rpm turbine.

c) Two-stage reheat using extraction steam in the first stage and primary steam in the second stage with a TCDF-38 in., 1800 rpm turbine.

d) A cycle similar to (c), but using the turbine described in (b).

e) Two-stage reheat, with a moisture removal stage preceding the reheaters. In this cycle, the extracted moisture is discharged to a feed water heater, and extraction steam and primary steam provide heat for the first and second stages of reheat respectively. The turbine is a TCDF-38 in., 1800 rpm machine.

f) A cycle similar to (e) but using a turbine as described in (b).

The results of calculations of the performance of each cycle are presented in Table 4.3.2-I. The conclusions formulated from these figures may be summarized as follows:

a). For a given turbine, the cycle utilizing two stages of reheat with moisture separation preceding the first stage results in the most efficient cycle.

b) For a given cycle, the use of an 1800 rpm turbine results in the most efficient plant.

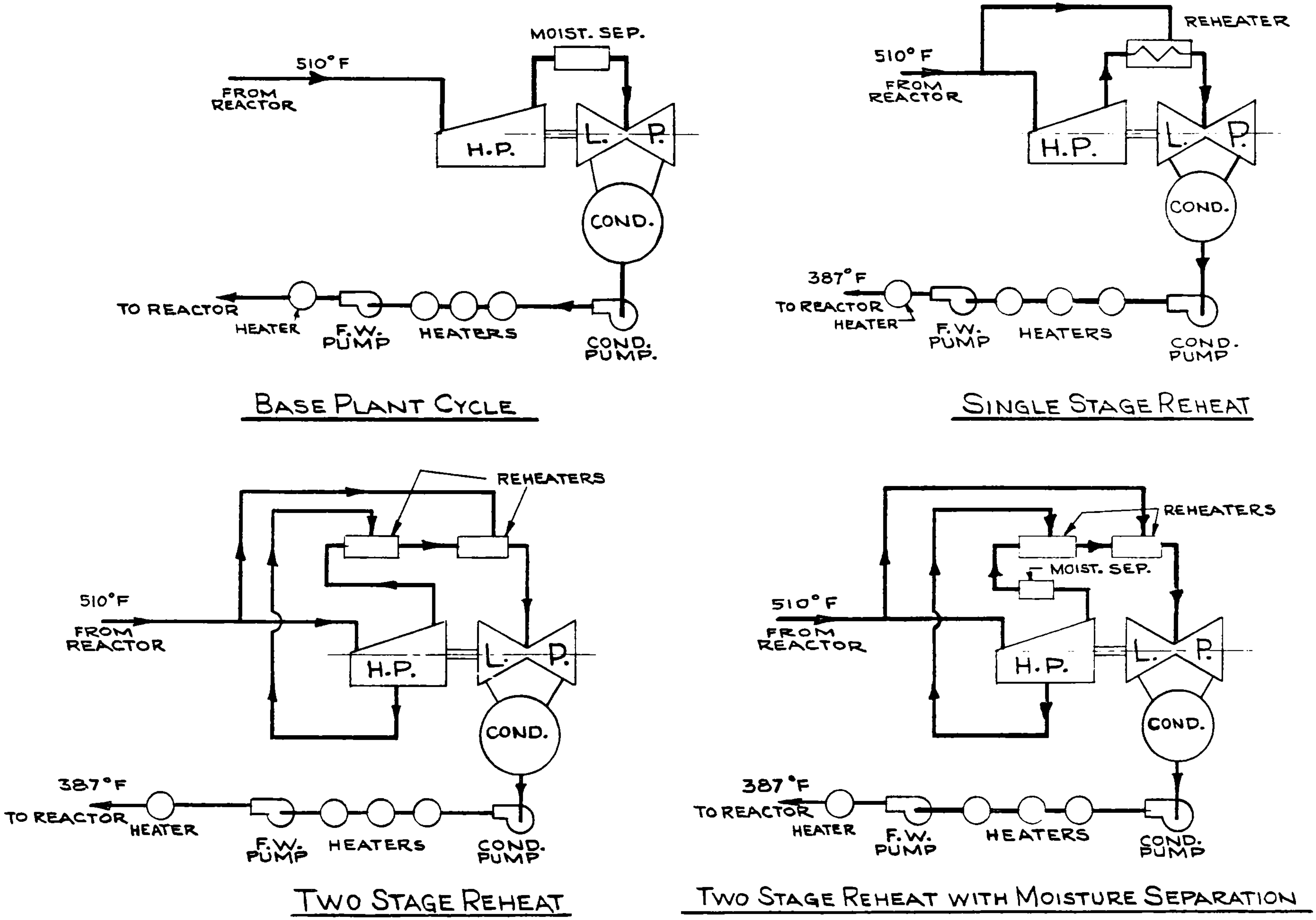


FIG. 4.3.2-1 SIMPLIFIED FLOW DIAGRAMS-REHEAT CYCLE ANALYSIS

TABLE 4.3.2-I
TURBINE HEAT RATES FOR REHEAT CYCLES
200 MWe BOILING D_2O PRESSURE TUBE DIRECT CYCLE REACTOR PLANT

	(a)	(b)	(c)	(d)	(e)	(f)
Turbine Type	TCDF-38" 1800 rpm Nonreheat	TC4F-23" 3600 rpm 1 stage reheat	TCDF-38" 1800 rpm 2 stage reheat	TC4F-23" 3600 rpm 2 stage reheat	TCDF-38" 1800 rpm Ext. Moist. Removal and 2 stage reh.	TC4F-23" 3600 rpm Ext. Moist. Removal and 2 stage reh.
Throttle Pressure, psig	750	750	750	750	750	750
Steam Temperature, F	510	510/480	510/480	510/480	510/480	510/480
Number of Feed Water Heaters	4	4	4	4	4	4
Gross Generation, kw	220,000	210,050	224,886	217,130	227,240	219,300
Gross Gen. Over Base, kw	Base	-9,950	+4,886	-2,870	+7,240	-700
Throttle Flow, lb/hr.	3,270,500	2,765,920	3,101,430	3,099,900	3,101,590	3,100,000
Condenser Flow, lb/hr.	1,882,570	1,953,660	1,910,520	1,920,800	1,899,930	1,910,570
Turbine Heat Rate, Btu/kwh	11,397	11,933	11,149	11,544	11,031	11,426
Turbine Heat Rate Over Base, Btu/kwh	Base	+536	-248	+147	-366	+29
Reactor Heat Input, Btu/hr.	2.506×10^9	2.506×10^9	2.506×10^9	2.506×10^9	2.506×10^9	2.506×10^9
Reactor Flow, lb/hr.	3,270,500	3,371,390	3,308,700	3,307,890	3,307,630	3,306,820

Assumptions: Constant reactor heat input, constant feed water heater pressure and temperature rise, and cond. vac. at 3.5 in. HgA.

c) The cycles with the greatest potential from the point of view of thermal efficiency are those using the 1800 rpm turbine. However, cycle (f), with a 3600 rpm turbine and two reheat stages with moisture separation preceding the first stage is marginal in this respect.

4.3.3 ECONOMIC ANALYSIS

The costs of the various reheat cycles were compared on the basis of the direct cycle non-reheat plant. For purposes of this analysis, the estimated change in investment for equipment was compared to the change in investment that could be justified on the basis of the change in plant heat rate. The investment required for the turbine reheaters and pumps was evaluated using preliminary estimates, and all other charges for buildings, reactor equipment, etc., were assumed to be equal for all plants. The worth of a change in plant heat rate of one Btu per kwh was determined from a fuel cost of 2.3 mills/kwh, an annual fixed charge rate on investment of 14%, and a load factor of 80%. These figures result in a capitalized worth of $1,820 per Btu per kwh reduction in heat rate.

The results of the analysis are presented in Table 4.3.3-I. Cycle (f), using two stage reheat, moisture separation and the 3600 rpm turbine shows a net capitalized gain, of about $603,000, indicating that the reduction in turbine price is more than sufficient to offset the additional cost of the reheater and the increase in heat rate.

The first three cycles, (b), (c), and (d), were eliminated from further consideration for the following reasons:

Cycle (b) The reduction in estimated turbine cost is insufficient to offset the additional cost of the reheat equipment and the increase in fuel cost attributable to the increase in turbine heat rate.

Cycle (c) The reduction in fuel cost resulting from a more efficient cycle does not balance the additional costs of reheat equipment, and a reheat turbine.

In addition, it has been found that although a two-stage reheat cycle is more efficient than a single stage reheat cycle, the total cost of the two-stage reheat equipment is almost double that of the single stage reheat equipment. The energy exchange in the first stage reheater is approximately 66% of the total heat load of the single stage reheater. As a result, each stage of the two-stage reheater approaches the physical size of the single stage reheat unit.

TABLE 4.3.3-I
COST SUMMARY FOR REHEAT CYCLES
200 MWe BOILING D_2O PRESSURE TUBE DIRECT CYCLE REACTOR PLANT

	(a)	(b)	(c)	(d)	(e)	(f)
Turbine Type	TCDF-38" 1800 rpm Nonreheat	TC4F-23" 3600 rpm 1 stage reheat	TCDF-38" 1800 rpm 2 stage eheat	TC4F-23" 3600 rpm 2 stage reheat	TCDF-38" 1800 rpm Ext. Moist. Removal and 2 stage reh.	TC4F-23" 3600 rpm Ext. Moist. Removal and 2 stage reh.
Turbine Heat Rate Over Base	--	+536 Btu/kwh	-248 Btu/kwh	+147 Btu/kwh	-366 Btu/kwh	+29 Btu/kwh
Cost Diff. of Turbine Over Base	--	-$1,346,820	+$457,980	-$1,177,420	+$485,280	-$1,155,320
Cost of Reheaters	--	$820,000	$1,443,000	$1,443,000	$479,400	$479,400
Cost of Reheater Drain Pumps	--	$30,000	$20,000	$20,000	$20,000	$20,000
Cost of Moist. Separators	--	--	--	--	Incl. in Turb. Price	Incl. in Turb. Price
Justified Capital Invest. Due to Change in Heat Rate	--	-$975,000	+$451,000	-$268,000	+$666,000	-$52,800
Net Capitalized Gain	--	-$478,180	-$1,469,980	-$553,580	-$318,680	+603,120

a) Based on annual worth of 1 Btu/kwh = $255/yr.

b) Justified capital investment at 14% - $1,820 per Btu/kwh

c) Fuel cost for natural uranium - 2.30 mills/kwh
Annual generation at 80% load factor

Cycle (d) The reduction in estimated turbine cost is insufficient to offset the additional cost of the reheat equipment and the increase in fuel cost attributable to the increase in turbine heat rate.

In view of their apparent advantages, more definitive investigations of the two-stage reheat cycles with moisture separation preceding the first stage were conducted.

A performance diagram of the plant with the 1800 rpm turbine is shown on Dwg. HB-470. Dwg. HB-473 is a similar diagram for the 3600 rpm turbine plant.

The turbine building for the base plant is adequate for the installation of the turbine and reheat equipment for both reheat cycles. The arrangement of the turbine plant for the 1800 rpm turbine is shown in plan on Dwgs. NS-470 and 471. The reheaters and the moisture separators are located on the main floor adjacent to the turbine. An elevation of the plant is shown on Dwg. NS-472. Similar studies of the 3600 rpm turbine plant are shown on Dwgs. NS-473, 474 and 475. As in the case of the 1800 rpm turbine, the space on the main floor near the turbine is adequate for installation of the reheat equipment.

A summary of the estimated increments in investment for the two reheat plants, based on estimated equipment and construction costs, operating costs and D_2O inventories is presented in Table 4.3.-II. The equipment costs in this table are estimates of the cost of material and labor for installing the reheaters and associated pumps and piping. The turbine cost is shown as a differential, with the direct cycle non-reheat turbine plant as base. The effects of indirect costs; i.e., 10% for contingencies, 12% for escalation and 15% for top charges, have also been included. The change in turbine heat rate is treated as a capitalized fuel cost differential, on the basis of an annual capital cost of 14%. A fuel cost of 2.3 mills/kwh was used. This is the estimated fuel cost for the 200 MWe boiling D_2O direct cycle nonreheat plant.

The D_2O inventory of the reheat cycle is larger than that of the nonreheat cycle plant by the amount of D_2O condensate in the reheater water boxes and associated pumps and piping. The difference is indicated in Table 4.3.3-II as an increment in capital investment of about \$182,000.

As shown in Table 4.3.3-II, the cycle utilizing the 1800 rpm turbine requires an increase in investment for the turbine, reheat equipment and D_2O which is only partially offset by the decrease in heat rate. The increment in annual cost attributed to the increased capital investment is \$254,800 per year. The reduction in fuel cost resulting from the improved heat rate for this cycle is approximately \$93,000/yr., with a net increase in energy cost of 0.112 mills/kwh over that of the direct cycle, nonreheat plant.

TABLE 4.3.3-II

ECONOMIC EVALUATION

200 MWe BOILING D_2O PRESSURE TUBE DIRECT CYCLE REACTOR PLANT

Turbine Type	TCDF-38" 1800 Rpm Non-reheat	TCDF-38" 1800 Rpm Ext. Moist. Removal and 2-Stage Reheat	TC4F-23" 3600 Rpm Ext. Moist. Removal and 2-Stage Reheat
Turbine Cost Differential	Base	+$485,300	-$1,155,300
Reheaters	--	479,400	479,400
Reheater Drain Pumps	--	20,000	20,000
Piping & Erection	--	187,000	187,000
Total Direct Construction Cost Differential	Base	+$1,171,700	-$ 468,900
Total Diff. Cost after 10% Cont., 12% Allow. for Escalation and 15% for Top Charges		+$1,660,000	-$ 664,000
D_2O Inventory Differential	Base	+ 182,000	+ 182,000
Capitalized Fuel Cost Differential	Base	- 666,000	+ 52,800
Net Capitalized Differential	Base	+$1,176,000	-$ 429,200
Net Differential Cost, mills/kwh	Base	+0.112	-0.0415

The total construction cost of the 3600 rpm reheat turbine and reheat equipment is approximately $664,000 less than that of the nonreheat base plant. The increase in D_2O inventory, however, results in a net reduction in annual capital cost of $70,000. This when combined with an increase in annual fuel costs attributable to the increased heat rate, results in a net reduction in energy cost of 0.042 mills/kwh.

4.4 ALTERNATE METHODS OF HEAT DISSIPATION FOR THE BOILING PROTOTYPE PLANT

A study has been made to evaluate the economy of using a dual energy dissipating scheme in the boiling direct cycle prototype plant. The design provides for the generation of a nominal 25 MWe net in lieu of the 70 MWe as presently envisaged, with the excess reactor power dissipated using a heat sink.

The design provides for diverting 60% of the prototype reactor primary D_2O steam, at 515 F and 795 psia to an evaporator and subcooler where it is used to generate 4.51 x 10^5 lb/hr. of saturated H_2O steam at 200 psig. The operating features of this system are given in the performance diagram, Figure 4.4-1. The coolant and operating conditions of the reactor are identical to those of the 70 MWe boiling prototype described in Section 4.1 and Reference (3). The primary D_2O returning to the reactor from both the turbine cycle and the H_2O steam generating facility are at 387 F, similar to the feed water return temperature in the prototype plant.

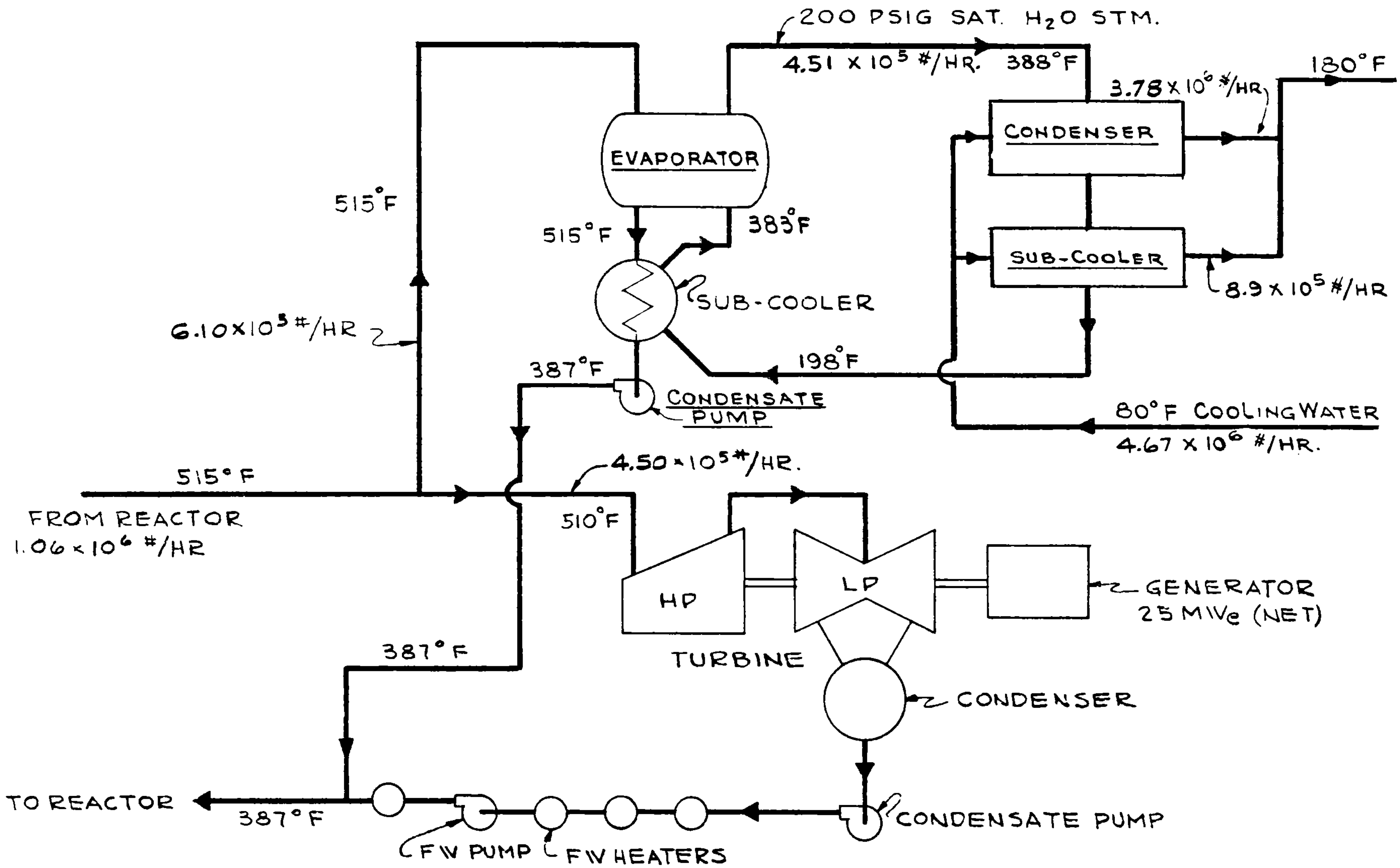
The plant general arrangements are shown on Dwg. NP-490. Except for the addition of the H_2O steam generating equipment in a shielded room adjacent to the upper header room the reactor building is identical to that provided for the 70 MWe prototype.

The turbine plant, shown in Dwg. NP-490, provides for the generation of 25 MWe net. All the turbine plant equipment, except for size, is similar both in design and in number of components to that of the 70 MWe plant. The turbine building is also similar in construction to that of the 70 MWe unit.

4.4.1 HEAT SINK CONSIDERATIONS

Two modes of dissipating heat were examined: air cooled and water cooled heat exchangers. In both cases, 4.51 x 10^5 lb/hr. of saturated 200 psig H_2O steam, generated as an expedient to minimize D_2O inventory, is condensed at 388 F and then subcooled to return to the D_2O subcooler at 198 F.

Table 4.4-I gives the design features and comparative economics of the two schemes considered. Because of its advantage both in capital cost and in operating expense, the water cooled heat exchangers were selected for detailed examination.



PROTOTYPE ~ ALTERNATE DISSIPATION CYCLE

FIG. 4.4-1

TABLE 4.4-I

COMPARISON OF AIR COOLED AND WATER COOLED HEAT SINK CHARACTERISTICS

	Air Cooled	Water Cooled
Steam Flow to Heat Sink, #/hr.	4.51×10^5	4.51×10^5
Inlet Sat'd Steam Pressure, psig	200	200
Feed Water Outlet Temperature, F	387	387
Heat Sink Pumping Power Req'd, H.P.	700	100
Capital Cost of Heat Exchange Equipment, exclusive of Piping and Structures, $	223,000	96,000

Water Cooled Heat Sink

As shown on Dwg. NP-490, the circulating water cooled condenser and subcooler have been located on a concrete pad adjacent to the plant crib house equipment. In order to provide heat dissipation, 4.67×10^6 lb/hr. of circulating water enters the condenser and subcooler, which are connected in parallel, at an average temperature of 80 F. The circulating water leaves these units at 180 F to return to the river through the circulating water discharge flume.

As a result of the decreased power plant capacity, from 69.1 MWe to 26.7 MWe, the two main condenser circulating pump capacities have been reduced from 37,500 gpm to 15,000 gpm each, thereby providing a reduction in the circulating water pumping requirements and piping costs. This reduction is partially offset by the cost of two additional pumps with a capacity of 5,000 gpm each to provide cooling water flow for the heat sink.

4.4.2 ECONOMICS

A comparison of the capital costs for the 70 MWe and the 25 MWe Heat Sink plants is given in Table 4.4-II. The capital and operating cost comparison is given in Table 4.4-III. If it is assumed that a credit of 6 mills/kwh is applied to the net electric power produced when the plant is operated at an 80% load factor, then the two plants may be compared, on the basis of net annual expenditure, as follows:

	70 MWe Prototype	25 MWe-Heat Sink Prototype
Ann. Plant Capital and Operating Cost, \$/yr. (10^6)	8.955	7.951
Ann. Generation @ 0.8 L.F. , kwh	484×10^6	187×10^6
Ann. Income From Sale of Power @ 6 mills/kwh, \$/yr. (10^6)	2.904	1.122
Net. Ann. Cost of Plant, \$/yr. (10^6)	6.051	6.829

TABLE 4.4-II
COMPARISON OF CAPITAL COST ESTIMATES
70 MWe BOILING PROTOTYPE AND 25 MWe - HEAT SINK,
BOILING PROTOTYPE

	70 MWe Prototype	25 MWe-Heat Sink Prototype
L-Land	$20,000	$20,000
A-Structures		
Ground Improvements	544,500	544,500
Reactor Plant	2,009,900	2,068,100
Turbine-Generator Building	720,000	230,000
Waste Disposal Building	210,500	210,500
Fuel Handling Building	215,000	215,500
D_2O Distillation Structures	15,000	15,000
Circulating Water System Structures	187,000	175,000
Miscellaneous Other Buildings	148,300	148,300
Total Structures - "A"	$4,050,200	$3,606,900
B-Equipment		
Reactor Plant		
1. Reactor Equipment	6,667,000	6,667,000
2. Auxiliaries	358,750	511,950
3. Piping	586,500	641,500
4. Instrumentation	200,000	210,000
Total B-I	$7,812,250	$8,030,450

Table 4.4-II (Cont.)

	70 MWe Prototype	25 MWe-Heat Sink Prototype
Turbine-Generator Plant	\$5,903,120	\$2,462,000
Crib House	255,500	351,500
D_2O Distillation Plant	136,680	136,680
Waste Disposal System	206,480	206,480
Fuel Handling Plant	1,241,110	1,241,110
Total Equipment - "B"	\$15,555,140	\$12,428,220
C-Electrical		
Reactor Plant	646,100	648,100
Turbine-Generator Plant	1,145,800	756,900
Crib House	11,000	16,000
D_2O Distillation Plant	Incl. C-VI	Incl. C-VI
Waste Disposal System	11,100	11,100
Fuel Handling Plant	11,700	11,700
Total Electrical - "C"	\$1,825,700	\$1,443,800
D-Miscellaneous Equipment		
Health	127,250	127,250
Offices and Locker Rooms	10,000	10,000
Machine Shop and Store Room	64,500	64,500
Fire Protection	1,200	1,200
Total Miscellaneous Equipment - "D"	\$202,950	\$202,950
Sub-Total (L Plus A to D Inclusive)	\$21,653,990	\$17,701,870

Table 4.4-II (Cont.)

	70 MWe Prototype	25 MWe-Heat Sink Prototype
E-Contractor's Overhead and Profit	$ 1,056,000	$ 862,000
Sub-Total (L Plus A to E Inclusive)	22,709,990	18,563,870
F-Contingency - 10%	2,271,010	1,856,387
Sub-Total (L Plus A to F Inclusive)	$24,981,000	$20,420,257
G-Allowance For Escalation (3 Years - 4% Per Year) - 12%	3,000,000	2,450,000
Sub-Total (L Plus A to G Inclusive)	$27,981,000	$22,870,257
H-Top Charges		
Professional Services		
1. Reactor Design	$3,350,000	$3,350,000
2. Reactor and Turbine Systems and Plant	1,750,000	1,435,000
Other Charges (Purchasing, Field Supervision, Interest During Construction, Etc.) - 10%	2,798,000	2,287,000
Total Top Charges- "H"	$ 7,898,000	$ 7,072,000
Total Estimated Cost	$35,879,000	$29,942,257

Notes:

1. Personnel training and preliminary operating expenses are not included.
2. D_2O Inventory is not included.

TABLE 4.4-III

COMPARISON OF CAPITAL AND OPERATING COSTS

70 MWe BOILING PROTOTYPE AND 25 MWe-HEAT SINK BOILING PROTOTYPE

Plant	70 MWe Prototype			25 MWe-Heat Sink		
Annual Generation @ 0.8 L.F., kwh	484×10^6			187×10^6		
	Invest. $\$10^6$	Ann. Cost $\$10^6$/yr.	Power Cost mills/kwh	Invest. $\$10^6$	Ann. Cost $\$10^6$/yr.	Power Cost mills/kwh
Investment						
Plant	35.879	5.023	10.400	29.942	4.192	22.400
D_2O Inventory	10.250	1.281	2.650	9.052	1.132	6.050
Total Investment	46.129	6.304	13.050	38.994	5.324	28.450
Operation and Maintenance						
Total Fuel Cost		1.552	3.210		1.552	8.300
D_2O - Costs						
Losses		0.205	0.424		0.181	0.970
Dist. Plant Operation		0.004	0.008		0.004	0.022
Total D_2O Costs		0.209	0.432		0.185	0.992
Operating Payroll		0.450	0.930		0.450	2.405
Maint. Labor and Material		0.210	0.434		0.210	1.120
Supplies		0.050	0.103		0.050	0.267
Insurance		0.180	0.372		0.180	0.963
Total Operation and Maint.		2.651	5.481		2.627	14.047
Total Capital and Operating Costs		8.955	18.531		7.951	42.497

5.0 PRESSURIZED D_2O COOLED REACTOR PLANTS

To establish the current economic status of the liquid D_2O cooled and moderated power reactors for Report DP-480, cost estimates were prepared for these plants using both pressure vessel and pressure tube type reactors fueled with either natural UO_2 or natural U-metal. These estimates are for plants of 200 and 300 MWe capacity.

For comparative purposes, plant designs and cost estimates were prepared for a 70 MWe natural U-metal prototype of each of the pressurized D_2O cooled reactor concepts. These prototype plants compare, both in capacity and in design detail, with the 70 MWe boiling D_2O cooled prototype plant. However, unlike the UO_2 fueled boiling prototype plant, they do not necessarily correspond to a minimum size for natural uranium operation.

All costs presented in this section were established using the bases given in Section 3.1 above.

5.1 PROTOTYPE REACTOR PLANTS

The prototype, pressurized D O reactor plants consist of a uranium metal fueled, pressurized D_2O cooled pressure tube or pressure vessel reactor, whose heat is used in an indirect cycle to generate light water steam for a nominal 70 MWe turbine-generator. Each plant includes a reactor containment building, a turbine building and crib house, as well as fuel handling and waste disposal facilities and other systems necessary for commercial operation as a power plant.

The pertinent operating and design characteristics of both the pressure vessel and pressure tube reactor plants are summarized in Table 5.1-I. A detailed description of each plant is presented in the succeeding sections.

The designs for each of the liquid cooled reactors are based on design data and arrangements established by du Pont (Ref. 6) for 100 MWe size plants. The reactors herein reported use this data, however, scaled down to correspond to a plant size of 70 MWe. One change was made in the design arrangement of the pressure tube unit. Du Pont's design uses insulated pressure tubes which pass through a stainless steel vessel. The pressure tube, liquid cooled reactor described in Section 5.1.3.1 employs Zr-2 pressure tubes which pass through an aluminum calandria. An air gap between the pressure tube and calandria tube serves as thermal insulation in this design. In accordance with this change, appropriate allowance was made in the cost estimate for the reactor.

5.1.1 Pressure Vessel Prototype Plant

The pressurized D_2O pressure vessel plant provides 1.135×10^6 lbs/hr. of saturated light water steam at 160 psia to a turbine-generator

TABLE 5.1-I
70 MWe PRESSURIZED D_2O REACTORS
CHARACTERISTICS AND PARAMETERS

A. CYCLE PERFORMANCE	Pressure Vessel	Pressure Tube
1. Total thermal power, MW	305	298
2. Power to coolant, MW	305	276
3. Heat generation in moderator, MW	-	22
4. Gross generator output, MW	73.3	74.4
5. Auxiliary power, MW	4.5	4.6
6. Net generator output, MW	68.8	69.8
7. Net plant heat rate, Btu/kwh	15,100	14,550
8. Net plant efficiency, %	22.5	23.4
B. TURBINE CONDITIONS		
1. Type	23 in.-TCDF	23 in.-TCDF
2. Speed, rpm	3600	3600
3. Throttle pressure, psia	160	277
4. Throttle temperature, F	363.5	410.1
5. Throttle steam flow rate, lbs/hr.	1.135×10^6	1.055×10^6
C. REACTOR DESCRIPTION		
1. Pressure Vessel or Calandria	Vessel	Calandria
a. Inside diameter, ft.	13.05	13.83
b. Inside height, ft.	31.80	12.50
c. Wall thickness, in.	2.50	1.0
d. Head thickness, in.	7.125 & 5.00	3.0
e. Material	SA-302 Gr. B-C.S	5052-0 Al
f. Stainless steel liner thickness, in.	0.125	---
g. Weight, tons	91	8
h. Design pressure, psig	620	8
2. Core Geometry		
a. Active diameter, ft.	10.05	11.83
b. Active height, ft.	14.25	10.00
c. Active core volume, ft^3	1130	1100
d. Lattice spacing, in.	6.5	7.8
e. Number of fuel positions	250	236
f. Fuel volume, ft^3 uranium	34.6	23
3. Reflector		
a. Reflector material	D_2O	D_2O
b. Axial thickness, ft.	1.0	1.0
c. Radial thickness, ft.	1.0	1.0
d. Reflector volume, ft^3	1030	700

Table 5.1-I (Cont.)

Reactor Description, Cont.	Pressure Vessel	Pressure Tube
4. Calandria Tubes		
a. Material	--	5052-0 Al
b. Inside diameter, in.	--	4.375
c. Outside diameter, in.	--	4.500
d. Length, ft.	--	13.0
e. Total weight of tubes, lbs.	--	3240
5. Pressure or Housing Tubes		
a. Material	Zircaloy-2	Zircaloy-2
b. Inside diameter, in.	2,900	2,900
c. Outside diameter, in.	2,960	3,272
d. Length, ft.	17.25	29.00
e. Total weight of tubes, lbs.	3800	34,400
6. Fuel Elements		
a. Fuel configuration	Hol. Cyl.	Hol. Cyl.
b. Fuel material	U-2w/oZr	U-2w/oZr
c. Cladding material	Zircaloy-2	Zircaloy-2
d. Fuel clad OD, in.	2.060	2.060
e. Fuel clad ID, in.	1.467	1.467
f. Cladding thickness, in.	0.015	0.015
g. Fuel OD, in.	2.030	2.030
h. Fuel ID, in.	1.497	1.497
i. Fuel element length (active), ft.	14.25	10,00
j. Number of fuel elements	250	236
k. Heat transfer area, ft^2	3290	2180
l. Average heat flux, $Btu/hr\text{-}ft^2$	3.16×10^5	4.67×10^5

D. MATERIAL INVENTORIES

	Pressure Vessel	Pressure Tube
1. Uranium, metric tons	18.15	12.00
2. Zircaloy in cladding, lbs.	1705	1092
3. Zircaloy in pressure or housing tubes, lbs.	3860	34,400
4. Aluminum in calandria, lbs.	--	19,390
5. D_2O in reflector, metric tons at 70 F	32.26	22.00
6. D_2O in moderator, metric tons at 70 F	29.52	23.80
7. D_2O in coolant channels, metric tons at 70 F	3.85	19.20
8. D_2O shields, metric tons at 70 F	10.87	--
9. Total D_2O in reactor, metric tons at 70 F	76.50	65.00
10. D_2O in coolant piping, metric tons at 70 F	18.20	17.40

Table 5.1-I Cont.

Material Inventories, Cont.	Pressure Vessel	Pressure Tube
11. D_2O in steam generators, metric tons at 70 F	14.40	13.28
12. D_2O in moderator cooling system, metric tons at 70 F	--	10.23
13. D_2O in other systems, metric tons at 70 F	8.76	10.07
14. D_2O in storage, metric tons at 70 F	5.64	5.55
15. Total plant D_2O, metric tons at 70 F	123.5	121.5
E. CYCLE CONDITIONS		
1. Coolant pressure, psia	562	790
2. Coolant outlet temperature, F	450	490
3. Coolant inlet temperature, F	402	446
4. Coolant flow rate, lbs/hr.	19.75×10^6	18.8×10^6
5. Moderator pressure, psia	562	14.7
6. Moderator outlet temperature, F	406	130
7. Moderator inlet temperature, F	402	110
8. Moderator flow rate, lbs/hr.	19.75×10^6	3.69×10^6
9. Steam pressure, psia	160	277
10. Steam temperature, F	363.5	410.1
11. Steam flow rate, lbs/hr.	1.135×10^6	1.055×10^6
12. Feed water temperature, F	310	333
13. Specific power, kw/kgU	16.80	24.80
F. CONTAINMENT BUILDING		
1. Diameter, ft.	90	100
2. Height, ft.	158	157
3. Gross volume, ft^3	8.60×10^5	10.36×10^5
4. Net free volume, ft^3	6.02×10^5	7.57×10^5
5. Liquid contributing to pressure rise, lbs.	2.042×10^5	$.893 \times 10^5$
6. Equivalent liquid resulting from Zr-2 reaction, lbs.	0.166×10^5	0.0325×10^5
7. Total pressure rise (design), psig	36	18.3
8. Plate thicknesses		
a. Cylinder, in.	1.375	0.875
b. Dome, in.	0.750	0.500
c. Base, in.	1.375	0.875

nominally rated at 70 MWe. The steam is generated in two vertical steam generators utilizing heat from 19.75 x 10^6 lbs/hr. of D_2O reactor coolant which is pressurized to 562 psia to prevent boiling and leaves the reactor at 450 F. A heat balance for the cycle is shown on Dwg. HB-429. The plant heat rate for these conditions is 15,100 Btu/kwh, representing an overall thermal efficiency of 22.5%.

5.1.1.1 Reactor

The reactor consists of a vertical pressure vessel in which is mounted, between upper and lower neutron shield tanks, a core of 250 parallel fuel elements.

Heavy water acts as both a coolant and a moderator; first flowing around the individual fuel housings as a moderator before entering the fuel housings and flowing through them as a coolant.

The coolant-moderator, flowing at a rate of 19.75 x 10^6 lbs/hr. and a pressure of 562 psia, enters the vessel above the lower neutron shield at 402 F, flows upward outside the fuel housings in the moderator and internal thermal shield regions, and passes through the upper neutron shield tank where it reverses direction and flows down through the fuel channels as coolant. The average moderator temperature is 406 F. The D_2O then discharges from the fuel housing tubes into a plenum below the lower neutron shield tank and leaves the bottom of the vessel at 450 F.

Pressure Vessel

The reactor pressure vessel is fabricated of carbon steel and is internally clad with stainless steel. It has an inside diameter of 13.05 ft., an inside height of 31.8 ft., and a shell thickness of 2.625 in. The top head has a thickness of 7.25 in. and the bottom head 5.125 in. The above thicknesses are based on the use of SA-302-Grade B carbon steel at a design pressure of 620 psig and includes a 1/8 in. thick cladding of stainless steel.

A nozzle is provided in the top head at each fuel position to permit fuel replacement without disturbing the sealed head joint. Removal of the top head, however, is necessary for replacement of housing tubes, control rods, and safety rods. The bottom head of the vessel is pierced by control rods, safety rods, and instrumentation connections.

The lower portion of the vessel shell has two 20 in. moderator-coolant inlet nozzles and the bottom head has two 20 in. outlet nozzles.

The estimated weight of the pressure vessel, without internal shielding, is 91 tons.

Fuel Elements

The 250 fuel elements in the reactor are arranged in a regular hexagonal lattice with a 6.5 in. triangular pitch.

The characteristics of the fuel elements are as follows:

Fuel Material	U-2w/o Zr
Shape	hollow cylinder
	2.030 in. OD x 1.497 in. ID
Active Length	14.25 ft.
Cladding Material	Zircaloy-2
Cladding Thickness	0.015 in.
Housing Tube Material	Zircaloy-2
Shape	tubular
	2.960 in. OD x 2.900 in. ID

Each fuel element is positioned in a housing tube inside the reactor. Moderator flows upward outside the housing tubes and coolant flows downward inside the housing tubes. The fuel housings are anchored at the upper and lower neutron shield tanks. An orifice at the top of each housing tube provides proper coolant flow distribution throughout the core. Coolant flows both on the inside and outside of the fuel element. A suitable grappling head is incorporated at the top of each fuel element for use with a refueling machine.

The active core diameter and height are 10.05 ft. and 14.25 ft., respectively.

Control Rods and Drives

Control of reactivity is accomplished by safety, shim and regulating rods. The control rods are designed to enter the bottom of the pressure vessel. The safety rods are normally positioned above the core to permit them to fall by gravity when a reactor scram is required. Thimbles, which project about 5-1/2 ft. above the top head of the vessel, house the upper end of the safety rods when the rods are in a raised position. The shim rods provide slow, coarse control of reactivity, and are driven into the core from below the reactor by electric motors at a relatively slow rate. They are not detachable from their drives, except for disassembly purposes. The regulating rods are similar to the shim rods, with the exception that their drive motors are capable of greater speeds and accelerations.

The number of safety rods, shim rods and regulating rods are 19, 17 and 2 respectively. All control rods are of a hollow cylindrical shape. The poison section of the shim and regulating rods is cadmium and that of the safety rods is 1% boron steel.

Reactor Support

The reactor vessel has support brackets equally spaced around its periphery in close proximity to the base of the vessel. A system of steel framing is provided to transfer the weight of the reactor to steel columns. The base of the vessel is supported on this steel frame with provisions for radial expansion while maintaining accurate horizontal alignment. The upper end of the vessel is guided for vertical expansion and alignment without introducing additional stresses in the vessel wall or binding of the control rods.

Thermal Shields

The function of the thermal shields is to absorb a major portion of the radiation energy emitted from the reactor core, and in so doing protect the vessel walls from radiation damage and excessive thermal stresses. It also serves to protect the concrete structure near the reactor from overheating.

The thermal shields are attached to the inner vertical walls of the vessel and consist of three layers of cylindrical plate sections mounted concentrically within the vessel. D_2O flows between these layers to remove the heat generated due to radiation absorption in them. The three thermal shields are fabricated from 1 in. thick plate and are spaced 1 in. apart. Two of the shields are fabricated of 304 stainless steel and the third, which is placed between the two stainless steel shields, is boron-stainless steel plate. Total weight of the shields is 40 tons.

Neutron Shields

The function of the neutron shields is to limit the gamma activation of reactor components above and below the vessel.

The upper and lower neutron shields are located inside the pressure vessel above and below the core, respectively.

Both the upper and lower neutron shields consist of shot filled stainless steel tanks with penetrations for the fuel housing tubes and control rods. The shot is borated iron and occupies 54% of the tank free volume. The remaining 46% is D_2O coolant flowing through the tank to remove the heat generated by absorption of radiation. Suitable offsets are provided in the penetrations and supports to reduce neutron streaming.

The shield tanks are fabricated of 1 in. thick stainless steel plate and are 12.97 ft. OD by 32 in. high. The total weight of the shields is 60 tons.

Biological Shield

The function of the biological shield is to protect personnel from radiation. In general, the biological shield is constructed of ordinary concrete and consists of the walls, ceilings and floors surrounding the reactor and its auxiliary systems. Wherever access to compartments is required, a removable concrete slab with suitable offsets and overlaps to insure continuous, effective shielding is located in the biological shield.

The thicknesses of the various biological shields were selected on the basis of an average dose rate of 2.5 mr/hr. immediately outside the shield.

The biological shield absorbs energy from core radiation, as well as heat from the reactor vessel. To prevent damage to the concrete from excessive temperatures and thermal gradients, heat is removed by cooling water which is circulated through coils imbedded in the concrete. The estimated heat load on the cooling system is 300 kw, which requires a flow rate of about 100 gpm at inlet and outlet temperatures of 110 and 130 F, respectively.

Reactor Instrumentation

The nuclear instruments measure the neutron flux and the rate of change of neutron flux from start-up to full power. The arrangement of the flux instruments is shown in Dwg. NP-435. These measurements provide signals to the safety system which prevents rod withdrawal, prevents excessive rate of change in power level and limits the power level to a set maximum.

Scram	- The safety and shim rods are immediately inserted by releasing the rods from the drives.
Slow Scram	- The safety and shim rods are inserted at the maximum drive speed.
Automatic Power Reduction	- The regulating rods are inserted for automatic control of reactor power level upon decreased power demand.
Withdrawal Prohibit	- The safety and shim rod drive circuits are de-energized to prevent withdrawal of rods.
Alarm	- Any abnormal condition causes a visible and audible signal in the control room. In addition, the abnormal condition causes one or more of the above listed safety circuits to function.

The instrumentation consists of eight channels as follows:

> Two start-up channels, which are withdrawn to provide flux level indication for either cold or hot start-up.
>
> Two log-N channels to provide information regarding rate of change of reactor power.
>
> Three power level safety channels to determine reactor power level in the operating range. In addition, these channels prevent the reactor power from exceeding a set value.
>
> One power level control channel which provides a signal to the automatic reactor flux limiter.

Primary System Instrumentation

The instrumentation of the primary system provides for monitoring and recording all pertinent variables such as flow, pressure, and reactor inlet and outlet temperature so that proper operation is assured. The malfunctioning of the essential equipment or primary conditions exceeding a set value causes a visible and audible alarm in the control room, so that proper corrective measures can be taken.

Steam Instrumentation

The steam system has instrumentation to determine actual operating conditions at any time and provides signals for steam and reactor control. The quantities required for automatic control are total steam flow, bypass steam flow, steam pressure, feed water flow, and water level in the steam generators. In addition to these quantities, various other temperatures, pressures, and liquid levels are indicated by control room mounted instruments and/or local gauges. Visible and audible alarms are energized when the measured conditions exceed the set limits or by the failure of major equipment.

Plant Control System

The plant control system is based on maintenance of a constant average reactor coolant temperature, with separate controls for reactor pressure, turbine steam pressure, steam generator level, and hot well level. Neutron flux is used as a limiting function, with neutron flux level and period serving as limits on the movement of the reactor regulating rods. The control block diagram of the system is shown on Dwg. NP-434, and the control system is shown in greater detail on Dwgs. NP-436 and NP-437.

As shown on these drawings, the average temperature of the reactor coolant is controlled by automatic or manual control of the coolant flow rate. Under automatic control, deviation of the reactor average temperature from the set point causes an automatic adjustment of the coolant flow rate to correct the error.

Method of Reactor Control

Neutron flux level and rate of change of flux level are used as limits on regulating rod withdrawal by acting through the core temperature limit control on the regulating rod drives. Thus, neutron flux serves as a limiting function rather than a direct control function, and reduces the need for extreme accuracy of neutron flux instruments over the lifetime of the core.

Reactor pressure is automatically controlled by a pressure signal from the reactor vessel which operates through a controller to inject high-pressure helium or bleed helium to the off-gas system, depending on the magnitude of the reactor pressure relative to the pressure set point.

Turbine steam pressure control is affected by controllers using signals of steam pressure at the steam generator and steam flow through the by-pass valve. Excessive pressure in the secondary system is relieved through the turbine bypass valve to the condenser, the valve being controlled by the steam pressure controller. A separate flow control, activated by the steam bypass flow, provides a signal to the reactor temperature controller to change the reactor power to maintain zero flow through the bypass. The rate of change of the reactor power level is limited by the flux rate of change limiter.

A conventional three-element steam and feed water control system is used in the secondary cycle, with steam flow being matched to feed water flow. Corrections are applied to the feed water flow in accordance with the deviation of steam generator level from the set point.

The reactor and plant safety circuits are outlined in block form on Dwg. NP-437. In general, the safety circuits provide automatic scram or rundown, and alarms for unsafe operating conditions in the plant. The alarm circuits are subdivided into:

Reactor

Reactor Auxiliaries

Turbine

Generator and Generator Auxiliaries

Radiation Monitors

The radiation monitoring system is designed to provide a record of the radiation level at various locations throughout the plant. The arrangement of the devices in this system are shown on Dwg. NP-435. Monitors are provided for gaseous wastes to the stack, liquid waste to the sewer, and general areas. In addition, a fission products monitor is provided to detect fuel element rupture. Since heavy water can give rise to photoneutrons in the presence of a gamma flux, it is necessary to provide neutron monitors as well as gamma monitoring.

The area monitors consist of gamma and/or neutron sensitive remote units which are connected to a strip chart recorder in the control room. An alarm is initiated both locally and in the control room when the radiation level rises above tolerance.

The stack gas and sewer monitors will initiate an alarm upon detection of an above tolerance level of radiation. In addition, discharge dampers or valves are closed so that the radioactive waste is not discharged from the reactor building.

All permanently installed radiation monitoring equipment includes the necessary indicators, recorders, and connections to annunciator circuits.

D_2O Leak Detection

Small leaks are detected locally by means of capacitance probes and vapor detectors. Capacitance probes are used instead of resistance probes because of the low conductivity of the essentially pure D_2O. Depending on the location, probes will be mounted in either collection cups or behind weirs in catch pans.

Major leaks will be detected by means of changes in level and make-up flow rates.

The following type of leak detectors are installed:

Capacitance probes in catch pans below any equipment containing D_2O. The pans may cover the entire floor areas of D_2O equipment or may be designed just to collect leakage from individual pieces of process equipment.

Vapor detectors in the D_2O equipment rooms.

Coolant system level indication.

Coolant system make-up flow rates.

5.1.1.2 Reactor Coolant System

The reactor is cooled by circulating a constant flow of 19.75×10^6 lbs/hr. of D_2O from the reactor through two main coolant loops. Each loop consists of a steam generator, circulating pump, and interconnecting piping and valves. A diagram of the main coolant system is shown on Dwg. NP-430.

Each loop is designed for a coolant flow rate of 9.875×10^6 lbs/hr. The coolant velocity in the piping system is about 25 fps. D_2O leaves the reactor at 450 F and 562 psia, flows through the tube side of the steam generators to produce 160 psia saturated steam from light water on the shell side, and is returned to the reactor at 402 F by the circulating pumps. Each steam generator produces 5.675×10^6 lbs/hr. of steam, and the two steam generators provide a total of 1.135×10^6 lbs/hr. to the turbine under full design load conditions.

Steam Generators

The steam generators are vertical shell and tube heat exchangers in which the reactor coolant flows through water boxes and U-tubes. Inverted U-tubes extend upward from the water box which is located at the lower end of the unit. Steam for the turbine is generated as light water on the shell side of the heat exchanger. The upper portion of the shell is used as a steam separator and collection drum.

The selection of tube size, material and coolant velocity in the tubes involved consideration of D_2O inventory as well as heat transfer characteristics, pressure drop, and corrosion and erosion. The combination of high velocity fluid flow and small diameter tubes is beneficial from the point of view of reducing D_2O inventory and increasing the heat transfer rate, however excessive velocity results in increased erosion, or impingement corrosion and increased pressure drop. For this study, stainless steel tubes of 0.5 in. diameter and a coolant velocity of 12 fps were selected as offering a satisfactory compromise.

The tube sheets and other interior surfaces of the water box which comes in contact with the D_2O are either stainless steel or stainless steel clad. The shell of the steam generator is fabricated of carbon steel. Each steam generator has estimated dimensions of 7 ft. dia. with heat transfer surface area of 12,700 ft^3.

Coolant Pumps

Two reactor circulating pumps are provided with a capacity of 21,200 gpm each at a NDH of 164 ft. of D_2O. Each pump is driven by a direct connected 1200 hp motor. The impellers of the pumps are stainless steel, and the casings are a chrome-moly alloy. The pumps are otherwise of conventional design except for the shaft seals, which are of the double balanced mechanical type. Any leakage of D_2O from the seals is drained to the miscellaneous D_2O drain tank, thereby recovering D_2O leakage.

The pumps are of centrifugal type with vertical shafts.

Coolant Piping and Valves

The coolant circulating piping is 20 in. schedule 40 pipe fabricated of Type 304 stainless steel. The piping is sized for a velocity of about 25 fps to minimize the D_2O inventory in the system. All piping connections are butt welded.

The valves in the primary coolant system are fabricated of stainless steel and are butt welded into the piping system. The glands are provided with lantern rings and double packing to permit collection of coolant leakage from the stems.

Each loop has a 20 in. motor operated valve in the reactor coolant outlet line and another in the coolant return line. This arrangement permits shutdown of one loop and isolation of the steam generator and circulating pump from the system while the other loop remains in service.

During emergencies, if plant auxiliary power is lost, the above motor-operated valves may be closed using power from the emergency diesel generator. With both loops closed, the D_2O coolant is sent through an emergency shutdown cooling system.

5.1.1.3 Reactor Auxiliaries

The reactor auxiliaries are considered to be the coolant purification system, coolant pressurization system and level control, coolant recombiner and off-gas system, shield cooling system, shutdown cooling system, waste disposal system, fuel handling system, and the D_2O distillation system.

All of the systems described in this section, except the fuel handling and waste disposal systems, are shown in elementary form on the composite flow diagram, Dwg. NP-429. More detailed diagrams of these systems are provided on Dwgs. NP-430 through NP-433.

Coolant Purification System

The D_2O coolant in the reactor is maintained at a purity of 1 ppm total dissolved solids by providing a bypass filtering and demineralizing system to remove particulate matter and dissolved impurities.

The coolant purification system is shown on Dwg. NP-431. This drawing also shows the piping associated with deuterizing and de-deuterizing the demineralizer resins together with the spent resin transfer equipment.

During normal operation, 8.3×10^6 lbs/hr. of coolant D_2O at 402 F is drawn off at the reactor inlet and circulated through the demineralizer loop. The coolant passes through a regenerative heat exchanger where the temperature is reduced to 258 F. The D_2O temperature is finally reduced to 110 F by a service water cooled heat exchanger. After passing through a mixed bed ion exchanger and strainer, the coolant is brought to a final return temperature of 254 F in the regenerative heat exchanger, thereby recovering a portion of the heat extracted from the influent. Since the main reactor circulating pumps alone do not provide sufficient head for purification system operation, a booster pump is provided in the purification system to return the coolant to the reactor.

The piping and purification equipment are all sized to pass an emergency flow of four times the normal flow rate or 3.32 x 10^6 lbs/hr., in order that rapid system cleanup may be accomplished should a fuel element rupture in the core.

Before emergency cleanup operation begins, the reactor is shut down and the bulk coolant temperature reduced to 180 F or less using the shutdown cooling system. Water normally entering the tubes of the regenerative heat exchanger is bypassed directly to the service water cooled heat exchanger where it is cooled to below the maximum allowable resin temperature of the mixed bed ion exchanger. After passing through the purification equipment, the water is returned to the reactor by the purification booster pump.

The coolant purification system piping, valves, heat exchangers, and other related equipment in contact with D_2O are constructed of Type 304 stainless steel.

The strainer is a 100 mesh stainless steel screen provided to prevent any material which breaks loose from the mixed bed exchanger from entering the coolant system.

The mixed bed exchanger contains 15 ft^3 of nuclear grade resin, based on a one year lifetime, with a bed depth of 4 ft.

Coolant Pressurizing System and Level Control

To prevent boiling in the primary system, the coolant is maintained at a pressure well above its vapor pressure. This is accomplished by the helium cover gas in the reactor vessel. A diagram of the system is shown on Dwg. NP-432.

The 562 psia coolant pressure in the reactor vessel is maintained by a high pressure helium storage tank and a pressure controller. Should the reactor pressure decrease, the controller will actuate a valve in the high pressure helium supply line from the storage tank and, thereby, restore the coolant pressure to its normal level. A pressure increase will cause the controller to actuate another valve, this time relieving the helium in the vessel to the recombiner system where it is compressed and sent back to the helium storage tank. A 300 ft^3 helium storage tank, therefore, serves as a surge tank for the cover gas system.

Normal operating pressure in the storage tank is 700 psig. Should this pressure drop considerably for any reason, make-up is provided from high pressure helium supply cylinders.

Coolant level in the reactor vessel is allowed to vary plus or minus 6 in. from its normal operating level. Should the coolant exceed its upper level, a level controller in the reactor vessel actuates a valve and sends the excess coolant to the coolant storage tank. Since this storage tank is at atmospheric pressure, a drain cooler is provided to condense any coolant that flashes into steam during the expansion process. The overflow rate is not expected to exceed 85 gpm.

Should the coolant level decrease below its minimum level, the controller actuates a D_2O transfer pump and sends coolant from the storage tank to the suction side of a reactor circulating pump. The level control system is shown on Dwg. NP-431.

All piping, valves, and related equipment in contact with helium or D_2O are constructed of Type 304 stainless steel.

A 660 ft^3 helium hold-up tank is also provided in the gas system. This tank provides storage of reactor vessel and D_2O coolant storage tank cover gases at 300 psig during periods when the primary system coolant is drained. This gas is returned to the system during coolant refilling, thereby recovering helium gas which would otherwise be vented to the atmosphere after sufficient decay. The hold-up tank is constructed of carbon steel.

Helium Inventory

Helium is used not only for pressurization but also as a cover gas for all D_2O in the plant. The total inventory in the systems during normal plant operation is 25,000 scf. A breakdown of this is as follows:

Helium storage tank	13,300 scf.
Reactor vessel	7,350 scf.
D_2O coolant storage tank	3,175 scf.
Other	1,175 scf.
Total	25,000 scf.

Helium make-up is provided by two banks of cylinders located on the main floor in the reactor building.

Coolant Recombiner and Off-Gas System

As a result of the radiation field in the reactor, a small portion of the D_2O coolant dissociates. D_2 and O_2 formed in the reactor is collected in the helium blanket cover gas over the D_2O coolant in the vessel. The D_2 and O_2 gas is removed by a continuous flow of helium at 5 scfm across the free surface of the coolant in the reactor. This gas is circulated through a moisture separator, a catalytic recombiner, condenser, another moisture separator, and then compressed for return to the reactor vessel via the helium storage tank. In this way dissociated D_2 and O_2 formed in the reactor and collected in the blanket gas is effectively recombined and recovered. An oxygen supply actuated by a gas analyzer is introduced just ahead of the recombiner to insure total recombination of dissociated deuterium. A diagram of this system is shown on Dwg. NP-432.

All D_2O recovered in the moisture separators and condenser is sent to the miscellaneous D_2O drain tank. In the drain tank it is batch monitored for D_2O purity and either returned to the system or sent to the distillation plant for upgrading.

To prevent a build up of noncondensibles in the blanket gas system, small amounts of the helium cover gas are intermittently passed to the off-gas system, where, after sufficient decay, it is vented to the atmosphere.

All metals in contact with helium in the recombiner system are of Type 304 stainless steel.

The off-gas system permits disposal of gaseous wastes from the reactor plant. A diagram of the system is shown on Dwg. NP-432. Waste gases vented to this system are first passed through one of two alumina D_2O adsorbers to remove the heavy water vapor content. Two drying vessels are provided so that one can be regenerated while the other remains in service. After passing through the adsorbers, the gases are monitored for activity level and then passed directly to a stack for disposal to the atmosphere if the activity is such that release without further handling is permitted. If not, the gas is compressed to 300 psig and sent to one of two 750 ft^3 waste gas holdup tanks for holdup and decay to a maximum permissible level. The stored gas is monitored and eventually discharged out a 200 ft. high waste disposal stack. At the stack the effluent is diluted by building ventilation exhaust and an additional 15,000 cfm dilution blower. All gases being discharged by the stack first pass through high efficiency filters to remove any particulate matter.

Primary off-gases are collected from the following equipment or gas systems:

1. D_2O distillation plant.
2. Reactor cavity exhaust gas.
3. D_2O equipment room exhaust gases.
4. Bleed gas from coolant cover gas system.
5. Vent from coolant purification system.
6. Blanket gas vents from miscellaneous tanks.

Normally, the off-gas system has a continuous flow rate of 60 scfm. This flow rate is allocated to the reactor cavity and D O equipment room exhausts. The contribution from the other sources listed will either be intermittent or at most small. However, the system is designed for a 150 scfm flow rate to handle any additional purge volumes.

All metals in contact with waste gases containing D_2O vapor up to and including the adsorbers are of Type 304 stainless steel. After the adsorbers, the system is constructed of carbon steel.

Shield Cooling System

Approximately 0.3 MW of radiative and thermal heat is deposited in the reactor biological shields at full reactor power and is removed by the shield cooling system.

A flow diagram of the shield cooling system is shown on Dwg. NP-431. The shield coolant is demineralized ordinary water and flows at a total rate of 5.1×10^4 lbs/hr. with a 20 F temperature rise in the shields.

The inlet cooling water, at 110 F, is distributed to coils imbedded in the concrete biological shield. The outlet water, at 130 F, is carried through a full-flow filter to a 170 gal. holdup tank. The hold-up tank is internally baffled to insure a 40 second holdup of the shield cooling water to permit almost all induced N^{16} activity to decay. The combination of the full flow filter and holdup tank, located in a concrete shielded room, allows the remainder of the shield cooling system equipment to be located in unshielded spaces.

The essentially nonradioactive water is taken from the holdup tank through one of two full size circulating pumps, through a service water cooled heat exchanger and returned to the coils in the biological shield, thus completing the circuit.

Any dissociated H_2 and O_2 formed in the shield cooling water is collected at the holdup tank and vented directly to the waste disposal stack.

The entire shield cooling system is constructed of carbon steel.

Shutdown Cooling System

A shutdown cooling system is provided for the reactor as a part of the primary cooling system. The equipment provided for shutdown cooling consists of the steam generators, main condenser, and a shutdown cooler. The latter unit is connected to receive heavy water directly from the reactor, extract heat and return the cooled heavy water to the reactor through a shutdown coolant pump. A diagram of the system is shown on Dwg.NP-430.

The system is designed to provide cooling for normal shutdown and for shutdowns under emergency conditions when plant auxiliary power may be lost.

To provide cooling after a normal shutdown, the reactor coolant is circulated through the steam generators, producing steam which is by-passed to the main condenser. The heat is removed by the condenser circulating water. When heat being generated in the reactor falls to the level where the coolant will no longer produce steam in the steam generators, the main coolant lines to the steam generators are closed and the water from the reactor passed to a shutdown cooler. Heat is removed from the shutdown cooler by plant service water. Coolant circulation is provided by a shutdown coolant pump. Operation in this way is continued until it is no longer necessary to remove decay heat from the core.

Emergency shutdown can arise from numerous situations, including high power excursions, major fission product release, and loss of plant auxiliary power. All but the latter can be handled in a manner similar to that described for normal shutdown.

Should the plant auxiliary power be lost during plant operation, the reactor will be scrammed, and the coolant immediately passed to the shutdown cooler. Coolant circulation will be maintained by the shutdown coolant pump, which will be automatically connected to an emergency power supply. The shutdown cooler is designed to remove 7% of full reactor power, which is sufficient to remove reactor decay heat and stored heat in the coolant system.

All metal surfaces in contact with D_2O are of Type 304 stainless steel. The pump gland seals are of the double balanced mechanical type.

Radioactive Waste Disposal System

Complete facilities are provided at the plant site for permanent disposal of all radioactive wastes of plant origin during normal operation. Radioactive wastes are classified as solid, liquid and gaseous, and all are finally handled by the waste treatment equipment located in a separate building at the west end of the site, as indicated on Dwg. NP-438. The waste disposal system control board and non-radioactive equipment are housed in the waste disposal building service and control area.

Solid Wastes

A 1200 ft^3 underground storage vault is provided for disposal of dry, solid wastes, both compressible and noncompressible.

Spent ion exchange resins used in the reactor purification system are sent to a deuterizing column where the heavy water is removed and the spent resin sluiced with H_2O directly to an underground permanent resin storage tank. The solids are allowed to settle and the liquid decanted and recycled to the liquid waste system for disposal. The resin storage tank is a 3000 ft^3 tank, (concrete enclosure with a stainless steel lining) sized to contain depleted resin and filter material expected to accumulate in twenty years of plant operation.

Liquid Wastes

The waste disposal system is equipped to handle the decontamination of liquid wastes by chemical neutralization, filtering, decay by temporary storage or by demineralization. All liquid effluent sent to the waste disposal building flows either to a 3,000 gal. waste collector tank or to the 1,000 gal. waste neutralizer tank. A diagram of the system is shown on Dwg. NP-433.

The waste collector tank is used to formulate batches for processing as required by the chemical or radio-chemical content of the liquid. Liquid waste from the containment vessel, the fuel element storage pool, and the shield cooling blowdown, are routed to the waste collector tank.

A waste neutralizer tank is used for chemical treatment of liquid wastes from the laboratory, shop, and fuel building decontamination stations. A 5,000 gal. caustic storage tank and a 5,000 gal. concentrated acid storage tank are provided for chemicals.

From these tanks, a batch may follow one or more of several routes. If the radioactivity level is below tolerance, the liquid may be sent to the condenser circulating water discharge where it is diluted and released into the river. High level radio-active liquid is passed through a demineralizing system, and then to one of two 10,000 gal. waste holdup tanks. Short lived radioactivity is allowed to decay to a safe level before discharge into the circulating water discharge.

A bypass is provided around the holdup tanks such that if the activity after purification is within permissible levels, it may be routed directly to the river. In the event the processed liquid is not releasable after the first treatment, it is recycled from the holdup tanks for further processing.

The spent resin and alpha-cellulose filter material from the waste disposal purification system is sluiced to the permanent resin storage tank. New resin is hydraulically transferred to the exchanger and new cellulose material is pumped onto the filters until the elements are properly coated. The new resin storage tank and the alpha-cellulose fill tank are 1,000 gal. and 50 gal. tanks, respectively.

The ion exchangers are designed to handle a normal flow of 25 gpm at 8 gpm/ft^2 of bed surface. These units are capable of handling an emergency flow of 50 gpm.

Gaseous Wastes

Gaseous radioactive wastes evolving from various decontamination equipment are vented to a common header. The gases pass through an adsorber, are monitored for activity level and passed directly to the stack if the activity is such that release without further handling is permitted. A flow diagram of the waste gas system is shown on Dwg. NP-432.

If the activity of the gas is above the permissible level, the gas is compressed to 300 psig and sent to one of two 750 ft^3 underground gas holdup tanks where any short-lived activity is allowed to decay. Effluent from the gas holdup tanks is bled to and diluted by the building ventilation air exhaust, and a 15,000 cfm dilution blower, and finally discharged to the stack. All air discharged to the stack first passes through high efficiency filters to remove any particulate matter.

Fuel Handling System

The fuel handling system consists of a fuel handling machine (coffin and carrier), indexing top shield, temporary spent fuel storage pit, temporary fresh fuel storage pit, spent fuel well and transfer canal, fuel storage racks and storage pool located in the fuel handling building. The fuel handling system is designed to accommodate all phases of fuel handling from receipt of new fuel elements to shipment of spent fuel.

Fuel Handling Machine

The fuel handling machine is located on the reactor building main floor as shown on Dwgs. NP-439 and 440. The machine is arranged on a set of rails so that it has access to all the reactor fuel positions, temporary fresh fuel storage pit, spent fuel storage pit, and the spent fuel transfer well.

The fuel transfer coffin consists of a thick wall lead cylinder sheathed in steel with sufficient thickness of lead to permit safe unloading of fuel elements. Hoists are provided for raising and lowering fuel elements. The fuel handling machine is controlled by an operator on the reactor building main floor.

Fresh Fuel and Spent Fuel Temporary Storage Pits

Two temporary fuel storage pits are provided below the main operating floor of the reactor building for receiving and storing new and spent fuel elements under water without interfering with the containment or shielding of the main floor of the reactor building. Each pit is sized to hold approximately 40% of a core loading.

Spent Fuel Transfer Well and Canal

The spent fuel transfer well consists of a water filled tube which extends from the main floor of the reactor building down to the transfer canal. A motorized hoist is used to lower the spent fuel to the spent fuel basket and carriage located under water in the transfer canal. The carriage rides on a set of rails through the canal to the fuel handling building. In the fuel handling building fuel elements are removed from the carriage and placed in the storage pool prior to shipment to reprocessing facilities.

Fueling the Reactor

Fresh fuel elements are normally delivered to the main floor of the reactor building through an equipment hatch and transferred to the temporary fresh fuel storage pit for loading into the reactor. From the temporary fresh fuel storage pit, the fuel elements are loaded into the reactor by the fuel handling machine, which is normally controlled and positioned by indexing devices over the proper fuel removal nozzle of the reactor.

For refueling operations the reactor must be shut down before removing a fuel element from the core. Fuel elements which are to be removed from the core and replaced in a different lattice position are stored in the temporary spent fuel storage pit during the refueling operations. Spent fuel is transferred through the spent fuel well and canal to the fuel handling building where it is placed in the storage pool prior to shipment.

D_2O Distillation System

A D_2O distillation plant located adjacent to the reactor building is used to remove H_2O contamination from the D_2O within the plant. This system is designed to remove about one pound of H_2O per day when operating on a continuous basis. The stripped effluent from the distillation system is 25% H_2O and 75% D_2O. It is proposed that this effluent be sent off-site for upgrading to 99.75% D_2O purity. The distillation plant flow diagram is shown on Dwg. NP-429.

The piping system, tanks, columns, and other related equipment in contact with D_2O is constructed of Type 304 stainless steel.

A detailed description of the D_2O distillation system is presented in Report SL-1581 Volume 1.

D_2O Losses and Recovery

Throughout the plant systems, every attempt is made to minimize leakage and loss of D_2O. In many instances, the value of the D_2O justifies the use of apparatus of special design to fulfill the philosophy of zero leakage. Examples of such apparatus are the D_2O pumps, valves, D_2O-H_2O heat exchangers, and the vent and off-gas system. In addition, it is expected that some special plant maintenance procedures will be required.

All D_2O pumping equipment is provided with mechanical shaft seals, backed up by bushing type seals. The leakage from the seals is collected at the pump and piped to D_2O miscellaneous drain tanks. A leak off connection is provided on the outboard side of the bushing seal to provide an emergency drain in the event of a mechanical seal failure. This leak off connection is piped to an oversized normal drain line, located on the inboard side of the bushing type seal. Pressurized D_2O from the pump seal pressure accumulator is fed into a gland at the shaft seal to maintain a pressure at the seal slightly higher than the fluid being pumped and therefore any leakage is clean D_2O.

Integral pumping rings circulate the seal fluid through a small heat exchanger to maintain the temperature at the seals below 160 F at all times. A water jacket is used to supplement cooling during operation and maintain cooling when the pump is shut down.

A major source of D_2O loss occurs from valve steam leakage. To minimize leakage losses, the following provisions in valve design have been made:

a) All valves are furnished with butt welding or socket welding ends.

b) Provisions for seal welding the bonnet joints are made.

c) All valves are of back seat construction with an extra long stuffing box.

d) All valves in sizes 2 in. and larger are furnished with a stuffing box leak off pipe connection and lantern gland.

e) All valves subjected to vacuum conditions are furnished with a stuffing box liquid injection seal connection as well as a leak off connection.

f) Major control valves operated frequently are furnished with stuffing box leak off piping connections as well as seal gas piping connections.

Operating experience will dictate the extent of maintenance required to minimize leakage.

The drain connection from the lantern rings of the large valves in D_2O systems is piped to a recovery tank. A valved bypass is installed in the drain line, with a visual leak collector serving to indicate the rate of leakage and therefore the condition of the valve stem packing.

Small valves in the D_2O systems are not piped to the recovery tank but are provided with a visual leak collector which serves to indicate when the valve stem packing should be tightened or replaced. Leakage into the reactor cavity is picked up as a vapor by a continuous air flow maintained throughout the reactor cavity and carried to a drying system for removal. To provide for major leakage into a cavity, a D_2O sump and sump pump are provided. The reactor cavity ventilation system is discussed elsewhere in this report.

In spite of all attempts made to minimize D_2O loss, some will occur during normal plant operation. The following is a breakdown of the estimated unrecoverable D_2O losses:

Item	Leakage lb/day	Unrecoverable leakage lb/day
Valves, Average per Valve	0.1	0.01
Pumps, Total	40.0	2.00
Control Rods, per Rod	0.018	0.002
Off-Gas System	---	0.1
Miscellaneous	10.0	1.0

These figures result in an estimated unrecovered loss rate of 6.6 lbs/day or 2400 lbs/year. The estimated annual loss from the refueling operations is estimated to be 300 pounds. Thus the total estimated loss, not including allowances for spills or ruptures is 2700 lbs/year, which amounts to about 1% of the plant D_2O inventory of 123.5 metric tons.

Losses arising from accidents, spills and equipment breakdowns are estimated at an additional 1% per year of D_2O. Therefore, the total estimated D_2O loss is about 2% of the total plant D_2O inventory, or 5430 lbs/year.

The above tabulation is based upon a liquid recovery system which is 90% efficient and a vapor recovery system which is expected to operate at an efficiency of 99%.

5.1.1.4 Turbine Plant

The turbine plant, consisting of the turbine-generator, condenser, feed-water heaters, circulating water system, and associated auxiliaries, utilizes saturated steam from two steam generators to produce a net electrical power output of approximately 68,800 kw, with a total steam flow of 1,135,000 lbs/hr. and a condenser pressure of 1.5 in. HgA. Condensate from the condenser is returned to the steam generators through three stages of feed-water heating. A flow diagram of the steam, condensate, and feed water cycle appears on Dwg. NP-430.

Turbine-Generator

The turbine is a tandem-compound, double flow unit with 23 in. exhaust blades and operates at 3600 rpm. Dry and saturated steam at 160 psia is supplied to the turbine through two turbine stop valves. Moisture removal devices are furnished with the turbine.

Condensing Equipment

The main condenser is a two pass unit with a heat transfer surface of 100,000 ft^2 Admiralty metal tubes 26 ft. long and 1 in. OD x 18 BWG are used for the heat transfer surface.

The quantity of steam to be condensed is 825,800 lbs/hr. The condenser is provided with divided water boxes and valved for backwashing to clean the condenser tubes. A circulating water flow of 107,200 gpm at 70 F is required for condensing purposes at 1-1/2 in. HgA. An expansion joint is provided between the turbine and condenser to absorb movement due to thermal expansion.

A two element steam jet air ejector is furnished with an automatic steam pressure reducing valve in the steam supply line to the jets. The ejector removes noncondensable gases from the condenser. A noncondensing auxiliary ejector is provided to aid in the rapid evacuation of air from the condenser, and a priming ejector is supplied for the evacuation of the water box space in the circulating water system.

Condensate Pumps

Two half-capacity, horizontal, centrifugal condensate pumps are provided, to take their suction from the condenser hot well. The condensate pumps provide the head necessary to pump the condensate from the condenser through the air ejector, gland steam condenser, low-pressure heater and to the deaerating heater. Each pump delivers 965 gpm and is driven by a direct connected 125 hp motor. The pump is of conventional design and material.

Feed Water Pumps

The feed water pumps provide the head necessary to return the feed water to the high-pressure heater and the steam generators. Two half-capacity, horizontal, centrifugal feed pumps are provided, taking their suction from the deaerating heater. Each pump delivers 1195 gpm and is driven by a direct-connected 175 hp motor. Recirculation is required to cool the pump under low flow conditions. The recirculation line carries the feed water back to the deaerating heater where it again enters the cycle to the feed water pump suction. A warming line is also provided at each pump. The pumps are of conventional design and material.

Feed-Water Heaters

Three stages of feed water heating are provided, yielding a final feed water temperature of 310 F. Each feed-water heater is equipped with normal and emergency level controllers which maintain normal water level in the heater hot well. All heaters are of conventional design and material.

Low-Pressure Heater

Condensate from the condenser hot well is pumped through the air ejector, gland steam condenser and the low-pressure heater. This heater receives steam extracted from the turbine, and moisture from the moisture separator, for feed water heating. The heater is of the horizontal type with 3/4 in. x 18 BWG Admiralty metal tubes. At this heater, the drain is pumped and returned to the condensate line after the heater. The low-pressure heater is located on the mezzanine floor in the turbine building.

Deaerating Heater

Condensate from the low-pressure heater flows to the deaerating heater. The heater receives extraction steam from the turbine, and a steam water mixture from the high-pressure heater drain, for deaerating and heating purposes. The deaerating heater is arranged as a vertical deaerating unit on a horizontal storage tank. The feed water pumps take their suction directly from this storage tank which is located on the turbine building roof.

High-Pressure Heater

Water from the feed water pumps flows to the high-pressure heater and the steam generators. The heater receives extraction steam from the turbine for feed water heating. The heater drain is cascaded to the deaerating heater. The heater is of the vertical type with 3/4 in. x 18 BWG Admiralty metal tubes. The high-pressure heater is located on the ground floor extending upward through the mezzanine floor.

Piping

The main steam piping consists of two 24 in. schedule 40 carbon steel pipes, running directly from the steam generators to the turbine stop valves. Each line is sized to handle a steam flow of 567,500 lbs/hr. at a velocity of approximately 9500 fpm. A 10 in. schedule 40 pipe is provided as a dump line to the condenser to handle changes in load and normal and emergency shutdown conditions. This line is sized to handle 10% of full steam flow.

The extraction steam piping from the extraction stages of the turbine to the high-pressure heater, deaerating heater and low-pressure heater connections are sized for velocities of 7600, 7200, and 5700 fpm respectively.

Condensate piping from the condenser hot well to the deaerating heater is sized for velocities of 8-15 fps. The velocity of the condensate in the condensate pump suction line and the feed-water pump suction line is 2.5 and 5.5 fps respectively. Piping from the feed water pumps discharge to the steam generators and is sized for a velocity of 8-15 fps.

The circulating water piping system consists of one 48 in. line from each pump running into the condenser and two 48 in. outlets converging into a 66 in. main outlet to the crib house. A 72 in. pipe carries the discharge from the crib house to the river.

The piping systems in the plant are designed in accordance with the appropriate codes presently in effect. All piping is carbon steel. Pipe sizes in the turbine building are shown on Dwg. NP-430.

The remaining piping systems in the turbine plant are of conventional materials and construction.

Valves

All valves in the turbine system are of standard design and construction.

Main Power Electrical Equipment

The electrical power is generated at 13,800 volts, with a capacity of 73,300 kw at design turbine inlet conditions and 1.5 in. HgA condenser pressure. Plant auxiliary requirements reduce the output to a net of 68,800 kw. The electrical single line diagram is shown on Dwg. NP-449.

A tie-in with the existing 115 kv system on the project is assumed, and the main power transformer provides step-up from generator voltage to 115 kv.

Generator

The generator is a 13.8 kv, 3-phase, 60-cycle, 3600 rpm, 88,235 kva, 0.85 pf, 0.64 short circuit ratio, hydrogen cooled (pressure 30 psi), generating unit. The excitation system consists of 250 volt, 200 kw, main and reserve motor-driven exciters with a d-c amplifier type voltage regulator. Field breakers and voltage regulator equipment are located in the excitation switchgear.

The generator neutral is grounded through a 13,800 volt - 240 volt, 25 kva distribution transformer with a resistor across the low voltage winding, all mounted in a metal enclosure.

Main Power Transformer

The main power transformer is Type FOA, 80,000 kva, 13.2 kv delta, 115 kv type, solidly grounded 3-phase, 60-cycle. It is direct-connected to the generator through isolated phase bus duct.

Electrical Auxiliaries

A single line diagram of the electrical auxiliaries for the reactor and turbine plant is shown on Dwg. NP-449. During start-up, power is supplied from the switchyard bus through the reserve auxiliary transformer. Under normal operating conditions the unit auxiliary transformer feeds the auxiliary buses.

Auxiliary Transformers

An outdoor unit auxiliary transformer is provided, rated 6000/7500 kva, 13.2-2.4 kv, OA/FA. The connections to the high voltage terminals are isolated phase bus duct, tapped off the generator bus duct connections to the main power transformer. The low voltage terminals are connected to the 2.3 kv switchgear.

An outdoor reserve auxiliary transformer rated 6000/7500 kva, 115-2.4 kv, OA/FA serves as a reserve for the unit auxiliary transformer and provides auxiliary power for starting. The reserve transformer is supplied from the switchyard bus. The low voltage terminals are connected to the 2.3 kv switchgear.

The neutrals of the low voltage windings of the unit and reserve auxiliary transformers are grounded through a common 1.15 ohm, 1200 amp. resistor.

2300 Volt Switchgear

There are two sections of indoor metal-clad switchgear with removable air circuit breakers. Both sections are normally supplied by the unit auxiliary transformer for emergency or start-up operation. In the event of loss of power to one of the switchgear sections, automatic transfer is provided to restore power to the affected 2300 volt bus immediately. The switchgear has an interrupting capacity of 100 mva. The breaker control voltage is 125 volt d-c. The switchgear provides power to all 2300 volt auxiliaries in the turbine and reactor plant areas.

480 Volt Substations and Control Centers

There is a 480 volt indoor unit substation in both the turbine and reactor plants. Each consists of a direct connected 750/1,000 kva, 2400-480 volt dry type transformer and metal-clad 480 volt switchgear with removable air circuit breakers. The transformers are supplied from the 2300 volt switchgear. Each transformer is capable of supplying the total 480 volt load of both the turbine and reactor plants. In case of power failure to either the turbine or reactor plant buses, automatic transfer is provided to restore power to the affected 480 volt bus instantaneously from the other transformer.

The switchgear provides power to all 480 volt auxiliaries in the turbine and reactor plant and outlying areas. The transformer 480 volt neutrals are solidly grounded.

Motor control centers are provided for the small auxiliary motors.

Emergency Power Supply System

An emergency diesel unit rated at 200 kw, 480 volts, is provided for emergency shutdown. In the event all other a-c power sources fail, this unit starts automatically and supplies shutdown power for the station.

There are emergency battery operated essential shutdown auxiliaries which start automatically when required, and permit shutdown operation of the reactor unit until the diesel unit is started automatically, or manually if necessary.

120 Volt Control and Safety System Power Supply

A 120 volt a-c distribution panel for the reactor control and safety system is normally supplied by a d-c to a-c inverter set to provide a reliable power supply, free of voltage fluctuations. A 480-120 volt, 10 kva, transformer serves as a reserve supply to allow maintenance of the inverter set. Automatic transfer to this source is also provided for shutdown control and safety power if the inverter set fails.

125 Volt Batteries

Two 125 volt batteries are provided. One is located in the turbine plant and the other in the reactor plant. The battery chargers are fed from 480 volt motor control centers. Each battery feeds a 125 volt bus. Tie breakers are provided so each battery can feed both buses under emergency conditions.

One bus will provide the normal d-c feed for turbine plant auxiliaries and provide an alternate feed for reactor plant d-c. The other bus provides the normal d-c feed for reactor plant auxiliaries, including the d-c - a-c inverter for supplying reactor instrument power, and serves as an alternate feed for turbine auxiliaries.

Control Room

A centralized control room is furnished in the turbine and office building with a console type benchboard and vertical panels.

Control and indication, including control switches, push buttons, indicating lights and meters, are provided at the benchboard for all equipment required for the operation of the turbine and reactor. Recorders, large indicators, relays and the annunciators are mounted on the vertical panels.

Motors

Motors rated 150 hp and over are fed from the 2300 volt switchgear. All essential motors under 150 hp are fed from the 480 volt switchgear. Indoor motors are of standard open frame type with protection against drip. For outdoor service, enclosed weather protected motors are used.

Thermocouples for bearing temperatures are provided for critical motors and their associated driven equipment, such as the feed water pumps and reactor circulating pumps.

Auxiliary Power and Control Cable

The cable for the 2300 volt auxiliaries has 4.5 kv ozone resistant rubber insulation with chloroprene sheath. The cable for the 480 volt auxiliaries is rated at 600 volts with ozone resistant rubber insulation and chloroprene sheath. For control, multiconductor cables with 600 volt ozone resistant rubber insulation and chloroprene sheath are used.

Cable Distribution System

Cable pans and conduits are used for routing various power and control cables within the reactor containment vessel and turbine plant. Cables for the reactor and turbine auxiliaries are segregated insofar as practical to minimize loss of output in event of damage in the reactor or turbine area. A cable pan is used for cables between the reactor containment vessel and turbine plant. A special seal is used for cables penetrating the containment vessel. The seal consists of a pressurized chamber adjacent to the vessel wall with compression type cable fittings for each cable both at the vessel wall and the outside chamber wall. The pressurized chamber is continuously monitored for leaks.

Cables for outlying facilities, such as the gatehouse, waste building, fuel handling building, crib house, etc., are buried in earth.

Lighting and Receptacles

The plant lighting system is 480/277 volts supplied from the reactor and turbine plant 480 volt switchgear. Main floor lighting consists of color corrected mercury vapor units, with fluorescent fixtures for all other indoor locations where practical. Where fluorescent fixtures are not feasible, such as outdoor and emergency locations, incandescent lighting is used. Emergency d-c lights are provided only at gauge boards, switchgear and stairwells. The control room has "Louverall" ceiling type lighting. Convenience receptacles are 120 volts fed from small transformers supplied from the lighting system.

480 volt receptacles are provided in the reactor and turbine plant for welders, stress relievers, etc., and are fed from the 480 volt switchgear.

Communications

Private (PAX) telephone facilities complete with code call system are provided as well as a public address system. Local telephone company facilities also are provided.

5.1.1.5 Plant Utilities

The plant utilities include those systems provided for maintaining the equipment, disposing of non-radioactive plant wastes, safety and health of personnel, protection of equipment, and for heating and cooling the plant buildings.

Control Air System

The control air system of the plant supplies air operated control devices at a header pressure of 115 psia and is reduced to 55 psia and 45 psia for supply to various drive units and instrument transmitters.

Control air is supplied by two single stage compressors rated at 180 cfm each, at 115 psia, which discharge through aftercoolers into a common 34 ft^3 air receiver. Air from the receiver then passes through a dryer and a bank of filters insuring a clean, dry air supply to instrument transmitters and control devices.

Station Air System

The station air system supplies 115 psia air for distribution throughout the plant. The station air supply is cross-connected for emergency air to the control air system. Station air is supplied by a single stage compressor rated at 500 cfm and 115 psia, discharging through an after-cooler into a 96 ft^3 station air receiver.

Air Conditioning and Ventilation

The ventilation system provided for the plant is designed to furnish positive control of air flow throughout the buildings. As the reactor operates, tritium builds up in the coolant D_2O and, therefore, any D_2O leakage into occupied areas will impose radiation access limits unless carefully controlled. For this reason all principal D_2O equipment in the reactor building is isolated in shielded cavities where a negative air pressure is maintained so that any leakage of building air is inward, Ventilation of the turbine building poses no special problem since light water is used in this system.

Reactor Building

Two air handling units are provided in the operating area of the reactor building for heating, air conditioning and ventilation. These units circulate a total of 35,000 cfm to all floor levels of the reactor building and maintain an inside temperature of 90 F at 50% R. H. and 60 F when the outside temperatures are 95 F and 10 F, respectively. These represent the summer air conditioning and winter heating system design conditions based on 9000 cfm continuous fresh air intake and exhaust.

System layout provides an air intake plenum around the water storage tank at the top of the containment vessel. All exhaust air is removed at the basement and grade floor levels to insure a constant general downward flow of air in the building. The exhaust air is monitored, filtered and discharged out the waste disposal stack.

Pneumatically operated butterfly valves are installed on the air intake and exhaust ducts into and out of the building. These valves close on high radiation levels in the exhaust air or in the event of an incident requiring containment.

Reactor Cavity and D_2O Equipment Rooms

A continuous flow of air is maintained through the reactor cavity and all D_2O equipment rooms to extract all motor and equipment heat losses. This is accomplished by passing the air through individual chilled water type unit coolers.

The reactor cavity and all D_2O equipment rooms are maintained at a negative pressure by continuously exhausting 5 cfm per space. This means that any leakage of building air is inward. The exhaust air from these spaces containing D_2O vapor is sent through the off-gas system dryer for D_2O recovery and then compressed and sent to the high-pressure waste gas holdup tanks for decay before rejection to the atmosphere.

Turbine Building

Forced ventilation air is distributed to the turbine building equipment area using two air handling units. Since there is no D_2O in the turbine building, the exhaust air is discharged to the atmosphere directly.

Design conditions for normal operation are such that during the summer 50,000 cfm of outside air at 95 F-D.B. and 76 F-W.B. is brought into the building, cooled to 85 F-D.B., circulated through the building, and discharged to the atmosphere at 105 F-D.B. During the winter 25,000 cfm of heated air is continuously circulated with 4000 cfm of fresh air make-up and 4000 cfm exhaust from the building to the surroundings.

Steam unit heaters are distributed throughout the area as required to maintain an inside temperature of 65 F.

Offices, Control Room, Locker Room and Laboratories

Approximately 11,500 cfm of conditioned air is circulated through the offices and control room the year round to maintain comfort conditions for continuous occupancy. The fresh air make-up and exhaust rate in these spaces is approximately 10%.

The laboratories are provided with exhaust hoods exhausting 100% of the 500 cfm room ventilation air directly to the waste disposal stack.

The locker room is ventilated by 2500 cfm of outside air, which in turn is exhausted by an independent exhauster.

Wall type convectors are provided throughout the offices, control room, locker room and laboratories to supplement the winter heating load.

Service Water

The service water system serves as a source of cooling water for the plant auxiliaries, and supply to the suction of the traveling screen wash pumps, and the motor driven fire pumps.

The system supplies water for cooling the generator hydrogen gas, turbine oil, and other equipment in the turbine room requiring cooling water.

In the reactor plant, this water is used as the cooling medium in various heat exchangers such as the shield cooler, purification cooler, and shutdown cooler.

The service water system is supplied by two 6000gpm pumps located in the circulating water intake structure. During normal operation, one pump supplies the system with 60 psig water, with the second unit as a stand-by. In addition to the service water pumps, fire pump and circulating water pumps, a 1475 gpm emergency shutdown cooling pump is also located in the crib house.

The service water pumps discharge into two twin basket backwashing type strainers. Conventional materials are used throughout the service water system.

Fire Protection

The fire protection system provided is expected to give the station adequate protection and the lowest possible fire insurance rate commensurate with investment.

The fire protection piping system is normally served by two motor-driven pumps with a capacity of 1000 gpm each at 150 psia discharge pressure. A stand-by 2000 gpm engine driven fire pump is also connected in the fire protection system for emergency use. The fire pumps are located in the turbine building and the emergency fire pump is located in the circulating water intake structure and takes direct suction from the circulating water discharge seal well. Valving is provided in the discharges of both the fire pumps and the engine driven fire pumps in order that water may be supplied to the 15,000 gal. reactor plant emergency cooling water tank. A valve is also installed on the discharge side of the engine driven pump to permit water flow to the service water system in an emergency.

The internal fire protection equipment consists of water headers supplying fire hose connections. The external fire protection equipment consists of water headers supplying fire hydrants located strategically throughout the yard area.

The main, unit auxiliary, and the reserve auxiliary transformers are protected by a water deluge system consisting of fixed spray nozzles located to quench any fire on, beneath, or close to the transformers. Fire protection devices automatically actuate the deluge system.

A low-pressure carbon dioxide fire protection system is provided for the turbine-generator unit. This system consists of CO_2 discharge nozzles located at strategic points beneath the turbine-generator unit. These nozzles are supplied by a 300 psia, 5-ton capacity CO_2 storage tank complete with refrigeration and control devices.

Sewage Disposal

The sewage disposal system for the plant consists of a septic tank, and a tile absorption field. The location of this system is shown on Dwg. NP-438. The geological characteristics of the area are ideal for this type of system. The surface allows the effluent to percolate through the porous soil absorbing the oxygen necessary for complete purification and also affording some evaporation.

Plumbing and Drainage

A complete sanitary system is provided for the plant. Water supply piping is galvanized steel pipe with galvanized malleable iron fittings. Soil, waste, and vent piping consist of I.P.S. cast iron pipe with cast iron screwed drainage fittings. Fixtures include water closets, lavatories, urinals, showers, and water coolers. The I.P.S. pipe is terminated approximately 5 ft. beyond the building line. Vitrified clay pipe is used to make connections to the septic tank. A concrete collar connects the cast iron pipe to the vitrified clay pipe.

5.1.1.6 Buildings and Site

The characteristics of the site pertinent to construction and operation of the prototype are presented in Report SL-1581 Vol. I. Descriptions of the various buildings housing the plant equipment are presented in the following sections.

Roadways and Walkways

An existing well-graded dirt road connects the site to a highway system three miles from the site. This road would be widened and surfaced. The plant roads and parking lot are also surfaced. The plant roads and parking lot are shown on Dwg. NP-438. The parking lot has accommodations for 54 automobiles.

Pedestrian walks as required are provided between buildings and between buildings and roadways.

Railroad

A single standard gauge track connects to existing trackage three miles from the plant site. The main track and spur is laid out to serve the various buildings as shown on Dwg. NP-438. Grade crossings are precast concrete slabs with hardwood creosoted flangeways.

Reactor Building

Reactor containment is provided by a cylindrical steel vessel 90 ft. in dia., with an overall height of 158 ft. from the top of the hemispherical dome to the bottom of the hemiellipsoidal base. The vessel is designed in accordance with applicable codes. The steel specified is SA-201 Grade B. Previous studies have proved the economic advantage of a cylindrical containment vessel as compared to a spherical vessel. General arrangements and cross-sections of the building and equipment are shown on Dwgs. NP-439, 440, 441.

The vessel is designed to contain an internal pressure of 36 psig which would result from a rupture of the primary coolant system. It is also designed for a combination of external loads. Any excessive external pressure is resisted by the concrete shadow shielding which is separated from the inside of the steel plate by 1 in. of flexcell. Steel plate for the cylindrical portion of the containment vessel and base is 1.375 in. thick. Plate for the spherical portion is 0.75 in. thick.

Access to the reactor building is gained by way of the personnel air lock which connects the turbine room main floor to the reactor building intermediate floor. An escape lock is also provided to the gallery around the D_2O distillation column from the main floor of the reactor building. Both air locks are equipped with double interlocking doors for maintaining integrity of the containment vessel during normal operation. A large freight door is also provided for maintenance and removal of equipment. Other penetrations through the shell are for electrical conduits, piping and the fuel handling port which enters from below grade.

A 15,000 gal. service water tank is located in the apex of the dome to supply spray water in the event of a primary system rupture. In such a case this water is released to lower the internal pressure and temperature.

The exposed exterior of the shell is covered with factory-formed foam glass insulation and roofing. This prevents condensation from accumulating on the inside of the shell and also minimizes differential expansion and contraction due to external temperature variation.

Two stair systems provide access between the main floor, intermediate floors, and the basement. A 50/5 ton crane services the area between the equipment hatches and the reactor. Floors consist of concrete slabs supported on a structural steel frame. Reference is made to the above mentioned drawings for locations of the various pieces of equipment.

Reactor Building Foundation

The concrete in the hemiellipsoidal bottom of the vessel is reinforced for uniform distribution of the loads which are carried down through the interior walls and columns. The space between the bottom of the shell and the excavation is filled with concrete for transmitting the loads from shell to soil.

The contract area of the concrete fill and the supporting soil below the shell is spread over a sufficient area to allow for a workable soil bearing value.

Turbine and Office Building

The turbine and office building is a grade level structure with no basement. The general arrangements and cross-sections of the building and their equipment are shown on Dwgs. NP-442, 443, 444, 445 and 446.

The operating floor of the turbine building is at the same elevation as the intermediate floor in the reactor building. The containment building main air lock provides access at these floor levels. A 20 ft. wide, one story bay adjoins the turbine building on the north. This bay houses compressors, station air receivers and other equipment. A mezzanine floor about half the area of the turbine room operating floor is utilized to provide support and access for heaters and auxiliary equipment. The turbine building is serviced by a 50/10 ton overhead crane.

Adjoining the turbine building on the south side is the office building. The office building is subdivided into a 26 ft. wide control area and a 33 ft. 6 in. wide office area. The main floor, mezzanine floor, and ground floor of the office building are located at the same level as the respective floors in the turbine building.

The main floor of the office building contains the plant control room in one section, and general office space, toilet facilities, and kitchen facilities in the other section.

The office building mezzanine floor houses the switchgear equipment, locker room, instrument shop, shower and toilet facilities.

Access to the office building is provided through a lobby centrally located between the office and control room sections on the ground floor. From this lobby any floor may be reached by passenger elevator or stairs, and direct access is provided to the turbine building at the ground, mezzanine or main floors. Two other stair systems are provided: one at the southeast corner of the turbine building, and the other in the turbine room near the main air lock to the reactor building.

The turbine and office building are framed with structural steel and have floors of cast-in-place concrete. Roof girders support precast concrete slabs, insulation and built-up roofing.

The exterior walls of the turbine and office building consist of insulated aluminum panels. Horizontal bands of windows are provided in the turbine room and office sections. The turbine room has a conventional forced ventilation system.

In the office building and control room, exterior walls are backed up with concrete block and plaster. Interior partitions are concrete block and glazed tile or faced with glazed tile soaps, or plastered and painted. Switchgear rooms and the machine shop have no backup inside the exterior wall panels. Ceilings are of the suspended type or exposed. The control room uses an illuminated egg crate type ceiling. Floors are either mosaic tile, quarry tile, rubber tile, asphalt tile, or steel troweled surface, depending on the type of service. The mezzanine floor is grating with some areas of concrete slabs.

Turbine Building Foundations

The turbine building, including the office area, is constructed on spread footings carried down to firm undisturbed soil. Loads from the building and crane columns are transmitted to concrete piers extending down to the spread footings. Heavy equipment is supported on mat foundations bearing on firm undisturbed soil, having a minimum total concrete weight of 2-1/2 times the weight of the machinery. Upon completion of footing and equipment mats, the ground floor slab is poured on compacted backfill, tied and seated into the piers and foundations.

Radioactive Waste Disposal Building

The radioactive waste disposal building, as shown on Dwg. NP-447, is a reinforced concrete structure with the equipment in the basement and the control room at grade level. Concrete interior walls and roof, 36 in. thick, protect personnel from radiation from equipment in the basement. Shielding design incorporates a compartment type arrangement to permit servicing of the equipment during operation.

A trolley beam arrangement supported from the roof of the ground level room permits equipment removal from the basement through a service hatch.

Buried underground adjacent to the building are the permanent resin storage tank, solid waste burial pit, two radioactive gas holdup tanks, and two waste holdup tanks. The permanent resin storage tank is a concrete vault with a stainless steel liner. The concrete permits containment in event of a tank rupture. The solid waste burial pit is a rectangular tank with reinforced concrete roof and walls.

For tank capacities and locations reference is made to Dwgs. NP-433, 438, 447 and the section of this report dealing with the waste disposal system.

Fuel Handling Building

The fuel handling building is a steel frame structure enclosed with corrugated asbestos cement siding. Facilities for receiving and storing new fuel, as well as for storing spent fuel during decay, and loading into casks for shipment, are provided in the fuel handling building.

A railroad spur is located in the north end of the building for shipping the spent fuel in casks to processing plants. Also furnished is a 25/5 ton crane to facilitate the handling of the fuel and shipping casks. Located between the fuel handling building and the reactor building is an interconnecting tunnel for transferring new and spent fuel to the storage pools.

The fuel handling building is extended on the east side to provide an enclosure for the heavy water distillation equipment.

The arrangement of the building, storage pools, and service area is shown on Dwg. NP-447.

Circulating Water Intake Structure

The circulating water intake is an unenclosed structure consisting of a substructure of reinforced concrete. Two 11 ft. wide chambers are provided for circulating water intake. Traveling screens installed in each chamber remove debris from the water. A bar grille protects the screens against damage by heavy debris. A stop log arrangement permits dewatering for inspection and maintenance of the water intake structure.

Location of equipment, and dimensions of the structure are shown on Dwg. NP-445.

Gatehouse

The gatehouse is a one story concrete brick building of about 260 ft^2 , located on the entrance roadway. It is equipped with toilet facilities and a closet, and designed so that one guard can register all incoming and outgoing visitors. The front half of the building is composed of window-wall panels affording uninterrupted visibility both toward and away from the plant.

Chimney

Radioactive gases are dispersed to the atmosphere through a concrete chimney, 13 ft. in dia. by 200 ft. high, supported on an independent, soil bearing, concrete mat foundation adjacent to the containment vessel.

Foundations

The waste disposal and fuel handling building are constructed on spread footings carried down to firm undisturbed soil. Where the structure or any portion of the structure is sufficiently below grade, the concrete bears directly on the soil without additional footing.

5.1.2 Cost Estimates

Estimates are presented in this section for the costs of design and construction, heavy water requirements, and operating and maintenance, for the liquid D_2O cooled, pressure vessel prototype plant.

Design and Construction

The estimated investment for design and construction including material, labor, contractor's overhead, contingency, escalation, and engineering design for the plant, are summarized in Table 5.1.2-I. This estimate includes a 10% contingency, 12% escalation (4% per year) and $7,790,000 top charges.

TABLE 5.1.2-I

SUMMARY OF ESTIMATED ENGINEERING AND CONSTRUCTION COSTS

	Total
L-Land	$20,000
A-Structures	
I. Ground Improvements	544,500
II. Reactor Plant	1,917,000
III. Turbine-Generator Building	753,000
IV. Waste Disposal Building	210,500
V. Fuel Handling Building	250,000
VI. D_2O Distillation Structures	15,000
VII. Circulating Water System Structures	187,000
VIII. Miscellaneous Other Buildings	148,300
Total Structures "A"	$4,025,300
B-Equipment	
I. Reactor Plant	
1. Reactor Equipment	$6,148,000
2. Auxiliaries	388,700
3. Piping	423,500
4. Instrumentation	200,000
Total B-I	$7,160,200

Table 5.1.2-I, Cont.

II. Turbine-Generator Plant	$5,889,020
III. Crib House	268,200
IV. D_2O Distillation Plant	136,680
V. Waste Disposal System	206,980
VI. Fuel Handling Plant	1,253,110
Total Equipment "B"	$14,914,190
C-Electrical	
I. Reactor Plant	$562,600
II. Turbine-Generator Plant	1,138,500
III. Crib House	11,000
IV. D_2O Distillation Plant	Incl. C-VI
V. Waste Disposal System	11,100
VI. Fuel Handling Plant	11,700
Total Electrical "C"	$1,734,900
D-Miscellaneous Equipment	
I. Health	$127,250
II. Offices and Locker Rooms	10,000
III. Machine Shop and Storeroom	64,500
IV. Fire Protection	1,200
Total Miscellaneous Equipment "D"	$202,950
Sub-Total (L Plus A to D Inclusive)	$20,897,340
E-Contractor's Overhead & Profit	940,000
Sub-Total (L Plus A to E Inclusive)	$21,837,340

Table 5.1.2-I, Cont.

F-Contingency - 10%	2,183,660
Sub-Total (L Plus A to F Inclusive)	$24,021,000
G-Allowance For Escalation	
(3 Years - 4% Per Year) - 12%	2,880,000
Sub-Total (L Plus A to G Inclusive)	$26,901,000
H-Top Charges	
I. Professional Services	
1. Reactor Design	$3,350,000
2. Reactor and Turbine Systems and Plant	1,750,000
II. Other Charges (Purchasing, Field Supervision, Interest During Construction, Etc.) - 10%	2,690,000
Total Top Charges "H"	$7,790,000
Total Estimated Cost	$34,691,000

Notes:

1. Personnel Training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

Heavy Water Inventory

For purposes of this study the heavy water inventory for the plant has been treated as an investment. At the announced purchase price of \$28.00 per pound, the D_2O inventory of 123.5 metric tons is valued at \$7,607,600. A breakdown of this investment in the various sections of the plant is as follows:

	Inventory Metric Tons	Investment
Reactor	76.5	\$4,712,400
External Coolant System	32.6	2,008,160
Other Systems	14.4	887,040
Total	123.5	\$7,607,600

Operating Costs

The operating costs for the prototype plant consist of fuel costs, heavy water make-up, operating salaries, maintenance, labor, and material, supplies, and insurance.

The annual operating costs associated with the use of heavy water arise from the loss of heavy water from the system and the operation of the heavy water distillation unit used to remove light water from contaminated heavy water.

The annual heavy water losses are estimated to be 5430 lbs., as described in Section 5.2.1.3, resulting in an annual cost of \$152,000 for make-up. The costs associated with the operation of heavy water distillation plant are estimated to be \$4,000/year. Thus the total annual operating cost for heavy water is \$156,000.

The fixed charges for D_2O inventory are based on 12.5%/year, resulting in an annual cost of \$952,000. The total annual cost of D_2O for the prototype plant is thus \$1,108,000.

The annual costs for operating and maintaining the plant are estimated as follows, including a staff of 70 persons:

Operating payroll	\$450,000
Maintenance labor, and materials	210,000
Supplies	50,000
Insurance	180,000
Total	\$890,000

Summary

A summary of the capital and operating costs for the plant when using metallic natural uranium fuel is presented in Table 5.1.2-II.

5.1.3 Pressure Tube Prototype Plant

The pressurized D_2O pressure tube reactor plant provides 1.055 x 10^6 lbs/hr. of saturated light water steam at 277 psia to a turbine-generator nominally rated at 70 MWe. The steam is generated in a pair of vertical steam generators utilizing heat from 18.8 x 10^6 lbs/hr. of D_2O reactor coolant which is pressurized to 790 psia to prevent boiling, and leaves the reactor at 490 F. A heat balance for the cycle is shown on Dwg. HB-452. The plant heat rate for these conditions is 14,550 Btu/kwh, representing an overall thermal efficiency of 23.4%.

5.1.3.1 Reactor

The reactor consists of a low-pressure aluminum calandria which contains cold D_2O moderator and which is pierced by vertical aluminum tubes arranged in an equilateral triangular lattice array. Zircaloy-2 pressure tubes passing through the calandria tubes contain the pressurized D_2O coolant and the fuel elements.

The coolant and moderator are operated as completely independent systems, affording a means of maintaining low moderator temperature. The air filled annulus between the pressure tube and calandria tube provides thermal insulation between the hot coolant and the cold moderator.

The coolant D_2O, flowing at 18.8 x 10^6lbs/hr., enters a plenum distribution system below the reactor at 446 F, passes upward through the pressure tubes where it is heated by the fuel elements, and passes out through an upper plenum at 490 F to two steam generators.

Calandria

The calandria is a cylindrical aluminum vessel, 13.83 ft. ID with an inside height of 12.50 ft., containing the moderator and reflector, which is one foot thick radially and axially. The vessel has 274 vertical calandria tubes which surround the pressure tubes and control rods. The shell and head thicknesses are 1 in. and 3 in., respectively. The material of the calandria and calandria tubes is 5052-0 aluminum alloy.

The calandria has a 12 in. aluminum inlet and outlet line for circulation of the moderator D_2O through a moderator cooling system. Two 16 inch aluminum fast drain lines near the bottom of the calandria provide a means for emptying the D_2O moderator in a very short time as a backup scram in case of control and safety rod failure during an emergency shutdown. Helium is used as a cover gas over the D_2O surface in the calandria. Continuous helium flow is provided through an inlet at one

TABLE 5.1.2-II

CAPITAL AND OPERATING COSTS FOR 70MWe, PRESSURIZED D_2O, PRESSURE VESSEL, INDIRECT CYCLE, PROTOTYPE

Annual Generation - 484×10^6 KWH at 0.8 L.F.

Fuel		Metal Fuel
Design Burnup, MWD/metric ton-U		3600
Refueling Scheme		100% Batch
	Invest. $\$10^6$	Annual Cost $\$ 10^6$/yr.
Investment		
Reactor Plant	19.587	2.743
Turbine Plant	14.628	2.050
Miscellaneous, Buildings and Equipment	0.476	0.067
Sub-Total	34.691	4.860
D_2O Inventory	7.620	0.952
Total Investment	42.311	5.812
Operation and Maintenance		
Fuel		
Inventory		0.050
Non-nuclear Inventory		0.092
Replacement		1.330
Total Fuel Costs		1.472

Table 5.1.2-II, Cont.

<u>Heavy Water</u>	
Losses	0.152
Dist. Plant Operation	0.004
Total D_2O Costs	0.156
Operating Payroll	0.450
Maintenance labor, and material	0.210
Supplies	0.050
Insurance	0.180
Total Operating and Maintenance	2.518
Total Capital and Operating Costs	8.330

side of the top head above the D_2O level and an outlet at the opposite side of the vessel. A 10 in. vent line between the calandria and moderator storage tank is used to maintain near atmospheric helium pressure in the vessel during a fast drain of the moderator.

The weight of the empty aluminum calandria is approximately 8 tons.

Pressure Tubes and Plenums

Pressure tubes and plenums provide the means for carrying the coolant flow through the reactor. D_2O at 446 F enters the lower plenum where it is distributed to the pressure tubes. The coolant flows upward in the pressure tubes and through the fuel elements at a total flow rate of 18.8×10^6 lbs/hr. Heat produced in the fuel is transferred to the coolant so that at the reactor outlet, the coolant temperature is 490 F. The effluent continues through the pressure tubes to the upper plenum from which the coolant flows to the steam generators.

Zr-2 is used for the pressure tubes because of its corrosion resistance and low absorption cross-section for thermal neutrons. Each tube is 29 ft. long between connectors at the upper and lower plenums. The connectors are stainless steel pipe sections and are joined to the Zr-2 pressure tube by means of a mechanical joint located 12 in. above and below the lower and upper plenums, respectively. The pressure tube outside diameter is 3.272 in. and the inside dia. 2.900 in. A total of 236 pressure tubes is required.

The upper and lower plenums are located in separate rooms above and below the reactor as shown on Dwg. NP-462. The lower plenum distributes the D_2O coolant to the 236 pressure tubes and the top plenum collects the D_2O from them. Flow of the coolant to and from the pressure tubes is controlled by orifices in the pressure tube end fittings which extend through the plenum. These stainless steel end fittings are welded to the plenum at the top and bottom head plates thereby providing internal stays to resist the pressure developed by the coolant.

The 13.0 ft. OD by 16 in. high plenums are fabricated of Type 304 stainless steel. The head and wall thicknesses are 1.375 in. and 5.25 in. respectively.

Fuel Elements

The 236 fuel elements in the reactor are arranged in a regular hexagonal lattice with a 7.8 in. pitch.

The fuel element design and thermal characteristics are based on those developed by du Pont, as reported in DP-385. A summary of the fuel data is presented below:

Fuel material	U-2 w/o Zr alloy
Shape	Hollow cylinder 2.030 in. OD x 1.497 in. ID

Active length	5.00 ft.
Number of elements per press. tube	2
Cladding material	Zircaloy-2
Cladding thickness	0.015 in.

Each fuel element is positioned in a pressure tube inside the reactor. The pressure tubes are supported by the upper and lower plenums. Coolant D_2O flows both on the inside and outside of the fuel tube. A suitable grappling head is incorporated at the top of each fuel element for use by a refueling machine. The active core diameter and height are 11.83 ft. and 10.00 ft., respectively.

Control Rods and Drives

Reactivity is controlled by three sets of control rods classified as safety, shim and regulating rods. The reactor is designed for bottom entry of the control rods. The safety rods are normally positioned above the core to permit them to fall by gravity when a reactor scram is required. Each safety rod system is enclosed in a thimble extending from above the upper neutron shield (where the latching device is located) down into the control rod access pit below the reactor. The shim rods provide slow, coarse control of reactivity. They are driven into the core from below the reactor by electric motors at a relatively slow rate and are not detached from their drives, except for disassembly purposes. The regulating rods are similar to shim rods with the exception that their drive motors are capable of greater speeds and accelerations.

The number of safety rods, shim rods and regulating rods are 19, 17, and 2, respectively. All control rods are of a hollow cylindrical shape. The shim and regulating rod poison sections are fabricated of cadmium, and that of the safety rods is 1% boron steel.

Reactor Shields

Three types of reactor shields are provided: thermal shields, neutron shields and biological shields. They are described below.

Thermal Shields

The function of the thermal shields is to absorb a major portion of the radiation energy emitted from the reactor core and in so doing, to protect the concrete structure around the reactor from overheating.

The thermal shield is a one foot thick tank that lines the calandria room so as to completely cover the exposed concrete. The thermal shield tank is fabricated of 1 in. thick carbon steel plate. Cooling water is circulated through the tank, which is internally baffled, to remove the heat that is generated in the shield by absorption of core radiation. Demineralized light water is the coolant, which enters at 110 F and leaves at 130 F. The section of this report dealing with shield cooling gives a detailed description of the shield cooling system for the thermal, neutron, and biological shields.

Neutron Shields

The function of the neutron shields is to limit the activation of reactor components above and below the reactor.

The neutron shields are located directly above and below the calandria and are designated as upper and lower neutron shields, respectively. They are shown on Dwg. NP-462.

Both the upper and lower neutron shields consist of shot filled carbon steel tanks with penetrations for the lattice positions. The shot is borated iron. Suitable offsets are provided in the penetrations and supports to reduce neutron streaming. The use of shot permits cooling water to flow continuously throughout the mass of the shield thereby removing the heat generated by absorption of core radiation and by heat transferred from the D_2O pressure tubes passing through the shields. Demineralized light water is the coolant which enters at 110 F and leaving at 130 F.

Biological Shields

The function of the biological shields is to attenuate radiation to tolerance levels at all locations occupied by personnel. The concrete walls, ceilings and floors surrounding the reactor and its auxiliary systems constitute the biological shields. Wherever access to compartments is required, a removable concrete slab with suitable offsets and overlaps to insure continuous, effective shielding has been provided.

In attenuating escaping radiation the biological shield absorbs energy which appears as heat. In the reactor biological shields the heat generation is sufficient to require cooling to prevent damage to the concrete. This cooling is accomplished by circulating demineralized light water through coils embedded in the concrete. The coolant enters the coils at 110 F and leaves at 130 F.

The biological shields for the plant are shown on Dwgs. NP-461 and NP-462.

Plant Instrumentation

Measurement of reactor flux and coolant-moderator conditions for the pressure tube reactor requires instrumentation that is functionally similar to that provided for the pressure vessel reactor. The functions of the safety system, which are controlled by the reactor instrumentation, and those of the instrumentation channels, are basically similar to those described in Section 5.1.1.1. Radiation monitoring and D_2O leak detection systems are also similar to those of the pressure vessel reactor plant. The type of reactor vessel has little effect on the functions of these systems.

Plant Control System

The plant control system is based on maintenance of a constant average reactor coolant temperature, with separate controls for reactor pressure, turbine steam pressure, steam generator level and hot well level. Neutron flux serves as a limiting function, with flux level and period serving as limits on the movement of the regulating rods. The control block diagram of a tentative system is shown on Dwg. NP-456. An operational block diagram, which shows the arrangement of interlocks in the rod control circuits, in accordance with the control system philosophy, appears on Dwg. NP-458.

Because the average moderator temperature of the pressure tube reactor is constant, it is expected that the temperature variations in the coolant will have a small effect on the reactivity, and as a result, rod manipulation will be required to a greater extent than in the pressure vessel reactor. However, the same general control philosophy is applicable. A detailed analysis of control requirements for the pressure tube reactor requires a study of the dynamic response of the reactor system. Such a study was not within the scope of this investigation.

5.1.3.2 Reactor Coolant System

The reactor is cooled by circulating a constant flow of 18.8×10^6 lb/hr. of D_2O coolant through two main coolant loops. Each loop consists of a circulating pump, steam generator, and interconnecting piping and valves. A flow diagram of the main coolant system is shown on Dwg. NP-453.

Each loop is designed to handle a coolant flow rate of 9.4×10^6 lb/hr. The coolant leaves the reactor from the upper plenum at 490 F and 790 psia, flows through the steam generators producing 277 psia saturated light water steam, and is returned to the lower plenum at 446 F by the circulating pumps. Each steam generator produces steam at a rate of 5.275×10^5 lbs/hr. providing a total of 1.055×10^6 lbs/hr. to the turbine system.

Steam Generators

The two steam generators are vertical shell and tube heat exchangers in which the reactor coolant flows on the tube side. Inverted U-tubes extend upward from the water box which is located at the lower end of the unit. The upper portion of the shell is used as a steam separator and collection drum.

One-half in. tubes are used in the steam generators in order to obtain maximum heat transfer surface while holding the volume of D_2O in the unit to a minimum. Stainless steel tubes are used to minimize corrosion.

The tube sheets and other interior surfaces of the steam generators which come in contact with D_2O are either stainless steel or stainless steel clad. The shell of the steam generator is fabricated of carbon steel. The 6 ft. 10 in. OD by 26 ft. high steam generator has a heat transfer surface area of 11,600 ft^2.

Coolant Pumps

The two 20,600 gpm reactor circulating pumps are designed for the 790 psia operating pressure of the reactor coolant system. The pumps are of centrifugal type with vertical shafts and are driven by 1000 hp direct connected motors. The pump impellers are stainless steel, and the casings are fabricated of chrome-moly alloy. The pumps are otherwise of conventional design except for the shaft gland seals, which are of the double balanced mechanical type.

Coolant Piping and Valves

The circulating piping in both coolant loops is 20 in.-schedule 60 pipe fabricated of 304 stainless steel. The piping is sized for a fluid velocity of 25 fps to minimize the D_2O inventory in the system. All piping connections are butt-welded.

The valves in the primary coolant system are fabricated of stainless steel and are butt-welded into the piping system. The glands are provided with double packing and lantern rings to allow the collection of stem leakage.

Each primary coolant loop has two, 20 in., motor operated valves: one in the reactor coolant outlet line and the other in the coolant return line. This arrangement facilitates shutdown of one loop and permits isolation of the steam generator and circulating pump from the system while the other loop remains in service.

During emergencies, if the plant auxiliary power is lost, the above motor-operated valves may be closed by using power from the emergency diesel generator. With both loops closed, the D_2O coolant may be cooled using the emergency shutdown cooling system, which is described in a later section.

5.1.3.3 Reactor Auxiliaries

The reactor auxiliaries include those systems provided for coolant purification, moderator cooling and purification, coolant pressurization and level control, collection and treatment of off-gas, shield cooling, shutdown cooling, waste disposal, fuel handling, and D_2O distillation.

The composite flow diagram, Dwg. NP-452, shows the general flow of fluids in these systems and their interconnections, with the exception of the waste disposal and the fuel handling systems.

With the exception of the systems provided for cooling and purifying the moderator, which is separated from the coolant and therefore requires its own systems for these functions, the reactor auxiliaries provided for the pressure tube reactor are functionally equivalent to those of the pressure vessel reactor. Flow rates and temperatures differ slightly in certain systems to accommodate the differences in reactor coolant operating conditions.

Diagrams of the reactor auxiliaries are shown on the following drawings:

NP-454 Reactor Auxiliaries System Diagram

NP-455 Recombiner and Off-Gas Systems Diagram

Where a pressure tube-plenum configuration is used to contain the coolant in the reactor, as in the present plant, the use of a separate pressurizer tank is justified on the basis of (a) minimizing the volume of the upper plenum, and (b) rendering the pressurizing system more sensitive to coolant volume changes than would be possible if the pressurizing helium were admitted to the upper plenum. The coolant pressurizing system and the moderator systems are described in the following sections.

Coolant Pressurizing System and Level Control

To prevent boiling in the primary system, the coolant is maintained at a pressure well above its vapor pressure by the helium cover gas in the pressurizer tank. A diagram of the system is shown on Dwg. NP-455.

The coolant in the reactor is maintained at a pressure of 790 psia by a high-pressure helium system, with a helium storage tank and a pressure controller which controls the pressure in the coolant pressurizer. Decreases in pressure are compensated by the controller which actuates a valve in the helium supply line from the storage tank to restore the pressure to the level dictated by the set point on the controller. A pressure increase causes the controller to relieve the helium in the pressurizer tank to the recombiner system, where it is compressed and sent back to the helium storage tank. The 350 ft^3 helium storage tank, therefore, serves as a surge tank for the cover gas system.

Normal operating pressure in the helium storage tank is 940 psia. Should this pressure drop considerably for any reason, make-up is automatically provided from high-pressure helium supply cylinders.

Coolant volume in the 200 ft^3 pressurizer tank is allowed to vary plus or minus 50 ft^3 from its normal operating level at midpoint of the tank.

Should the coolant exceed its upper level, a level controller on the pressurizer tank actuates a valve to drain the excess coolant to the coolant storage tank. Since this storage tank is at atmospheric pressure, a drain cooler is provided to condense any coolant that flashes into steam during the expansion process. The overflow rate from the pressurizer tank is not expected to exceed 85 gpm.

Should the coolant level decrease below its minimum level, the controller actuates a D_2O transfer pump, and coolant is pumped from the coolant storage tank to the reactor system through the suction side of a reactor circulating pump. The level control system is shown on Dwg. NP-452.

A 350 ft^3 helium holdup tank provides storage of pressurizer tank and D_2O coolant storage tank cover gases at 300 psig during periods when the primary system coolant is drained. This gas is returned to the system during coolant refilling, thereby recovering large helium gas quantities which would otherwise be vented to the atmosphere.

All piping, valves, and related equipment in contact with helium or D_2O are constructed of Type 304 stainless steel.

Helium Inventory

Helium is used not only for pressurization but also as a cover gas for all D_2O in the plant. The total inventory in the systems during normal plant operation is 30,000 scf. A breakdown of this figure is as follows:

Helium storage tank	21,000 scf
Pressurizer tank	3,600 scf
D_2O coolant storage tank	1,900 scf
Moderator storage tank	2,000 scf
Other	1,500 scf
Total	30,000 scf

Helium make-up is provided by two banks of cylinders located on the main floor in the reactor building.

Moderator System

During normal operation, approximately 8% of the thermal power of the reactor is deposited in the moderator D_2O by neutron slowing down, gamma energy absorption, and heat transferred from the pressure tubes. A cooling system is provided to remove this heat energy, and to maintain an average moderator temperature of 120 F, thereby improving the reactivity of the core.

Moderator Cooling System

3.69×10^6 lb/hr. of moderator D_2O are removed from the calandria at 130 F, pumped through a cooler and returned to the calandria at 110 F, thereby maintaining an average moderator temperature of 120 F. A diagram of the moderator cooling system is shown on Dwg. NP-454.

The moderator cooling equipment is isolated in a concrete shielded room adjacent to the reactor. Access to this room during operation of the plant is prohibited by high radiation levels originating fron N^{16} and O^{19} formed in the D_2O. However, the space is accessible shortly after shutdown.

D_2O flows through the tube side of the cooler, and the heat is transferred to plant service water on the shell side. The water box of the cooler is divided, with two separate tube bundles and separate D_2O inlet and outlet connections, to permit the cooler to operate at half capacity in the event of a tube leak by isolating one bank of tubes. Thus, it may be possible to permit the moderator temperature difference across the cooler to rise while continuing operation. The level of power that can be maintained is dependent upon the condition of the reactor fuel at the time of tube failure and the variation in the effective multiplication factor with average moderator temperature.

The moderator cooler tubes, tube sheets and water boxes are aluminum while the shell is fabricated of carbon steel.

Two half-capacity horizontal centrifugal pumps, pumping 1.84×10^6 lbs/hr. each, take suction from the outlet side of the moderator cooler. If for some reason one of the pumps must be taken out of service, operation can continue subject to the restrictions noted above with respect to the moderator cooler.

Each of the moderator pumps is provided with single unbalanced mechanical shaft seals. All pump parts in contact with D_2O are fabricated of stainless steel.

All piping in the moderator system is fabricated of aluminum.

Moderator Make-up and Level Control

The moderator leak detection and level control system is shown on Dwg. NP-454. A continuous overflow of 3.6×10^4 lbs/hr. at the moderator operating level in the calandria is carried through an external standpipe and returned to the system at the moderator cooler discharge by means of a level control pump. Accurately controlled constant flow through this system is maintained using a flow control valve at the pump discharge. By balancing the flows of this system, the moderator level may be varied if desirable for reactor shim control.

Make-up D_2O is introduced into the standpipe from the moderator storage tank using a D_2O transfer pump at the tank. The occurrence of any leakage in the moderator system will be indicated by appropriate level alarms. The rate of leakage can be determined by measuring the make-up rate to the system.

The piping, valves and standpipe are fabricated of aluminum, while the pump parts coming in contact with D_2O are of stainless steel.

Moderator Fast Drain System

As a provision for backup reactor scram in the event all other scram devices fail to operate, two 16 in. aluminum pipes are furnished for draining the calandria. These lines run from outlets near the bottom of the calandria, through hydraulically operated quick opening valves, to the moderator storage tank in the basement of the reactor building. One 10 in. aluminum helium vent line is provided from the storage tank to the top of the calandria to insure unimpeded flow of fluid during a fast drain and to prevent a net external positive pressure on the calandria. A spray system in the calandria provides cooling of the calandria tubes while the moderator level is below normal.

Moderator Purification System

Two moderator contaminants are of major importance to reactor operation: H_2O and normal corrosion products.

H_2O contamination in the normally 99.75% pure D_2O moderator could reduce reactivity by poisoning and require plant shutdown. For this reason, every attempt has been made in the design to prevent inleakage of H_2O. Should a slight inleakage of H_2O occur, it can be removed by processing with the D_2O distillation system described under reactor auxiliaries in this report. The moderator purification system diagram is shown on Dwg. NP-454.

To remove corrosion products from the aluminum moderator system, 10 gpm of moderator D_2O is continuously passed through a demineralizer system to maintain system purity at 1 ppm total dissolved solids. The flow is taken from the discharge side of the moderator cooler at a temperature of 110 F and, therefore, may be passed through the demineralizer bed without further cooling. After passing through the demineralizer and a strainer, the purified D_2O is returned to the suction side of the moderator circulating pumps by one of two parallel connected booster pumps.

The strainer is a 100 mesh stainless steel screen which serves to prevent the carry-over of material from the mixed bed exchanger to the moderator system.

The demineralizer is a mixed bed exchanger containing 7 ft^3 of nuclear grade resin, based on a 2 year lifetime, with a bed depth of 4 ft.

The mixed bed exchanger vessel and all fluid contact surfaces of the pumps are fabricated of Type 304 stainless steel. Piping and valves are of aluminum.

Moderator Cover Gas and Recombiner Systems

A helium gas blanket is maintained over the free surface of the D_2O in the calandria, the standpipe and the moderator storage tank, as shown on Dwg. NP-455. This blanket serves to prevent H_2O contamination of the D_2O, to maintain an operating pressure of 3 in. of water in the moderator system by providing a surge volume and to collect any dissociated D_2 and O_2 formed in the reactor. A central high-pressure helium storage tank located within the reactor building supplies all helium to the system through pressure regulating controls.

A continuous flow of 3 scfm of helium is maintained across the free surface of the moderator in the calandria during normal operation by one of two helium blowers connected in parallel. This flow will collect any D_2 and O_2 dissociated in the moderator or reflector. The gas is circulated through a moisture recovery system which is similar to that of the coolant system for the pressure vessel reactor. In this way, all dissociated D_2 and O_2 is effectively recombined and recovered.

All D_2O recovered in the moisture separators and condenser is sent to the miscellaneous D_2O drain tank. In the drain tank it is batch monitored for D_2O purity and either returned to the system or sent to the distillation plant for upgrading.

A small, normally closed helium bleed line is provided in the cover gas system to be used if it becomes necessary to change and/or purify the cover gas. This bleed line passes the gas through the D_2O recovery system facilities in the off-gas system and ultimately to the waste gas disposal stack.

All metals in contact with helium in the recombiner system are of Type 304 stainless steel.

Radioactive Waste Disposal System

Complete facilities are provided at the plant site for processing and disposing of all radioactive wastes originating in the plant during normal operation. The radioactive waste disposal system provided for the pressure tube reactor plant is the same as that of the pressure vessel reactor plant, as described in Section 5.1.1.3, except that the capacity of the resin storage tank and the radioactive gas holdup tanks is somewhat larger. These tanks were increased in size to provide storage for the spent filters and resins of the moderator purification system and to accommodate the waste gases from the moderator cover gas system.

The off-gas system diagram is shown on Dwg. NP-455.

D_2O Losses and Recovery

Control of D_2O leakage from the various systems of the plant is provided by minimizing the rate of leakage from equipment shaft seals, pressure tube joints and control rod seals, and by recovering any leakage that does occur. The devices and systems that are provided for these functions are as described for the 70 MWe pressurized D_2O pressure vessel prototype plant in Section 5.1.1.3, with suitable additions as required to collect leakage from the separate moderator system.

The estimated rate of loss of D_2O from the entire system during normal operation is 6.6 lbs/day, or 2400 lbs/yr. The loss rate is based on estimates of leakage rates from plant components and estimates of the efficiency of the D_2O recovery systems, as described in Section 5.1.1.3. The total annual loss, including an allowance of 300 lbs/yr. for refuelling operations and approximately 1% per year for spills and accidents, is estimated to amount to 2% of the plant inventory, or 5346 lbs.

5.1.3.4 Turbine Plant

The turbine plant, consisting of the turbine-generator, condenser, feed-water heaters, circulating water system, and associated auxiliaries, utilizes saturated steam from two steam generators to produce a net electrical power output of approximately 69,800 kw, with a total steam flow of 1.055 x 10^6 lbs/hr. and a condenser pressure of 1.5 in. HgA. Condensate from the condenser is returned to the steam generators through three stages of feed-water heating. A flow diagram of the steam, condensate, and feed-water cycle appears on Dwg. NP-453.

Turbine-Generator

The turbine is a tandem-compound, double flow unit with 23 in. exhaust blades and operates at 3600 rpm. Dry and saturated steam at 277 psia is supplied to the turbine through two turbine stop valves. Moisture removal devices are furnished with the turbine.

Condensing Equipment

The main condenser is a two pass unit with a heat transfer surface of 90,000 ft^2. Admiralty metal tubes 26 ft. long and 1 in. OD x 18 BWG are used for the heat transfer surface.

The quantity of steam to be condensed is 740,000 lbs/hr. The condenser is provided with divided water boxes and valved for backwashing to clean the condenser tubes. A circulating water flow of 95,700 gpm at 70 F is required for condensing purposes at 1-1/2 in. HgA. An expansion joint is provided between the turbine and condenser to absorb movement due to thermal expansion.

A two element steam jet air ejector is furnished with an automatic steam pressure reducing valve in the steam supply line to the jets.

The ejector removes noncondensable gases from the condenser. A non-condensing auxiliary ejector is provided to aid in the rapid evacuation of air from the condenser, and a priming ejector is supplied for the evacuation of the water box space in the circulating water system.

Condensate Pumps

Two half-capacity, horizontal, centrifugal condensate pumps are provided, taking their suction from the condenser hot well. The condensate pumps provide the head necessary to pump the condensate from the condenser through the air ejector, gland steam condenser, low-pressure heater and to the deaerating heater. Each pump delivers 880 gpm and is driven by a direct connected 100 hp motor. The pump is of conventional design and material.

Feed Water Pumps

Feed water pumps provide the head necessary to return the feed water to the high-pressure heater and the steam generators. Two half-capacity, horizontal, centrifugal feed pumps are provided, taking their suction from the deaerating heater. Each pump deliver 1055 gpm and is driven by a direct connected 300 hp motor. Recirculation is provided to cool the pump under low flow conditions. The recirculation line carries the feed water back to the deaerating heater where it again enters the cycle to the feed water pump suction. A warming line is also provided at each pump. The pumps are of conventional design and material.

Feed-water Heaters

Three stages of feed water heating are provided, yielding a final feed-water temperature of 333 F. Each feed-water heater is equipped with normal and emergency level controller which maintain normal water level in the heater hot well. All heaters are of conventional design and material, as described in Section 5.1.1.4.

Piping

The main steam piping consists of two 18 in. schedule 40 carbon steel pipes, running directly from the steam generators to the turbine stop valves. Each line is sized to handle a steam flow of 527,500 lbs/hr. at a velocity of approximately 9500 fpm. An 18 in. schedule 40 pipe is provided as a dump line to the condenser to handle changes in load and normal and emergency shutdown conditions. This line is sized to handle 50% of full steam flow.

The extraction steam piping from the turbine to the high-pressure heater, deaerating heater and low-pressure heater are sized for velocities of 7700, 6700, and 5400 fpm,respectively.

Condensate piping from the condenser hot well to the deaerating heater is sized for velocities of 8-15 fps. The velocity of the condensate in the condensate pump suction line and the feed water pump suction line is 2.4 and 5.3 fps, respectively. Piping from the feed water pump discharge to the steam generators is sized for a velocity of 8-15 fps.

The circulating water piping system consists of one 48 in. line from each pump running into the condenser and two 48 in. outlets converging into a 66 in. main outlet to the crib house. A 72 in. pipe carries the discharge from the crib house to the river.

The piping systems in the plant are designed in accordance with the appropriate codes presently in effect. All piping is carbon steel. Pipe sizes in the turbine building are shown on Dwg. NP-453.

The remaining piping systems in the turbine plant are of conventional materials and construction.

Valves

All valves in the turbine system are of standard design and construction.

Electrical Equipment

The electrical power is generated at 13,800 volts, with a capacity of 74,400 kw at design turbine inlet conditions and 1.5 in. HgA condenser pressure. Plant auxiliary requirements reduce the output to a net of 69,800 kw. The electrical single line diagram is shown on Dwg. NP-469. The major electrical equipment for this plant duplicates that of the pressurized D_2O pressure vessel prototype plant. Differences occur in the number of motors fed by the auxiliary switchgear and in the station auxiliary power requirements, however, these differences are of minor importance.

5.1.3.5 Plant Utilities

With the exception of the service water system, the plant utility systems provided for the pressure tube reactor plant duplicate those of the pressurized D_2O pressure vessel prototype plant, as described in Section 5.1.1.5. These systems consist of the following:

Control and station air

Air conditioning and ventilation

Fire protection

Sewage disposal

Plumbing and drainage

The service water supply system includes one additional pump, resulting in a total of three 6000 gpm pumps, all of which take suction from the circulating water intake structure at the crib house. The additional pump is required to supply cooling water for the moderator cooler. Normally, this pump and a second pump are operated to supply service water for the plant, with the third pump in stand-by condition.

5.1.3.6 Buildings and Site

The characteristics of the site pertinent to construction and operation of the prototype are presented in Report SL-1581, Vol. I. The plant access facilities are similar to those of the pressure vessel plant, as described in Section 5.1.1.6 of this report. The development of the site, and the arrangement of the buildings on the site are shown on Dwg. NP-460.

With the exception of the reactor building, all of the plant structures are similar in design and construction to those of the pressure vessel prototype plant. The turbine and office building are shown on Dwgs. NP-463 through NP-467. Dwg. NP-468 shows the arrangement of the waste disposal building and the fuel handling building.

Reactor Building

Reactor containment is provided by a cylindrical steel vessel 100 ft. in dia., with an overall height of 157 ft. from the bottom of the hemiellipsoidal base to the top of the hemispherical dome. General arrangements and cross-sections of the building and equipment are shown on Dwgs. NP-461 and 462.

The vessel is designed to contain an internal pressure of 18.3 psig which would result from a rupture of the primary coolant system. Steel plate for the cylindrical portion of the containment vessel and base is 0.875 in. thick. Plate for the spherical portion is 0.5 in. thick.

All other features of the reactor building are similar in design and arrangement to the building for the pressure vessel prototype reactor plant, as described in Section 5.1.1.6.

5.1.4 Cost Estimates

Estimates are presented in the following section for the costs of design and construction, heavy water requirements, and operating and maintenance for the prototype pressurized D_2O pressure tube reactor plant.

Design and Construction

The summary of estimated costs for design and construction, including material, labor, contractor's overhead, contingency, escalation and engineering design for the plant, is presented in Table 5.1.4-I. This estimate includes a 10% contingency, 12% escalation (4% per year) and $7,846,000 top charges. The total estimated design and construction investment is $35,306,000.

TABLE 5.1.4-I

SUMMARY OF ESTIMATED ENGINEERING AND CONSTRUCTION COSTS

	Total
L-Land	$20,000
A-Structures	
I. Ground Improvements	$544,500
II. Reactor Plant	1,871,300
III. Turbine-Generator Building	753,000
IV. Waste Disposal Building	210,500
V. Fuel Handling Building	250,000
VI. D_2O Distillation Structures	15,000
VII. Circulating Water Systems Structures	187,000
VIII. Miscellaneous Other Buildings	148,300
Total Structures "A"	$3,979,600
B-Equipment	
I. Reactor Plant	
1. Reactor Equipment	$6,248,000
2. Auxiliaries	451,250
3. Piping	556,500
4. Instrumentation	200,000
Total B-I	$7,455,750

Table 5.1.4-I, Cont.

II. Turbine-Generator Plant	$5,885,020
III. Crib House	268,200
IV. D_2O Distillation Plant	136,680
V. Waste Disposal System	206,980
VI. Fuel Handling Plant	1,253,110
Total Equipment "B"	$15,205,740
C-Electrical	
I. Reactor Plant	$606,500
II. Turbine-Generator Plant	1,138,500
III. Crib House	11,000
IV. D_2O Distillation Plant	Incl. C-VI
V. Waste Disposal System	11,100
VI. Fuel Handling Plant	11,700
Total Electrical "C"	$1,778,800
D-Miscellaneous Equipment	
I. Health	$127,250
II. Offices and Locker Rooms	10,000
III. Machine Shop and Store Room	64,500
IV. Fire Protection	1,200
Total Misc. Equipment "D"	$202,950
Sub-Total (L Plus A to D Inclusive)	$21,187,090
E-Contractors Overhead and Profit	1,104,000
Sub-Total (L Plus A to E Inclusive)	$22,291,090

Table 5.1.4-I, Cont.

F-Contingency -10%	2,228,910
Sub-Total (L Plus A to F Inclusive)	$24,520,000
G-Allowance for Escalation (3 Years - 4%/yr.) -12%	2,940,000
Sub-Total (L Plus A to G Inclusive)	$27,460,000
H-Top Charges	
I. Professional Services	
1. Reactor Design	$3,350,000
2. Reactor and Turbine Systems & Plant	1,750,000
II. Other Charges (Purchasing, Field Supervision, Interest During Construction, Etc.) -10%	2,746,000
Total Top Charges "H"	$7,846,000
Total Estimated Cost	$35,306,000

Notes:

1. Personnel training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

Heavy Water Inventory

For purposes of this study the heavy water inventory for the plant has been treated as an investment. At the announced purchase price of \$28.00/lb., the D_2O inventory of 121.5 metric tons is worth \$7,484,400. A breakdown of this investment in the various sections of the plant is as follows:

	Inventory Metric Tons	Investment
Reactor	65.0	\$4,004,000
External coolant system	30.7	1,891,120
External moderator system	10.2	628,320
Other systems	15.6	960,960
Total	121.5	\$7,484,400

Operating Costs

The operating costs for the pressure tube, pressurized D_2O prototype plant, consist of fuel cost, heavy water make-up, operating salaries, maintenance, labor, and materials, supplies, and insurance.

The annual operating costs associated with the use of heavy water arise from the loss of heavy water from the system and the operation of the heavy water distillation unit used to remove light water from contaminated heavy water.

The annual heavy water inventory loss is estimated to be 5346 lbs., as described in Section 5.1.3.3, resulting in an annual cost of \$149,688. The costs associated with the operation of heavy water distillation plant are estimated to be \$4,000 per year. Thus, the total annual operating costs for heavy water is \$153,688.

The fixed charges for D_2O inventory are based on 12.5%/yr., resulting in an annual cost of \$937,000, thereby bringing the total annual cost of D_2O to \$1,090,688.

It is estimated that a staff of 70 persons will fulfill the operating and maintenance requirements of the plant. The staff payroll, combined with supplies and insurance, is estimated to cost \$890,000/yr. broken down as follows:

Operating Payroll	\$450,000
Maintenance, Labor and Supplies	210,000
Supplies	50,000
Insurance	180,000
Total	\$890,000

Summary

A summary of the estimated capital and operating costs for the plant when using natural uranium metal fuel is presented in Table 5.1.4-II.

5.2 FULL SCALE, PRESSURIZED D_2O, INDIRECT CYCLE PLANTS

Two reactor concepts using pressurized D_2O coolant were evaluated: pressure vessel hot moderator and pressure tube cold moderator types. Basically, the reactors fueled with natural UO_2 are similar to those previously reported in SL-1565 as Concepts 1 and 2, for the pressure vessel and pressure tube unit, respectively. The metal fueled reactor designs are based on those prepared by duPont and have been reported as the 1-B and 1-D series for the pressure vessel and pressure tube types, respectively, in DP-385. The metal fueled reactors incorporated in the plant designs reported herein differ from those in DP-385 in that their operating pressures and coolant temperatures were adjusted to correspond to those used by SL-NDA for the oxide fueled plants. Thus, the only difference occurring between reactors of the same concept in identical capacities, but using different fuels; i.e. metal or oxide, appears in the reactor arrangements.

5.2.1 Plant Design Descriptions

Specific design characteristics for the 200 and 300 Mwe pressurized D_2O cooled plants fueled with natural uranium metal or natural uranium oxide are given in Tables 5.2.1-I and 5.2.1-II for the pressure vessel and pressure tube concepts respectively. General arrangement drawings for each of the pressurized D_2O cooled indirect cycle plants appear as follows:

Drawing No.	Plant
NS-730	200 MWe, Pressure Vessel, Metal Fueled
NS-740	300 Mwe, Pressure Vessel, Metal Fueled
NS-750	300 MWe, Pressure Vessel, Oxide Fueled
NS-760	200 MWe, Pressure Tube, Metal Fueled
NS-770	300 MWe, Pressure Tube, Metal Fueled
NS-780	300 MWe, Pressure Tube, Oxide Fueled

For detailed general arrangements and more specific discussion of the concepts, reference is made to SL-1565.

Pressure Vessel Reactors

The full scale reactors are similar in design and construction; they are natural uranium fueled, pressurized D_2O moderated and cooled and housed in a stainless steel clad, carbon steel pressure vessel operating at

TABLE 5.1.4 -II

CAPITAL AND OPERATING COSTS FOR 70 MWe, PRESSURIZED D_2O, PRESSURE TUBE, PROTOTYPE PLANT

Annual Generation - 484×10^6 KWH at 0.8 L.F.

Fuel		Natural U-Metal
Design Burnup MWD/metric ton-U		3800
Refueling Scheme		100% Batch
	Invest. $\$10^6$	Annual Cost $\$10^6$/yr.
<u>Investment</u>		
Reactor Plant	20.670	2.893
Turbine Plant	14.160	1.980
Miscellaneous, Buildings and Equipment	0.476	0.067
Sub-Total	35.306	4.940
D_2O Inventory	7.500	0.937
Total Investment	42.806	5.877
<u>Operation and Maintenance</u>		
<u>Fuel</u>		
Inventory		0.054
Non-Nuclear Inventory		0.061
Replacement		1.266
Total Fuel Costs		1.381

Heavy Water

Losses	0.150
Dist. Plant Operations	0.004
Total D_2O Costs	0.154
Operating Payroll	0.450
Maintenance, Labor and Material	0.210
Supplies	0.050
Insurance	0.180
Total Operating and Maintenance	2.425
Total Annual Capital and Operating Costs	8.302

TABLE 5.2.1-I

PLANT DESIGN CHARACTERISTICS FOR 200 AND 300 MWe
PRESSURIZED D_2O PRESSURE VESSEL, INDIRECT CYCLE REACTORS

Reactor Type	Pressurized-D_2O, Indirect Cycle, Pressure Vessel			
Nominal Plant Capacity, MWe	200		300	
Fuel Material	UO_2	U-Metal	UO_2	U-Metal
Total Thermal Power, MW	790	790	1080	1080
Net Plant Power, MWe	217	217	300	300
Net Plant Efficiency, %	27.5	27.5	27.7	27.7
Turbine Throttle Temperature, F	448	448	448	448
Turbine Throttle Pressure, psig	400	400	400	400
Condenser Pressure, in. HgA	1.5	1.5	1.5	1.5
Reactor Core				
Active diameter, ft.	16.8	12.0	18.9	13.0
Active height, ft.	17.5	15.0	20.4	15.0
Lattice geometry	Triang.	Triang.	Triang.	Triang.
Lattice pitch, in.	10.9	6.25	10.9	6.25
Number of fueled lattice positions	287	390	366	507
Number of control rods	20	22	26	25
Number of safety rods	20	22	26	25
Reactor Vessel	Pressure Vessel		Pressure Vessel	
Material	ss. clad cs.		ss. clad cs.	
ID., ft.	19.8	14.4	21.9	16.1
Overall height, ft.	47.8	34.3	53.6	38.5
Reflector	D_2O	D_2O	D_2O	D_2O
Thickness, ft.	1.0	1.0	1.0	1.0
Core Structural Material	Zr-2	Zr-2	Zr-2	Zr-2
Primary Coolant				
Outlet temperature, F	530	530	530	530
Inlet temperature, F	475	475	475	475
Primary system pressure, psia	1200	1200	1200	1200
Total Primary Coolant Flow, lbs/hr (10^6)	44.6	44.6	60.6	60.6
Maximum Core Heat Flux, Btu/hr-ft^2 (nom.)	318,000	777,000	318,000	791,000

Table 5.2.1-I

Fuel				
Core loading, metric ton-U	63.1	27.2	89.6	32.0
Average design burnup, MWD/metric ton-U	7100	2900	8800	3300
Total D_2O Inventory, metric tons	325.5	214.5	415	305

TABLE 5.2.1-II

PLANT DESIGN CHARACTERISTICS FOR 200 AND 300 MWe
PRESSURIZED D_2O PRESSURE TUBE INDIRECT CYCLE REACTORS

Reactor Type	Pressurized-D_2O, Indirect Cycle, Pressure Tube			
Nominal Plant Capacity, MWe	200		300	
Fuel Material	UO_2	U-Metal	UO_2	U-Metal
Total Thermal Power, MW	835	835	1145	1145
Net Plant Power, MWe	217	217	300	300
Net Plant Efficiency, %	26.0	26.0	26.2	26.2
Turbine Throttle Temperature, F	448	448	448	448
Turbine Throttle Pressure, psig	400	400	400	400
Condenser Pressure, in. HgA	1.5	1.5	1.5	1.5
Reactor Core				
Active diameter, ft.	16.8	11.4	18.7	13.8
Active height, ft.	17.5	15.0	20.5	15.0
Lattice geometry	Triang.	Triang.	Triang.	Triang.
Lattice pitch, in.	11.1	9.5	11.1	9.5
Number of fueled lattice positions	284	166	356	250
Number of control rods	20	31	25	31
Number of safety rods	20	31	25	31
Reactor Vessel	Calandria		Calandria	
Material	Al	SS	Al	SS
I.D. ft.	18.8	14.1	20.7	16.5
Height, ft.	20.5	20.8	24.0	20.8
Reflector	D_2O	D_2O	D_2O	D_2O
Radial and Axial Thickness, ft.	1.0	1.0	1.0	1.0
Pressure Tube Material	Zr-2	Zr-2	Zr-2	Zr-2
I.D., in.	4.650	4.330	4.650	4.330
Wall Thickness, in.	0.162	0.240	0.162	0.240
Primary Coolant				
Outlet temperature, F	515	515	515	515
Inlet temperature, F	468	468	468	468
Primary system pressure, psia	960	960	960	960
Total Primary Coolant Flow Rate, lbs/hr (10^6)	52.5	52.5	71.5	71.5

Table 5.2.1-II, Cont.

Maximum Core Heat Flux, Btu/hr-ft^2 (nom.)	318,000	791,000	318,000	791,000
Fuel				
Core loading, metric ton-U	62.2	29.1	91.2	43.6
Average design burnup, MWD/metric ton-U	7100	3500	8100	3800
Total D_2O Inventory, metric tons	326.5	274	410	320

1200 psia. Specific design details for the 200 and 300 MWe oxide* and metal fueled units are given in Table 5.2.1-I.

The core is made up of Zr-2 clad fuel elements arranged in an equilateral triangular lattice array with a pitch of 6.25 in. and 10.9 in. for the metal and oxide fueled units respectively. Coolant and moderator D_2O enters the pressure vessel at the bottom at 475 F and passes up through the core-moderator region. At the top of the vessel, coolant-moderator flow is reversed and the liquid passes downward through shroud tubes surrounding each fuel element. The coolant leaves the pressure vessel near the bottom at a temperature of 530 F.

Control is effected by means of rods located on lattice positions and entering from the bottom of the core. Separate safety rods located at off-lattice positions provide for reactor scram.

Pressure Tube Reactors

The full scale reactors are similar in design and construction; they are natural uranium fueled, pressurized D_2O cooled, pressure tube reactors with cold D_2O moderator. Specific design details for the 200 and 300 MWe oxide and metal fueled units are given in Table 5.2.1-II.

The core consists of a calandria, containing cold D_2O moderator, which is penetrated by a number of tubes fastened to upper and lower tube sheets. Zr-2 pressure tubes pass through the calandria tubes and are used to house the fuel and contain the primary system pressure. Coolant D_2O enters the core at 498 F through a pigtail arrangement beneath the reactor and passes up past the fuel where heating occurs. Coolant leaves the core at 515 F and a pressure of 960 psia and flows out through a headering system.

The fueled lattice positions are assembled on an equilateral triangular pitch of 8.5 and 11.1 inches for the metal and oxide fueled reactors respectively. Control is effected by means of rods located on lattice positions and entering from the bottom of the core. Separate safety rods located at off lattice positions provide for reactor scram. In addition each reactor has a backup scram provision in the form of a fast drain of the cold D_2O moderator.

Heavy water moderator is maintained at an average temperature of 155 F in the core of the full scale reactors by circulating the D_2O through an all-aluminum external moderator cooling system made up of a circulating pump, service water cooled heat exchanger, and a bypass purification system. The moderator fluid enters the calandria at 110 F and flows down through a one foot thick reflector region. It then passes up through the core and exits at 200 F. No attempt is made in any of the present pressure tube designs to recover the heat deposited in the moderator.

*The data for the 300 MWe, oxide fueled unit are for illustrative purposes only. The vessel size for this unit, when coupled with reactivity requirements, may be a feasibility problem.

Primary System

In each of the pressurized D_2O cooled reactor plants, the coolant leaving the core is piped through all stainless steel systems to multiple sets of steam generators where it is used to generate 400 psig dry and saturated H_2O steam. The steam generators are vertical type and have stainless steel tubes, containing primary D_2O, and carbon steel shells. Primary coolant is returned to the core inlet by means of circulating pumps which are specially equipped with liquid injection seals to minimize D_2O leakage.

Bypass demineralization loop systems are connected to each of the reactors to provide for normal corrosion product removal from the coolant. The purification loops are sized to be capable of processing four times their normal flow capacity to provide rapid emergency cleanup in the event of a fission product release from ruptured fuel.

Secondary Systems and Auxiliaries

All turbine-generators are supplied by non-radioactive secondary H_2O steam and are therefore of conventional construction. The main condensers are conventionally constructed of Admiralty tubes and carbon steel shell. The condensate system uses three one-half capacity condensate pumps and three one-half capacity feed water pumps connected in parallel to pump the H_2O feed water through a series of extraction feed-water heaters. Each of the feed-water heaters are connected such that the extraction steam is cascaded to the main condenser for deaeration. All of the feed-water cycles are closed.

The circulating water systems for the plants consist of the requisite number of vertical circulating water pumps located in an insulated metal panel crib house. Conventional intake screens and screen washing equipment are provided in all plants. All circulating water piping and discharge flumes are of conventional power plant construction.

Conventional auxiliary plant power supply equipment has been provided. Heating, air conditioning, ventilation and plumbing services have also been provided with special consideration given to the possible presence of airborne H^3 in the reactor building. Service water for component cooling is supplied to the plants by dual half capacity service water pumps located in the crib house. Also located in the crib house are the normal electric and diesel powered fire pumps for normal and emergency conditions respectively. A diesel powered motor generator located in the crib house supplies emergency power in the event of normal power supply failure. Compressed air is supplied by a normal station air compressor and a control air compressor connected such that, should instrument air supply fail, it can be backed up by station compressed air.

Each of the plants is provided with a D_2O distillation facility used to remove possible H_2O contaminant from the moderator or coolant.

On site, radioactive waste disposal facilities for solid, liquid and gaseous wastes have been provided for the plants. High activity solid and liquid wastes are permanently disposed of in on-site underground storage containers. Low level liquid wastes are held up as necessary for decay and diluted into the circulating water discharge stream. Gaseous wastes can be compressed and held up for decay and then discharged into a waste disposal stack where they are diluted to tolerable levels by building ventilation or dilution air discharging out the stack.

Buildings and Site

Features common to all the pressurized D_2O, indirect cycle plants are the turbine, office and service buildings, the crib house and circulating water systems, switchyard equipment and waste disposal facilities. In addition, because a similar site was used for all designs, it was possible to generalize on the yard features, such as fencing, outdoor fire protection equipment, gate house, parking facilities and oil storage tanks.

The reactor building is a spherical vapor tight containment vessel which houses the reactor and its auxiliaries. All primary system equipment within the reactor building is housed in sealed compartments with controlled air flow so that any D_2O leakage can be recovered and tritium contamination of the building minimized.

The turbine buildings are of conventional insulated metal panel construction. Adjacent to, and an integral part of the turbine building, is a similarly constructed office building containing the plant control room, general offices, machine shop, maintenance area, switchgear, locker rooms and storage areas.

Spent fuel is transferred out of the reactor building through a vertical chute, into a transfer tunnel beneath the reactor building, and finally into a separate fuel handling building. This building is used to receive and store fresh fuel and to hold up and process spent fuel for shipping.

5.2.2 Cost Estimates

Estimates for the capital and operating costs associated with each of the pressurized D_2O,indirect cycle plants using natural uranium metal and natural UO_2 fuel have been prepared and are presented as follows:

CAPITAL COSTS

Table No.	Plant
5.2.2-I	200 MWe, Pressure Vessel, Metal Fueled
5.2.2-II	200 MWe, Pressure Vessel, Oxide Fueled
5.2.2-III	300 MWe, Pressure Vessel, Metal Fueled
5.2.2-IV	300 MWe, Pressure Vessel, Oxide Fueled

Capital Costs, Cont.

Table No.	Plant
5.2.2-V	200 MWe, Pressure Tube, Metal Fueled
5.2.2-VI	200 MWe, Pressure Tube, Oxide Fueled
5.2.2-VII	300 MWe, Pressure Tube, Metal Fueled
5.2.2-VIII	300 MWe, Pressure Tube, Oxide Fueled
	CAPITAL AND OPERATING COSTS
5.2.2-IX	200 and 300 MWe, Pressure Vessel, Metal and Oxide Fueled
5.2.2-X	200 and 300 MWe, Pressure Tube, Metal and Oxide Fueled

Each of these estimates was prepared using the bases given in Section 3.1 above and constitute the detailed breakdowns of the summary costs reported in DP-480.

All power costs for the full scale plants are based on the annual generation when operating with a condenser back pressure of 1.5 in. HgA.

TABLE 5.2.2-I

200 MWe PRESSURIZED D_2O PRESSURE VESSEL
INDIRECT CYCLE POWER REACTOR PLANT
NATURAL U-METAL FUEL

ESTIMATED ENGINEERING AND CONSTRUCTION COSTS

L-Land	\$10,000
A-Structures	
I. Ground Improvements	636,000
II. Reactor Plant	4,690,000
III. Turbine-Generator Building	1,470,000
IV. Waste Disposal Building	246,000
V. Fuel Handling Building	320,000
VI. D_2O Distillation Structures	15,000
VII. Circulating Water System Structures	432,000
VIII. Miscellaneous Other Buildings	174,000
Total Structures "A"	\$7,983,000
B-Equipment	
I. Reactor Plant	
1. Reactor Equipment	\$ 7,810,000
2. Auxiliaries	4,634,300
3. Piping	3,003,000
4. Instrumentation	220,000
Total B-1	\$15,667,300

Table 5.2.2-I

II. Turbine-Generator	$12,537,000
III. Crib House	725,700
IV. D_2O Distillation Plant	164,700
V. Waste Disposal System	275,300
VI. Fuel Handling Plant	1,792,800
Total Equipment "B"	$ 31,162,800
C-Electrical	
I. Reactor Plant	$608,000
II. Turbine-Generator Plant	2,338,000
III. Crib House	12,000
IV. D_2O Distillation Plant	5,600
V. Waste Disposal System	12,500
VI. Fuel Handling System	9,800
Total Electrical "C"	$ 2,985,900
D-Miscellaneous Equipment	
I. Health	$ 120,000
II. Offices and Locker Rooms	13,000
III. Machine Shop and Store Room	90,000
IV. Fire Protection	2,000
Total Miscellaneous Equipment "D"	$ 225,000
Sub-Total (L Plus A to D Inclusive)	42,366,700
E-Contractor's Overhead and Profit	1,981,100
Sub-Total (L Plus A to E Inclusive)	$44,347,800

Table 5.2.2-I

F-Contingency - 10%	$4,434,800
Sub-Total (L Plus A to F Inclusive)	48,782,600
G-Allowance For Escalation (3 Years - 4% Per Year) - 12%	5,853,900
Sub-Total (L Plus A to G Inclusive)	54,636,500
H-Top Charges (Engineering, Field Supervision, Interest During Construction, Etc.) - 15%	8,195,500
Total Estimated Cost	$62,832,000

Notes:

1. Personnel training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

TABLE 5.2.2-II

200 MWe PRESSURIZED D_2O PRESSURE VESSEL
INDIRECT CYCLE POWER REACTOR PLANT
NATURAL UO_2 FUEL

ESTIMATED ENGINEERING AND CONSTRUCTION COSTS

L-Land	$10,000
A-Structures	
I. Ground Improvements	636,000
II. Reactor Plant	4,769,000
III. Turbine-Generator Building	1,470,000
IV. Waste Disposal Building	246,000
" Fuel Handling Building	320,000
VI. D_2O Distillation Structures	15,000
VII. Circulating Water System Structures	432,000
VIII. Miscellaneous Other Buildings	174,000
Total Structures "A"	$8,062,000
B-Equipment	
I. Reactor Plant	
1. Reactor Equipment	$11,315,000
2. Auxiliaries	4,634,300
3. Piping	3,005,000
4. Instrumentation	220,000
Total B-1	$19,174,300

Table 5.2.2-II, Cont.

II. Turbine-Generator Plant	$12,537,000
III. Crib House	725,700
IV. D_2O Distillation Plant	164,700
V. Waste Disposal System	275,300
VI. Fuel Handling Plant	1,792,800
Total Equipment "B"	$34,669,800
C-Electrical	
I. Reactor Plant	$608,000
II. Turbine Generator Plant	2,338,000
III. Crib House	12,000
IV. D_2O Distillation Plant	5,600
V. Waste Disposal System	12,500
VI. Fuel Handling System	9,800
Total Electrical "C"	$2,985,900
D-Miscellaneous Equipment	
I. Health	$120,000
II. Offices and Locker Rooms	13,000
III. Machine Shop and Store Room	90,000
IV. Fire Protection	2,000
Total Miscellaneous Equipment "D"	225,000
Sub-Total (L Plus A to D Inclusive)	$45,952,700
E-Contractor's Overhead and Profit	2,008,300
Sub-Total (L Plus A to E Inclusive	$47,961,000

Table 5.2.2-II, Cont.

F-Contingency - 10%	$4,796,100
Sub-Total (L Plus A to F Inclusive)	$ 52,757,100
G-Allowance For Escalation (3 Years - 4% Per Year) - 12%	6,330,900
Sub-Total (L Plus A to G Inclusive)	$ 59,088,000
H-Top Charges (Engineering, Field Supervision, Interest During Construction, Etc.) - 15%	8,863,700
Total Estimated Cost	$ 67,951,700

Note:

1. Personnel training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

TABLE 5.2.2-III

300 MWe PRESSURIZED D_2O PRESSURE VESSEL
INDIRECT CYCLE POWER REACTOR PLANT
NATURAL U-METAL FUEL

ESTIMATED ENGINEERING AND CONSTRUCTION COSTS

L-Land	$10,000
A-Structures	
I. Ground Improvements	636,000
II. Reactor Plant	4,900,000
III. Turbine-Generator Building	2,025,000
IV. Waste Disposal Building	276,000
V. Fuel Handling Building	320,000
VI. D_2O Distillation Structures	15,000
VII. Circulating Water System Structures	535,000
VIII. Miscellaneous Other Buildings	174,000
Total Structures "A"	$8,881,000
B-Equipment	
I. Reactor Plant	
1. Reactor Equipment	8,650,000
2. Auxiliaries	6,196,800
3. Piping	4,085,000
4. Instrumentation	280,000
Total B-1	$19,211,800

Table 5.2.2-III, Cont.

II. Turbine-Generator Plant	$ 16,419,600
III. Crib House	903,000
IV. D_2O Distillation Plant	164,700
V. Waste Disposal System	319,900
VI. Fuel Handling Plant	2,016,600
Total Equipment "B"	$ 39,035,600
C-Electrical	
I. Reactor Plant	$ 673,000
II. Turbine-Generator Plant	2,705,000
III. Crib House	13,500
IV. D_2O Distillation Plant	5,600
V. Waste Disposal System	12,500
VI. Fuel Handling System	10,500
Total Electrical "C"	$ 3,420,100
D-Miscellaneous Equipment	
I. Health	$120,000
II. Offices and Locker Rooms	15,600
III. Machine Shop and Store Room	99,300
IV. Fire Protection	2,500
Total Miscellaneous Equipment "D"	$237,400
Sub-Total (L Plus A to D Inclusive)	51,584,100
E-Contractor's Overhead and Profit	2,347,300
Sub-Total (L Plus A to E Inclusive)	$ 53,931,400

Table 5.2.2-III, Cont.

F-Contingency - 10%	$5,393,100
Sub-Total (L Plus A to F Inclusive)	59,324,500
G-Allowance For Escalation (3 Years - 4% Per Year) - 12%	7,118,900
Sub-Total (L Plus A to G Inclusive)	$66,443,400
H-Top Charges (Engineering, Field Supervision, Interest During Construction, Etc.) - 15%	9,966,500
Total Estimated Cost	$76,409,900

Notes:

1. Personnel training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

TABLE 5.2.2-IV

300 MWe PRESSURIZED D_2O PRESSURE VESSEL
INDIRECT CYCLE POWER REACTOR PLANT
NATURAL UO_2 FUEL

ESTIMATED ENGINEERING AND CONSTRUCTION COSTS

L-Land	\$10,000
A-Structures	
I. Ground Improvements	636,000
II. Reactor Plant	5,045,000
III. Turbine-Generator Building	2,025,000
IV. Waste Disposal Building	276,000
V. Fuel Handling Building	320,000
VI. D_2O Distillation Structures	15,000
VII. Circulating Water System Structures	535,000
VIII. Miscellaneous Other Buildings	174,000
Total Structures "A"	\$ 9,026,000
B-Equipment	
I. Reactor Plant	
1. Reactor Equipment	\$15,020,000
2. Auxiliaries	6,196,800
3. Piping	4,085,000
4. Instrumentation	280,000
Total B-1	\$ 25,581,800

Table 5.2.2-IV, Cont.

II. Turbine-Generator Plant	$ 16,419,600
III. Crib House	903,000
IV. D_2O Distillation Plant	164,700
V. Waste Disposal System	319,900
VI. Fuel Handling Plant	2,016,600
Total Equipment "B"	$ 45,405,600
C-Electrical	
I. Reactor Plant	$ 673,000
II. Turbine-Generator Plant	2,705,000
III. Crib House	13,500
IV. D_2O Distillation Plant	5,600
V. Waste Disposal System	12,500
VI. Fuel Handling System	10,500
Total Electrical "C"	$3,420,100
D-Miscellaneous Equipment	
I. Health	$ 120,000
II. Offices and Locker Rooms	15,600
III. Machine Shop and Store Room	99,300
IV. Fire Protection	2,500
Total Miscellaneous Equipment "D"	$ 237,400
Sub-Total (L Plus A to D Inclusive)	58,099,100
E-Contractor's Overhead and Profit	2,375,200
Sub-Total (L Plus A to E Inclusive)	$ 60,474,300

Table 5.2.2-IV, Cont.

F-Contingency - 10%	$6,047,400
Sub-Total (L Plus A to F Inclusive)	66,521,700
G-Allowance For Escalation (3 Years - 4% Per Year) - 12%	7,982,600
Sub-Total (L Plus A to G Inclusive)	74,504,300
H-Top Charges (Engineering, Field Supervision, Interest During Construction, Etc.) - 15%	11,175,600
Total Estimated Cost	$85,679,900

Notes:

1. Personnel training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

TABLE 5.2.2-V

200 MWe PRESSURIZED D_2O PRESSURE TUBE
INDIRECT CYCLE POWER REACTOR PLANT
NATURAL U-METAL FUEL

ESTIMATED ENGINEERING AND CONSTRUCTION COSTS

L-Land	$10,000
A-Structures	
I. Ground Improvements	636,000
II. Reactor Plant	4,814,000
III. Turbine-Generator Building	1,470,000
IV. Waste Disposal Building	246,000
V. Fuel Handling Building	320,000
VI. D_2O Distillation Structures	15,000
VII. Circulating Water System Structures	432,000
VIII. Miscellaneous Other Buildings	174,000
Total Structures "A"	$ 8,107,000
B-Equipment	
I. Reactor Plant	
1. Reactor Equipment	$ 7,680,000
2. Auxiliaries	4,895,000
3. Piping	3,320,000
4. Instrumentation	220,000
Total B-1	$16,115,000

Table 5.2.2-V, Cont.

II. Turbine-Generator Plant	$12,537,000
III. Crib House	725,700
IV. D_2O Distillation Plant	164,700
V. Waste Disposal System	275,300
VI. Fuel Handling Plant	1,892,800
Total Equipment "B"	$31,710,500
C-Electrical	
I. Reactor Plant	$651,000
II. Turbine Generator Plant	2,338,000
III. Crib House	12,000
IV. D_2O Distillation Plant	5,600
V. Waste Disposal System	12,500
VI. Fuel Handling System	9,800
Total Electrical "C"	$3,028,900
D-Miscellaneous Equipment	
I. Health	$127,000
II. Offices and Locker Rooms	13,000
III. Machine Shop and Store Room	90,000
IV. Fire Protection	2,000
Total Miscellaneous Equipment "D"	$232,000
Sub-Total (L Plus A to D Inclusive)	43,088,400
E-Contractor's Overhead and Profit	2,176,200
Sub-Total (L Plus A to E Inclusive)	$45,264,600

Table 5.2.2-V, Cont.

F-Contingency - 10%	$4,526,500
Sub-Total (L Plus A to F Inclusive)	49,791,100
G-Allowance For Escalation (3 Years - 4% Per Year) - 12%	5,974,900
Sub-Total (L Plus A to G Inclusive)	55,766,000
H-Top Charges (Engineering, Field Supervision, Interest During Construction, Etc.) - 15%	8,364,900
Total Estimated Cost	$ 64,130,900

Notes:

1. Personnel training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

TABLE 5.2.2-VI

200 MWe PRESSURIZED D_2O PRESSURE TUBE
INDIRECT CYCLE POWER REACTOR PLANT
NATURAL UO_2 FUEL

ESTIMATED ENGINEERING AND CONSTRUCTION COSTS

L-Land	$10,000
A-Structures	
I. Ground Improvements	636,000
II. Reactor Plant	4,882,000
III. Turbine-Generator Building	1,470,000
IV. Waste Disposal Building	246,000
V. Fuel Handling Building	320,000
VI. D_2O Distillation Structures	15,000
VII. Circulating Water System Structures	432,000
VIII. Miscellaneous Other Buildings	174,000
Total Structures "A"	$8,175,000
B-Equipment	
I. Reactor Plant	
1. Reactor Equipment	$10,034,000
2. Auxiliaries	4,895,000
3. Piping	3,320,000
4. Instrumentation	220,000
Total B-I	$18,469,000

Table 5.2.2-VI, Cont.

II. Turbine-Generator Plant	$12,537,000
III. Crib House	725,700
IV. D_2O Distillation Plant	164,700
V. Waste Disposal System	275,300
VI. Fuel Handling Plant	1,892,800
Total Equipment "B"	$34,064,500
C-Electrical	
I. Reactor Plant	$ 651,000
II. Turbine Generator Plant	2,338,000
III. Crib House	12,000
IV. D_2O Distillation Plant	5,600
V. Waste Disposal System	12,500
VI. Fuel Handling System	9,800
Total Electrical "C"	$ 3,028,900
D-Miscellaneous Equipment	
I. Health	$127,000
II. Offices and Locker Rooms	13,000
III. Machine Shop and Store Room	90,000
IV. Fire Protection	2,000
Total Miscellaneous Equipment "D"	$ 232,000
Sub-Total (L Plus A to D Inclusive)	45,510,400
E-Contractor's Overhead and Profit	2,196,300
Sub-Total (L Plus A to E Inclusive)	$47,706,700

Table 5.2.2-VI, Cont.

F-Contingency - 10%	$4,770,700
Sub-Total (L Plus A to F Inclusive)	52,477,400
G-Allowance For Escalation (3 Years - 4% Per Year) - 12%	6,297,300
Sub-Total (L Plus A to G Inclusive)	58,774,700
H-Top Charges (Engineering, Field Supervision, Interest During Construction, Etc.) - 15%	8,816,200
Total Estimated Cost	$67,590,900

Notes:

1. Personnel training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

TABLE 5.2.2-VII

300 MWe PRESSURIZED D_2O PRESSURE TUBE
INDIRECT CYCLE POWER REACTOR PLANT
NATURAL U-METAL FUEL

ESTIMATED ENGINEERING AND CONSTRUCTION COSTS

L-Land	$10,000
A-Structures	
I. Ground Improvements	636,000
II. Reactor Plant	5,665,000
III. Turbine-Generator Building	2,025,000
IV. Waste Disposal Building	276,000
V. Fuel Handling Building	320,000
VI. D_2O Distillation Structures	15,000
VII. Circulating Water System Structures	535,000
VIII. Miscellaneous Other Buildings	174,000
Total Structures "A"	$ 9,646,000
B-Equipment	
I. Reactor Plant	
1. Reactor Equipment	$ 9,520,000
2. Auxiliaries	6,921,100
3. Piping	4,700,000
4. Instrumentation	280,000
Total B-1	$ 21,421,100

Table 5.2.2-VII, Cont.

II. Turbine-Generator Plant	$16,419,600
III. Crib House	903,000
IV. D_2O Distillation Plant	164,700
V. Waste Disposal System	319,900
VI. Fuel Handling Plant	2,116,600
Total Equipment "B"	$ 41,344,900
C-Electrical	
I. Reactor Plant	$719,000
II. Turbine-Generator Plant	2,705,000
III. Crib House	13,500
IV. D_2O Distillation Plant	5,600
V. Waste Disposal System	12,500
VI. Fuel Handling System	10,500
Total Electrical "C"	$3,466,100
D-Miscellaneous Equipment	
I. Health	$127,000
II. Offices and Locker Rooms	15,600
III. Machine Shop and Store Room	99,300
IV. Fire Protection	2,500
Total Miscellaneous Equipment "D"	$244,400
Sub-Total (L Plus A to D Inclusive)	54,711,400
E-Contractor's Overhead and Profit	2,572,600
Sub-Total (L Plus A to E Inclusive)	$57,284,000

Table 5.2.2-VII, Cont.

F-Contingency - 10%	$ 5,728,400
Sub-Total (L Plus A to F Inclusive)	63,012,400
G-Allowance For Escalation (3 Years - 4% Per Year) - 12%	7,561,500
Sub-Total (L Plus A to G Inclusive)	70,573,900
H-Top Charges (Engineering, Field Supervision, Interest During Construction, Etc.) - 15%	10,586,100
Total Estimated Cost	$81,160,000

Notes:

1. Personnel training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

TABLE 5.2.2-VIII

300 MWe PRESSURIZED D_2O PRESSURE TUBE
INDIRECT CYCLE POWER REACTOR PLANT
NATURAL UO_2 FUEL

ESTIMATED ENGINEERING AND CONSTRUCTION COSTS

L-Land	$10,000
A-Structures	
I. Ground Improvements	636,000
II. Reactor Plant	5,772,000
III. Turbine-Generator Building	2,025,000
IV. Waste Disposal Building	276,000
V. Fuel Handling Building	320,000
VI. D_2O Distillation Structures	15,000
VII. Circulating Water System Structures	535,000
VIII. Miscellaneous Other Buildings	174,000
Total Structures "A"	$ 9,753,000
B-Equipment	
I. Reactor Plant	
1. Reactor Equipment	$12,200,000
2. Auxiliaries	6,921,100
3. Piping	4,700,000
4. Instrumentation	280,000
Total B-1	$24,101,100

Table 5.2.2-VIII, Cont.

II. Turbine-Generator Plant	$16,419,600
III. Crib House	903,000
IV. D_2O Distillation Plant	164,700
V. Waste Disposal System	319,900
VI. Fuel Handling Plant	2,116,600
Total Equipment "B"	$44,024,900
C-Electrical	
I. Reactor Plant	$719,000
II. Turbine-Generator Plant	2,705,000
III. Crib House	13,500
IV. D_2O Distillation Plant	5,600
V. Waste Disposal System	12,500
VI. Fuel Handling System	10,500
Total Electrical "C"	$ 3,466,100
D-Miscellaneous Equipment	
I. Health	$ 127,000
II. Offices and Locker Rooms	15,600
III. Machine Shop and Store Room	99,300
IV. Fire Protection	2,500
Total Miscellaneous Equipment "D"	$ 244,400
Sub-Total (L Plus A to D Inclusive)	57,498,400
E-Contractor's Overhead and Profit	2,601,800
Sub-Total (L Plus A to E Inclusive)	$ 60,100,200

Table 5.2.2-VIII, Cont.

F-Contingency - 10%	$6,010,000
Sub-Total (L Plus A to F Inclusive)	66,110,200
G-Allowance For Escalation (3 Years - 4% Per Year) - 12%	7,933,200
Sub-Total (L Plus A to G Inclusive)	74,043,400
H-Top Charges (Engineering, Field Supervision, Interest During Construction, Etc.) - 15%	11,106,500
Total Estimated Cost	$85,149,900

Notes:

1. Personnel training and preliminary operating expenses are not included.

2. D_2O Inventory is not included.

TABLE 5.2.2- IX
CAPITAL AND OPERATING COSTS FOR 200 AND
300 MWe, PRESSURIZED- D_2O, INDIRECT CYCLE, PRESSURE VESSEL REACTOR PLANTS

Nominal Plant Capacity	200 MWe (Annual Generating Capacity 1520 x 10^6 kwh)						300 MWe (Annual Generating Capacity 2103 x 10^6 kwh)					
Fuel Material	Natural U-metal			Natural UO_2			Natural U-metal			Natural UO_2		
Design Burnup MWD/metric ton-U	2900			7100			3300			8800		
Refueling Scheme	100% batch			4-zone			100% batch			4-zone		
	Invest., $\$10^6$	Ann. Cost, $\$10^6$/yr.	Power Cost, mills/kwh	Invest., $\$10^6$	Ann. Cost, $\$10^6$/yr.	Power Cost, mills/kwh	Invest., $\$10^6$	Ann. Cost, $\$10^6$/yr.	Power Cost, mills/kwh	Invest., $\$10^6$	Ann. Cost $\$10^6$/yr.	Power Cost, mills/kwh
Investment												
Reactor plant	37.204	5.209	3.427	42.324	5.925	3.898	44.925	6.290	2.990	54.195	7.589	3.608
Turbine plant	25.037	3.502	2.304	25.037	3.502	2.304	30.615	4.290	2.040	30.615	4.290	2.040
Miscellaneous buildings and equipment	0.591	0.083	0.055	0.591	0.083	0.055	0.870	0.121	0.058	0.870	0.121	0.058
Sub-total	62.832	8.794	5.786	67.952	9.510	6.257	76.410	10.701	5.088	85.680	12.000	5.706
D_2O inventory	13.250	1.656	1.090	20.118	2.510	1.650	18.830	2.357	1.120	25.620	3.205	1.525
Total investment	76.082	10.450	6.876	88.070	12.020	7.907	95.240	13.058	6.208	111.300	15.205	7.231
Operation and Maintenance												
Fuel												
Inventory		0.071	0.047		0.145	0.095		0.083	0.039		0.195	0.093
Nonnuclear inventory		0.131	0.086		0.687	0.452		0.154	0.073		0.925	0.439
Replacement		3.883	2.547		2.938	1.932		4.720	2.248		3.245	1.543
Total fuel costs		4.085	2.680		3.770	2.479		4.957	2.360		4.365	2.075
Heavy Water												
Losses		0.265	0.174		0.402	0.264		0.376	0.179		0.512	0.244
Dist. plant operation		0.006	0.004		0.006	0.004		0.008	0.004		0.008	0.004
Total D_2O costs		0.271	0.178		0.408	0.268		0.384	0.183		0.520	0.248
Operating payroll		0.610	0.401		0.610	0.401		0.715	0.339		0.715	0.339
Maintenance labor and material		0.406	0.267		0.406	0.267		0.510	0.240		0.510	0.240
Supplies		0.140	0.092		0.140	0.092		0.175	0.082		0.175	0.082
Insurance		0.490	0.322		0.490	0.322		0.570	0.268		0.570	0.268
Total operation and maintenance		6.002	3.940		5.824	3.829		7.311	3.472		6.855	3.252
Total Capital and Operating Costs		16.452	10.816		17.844	11.736		20.369	9.680		22.060	10.483

TABLE 5.2.2-X
CAPITAL AND OPERATING COSTS FOR 200 AND
300 MWe, PRESSURIZED- D_2O, INDIRECT CYCLE, PRESSURE TUBE REACTOR PLANTS

Nominal Plant Capacity	200 MWe (Annual Generating Capacity 1520 x 10^6 kwh)						300 MWe (Annual Generating Capacity 2103 x 10^6 kwh)					
Fuel Material	Natural U-metal			Natural UO_2			Natural U-metal			Natural UO_2		
Design Burnup MW-d/metric ton U	3500			6800			3800			7800		
Refueling Scheme	100% batch			Multizone			100% batch			Multizone		
	Invest. $\$10^6$	Ann. Cost, $\$10^6$/yr.	Power Cost, mills/kwh	Invest. $\$10^6$	Ann. Cost, $\$10^6$/yr.	Power Cost, mills/kwh	Invest. $\$10^6$	Ann. Cost, $\$10^6$/yr.	Power Cost, mills/kwh	Invest. $\$10^6$	Ann. Cost $\$10^6$/yr.	Power Cost, mills/kwh
Investment												
Reactor plant	38.352	5.369	3.535	41.812	5.850	3.849	49.380	6.913	3.290	53.370	7.449	3.541
Turbine plant	25.188	3.526	2.319	25.188	3.526	2.319	30.910	4.330	2.060	30.910	4.330	2.060
Miscellaneous buildings and equipment	0.591	0.083	0.055	0.591	0.083	0.055	0.870	0.121	0.058	0.870	0.121	0.058
Subtotal	64.131	8.978	5.909	67.591	9.459	6.223	81.160	11.364	5.408	85.150	11.900	5.659
D_2O inventory	16.900	2.113	1.390	20.160	2.520	1.660	19.890	2.485	1.180	25.300	3.160	1.505
Total investment	81.031	11.091	7.299	87.751	11.979	7.883	101.050	13.849	6.588	110.450	15.060	7.164
Operating and Maintenance												
Fuel												
Inventory		0.075	0.049		0.143	0.094		0.113	0.054		0.201	0.096
Nonnunclear inventory		0.140	0.092		0.676	0.445		0.209	0.100		0.952	0.453
Replacement		3.364	2.214		3.020	1.986		4.040	1.920		3.665	1.742
Total fuel costs		3.579	2.355		3 839	2 525		4.362	2 074		4.818	2.291
Heavy Water												
Losses		0.338	0.222		0.403	0.265		0.398	0.189		0.506	0.241
Dist. plant operation		0.006	0.004		0.006	0.004		0.008	0.004		0.008	0.004
Total D_2O costs		0.344	0.226		0.409	0.269		0.406	0.193		0.514	0.245
Operating payroll		0.610	0.401		0.610	0.401		0.715	0.339		0.715	0.339
Maintenance labor and material		0.406	0.267		0.406	0.267		0.510	0.240		0.510	0.240
Supplies		0.140	0.092		0.140	0.092		0.175	0.082		0.175	0.082
Insurance		0.490	0.322		0.490	0.322		0.570	0.268		0.570	0.268
Total operation and maintenance		5.569	3.663		5.894	3.876		6.738	3.196		7.302	3.465
Total Capital and Operating Costs		16.660	10.962		17.873	11.759		20.587	9.784		22.362	10.629

6.0 REFERENCES

1. Design Study, Heavy Water Moderated Power Reactor Plants, Part I, SL-1565, Vol. I, II, III, January 28, 1959.

2. Design Study, Heavy Water Moderated Power Reactor Plants, SL-1565 Addendum No. 1, March 20, 1959.

3. Design Study, Heavy Water Moderated Power Reactor Plants, Part 2, SL-1581, Vol. I, II, III, February 28, 1959.

4. Design Study, Heavy Water Moderated Power Reactor Plants, Part 3, SL-1653, June 19, 1959.

5. Evaluation and Design, Heavy Water Moderated Power Reactor Plants, Monthly Progress Reports, SL-1685-1 through 9.

6. D. F. Babcock, Heavy Water Moderated Power Reactors, Progress Report for February through April, 1959, DP-385 (July 1959).

7. D. F. Babcock, et al., Civilian Power Reactor Program, Status of Heavy Water Moderated Power Reactors, DPW-59-264 (June 19, 1959).

8. D. F. Babcock et al., Heavy Water Moderated Power Reactors, A Status Report, DP-480 (March, 1960).

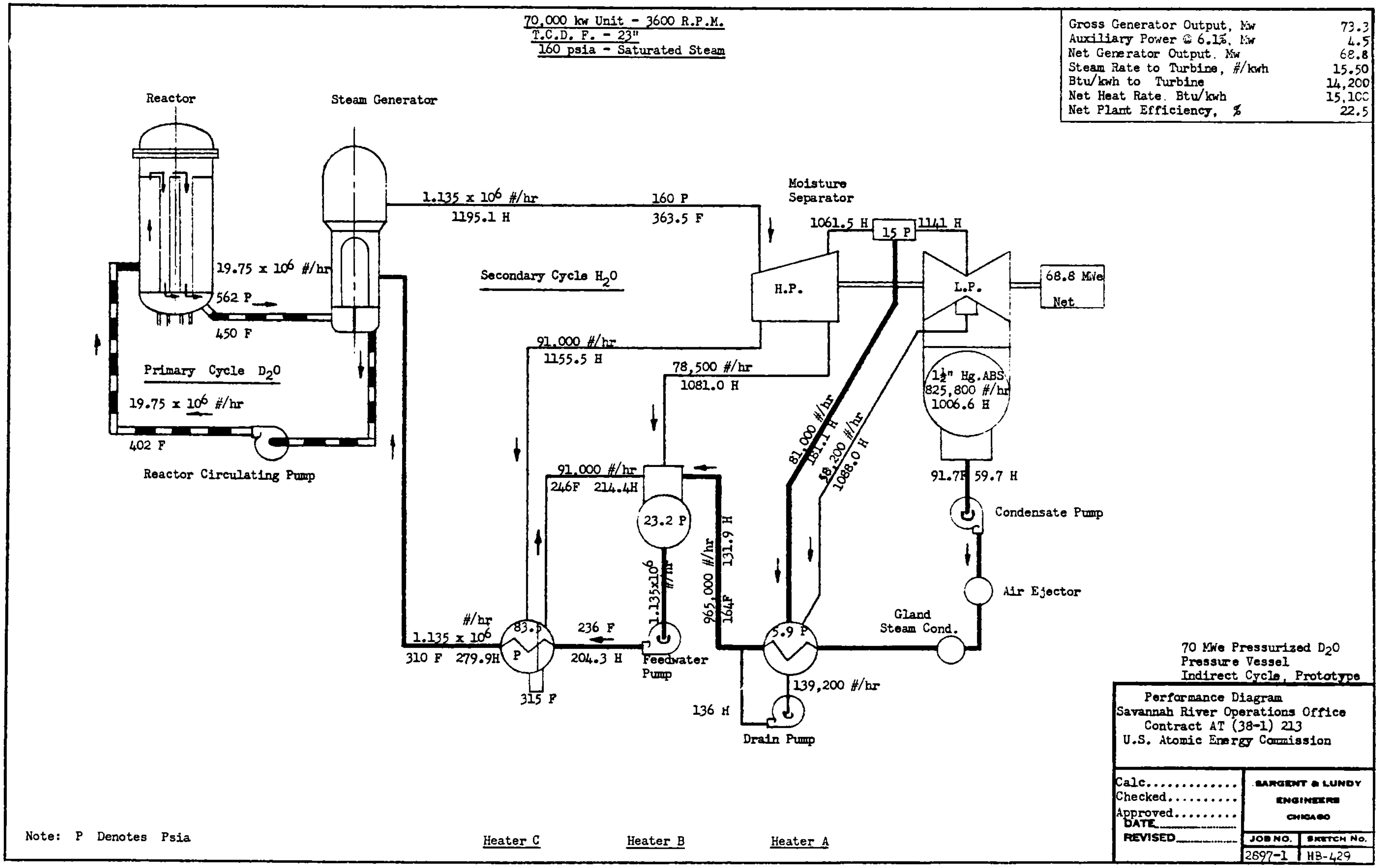
7.0 DRAWING LIST

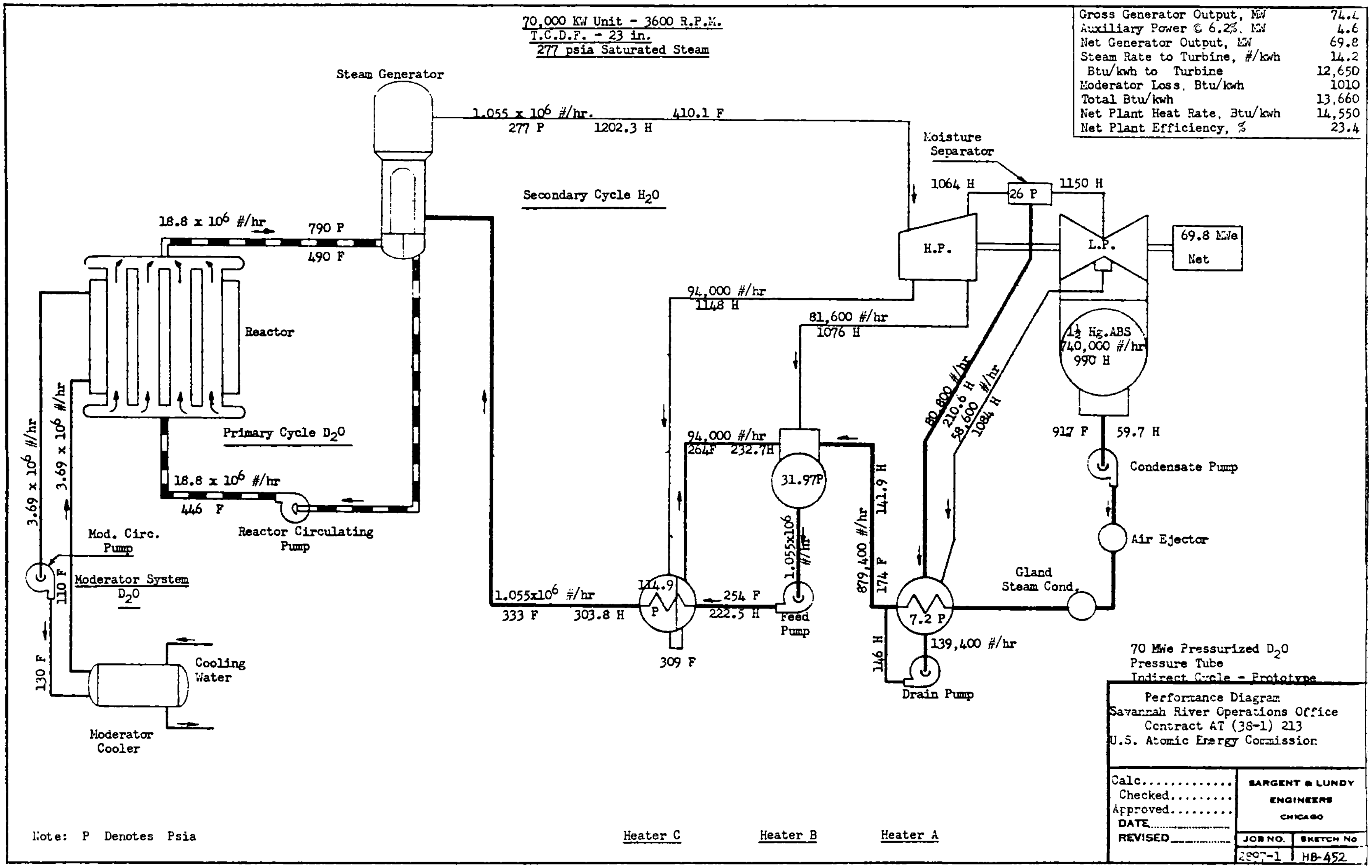
Drawing No.	Title
HB-429	70 MWe, Press'd. D_2O, Pressure Vessel Prototype Plant Performance Diagram
HB-452	70 MWe, Press'd. D_2O, Pressure Tube Prototype Plant Performance Diagram
HB-470	200 MWe, Boiling D_2O, Direct Cycle Plant with Reheat, Performance Diagram - 1800 rpm Turbine
HB-473	200 MWe, Boiling D_2O, Direct Cycle Plant with Reheat, Performance Diagram - 3600 rpm Turbine
	70 MWe BOILING D_2O PRESSURE TUBE DIRECT CYCLE, PROTOTYPE
NP-414	Property Plat
NP-415	General Arrangement-Plan "A-A"-Reactor Building
NP-416	General Arrangement-Plans "B-B" & "C-C"-Reactor Building
NP-417	General Arrangement-Plans "D-D" & "E-E"-Reactor Building
NP-418	General Cross Sections-Plans "F-F" & "G-G"-Reactor Building
NP-419	General Cross Sections-Plans "H-H" & "J-J"-Reactor Building
NP-420	General Cross Sections-Plans "K-K" & "L-L"-Reactor Building
NP-421	General Arrangement Fuel Handling & Waste Disposal Building
NP-424	General Arrangement Plan-Main Floor-Turbine Building
NP-425	General Arrangement Plan-Mezzanine Floor-Turbine Building
NP-426	General Arrangement Plan-Ground Floor-Turbine Building
NP-427	General Arrangement-Long. Sections "A-A" & "B-B"-Turbine Building
NP-428	General Arrangement-Cross Sections "C-C"-Turbine Building
NP-495	Nuclear Instrumentation Block Diagram

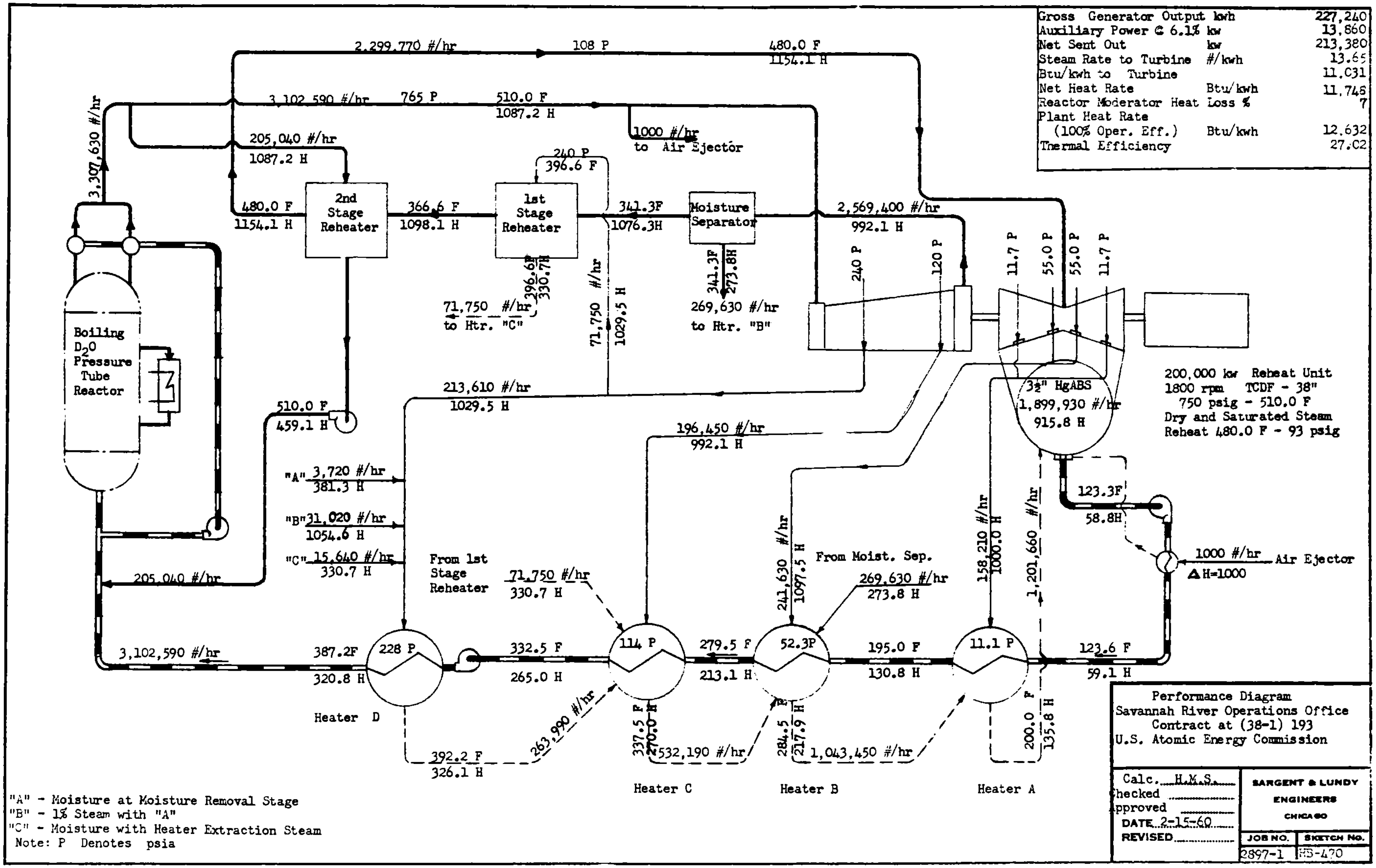
Drawing No.	Title
	70 MWe, PRESSURIZED D_2O, PRESSURE VESSEL INDIRECT CYCLE, PROTOTYPE
NP-429	Composite Flow Diagram
NP-430	Main Coolant Steam & Condensate Diagram
NP-431	Reactor Auxiliaries Systems Diagram
NP-432	Recombiner & Off-Gas Systems Diagram
NP-433	Waste Disposal System Diagram
NP-434	Plant Control Block Diagram
NP-435	Nuclear Instrumentation-Block Diagram
NP-436	Operational Block Diagram
NP-437	Safety Block Diagram
NP-438	Property Plat
NP-439	General Arrangement Plans-Reactor Building
NP-440	General Cross Sections-"E-E", "F-F", "G-G"-Reactor Building
NP-441	General Cross Sections- "H-H", "J-J", "K-K"-Reactor Building
NP-442	General Arrangement Plan-Main Floor-Turbine Room
NP-443	General Arrangement Plan-Mezzanine Floor-Turbine Room
NP-444	General Arrangement Plan-Ground Floor-Turbine Room
NP-445	General Cross Section "A-A"-Turbine Room
NP-446	General Long. Section "B-B"-Turbine Room
NP-447	General Arrangement-Fuel Handling & Waste Disposal Buildings
NP-448	Electrical Diagram
NP-449	Single Line Diagram
NP-450	Key Diagram-Turbine Plant Auxiliaries
NP-451	Key Diagram-Reactor Plant Auxiliaries

Drawing No.	Title
	70 MWe, PRESSURIZED D_2O PRESSURE TUBE INDIRECT CYCLE PROTOTYPE
NP-452	Composite Flow Diagram
NP-453	Main Coolant, Steam & Condensate Diagram
NP-454	Reactor Auxiliaries Systems Diagram
NP-455	Recombiner & Off-Gas Systems Diagram
NP-456	Plant Control Block Diagram
NP-457	Nuclear Instr. Block Diagram
NP-458	Operational Block Diagram
NP-459	Safety Block Diagram
NP-460	Property Plat
NP-461	General Arrangement Plans-Reactor Building
NP-462	General Cross Sections-"E-E", "F-F"-Reactor Building
NP-463	General Arrangement Plan-Main Floor-Turbine Building
NP-464	General Arrangement Plan-Mezzanine Floor-Turbine Building
NP-465	General Arrangement Plan-Ground Floor-Turbine Building
NP-466	General Cross Section "A-A"-Turbine Building
NP-467	General Long. Section "B-B"-Turbine Building
NP-468	General Arrangement-Fuel Handling & Waste Disposal Buildings
NP-469	Electrical Diagram
	200 MWe, BOILING D_2O, PRESSURE TUBE DIRECT CYCLE WITH REHEAT TURBINES 1800 & 3600 RPM
NS-470	General Arrangement Plan-Main Floor-Turbine Building
NS-471	General Arrangement Plan-Grade Floor-Turbine Building

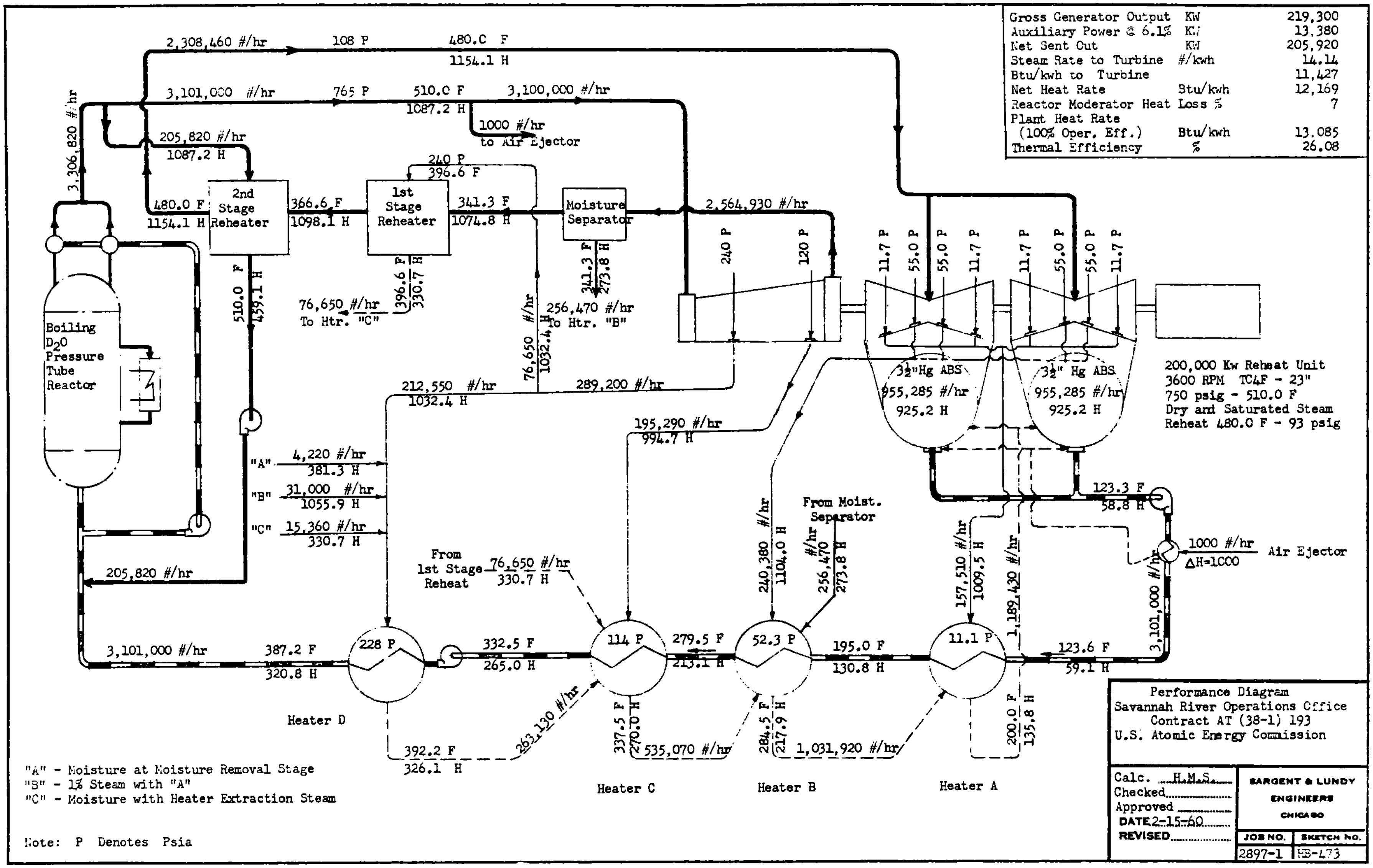
Drawing No.	Title
	200 MWe, BOILING D_2O PRESSURE TUBE DIRECT CYCLE WITH REHEAT TURBINES 1800 & 3600 RPM
NS-472	General Cross Section-Turbine Building
NS-473	General Arrangement Plan-Main Floor-Turbine Building
NS-474	General Arrangement Plan-Grade Floor-Turbine Building
NS-475	General Cross Section-Turbine Building
	BOILING D_2O, PRESSURE TUBE, DIRECT CYCLE PROTOTYPE, ALTERNATE HEAT DISSIPATION
NP-490	General Arrangement-Plan & Sections
	BOILING D_2O, PRESSURE TUBE DIRECT CYCLE, METAL FUEL
NS-700	200 MWe-General Arrangement-Plan & Section
NS-710	300 MWe-General Arrangement-Plan & Section
	BOILING D_2O, PRESSURE TUBE DIRECT CYCLE, OXIDE FUEL
NS-720	300 MWe-General Arrangement-Plan & Section
	PRESSURIZED D_2O, PRESSURE VESSEL INDIRECT CYCLE
NS-730	200 MWe, Metal Fuel-Gen. Arrgt. Plan & Section
NS-740	300 MWe, Metal Fuel-Gen. Arrgt. Plan & Section
NS-750	300 MWe, Oxide Fuel-Gen. Arrgt. Plan & Section
	PRESSURIZED D_2O, PRESSURE TUBE INDIRECT CYCLE
NS-760	200 MWe, Metal Fuel-Gen. Arrgt. Plan & Section
NS-770	300 MWe, Metal Fuel-Gen. Arrgt. Plan & Section
NS-780	300 MWe, Oxide Fuel-Gen. Arrgt. Plan & Section


70,000 kw Unit - 3600 R.P.M.
T.C.D. F. - 23"
160 psia - Saturated Steam
Gross Generator Output, Mw 73.3
Auxiliary Power @ 6.1%, Mw 4.5
Net Generator Output, Mw 68.8
Steam Rate to Turbine, #/kwh 15.50
Btu/kwh to Turbine 14,200
Net Heat Rate, Btu/kwh 15,100
Net Plant Efficiency, % 22.5
Reactor
Steam Generator
1.135 x 10^6 #/hr
1195.1 H
160 P
363.5 F
Moisture Separator
1061.5 H
15 P
1141 H
H.P.
L.P.
68.8 MWe Net
Secondary Cycle H2O
19.75 x 10^6 #/hr
562 P
450 F
Primary Cycle D2O
19.75 x 10^6 #/hr
402 F
Reactor Circulating Pump
91,000 #/hr
1155.5 H
78,500 #/hr
1081.0 H
81,000 #/hr
1181.1 H
58,200 #/hr
1088.0 H
1½" Hg.ABS
825,800 #/hr
1006.6 H
91.7F 59.7 H
Condensate Pump
Air Ejector
91,000 #/hr
246F 214.4H
23.2 P
1.135x10^6 #/hr
965,000 #/hr
131.9 H
164F
Gland Steam Cond.
#/hr
1.135 x 10^6
83.5 P
310 F 279.9H
236 F
204.3 H
Feedwater Pump
315 F
5.9 P
139,200 #/hr
136 H
Drain Pump
70 MWe Pressurized D2O
Pressure Vessel
Indirect Cycle, Prototype
Performance Diagram
Savannah River Operations Office
Contract AT (38-1) 213
U.S. Atomic Energy Commission
Calc.
Checked
Approved
DATE
REVISED
SARGENT & LUNDY
ENGINEERS
CHICAGO
JOB NO. 2897-1
SKETCH No. HB-429
Note: P Denotes Psia
Heater C
Heater B
Heater A

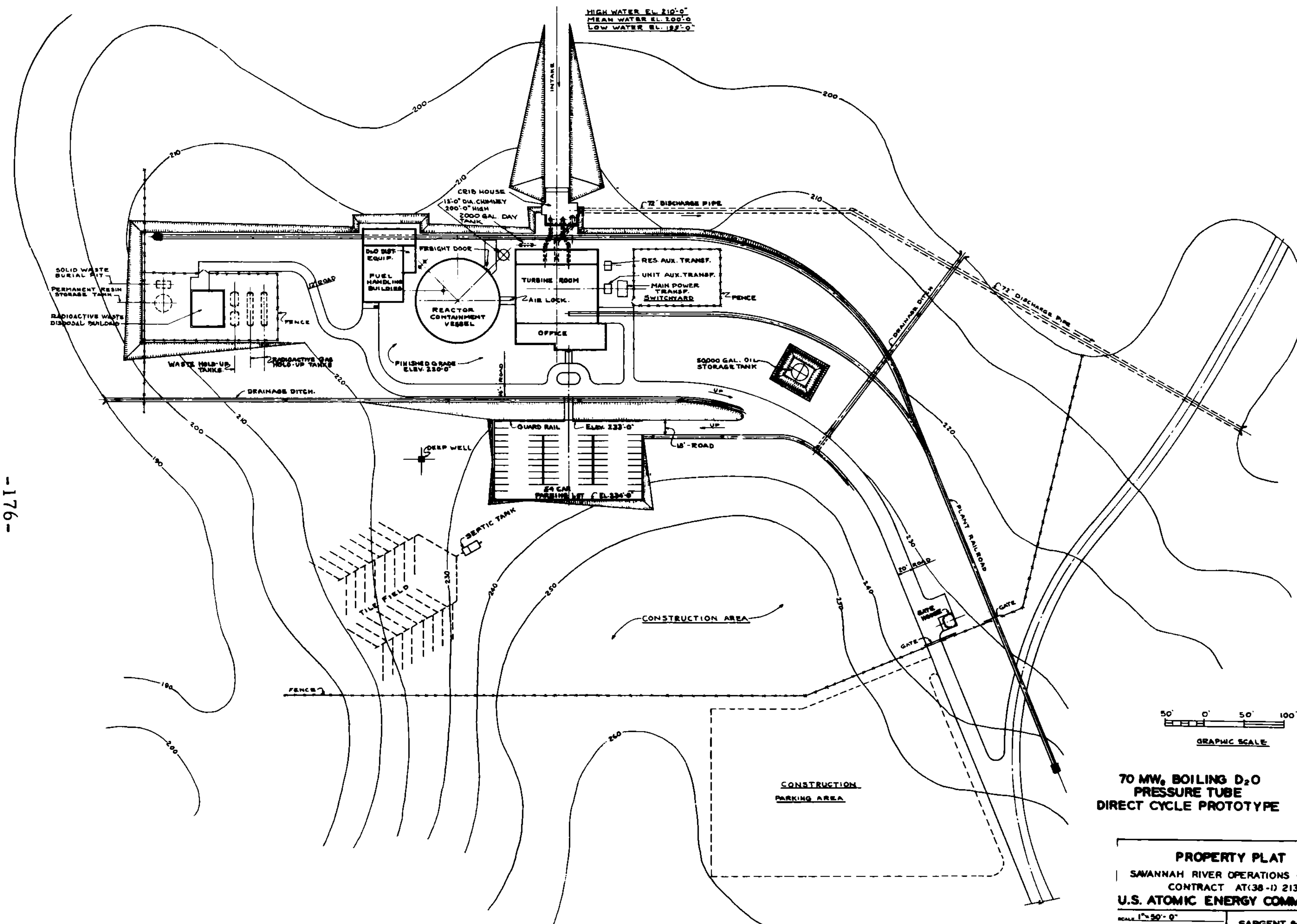

70,000 KW Unit - 3600 R.P.M.
T.C.D.F. - 23 in.
277 psia Saturated Steam
Gross Generator Output, MW 74.4
Auxiliary Power @ 6.2%, MW 4.6
Net Generator Output, MW 69.8
Steam Rate to Turbine, #/kwh 14.2
Btu/kwh to Turbine 12,650
Moderator Loss, Btu/kwh 1010
Total Btu/kwh 13,660
Net Plant Heat Rate, Btu/kwh 14,550
Net Plant Efficiency, % 23.4
Steam Generator
1.055 x 10^6 #/hr.
410.1 F
277 P
1202.3 H
Moisture Separator
1064 H
26 P
1150 H
Secondary Cycle H2O
18.8 x 10^6 #/hr
790 P
490 F
H.P.
L.P.
69.8 MWe Net
Reactor
94,000 #/hr
1148 H
81,600 #/hr
1076 H
1½ Hg.ABS
740,000 #/hr
990 H
80,800 #/hr
210.6 H
58,600 #/hr
1084 H
3.69 x 10^6 #/hr
3.69 x 10^6 #/hr
Primary Cycle D2O
94,000 #/hr
264F 232.7H
31.97P
917 F
59.7 H
Condensate Pump
18.8 x 10^6 #/hr
446 F
Reactor Circulating Pump
141.9 H
879,400 #/hr
174 F
1.055x10^6 #/hr
Air Ejector
Mod. Circ. Pump
Moderator System D2O
110 F
1.055x10^6 #/hr
333 F
303.8 H
114.9 P
254 F
222.5 H
Feed Pump
7.2 P
Gland Steam Cond.
139,400 #/hr
146 H
309 F
Drain Pump
130 F
Cooling Water
Moderator Cooler
70 MWe Pressurized D2O
Pressure Tube
Indirect Cycle - Prototype
Performance Diagram
Savannah River Operations Office
Contract AT (38-1) 213
U.S. Atomic Energy Commission
Calc.
Checked
Approved
DATE
REVISED
SARGENT & LUNDY ENGINEERS CHICAGO
JOB NO.
SKETCH No
2897-1
HB-452
Note: P Denotes Psia
Heater C
Heater B
Heater A



Gross Generator Output kwh 227,240
Auxiliary Power @ 6.1% kw 13,860
Net Sent Out kw 213,380
Steam Rate to Turbine #/kwh 13.65
Btu/kwh to Turbine 11,031
Net Heat Rate Btu/kwh 11,746
Reactor Moderator Heat Loss % 7
Plant Heat Rate (100% Oper. Eff.) Btu/kwh 12,632
Thermal Efficiency 27.02
2,299,770 #/hr
108 P
480.0 F
1154.1 H
3,102,590 #/hr
765 P
510.0 F
1087.2 H
1000 #/hr to Air Ejector
205,040 #/hr
1087.2 H
3,307,630 #/hr
240 P
396.6 F
480.0 F
1154.1 H
2nd Stage Reheater
366.6 F
1098.1 H
1st Stage Reheater
341.3F
1076.3H
Moisture Separator
2,569,400 #/hr
992.1 H
240 P
120 P
11.7 P
55.0 P
55.0 P
11.7 P
396.6F
330.7H
71,750 #/hr to Htr. "C"
71,750 #/hr
1029.5 H
341.3F
273.8H
269,630 #/hr to Htr. "B"
Boiling D2O Pressure Tube Reactor
510.0 F
459.1 H
213,610 #/hr
1029.5 H
3½" HgABS
1,899,930 #/hr
915.8 H
200,000 kw Reheat Unit
1800 rpm TCDF - 38"
750 psig - 510.0 F
Dry and Saturated Steam
Reheat 480.0 F - 93 psig
196,450 #/hr
992.1 H
"A" 3,720 #/hr
381.3 H
"B" 31,020 #/hr
1054.6 H
"C" 15,640 #/hr
330.7 H
From 1st Stage Reheater
71,750 #/hr
330.7 H
241,630 #/hr
1097.5 H
From Moist. Sep.
269,630 #/hr
273.8 H
158,210 #/hr
1000.0 H
1,201,660 #/hr
123.3F
58.8H
1000 #/hr Air Ejector
ΔH=1000
205,040 #/hr
3,102,590 #/hr
387.2F
320.8 H
228 P
332.5 F
265.0 H
114 P
279.5 F
213.1 H
52.3P
195.0 F
130.8 H
11.1 P
123.6 F
59.1 H
Heater D
392.2 F
326.1 H
263,990 #/hr
337.5 F
270.0 H
532,190 #/hr
284.5 F
217.9 H
1,043,450 #/hr
200.0 F
135.8 H
Heater C
Heater B
Heater A
"A" - Moisture at Moisture Removal Stage
"B" - 1% Steam with "A"
"C" - Moisture with Heater Extraction Steam
Note: P Denotes psia
Performance Diagram
Savannah River Operations Office
Contract at (38-1) 193
U.S. Atomic Energy Commission
Calc. H.M.S.
Checked
Approved
DATE 2-15-60
REVISED
SARGENT & LUNDY ENGINEERS CHICAGO
JOB NO. 2897-1
SKETCH NO. HS-470



Gross Generator Output	KW	219,300
Auxiliary Power @ 6.1%	KW	13,380
Net Sent Out	KW	205,920
Steam Rate to Turbine	#/kwh	14.14
Btu/kwh to Turbine		11,427
Net Heat Rate	Btu/kwh	12,169
Reactor Moderator Heat Loss	%	7
Plant Heat Rate (100% Oper. Eff.)	Btu/kwh	13,085
Thermal Efficiency	%	26.08



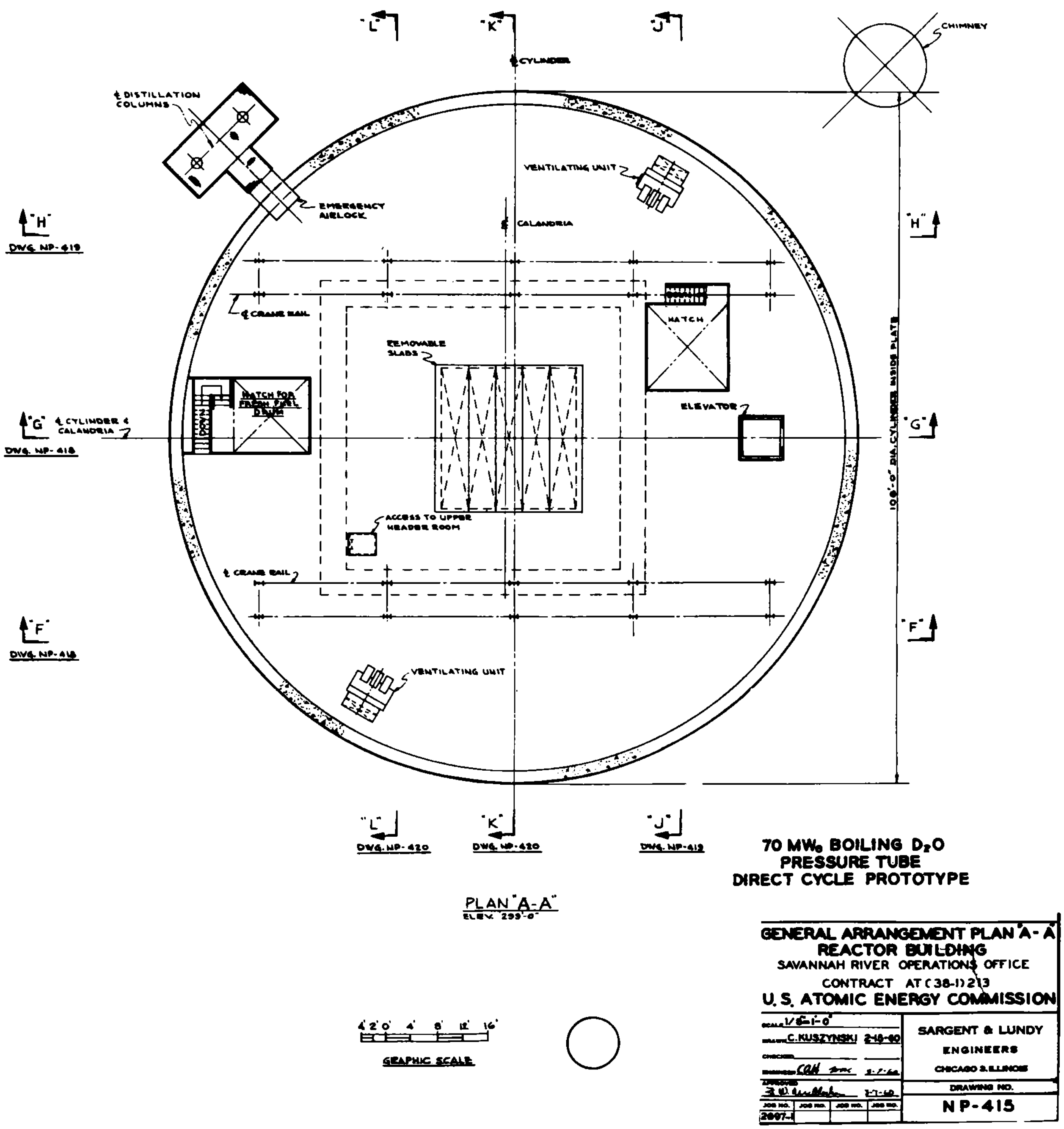
70 MW$_e$ BOILING D_2O PRESSURE TUBE DIRECT CYCLE PROTOTYPE

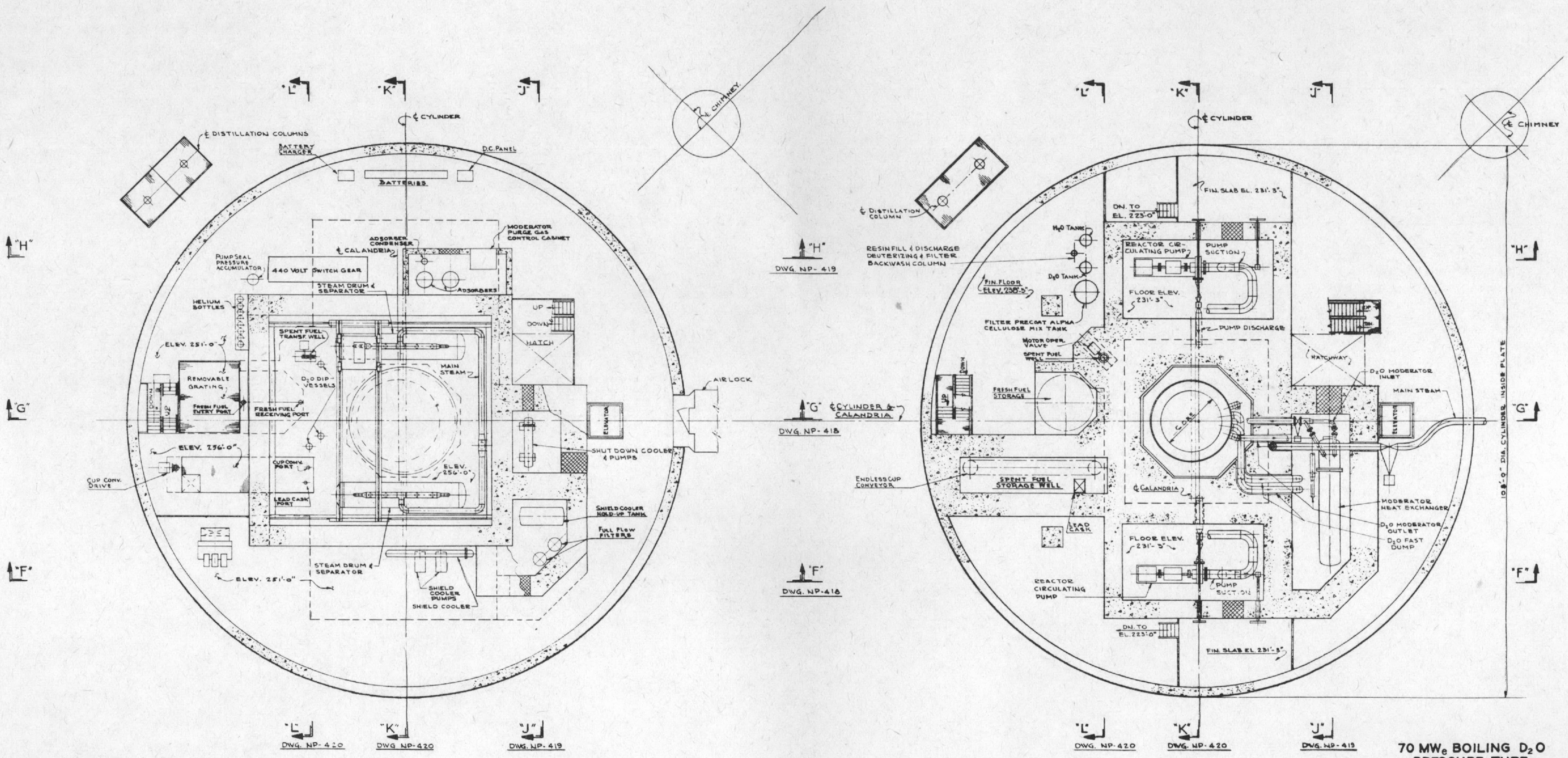
PROPERTY PLAT

SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1) 213

U.S. ATOMIC ENERGY COMMISSION

SCALE 1" = 50'-0"	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWN A. HEDBREDER 2-15-60	
CHECKED	
ENGINEER CRH 2-7-60	
APPROVED B. W... 2-7-60	DRAWING NO.
JOB NO. 3807-1	NP-414


CHIMNEY
℄ CYLINDER
℄ DISTILLATION COLUMNS
EMERGENCY AIRLOCK
VENTILATING UNIT
℄ CALANDRIA
℄ CRANE RAIL
HATCH
REMOVABLE SLABS
HATCH FOR FRESH FUEL DRUM
DOWN
℄ CYLINDER & CALANDRIA
ELEVATOR
ACCESS TO UPPER HEADER ROOM
108'-0" DIA. CYLINDER INSIDE PLATE
"H"
DWG. NP-419
"G"
DWG. NP-418
"F"
DWG. NP-418
"L"
DWG. NP-420
"K"
DWG. NP-420
"J"
DWG. NP-419
70 MWe BOILING D2O
PRESSURE TUBE
DIRECT CYCLE PROTOTYPE
PLAN "A-A"
ELEV. 293'-0"
GRAPHIC SCALE
GENERAL ARRANGEMENT PLAN "A-A"
REACTOR BUILDING
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1)213
U.S. ATOMIC ENERGY COMMISSION
C. KUSZYNSKI 2-18-60
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-415



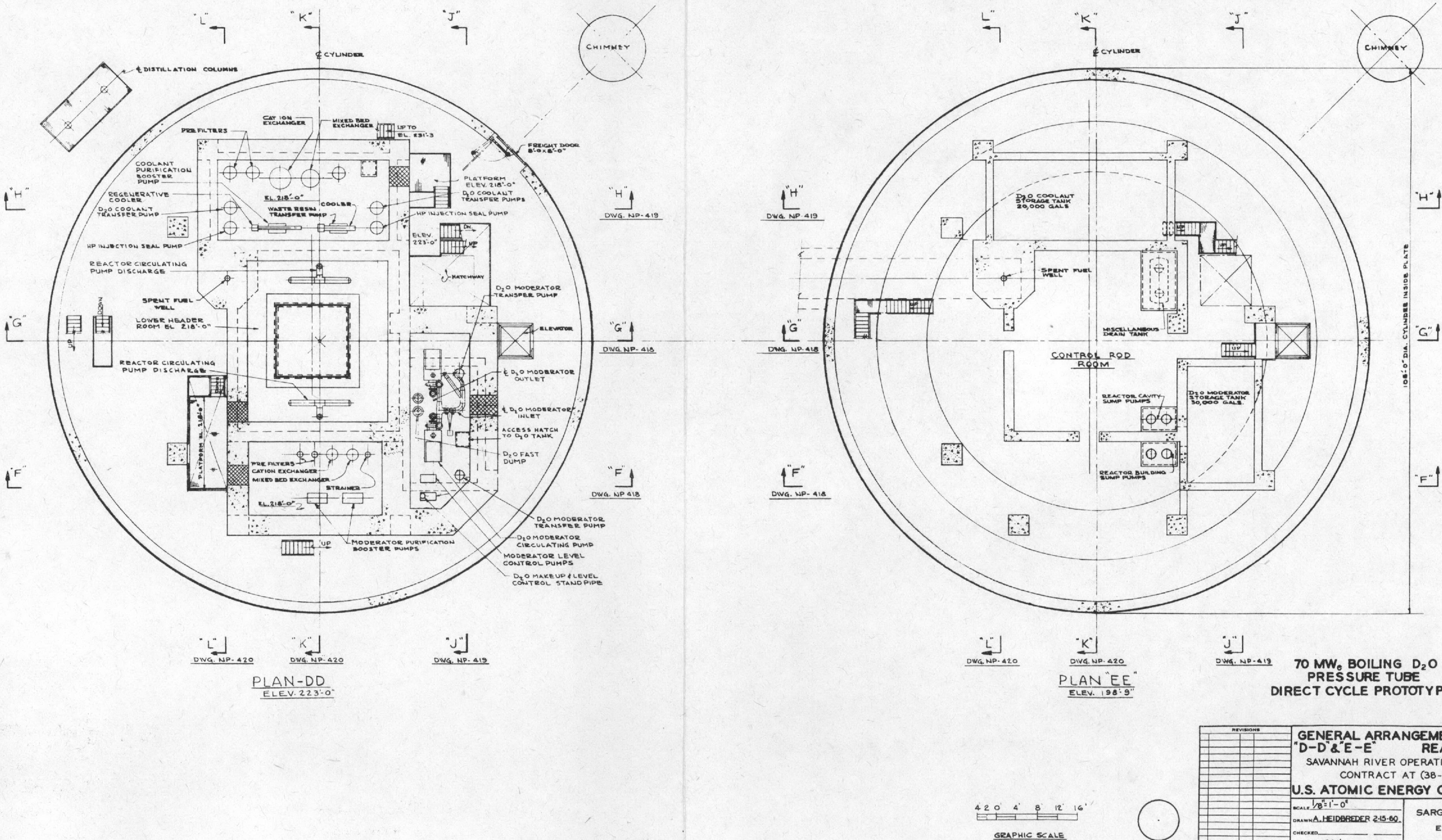
PLAN "B-B"
ELEV. 251'-0"

PLAN "C-C"
ELEV. 231'-3" & 230'-3"

70 MW$_e$ BOILING D_2O
PRESSURE TUBE
DIRECT CYCLE PROTOTYPE

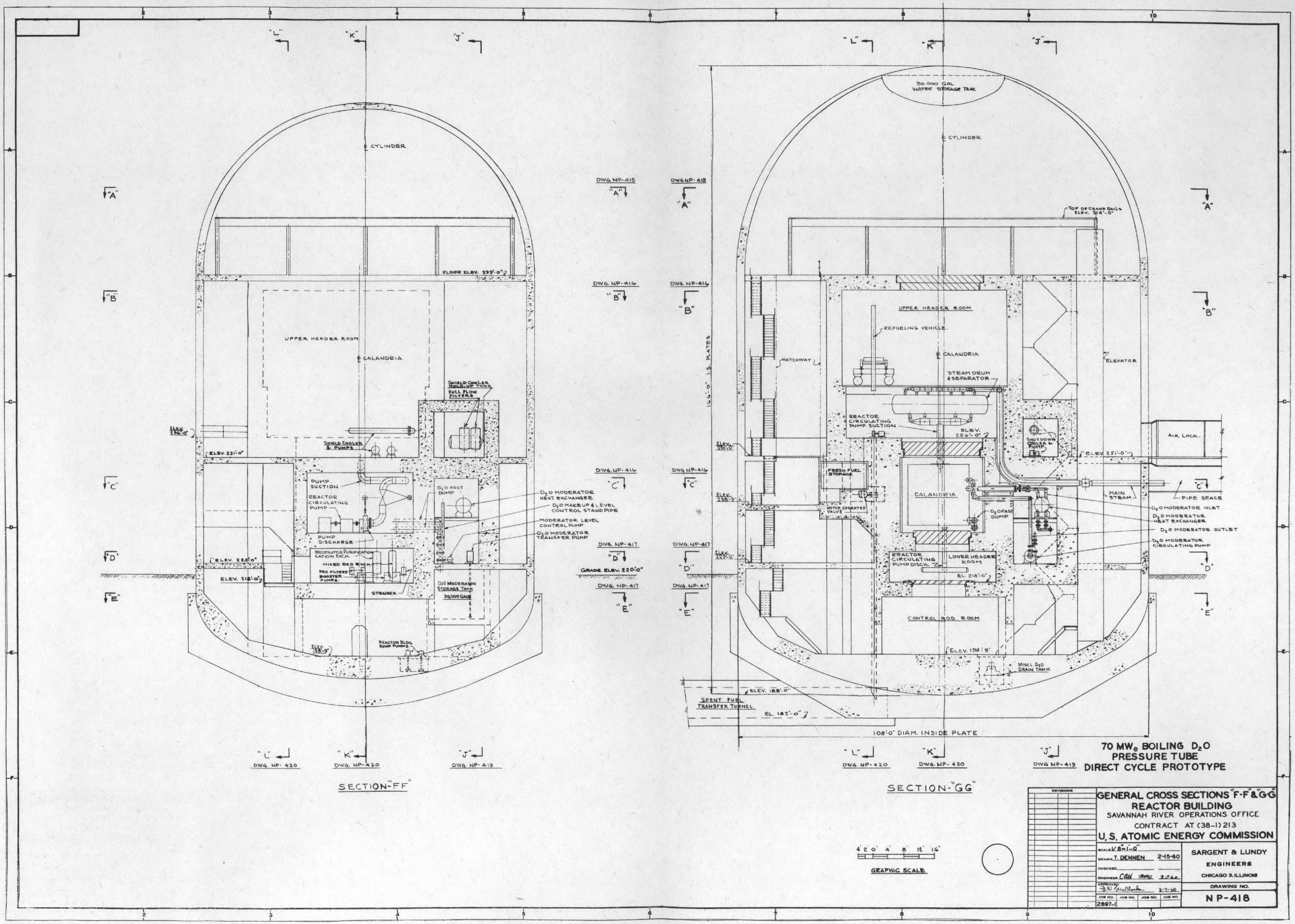
GRAPHIC SCALE (4 2 0 4 8 12 16)

REVISIONS	GENERAL ARRANGEMENT PLANS "B-B" & "C-C" REACTOR BLDG. SAVANNAH RIVER OPERATIONS OFFICE CONTRACT AT (38-1) 213 U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWN T. DENNEN 2-15-60	
CHECKED	
ENGINEER [illegible] 3-7-60	
APPROVED [illegible] 3-7-60	DRAWING NO.
JOB NO. 2897-1	NP-416

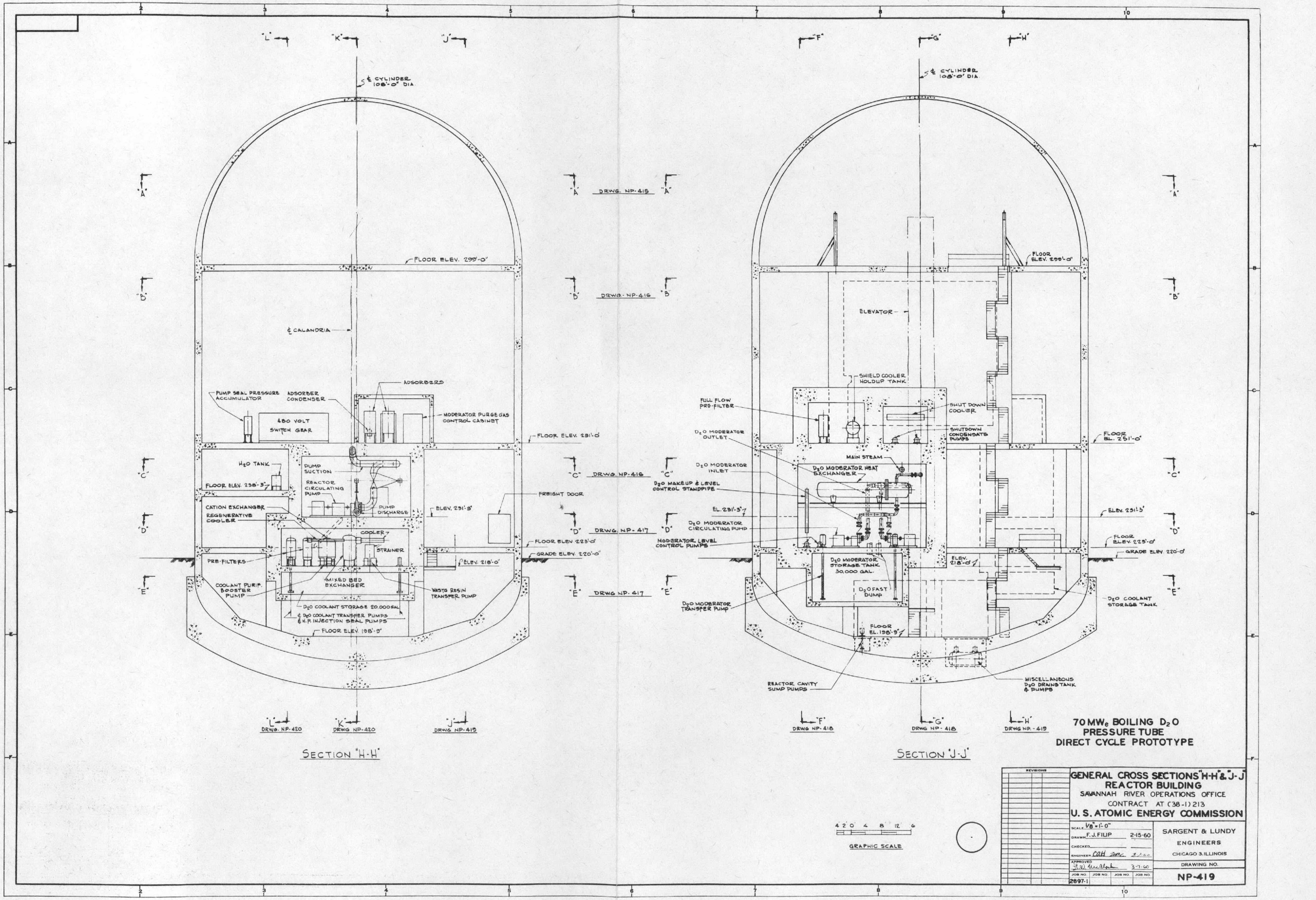


70 MW$_e$ BOILING D_2O
PRESSURE TUBE
DIRECT CYCLE PROTOTYPE

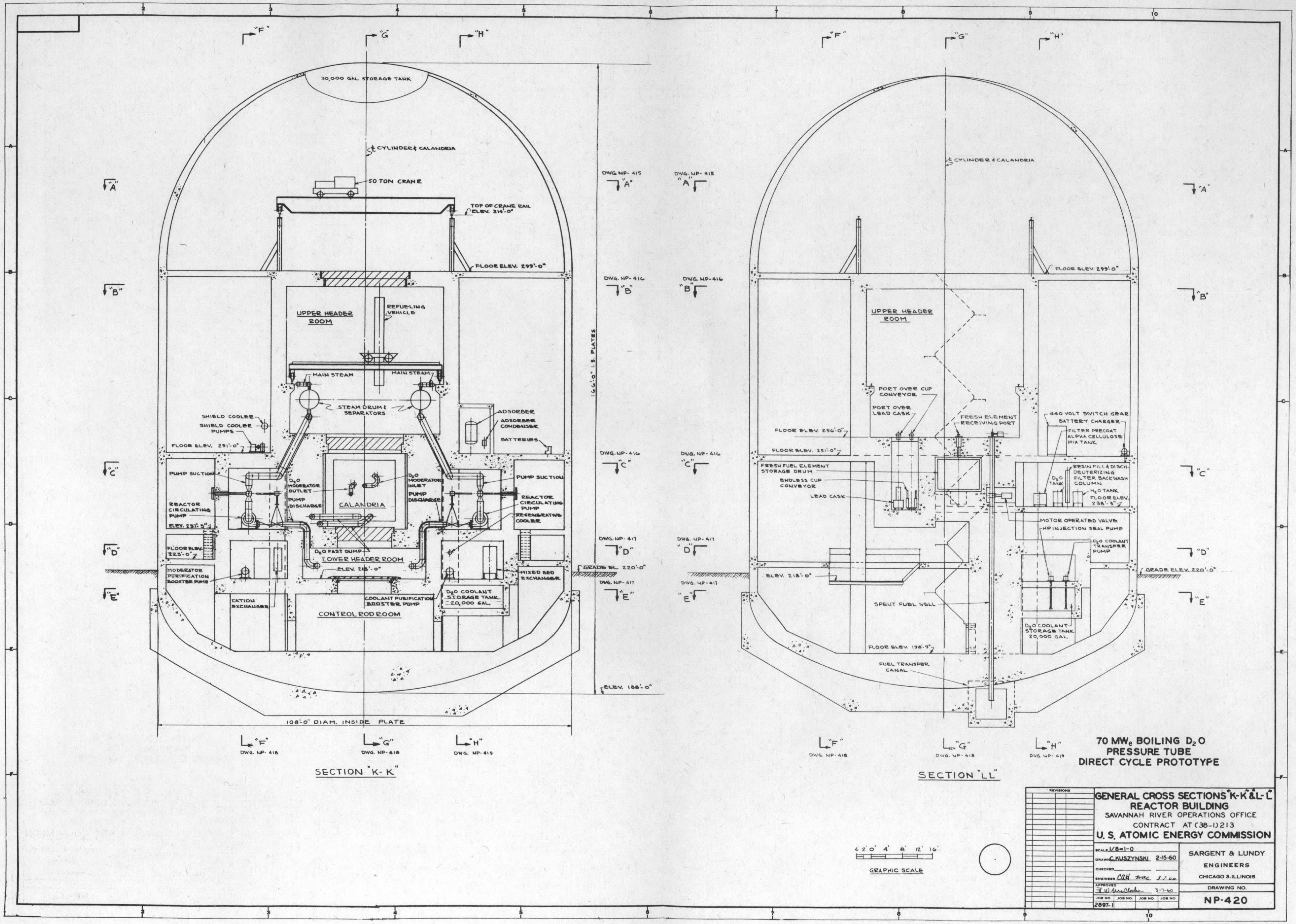
REVISIONS	
	GENERAL ARRANGEMENT PLANS "D-D" & "E-E" REACTOR BLDG. SAVANNAH RIVER OPERATIONS OFFICE CONTRACT AT (38-1) 213 **U.S. ATOMIC ENERGY COMMISSION**
SCALE 1/8" = 1'-0" DRAWN A. HEIDBREDER 2-15-60 CHECKED ENGINEER CAH 3-7-60 APPROVED [signature] 3-7-60 JOB NO. 2897-1	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS DRAWING NO. **NP-417**

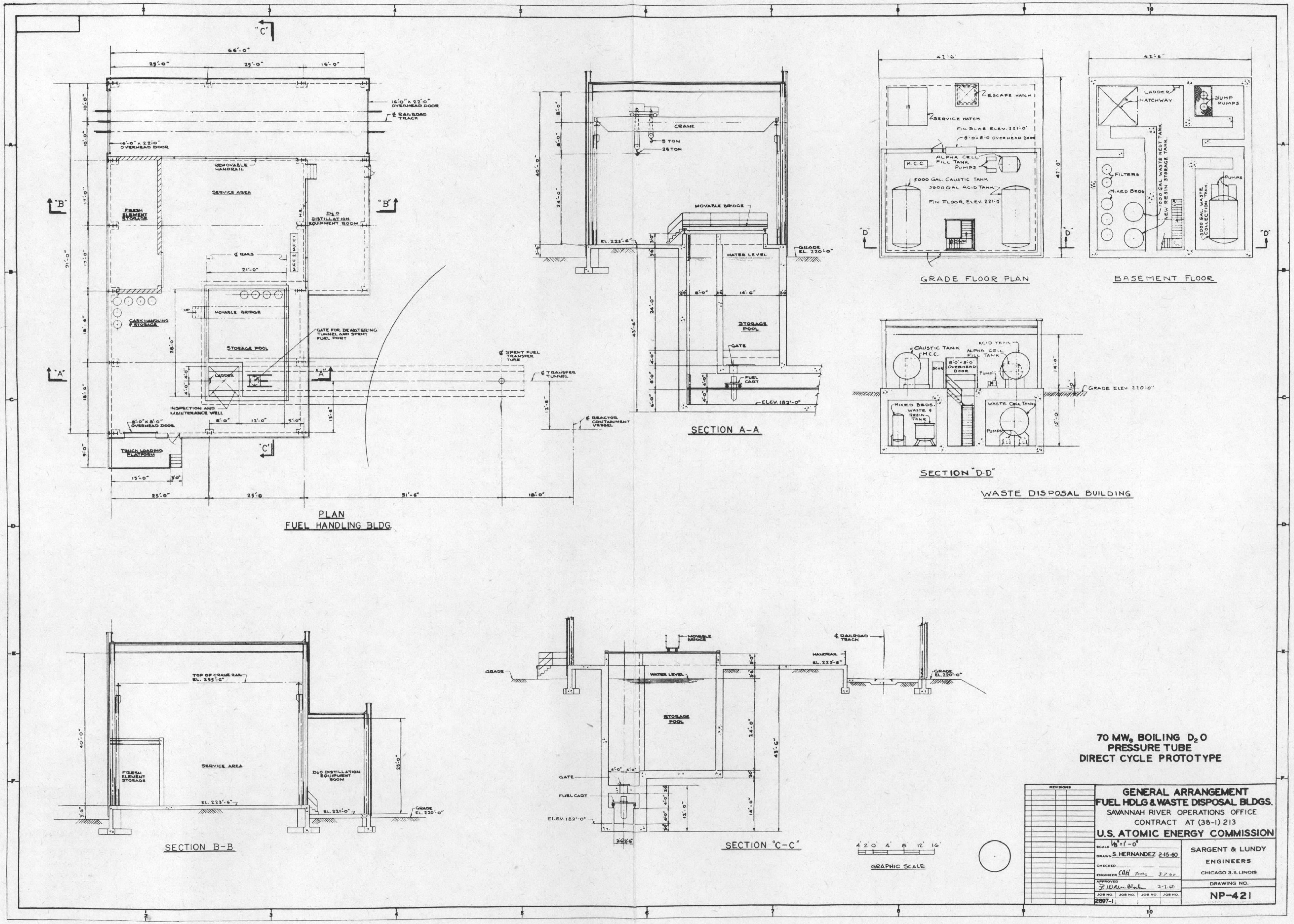


SECTION "FF"
SECTION "GG"
UPPER HEADER ROOM
CALANDRIA
CYLINDER
FLOOR ELEV. 299'-0"
SHIELD COOLER HOLD-UP TANK
FULL FLOW FILTERS
SHIELD COOLER & PUMPS
PUMP SUCTION
REACTOR CIRCULATING PUMP
PUMP DISCHARGE
D2O DUMP
D2O MODERATOR HEAT EXCHANGER
D2O MAKEUP & LEVEL CONTROL STAND PIPE
MODERATOR LEVEL CONTROL PUMP
D2O MODERATOR TRANSFER PUMP
MODERATOR PURIFICATION CATION EXCH.
MIXED BED EXCH.
PRE FILTERS
BOOSTER PUMPS
STRAINER
D2O MODERATOR STORAGE TANK 30,000 GALS
REACTOR BLDG. SUMP PUMPS
ELEV. 251'-0"
ELEV. 223'-0"
ELEV. 218'-0"
GRADE ELEV. 220'-0"
30,000 GAL WATER STORAGE TANK
TOP OF CRANE RAILS ELEV. 314'-0"
REFUELING VEHICLE
HATCHWAY
STEAM DRUM & SEPARATOR
ELEVATOR
REACTOR CIRCULATING PUMP SUCTION
SHUTDOWN COOLER & PUMP
AIR LOCK
FRESH FUEL STORAGE
MOTOR OPERATED VALVE
MAIN STEAM
PIPE SPACE
D2O MODERATOR INLET
D2O MODERATOR HEAT EXCHANGER
D2O MODERATOR OUTLET
D2O MODERATOR CIRCULATING PUMP
REACTOR CIRCULATING PUMP DISCH.
LOWER HEADER ROOM
EL. 218'-0"
CONTROL ROD ROOM
ELEV. 198'-9"
MISC. D2O DRAIN TANK
ELEV. 188'-0"
SPENT FUEL TRANSFER TUNNEL
EL. 182'-0"
108'-0" DIAM. INSIDE PLATE
166'-0" I.S. PLATES
DWG. NP-415
DWG. NP-416
DWG. NP-417
DWG. NP-419
DWG. NP-420
70 MWe BOILING D2O PRESSURE TUBE DIRECT CYCLE PROTOTYPE
GRAPHIC SCALE
REVISIONS
GENERAL CROSS SECTIONS "F-F" & "G-G"
REACTOR BUILDING
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8"=1'-0"
DRAWN T. DENNEN 2-15-60
CHECKED
ENGINEER
APPROVED
JOB NO. 2897-1
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-418

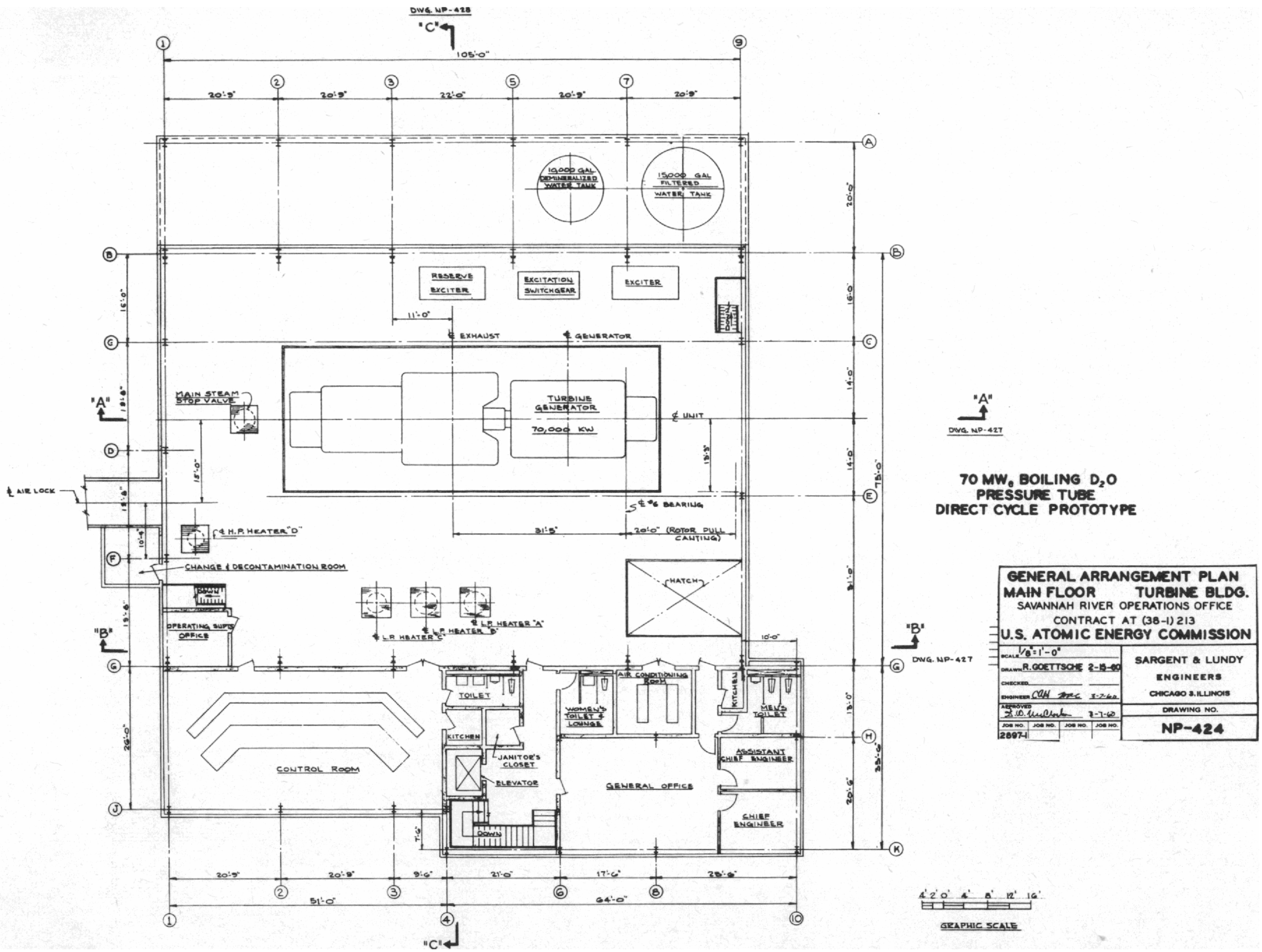


SECTION "H-H"
SECTION "J-J"
℄ CYLINDER 108'-0" DIA.
FLOOR ELEV. 299'-0"
℄ CALANDRIA
ADSORBERS
PUMP SEAL PRESSURE ACCUMULATOR
ADSORBER CONDENSER
480 VOLT SWITCH GEAR
MODERATOR PURGE GAS CONTROL CABINET
FLOOR ELEV. 251'-0"
H2O TANK
FLOOR ELEV. 238'-3"
DUMP SUCTION
REACTOR CIRCULATING PUMP
PUMP DISCHARGE
CATION EXCHANGER
REGENERATIVE COOLER
COOLER
STRAINER
PRE-FILTERS
FREIGHT DOOR
ELEV. 231'-3"
FLOOR ELEV. 223'-0"
GRADE ELEV. 220'-0"
ELEV. 218'-0"
COOLANT PURIF. BOOSTER PUMP
MIXED BED EXCHANGER
WASTE RESIN TRANSFER PUMP
D2O COOLANT STORAGE 20,000 GAL.
D2O COOLANT TRANSFER PUMPS & H.P. INJECTION SEAL PUMPS
FLOOR ELEV. 198'-9"
DRWG. NP-415
DRWG. NP-416
DRWG. NP-417
DRWG. NP-420
ELEVATOR
SHIELD COOLER HOLDUP TANK
FULL FLOW PRE-FILTER
SHUT DOWN COOLER
SHUTDOWN CONDENSATE PUMPS
D2O MODERATOR OUTLET
MAIN STEAM
D2O MODERATOR INLET
D2O MODERATOR HEAT EXCHANGER
D2O MAKEUP & LEVEL CONTROL STANDPIPE
D2O MODERATOR CIRCULATING PUMP
MODERATOR LEVEL CONTROL PUMPS
D2O MODERATOR STORAGE TANK 30,000 GAL.
D2O FAST DUMP
D2O MODERATOR TRANSFER PUMP
D2O COOLANT STORAGE TANK
FLOOR EL. 198'-9"
REACTOR CAVITY SUMP PUMPS
MISCELLANEOUS D2O DRAINS TANK & PUMPS
DRWG. NP-418
DRWG. NP-419
GRAPHIC SCALE
70 MWe BOILING D2O PRESSURE TUBE DIRECT CYCLE PROTOTYPE
REVISIONS
GENERAL CROSS SECTIONS "H-H" & "J-J"
REACTOR BUILDING
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U. S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN F. J. FILIP 2-15-60
CHECKED
ENGINEER CAH 3-7-60
APPROVED 3-7-60
JOB NO. 2897-1
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-419

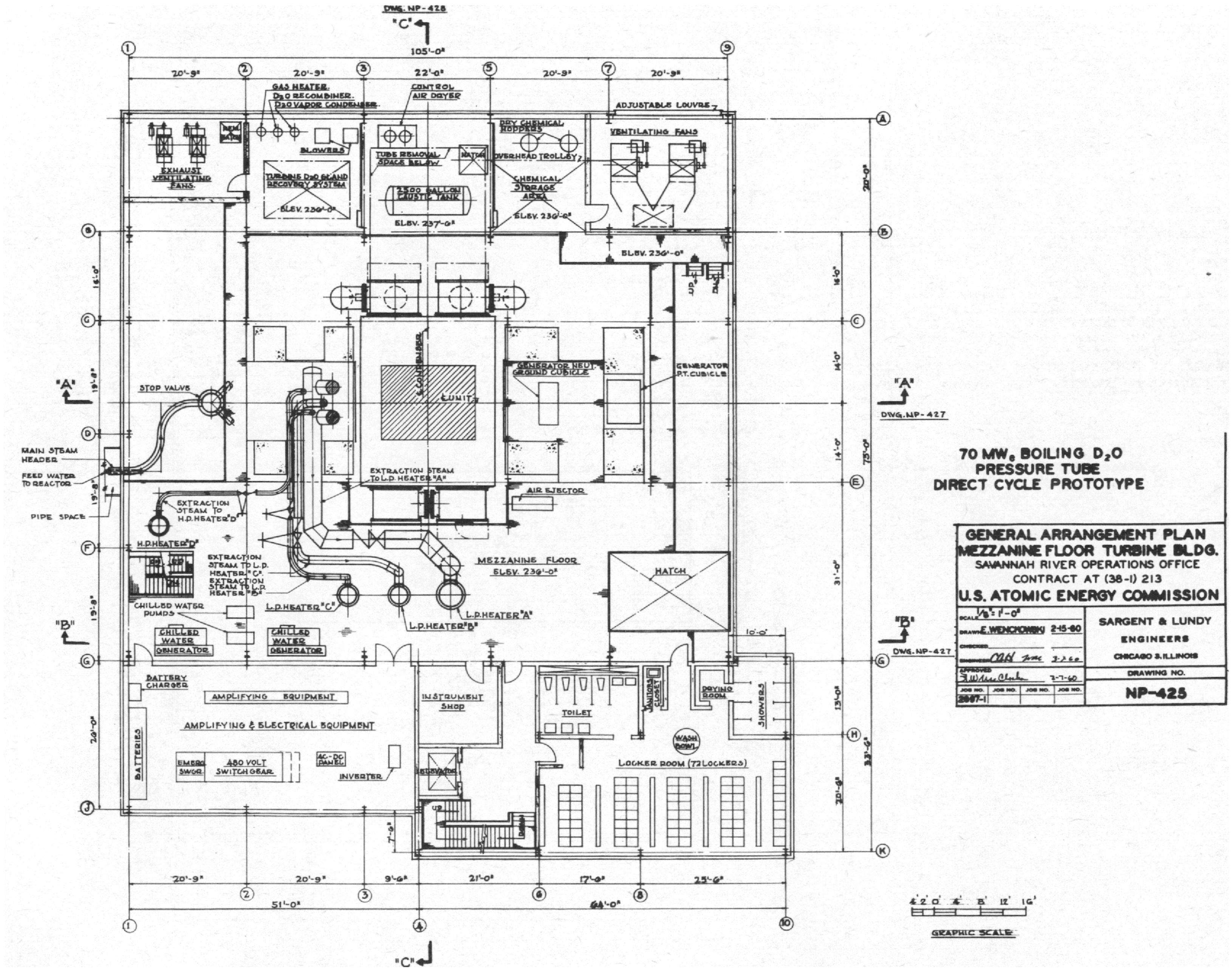

30,000 GAL. STORAGE TANK
CYLINDER & CALANDRIA
50 TON CRANE
TOP OF CRANE RAIL ELEV. 314'-0"
FLOOR ELEV. 299'-0"
UPPER HEADER ROOM
REFUELING VEHICLE
MAIN STEAM
STEAM DRUM & SEPARATORS
SHIELD COOLER
SHIELD COOLER PUMPS
ADSORBER
ADSORBER CONDENSER
BATTERIES
FLOOR ELEV. 251'-0"
PUMP SUCTION
REACTOR CIRCULATING PUMP
D_2O MODERATOR OUTLET
D_2O MODERATOR INLET
PUMP DISCHARGE
CALANDRIA
REGENERATIVE COOLER
ELEV. 231'-9"
FLOOR ELEV. 225'-0"
D_2O FAST DUMP
LOWER HEADER ROOM
ELEV. 218'-0"
MODERATOR PURIFICATION BOOSTER PUMP
CATION EXCHANGER
COOLANT PURIFICATION BOOSTER PUMP
D_2O COOLANT STORAGE TANK 20,000 GAL.
MIXED BED EXCHANGER
CONTROL ROD ROOM
GRADE EL. 220'-0"
166'-0" I.S. PLATES
ELEV. 188'-0"
108'-0" DIAM. INSIDE PLATE
DWG. NP-415
DWG. NP-416
DWG. NP-417
DWG. NP-418
DWG. NP-419
SECTION "K-K"
UPPER HEADER ROOM
PORT OVER CUP CONVEYOR
PORT OVER LEAD CASK
FRESH ELEMENT RECEIVING PORT
FLOOR ELEV. 256'-0"
FLOOR ELEV. 251'-0"
FRESH FUEL ELEMENT STORAGE DRUM
ENDLESS CUP CONVEYOR
LEAD CASK
440 VOLT SWITCH GEAR
BATTERY CHARGER
FILTER PRECOAT ALPHA CELLULOSE MIX TANK
RESIN FILL & DISCH. DEUTERIZING FILTER BACKWASH COLUMN
D_2O TANK
H_2O TANK
FLOOR ELEV. 238'-3"
MOTOR OPERATED VALVE
HP INJECTION SEAL PUMP
D_2O COOLANT TRANSFER PUMP
GRADE ELEV. 220'-0"
ELEV. 218'-0"
SPENT FUEL WELL
D_2O COOLANT STORAGE TANK 20,000 GAL.
FLOOR ELEV. 198'-9"
FUEL TRANSFER CANAL
SECTION "LL"
70 MW$_e$ BOILING D_2O
PRESSURE TUBE
DIRECT CYCLE PROTOTYPE
GRAPHIC SCALE
REVISIONS
GENERAL CROSS SECTIONS "K-K" & "L-L"
REACTOR BUILDING
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U. S. ATOMIC ENERGY COMMISSION
SCALE 1/8=1-0
DRAWN C. KUSZYNSKI 2-15-60
CHECKED
ENGINEER CQH 3-7-60
APPROVED 3-7-60
JOB NO. 2897-1
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-420

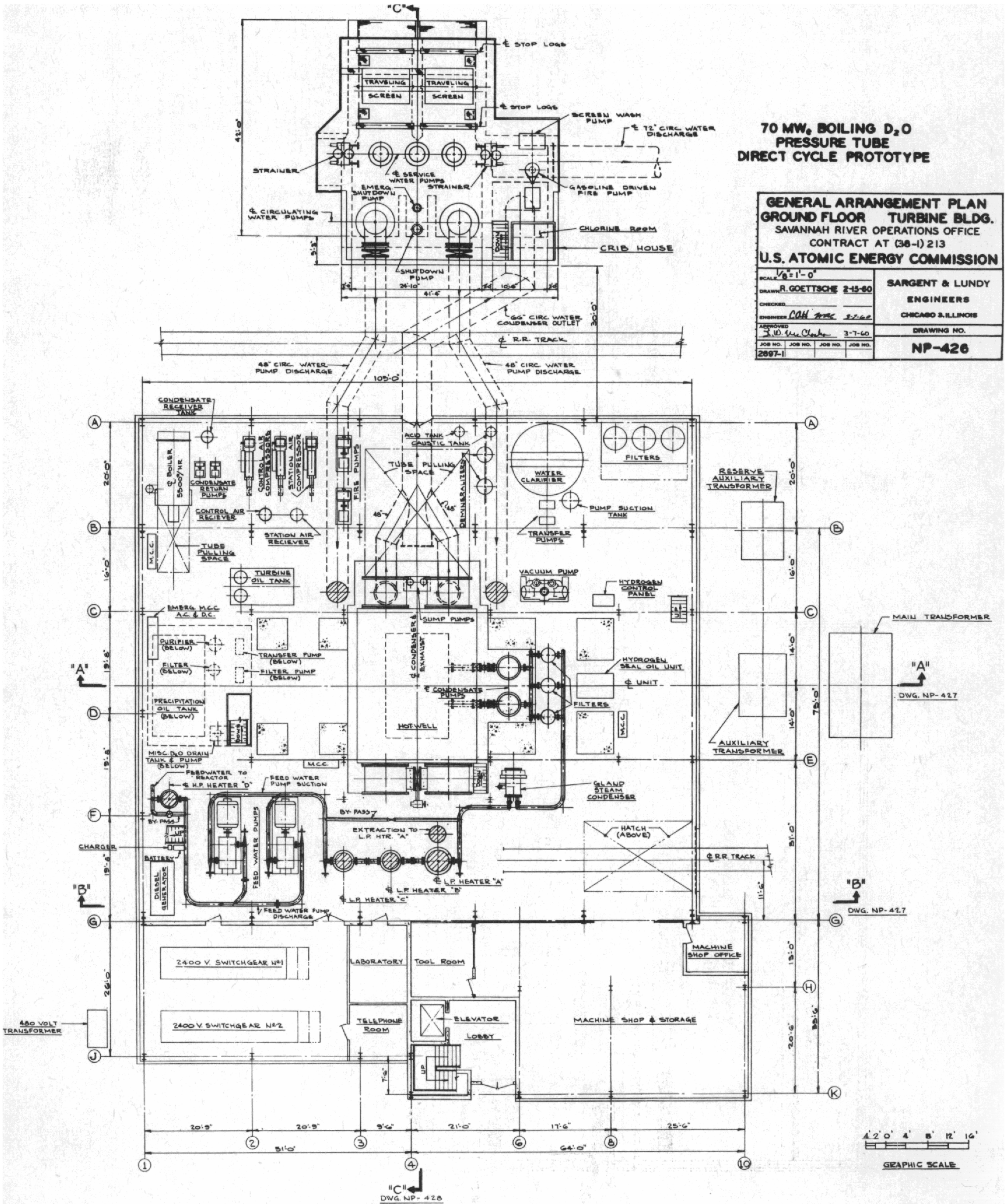


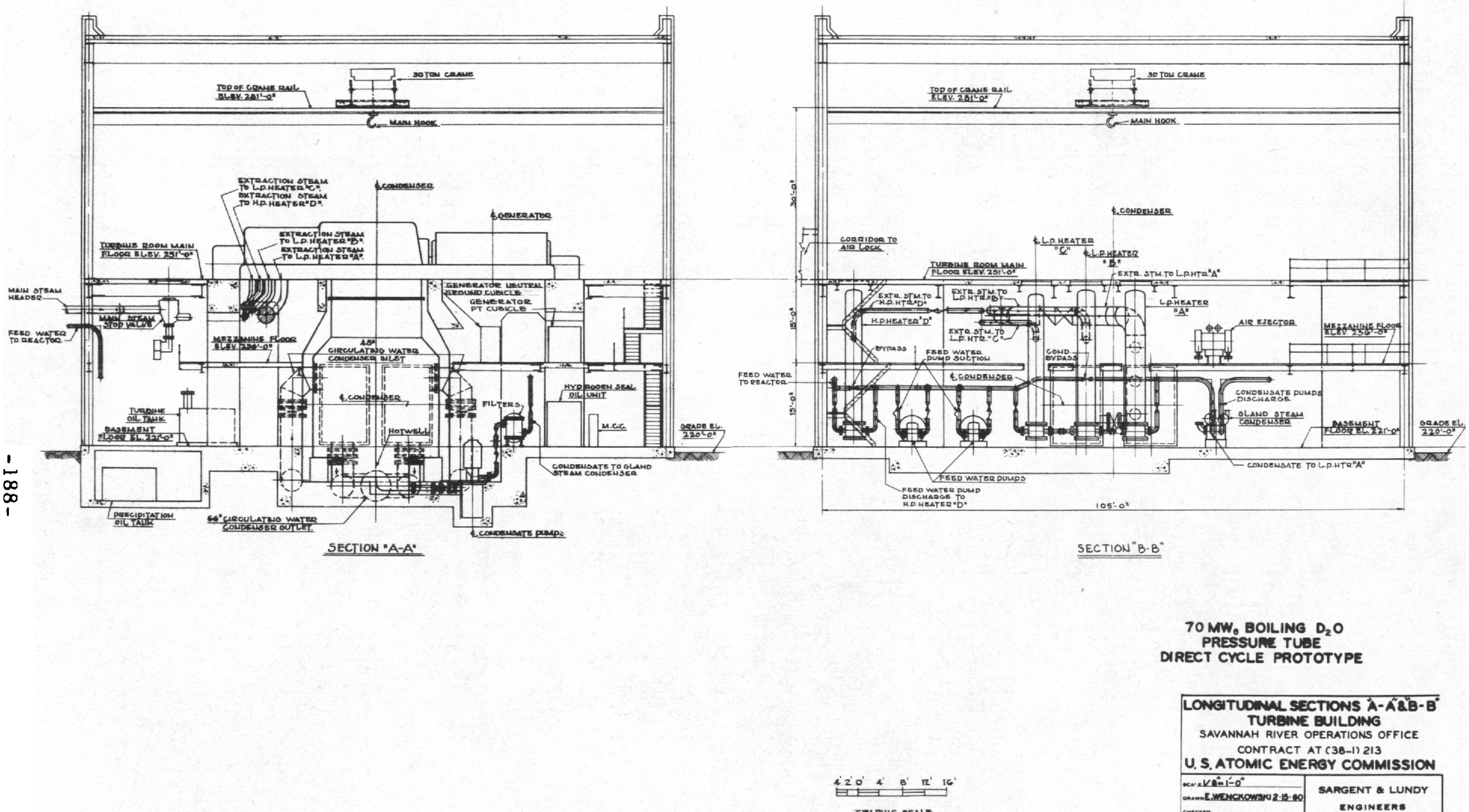
PLAN
FUEL HANDLING BLDG.
SERVICE AREA
FRESH ELEMENT STORAGE
D_2O DISTILLATION EQUIPMENT ROOM
CASK HANDLING & STORAGE
MOVABLE BRIDGE
STORAGE POOL
LADDER
INSPECTION AND MAINTENANCE WELL
TRUCK LOADING PLATFORM
GATE FOR DEWATERING TUNNEL AND SPENT FUEL POOL
℄ SPENT FUEL TRANSFER TUBE
℄ TRANSFER TUNNEL
℄ REACTOR CONTAINMENT VESSEL
16'-0" x 22'-0" OVERHEAD DOOR
℄ RAILROAD TRACK
REMOVABLE HANDRAIL
SECTION A-A
CRANE
5 TON
25 TON
MOVABLE BRIDGE
WATER LEVEL
STORAGE POOL
GATE
FUEL CART
EL. 223'-6"
GRADE EL. 220'-0"
ELEV. 182'-0"
GRADE FLOOR PLAN
ESCAPE HATCH
SERVICE HATCH
FIN. SLAB ELEV. 221'-0"
8'-0 x 8'-0 OVERHEAD DOOR
M.C.C.
ALPHA CELL FILL TANK
PUMPS
5000 GAL. CAUSTIC TANK
5000 GAL. ACID TANK
FIN. FLOOR ELEV. 221'-0
BASEMENT FLOOR
LADDER HATCHWAY
SUMP PUMPS
FILTERS
MIXED BEDS
1000 GAL WASTE HEUT TANK
NEW RESIN STORAGE TANK
2000 GAL WASTE COLLECTION TANK
PUMPS
SECTION "D-D"
CAUSTIC TANK
ACID TANK
ALPHA CELL FILL TANK
8'-0 x 8'-0 OVERHEAD DOOR
GRADE ELEV. 220'-0"
MIXED BEDS
WASTE & RESIN TANK
WASTE COLL TANK
PUMPS
WASTE DISPOSAL BUILDING
SECTION B-B
TOP OF CRANE RAIL EL. 255'-6"
SERVICE AREA
FRESH ELEMENT STORAGE
D_2O DISTILLATION EQUIPMENT ROOM
EL. 223'-6"
EL. 221'-0"
GRADE EL. 220'-0"
SECTION "C-C"
MOVABLE BRIDGE
℄ RAILROAD TRACK
HANDRAIL
GRADE
WATER LEVEL
STORAGE POOL
GATE
FUEL CART
ELEV. 182'-0"
GRAPHIC SCALE
70 MW_e BOILING D_2O
PRESSURE TUBE
DIRECT CYCLE PROTOTYPE
REVISIONS
GENERAL ARRANGEMENT
FUEL HDLG & WASTE DISPOSAL BLDGS.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN S. HERNANDEZ 2-15-60
CHECKED
ENGINEER
APPROVED
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-421
2097-1



70 MWe BOILING D2O
PRESSURE TUBE
DIRECT CYCLE PROTOTYPE
GENERAL ARRANGEMENT PLAN
MAIN FLOOR TURBINE BLDG.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN R. GOETTSCHE 2-15-60
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-424
JOB NO.
2897-1
GRAPHIC SCALE
DWG. NP-428
DWG. NP-427
10,000 GAL DEMINERALIZED WATER TANK
15,000 GAL FILTERED WATER TANK
RESERVE EXCITER
EXCITATION SWITCHGEAR
EXCITER
℄ EXHAUST
℄ GENERATOR
TURBINE GENERATOR
70,000 KW
℄ UNIT
MAIN STEAM STOP VALVE
℄ AIR LOCK
℄ #6 BEARING
20'-0" (ROTOR PULL CANTING)
℄ H.P. HEATER "D"
CHANGE & DECONTAMINATION ROOM
HATCH
℄ L.P. HEATER "A"
℄ L.P. HEATER "B"
℄ L.P. HEATER "C"
OPERATING SUPT'S OFFICE
TOILET
KITCHEN
JANITOR'S CLOSET
ELEVATOR
DOWN
CONTROL ROOM
WOMEN'S TOILET & LOUNGE
AIR CONDITIONING ROOM
KITCHEN
MEN'S TOILET
ASSISTANT CHIEF ENGINEER
GENERAL OFFICE
CHIEF ENGINEER
105'-0"
51'-0"
64'-0"
75'-0"

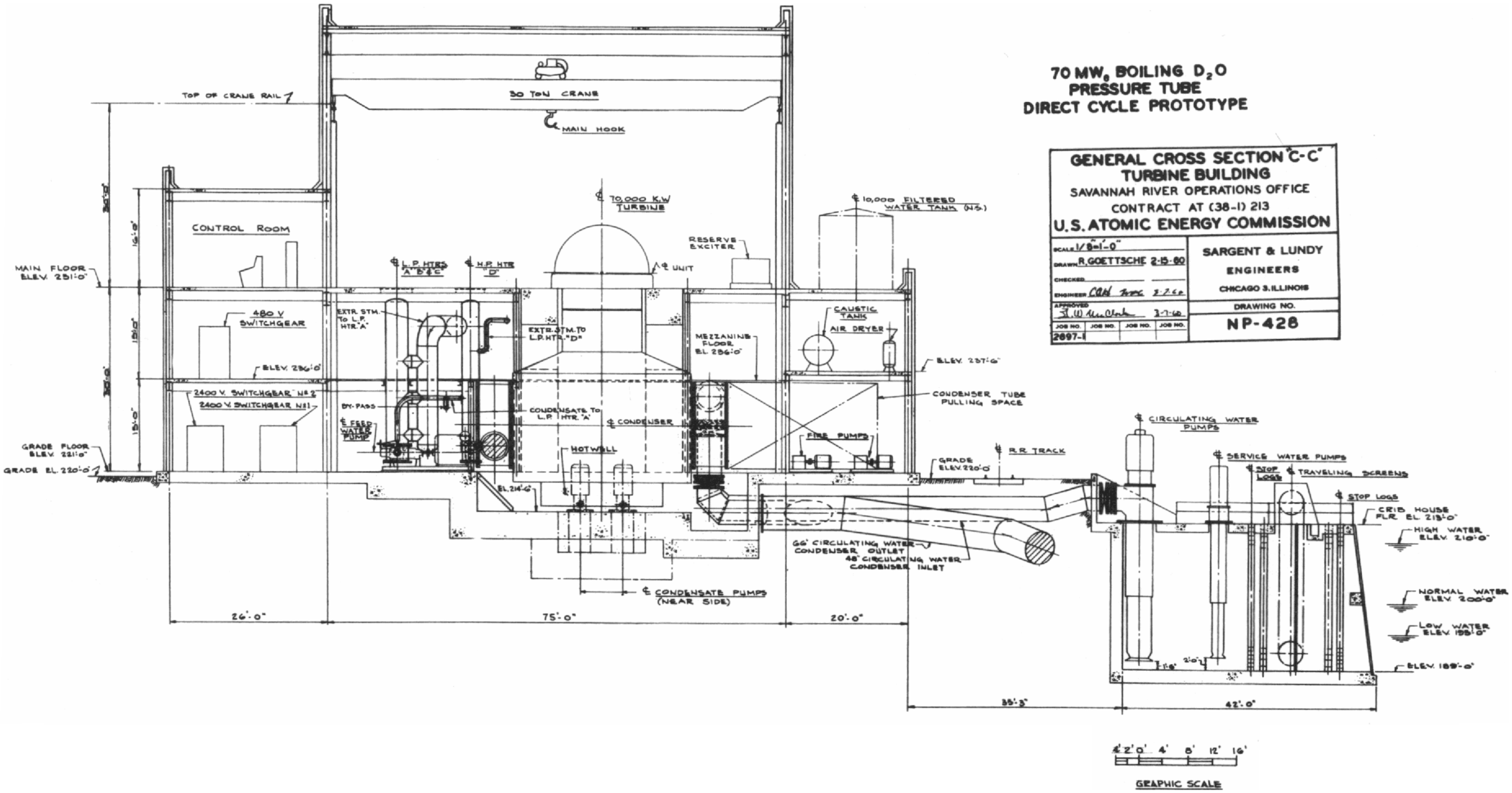

DWG. NP-428
"C"
105'-0"
20'-9"
20'-9"
22'-0"
20'-9"
20'-9"
GAS HEATER
D2O RECOMBINER
D2O VAPOR CONDENSER
CONTROL AIR DRYER
ADJUSTABLE LOUVRE
DRY CHEMICAL HOPPERS
VENTILATING FANS
BLOWERS
TUBE REMOVAL SPACE BELOW
OVERHEAD TROLLEY
EXHAUST VENTILATING FANS
TURBINE D2O GLAND RECOVERY SYSTEM
2500 GALLON CAUSTIC TANK
CHEMICAL STORAGE AREA
ELEV. 236'-0"
ELEV. 237'-0"
ELEV. 236'-0"
ELEV. 236'-0"
UNIT
GENERATOR NEUT. GROUND CUBICLE
GENERATOR P.T. CUBICLE
STOP VALVE
"A"
DWG. NP-427
MAIN STEAM HEADER
FEED WATER TO REACTOR
PIPE SPACE
EXTRACTION STEAM TO L.P. HEATER "A"
AIR EJECTOR
EXTRACTION STEAM TO H.P. HEATER "D"
H.P. HEATER "D"
EXTRACTION STEAM TO L.P. HEATER "C"
EXTRACTION STEAM TO L.P. HEATER "B"
MEZZANINE FLOOR
ELEV. 236'-0"
HATCH
CHILLED WATER PUMPS
L.P. HEATER "C"
L.P. HEATER "B"
L.P. HEATER "A"
CHILLED WATER GENERATOR
CHILLED WATER GENERATOR
"B"
DWG. NP-427
10'-0"
BATTERY CHARGER
AMPLIFYING EQUIPMENT
INSTRUMENT SHOP
JANITOR'S CLOSET
DRYING ROOM
SHOWERS
TOILET
WASH BOWL
AMPLIFYING & ELECTRICAL EQUIPMENT
BATTERIES
EMERG. SWGR.
480 VOLT SWITCHGEAR
AC-DC PANEL
INVERTER
ELEVATOR
LOCKER ROOM (72 LOCKERS)
20'-9"
20'-9"
9'-6"
21'-0"
17'-0"
25'-6"
51'-0"
64'-0"
"C"
20'-0"
16'-0"
14'-0"
14'-0"
31'-0"
13'-0"
20'-0"
75'-0"
33'-6"
19'-8"
19'-8"
19'-8"
20'-0"
7'-0"
GRAPHIC SCALE
70 MW$_e$ BOILING D$_2$O
PRESSURE TUBE
DIRECT CYCLE PROTOTYPE
GENERAL ARRANGEMENT PLAN
MEZZANINE FLOOR TURBINE BLDG.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN E. WENCKOWSKI 2-15-60
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-425
2887-1

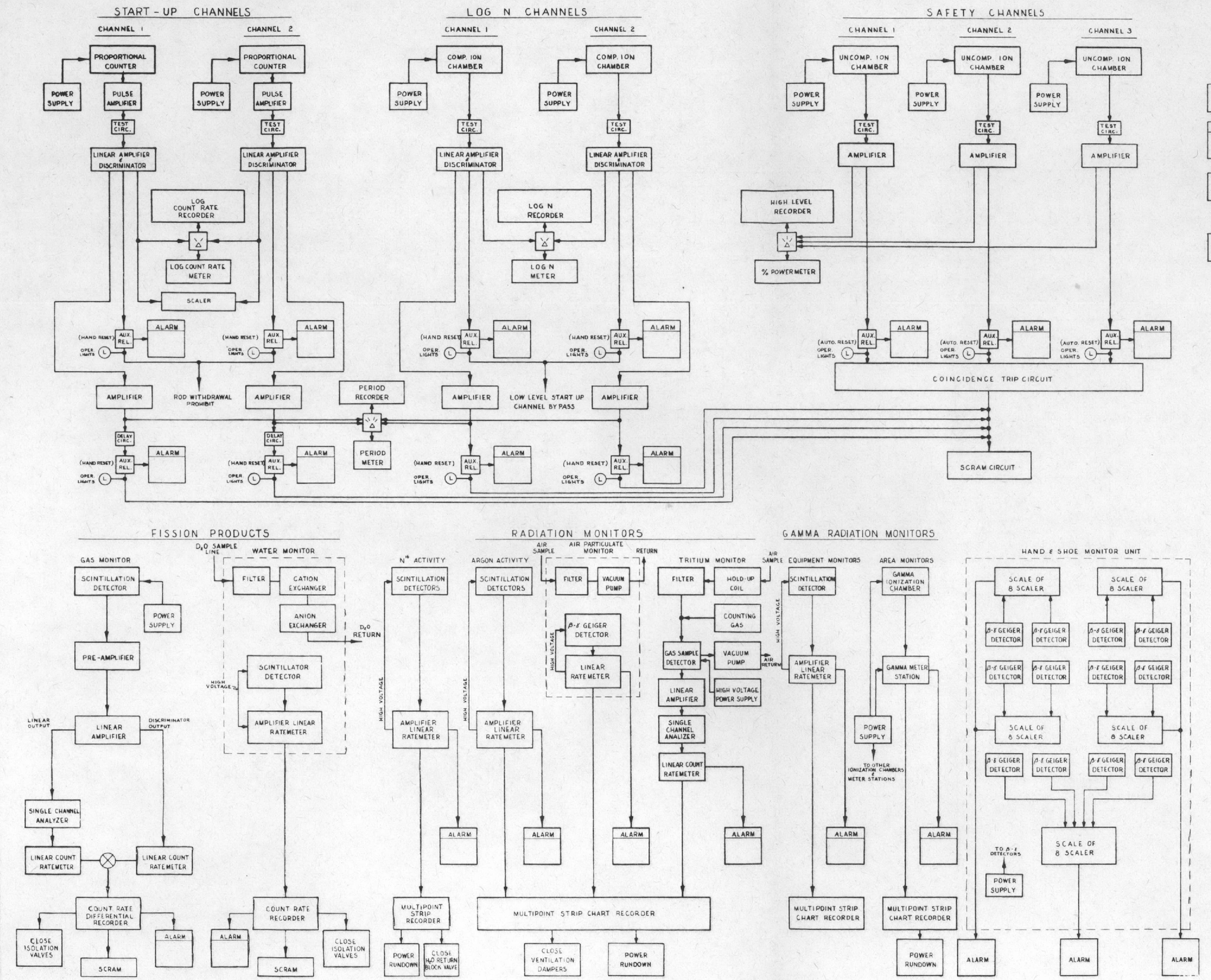

70 MWe BOILING D2O
PRESSURE TUBE
DIRECT CYCLE PROTOTYPE
GENERAL ARRANGEMENT PLAN
GROUND FLOOR TURBINE BLDG.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN R. GOETTSCHE 2-15-60
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-426
2897-1
CRIB HOUSE
CHLORINE ROOM
TRAVELING SCREEN
TRAVELING SCREEN
STRAINER
SCREEN WASH PUMP
GASOLINE DRIVEN FIRE PUMP
EMERG. SHUTDOWN PUMP
SHUTDOWN PUMP
℄ CIRCULATING WATER PUMPS
℄ SERVICE WATER PUMPS
℄ STOP LOGS
℄ 72" CIRC. WATER DISCHARGE
66" CIRC. WATER CONDENSER OUTLET
℄ R.R. TRACK
48" CIRC. WATER PUMP DISCHARGE
CONDENSATE RECEIVER TANK
℄ BOILER 5500#/HR
CONDENSATE RETURN PUMPS
CONTROL AIR COMPRESSORS
STATION AIR COMPRESSOR
FIRE PUMPS
ACID TANK
CAUSTIC TANK
TUBE PULLING SPACE
DEMINERALIZERS
WATER CLARIFIER
FILTERS
PUMP SUCTION TANK
TRANSFER PUMPS
CONTROL AIR RECIEVER
STATION AIR RECIEVER
M.C.C.
TURBINE OIL TANK
VACUUM PUMP
HYDROGEN CONTROL PANEL
RESERVE AUXILIARY TRANSFORMER
MAIN TRANSFORMER
EMERG. M.C.C. A.C. & D.C.
PURIFIER (BELOW)
FILTER (BELOW)
TRANSFER PUMP (BELOW)
FILTER PUMP (BELOW)
PRECIPITATION OIL TANK (BELOW)
SUMP PUMPS
℄ CONDENSER & EXHAUST
℄ CONDENSATE PUMPS
HOTWELL
HYDROGEN SEAL OIL UNIT
℄ UNIT
AUXILIARY TRANSFORMER
MISC. D2O DRAIN TANK & PUMP (BELOW)
FEEDWATER TO REACTOR
℄ H.P. HEATER "D"
FEED WATER PUMP SUCTION
FEED WATER PUMPS
GLAND STEAM CONDENSER
BY-PASS
EXTRACTION TO L.P. HTR. "A"
HATCH (ABOVE)
CHARGER
BATTERY
DIESEL GENERATOR
℄ L.P. HEATER "A"
℄ L.P. HEATER "B"
℄ L.P. HEATER "C"
FEED WATER PUMP DISCHARGE
2400 V. SWITCHGEAR No1
2400 V. SWITCHGEAR No2
480 VOLT TRANSFORMER
LABORATORY
TOOL ROOM
TELEPHONE ROOM
ELEVATOR
LOBBY
MACHINE SHOP OFFICE
MACHINE SHOP & STORAGE
DWG. NP-427
DWG. NP-428
GRAPHIC SCALE

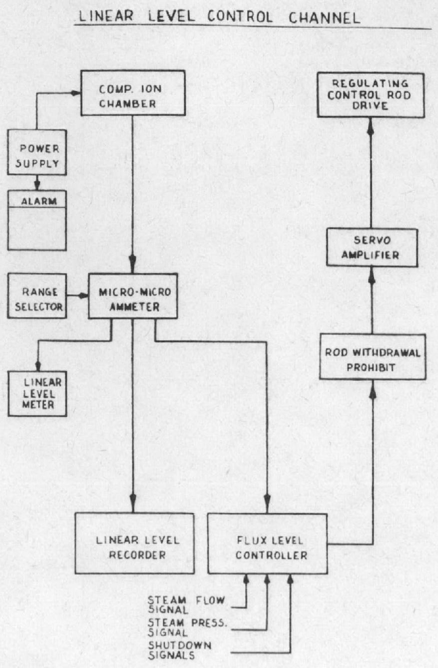


70 MW$_e$ BOILING D_2O PRESSURE TUBE DIRECT CYCLE PROTOTYPE

LONGITUDINAL SECTIONS "A-A" & "B-B" TURBINE BUILDING	
SAVANNAH RIVER OPERATIONS OFFICE	
CONTRACT AT (38-1) 213	
U.S. ATOMIC ENERGY COMMISSION	
SCALE 1/8" = 1'-0"	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWN E. WENCKOWSKI 2-15-60	
CHECKED	
ENGINEER CAH 3-7-60	
APPROVED 3-7-60	DRAWING NO.
JOB NO. 2897-1	NP-427


70 MW BOILING D_2O
PRESSURE TUBE
DIRECT CYCLE PROTOTYPE
GENERAL CROSS SECTION "C-C"
TURBINE BUILDING
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8"=1'-0"
DRAWN R. GOETTSCHE 2-15-60
CHECKED
ENGINEER
APPROVED
JOB NO.
2897-1
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-428
TOP OF CRANE RAIL
30 TON CRANE
MAIN HOOK
CONTROL ROOM
70,000 K.W. TURBINE
10,000 FILTERED WATER TANK
RESERVE EXCITER
MAIN FLOOR ELEV. 251'-0"
L.P. HTRS "A" "B" & "C"
H.P. HTR "D"
480 V SWITCHGEAR
EXTR. STM. TO L.P. HTR "A"
EXTR. STM. TO L.P. HTR "D"
MEZZANINE FLOOR EL. 236'-0"
CAUSTIC TANK
AIR DRYER
ELEV. 236'-0"
ELEV. 237'-6"
2400 V. SWITCHGEAR No 2
2400 V. SWITCHGEAR No 1
CONDENSER TUBE PULLING SPACE
BY-PASS
CONDENSATE TO L.P. HTR. "A"
CONDENSER
FEED WATER PUMP
CIRCULATING WATER PUMPS
HOTWELL
FIRE PUMPS
GRADE FLOOR ELEV. 221'-0"
GRADE EL. 220'-0"
GRADE ELEV. 220'-0"
R.R. TRACK
SERVICE WATER PUMPS
STOP LOGS
TRAVELING SCREENS
STOP LOGS
CRIB HOUSE FLR. EL. 213'-0"
HIGH WATER ELEV. 210'-0"
EL. 214'-6"
66" CIRCULATING WATER CONDENSER OUTLET
48" CIRCULATING WATER CONDENSER INLET
CONDENSATE PUMPS (NEAR SIDE)
NORMAL WATER ELEV. 200'-0"
LOW WATER ELEV. 195'-0"
ELEV. 189'-0"
26'-0"
75'-0"
20'-0"
35'-3"
42'-0"
GRAPHIC SCALE





RADIATION MONITORS

No.	DESCRIPTION	LOCATION	REC. No.
γE-101-1	FISSION PRODUCTS WATER MONITOR	COOLANT PURIF. LOOP	γR-101
γE-111-1	FISSION PRODUCTS GAS MONITOR	AIR EJECTOR INTERCOOLER	γR-111
γE-108-1	N¹⁶ ACTIVITY MONITOR	CIRC. WATER FROM COND.	γR-108
γE-123-1	N¹⁶ ACTIVITY MONITOR	PURIFICATION COOLER	γR-108
γE-104-1	N¹⁶ ACTIVITY MONITOR	SHUTDOWN COOLER	γR-108
γE-204-1	N¹⁶ ACTIVITY MONITOR	MODERATOR COOLER	γR-108
γE-401-1	ARGON ACTIVITY MONITOR	WASTE GAS STACK	βγR-401
γE-501-1	ARGON ACTIVITY MONITOR	OPER. AREA GAS EXHAUST	βγR-501
βγE-502-1	ARGON ACTIVITY MONITOR	HEADER RM. GAS EXHAUST	βγR-501
βE-401-3	TRITIUM MONITOR	WASTE GAS STACK	βγR-401
βE-402-2	TRITIUM MONITOR	GAS HOLDUP TANKS MANIFOLD	βγR-402
βE-504-1	TRITIUM MONITOR	TURBINE ROOM	βR-504
βE-503-1	TRITIUM MONITOR	PROC. EQUIP. OFF GAS VENT	βγR-501
γE-402-1	EQUIPMENT MONITOR	GAS HOLDUP TANKS MANIFOLD	βγR-402
γE-605-1	EQUIPMENT MONITOR	FUEL STORAGE WELL	γR-605
γE-701-1	EQUIPMENT MONITOR	LIQUID HOLDUP TANK No. 1	γR-701
γE-701-2	EQUIPMENT MONITOR	LIQUID HOLDUP TANK No. 2	γR-701
γE-701-3	EQUIPMENT MONITOR	WASTE TO FILTER	γR-701
γE-701-4	EQUIPMENT MONITOR	WASTE FROM FILTER	γR-701
γE-602-1	AREA MONITOR	REACTOR BLDG	γR-602
γE-602-2	AREA MONITOR	REACTOR BLDG	γR-602
γE-602-3	AREA MONITOR	REACTOR BLDG	γR-602
γE-602-4	AREA MONITOR	REACTOR BLDG.	γR-602
γE-602-5	AREA MONITOR	REACTOR BLDG.	γR-602
γE-602-6	AREA MONITOR	REACTOR BLDG.	γR-602
γE-602-7	AREA MONITOR	REACTOR BLDG.	γR-602
γE-602-8	AREA MONITOR	REACTOR BLDG.	γR-602
γE-602-9	AREA MONITOR	REACTOR BLDG.	γR-602
γE-602-10	AREA MONITOR	REACTOR BLDG.	γR-602
γE-602-11	AREA MONITOR	TURBINE AREA	γR-602
γE-602-12	AREA MONITOR	TURBINE AREA	γR-602
γE-602-13	AREA MONITOR	TURBINE AREA	γR-602
γE-602-14	AREA MONITOR	CONTROL ROOM	γR-602
γE-602-15	AREA MONITOR	FUEL HANDLING BLDG	γR-602
γE-602-16	AREA MONITOR	FUEL HANDLING BLDG	γR-602
γE-602-17	AREA MONITOR	DISTILLATION COLUMN BLDG.	γR-602
βγE-602-18	AREA MONITOR	WASTE DISPOSAL	γR-602
βγE-602-19	AREA MONITOR	FAN HOUSE	γR-602
βγE-603-1 THRU βγE-603-12	HAND & SHOE MONITOR	REACTOR BLDG	
βγE-604-1 THRU βγE-604-12	HAND & SHOE MONITOR	FUEL STORAGE BLDG.	
βγE-401-2	AIR PARTICULATE MONITOR	WASTE GAS STACK	βγR-401
βγE-501-2	AIR PARTICULATE MONITOR	OPER. AREA GAS EXHAUST	βγR-501
βγE-601-1	AIR PARTICULATE MONITOR	FUEL HANDLING BLDG.	βγR-601

70 MW$_e$ BOILING D_2O
PRESSURE TUBE
DIRECT CYCLE PROTOTYPE

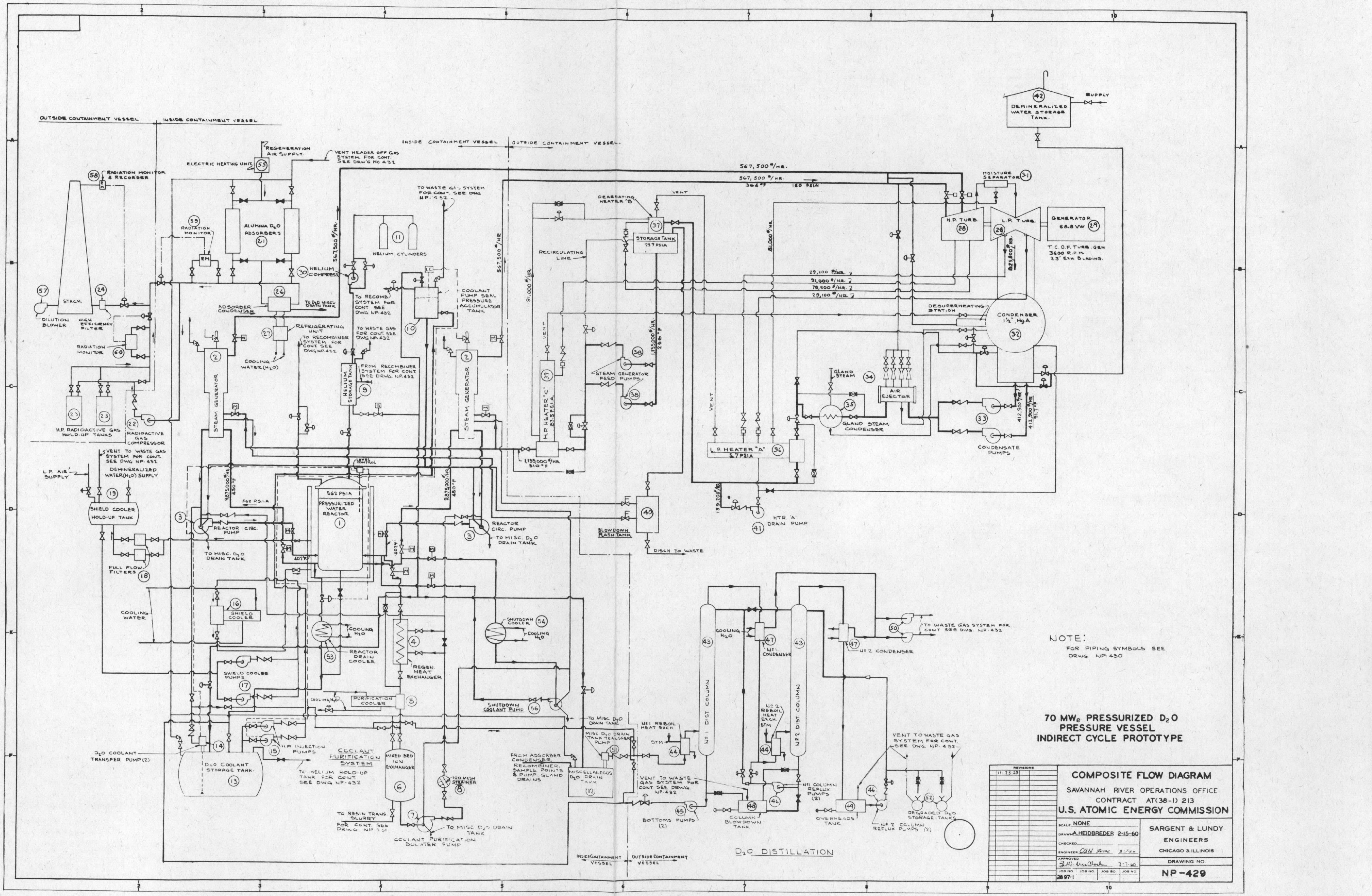
REVISIONS

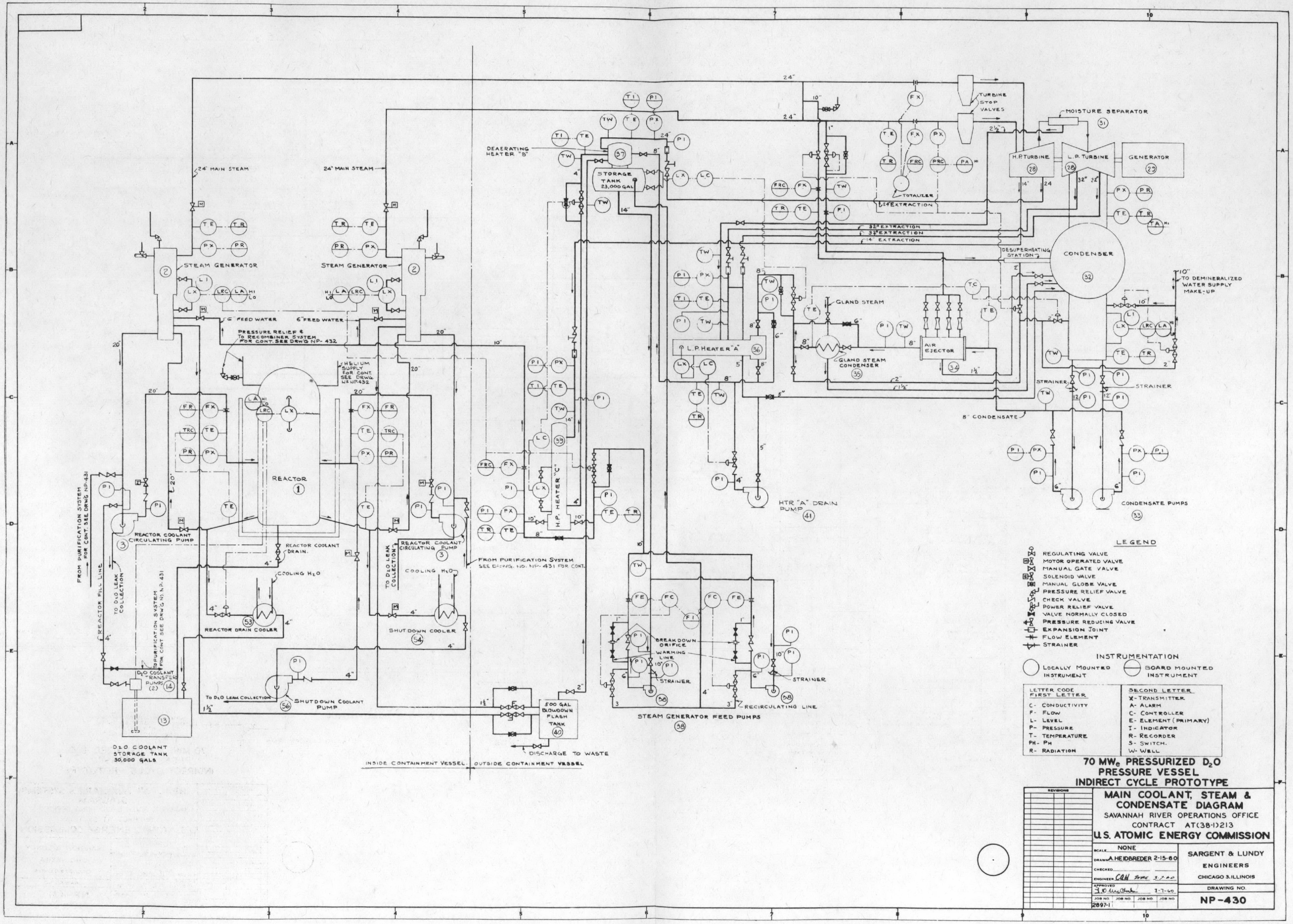
NUCLEAR INSTRUMENTATION
BLOCK DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION

SCALE NONE
DRAWN N.A. 2-15-60
CHECKED
ENGINEER [signature] 3-7-60
APPROVED J. W. [signature] 3-7-60
JOB NO. 2697-1 | JOB NO. | JOB NO. | JOB NO.

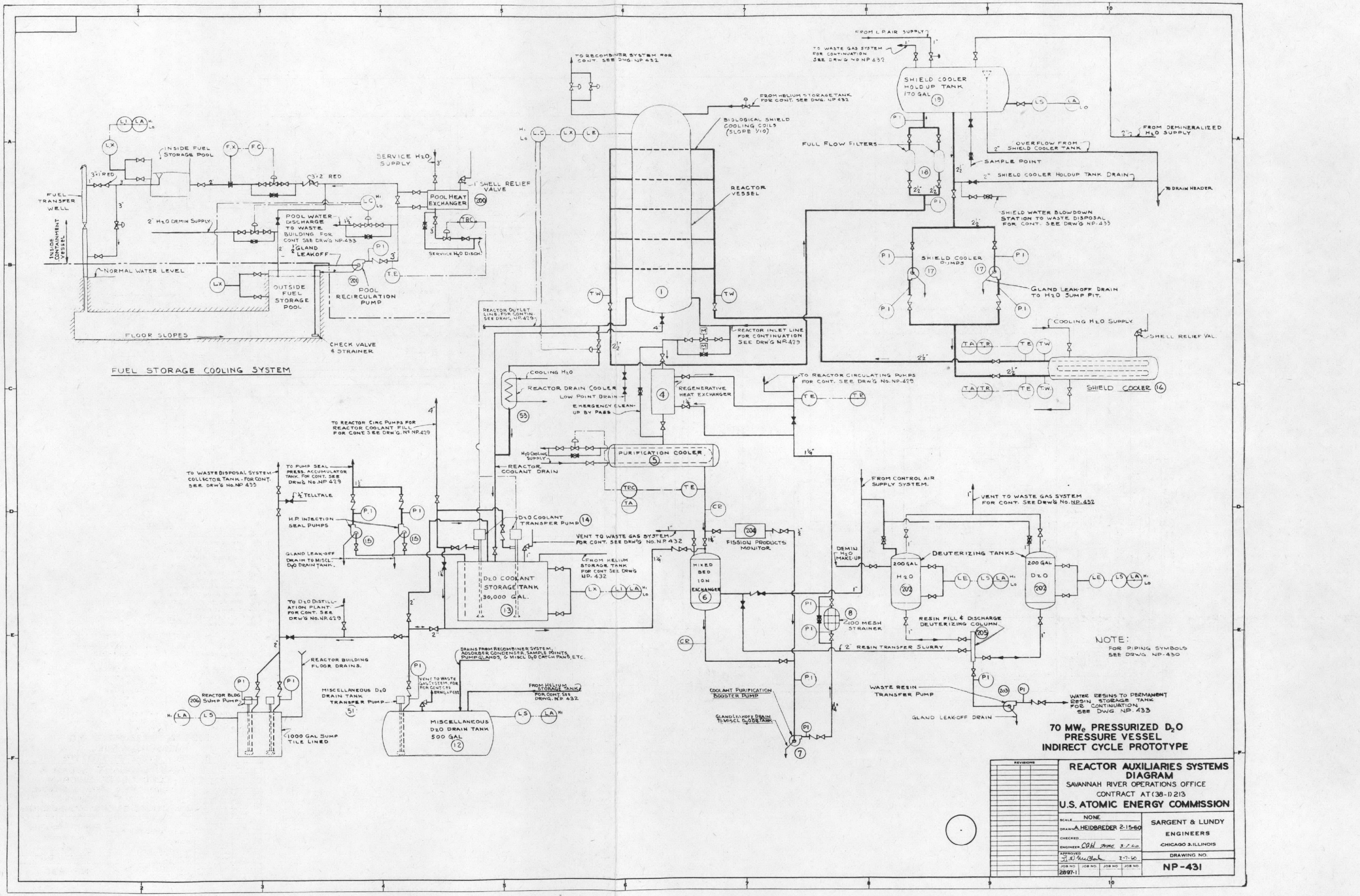
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

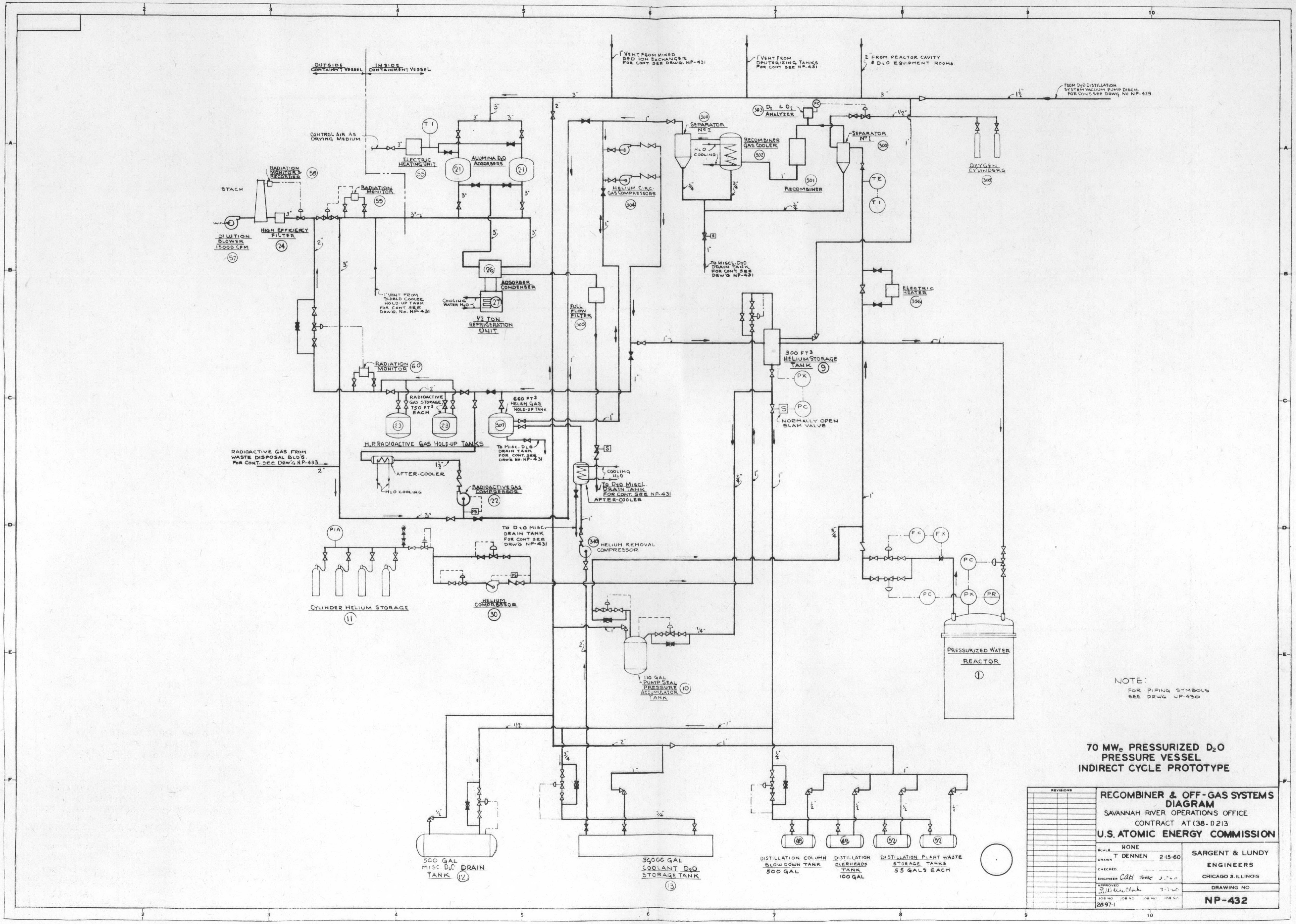
DRAWING NO.
NP-495

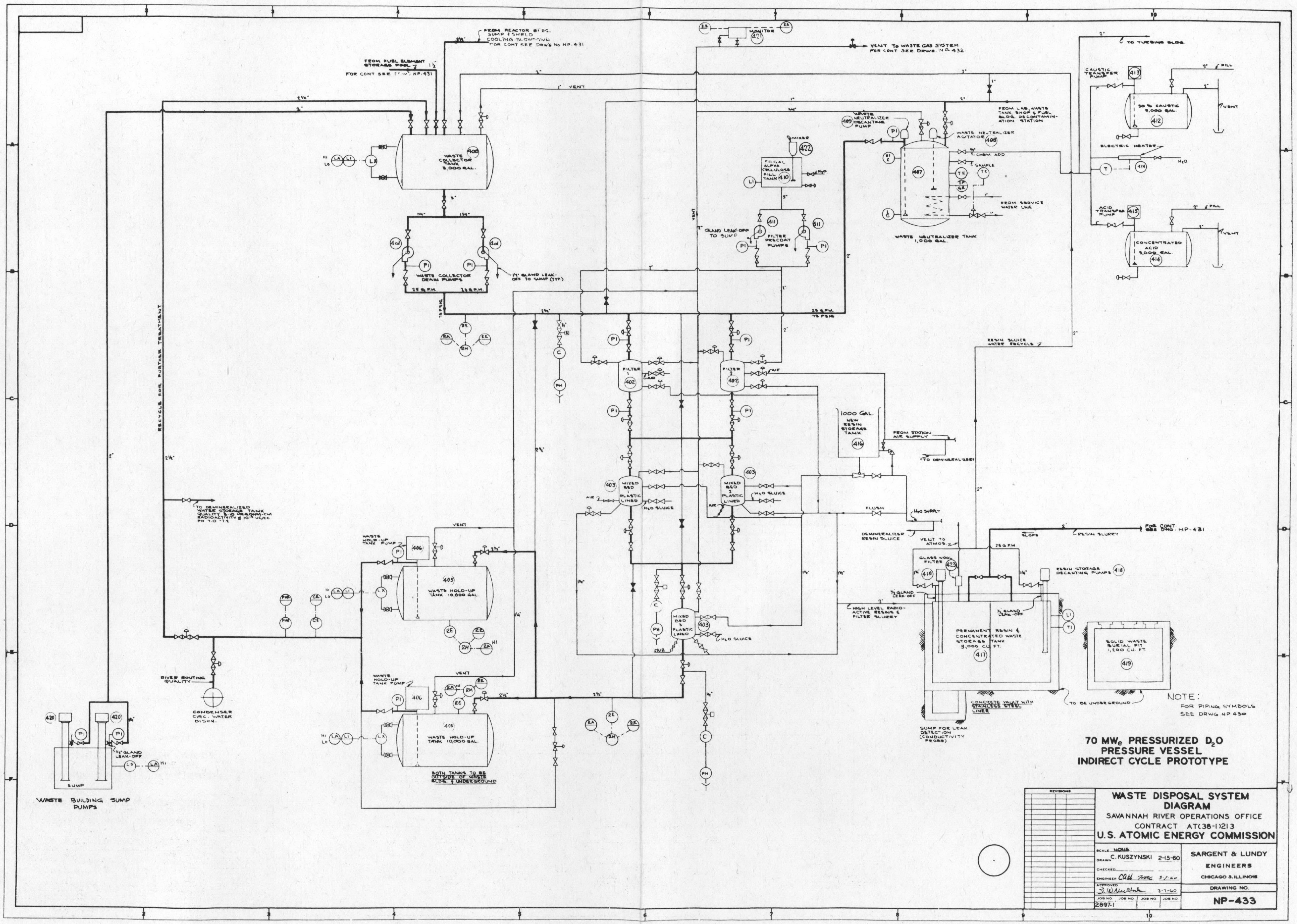

COMPOSITE FLOW DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-429
SCALE NONE
DRAWN A. HEIDBREDER 2-15-60
70 MWe PRESSURIZED D2O
PRESSURE VESSEL
INDIRECT CYCLE PROTOTYPE
NOTE:
FOR PIPING SYMBOLS SEE
DRWG NP-430
OUTSIDE CONTAINMENT VESSEL
INSIDE CONTAINMENT VESSEL
PRESSURIZED WATER REACTOR
562 PSIA
STEAM GENERATOR
REACTOR CIRC. PUMP
ALUMINA D2O ADSORBERS
HELIUM CYLINDERS
HELIUM COMPRESSOR
ADSORBER CONDENSER
REFRIGERATING UNIT
HELIUM STORAGE TANK
COOLANT PUMP SEAL PRESSURE ACCUMULATOR TANK
STACK
DILUTION BLOWER
HIGH EFFICIENCY FILTER
RADIATION MONITOR
RADIATION MONITOR & RECORDER
ELECTRIC HEATING UNIT
REGENERATION AIR SUPPLY
H.P. RADIOACTIVE GAS HOLD-UP TANKS
RADIOACTIVE GAS COMPRESSOR
SHIELD COOLER HOLD-UP TANK
FULL FLOW FILTERS
SHIELD COOLER
SHIELD COOLER PUMPS
REACTOR DRAIN COOLER
REGEN HEAT EXCHANGER
SHUTDOWN COOLER
SHUTDOWN COOLANT PUMP
PURIFICATION COOLER
COOLANT PURIFICATION SYSTEM
MIXED BED ION EXCHANGER
100 MESH STRAINER
COOLANT PURIFICATION BOOSTER PUMP
D2O COOLANT STORAGE TANK
D2O COOLANT TRANSFER PUMP (2)
H.P. INJECTION PUMPS
MISCELLANEOUS D2O DRAIN TANK
BLOWDOWN FLASH TANK
DISCH TO WASTE
HTR "A" DRAIN PUMP
L.P. HEATER "A" 5.7 PSIA
H.P. HEATER "C"
STEAM GENERATOR FEED PUMPS
DEAERATING HEATER "B"
STORAGE TANK 137 PSIA
RECIRCULATING LINE
H.P. TURB.
L.P. TURB.
GENERATOR 68.8 MW
T.C.D.F. TURB.-GEN
3600 R.P.M.
23" EXH BLADING
MOISTURE SEPARATOR
DEMINERALIZED WATER STORAGE TANK
SUPPLY
CONDENSER 1½" Hg A
DESUPERHEATING STATION
GLAND STEAM
AIR EJECTOR
GLAND STEAM CONDENSER
CONDENSATE PUMPS
567,500 #/HR.
180 PSIA
NO. 1 DIST. COLUMN
NO. 2 DIST. COLUMN
NO. 1 CONDENSER
NO. 2 CONDENSER
NO. 1 REBOIL HEAT EXCH.
NO. 2 REBOIL HEAT EXCH.
BOTTOMS PUMPS (2)
COLUMN BLOWDOWN TANK
NO. 1 COLUMN REFLUX PUMPS (2)
OVERHEADS TANK
NO. 2 COLUMN REFLUX PUMPS (2)
DEGRADED D2O STORAGE TANKS
D2O DISTILLATION
VENT TO WASTE GAS SYSTEM FOR CONT. SEE DWG NP-432
INSIDE CONTAINMENT VESSEL
OUTSIDE CONTAINMENT VESSEL



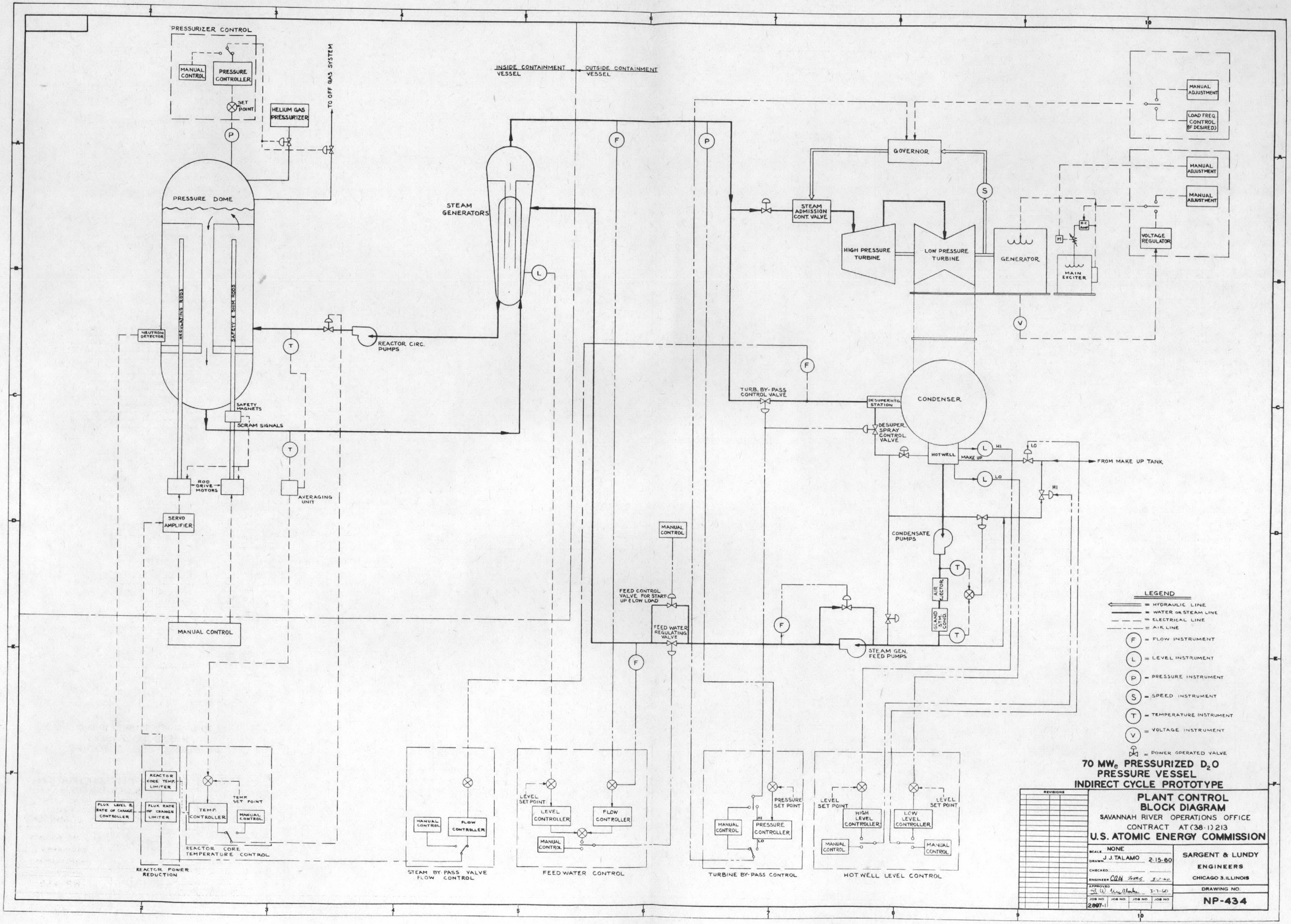
STEAM GENERATOR
REACTOR
REACTOR COOLANT CIRCULATING PUMP
REACTOR DRAIN COOLER
SHUTDOWN COOLER
SHUTDOWN COOLANT PUMP
D2O COOLANT STORAGE TANK 30,000 GALS
500 GAL BLOWDOWN FLASH TANK
DISCHARGE TO WASTE
INSIDE CONTAINMENT VESSEL | OUTSIDE CONTAINMENT VESSEL
DEAERATING HEATER "B"
STORAGE TANK 23,000 GAL
H.P. HEATER "C"
L.P. HEATER "A"
GLAND STEAM CONDENSER
AIR EJECTOR
HTR "A" DRAIN PUMP
STEAM GENERATOR FEED PUMPS
TURBINE STOP VALVES
MOISTURE SEPARATOR
H.P. TURBINE
L.P. TURBINE
GENERATOR
CONDENSER
DESUPERHEATING STATION
TO DEMINERALIZED WATER SUPPLY MAKE-UP
CONDENSATE PUMPS
LEGEND
REGULATING VALVE
MOTOR OPERATED VALVE
MANUAL GATE VALVE
SOLENOID VALVE
MANUAL GLOBE VALVE
PRESSURE RELIEF VALVE
CHECK VALVE
POWER RELIEF VALVE
VALVE NORMALLY CLOSED
PRESSURE REDUCING VALVE
EXPANSION JOINT
FLOW ELEMENT
STRAINER
INSTRUMENTATION
LOCALLY MOUNTED INSTRUMENT
BOARD MOUNTED INSTRUMENT
LETTER CODE FIRST LETTER
C- CONDUCTIVITY
F- FLOW
L- LEVEL
P- PRESSURE
T- TEMPERATURE
PH- PH
R- RADIATION
SECOND LETTER
X- TRANSMITTER
A- ALARM
C- CONTROLLER
E- ELEMENT (PRIMARY)
I- INDICATOR
R- RECORDER
S- SWITCH.
W- WELL
70 MWe PRESSURIZED D2O
PRESSURE VESSEL
INDIRECT CYCLE PROTOTYPE
MAIN COOLANT, STEAM & CONDENSATE DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1)213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN A.HEIDBREDER 2-15-60
SARGENT & LUNDY ENGINEERS
CHICAGO 3.ILLINOIS
DRAWING NO.
NP-430

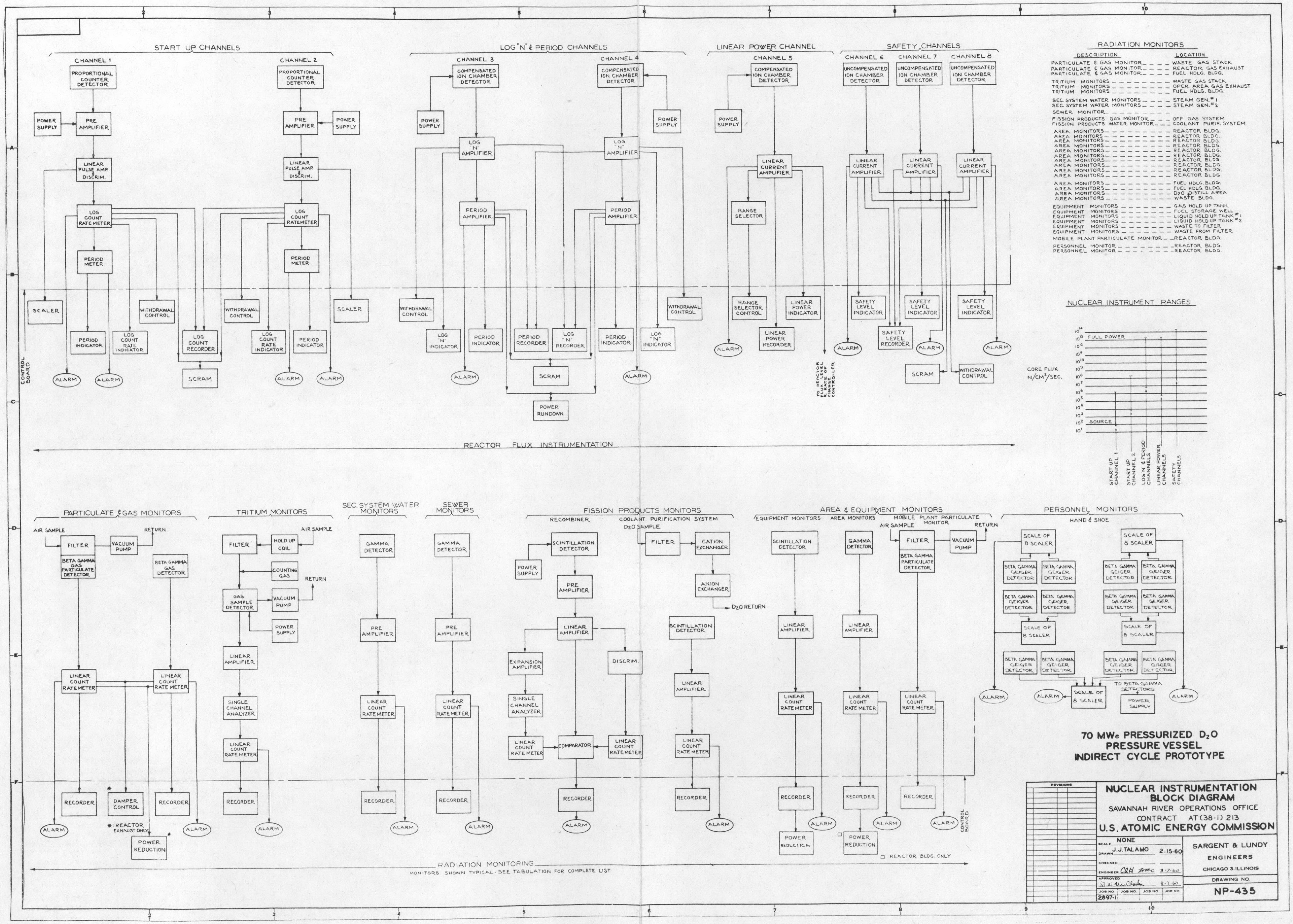

FUEL STORAGE COOLING SYSTEM
FUEL TRANSFER WELL
INSIDE CONTAINMENT VESSEL
INSIDE FUEL STORAGE POOL
NORMAL WATER LEVEL
OUTSIDE FUEL STORAGE POOL
FLOOR SLOPES
CHECK VALVE & STRAINER
POOL RECIRCULATION PUMP
POOL WATER DISCHARGE TO WASTE BUILDING FOR CONT SEE DRW'G NP-433
GLAND LEAKOFF
2" H2O DEMIN SUPPLY
SERVICE H2O SUPPLY
POOL HEAT EXCHANGER
SHELL RELIEF VALVE
SERVICE H2O DISCH.
TO RECOMBINER SYSTEM FOR CONT. SEE DWG. NP 432
FROM HELIUM STORAGE TANK FOR CONT. SEE DWG. NP 432
BIOLOGICAL SHIELD COOLING COILS (SLOPE 1/10)
REACTOR VESSEL
REACTOR OUTLET LINE. FOR CONTIN. SEE DRW'G. NP-429
REACTOR INLET LINE FOR CONTINUATION SEE DRW'G NP-429
REACTOR DRAIN COOLER
COOLING H2O
LOW POINT DRAIN
EMERGENCY CLEAN-UP BY PASS
REGENERATIVE HEAT EXCHANGER
TO REACTOR CIRCULATING PUMPS FOR CONT. SEE DRW'G No. NP-429
PURIFICATION COOLER
H2O COOLING SUPPLY
REACTOR COOLANT DRAIN
TO REACTOR CIRC PUMPS FOR REACTOR COOLANT FILL FOR CONT SEE DRW'G. No NP-429
TO WASTE DISPOSAL SYSTEM COLLECTOR TANK - FOR CONT. SEE DRW'G No. NP 433
TO PUMP SEAL PRESS. ACCUMULATOR TANK. FOR CONT. SEE DRW'G No. NP 429
1/2" TELLTALE
H.P. INJECTION SEAL PUMPS
GLAND LEAK-OFF DRAIN TO MISCL. D2O DRAIN TANK.
TO D2O DISTILLATION PLANT. FOR CONT. SEE DRW'G No. NP-429
D2O COOLANT TRANSFER PUMP
VENT TO WASTE GAS SYSTEM FOR CONT. SEE DRW'G No. N.P. 432
FROM HELIUM STORAGE TANK FOR CONT SEE DRW'G NP. 432
D2O COOLANT STORAGE TANK 30,000 GAL.
FISSION PRODUCTS MONITOR
MIXED BED ION EXCHANGER
100 MESH STRAINER
COOLANT PURIFICATION BOOSTER PUMP
GLAND LEAKOFF DRAIN TO MISCL D2O DR. TANK
REACTOR BUILDING FLOOR DRAINS.
REACTOR BLDG SUMP PUMP
1000 GAL SUMP TILE LINED
MISCELLANEOUS D2O DRAIN TANK TRANSFER PUMP
VENT TO WASTE GAS SYSTEM FOR CONT. SEE DRW'G NP 432
DRAINS FROM RECOMBINER SYSTEM, ADSORBER CONDENSER, SAMPLE POINTS, PUMP GLANDS, & MISCL D2O CATCH PANS, ETC.
FROM HELIUM STORAGE TANKS FOR CONT. SEE DRW'G. NP 432
MISCELLANEOUS D2O DRAIN TANK 500 GAL
FROM L.P. AIR SUPPLY
TO WASTE GAS SYSTEM FOR CONTINUATION SEE DRW'G No NP 432
SHIELD COOLER HOLD UP TANK 170 GAL
FROM DEMINERALIZED H2O SUPPLY
FULL FLOW FILTERS
OVERFLOW FROM SHIELD COOLER TANK
SAMPLE POINT
SHIELD COOLER HOLDUP TANK DRAIN
TO DRAIN HEADER
SHIELD WATER BLOWDOWN STATION TO WASTE DISPOSAL FOR CONT. SEE DRW'G NP-433
SHIELD COOLER PUMPS
GLAND LEAK-OFF DRAIN TO H2O SUMP PIT.
COOLING H2O SUPPLY
SHELL RELIEF VAL.
SHIELD COOLER
FROM CONTROL AIR SUPPLY SYSTEM.
VENT TO WASTE GAS SYSTEM FOR CONT. SEE DRW'G No. NP 432
DEMIN H2O MAKE-UP
DEUTERIZING TANKS
200 GAL H2O
200 GAL D2O
RESIN FILL & DISCHARGE DEUTERIZING COLUMN
2" RESIN TRANSFER SLURRY
WASTE RESIN TRANSFER PUMP
GLAND LEAK-OFF DRAIN
WATER RESINS TO PERMANENT RESIN STORAGE TANK FOR CONTINUATION SEE DWG NP 433
NOTE: FOR PIPING SYMBOLS SEE DRWG NP-430
70 MWe PRESSURIZED D2O PRESSURE VESSEL INDIRECT CYCLE PROTOTYPE
REVISIONS
REACTOR AUXILIARIES SYSTEMS DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1)213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN A. HEIDBREDER 2-15-60
CHECKED
ENGINEER
APPROVED
SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWING NO. NP-431
JOB NO. 2897-1


70 MWe PRESSURIZED D_2O
PRESSURE VESSEL
INDIRECT CYCLE PROTOTYPE
RECOMBINER & OFF-GAS SYSTEMS DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1)213
U.S. ATOMIC ENERGY COMMISSION
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO
NP-432
SCALE NONE
DRAWN T DENNEN 2-15-60
2897-1
NOTE: FOR PIPING SYMBOLS SEE DRWG NP-430
OUTSIDE CONTAINMENT VESSEL
INSIDE CONTAINMENT VESSEL
STACK
DILUTION BLOWER 15000 CFM
HIGH EFFICIENCY FILTER
RADIATION MONITOR
CONTROL AIR AS DRYING MEDIUM
ELECTRIC HEATING UNIT
ALUMINA D_2O ADSORBERS
ADSORBER CONDENSER
1/2 TON REFRIGERATION UNIT
RADIOACTIVE GAS STORAGE 750 FT3 EACH
660 FT3 HELIUM GAS HOLD-UP TANK
H.P. RADIOACTIVE GAS HOLD-UP TANKS
RADIOACTIVE GAS FROM WASTE DISPOSAL BLD'G. FOR CONT. SEE DRW'G NP-433
AFTER-COOLER
H_2O COOLING
RADIOACTIVE GAS COMPRESSOR
CYLINDER HELIUM STORAGE
HELIUM COMPRESSOR
HELIUM CIRC GAS COMPRESSORS
FULL FLOW FILTER
HELIUM REMOVAL COMPRESSOR
110 GAL PUMP SEAL PRESSURE ACCUMULATOR TANK
SEPARATOR No 2
SEPARATOR No 1
RECOMBINER GAS COOLER
RECOMBINER
D_2 & O_2 ANALYZER
OXYGEN CYLINDERS
ELECTRIC HEATER
300 FT3 HELIUM STORAGE TANK
NORMALLY OPEN SLAM VALVE
PRESSURIZED WATER REACTOR
1" VENT FROM MIXED BED ION EXCHANGER FOR CONT SEE DRWG. NP-431
1" VENT FROM DEUTERIZING TANKS FOR CONT SEE NP-431
2" FROM REACTOR CAVITY & D_2O EQUIPMENT ROOMS
FROM D_2O DISTILLATION SYSTEM VACUUM PUMP DISCH. FOR CONT. SEE DRWG. No NP-429
500 GAL MISC D_2O DRAIN TANK
30,000 GAL COOLANT D_2O STORAGE TANK
DISTILLATION COLUMN BLOW DOWN TANK 500 GAL
DISTILLATION OVERHEADS TANK 100 GAL
DISTILLATION PLANT WASTE STORAGE TANKS 55 GALS EACH

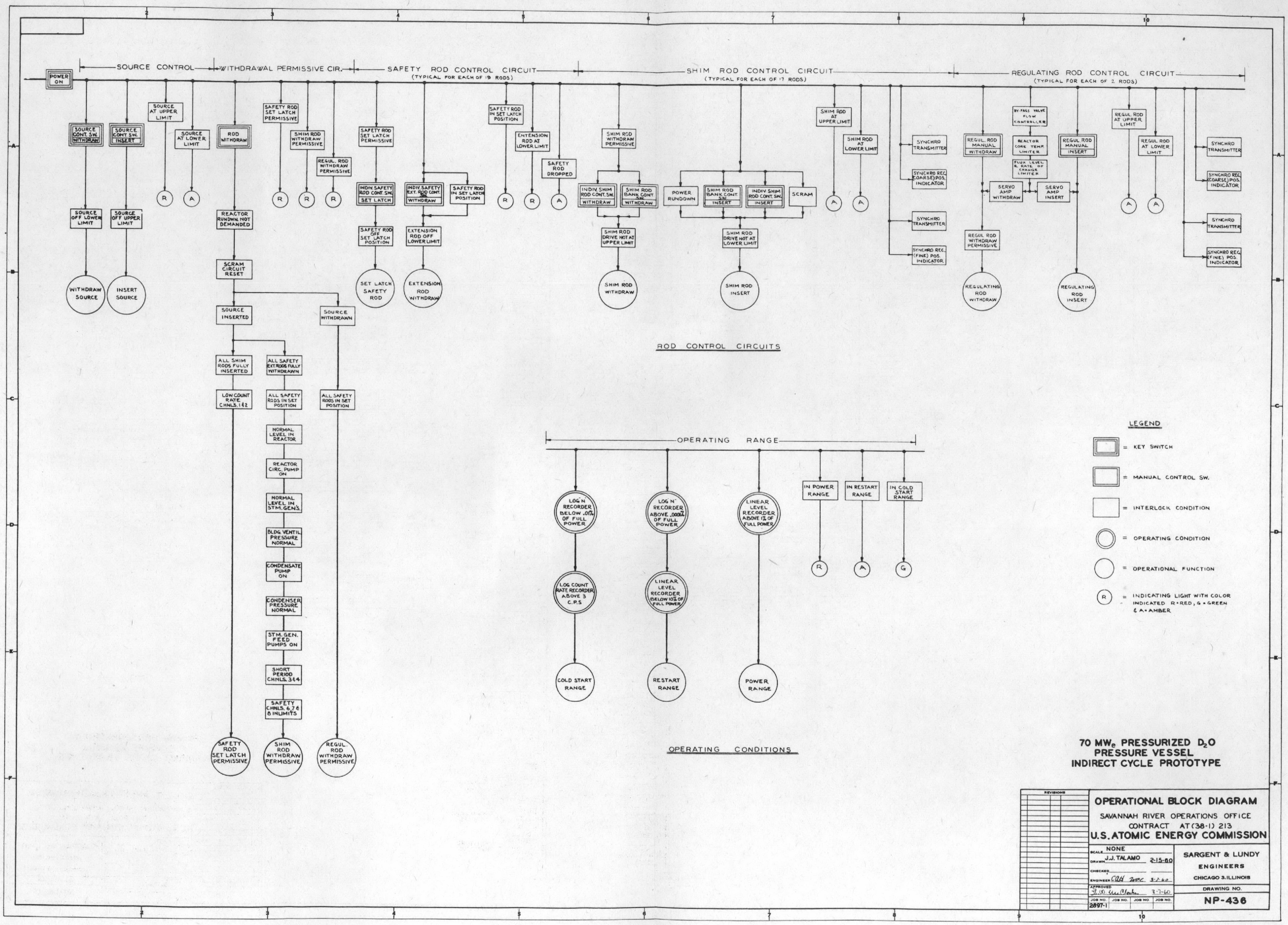


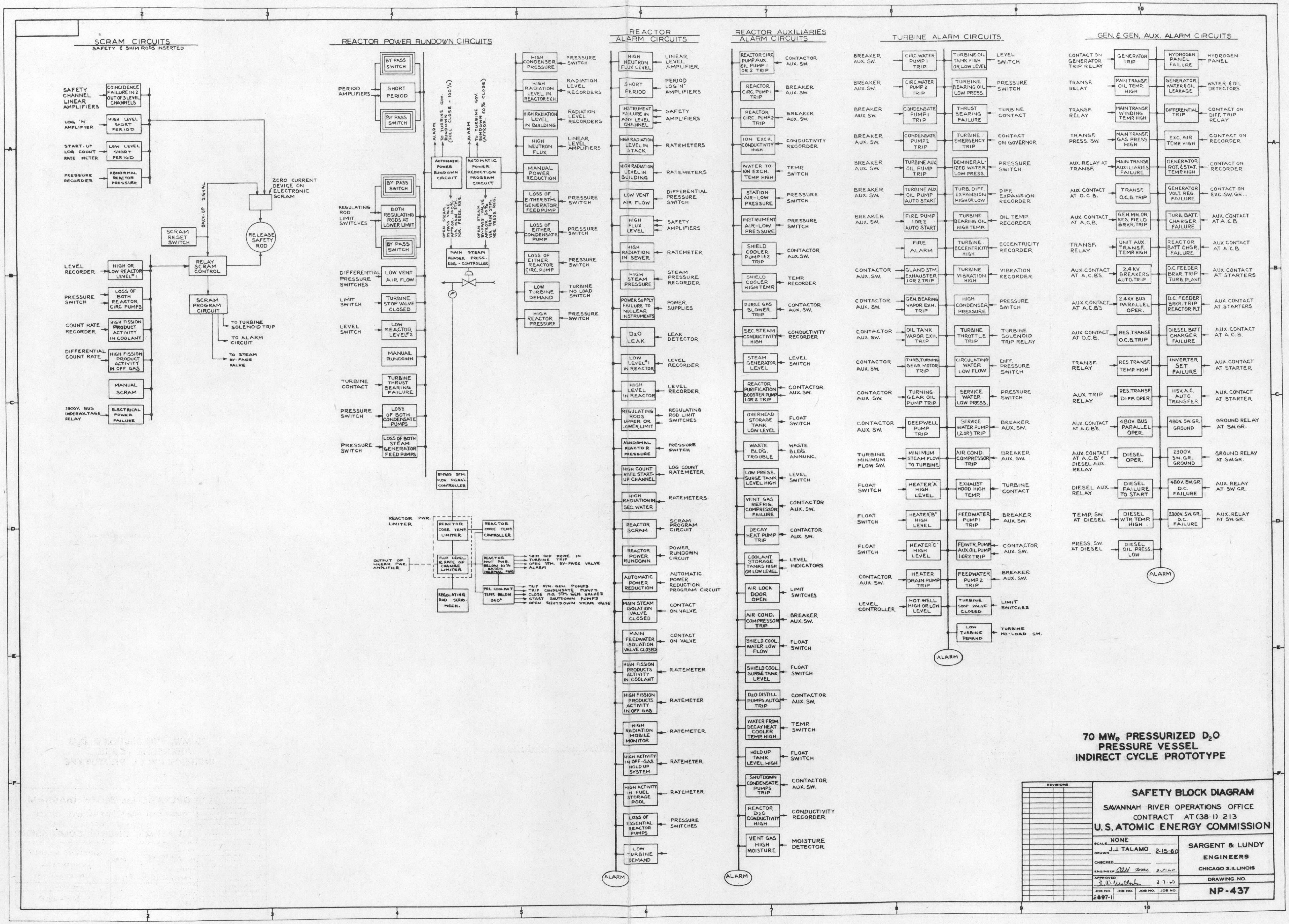
WASTE COLLECTOR TANK 3,000 GAL.
WASTE COLLECTOR DRAIN PUMPS
WASTE NEUTRALIZE TANK 1,000 GAL.
FILTER PRECOAT PUMPS
WASTE HOLD-UP TANK 10,000 GAL.
WASTE BUILDING SUMP PUMPS
CONDENSER CIRC. WATER DISCH.
RECYCLE FOR FURTHER TREATMENT
1000 GAL. NEW RESIN STORAGE TANK
PERMANENT RESIN & CONCENTRATED WASTE STORAGE TANK 3,000 CU. FT.
SOLID WASTE BURIAL PIT 1,200 CU. FT.
BOTH TANKS TO BE OUTSIDE OF WASTE BLDG. & UNDERGROUND
NOTE: FOR PIPING SYMBOLS SEE DRWG NP-430
70 MWe PRESSURIZED D2O PRESSURE VESSEL INDIRECT CYCLE PROTOTYPE
WASTE DISPOSAL SYSTEM DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1)213
U.S. ATOMIC ENERGY COMMISSION
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
SCALE NONE
DRAWN C. KUSZYNSKI 2-15-60
DRAWING NO.
NP-433
2897-1

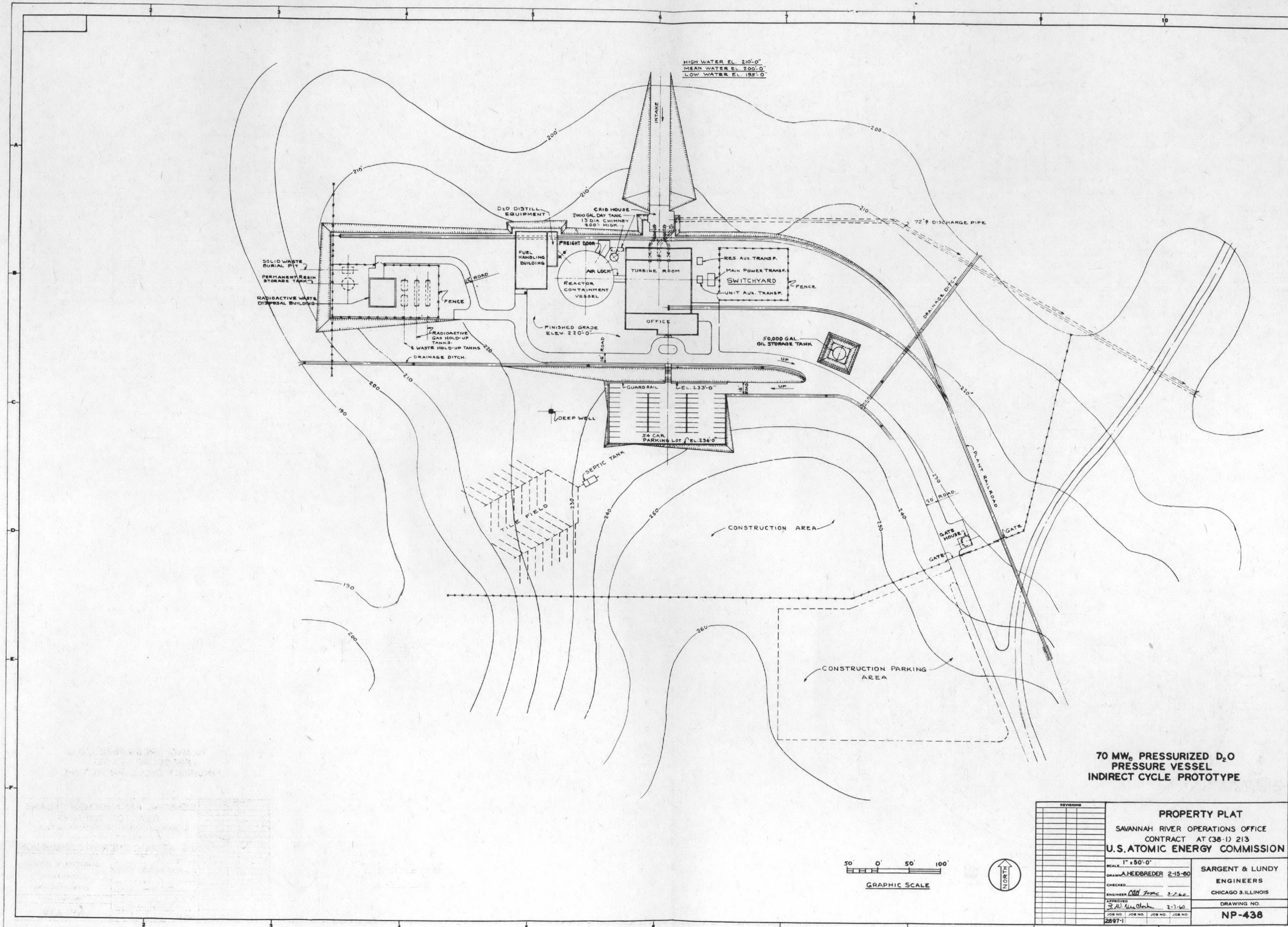

PRESSURIZER CONTROL
MANUAL CONTROL
PRESSURE CONTROLLER
SET POINT
HELIUM GAS PRESSURIZER
TO OFF GAS SYSTEM
PRESSURE DOME
NEUTRON DETECTOR
REGULATING RODS
SAFETY & SHIM RODS
SAFETY MAGNETS
SCRAM SIGNALS
ROD DRIVE MOTORS
AVERAGING UNIT
SERVO AMPLIFIER
MANUAL CONTROL
REACTOR CIRC. PUMPS
INSIDE CONTAINMENT VESSEL
OUTSIDE CONTAINMENT VESSEL
STEAM GENERATORS
MANUAL CONTROL
FEED CONTROL VALVE FOR START-UP & LOW LOAD
FEED WATER REGULATING VALVE
STEAM GEN. FEED PUMPS
GOVERNOR
STEAM ADMISSION CONT. VALVE
HIGH PRESSURE TURBINE
LOW PRESSURE TURBINE
GENERATOR
MAIN EXCITER
VOLTAGE REGULATOR
MANUAL ADJUSTMENT
LOAD FREQ. CONTROL (IF DESIRED)
MANUAL ADJUSTMENT
MANUAL ADJUSTMENT
TURB. BY-PASS CONTROL VALVE
DESUPERHTG. STATION
DESUPER. SPRAY CONTROL VALVE
CONDENSER
HOTWELL
MAKE UP
HI
LO
FROM MAKE UP TANK
CONDENSATE PUMPS
AIR EJECTOR
GLAND STM. COND.
FLUX LEVEL & RATE OF CHANGE CONTROLLER
REACTOR CORE TEMP. LIMITER
FLUX RATE OF CHANGE LIMITER
TEMP. CONTROLLER
TEMP. SET POINT
MANUAL CONTROL
REACTOR CORE TEMPERATURE CONTROL
REACTOR POWER REDUCTION
MANUAL CONTROL
FLOW CONTROLLER
STEAM BY-PASS VALVE FLOW CONTROL
LEVEL SET POINT
LEVEL CONTROLLER
FLOW CONTROLLER
MANUAL CONTROL
FEEDWATER CONTROL
MANUAL CONTROL
PRESSURE CONTROLLER
PRESSURE SET POINT
TURBINE BY-PASS CONTROL
LEVEL SET POINT
HIGH LEVEL CONTROLLER
LOW LEVEL CONTROLLER
LEVEL SET POINT
MANUAL CONTROL
MANUAL CONTROL
HOTWELL LEVEL CONTROL
LEGEND
= HYDRAULIC LINE
= WATER OR STEAM LINE
= ELECTRICAL LINE
= AIR LINE
F = FLOW INSTRUMENT
L = LEVEL INSTRUMENT
P = PRESSURE INSTRUMENT
S = SPEED INSTRUMENT
T = TEMPERATURE INSTRUMENT
V = VOLTAGE INSTRUMENT
= POWER OPERATED VALVE
70 MWe PRESSURIZED D2O PRESSURE VESSEL INDIRECT CYCLE PROTOTYPE
REVISIONS
PLANT CONTROL BLOCK DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1)213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN J. J. TALAMO 2-15-60
CHECKED
ENGINEER
APPROVED
JOB NO. 2807-1
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-434

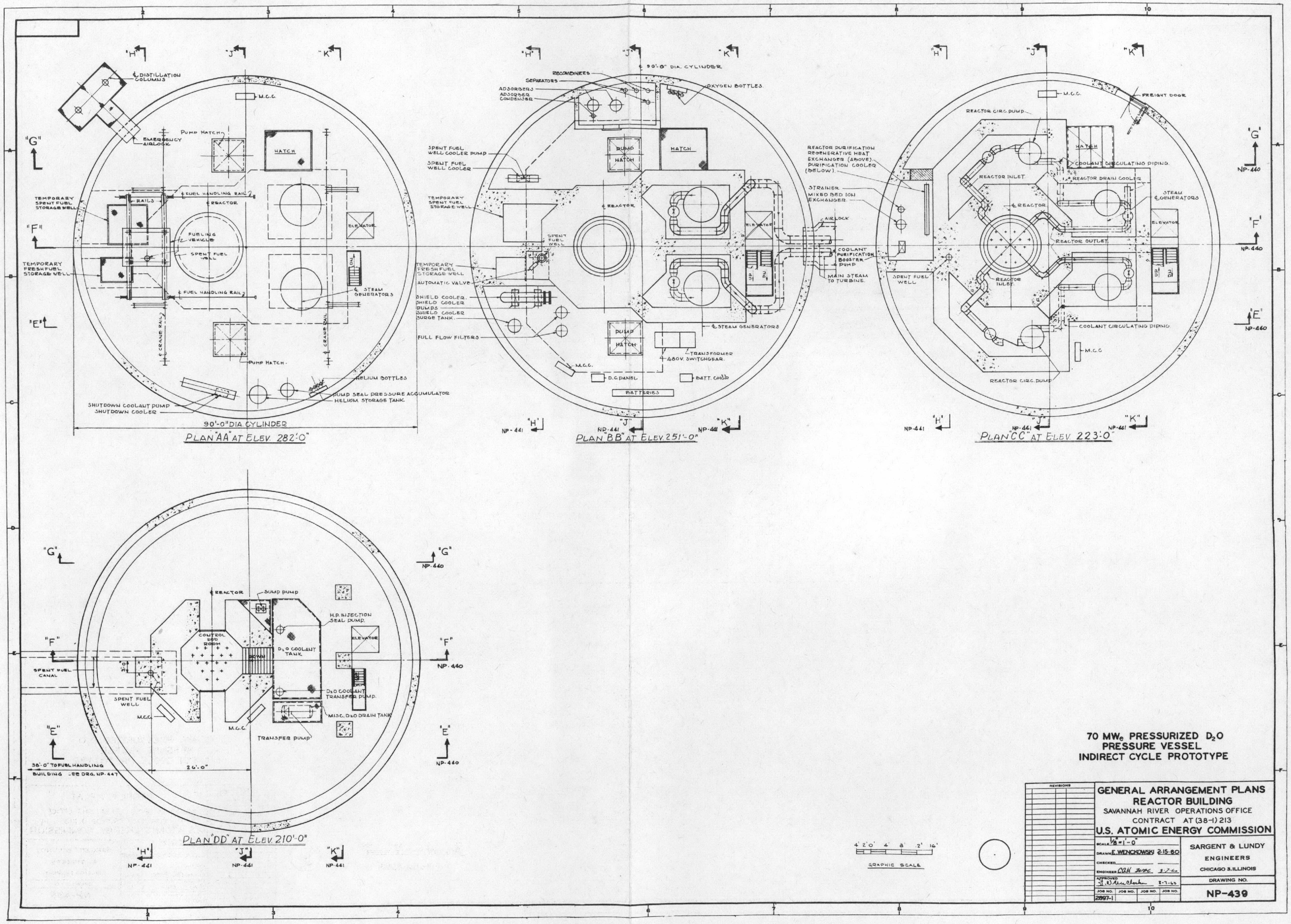


START UP CHANNELS
CHANNEL 1
CHANNEL 2
PROPORTIONAL COUNTER DETECTOR
POWER SUPPLY
PRE AMPLIFIER
LINEAR PULSE AMP. & DISCRIM.
LOG COUNT RATE METER
PERIOD METER
SCALER
WITHDRAWAL CONTROL
PERIOD INDICATOR
LOG COUNT RATE INDICATOR
LOG COUNT RECORDER
SCRAM
ALARM
CONTROL BOARD
LOG "N" & PERIOD CHANNELS
CHANNEL 3
CHANNEL 4
COMPENSATED ION CHAMBER DETECTOR
LOG "N" AMPLIFIER
PERIOD AMPLIFIER
PERIOD RECORDER
LOG "N" RECORDER
LOG "N" INDICATOR
POWER RUNDOWN
LINEAR POWER CHANNEL
CHANNEL 5
LINEAR CURRENT AMPLIFIER
RANGE SELECTOR
RANGE SELECTOR CONTROL
LINEAR POWER INDICATOR
LINEAR POWER RECORDER
TO REACTOR POWER AND RATE OF CHANGE CONTROLLER
SAFETY CHANNELS
CHANNEL 6
CHANNEL 7
CHANNEL 8
UNCOMPENSATED ION CHAMBER DETECTOR
SAFETY LEVEL INDICATOR
SAFETY LEVEL RECORDER
REACTOR FLUX INSTRUMENTATION
RADIATION MONITORS
DESCRIPTION
LOCATION
PARTICULATE & GAS MONITOR — WASTE GAS STACK
PARTICULATE & GAS MONITOR — REACTOR GAS EXHAUST
PARTICULATE & GAS MONITOR — FUEL HDLG. BLDG.
TRITIUM MONITORS — WASTE GAS STACK
TRITIUM MONITORS — OPER AREA GAS EXHAUST
TRITIUM MONITORS — FUEL HDLG. BLDG.
SEC. SYSTEM WATER MONITORS — STEAM GEN. #1
SEC. SYSTEM WATER MONITORS — STEAM GEN. #2
SEWER MONITOR
FISSION PRODUCTS GAS MONITOR — OFF GAS SYSTEM
FISSION PRODUCTS WATER MONITOR — COOLANT PURIF. SYSTEM
AREA MONITORS — REACTOR BLDG.
AREA MONITORS — FUEL HDLG. BLDG.
AREA MONITORS — D2O DISTILL AREA
AREA MONITORS — WASTE BLDG.
EQUIPMENT MONITORS — GAS HOLD UP TANK
EQUIPMENT MONITORS — FUEL STORAGE WELL
EQUIPMENT MONITORS — LIQUID HOLD UP TANK #1
EQUIPMENT MONITORS — LIQUID HOLD UP TANK #2
EQUIPMENT MONITORS — WASTE TO FILTER
EQUIPMENT MONITORS — WASTE FROM FILTER
MOBILE PLANT PARTICULATE MONITOR — REACTOR BLDG.
PERSONNEL MONITOR — REACTOR BLDG.
PERSONNEL MONITOR — REACTOR BLDG.
NUCLEAR INSTRUMENT RANGES
FULL POWER
SOURCE
CORE FLUX N/CM²/SEC.
START UP CHANNEL 1
START UP CHANNEL 2
LOG N & PERIOD CHANNELS
LINEAR POWER CHANNELS
SAFETY CHANNELS
PARTICULATE & GAS MONITORS
AIR SAMPLE
RETURN
FILTER
VACUUM PUMP
BETA GAMMA GAS PARTICULATE DETECTOR
BETA GAMMA GAS DETECTOR
LINEAR COUNT RATE METER
RECORDER
DAMPER CONTROL
*REACTOR EXHAUST ONLY
POWER REDUCTION
TRITIUM MONITORS
HOLD UP COIL
COUNTING GAS
GAS SAMPLE DETECTOR
LINEAR AMPLIFIER
SINGLE CHANNEL ANALYZER
SEC. SYSTEM WATER MONITORS
SEWER MONITORS
GAMMA DETECTOR
FISSION PRODUCTS MONITORS
RECOMBINER
COOLANT PURIFICATION SYSTEM
D2O SAMPLE
SCINTILLATION DETECTOR
CATION EXCHANGER
ANION EXCHANGER
D2O RETURN
EXPANSION AMPLIFIER
DISCRIM.
COMPARATOR
AREA & EQUIPMENT MONITORS
EQUIPMENT MONITORS
AREA MONITORS
MOBILE PLANT PARTICULATE MONITOR
BETA GAMMA PARTICULATE DETECTOR
□ REACTOR BLDG. ONLY
PERSONNEL MONITORS
HAND & SHOE
SCALE OF 8 SCALER
BETA GAMMA GEIGER DETECTOR
TO BETA GAMMA DETECTORS
RADIATION MONITORING
MONITORS SHOWN TYPICAL - SEE TABULATION FOR COMPLETE LIST
70 MWe PRESSURIZED D2O PRESSURE VESSEL INDIRECT CYCLE PROTOTYPE
REVISIONS
NUCLEAR INSTRUMENTATION BLOCK DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN J.J. TALAMO 2-15-60
CHECKED
ENGINEER
APPROVED
JOB NO. 2897-1
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-435

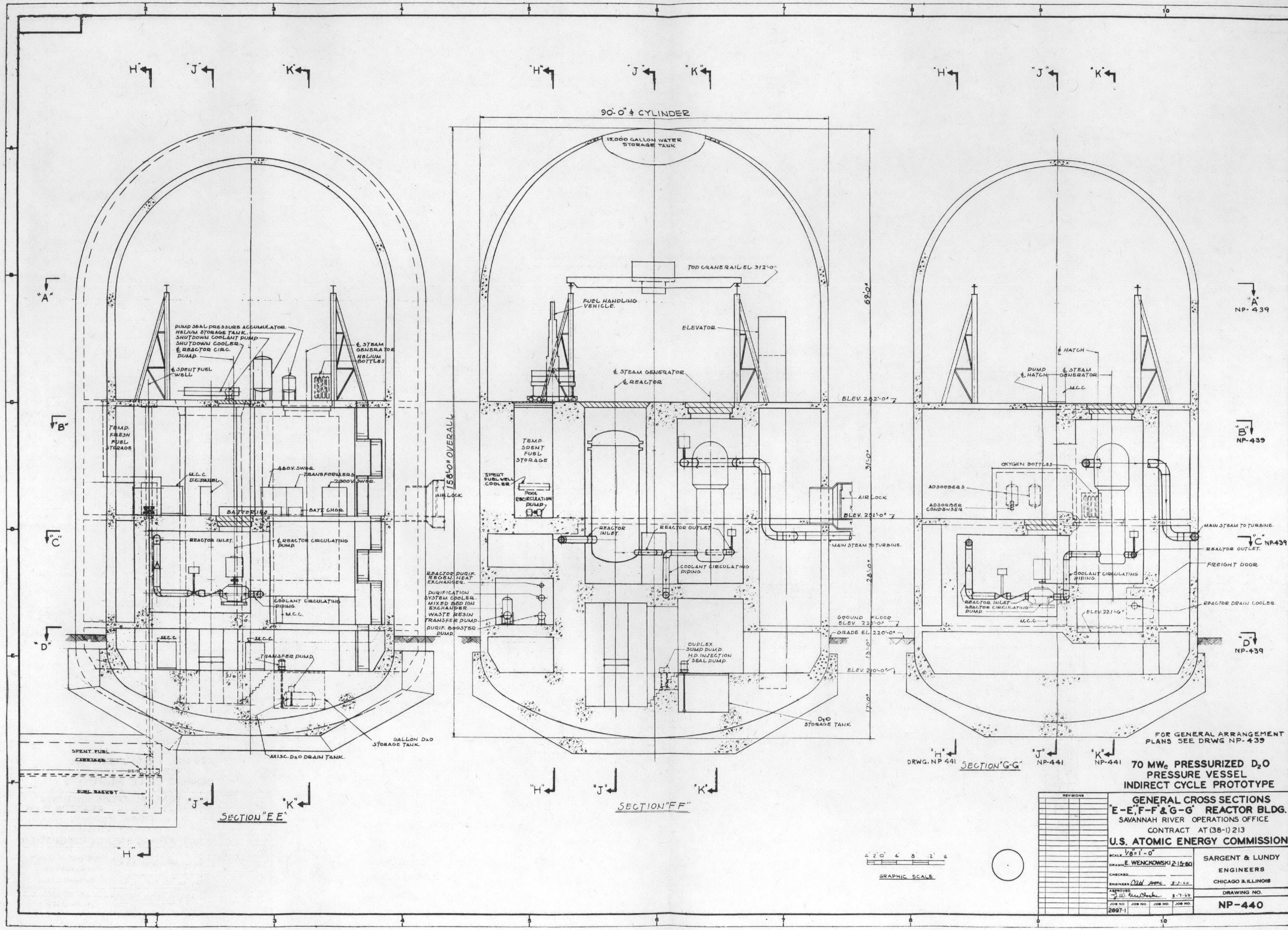

POWER ON
SOURCE CONTROL
WITHDRAWAL PERMISSIVE CIR.
SAFETY ROD CONTROL CIRCUIT
(TYPICAL FOR EACH OF 19 RODS)
SHIM ROD CONTROL CIRCUIT
(TYPICAL FOR EACH OF 17 RODS)
REGULATING ROD CONTROL CIRCUIT
(TYPICAL FOR EACH OF 2 RODS)
SOURCE CONT. SW. WITHDRAW
SOURCE CONT. SW. INSERT
SOURCE AT UPPER LIMIT
SOURCE AT LOWER LIMIT
SOURCE OFF LOWER LIMIT
SOURCE OFF UPPER LIMIT
WITHDRAW SOURCE
INSERT SOURCE
ROD WITHDRAW
REACTOR RUNDWN. NOT DEMANDED
SCRAM CIRCUIT RESET
SOURCE INSERTED
SOURCE WITHDRAWN
ALL SHIM RODS FULLY INSERTED
ALL SAFETY EXT RODS FULLY WITHDRAWN
LOW COUNT RATE CHNLS. 1 & 2
ALL SAFETY RODS IN SET POSITION
ALL SAFETY RODS IN SET POSITION
NORMAL LEVEL IN REACTOR
REACTOR CIRC. PUMP ON
NORMAL LEVEL IN STM. GEN'S.
BLDG VENTIL PRESSURE NORMAL
CONDENSATE PUMP ON
CONDENSER PRESSURE NORMAL
STM. GEN. FEED PUMPS ON
SHORT PERIOD CHNLS. 3 & 4
SAFETY CHNLS. 6, 7 & 8 IN LIMITS
SAFETY ROD SET LATCH PERMISSIVE
SHIM ROD WITHDRAW PERMISSIVE
REGUL. ROD WITHDRAW PERMISSIVE
SAFETY ROD SET LATCH PERMISSIVE
SHIM ROD WITHDRAW PERMISSIVE
REGUL. ROD WITHDRAW PERMISSIVE
SAFETY ROD SET LATCH PERMISSIVE
INDIV. SAFETY ROD CONT. SW. SET LATCH
INDIV. SAFETY EXT. ROD CONT. SW. WITHDRAW
SAFETY ROD IN SET LATCH POSITION
SAFETY ROD OFF SET LATCH POSITION
EXTENSION ROD OFF LOWER LIMIT
SET LATCH SAFETY ROD
EXTENSION ROD WITHDRAW
SAFETY ROD IN SET LATCH POSITION
EXTENSION ROD AT LOWER LIMIT
SAFETY ROD DROPPED
SHIM ROD WITHDRAW PERMISSIVE
INDIV. SHIM ROD CONT. SW. WITHDRAW
SHIM ROD BANK CONT. SW. WITHDRAW
SHIM ROD DRIVE NOT AT UPPER LIMIT
SHIM ROD WITHDRAW
POWER RUNDOWN
SHIM ROD BANK CONT. SW. INSERT
INDIV. SHIM ROD CONT. SW. INSERT
SCRAM
SHIM ROD DRIVE NOT AT LOWER LIMIT
SHIM ROD INSERT
SHIM ROD AT UPPER LIMIT
SHIM ROD AT LOWER LIMIT
SYNCHRO TRANSMITTER
SYNCHRO REC. (COARSE) POS. INDICATOR
SYNCHRO TRANSMITTER
SYNCHRO REC. (FINE) POS. INDICATOR
REGUL. ROD MANUAL WITHDRAW
BY-PASS VALVE FLOW CONTROLLER
REACTOR CORE TEMP. LIMITER
FLUX LEVEL & RATE OF CHANGE LIMITER
REGUL. ROD MANUAL INSERT
SERVO AMP WITHDRAW
SERVO AMP INSERT
REGUL. ROD WITHDRAW PERMISSIVE
REGULATING ROD WITHDRAW
REGULATING ROD INSERT
REGUL. ROD AT UPPER LIMIT
REGUL. ROD AT LOWER LIMIT
SYNCHRO TRANSMITTER
SYNCHRO REC. (COARSE) POS. INDICATOR
SYNCHRO TRANSMITTER
SYNCHRO REC. (FINE) POS. INDICATOR
R
A
ROD CONTROL CIRCUITS
OPERATING RANGE
LOG N RECORDER BELOW .01% OF FULL POWER
LOG N RECORDER ABOVE .0001% OF FULL POWER
LINEAR LEVEL RECORDER ABOVE 1% OF FULL POWER
LOG COUNT RATE RECORDER ABOVE 3 C.P.S.
LINEAR LEVEL RECORDER BELOW 10% OF FULL POWER
COLD START RANGE
RESTART RANGE
POWER RANGE
IN POWER RANGE
IN RESTART RANGE
IN COLD START RANGE
G
OPERATING CONDITIONS
LEGEND
= KEY SWITCH
= MANUAL CONTROL SW.
= INTERLOCK CONDITION
= OPERATING CONDITION
= OPERATIONAL FUNCTION
= INDICATING LIGHT WITH COLOR INDICATED R = RED, G = GREEN & A = AMBER
70 MWe PRESSURIZED D2O PRESSURE VESSEL INDIRECT CYCLE PROTOTYPE
REVISIONS
OPERATIONAL BLOCK DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN J.J. TALAMO 2-15-60
CHECKED
ENGINEER
APPROVED
JOB NO. 2897-1
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-436

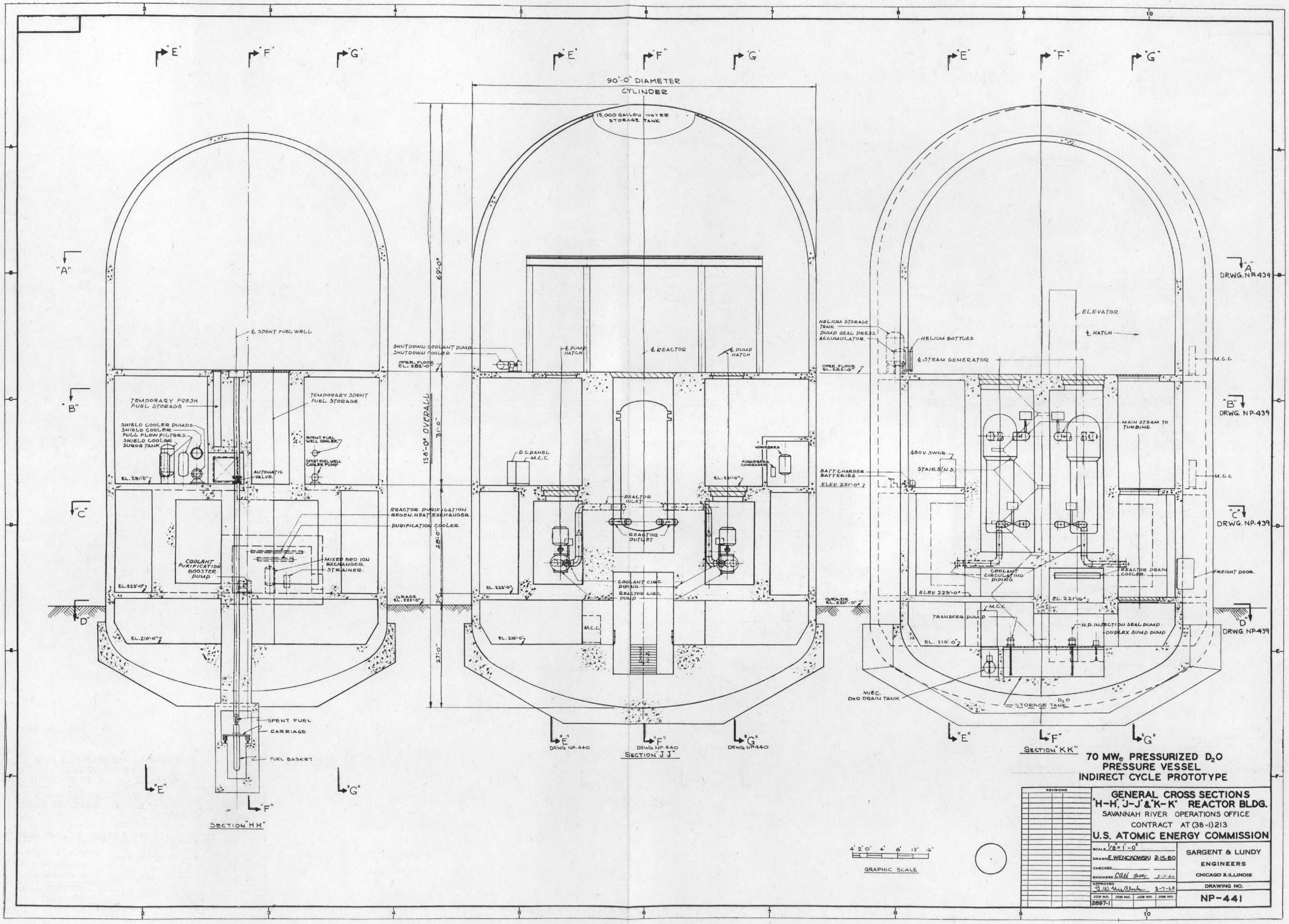

SCRAM CIRCUITS
SAFETY & SHIM RODS INSERTED
SAFETY CHANNEL LINEAR AMPLIFIERS
COINCIDENCE FAILURE IN 2 OUT OF 3 LEVEL CHANNELS
LOG "N" AMPLIFIER
HIGH LEVEL SHORT PERIOD
START-UP LOG COUNT RATE METER
LOW LEVEL SHORT PERIOD
PRESSURE RECORDER
ABNORMAL REACTOR PRESSURE
ZERO CURRENT DEVICE ON ELECTRONIC SCRAM
BACK-UP SIGNAL
SCRAM RESET SWITCH
RELEASE SAFETY ROD
RELAY SCRAM CONTROL
LEVEL RECORDER
HIGH OR LOW REACTOR LEVEL
PRESSURE SWITCH
LOSS OF BOTH REACTOR CIRC PUMPS
SCRAM PROGRAM CIRCUIT
TO TURBINE SOLENOID TRIP
TO ALARM CIRCUIT
TO STEAM BY-PASS VALVE
COUNT RATE RECORDER
HIGH FISSION PRODUCT ACTIVITY IN COOLANT
DIFFERENTIAL COUNT RATE
HIGH FISSION PRODUCT ACTIVITY IN OFF GAS
MANUAL SCRAM
2300V. BUS UNDERVOLTAGE RELAY
ELECTRICAL POWER FAILURE
REACTOR POWER RUNDOWN CIRCUITS
PERIOD AMPLIFIERS
BY PASS SWITCH
SHORT PERIOD
AUTOMATIC POWER RUNDOWN CIRCUIT
AUTOMATIC POWER REDUCTION PROGRAM CIRCUIT
REGULATING ROD LIMIT SWITCHES
BOTH REGULATING RODS AT LOWER LIMIT
MAIN STEAM HEADER PRESS. EQL.-CONTROLLER
DIFFERENTIAL PRESSURE SWITCHES
LOW VENT AIR FLOW
LIMIT SWITCH
TURBINE STOP VALVE CLOSED
LEVEL SWITCH
LOW REACTOR LEVEL
MANUAL RUNDOWN
TURBINE CONTACT
TURBINE THRUST BEARING FAILURE
PRESSURE SWITCH
LOSS OF BOTH CONDENSATE PUMPS
LOSS OF BOTH STEAM GENERATOR FEED PUMPS
BY-PASS STM. FLOW SIGNAL CONTROLLER
REACTOR PWR. LIMITER
REACTOR CORE TEMP. LIMITER
REACTOR CORE TEMP. CONTROLLER
OUTPUT OF LINEAR PWR. AMPLIFIER
FLUX LEVEL & RATE OF CHANGE LIMITER
REGULATING ROD SERV. MECH.
HIGH CONDENSER PRESSURE
HIGH RADIATION LEVEL IN REACTOR EXH.
HIGH RADIATION LEVEL IN BUILDING
RADIATION LEVEL RECORDERS
HIGH NEUTRON FLUX
LINEAR LEVEL AMPLIFIERS
MANUAL POWER REDUCTION
LOSS OF EITHER STM. GENERATOR FEEDPUMP
LOSS OF EITHER CONDENSATE PUMP
LOSS OF EITHER REACTOR CIRC. PUMP
LOW TURBINE DEMAND
TURBINE NO LOAD SWITCH
HIGH REACTOR PRESSURE
REACTOR ALARM CIRCUITS
HIGH NEUTRON FLUX LEVEL
SHORT PERIOD
INSTRUMENT FAILURE IN ANY LEVEL CHANNEL
HIGH RADIATION LEVEL IN STACK
HIGH RADIATION LEVEL IN BUILDING
LOW VENT AIR FLOW
HIGH FLUX LEVEL
HIGH RADIATION IN SEWER
HIGH STEAM PRESSURE
POWER SUPPLY FAILURE TO NUCLEAR INSTRUMENTS
D2O LEAK
LOW LEVEL IN REACTOR
HIGH LEVEL IN REACTOR
REGULATING RODS UPPER OR LOWER LIMIT
ABNORMAL REACTOR PRESSURE
HIGH COUNT RATE START-UP CHANNEL
HIGH RADIATION IN SEC. WATER
REACTOR SCRAM
REACTOR POWER RUNDOWN
AUTOMATIC POWER REDUCTION
MAIN STEAM ISOLATION VALVE CLOSED
MAIN FEEDWATER ISOLATION VALVE CLOSED
HIGH FISSION PRODUCTS ACTIVITY IN COOLANT
HIGH FISSION PRODUCTS ACTIVITY IN OFF GAS
HIGH RADIATION MOBILE MONITOR
HIGH ACTIVITY IN OFF-GAS HOLD UP SYSTEM
HIGH ACTIVITY IN FUEL STORAGE POOL
LOSS OF ESSENTIAL REACTOR PUMPS
LOW TURBINE DEMAND
ALARM
REACTOR AUXILIARIES ALARM CIRCUITS
TURBINE ALARM CIRCUITS
GEN. & GEN. AUX. ALARM CIRCUITS
ALARM
70 MWe PRESSURIZED D2O PRESSURE VESSEL INDIRECT CYCLE PROTOTYPE
REVISIONS
SAFETY BLOCK DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN J.J. TALAMO 2-15-60
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-437
JOB NO. 2897-1

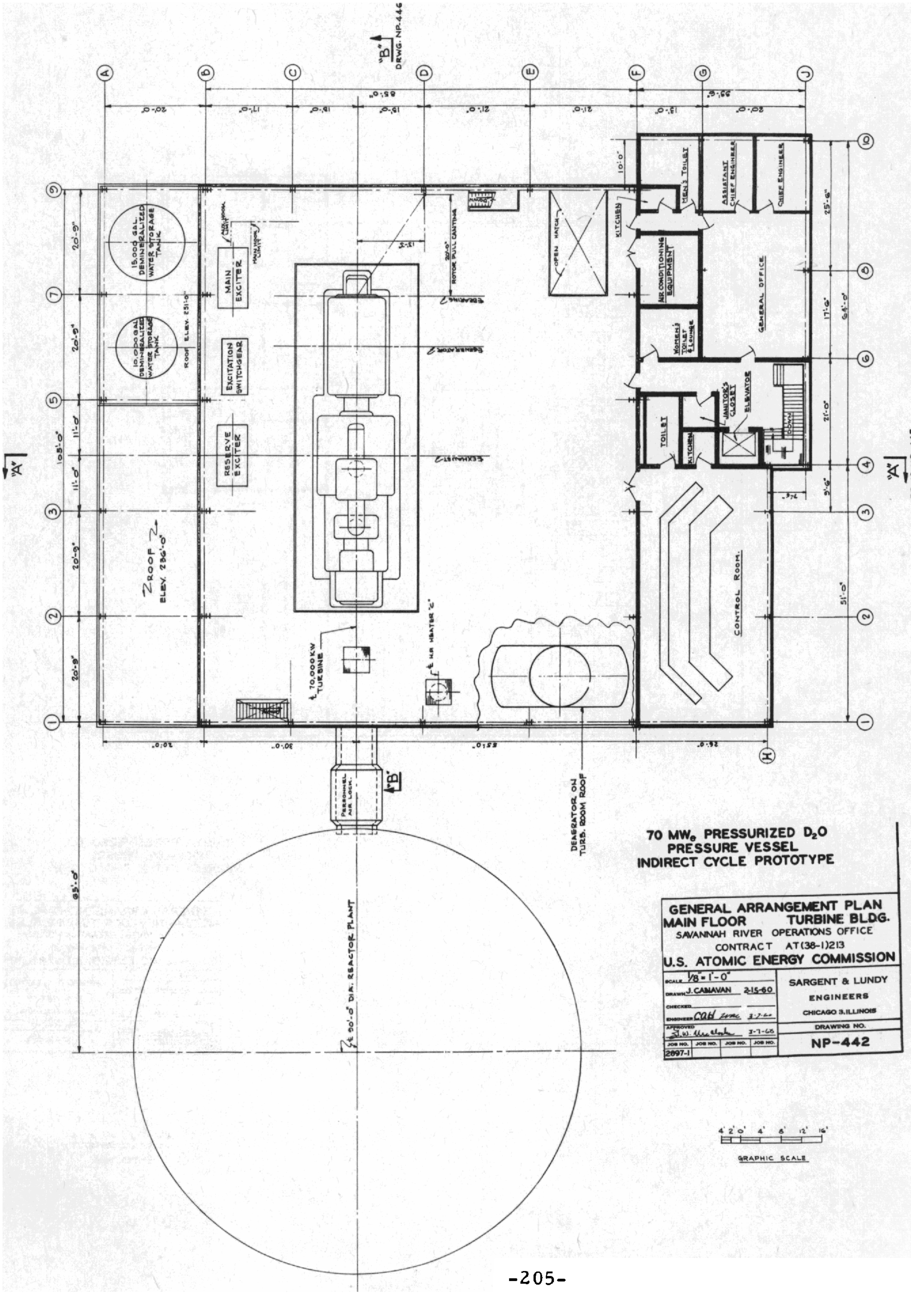

HIGH WATER EL. 210'-0"
MEAN WATER EL. 200'-0"
LOW WATER EL. 195'-0"
INTAKE
72" Φ DISCHARGE PIPE
D2O DISTILL. EQUIPMENT
CRIB HOUSE
2000 GAL. DAY TANK
13' DIA. CHIMNEY 200' HIGH
FREIGHT DOOR
FUEL HANDLING BUILDING
AIR LOCK
REACTOR CONTAINMENT VESSEL
TURBINE ROOM
RES. AUX. TRANSF.
MAIN POWER TRANSF.
SWITCHYARD
UNIT AUX. TRANSF.
FENCE
OFFICE
SOLID WASTE BURIAL PIT
PERMANENT RESIN STORAGE TANKS
RADIOACTIVE WASTE DISPOSAL BUILDING
RADIOACTIVE GAS HOLD-UP TANKS & WASTE HOLD-UP TANKS
DRAINAGE DITCH
FINISHED GRADE ELEV. 220'-0"
50,000 GAL. OIL STORAGE TANK
DRAINAGE DITCH
GUARD RAIL
EL. 233'-0"
54 CAR PARKING LOT EL. 234'-0"
DEEP WELL
SEPTIC TANK
TILE FIELD
CONSTRUCTION AREA
PLANT RAILROAD
20' ROAD
GATE HOUSE
GATE
CONSTRUCTION PARKING AREA
70 MWe PRESSURIZED D2O PRESSURE VESSEL INDIRECT CYCLE PROTOTYPE
PROPERTY PLAT
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1" = 50'-0"
DRAWN A. HEIDBREDER 2-15-60
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-438
GRAPHIC SCALE
NORTH

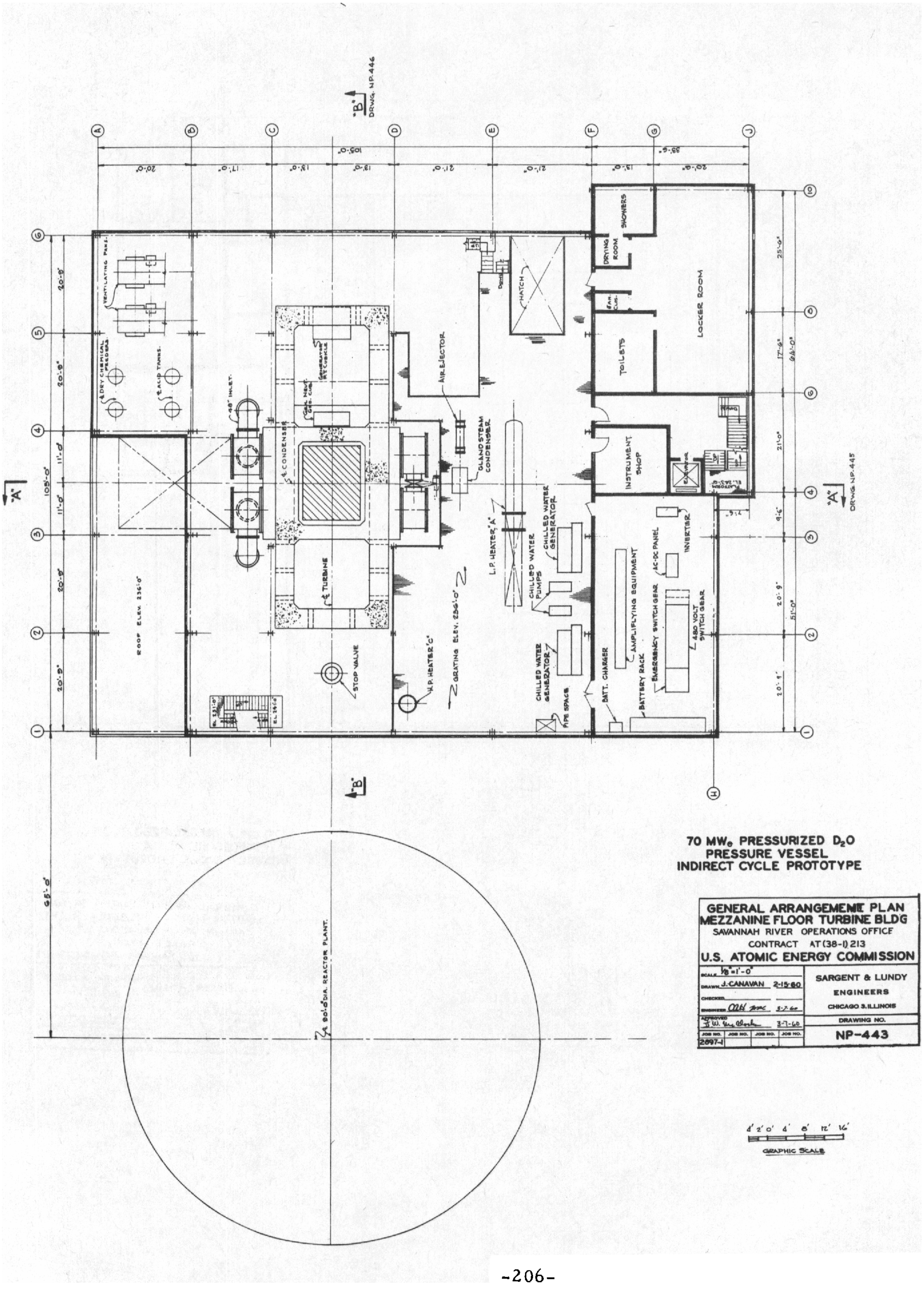


PLAN "AA" AT ELEV. 282'-0"
PLAN "BB" AT ELEV. 251'-0"
PLAN "CC" AT ELEV. 223'-0"
PLAN "DD" AT ELEV. 210'-0"
90'-0" DIA. CYLINDER
DISTILLATION COLUMNS
EMERGENCY AIRLOCK
M.C.C.
PUMP HATCH
HATCH
TEMPORARY SPENT FUEL STORAGE WELL
RAILS
FUEL HANDLING RAIL
REACTOR
FUELING VEHICLE
SPENT FUEL WELL
ELEVATOR
TEMPORARY FRESH FUEL STORAGE WELL
STEAM GENERATORS
CRANE RAIL
HELIUM BOTTLES
PUMP SEAL PRESSURE ACCUMULATOR
HELIUM STORAGE TANK
SHUTDOWN COOLANT PUMP
SHUTDOWN COOLER
RECOMBINERS
SEPARATORS
ADSORBERS
ADSORBER CONDENSER
OXYGEN BOTTLES
SPENT FUEL WELL COOLER PUMP
SPENT FUEL WELL COOLER
TEMPORARY SPENT FUEL STORAGE WELL
PUMP HATCH
TEMPORARY FRESH FUEL STORAGE WELL
AUTOMATIC VALVE
SHIELD COOLER SHIELD COOLER PUMPS
SHIELD COOLER SURGE TANK
FULL FLOW FILTERS
TRANSFORMER
480V. SWITCHGEAR
D.C. PANEL
BATT. CHGR
BATTERIES
REACTOR PURIFICATION REGENERATIVE HEAT EXCHANGER (ABOVE) PURIFICATION COOLER (BELOW)
STRAINER
MIXED BED ION EXCHANGER
AIR LOCK
COOLANT PURIFICATION BOOSTER PUMP
MAIN STEAM TO TURBINE
FREIGHT DOOR
REACTOR CIRC. PUMP
COOLANT CIRCULATING PIPING
REACTOR INLET
REACTOR DRAIN COOLER
STEAM GENERATORS
REACTOR OUTLET
SPENT FUEL WELL
COOLANT CIRCULATING PIPING
SUMP PUMP
H.P. INJECTION SEAL PUMP
CONTROL ROD ROOM
D_2O COOLANT TANK
SPENT FUEL CANAL
D_2O COOLANT TRANSFER PUMP
MISC. D_2O DRAIN TANK
TRANSFER PUMP
38'-0" TO FUEL HANDLING BUILDING SEE DRG. NP-447
24'-0"
NP-440
NP-441
GRAPHIC SCALE
70 MWe PRESSURIZED D_2O PRESSURE VESSEL INDIRECT CYCLE PROTOTYPE
REVISIONS
GENERAL ARRANGEMENT PLANS
REACTOR BUILDING
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8"=1'-0"
DRAWN E. WENCKOWSKI 2-15-60
CHECKED
ENGINEER
APPROVED
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-439
JOB NO. 2897-1

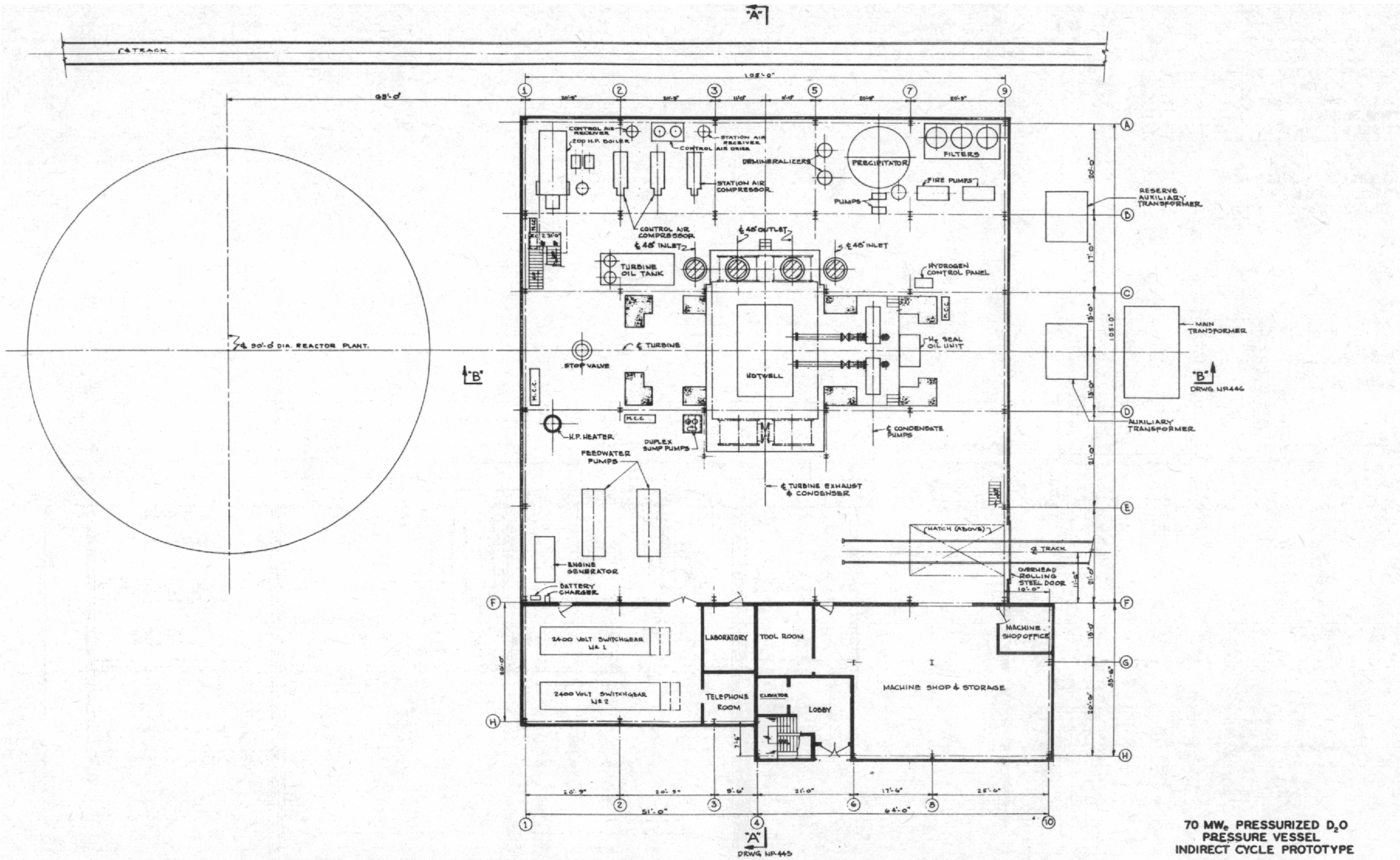

90'-0" ℄ CYLINDER
13,000 GALLON WATER STORAGE TANK
TOP CRANE RAIL EL. 312'-0"
FUEL HANDLING VEHICLE
ELEVATOR
℄ STEAM GENERATOR
℄ REACTOR
ELEV. 282'-0"
TEMP. SPENT FUEL STORAGE
SPENT FUEL WELL COOLER
POOL RECIRCULATION PUMP
AIR LOCK
ELEV. 251'-0"
REACTOR INLET
REACTOR OUTLET
COOLANT CIRCULATING PIPING
MAIN STEAM TO TURBINE
REACTOR PURIF. REGEN. HEAT EXCHANGER
PURIFICATION SYSTEM COOLER
MIXED BED ION EXCHANGER
WASTE RESIN TRANSFER PUMP
PURIF. BOOSTER PUMP
GROUND FLOOR ELEV. 229'-0"
GRADE EL. 220'-0"
DUPLEX SUMP PUMP
H.P. INJECTION SEAL PUMP
ELEV. 210'-0"
D_2O STORAGE TANK
158'-0" OVERALL
69'-0"
31'-0"
28'-0"
13'-0"
17'-0"
PUMP SEAL PRESSURE ACCUMULATOR
HELIUM STORAGE TANK
SHUTDOWN COOLANT PUMP
SHUTDOWN COOLER
℄ REACTOR CIRC. PUMP
℄ SPENT FUEL WELL
℄ STEAM GENERATOR
HELIUM BOTTLES
TEMP. FRESH FUEL STORAGE
M.C.C.
D.C. PANEL
480V. SWGR.
TRANSFORMERS
2300V. SWGR.
BATTERIES
BATT. CHGR.
REACTOR INLET
℄ REACTOR CIRCULATING PUMP
COOLANT CIRCULATING PIPING
M.C.C.
TRANSFER PUMP
GALLON D_2O STORAGE TANK
MISC. D_2O DRAIN TANK
SPENT FUEL
CARRIAGE
FUEL BASKET
SECTION "E-E"
SECTION "F-F"
SECTION "G-G"
℄ HATCH
PUMP ℄ HATCH
℄ STEAM GENERATOR
M.C.C.
OXYGEN BOTTLES
ADSORBERS
ADSORBER CONDENSER
MAIN STEAM TO TURBINE
REACTOR OUTLET
FREIGHT DOOR
COOLANT CIRCULATING PIPING
REACTOR INLET
℄ REACTOR CIRCULATING PUMP
ELEV. 221'-0"
REACTOR DRAIN COOLER
"A" NP-439
"B" NP-439
"C" NP-439
"D" NP-439
DRWG. NP 441
NP-441
FOR GENERAL ARRANGEMENT PLANS SEE DRWG NP-439
GRAPHIC SCALE
70 MWe PRESSURIZED D_2O PRESSURE VESSEL INDIRECT CYCLE PROTOTYPE
GENERAL CROSS SECTIONS "E-E", "F-F" & "G-G" REACTOR BLDG.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
REVISIONS
SCALE 1/8" = 1'-0"
DRAWN E. WENCKOWSKI 2-15-60
CHECKED
ENGINEER
APPROVED
JOB NO. 2897-1
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-440


90'-0" DIAMETER CYLINDER
15,000 GALLON WATER STORAGE TANK
69'-0"
31'-0"
158'-0" OVERALL
28'-0"
27'-0"
℄ SPENT FUEL WELL
TEMPORARY FRESH FUEL STORAGE
TEMPORARY SPENT FUEL STORAGE
SHIELD COOLER PUMPS
SHIELD COOLER
FULL FLOW FILTERS
SHIELD COOLER SURGE TANK
SPENT FUEL WELL COOLER
SPENT FUEL WELL COOLER PUMP
AUTOMATIC VALVE
EL. 251'-0"
REACTOR PURIFICATION REGEN. HEAT EXCHANGER
PURIFICATION COOLER
COOLANT PURIFICATION BOOSTER PUMP
MIXED BED ION EXCHANGER
STRAINER
EL. 223'-0"
GRADE EL. 220'-0"
EL. 210'-0"
SPENT FUEL
CARRIAGE
FUEL BASKET
SECTION "HH"
SHUTDOWN COOLANT PUMP
SHUTDOWN COOLER
OPER. FLOOR EL. 282'-0"
℄ PUMP HATCH
℄ REACTOR
D.C. PANEL
M.C.C.
ADSORBERS
ADSORBERS CONDENSER
REACTOR INLET
REACTOR OUTLET
COOLANT CIRC. PIPING
REACTOR CIRC. PUMP
DRWG. NP-440
SECTION "J J"
HELIUM STORAGE TANK
PUMP SEAL PRESS. ACCUMULATOR
HELIUM BOTTLES
℄ STEAM GENERATOR
ELEVATOR
℄ HATCH
M.C.C.
MAIN STEAM TO TURBINE
480V SWGR
STAIRS (N.S.)
BATT. CHARGER BATTERIES
ELEV. 251'-0"
COOLANT CIRCULATING PIPING
REACTOR DRAIN COOLER
FREIGHT DOOR
ELEV. 225'-0"
EL. 221'-0"
TRANSFER PUMP
H.P. INJECTION SEAL PUMP
DUPLEX SUMP PUMP
MISC. D₂O DRAIN TANK
D₂O STORAGE TANK
SECTION "KK"
DRWG. NP-439
GRAPHIC SCALE
70 MWe PRESSURIZED D₂O PRESSURE VESSEL INDIRECT CYCLE PROTOTYPE
REVISIONS
GENERAL CROSS SECTIONS
"H-H", "J-J" & "K-K" REACTOR BLDG.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN E. WENCKOWSKI 2-15-60
CHECKED
ENGINEER 3-7-60
APPROVED 3-7-60
JOB NO. 2897-1
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-441


70 MWe PRESSURIZED D2O
PRESSURE VESSEL
INDIRECT CYCLE PROTOTYPE
GENERAL ARRANGEMENT PLAN
MAIN FLOOR TURBINE BLDG.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1)213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN J. CAHAVAN 2-15-60
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-442
JOB NO.
2897-1
GRAPHIC SCALE



70 MWe PRESSURIZED D_2O
PRESSURE VESSEL
INDIRECT CYCLE PROTOTYPE
GENERAL ARRANGEMENT PLAN
MEZZANINE FLOOR TURBINE BLD'G
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN J. CANAVAN 2-15-60
CHECKED
ENGINEER
APPROVED
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-443
JOB NO.
2697-1
GRAPHIC SCALE
DRWG. NP-446
DRWG. NP-445
LOCKER ROOM
SHOWERS
DRYING ROOM
TOILETS
INSTRUMENT SHOP
HATCH
AIR EJECTOR
GLANDSTEAM CONDENSER
L.P. HEATER "A"
CHILLED WATER GENERATOR
CHILLED WATER PUMPS
AMPLIFYING EQUIPMENT
AC-DC PANEL
INVERTER
480 VOLT SWITCH GEAR
EMERGENCY SWITCH GEAR
BATTERY RACK
BATT. CHARGER
PIPE SPACE
H.P. HEATER "C"
GRATING ELEV. 236'-0"
STOP VALVE
℄ TURBINE
℄ CONDENSER
48" INLET
VENTILATING FANS
DRY CHEMICAL FEEDERS
ACID TANKS
ROOF ELEV. 236'-0"
80'-0" DIA. REACTOR PLANT
105'-0"
65'-0"

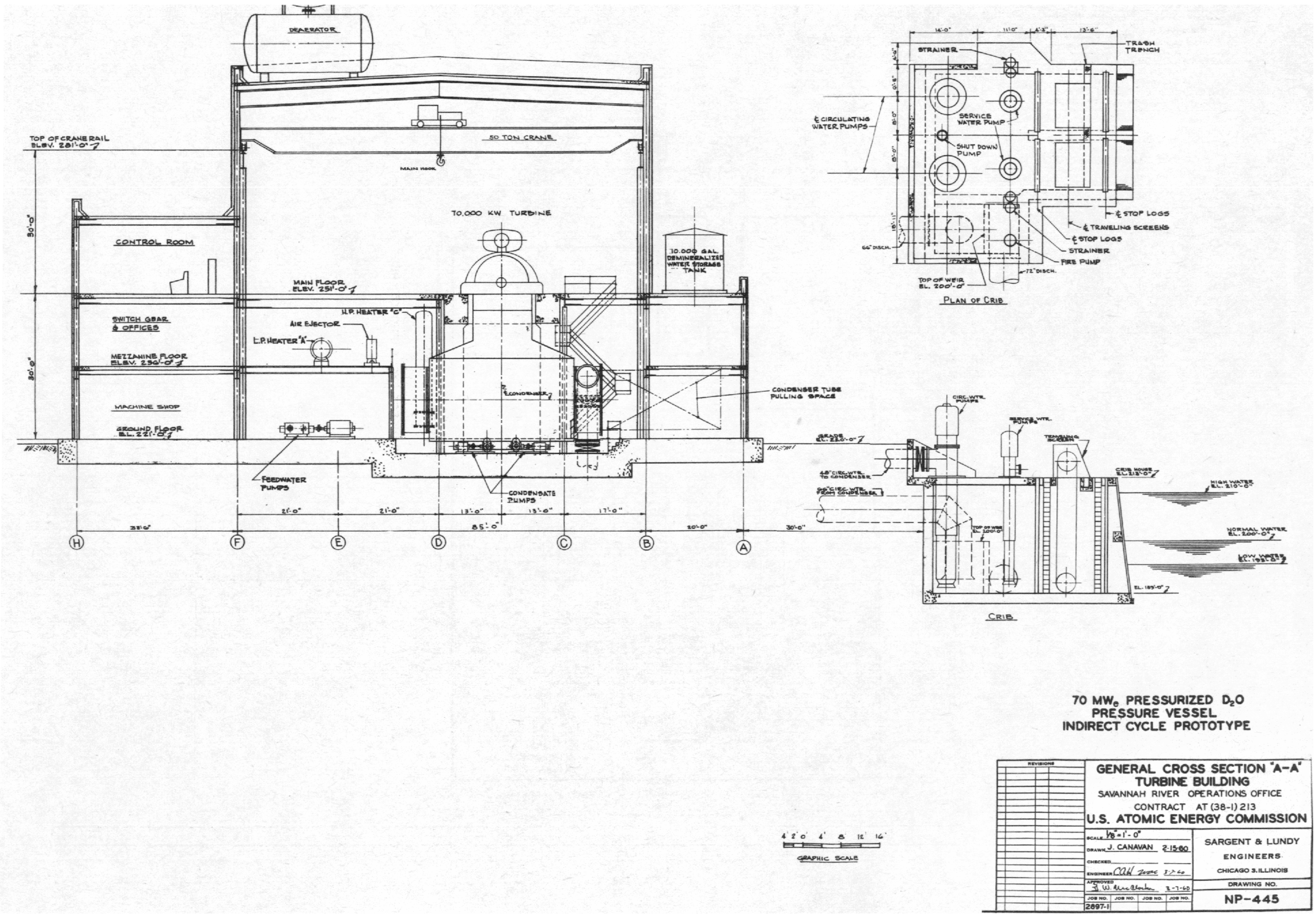


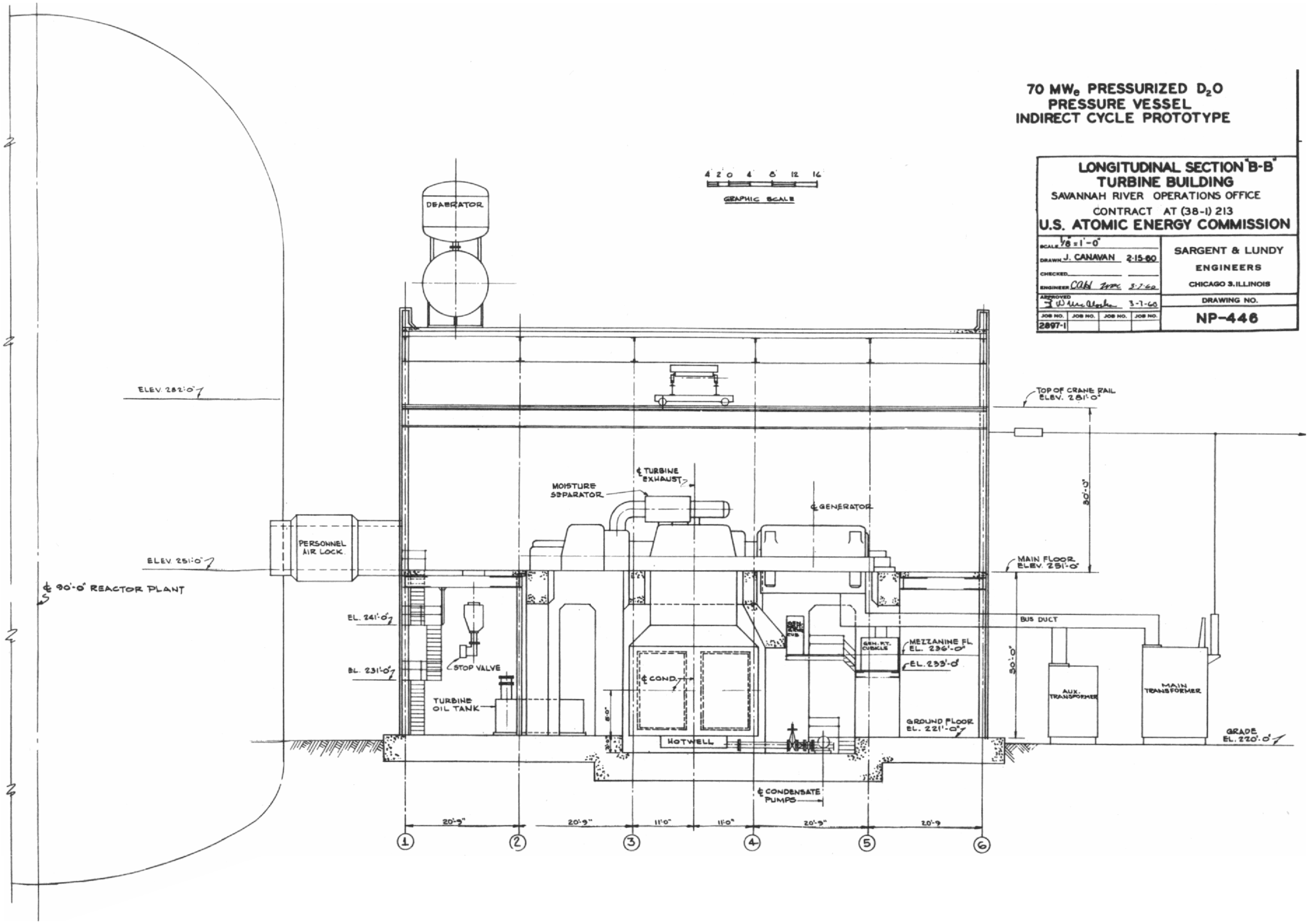
70 MW$_e$ PRESSURIZED D_2O
PRESSURE VESSEL
INDIRECT CYCLE PROTOTYPE

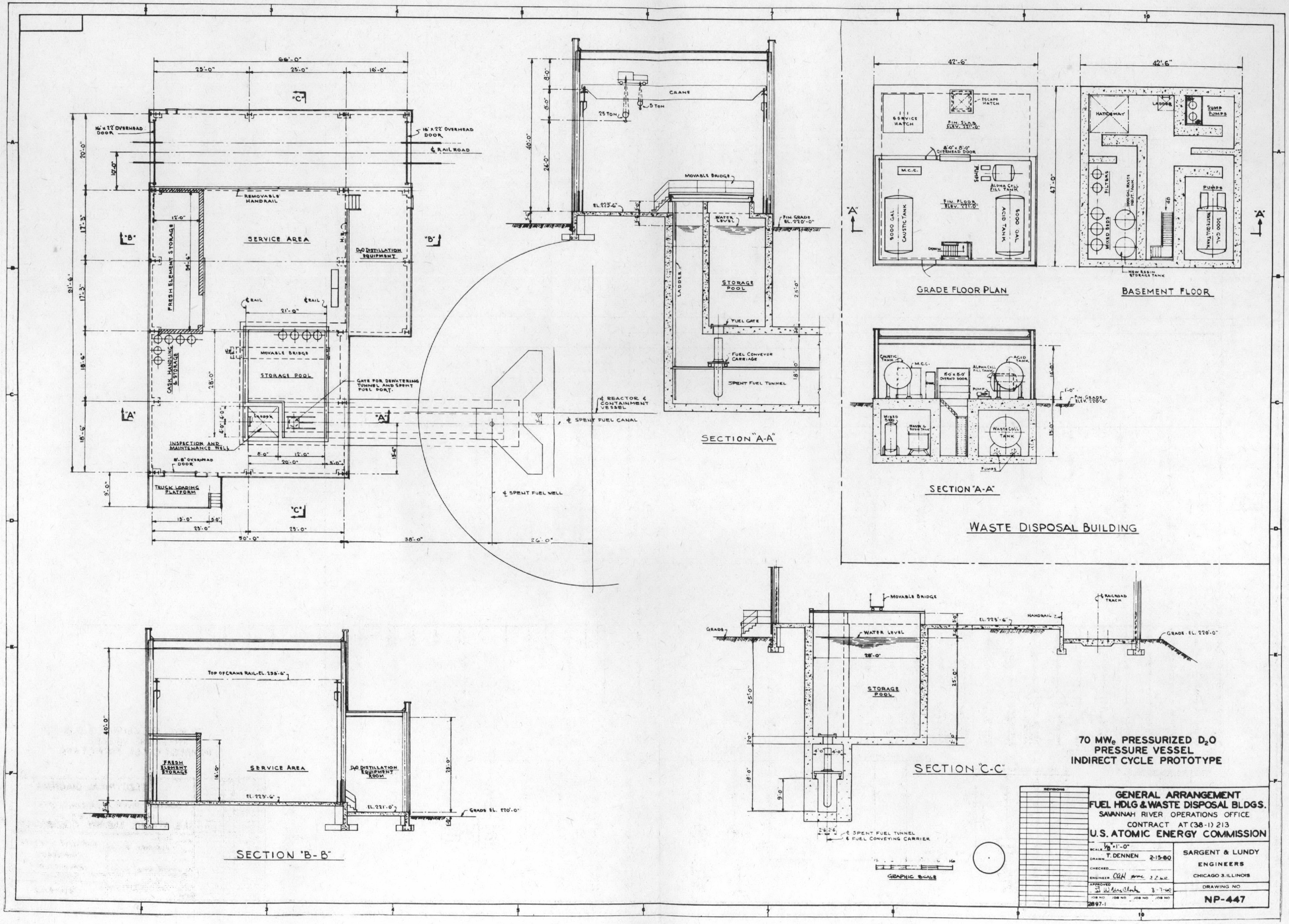
GENERAL ARRANGEMENT PLAN
GROUND FLOOR TURBINE BLDG.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION

GRAPHIC SCALE

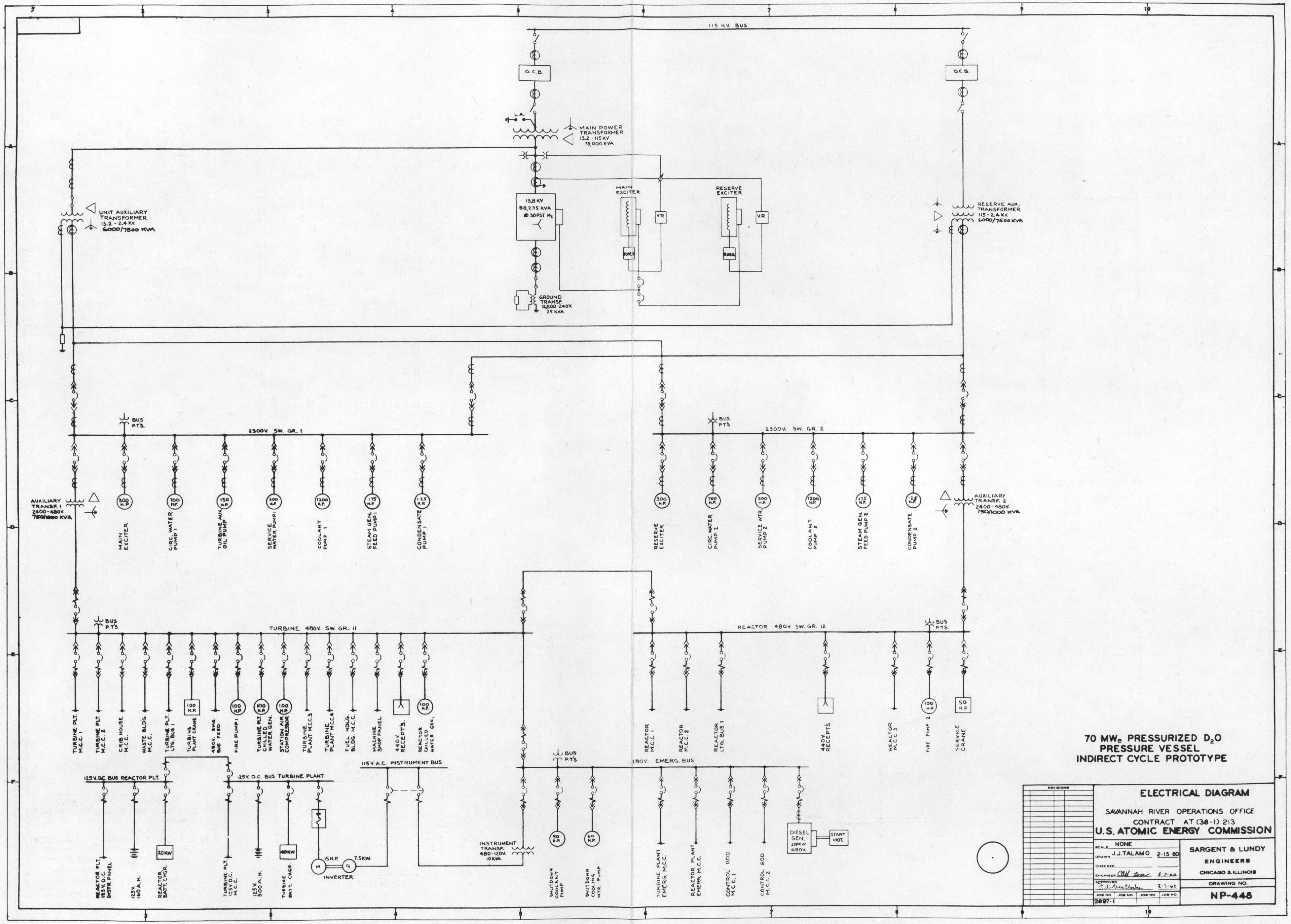
SCALE 1/8" = 1'-0"		SARGENT & LUNDY ENGINEERS
DRAWN J. CANAVAN	2-15-60	CHICAGO 3, ILLINOIS
CHECKED		
ENGINEER	3-7-60	
APPROVED	3-7-60	DRAWING NO.


DEAERATOR
50 TON CRANE
MAIN HOOK
TOP OF CRANE RAIL ELEV. 281'-0"
30'-0"
30'-0"
CONTROL ROOM
70,000 KW TURBINE
10,000 GAL. DEMINERALIZED WATER STORAGE TANK
MAIN FLOOR ELEV. 251'-0"
SWITCH GEAR & OFFICES
H.P. HEATER "C"
AIR EJECTOR
L.P. HEATER "A"
MEZZANINE FLOOR ELEV. 236'-0"
CONDENSER
CONDENSER TUBE PULLING SPACE
MACHINE SHOP
GROUND FLOOR EL. 221'-0"
FEEDWATER PUMPS
CONDENSATE PUMPS
21'-0"
21'-0"
13'-0"
13'-0"
17'-0"
33'-0"
85'-0"
20'-0"
30'-0"
H
F
E
D
C
B
A
TRASH TRENCH
STRAINER
℄ CIRCULATING WATER PUMPS
SERVICE WATER PUMP
SHUT DOWN PUMP
℄ STOP LOGS
℄ TRAVELING SCREENS
℄ STOP LOGS
STRAINER
FIRE PUMP
TOP OF WEIR EL. 200'-0"
72" DISCH.
PLAN OF CRIB
CIRC. WTR. PUMPS
SERVICE WTR. PUMPS
TRAVELING SCREEN
GRADE EL. 220'-0"
48" CIRC. WTR. TO CONDENSER
CRIB HOUSE EL. 212'-0"
HIGH WATER EL. 210'-0"
NORMAL WATER EL. 200'-0"
LOW WATER EL. 195'-0"
EL. 185'-0"
CRIB
70 MWe PRESSURIZED D2O PRESSURE VESSEL INDIRECT CYCLE PROTOTYPE
GRAPHIC SCALE
REVISIONS
GENERAL CROSS SECTION "A-A" TURBINE BUILDING
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN J. CANAVAN 2-15-60
CHECKED
ENGINEER
APPROVED
JOB NO. 2897-1
SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWING NO. NP-445

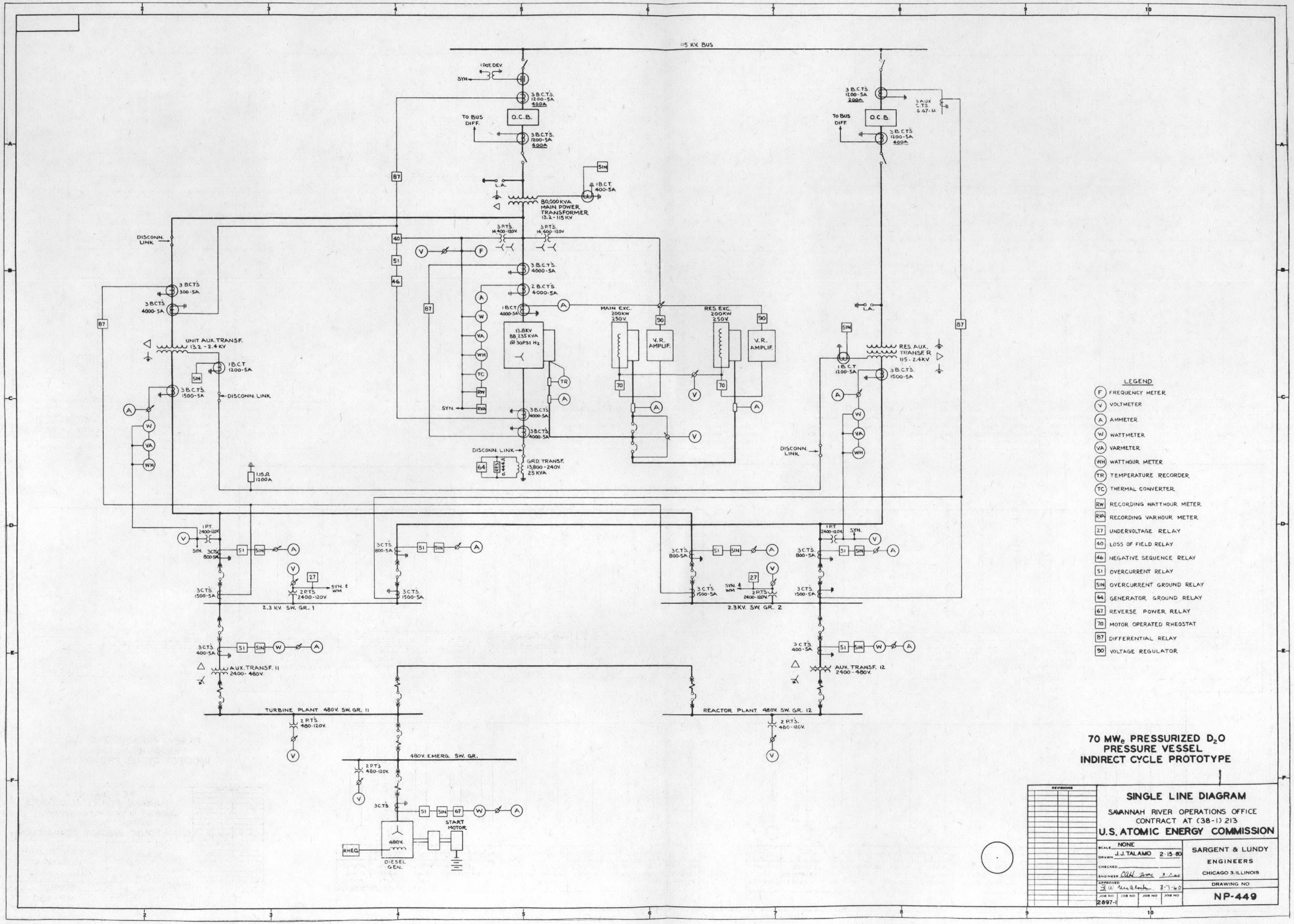

70 MWe PRESSURIZED D2O
PRESSURE VESSEL
INDIRECT CYCLE PROTOTYPE
LONGITUDINAL SECTION "B-B"
TURBINE BUILDING
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN J. CANAVAN 2-15-60
CHECKED
ENGINEER 3-7-60
APPROVED 3-7-60
JOB NO. 2897-1
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-446
GRAPHIC SCALE
4 2 0 4 8 12 16
DEAERATOR
ELEV. 282'-0"
TOP OF CRANE RAIL ELEV. 281'-0"
30'-0"
MOISTURE SEPARATOR
℄ TURBINE EXHAUST
℄ GENERATOR
PERSONNEL AIR LOCK
ELEV. 251'-0"
MAIN FLOOR ELEV. 251'-0"
℄ 90'-0" REACTOR PLANT
EL. 241'-0"
EL. 231'-0"
STOP VALVE
BUS DUCT
MEZZANINE FL. EL. 236'-0"
EL. 233'-0"
GEN. PT. CUBICLE
30'-0"
℄ COND.
8'-0"
TURBINE OIL TANK
AUX. TRANSFORMER
MAIN TRANSFORMER
GROUND FLOOR EL. 221'-0"
GRADE EL. 220'-0"
HOTWELL
℄ CONDENSATE PUMPS
20'-9"
20'-9"
11'-0"
11'-0"
20'-9"
20'-9
1
2
3
4
5
6



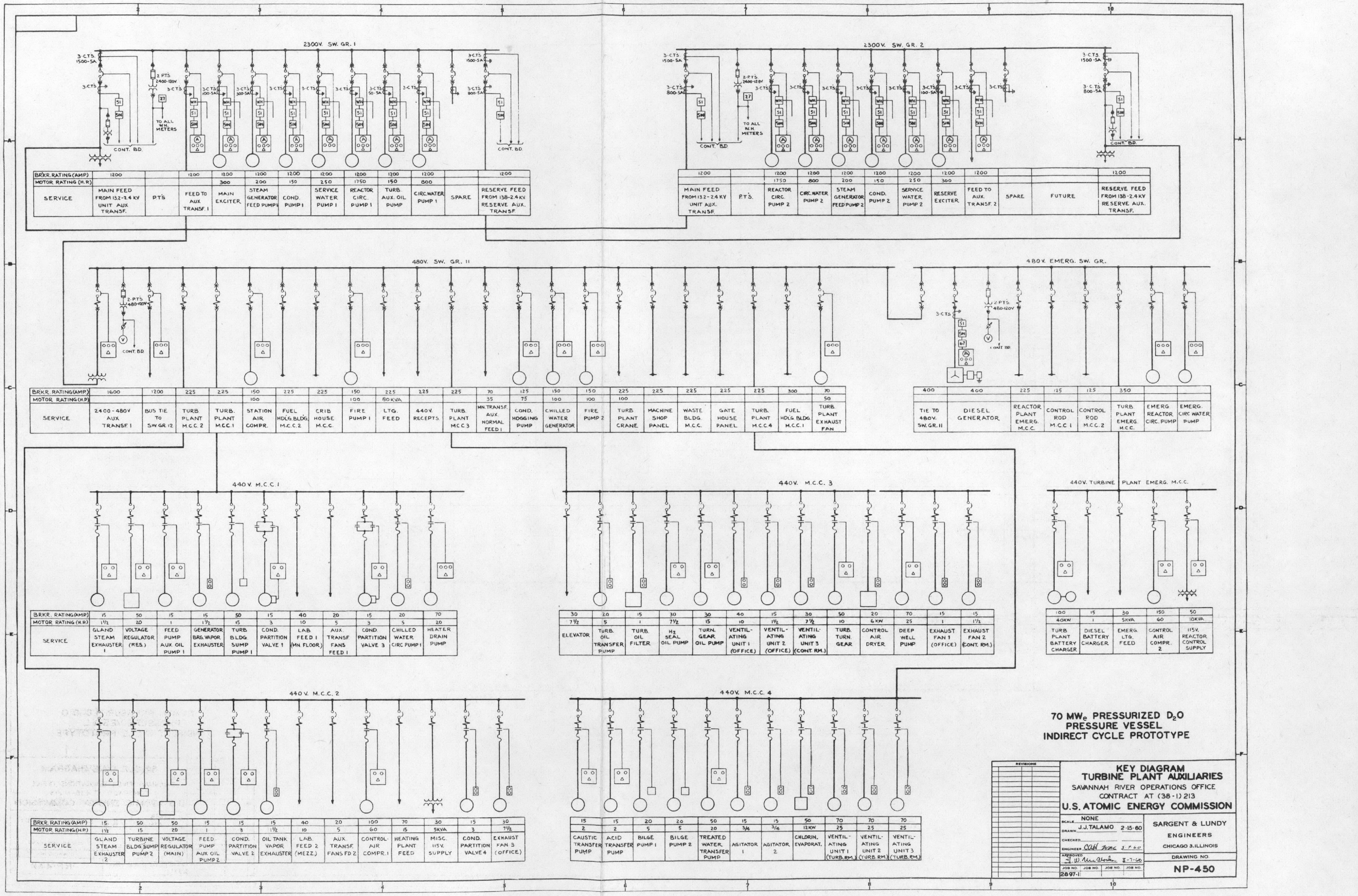
SERVICE AREA
D_2O DISTILLATION EQUIPMENT
FRESH ELEMENT STORAGE
CASK HANDLING & STORAGE
MOVABLE BRIDGE
STORAGE POOL
INSPECTION AND MAINTENANCE WELL
TRUCK LOADING PLATFORM
℄ RAILROAD
℄ REACTOR & CONTAINMENT VESSEL
℄ SPENT FUEL CANAL
℄ SPENT FUEL WELL
CRANE
SPENT FUEL TUNNEL
FUEL CONVEYOR CARRIAGE
SECTION "A-A"
GRADE FLOOR PLAN
BASEMENT FLOOR
SECTION "A-A"
WASTE DISPOSAL BUILDING
SECTION "B-B"
SECTION "C-C"
GRAPHIC SCALE
70 MWe PRESSURIZED D_2O
PRESSURE VESSEL
INDIRECT CYCLE PROTOTYPE
REVISIONS
GENERAL ARRANGEMENT
FUEL HDLG & WASTE DISPOSAL BLDGS.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN T. DENNEN 2-15-60
CHECKED
ENGINEER CAH 3-7-60
APPROVED 3-7-60
JOB NO 2897-1
SARGENT & LUNDY
ENGINEERS
CHICAGO 3. ILLINOIS
DRAWING NO
NP-447



115 KV. BUS
O.C.B.
O.C.B.
L.A.
MAIN POWER TRANSFORMER 13.2 - 115 KV 75,000 KVA
MAIN EXCITER
RESERVE EXCITER
VR
VR
13.8 KV 88,235 KVA @ 30 PSI H_2
GROUND TRANSF. 13,800-240V. 25 KVA
UNIT AUXILIARY TRANSFORMER 13.2 - 2.4 KV 6000/7500 KVA
RESERVE AUX. TRANSFORMER 115 - 2.4 KV 6000/7500 KVA
BUS P.T.S.
2300V. SW. GR. 1
2300V. SW. GR. 2
AUXILIARY TRANSF. 1 2400-480V. 750/1000 KVA
AUXILIARY TRANSF. 2 2400-480V. 750/1000 KVA
MAIN EXCITER
CIRC. WATER PUMP 1
TURBINE AUX. OIL PUMP
SERVICE WATER PUMP 1
COOLANT PUMP 1
STEAM GEN. FEED PUMP 1
CONDENSATE PUMP 1
RESERVE EXCITER
CIRC. WATER PUMP 2
SERVICE WTR. PUMP 2
COOLANT PUMP 2
STEAM GEN. FEED PUMP 2
CONDENSATE PUMP 2
TURBINE 480V. SW. GR. 11
REACTOR 480V. SW. GR. 12
TURBINE PLT. M.C.C. 1
TURBINE PLT. M.C.C. 2
CRIB HOUSE M.C.C.
WASTE BLDG. M.C.C.
TURBINE PLT. LTG. BUS 1
TURBINE PLANT CRANE
480V. RMG. BUS FEED
FIRE PUMP 1
TURBINE PLT. CHILLED WATER GEN.
STATION AIR COMPRESSOR
TURBINE PLANT M.C.C. 3
TURBINE PLANT M.C.C. 4
FUEL HDLG. BLDG. M.C.C.
MACHINE SHOP PANEL
440 V. RECEPTS.
REACTOR CHILLED WATER GEN.
REACTOR M.C.C. 1
REACTOR M.C.C. 2
REACTOR LTG. BUS 1
440 V. RECEPTS.
REACTOR M.C.C. 3
FIRE PUMP 2
SERVICE CRANE
125V. D.C. BUS REACTOR PLT.
125V. D.C. BUS TURBINE PLANT
115V. A.C. INSTRUMENT BUS
480V. EMERG. BUS
REACTOR PLT. 125V. D.C. DISTR. PANEL
125V. 160 A.H.
REACTOR BATT. CHGR.
TURBINE PLT. 125V. D.C. M.C.C.
125V. 500 A.H.
TURBINE BATT. CHGR.
15 H.P.
7.5 KW
INVERTER
INSTRUMENT TRANSF. 480-120V. 10 KVA
SHUTDOWN COOLANT PUMP
SHUTDOWN COOLING WTR. PUMP
TURBINE PLANT EMERG. M.C.C.
REACTOR PLANT EMERG. M.C.C.
CONTROL ROD M.C.C. 1
CONTROL ROD M.C.C. 2
DIESEL GEN. 200 KW 480V.
START MOT.
70 MW$_e$ PRESSURIZED D_2O PRESSURE VESSEL INDIRECT CYCLE PROTOTYPE
REVISIONS
ELECTRICAL DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN J.J. TALAMO 2-15-60
CHECKED
ENGINEER 3-2-60
APPROVED 3-7-60
JOB NO. 2697-1
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-448



115 KV. BUS
O.C.B.
TO BUS DIFF.
80,000 KVA MAIN POWER TRANSFORMER 13.2 - 115 KV
UNIT AUX. TRANSF. 13.2 - 2.4 KV
RES. AUX. TRANSF. R 115 - 2.4 KV
MAIN EXC. 200KW 250V
RES. EXC. 200KW 250V
V.R. AMPLIF.
GRD. TRANSF. 13,800-240V 25 KVA
DISCONN. LINK
2.3 KV. SW. GR. 1
2.3 KV. SW. GR. 2
AUX. TRANSF. 11 2400-480V.
AUX. TRANSF. 12 2400-480V.
TURBINE PLANT 480V. SW. GR. 11
REACTOR PLANT 480V. SW. GR. 12
480V. EMERG. SW. GR.
START MOTOR
RHEO.
DIESEL GEN.
LEGEND
F FREQUENCY METER
V VOLTMETER
A AMMETER
W WATTMETER
VA VARMETER
WH WATTHOUR METER
TR TEMPERATURE RECORDER
TC THERMAL CONVERTER
RW RECORDING WATTHOUR METER
RVA RECORDING VARHOUR METER
27 UNDERVOLTAGE RELAY
40 LOSS OF FIELD RELAY
46 NEGATIVE SEQUENCE RELAY
51 OVERCURRENT RELAY
51N OVERCURRENT GROUND RELAY
64 GENERATOR GROUND RELAY
67 REVERSE POWER RELAY
70 MOTOR OPERATED RHEOSTAT
87 DIFFERENTIAL RELAY
90 VOLTAGE REGULATOR
70 MWe PRESSURIZED D2O PRESSURE VESSEL INDIRECT CYCLE PROTOTYPE
SINGLE LINE DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
SCALE NONE
DRAWN J.J. TALAMO 2-15-60
DRAWING NO. NP-449
JOB NO. 2897-1



2300V. SW. GR. 1

BRKR. RATING (AMP)	MOTOR RATING (H.P.)	SERVICE
1200		MAIN FEED FROM 13.2-2.4 KV UNIT AUX. TRANSF.
		P.T.'S
1200		FEED TO AUX TRANSF. 1
1200	300	MAIN EXCITER
1200	200	STEAM GENERATOR FEED PUMP 1
1200	150	COND. PUMP 1
1200	250	SERVICE WATER PUMP 1
1200	1750	REACTOR CIRC. PUMP 1
1200	150	TURB. AUX. OIL PUMP
1200	800	CIRC. WATER PUMP 1
		SPARE
1200		RESERVE FEED FROM 138-2.4 KV. RESERVE AUX. TRANSF.

2300V. SW. GR. 2

BRKR. RATING (AMP)	MOTOR RATING (H.P.)	SERVICE
1200		MAIN FEED FROM 13.2-2.4 KV UNIT AUX. TRANSF.
		P.T.'S.
1200	1750	REACTOR CIRC. PUMP 2
1200	800	CIRC. WATER PUMP 2
1200	200	STEAM GENERATOR FEED PUMP 2
1200	150	COND. PUMP 2
1200	250	SERVICE WATER PUMP 2
1200	300	RESERVE EXCITER
1200		FEED TO AUX. TRANSF. 2
		SPARE
		FUTURE
1200		RESERVE FEED FROM 138-2.4 KV RESERVE AUX. TRANSF.

480V. SW. GR. 11

BRKR. RATING (AMP)	MOTOR RATING (H.P.)	SERVICE
1600		2400-480V AUX TRANSF. 1
1200		BUS TIE TO SW. GR. 12
225		TURB. PLANT M.C.C. 2
225		TURB. PLANT M.C.C. 1
150	100	STATION AIR COMPR.
225		FUEL HDLG. BLDG. M.C.C. 2
225		CRIB HOUSE M.C.C.
150	100	FIRE PUMP 1
225	80 KVA	LTG. FEED
225		440V. RECEPTS.
225		TURB. PLANT M.C.C. 3
70	35	MN. TRANSF. AUX. NORMAL FEED 1
125	75	COND. HOGGING PUMP
150	100	CHILLED WATER GENERATOR 1
150	100	FIRE PUMP 2
225	100	TURB. PLANT CRANE
225		MACHINE SHOP PANEL
225		WASTE BLDG. M.C.C.
225		GATE HOUSE PANEL
225		TURB. PLANT M.C.C. 4
300		FUEL HDLG. BLDG. M.C.C. 1
70	50	TURB. PLANT EXHAUST FAN

480V. EMERG. SW. GR.

BRKR. RATING (AMP)	MOTOR RATING (H.P.)	SERVICE
400		TIE TO 480V. SW. GR. 11
400		DIESEL GENERATOR
225		REACTOR PLANT EMERG. M.C.C.
125		CONTROL ROD M.C.C. 1
125		CONTROL ROD M.C.C. 2
350		TURB. PLANT EMERG. M.C.C.
		EMERG. REACTOR CIRC. PUMP
		EMERG. CIRC WATER PUMP

440V. M.C.C. 1

BRKR. RATING (AMP)	MOTOR RATING (H.P.)	SERVICE
15	1½	GLAND STEAM EXHAUSTER 1
50	20	VOLTAGE REGULATOR (RES.)
15	1	FEED PUMP AUX. OIL PUMP 1
15	1½	GENERATOR BRG. VAPOR EXHAUSTER
50	15	TURB. BLDG. SUMP PUMP 1
15	3	COND. PARTITION VALVE 1
40	10	LAB. FEED 1 (MN. FLOOR)
20	5	AUX. TRANSF. FANS FEED 1
15	3	COND. PARTITION VALVE 3
20	5	CHILLED WATER CIRC. PUMP 1
70	20	HEATER DRAIN PUMP

440V. M.C.C. 3

BRKR. RATING (AMP)	MOTOR RATING (H.P.)	SERVICE
30	7½	ELEVATOR
20	5	TURB. OIL TRANSFER PUMP
15	1	TURB. OIL FILTER
30	7½	H_2 SEAL OIL PUMP
30	15	TURN. GEAR OIL PUMP
40	10	VENTILATING UNIT 1 (OFFICE)
15	1½	VENTILATING UNIT 2 (OFFICE)
30	7½	VENTILATING UNIT 3 (CONT. RM.)
50	10	TURB. TURN. GEAR
20	6 KW	CONTROL AIR DRYER
70	25	DEEP WELL PUMP
15	1	EXHAUST FAN 1 (OFFICE)
15	1½	EXHAUST FAN 2 (CONT. RM.)

440V. TURBINE PLANT EMERG. M.C.C.

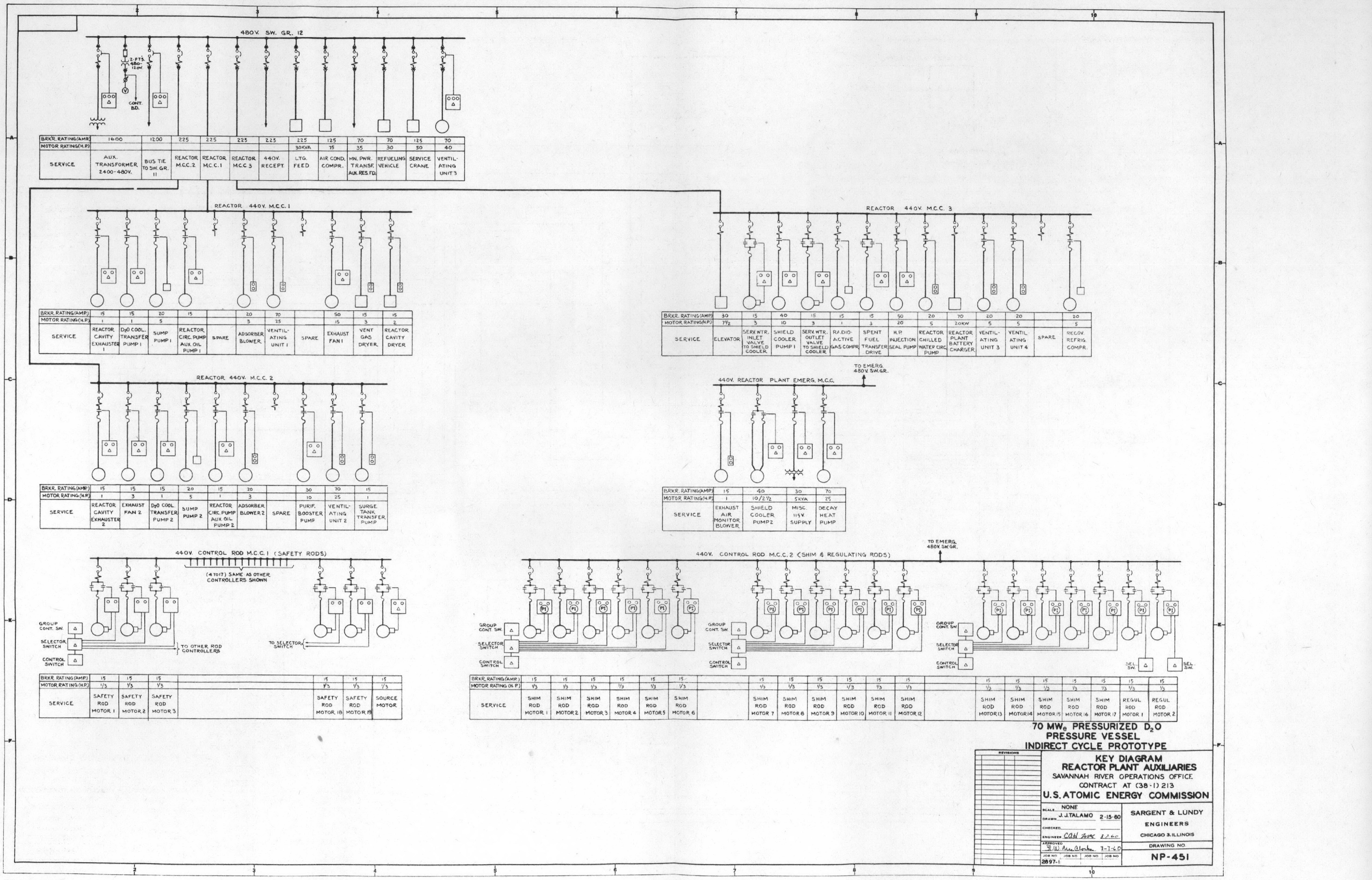
BRKR. RATING (AMP)	MOTOR RATING (H.P.)	SERVICE
100	40 KW	TURB. PLANT BATTERY CHARGER
15	1	DIESEL BATTERY CHARGER
30	5 KVA	EMERG. LTG. FEED
150	60	CONTROL AIR COMPR. 2
50	10 KVA	115V. REACTOR CONTROL SUPPLY

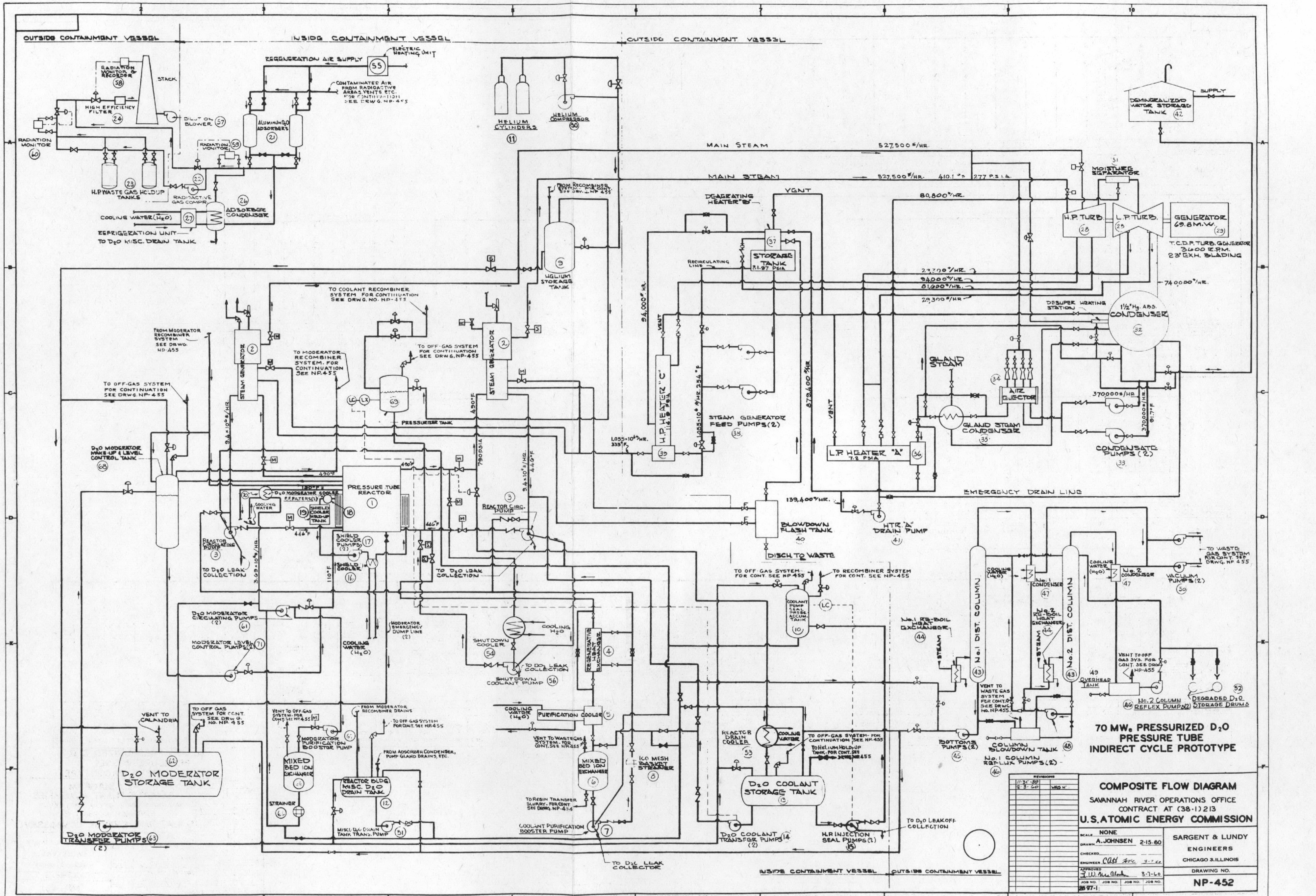
440V. M.C.C. 2

BRKR. RATING (AMP)	MOTOR RATING (H.P.)	SERVICE
15	1½	GLAND STEAM EXHAUSTER 2
50	15	TURBINE BLDG. SUMP PUMP 2
50	20	VOLTAGE REGULATOR (MAIN)
15	1	FEED PUMP AUX OIL PUMP 2
15	3	COND. PARTITION VALVE 2
15	1½	OIL TANK VAPOR EXHAUSTER
40	10	LAB. FEED 2 (MEZZ.)
20	5	AUX. TRANSF. FANS FD 2
100	60	CONTROL AIR COMPR. 1
70	15	HEATING PLANT FEED
30	5 KVA	MISC. 115V. SUPPLY
15	3	COND. PARTITION VALVE 4
30	7½	EXHAUST FAN 3 (OFFICE)

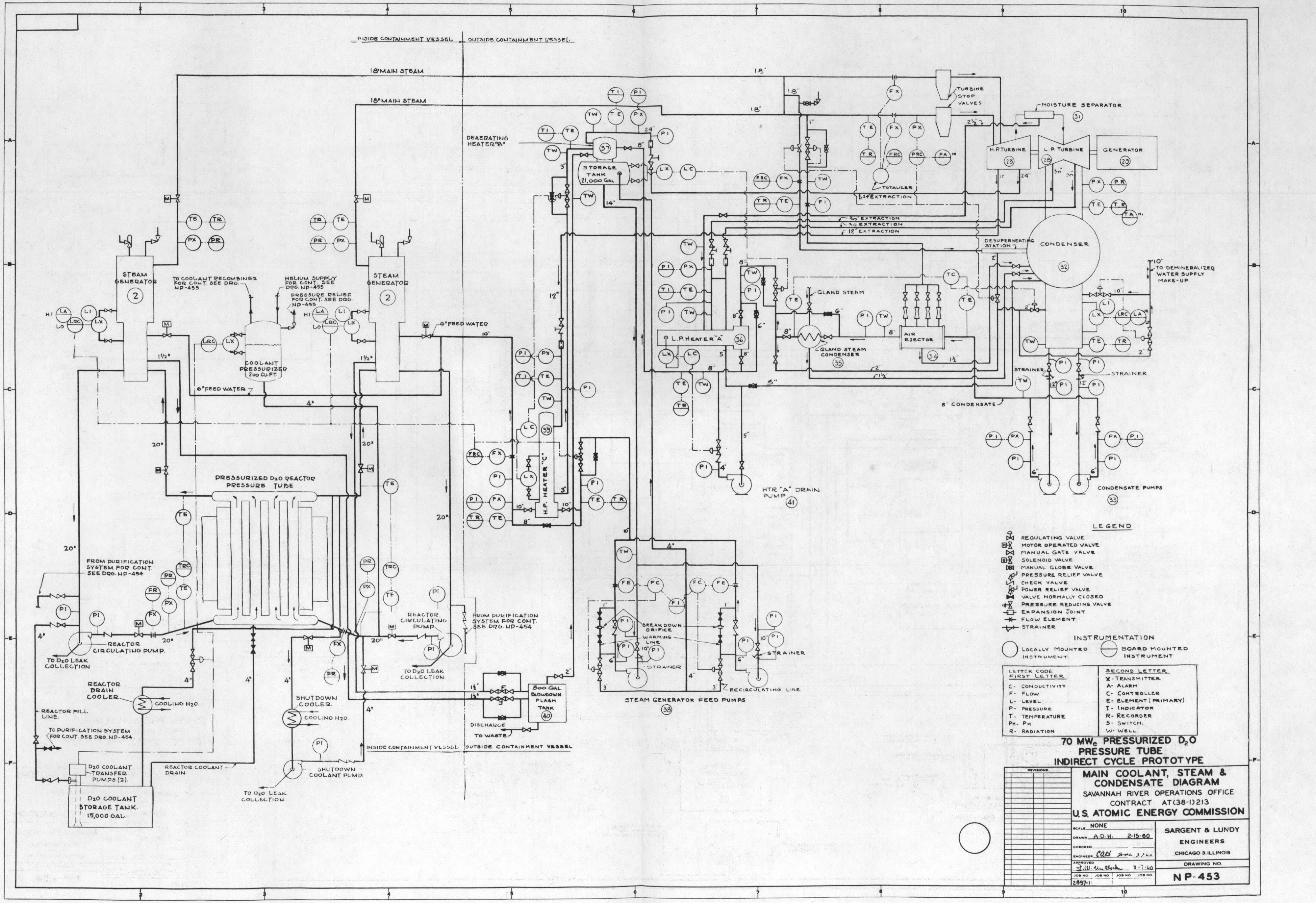
440V. M.C.C. 4

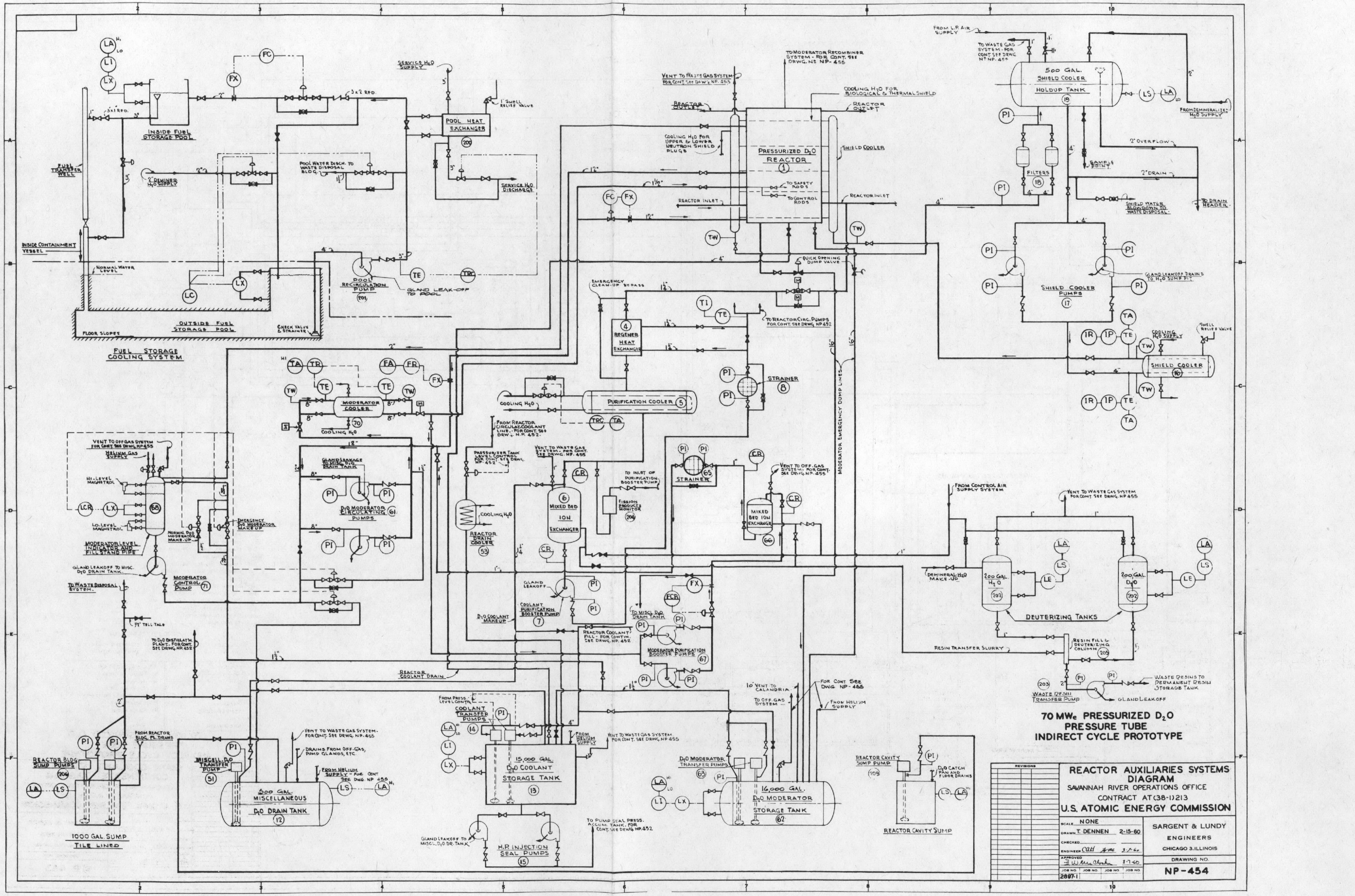
BRKR. RATING (AMP)	MOTOR RATING (H.P.)	SERVICE
15	2	CAUSTIC TRANSFER PUMP
15	2	ACID TRANSFER PUMP
20	5	BILGE PUMP 1
20	5	BILGE PUMP 2
50	20	TREATED WATER TRANSFER PUMP
15	3/4	AGITATOR 1
15	3/4	AGITATOR 2
50	12 KW	CHLORIN. EVAPORAT.
70	25	VENTILATING UNIT 1 (TURB. RM.)
70	25	VENTILATING UNIT 2 (TURB. RM.)
70	25	VENTILATING UNIT 3 (TURB. RM.)


480V. SW. GR. 12
2-PTS. 480-120V
CONT. BD.
BRKR. RATING (AMP.) 1600 1200 225 225 225 225 225 125 70 70 125 70
MOTOR RATING (H.P.) 30KVA 15 35 30 50 40
SERVICE: AUX. TRANSFORMER 2400-480V. / BUS TIE TO SW. GR. 11 / REACTOR M.C.C. 2 / REACTOR M.C.C. 1 / REACTOR M.C.C. 3 / 440V. RECEPT. / LTG. FEED / AIR COND. COMPR. / MN. PWR. TRANSF. AUX. RES. FD. / REFUELING VEHICLE / SERVICE CRANE / VENTILATING UNIT 3
REACTOR 440V. M.C.C. 1
BRKR. RATING (AMP.) 15 15 20 15 20 70 50 15 15
MOTOR RATING (H.P.) 1 1 5 1 3 25 15 3 2
SERVICE: REACTOR CAVITY EXHAUSTER 1 / D2O COOL. TRANSFER PUMP 1 / SUMP PUMP 1 / REACTOR CIRC. PUMP AUX. OIL PUMP 1 / SPARE / ADSORBER BLOWER / VENTILATING UNIT 1 / SPARE / EXHAUST FAN 1 / VENT GAS DRYER / REACTOR CAVITY DRYER
REACTOR 440V. M.C.C. 3
BRKR. RATING (AMP.) 30 15 40 15 15 15 50 20 70 20 20 20
MOTOR RATING (H.P.) 7½ 3 10 3 1 3 20 5 20KW 5 5 5
SERVICE: ELEVATOR / SERV. WTR. INLET VALVE TO SHIELD COOLER / SHIELD COOLER PUMP 1 / SERV. WTR. OUTLET VALVE TO SHIELD COOLER / RADIOACTIVE GAS COMPR. / SPENT FUEL TRANSFER DRIVE / H.P. INJECTION SEAL PUMP / REACTOR CHILLED WATER CIRC. PUMP / REACTOR PLANT BATTERY CHARGER / VENTILATING UNIT 3 / VENTILATING UNIT 4 / SPARE / RECOV. REFRIG. COMPR.
REACTOR 440V. M.C.C. 2
BRKR. RATING (AMP.) 15 15 15 20 15 20 30 70 15
MOTOR RATING (H.P.) 1 3 1 5 1 3 10 25 1
SERVICE: REACTOR CAVITY EXHAUSTER 2 / EXHAUST FAN 2 / D2O COOL. TRANSFER PUMP 2 / SUMP PUMP 2 / REACTOR CIRC. PUMP AUX. OIL PUMP 2 / ADSORBER BLOWER 2 / SPARE / PURIF. BOOSTER PUMP / VENTILATING UNIT 2 / SURGE TANK TRANSFER PUMP
TO EMERG. 480V. SW. GR.
440V. REACTOR PLANT EMERG. M.C.C.
BRKR. RATING (AMP.) 15 40 30 70
MOTOR RATING (H.P.) 1 10/2½ 5KVA 25
SERVICE: EXHAUST AIR MONITOR BLOWER / SHIELD COOLER PUMP 2 / MISC. 115V SUPPLY / DECAY HEAT PUMP
440V. CONTROL ROD M.C.C. 1 (SAFETY RODS)
(4 TO 17) SAME AS OTHER CONTROLLERS SHOWN
GROUP CONT. SW.
SELECTOR SWITCH
CONTROL SWITCH
TO OTHER ROD CONTROLLERS
TO SELECTOR SWITCH
BRKR. RATING (AMP.) 15 15 15 15 15 15
MOTOR RATING (H.P.) ⅓ ⅓ ⅓ ⅓ ⅓ ⅓
SERVICE: SAFETY ROD MOTOR 1 / SAFETY ROD MOTOR 2 / SAFETY ROD MOTOR 3 / SAFETY ROD MOTOR 18 / SAFETY ROD MOTOR 19 / SOURCE MOTOR
TO EMERG. 480V. SW. GR.
440V. CONTROL ROD M.C.C. 2 (SHIM & REGULATING RODS)
SEL. SW.
BRKR. RATING (AMP.) 15 (each)
MOTOR RATING (H.P.) ⅓ (each)
SERVICE: SHIM ROD MOTOR 1 / SHIM ROD MOTOR 2 / SHIM ROD MOTOR 3 / SHIM ROD MOTOR 4 / SHIM ROD MOTOR 5 / SHIM ROD MOTOR 6 / SHIM ROD MOTOR 7 / SHIM ROD MOTOR 8 / SHIM ROD MOTOR 9 / SHIM ROD MOTOR 10 / SHIM ROD MOTOR 11 / SHIM ROD MOTOR 12 / SHIM ROD MOTOR 13 / SHIM ROD MOTOR 14 / SHIM ROD MOTOR 15 / SHIM ROD MOTOR 16 / SHIM ROD MOTOR 17 / REGUL. ROD MOTOR 1 / REGUL. ROD MOTOR 2
70 MWe PRESSURIZED D2O
PRESSURE VESSEL
INDIRECT CYCLE PROTOTYPE
REVISIONS
KEY DIAGRAM
REACTOR PLANT AUXILIARIES
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN J. J. TALAMO 2-15-60
CHECKED
ENGINEER
APPROVED
JOB NO. 2897-1
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-451

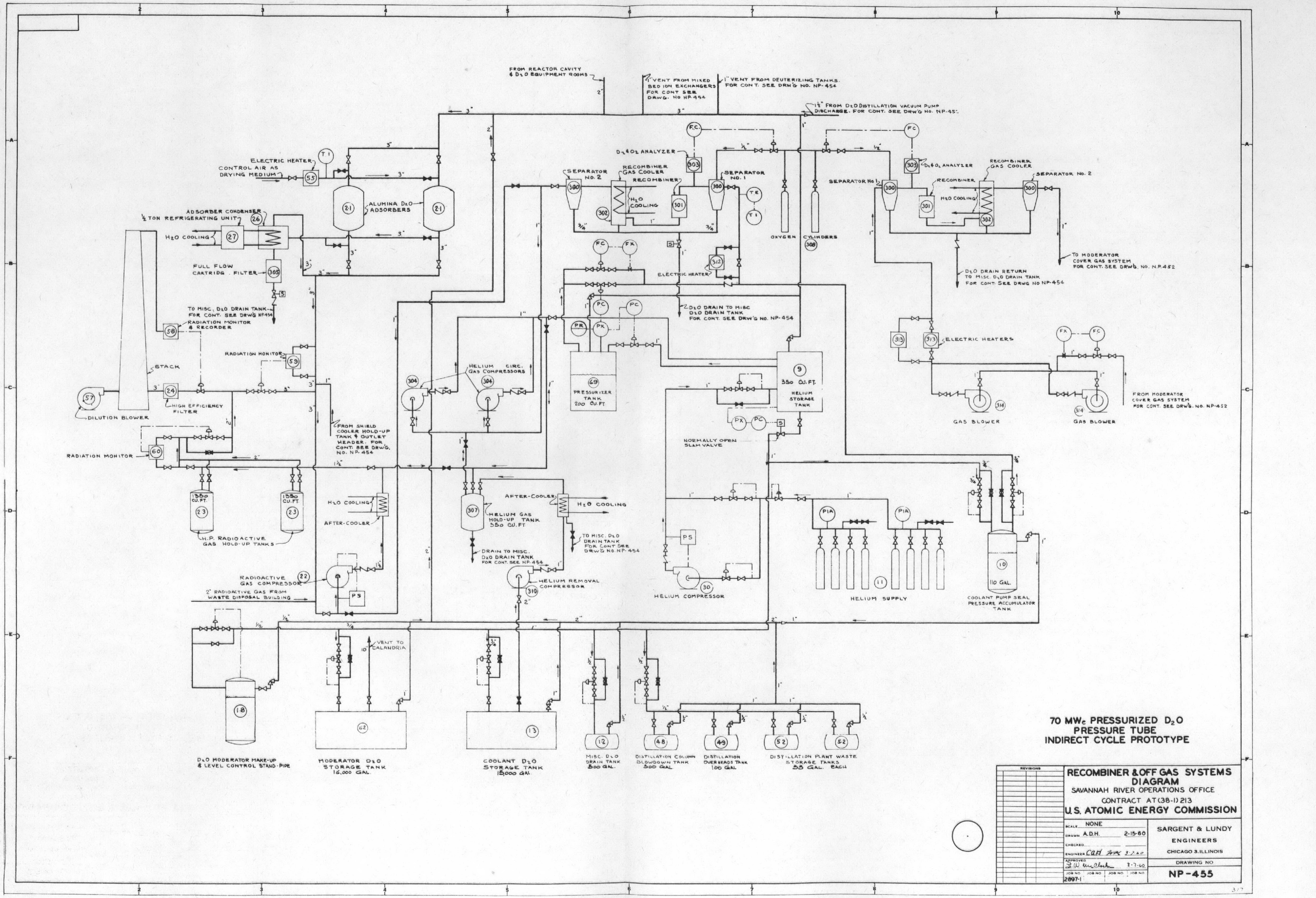


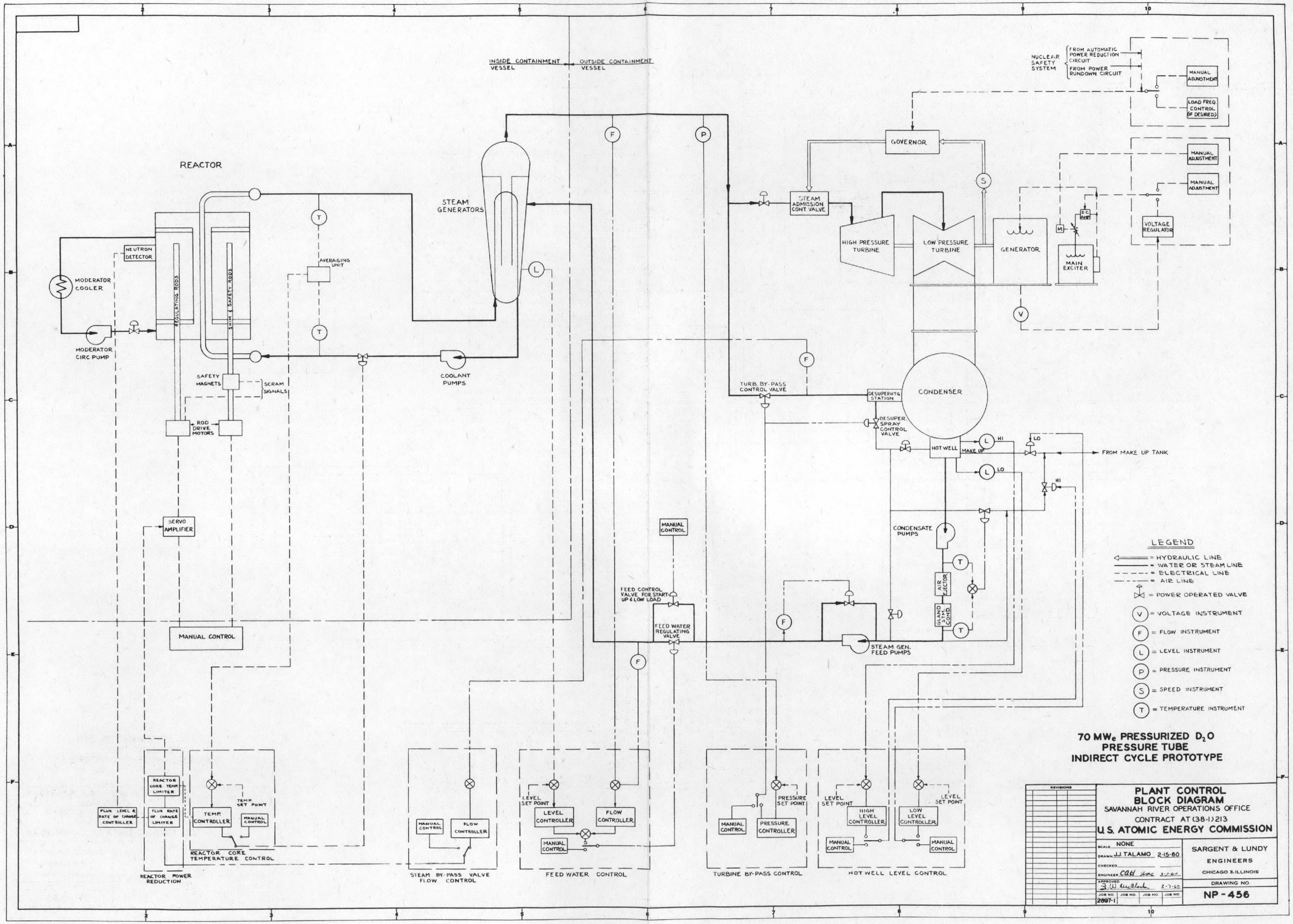
OUTSIDE CONTAINMENT VESSEL
INSIDE CONTAINMENT VESSEL
OUTSIDE CONTAINMENT VESSEL
MAIN STEAM
H.P. TURB.
L.P. TURB.
GENERATOR 69.8 M.W.
CONDENSER
PRESSURE TUBE REACTOR
D2O MODERATOR STORAGE TANK
D2O COOLANT STORAGE TANK
BLOWDOWN FLASH TANK
EMERGENCY DRAIN LINE
No.1 DIST. COLUMN
No.2 DIST. COLUMN
INSIDE CONTAINMENT VESSEL
OUTSIDE CONTAINMENT VESSEL
70 MWe PRESSURIZED D2O PRESSURE TUBE INDIRECT CYCLE PROTOTYPE
COMPOSITE FLOW DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1)213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN A. JOHNSEN 2-15-60
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-452


INSIDE CONTAINMENT VESSEL
OUTSIDE CONTAINMENT VESSEL
18" MAIN STEAM
TURBINE STOP VALVES
MOISTURE SEPARATOR
H.P. TURBINE
L.P. TURBINE
GENERATOR
DEAERATING HEATER "B"
STORAGE TANK 21,000 GAL
CONDENSER
DESUPERHEATING STATION
TO DEMINERALIZED WATER SUPPLY MAKE-UP
GLAND STEAM
GLAND STEAM CONDENSER
AIR EJECTOR
L.P. HEATER "A"
H.P. HEATER "C"
8" CONDENSATE
STRAINER
CONDENSATE PUMPS
HTR "A" DRAIN PUMP
STEAM GENERATOR
TO COOLANT RECOMBINER FOR CONT. SEE DRG. NP-455
HELIUM SUPPLY FOR CONT. SEE DRG. NP-455
PRESSURE RELIEF FOR CONT. SEE DRG. NP-455
COOLANT PRESSURIZER 200 CU.FT.
6" FEED WATER
PRESSURIZED D2O REACTOR PRESSURE TUBE
FROM PURIFICATION SYSTEM FOR CONT. SEE DRG. NP-454
REACTOR CIRCULATING PUMP
TO D2O LEAK COLLECTION
REACTOR DRAIN COOLER
COOLING H2O
REACTOR FILL LINE
TO PURIFICATION SYSTEM FOR CONT. SEE DRG. NP-454
D2O COOLANT TRANSFER PUMPS (2)
D2O COOLANT STORAGE TANK 15,000 GAL.
REACTOR COOLANT DRAIN
SHUTDOWN COOLER
SHUTDOWN COOLANT PUMP
500 GAL BLOWDOWN FLASH TANK
DISCHARGE TO WASTE
BREAKDOWN ORIFICE
WARMING LINE
RECIRCULATING LINE
STEAM GENERATOR FEED PUMPS
LEGEND
REGULATING VALVE
MOTOR OPERATED VALVE
MANUAL GATE VALVE
SOLENOID VALVE
MANUAL GLOBE VALVE
PRESSURE RELIEF VALVE
CHECK VALVE
POWER RELIEF VALVE
VALVE NORMALLY CLOSED
PRESSURE REDUCING VALVE
EXPANSION JOINT
FLOW ELEMENT
STRAINER
INSTRUMENTATION
LOCALLY MOUNTED INSTRUMENT
BOARD MOUNTED INSTRUMENT
LETTER CODE FIRST LETTER
C- CONDUCTIVITY
F- FLOW
L- LEVEL
P- PRESSURE
T- TEMPERATURE
PH- PH
R- RADIATION
SECOND LETTER
X- TRANSMITTER
A- ALARM
C- CONTROLLER
E- ELEMENT (PRIMARY)
I- INDICATOR
R- RECORDER
S- SWITCH.
W- WELL
70 MWe PRESSURIZED D2O PRESSURE TUBE INDIRECT CYCLE PROTOTYPE
REVISIONS
MAIN COOLANT, STEAM & CONDENSATE DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1)213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN A.D.H. 2-15-60
CHECKED
ENGINEER CAH 3-7-60
APPROVED 3-7-60
JOB NO. 2897-1
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-453

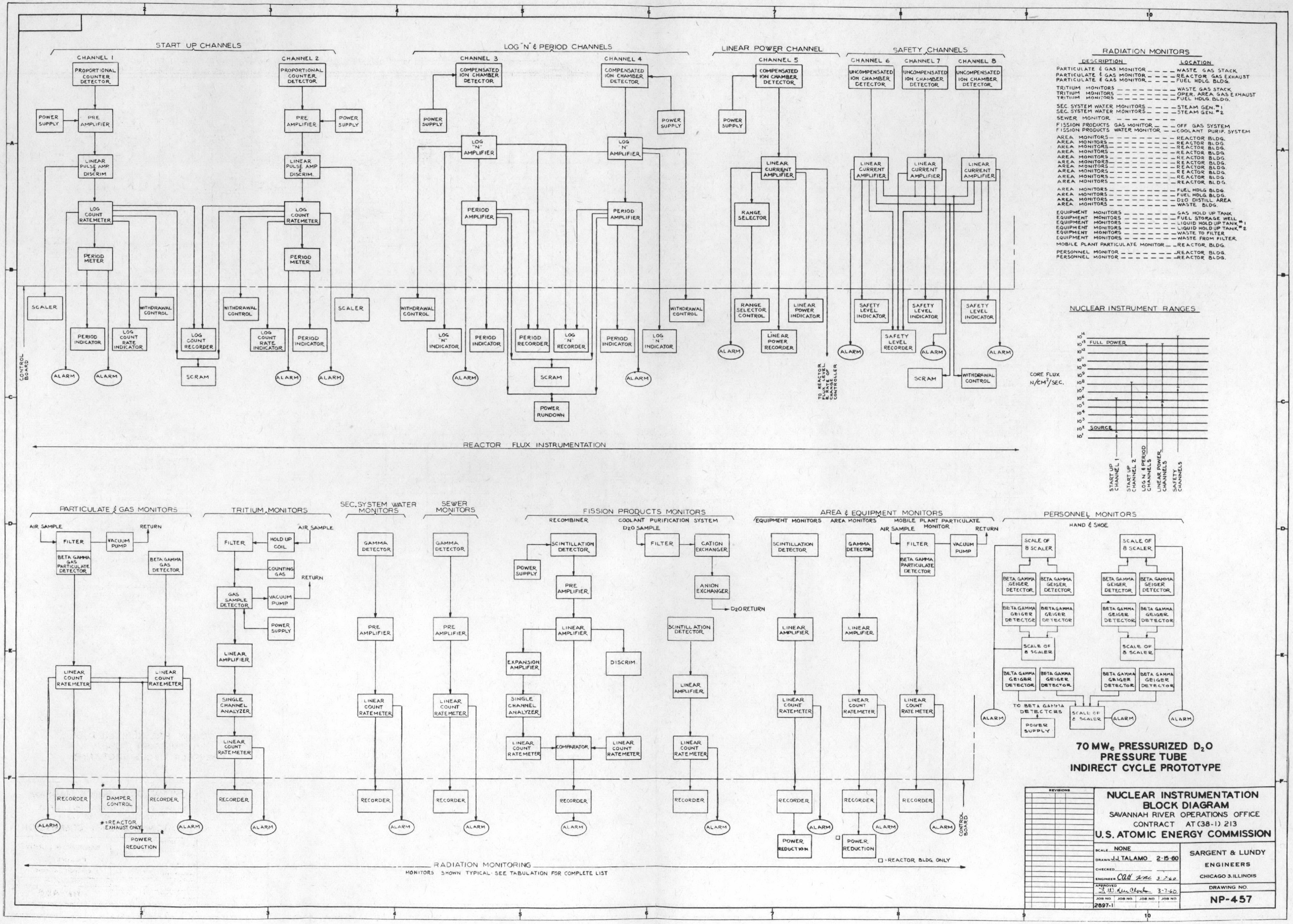


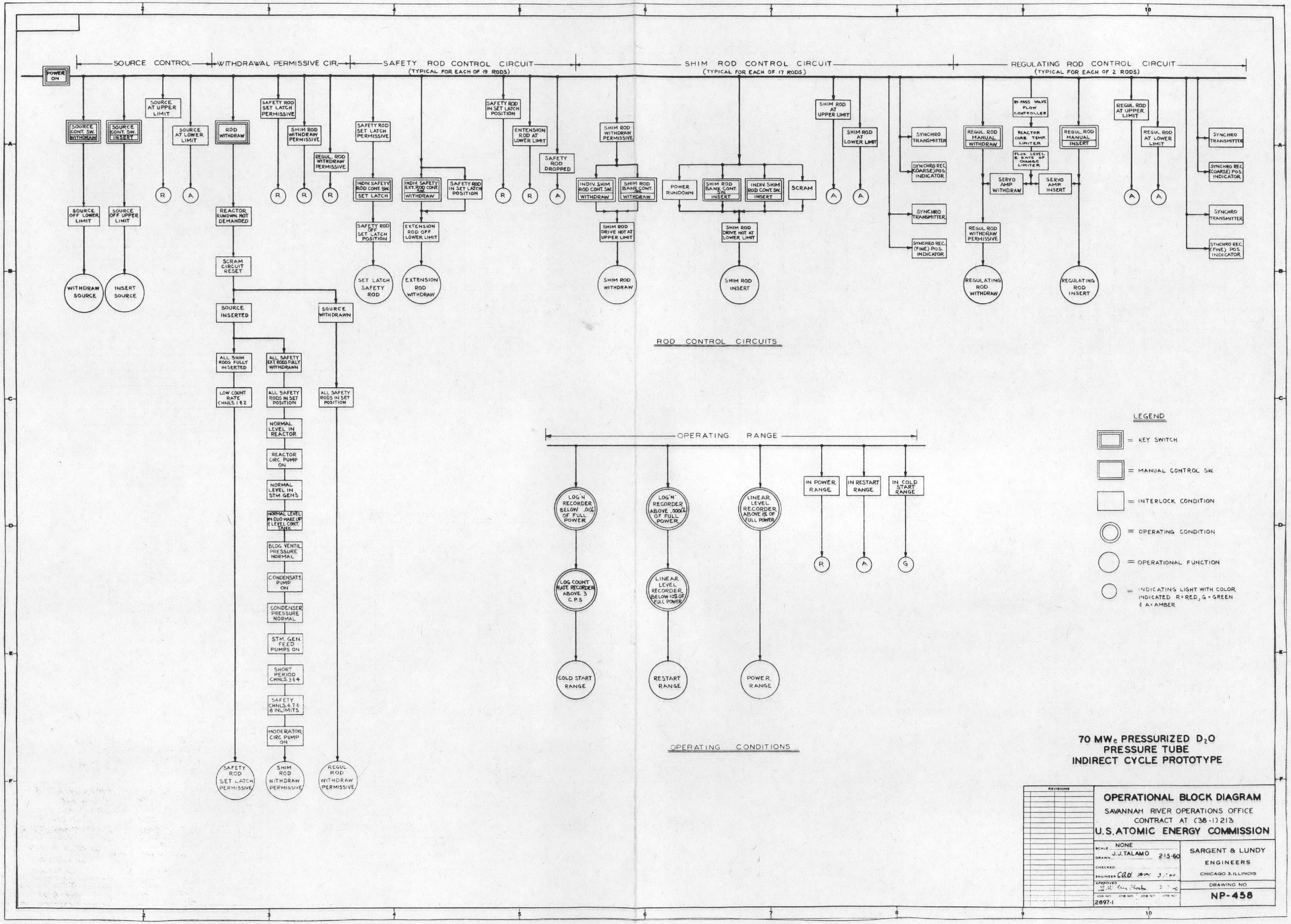
70 MWe PRESSURIZED D_2O
PRESSURE TUBE
INDIRECT CYCLE PROTOTYPE
REACTOR AUXILIARIES SYSTEMS
DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1)213
U.S. ATOMIC ENERGY COMMISSION
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
SCALE NONE
DRAWN T. DENNEN 2-15-60
DRAWING NO.
NP-454
2897-1
PRESSURIZED D_2O REACTOR 1
SHIELD COOLER
500 GAL. SHIELD COOLER HOLDUP TANK 19
FILTERS 18
SHIELD COOLER PUMPS 17
SHIELD COOLER 16
POOL HEAT EXCHANGER 200
INSIDE FUEL STORAGE POOL
OUTSIDE FUEL STORAGE POOL
FUEL STORAGE COOLING SYSTEM
POOL RECIRCULATION PUMP 201
FUEL TRANSFER WELL
MODERATOR COOLER 70
D_2O MODERATOR CIRCULATING PUMPS 61
MODERATOR CONTROL PUMP 71
REGENER HEAT EXCHANGER 4
PURIFICATION COOLER 5
STRAINER 8
STRAINER 65
MIXED BED ION EXCHANGER 6
MIXED BED ION EXCHANGER 66
REACTOR DRAIN COOLER 53
COOLANT PURIFICATION BOOSTER PUMP 7
MODERATOR PURIFICATION BOOSTER PUMPS 67
FISSION PRODUCTS MONITOR 204
DEUTERIZING TANKS
200 GAL. H_2O 202
200 GAL. D_2O 202
RESIN FILL & DEUTERIZING COLUMN 205
WASTE RESIN TRANSFER PUMP 203
REACTOR BLDG. SUMP PUMPS 206
1000 GAL SUMP TILE LINED
MISCELL. D_2O TRANSFER PUMP 51
500 GAL. MISCELLANEOUS D_2O DRAIN TANK 12
COOLANT TRANSFER PUMPS 14
15,000 GAL. D_2O COOLANT STORAGE TANK 13
H.P. INJECTION SEAL PUMPS 15
D_2O MODERATOR TRANSFER PUMPS 63
16,000 GAL. D_2O MODERATOR STORAGE TANK 62
REACTOR CAVITY SUMP PUMP 109
REACTOR CAVITY SUMP
MODERATOR EMERGENCY DUMP LINES


FROM REACTOR CAVITY & D2O EQUIPMENT ROOMS
1" VENT FROM MIXED BED ION EXCHANGERS FOR CONT. SEE DRWG. NO. NP-454
1" VENT FROM DEUTERIZING TANKS. FOR CONT. SEE DRW'G NO. NP-454
1½" FROM D2O DISTILLATION VACUUM PUMP DISCHARGE. FOR CONT. SEE DRW'G NO. NP-45
ELECTRIC HEATER
CONTROL AIR AS DRYING MEDIUM
ALUMINA D2O ADSORBERS
ADSORBER CONDENSER
½ TON REFRIGERATING UNIT
H2O COOLING
FULL FLOW CARTRIDG. FILTER
TO MISC. D2O DRAIN TANK. FOR CONT. SEE DRWG NP-454
RADIATION MONITOR & RECORDER
RADIATION MONITOR
STACK
HIGH EFFICIENCY FILTER
DILUTION BLOWER
RADIATION MONITOR
1500 CU.FT.
H.P. RADIOACTIVE GAS HOLD-UP TANKS
FROM SHIELD COOLER HOLD-UP TANK & OUTLET HEADER. FOR CONT. SEE DRWG. NO. NP-454
H2O COOLING
AFTER-COOLER
RADIOACTIVE GAS COMPRESSOR
2" RADIOACTIVE GAS FROM WASTE DISPOSAL BUILDING
D2O MODERATOR MAKE-UP & LEVEL CONTROL STAND-PIPE
MODERATOR D2O STORAGE TANK 16,000 GAL.
VENT TO CALANDRIA
HELIUM CIRC. GAS COMPRESSORS
AFTER-COOLER
H2O COOLING
HELIUM GAS HOLD-UP TANK 350 CU. FT
DRAIN TO MISC. D2O DRAIN TANK FOR CONT. SEE NP-454
TO MISC. D2O DRAIN TANK FOR CONT SEE DRW'G NO. NP-454
HELIUM REMOVAL COMPRESSOR
COOLANT D2O STORAGE TANK 15,000 GAL
SEPARATOR NO. 2
RECOMBINER GAS COOLER
RECOMBINER
D2 & O2 ANALYZER
SEPARATOR NO. 1
H2O COOLING
OXYGEN CYLINDERS
ELECTRIC HEATER
D2O DRAIN TO MISC D2O DRAIN TANK FOR CONT. SEE DRW'G NO. NP-454
PRESSURIZER TANK 200 CU. FT.
350 CU. FT. HELIUM STORAGE TANK
NORMALLY OPEN SLAM VALVE
HELIUM COMPRESSOR
HELIUM SUPPLY
COOLANT PUMP SEAL PRESSURE ACCUMULATOR TANK
110 GAL.
MISC. D2O DRAIN TANK 800 GAL.
DISTILLATION COLUMN BLOWDOWN TANK 500 GAL
DISTILLATION OVERHEADS TANK 100 GAL
DISTILLATION PLANT WASTE STORAGE TANKS 55 GAL. EACH
SEPARATOR No 1
D2 & O2 ANALYZER
RECOMBINER GAS COOLER
RECOMBINER
SEPARATOR NO. 2
H2O COOLING
TO MODERATOR COVER GAS SYSTEM FOR CONT. SEE DRWG. NO. NP-452
D2O DRAIN RETURN TO MISC. D2O DRAIN TANK FOR CONT. SEE DRWG NO NP-454
ELECTRIC HEATERS
GAS BLOWER
GAS BLOWER
FROM MODERATOR COVER GAS SYSTEM FOR CONT. SEE DRWG. NO. NP-452
70 MWe PRESSURIZED D2O PRESSURE TUBE INDIRECT CYCLE PROTOTYPE
REVISIONS
RECOMBINER & OFF GAS SYSTEMS DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN A.D.H. 2-15-60
CHECKED
ENGINEER
APPROVED
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO
NP-455
2897-1

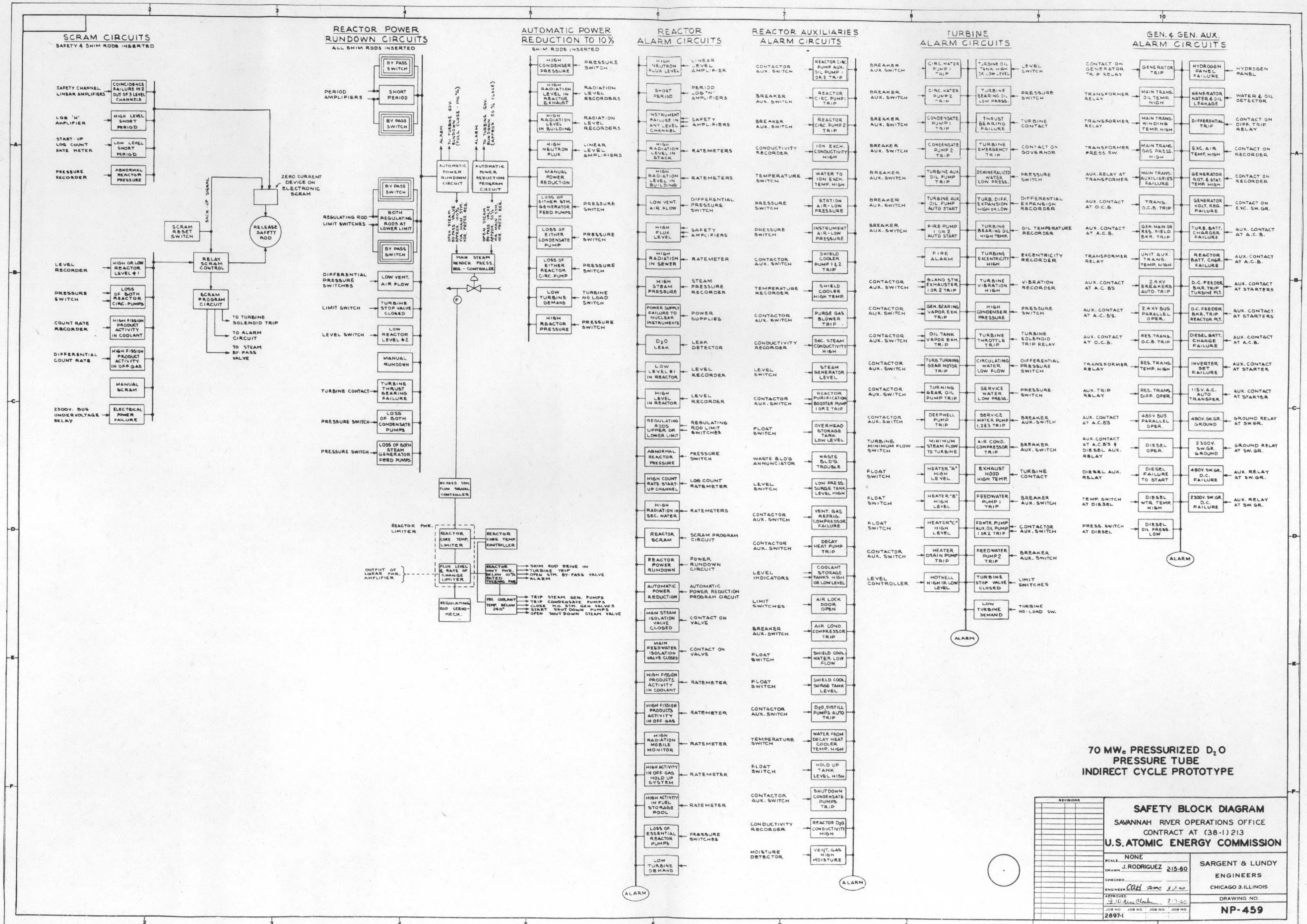


INSIDE CONTAINMENT VESSEL
OUTSIDE CONTAINMENT VESSEL
REACTOR
NEUTRON DETECTOR
MODERATOR COOLER
MODERATOR CIRC PUMP
REGULATING RODS
SHIM & SAFETY RODS
AVERAGING UNIT
STEAM GENERATORS
COOLANT PUMPS
SAFETY MAGNETS
SCRAM SIGNALS
ROD DRIVE MOTORS
SERVO AMPLIFIER
MANUAL CONTROL
NUCLEAR SAFETY SYSTEM
FROM AUTOMATIC POWER REDUCTION CIRCUIT
FROM POWER RUNDOWN CIRCUIT
MANUAL ADJUSTMENT
LOAD FREQ CONTROL (IF DESIRED)
GOVERNOR
STEAM ADMISSION CONT VALVE
HIGH PRESSURE TURBINE
LOW PRESSURE TURBINE
GENERATOR
MAIN EXCITER
VOLTAGE REGULATOR
CONDENSER
TURB. BY-PASS CONTROL VALVE
DESUPERHTG STATION
DESUPER SPRAY CONTROL VALVE
HOT WELL
MAKE UP
FROM MAKE UP TANK
HI
LO
CONDENSATE PUMPS
AIR EJECTOR
GLAND STM COND
STEAM GEN. FEED PUMPS
FEED CONTROL VALVE FOR START-UP & LOW LOAD
FEED WATER REGULATING VALVE
LEGEND
= HYDRAULIC LINE
= WATER OR STEAM LINE
= ELECTRICAL LINE
= AIR LINE
= POWER OPERATED VALVE
= VOLTAGE INSTRUMENT
= FLOW INSTRUMENT
= LEVEL INSTRUMENT
= PRESSURE INSTRUMENT
= SPEED INSTRUMENT
= TEMPERATURE INSTRUMENT
70 MWe PRESSURIZED D2O PRESSURE TUBE INDIRECT CYCLE PROTOTYPE
FLUX LEVEL & RATE OF CHANGE CONTROLLER
REACTOR CORE TEMP LIMITER
FLUX RATE OF CHANGE LIMITER
TEMP. CONTROLLER
TEMP SET POINT
MANUAL CONTROL
REACTOR CORE TEMPERATURE CONTROL
REACTOR POWER REDUCTION
FLOW CONTROLLER
STEAM BY-PASS VALVE FLOW CONTROL
LEVEL SET POINT
LEVEL CONTROLLER
FEED WATER CONTROL
PRESSURE SET POINT
PRESSURE CONTROLLER
TURBINE BY-PASS CONTROL
HIGH LEVEL CONTROLLER
LOW LEVEL CONTROLLER
HOT WELL LEVEL CONTROL
REVISIONS
PLANT CONTROL BLOCK DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN J.J. TALAMO 2-15-60
CHECKED
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-456
JOB NO. 2897-1

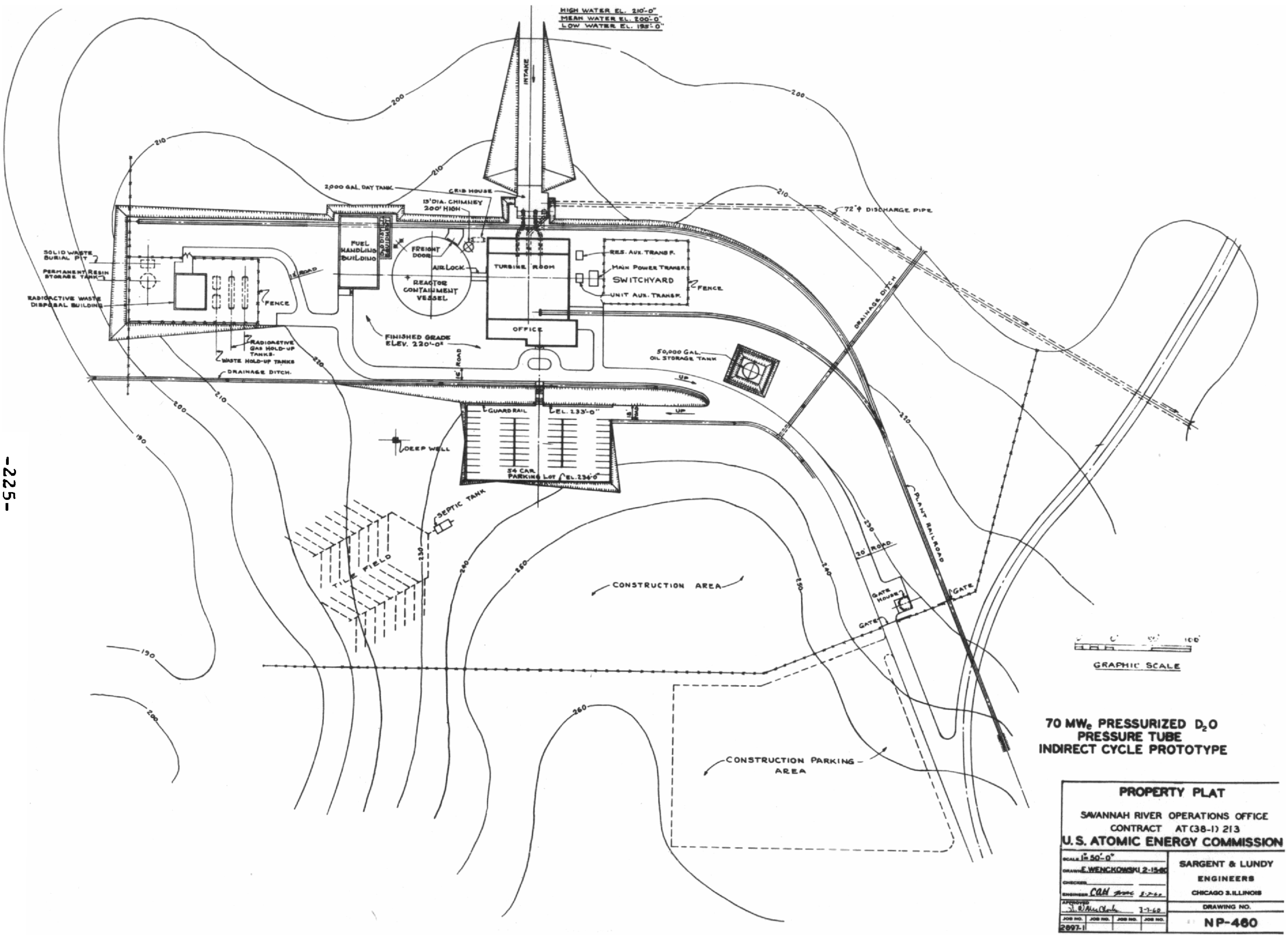

START UP CHANNELS
CHANNEL 1
CHANNEL 2
PROPORTIONAL COUNTER DETECTOR
POWER SUPPLY
PRE AMPLIFIER
LINEAR PULSE AMP & DISCRIM
LOG COUNT RATEMETER
PERIOD METER
SCALER
WITHDRAWAL CONTROL
PERIOD INDICATOR
LOG COUNT RATE INDICATOR
LOG COUNT RECORDER
SCRAM
ALARM
LOG "N" & PERIOD CHANNELS
CHANNEL 3
CHANNEL 4
COMPENSATED ION CHAMBER DETECTOR
LOG "N" AMPLIFIER
PERIOD AMPLIFIER
LOG "N" INDICATOR
PERIOD RECORDER
LOG "N" RECORDER
POWER RUNDOWN
LINEAR POWER CHANNEL
CHANNEL 5
LINEAR CURRENT AMPLIFIER
RANGE SELECTOR
RANGE SELECTOR CONTROL
LINEAR POWER INDICATOR
LINEAR POWER RECORDER
TO REACTOR & RATE OF STEAM GENERATOR CONTROLLER
SAFETY CHANNELS
CHANNEL 6
CHANNEL 7
CHANNEL 8
UNCOMPENSATED ION CHAMBER DETECTOR
SAFETY LEVEL INDICATOR
SAFETY LEVEL RECORDER
CONTROL BOARD
REACTOR FLUX INSTRUMENTATION
RADIATION MONITORS
DESCRIPTION
LOCATION
PARTICULATE & GAS MONITOR — WASTE GAS STACK
PARTICULATE & GAS MONITOR — REACTOR GAS EXHAUST
PARTICULATE & GAS MONITOR — FUEL HDLG. BLDG.
TRITIUM MONITORS — WASTE GAS STACK
TRITIUM MONITORS — OPER. AREA GAS EXHAUST
TRITIUM MONITORS — FUEL HDLG. BLDG.
SEC. SYSTEM WATER MONITORS — STEAM GEN. #1
SEC. SYSTEM WATER MONITORS — STEAM GEN. #2
SEWER MONITOR
FISSION PRODUCTS GAS MONITOR — OFF GAS SYSTEM
FISSION PRODUCTS WATER MONITOR — COOLANT PURIF. SYSTEM
AREA MONITORS — REACTOR BLDG.
AREA MONITORS — FUEL HDLG. BLDG.
AREA MONITORS — D2O DISTILL AREA
AREA MONITORS — WASTE BLDG.
EQUIPMENT MONITORS — GAS HOLD UP TANK
EQUIPMENT MONITORS — FUEL STORAGE WELL
EQUIPMENT MONITORS — LIQUID HOLD UP TANK #1
EQUIPMENT MONITORS — LIQUID HOLD UP TANK #2
EQUIPMENT MONITORS — WASTE TO FILTER
EQUIPMENT MONITORS — WASTE FROM FILTER
MOBILE PLANT PARTICULATE MONITOR — REACTOR BLDG.
PERSONNEL MONITOR — REACTOR BLDG.
PERSONNEL MONITOR — REACTOR BLDG.
NUCLEAR INSTRUMENT RANGES
FULL POWER
SOURCE
CORE FLUX N/CM²/SEC.
START UP CHANNEL 1
START UP CHANNEL 2
LOG N & PERIOD CHANNELS
LINEAR POWER CHANNELS
SAFETY CHANNELS
PARTICULATE & GAS MONITORS
AIR SAMPLE
FILTER
VACUUM PUMP
RETURN
BETA GAMMA GAS PARTICULATE DETECTOR
BETA GAMMA GAS DETECTOR
LINEAR COUNT RATEMETER
RECORDER
DAMPER CONTROL
*=REACTOR EXHAUST ONLY
POWER REDUCTION
TRITIUM MONITORS
HOLD UP COIL
COUNTING GAS
GAS SAMPLE DETECTOR
LINEAR AMPLIFIER
SINGLE CHANNEL ANALYZER
SEC. SYSTEM WATER MONITORS
GAMMA DETECTOR
SEWER MONITORS
FISSION PRODUCTS MONITORS
RECOMBINER
COOLANT PURIFICATION SYSTEM
D2O SAMPLE
SCINTILLATION DETECTOR
CATION EXCHANGER
ANION EXCHANGER
D2O RETURN
EXPANSION AMPLIFIER
DISCRIM.
COMPARATOR
AREA & EQUIPMENT MONITORS
EQUIPMENT MONITORS
AREA MONITORS
MOBILE PLANT PARTICULATE MONITOR
BETA GAMMA PARTICULATE DETECTOR
□ =REACTOR BLDG. ONLY
PERSONNEL MONITORS
HAND & SHOE
SCALE OF 8 SCALER
BETA GAMMA GEIGER DETECTOR
TO BETA GAMMA DETECTORS
RADIATION MONITORING
MONITORS SHOWN TYPICAL. SEE TABULATION FOR COMPLETE LIST
70 MWe PRESSURIZED D2O PRESSURE TUBE INDIRECT CYCLE PROTOTYPE
REVISIONS
NUCLEAR INSTRUMENTATION BLOCK DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN J.J. TALAMO 2-15-60
CHECKED
ENGINEER
APPROVED
JOB NO. 2897-1
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-457



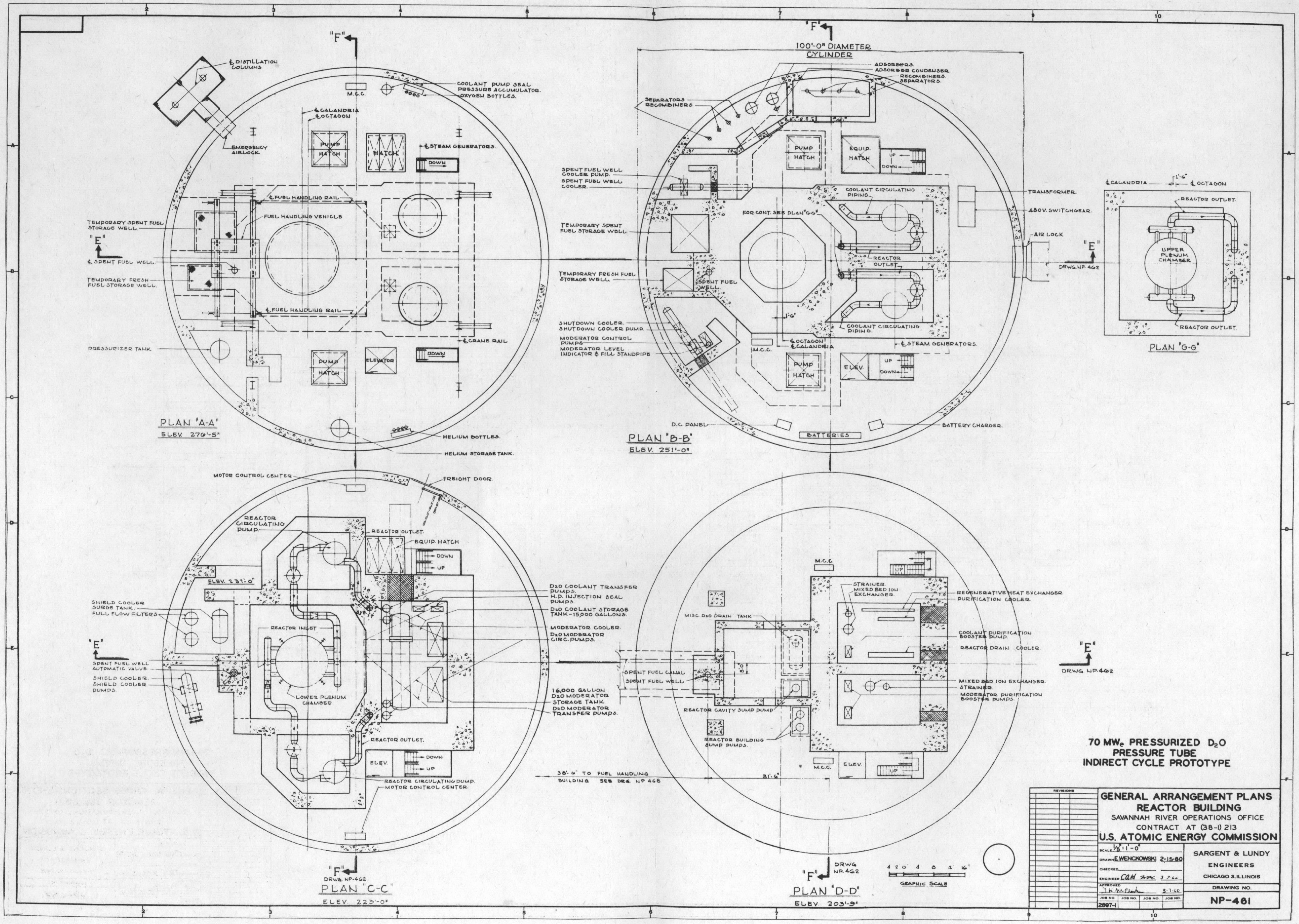
POWER ON
SOURCE CONTROL
WITHDRAWAL PERMISSIVE CIR.
SAFETY ROD CONTROL CIRCUIT
(TYPICAL FOR EACH OF 19 RODS)
SHIM ROD CONTROL CIRCUIT
(TYPICAL FOR EACH OF 17 RODS)
REGULATING ROD CONTROL CIRCUIT
(TYPICAL FOR EACH OF 2 RODS)
SOURCE CONT. SW. WITHDRAW
SOURCE CONT. SW. INSERT
SOURCE AT UPPER LIMIT
SOURCE AT LOWER LIMIT
SOURCE OFF LOWER LIMIT
SOURCE OFF UPPER LIMIT
WITHDRAW SOURCE
INSERT SOURCE
ROD WITHDRAW
REACTOR RUNDOWN NOT DEMANDED
SCRAM CIRCUIT RESET
SOURCE INSERTED
SOURCE WITHDRAWN
ALL SHIM RODS FULLY INSERTED
ALL SAFETY EXT. RODS FULLY WITHDRAWN
LOW COUNT RATE CHNLS. 1 & 2
ALL SAFETY RODS IN SET POSITION
NORMAL LEVEL IN REACTOR
REACTOR CIRC. PUMP ON
NORMAL LEVEL IN STM. GENS.
NORMAL LEVEL IN D_2O MAKE UP & LEVEL CONT. TANK
BLDG. VENTIL. PRESSURE NORMAL
CONDENSATE PUMP ON
CONDENSER PRESSURE NORMAL
STM. GEN. FEED PUMPS ON
SHORT PERIOD CHNLS. 3 & 4
SAFETY CHNLS. 6, 7, 8 IN LIMITS
MODERATOR CIRC. PUMP ON
SAFETY ROD SET LATCH PERMISSIVE
SHIM ROD WITHDRAW PERMISSIVE
REGUL. ROD WITHDRAW PERMISSIVE
SAFETY ROD SET LATCH PERMISSIVE
INDIV. SAFETY ROD CONT. SW. SET LATCH
SAFETY ROD OFF SET LATCH POSITION
SET LATCH SAFETY ROD
INDIV. SAFETY EXT. ROD CONT. SW. WITHDRAW
SAFETY ROD IN SET LATCH POSITION
EXTENSION ROD OFF LOWER LIMIT
EXTENSION ROD WITHDRAW
EXTENSION ROD AT LOWER LIMIT
SAFETY ROD DROPPED
SHIM ROD WITHDRAW PERMISSIVE
INDIV. SHIM ROD CONT. SW. WITHDRAW
SHIM ROD BANK CONT. SW. WITHDRAW
SHIM ROD DRIVE NOT AT UPPER LIMIT
SHIM ROD WITHDRAW
POWER RUNDOWN
SHIM ROD BANK CONT. SW. INSERT
INDIV. SHIM ROD CONT. SW. INSERT
SCRAM
SHIM ROD DRIVE NOT AT LOWER LIMIT
SHIM ROD INSERT
SHIM ROD AT UPPER LIMIT
SHIM ROD AT LOWER LIMIT
SYNCHRO TRANSMITTER
SYNCHRO REC. (COARSE) POS. INDICATOR
SYNCHRO REC. (FINE) POS. INDICATOR
REGUL. ROD MANUAL WITHDRAW
BY-PASS VALVE FLOW CONTROLLER
REACTOR CORE TEMP. LIMITER
FLUX LEVEL & RATE OF CHANGE LIMITER
REGUL. ROD MANUAL INSERT
SERVO AMP WITHDRAW
SERVO AMP INSERT
REGUL. ROD WITHDRAW PERMISSIVE
REGULATING ROD WITHDRAW
REGULATING ROD INSERT
REGUL. ROD AT UPPER LIMIT
REGUL. ROD AT LOWER LIMIT
R
A
G
ROD CONTROL CIRCUITS
OPERATING RANGE
LOG N RECORDER BELOW .01% OF FULL POWER
LOG COUNT RATE RECORDER ABOVE 3 C.P.S.
COLD START RANGE
LOG N RECORDER ABOVE .001% OF FULL POWER
LINEAR LEVEL RECORDER BELOW 10% OF FULL POWER
RESTART RANGE
LINEAR LEVEL RECORDER ABOVE 1% OF FULL POWER
POWER RANGE
IN POWER RANGE
IN RESTART RANGE
IN COLD START RANGE
OPERATING CONDITIONS
LEGEND
= KEY SWITCH
= MANUAL CONTROL SW.
= INTERLOCK CONDITION
= OPERATING CONDITION
= OPERATIONAL FUNCTION
= INDICATING LIGHT WITH COLOR INDICATED R = RED, G = GREEN & A = AMBER
70 MW_e PRESSURIZED D_2O PRESSURE TUBE INDIRECT CYCLE PROTOTYPE
REVISIONS
OPERATIONAL BLOCK DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN J.J. TALAMO 2-15-60
CHECKED
ENGINEER
APPROVED
JOB NO. 2897-1
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-458



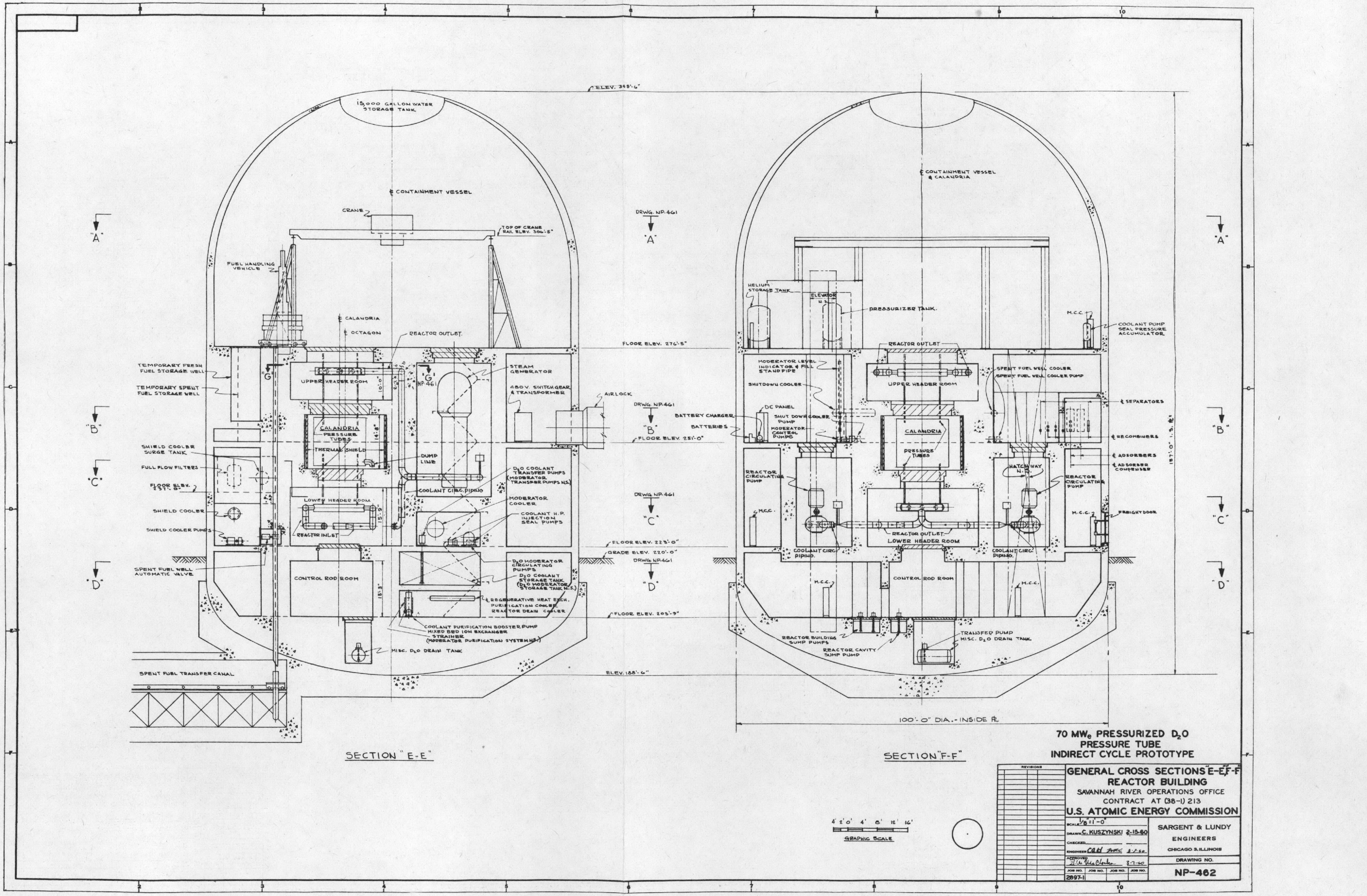
SCRAM CIRCUITS
SAFETY & SHIM RODS INSERTED
REACTOR POWER RUNDOWN CIRCUITS
ALL SHIM RODS INSERTED
AUTOMATIC POWER REDUCTION TO 10%
SHIM RODS INSERTED
REACTOR ALARM CIRCUITS
REACTOR AUXILIARIES ALARM CIRCUITS
TURBINE ALARM CIRCUITS
GEN. & GEN. AUX. ALARM CIRCUITS
ALARM
70 MWe PRESSURIZED D2O PRESSURE TUBE INDIRECT CYCLE PROTOTYPE
SAFETY BLOCK DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1)213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN J. RODRIGUEZ 2-15-60
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO. NP-459
JOB NO. 2897-1



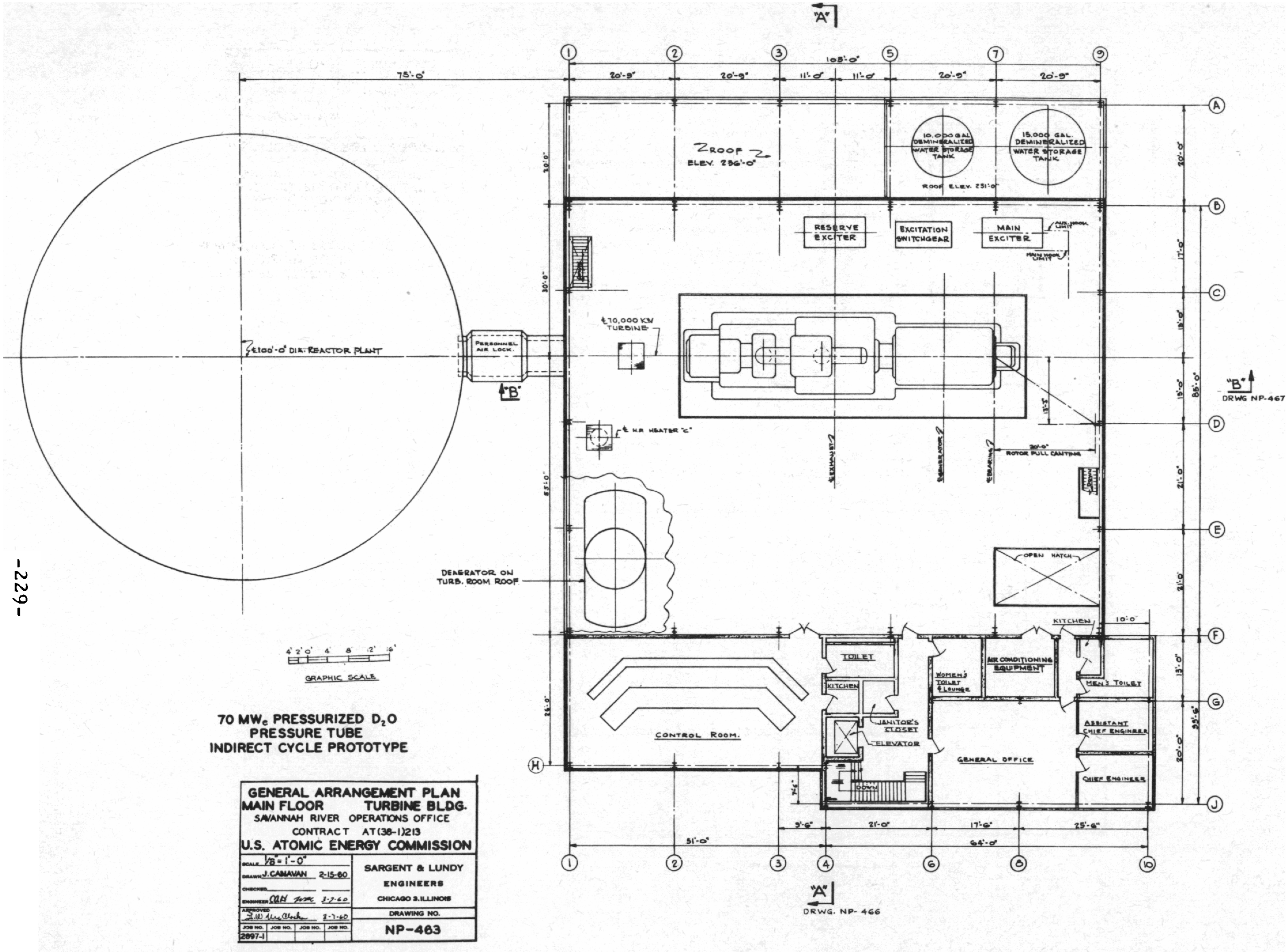
HIGH WATER EL. 210'-0"
MEAN WATER EL. 200'-0"
LOW WATER EL. 195'-0"
INTAKE
CRIB HOUSE
2,000 GAL. DAY TANK
13'DIA. CHIMNEY 200' HIGH
72"φ DISCHARGE PIPE
SOLID WASTE BURIAL PIT
PERMANENT RESIN STORAGE TANK
RADIOACTIVE WASTE DISPOSAL BUILDING
FENCE
RADIOACTIVE GAS HOLD-UP TANKS
WASTE HOLD-UP TANKS
FUEL HANDLING BUILDING
FREIGHT DOOR
AIR LOCK
REACTOR CONTAINMENT VESSEL
TURBINE ROOM
OFFICE
RES. AUX. TRANSF.
MAIN POWER TRANSF.
SWITCHYARD
UNIT AUX. TRANSF.
FINISHED GRADE ELEV. 220'-0"
16' ROAD
DRAINAGE DITCH
DRAINAGE DITCH
50,000 GAL. OIL STORAGE TANK
UP
GUARD RAIL
EL. 233'-0"
54 CAR PARKING LOT EL. 234'-0"
DEEP WELL
SEPTIC TANK
TILE FIELD
PLANT RAILROAD
20' ROAD
GATE HOUSE
GATE
GATE
CONSTRUCTION AREA
CONSTRUCTION PARKING AREA
GRAPHIC SCALE
70 MWe PRESSURIZED D2O
PRESSURE TUBE
INDIRECT CYCLE PROTOTYPE
PROPERTY PLAT
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1"=50'-0"
DRAWN E. WENCKOWSKI 2-15-60
CHECKED
ENGINEER CAH 3-7-60
APPROVED 3-7-60
JOB NO. 2897-1
SARGENT & LUNDY
ENGINEERS
CHICAGO 3. ILLINOIS
DRAWING NO.
NP-460

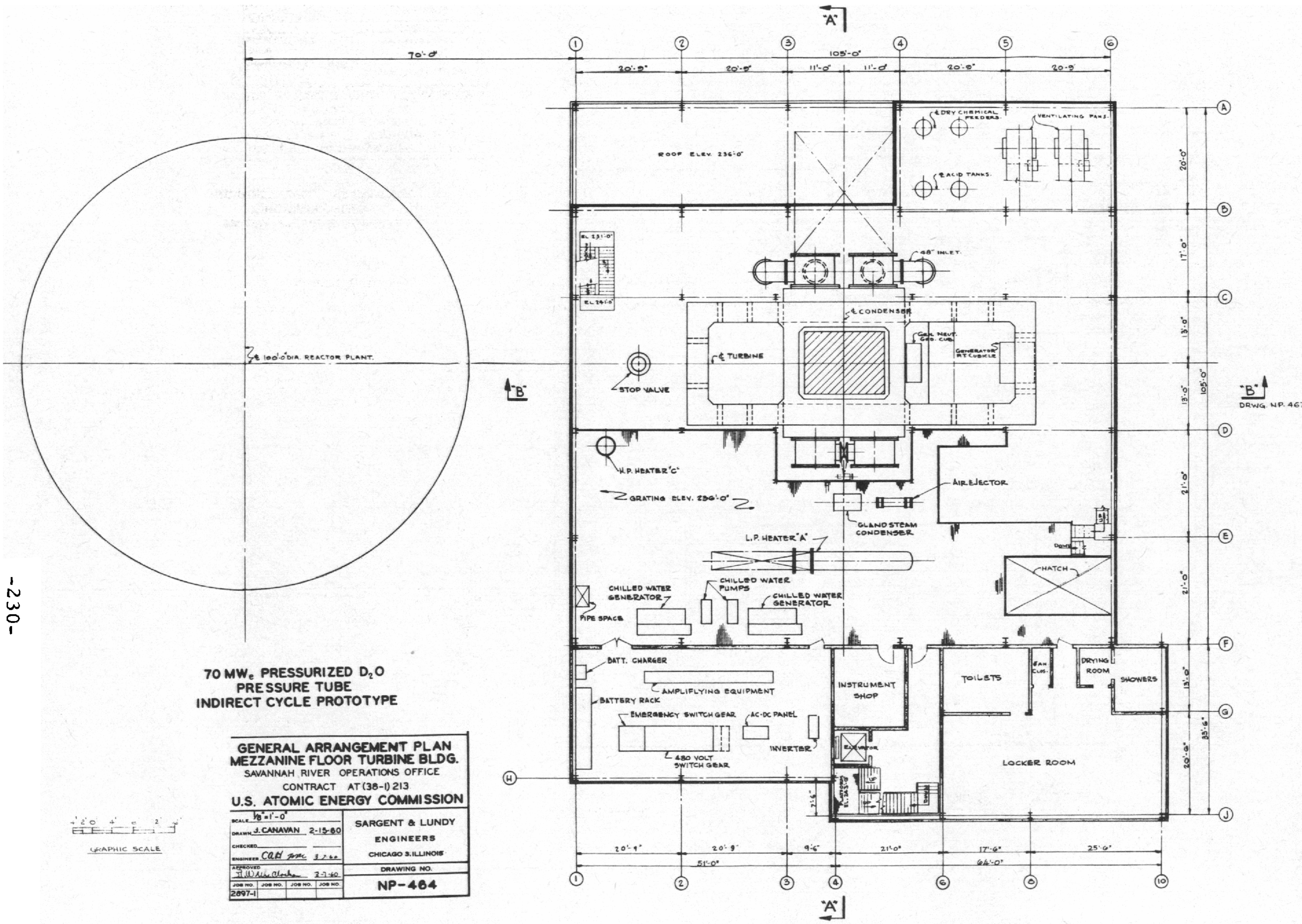


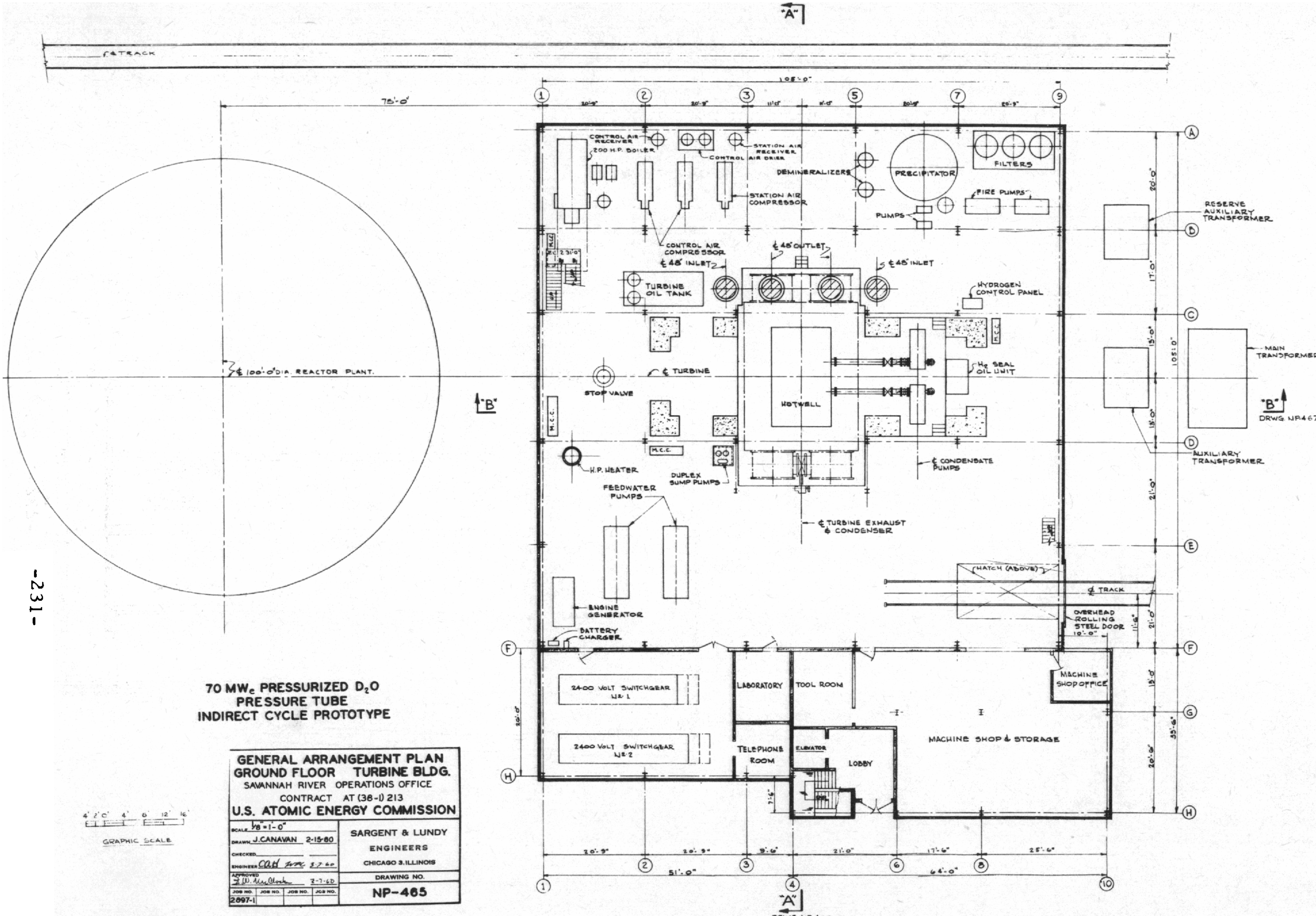
PLAN "A-A"
ELEV. 270'-5"
PLAN "B-B"
ELEV. 251'-0"
PLAN "C-C"
ELEV. 223'-0"
PLAN "D-D"
ELEV. 203'-9"
PLAN "G-G"
100'-0" DIAMETER CYLINDER
℄ DISTILLATION COLUMNS
EMERGENCY AIRLOCK
M.C.C.
COOLANT PUMP SEAL PRESSURE ACCUMULATOR
OXYGEN BOTTLES
℄ CALANDRIA
℄ OCTAGON
PUMP HATCH
HATCH
℄ STEAM GENERATORS
DOWN
℄ FUEL HANDLING RAIL
FUEL HANDLING VEHICLE
TEMPORARY SPENT FUEL STORAGE WELL
℄ SPENT FUEL WELL
TEMPORARY FRESH FUEL STORAGE WELL
PRESSURIZER TANK
ELEVATOR
℄ CRANE RAIL
HELIUM BOTTLES
HELIUM STORAGE TANK
ADSORBERS
ADSORBER CONDENSER
RECOMBINERS
SEPARATORS
SEPARATORS RECOMBINERS
SPENT FUEL WELL COOLER PUMP
SPENT FUEL WELL COOLER
EQUIP. HATCH
UP
COOLANT CIRCULATING PIPING
TRANSFORMER
480V. SWITCHGEAR
AIR LOCK
FOR CONT. SEE PLAN "G-G"
REACTOR OUTLET
SPENT FUEL WELL
SHUTDOWN COOLER
SHUTDOWN COOLER PUMP
MODERATOR CONTROL PUMPS
MODERATOR LEVEL INDICATOR & FILL STANDPIPE
℄ OCTAGON
℄ CALANDRIA
ELEV.
D.C. PANEL
BATTERIES
BATTERY CHARGER
DRWG. NP-462
UPPER PLENUM CHAMBER
MOTOR CONTROL CENTER
FREIGHT DOOR
REACTOR CIRCULATING PUMP
EQUIP. HATCH
ELEV. 231'-0"
SHIELD COOLER SURGE TANK
FULL FLOW FILTERS
REACTOR INLET
SPENT FUEL WELL AUTOMATIC VALVE
SHIELD COOLER
SHIELD COOLER PUMPS
LOWER PLENUM CHAMBER
D₂O COOLANT TRANSFER PUMPS
H.P. INJECTION SEAL PUMPS
D₂O COOLANT STORAGE TANK-15,900 GALLONS
MODERATOR COOLER
D₂O MODERATOR CIRC. PUMPS
16,000 GALLON D₂O MODERATOR STORAGE TANK
D₂O MODERATOR TRANSFER PUMPS
REACTOR CIRCULATING PUMP
38'-0" TO FUEL HANDLING BUILDING SEE DRG. NP 468
STRAINER
MIXED BED ION EXCHANGER
REGENERATIVE HEAT EXCHANGER
PURIFICATION COOLER
MISC. D₂O DRAIN TANK
COOLANT PURIFICATION BOOSTER PUMP
REACTOR DRAIN COOLER
SPENT FUEL CANAL
MIXED BED ION EXCHANGER
MODERATOR PURIFICATION BOOSTER PUMPS
REACTOR CAVITY SUMP PUMP
REACTOR BUILDING SUMP PUMPS
GRAPHIC SCALE
70 MWe PRESSURIZED D₂O PRESSURE TUBE INDIRECT CYCLE PROTOTYPE
REVISIONS
GENERAL ARRANGEMENT PLANS
REACTOR BUILDING
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8":1'-0"
DRAWN E. WENCKOWSKI 2-15-60
CHECKED
ENGINEER
APPROVED
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-461
2897-1



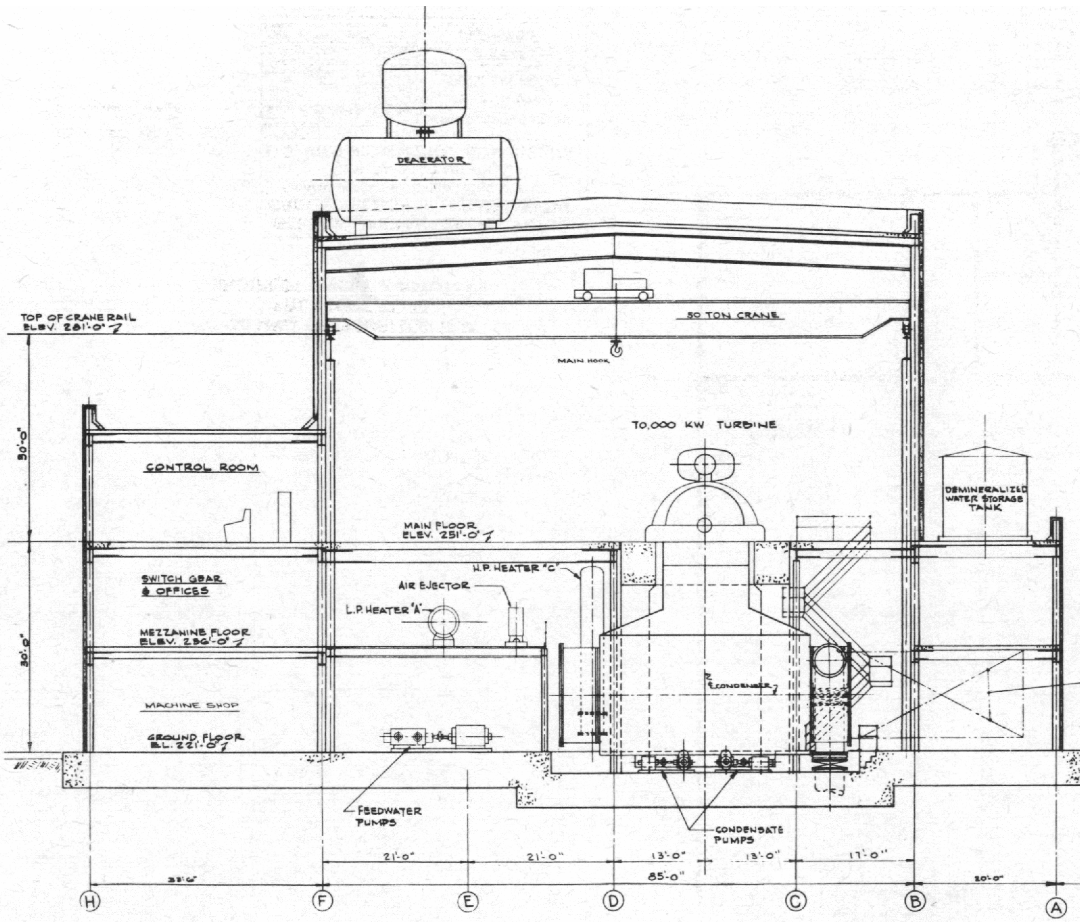
SECTION "E-E"
SECTION "F-F"
15,000 GALLON WATER STORAGE TANK
ELEV. 345'-6"
℄ CONTAINMENT VESSEL
℄ CONTAINMENT VESSEL & CALANDRIA
CRANE
TOP OF CRANE RAIL ELEV. 306'-5"
FUEL HANDLING VEHICLE
℄ CALANDRIA
℄ OCTAGON
REACTOR OUTLET
FLOOR ELEV. 276'-5"
TEMPORARY FRESH FUEL STORAGE WELL
TEMPORARY SPENT FUEL STORAGE WELL
UPPER HEADER ROOM
STEAM GENERATOR
480 V. SWITCHGEAR & TRANSFORMER
AIRLOCK
CALANDRIA
PRESSURE TUBES
THERMAL SHIELD
DUMP LINE
FLOOR ELEV. 251'-0"
SHIELD COOLER SURGE TANK
FULL FLOW FILTERS
FLOOR ELEV. 237'-0"
SHIELD COOLER
SHIELD COOLER PUMPS
LOWER HEADER ROOM
REACTOR INLET
COOLANT CIRC PIPING
D2O COOLANT TRANSFER PUMPS (MODERATOR TRANSFER PUMPS N.S.)
MODERATOR COOLER
COOLANT H.P. INJECTION SEAL PUMPS
FLOOR ELEV. 223'-0"
GRADE ELEV. 220'-0"
SPENT FUEL WELL AUTOMATIC VALVE
CONTROL ROD ROOM
D2O MODERATOR CIRCULATING PUMPS
D2O COOLANT STORAGE TANK (D2O MODERATOR STORAGE TANK N.S.)
REGENERATIVE HEAT EXCH. PURIFICATION COOLER REACTOR DRAIN COOLER
FLOOR ELEV. 203'-9"
COOLANT PURIFICATION BOOSTER PUMP MIXED BED ION EXCHANGER STRAINER (MODERATOR PURIFICATION SYSTEM N.S.)
MISC. D2O DRAIN TANK
SPENT FUEL TRANSFER CANAL
ELEV. 188'-6"
DRWG. NP-461
"A"
"B"
"C"
"D"
"G"
HELIUM STORAGE TANK
ELEVATOR
PRESSURIZER TANK
M.C.C.
COOLANT PUMP SEAL PRESSURE ACCUMULATOR
MODERATOR LEVEL INDICATOR & FILL STAND PIPE
SPENT FUEL WELL COOLER
SPENT FUEL WELL COOLER PUMP
SHUTDOWN COOLER
℄ SEPARATORS
DC PANEL
BATTERY CHARGER
BATTERIES
SHUT DOWN COOLER PUMP
MODERATOR CONTROL PUMPS
℄ RECOMBINERS
℄ ADSORBERS
℄ ADSORBER CONDENSER
HATCHWAY
REACTOR CIRCULATING PUMP
FREIGHT DOOR
REACTOR OUTLET
COOLANT CIRC PIPING
REACTOR BUILDING SUMP PUMPS
REACTOR CAVITY SUMP PUMP
TRANSFER PUMP
MISC. D2O DRAIN TANK
100'-0" DIA. - INSIDE ℄
70 MWe PRESSURIZED D2O PRESSURE TUBE INDIRECT CYCLE PROTOTYPE
REVISIONS
GENERAL CROSS SECTIONS "E-E", "F-F"
REACTOR BUILDING
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN C. KUSZYNSKI 2-15-60
CHECKED
ENGINEER
APPROVED
JOB NO. 2897-1
GRAPHIC SCALE
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-462

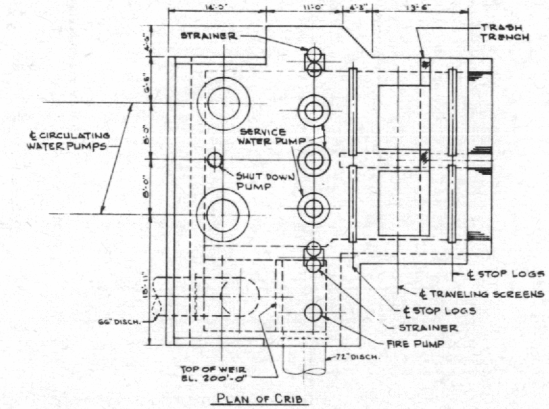

"A"
105'-0"
75'-0"
20'-9"
20'-9"
11'-0"
11'-0"
20'-9"
20'-9"
ROOF
ELEV. 256'-0"
10,000 GAL. DEMINERALIZED WATER STORAGE TANK
15,000 GAL. DEMINERALIZED WATER STORAGE TANK
ROOF ELEV. 251'-0"
RESERVE EXCITER
EXCITATION SWITCHGEAR
MAIN EXCITER
MAIN HOOK LIMIT
70,000 KW TURBINE
100'-0" DIA. REACTOR PLANT
PERSONNEL AIR LOCK
"B"
H.P. HEATER "C"
20'-0"
ROTOR PULL CANTING
DRWG NP-467
DEAERATOR ON TURB. ROOM ROOF
OPEN HATCH
KITCHEN
10'-0"
TOILET
KITCHEN
WOMEN'S TOILET & LOUNGE
AIR CONDITIONING EQUIPMENT
MEN'S TOILET
JANITOR'S CLOSET
ELEVATOR
ASSISTANT CHIEF ENGINEER
GENERAL OFFICE
CHIEF ENGINEER
CONTROL ROOM
DOWN
GRAPHIC SCALE
20'-0"
17'-0"
18'-0"
15'-0"
85'-0"
21'-0"
21'-0"
15'-0"
20'-0"
35'-6"
30'-0"
55'-0"
26'-0"
9'-6"
21'-0"
17'-6"
25'-6"
51'-0"
64'-0"
DRWG. NP-466
70 MWe PRESSURIZED D2O PRESSURE TUBE INDIRECT CYCLE PROTOTYPE
GENERAL ARRANGEMENT PLAN
MAIN FLOOR TURBINE BLDG.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT(38-1)213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN J. CANAVAN 2-15-60
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-463
2897-1

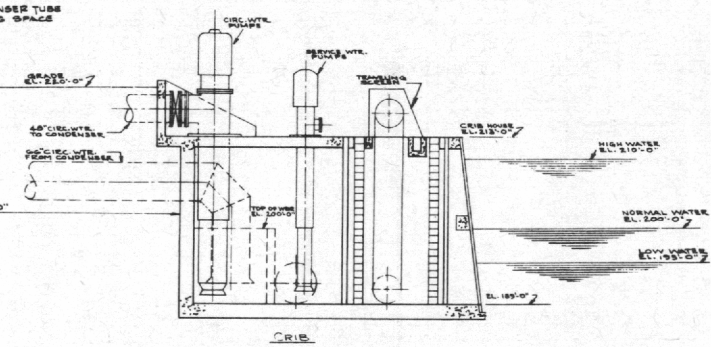

"A"
70'-0"
105'-0"
20'-9"
20'-9"
11'-0"
11'-0"
20'-9"
20'-9"
ROOF ELEV. 236'-0"
℄ DRY CHEMICAL FEEDERS.
VENTILATING FANS.
℄ ACID TANKS.
20'-0"
17'-0"
13'-0"
13'-0"
105'-0"
21'-0"
21'-0"
13'-0"
20'-6"
33'-6"
EL. 251'-0"
EL. 241'-0"
48" INLET.
℄ CONDENSER
℄ TURBINE
GEN. NEUT. GRD. CUB.
GENERATOR P.T. CUBICLE
℄ 100'-0" DIA. REACTOR PLANT.
STOP VALVE
"B"
DRWG. NP. 467
H.P. HEATER "C"
GRATING ELEV. 236'-0"
AIR EJECTOR
GLAND STEAM CONDENSER
L.P. HEATER "A"
HATCH
CHILLED WATER GENERATOR
CHILLED WATER PUMPS
CHILLED WATER GENERATOR
PIPE SPACE
BATT. CHARGER
AMPLIFLYING EQUIPMENT
BATTERY RACK
EMERGENCY SWITCH GEAR
AC-DC PANEL
INVERTER
480 VOLT SWITCH GEAR
INSTRUMENT SHOP
ELEVATOR
TOILETS
DRYING ROOM
SHOWERS
LOCKER ROOM
20'-9"
20'-9"
9'-6"
21'-0"
17'-6"
25'-6"
51'-0"
64'-0"
7'-6"
DRWG. NP. 466
GRAPHIC SCALE
70 MWₑ PRESSURIZED D₂O
PRESSURE TUBE
INDIRECT CYCLE PROTOTYPE
GENERAL ARRANGEMENT PLAN
MEZZANINE FLOOR TURBINE BLDG.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN J. CANAVAN 2-15-60
CHECKED
ENGINEER CAH 3-7-60
APPROVED 3-7-60
JOB NO. 2897-1
SARGENT & LUNDY
ENGINEERS
CHICAGO 3. ILLINOIS
DRAWING NO.
NP-464



"A"
℄ TRACK
105'-0"
75'-0"
CONTROL AIR RECEIVER
200 H.P. BOILER
CONTROL AIR DRIER
STATION AIR RECEIVER
DEMINERALIZERS
PRECIPITATOR
FILTERS
STATION AIR COMPRESSOR
FIRE PUMPS
PUMPS
RESERVE AUXILIARY TRANSFORMER
CONTROL AIR COMPRESSOR
℄ 48" OUTLET
℄ 48" INLET
℄ 48" INLET
TURBINE OIL TANK
HYDROGEN CONTROL PANEL
M.C.C.
℄ 100'-0" DIA. REACTOR PLANT.
℄ TURBINE
STOP VALVE
HOTWELL
H_2 SEAL OIL UNIT
MAIN TRANSFORMER
"B"
DRWG NP-467
AUXILIARY TRANSFORMER
H.P. HEATER
DUPLEX SUMP PUMPS
℄ CONDENSATE PUMPS
FEEDWATER PUMPS
℄ TURBINE EXHAUST & CONDENSER
HATCH (ABOVE)
℄ TRACK
ENGINE GENERATOR
OVERHEAD ROLLING STEEL DOOR 10'-0"
BATTERY CHARGER
2400 VOLT SWITCHGEAR Nº 1
2400 VOLT SWITCHGEAR Nº 2
LABORATORY
TOOL ROOM
MACHINE SHOP OFFICE
MACHINE SHOP & STORAGE
TELEPHONE ROOM
ELEVATOR
LOBBY
51'-0"
64'-0"
DRWG NP-466
70 MW$_e$ PRESSURIZED D_2O
PRESSURE TUBE
INDIRECT CYCLE PROTOTYPE
GENERAL ARRANGEMENT PLAN
GROUND FLOOR TURBINE BLDG.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN J. CANAVAN 2-15-60
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-465
GRAPHIC SCALE



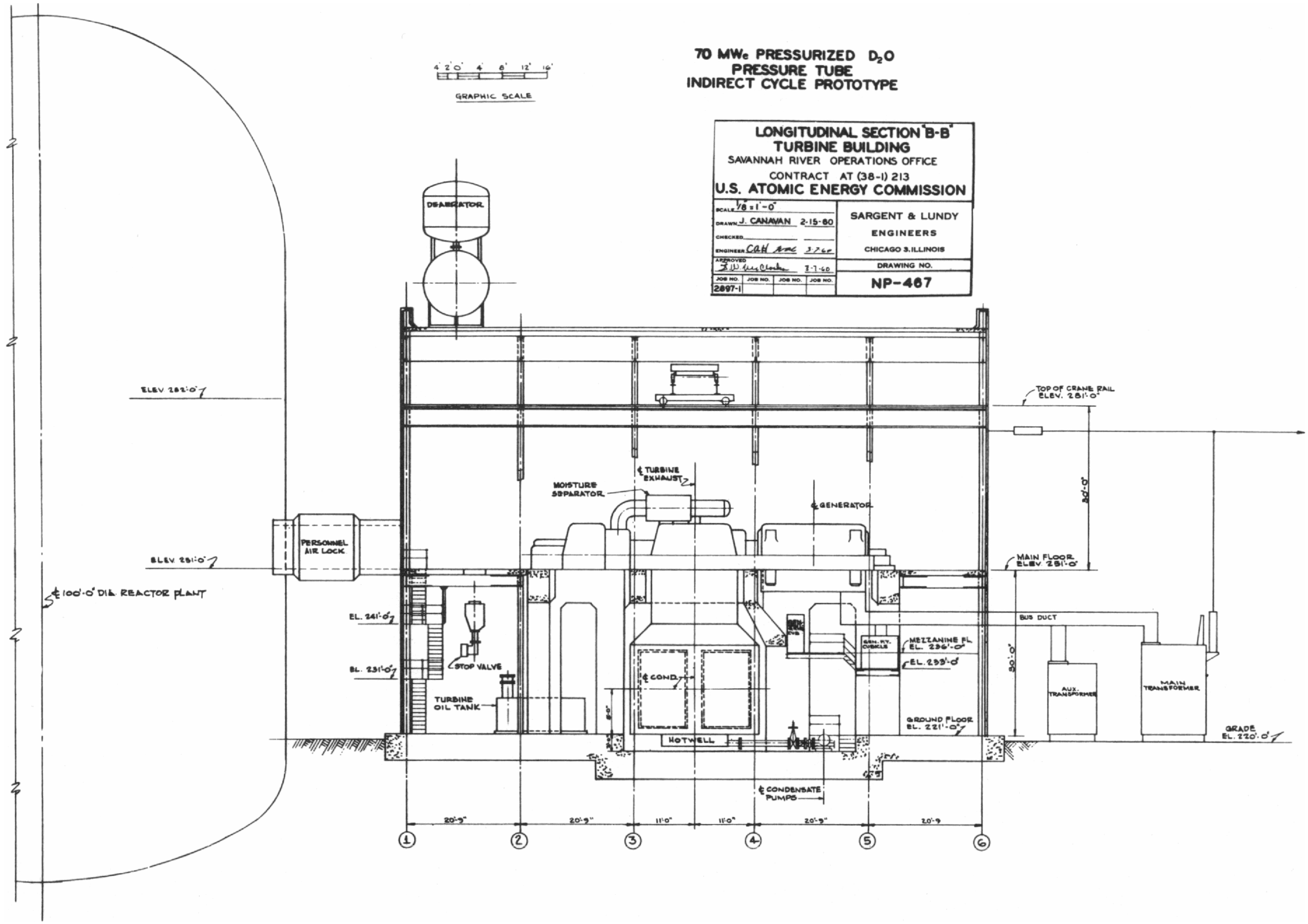




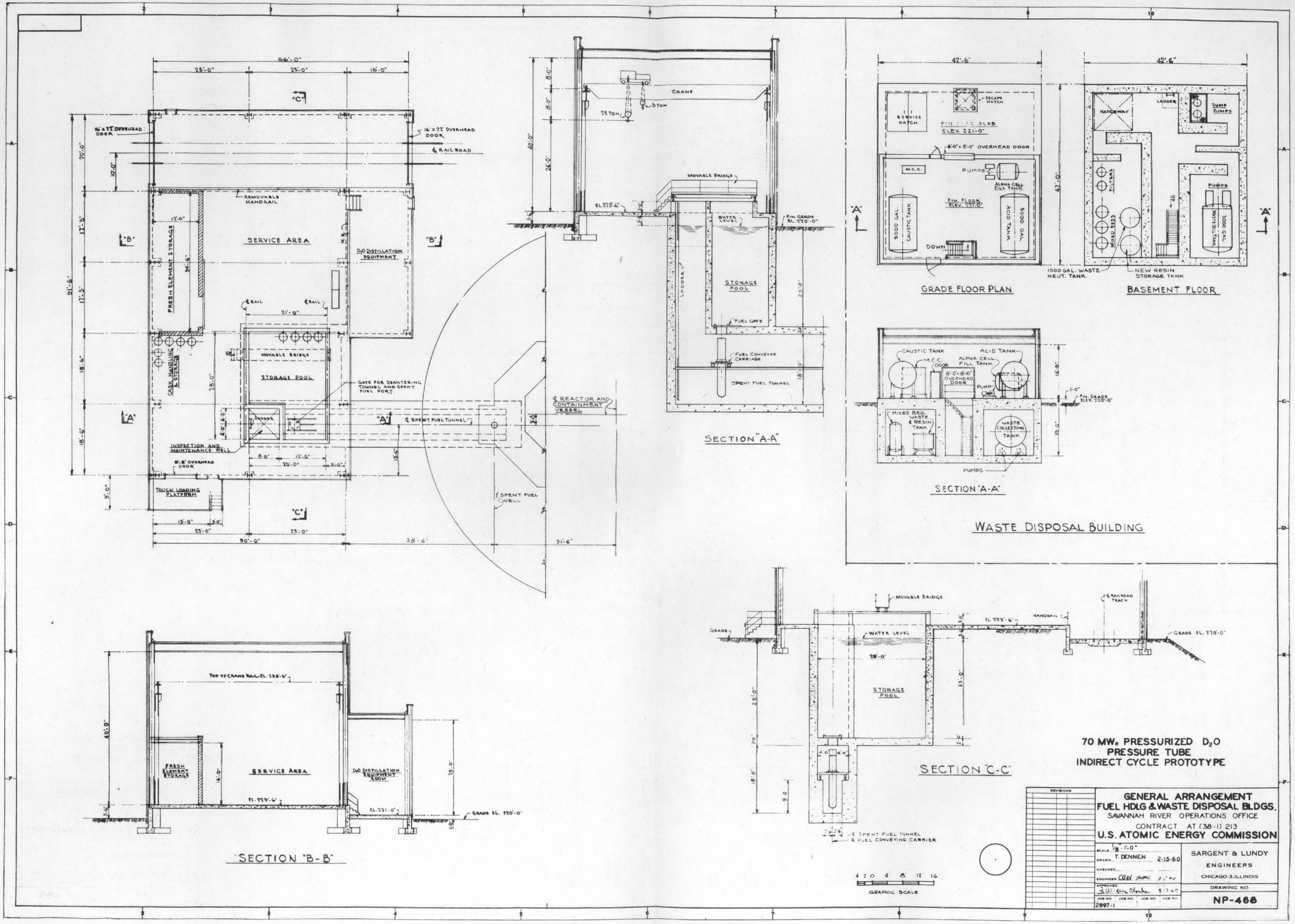
70 MW$_e$ PRESSURIZED D_2O PRESSURE TUBE INDIRECT CYCLE PROTOTYPE

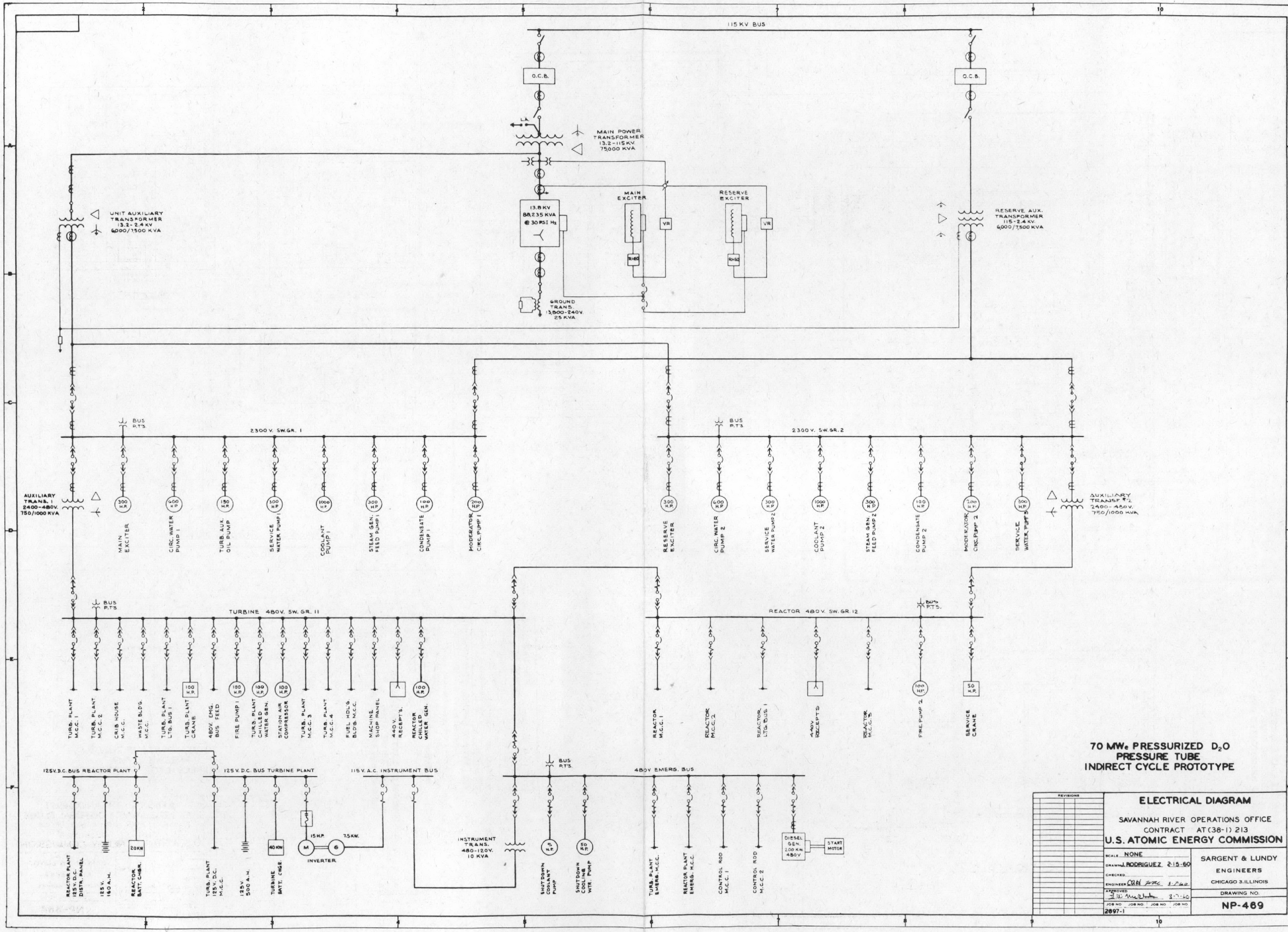
GRAPHIC SCALE

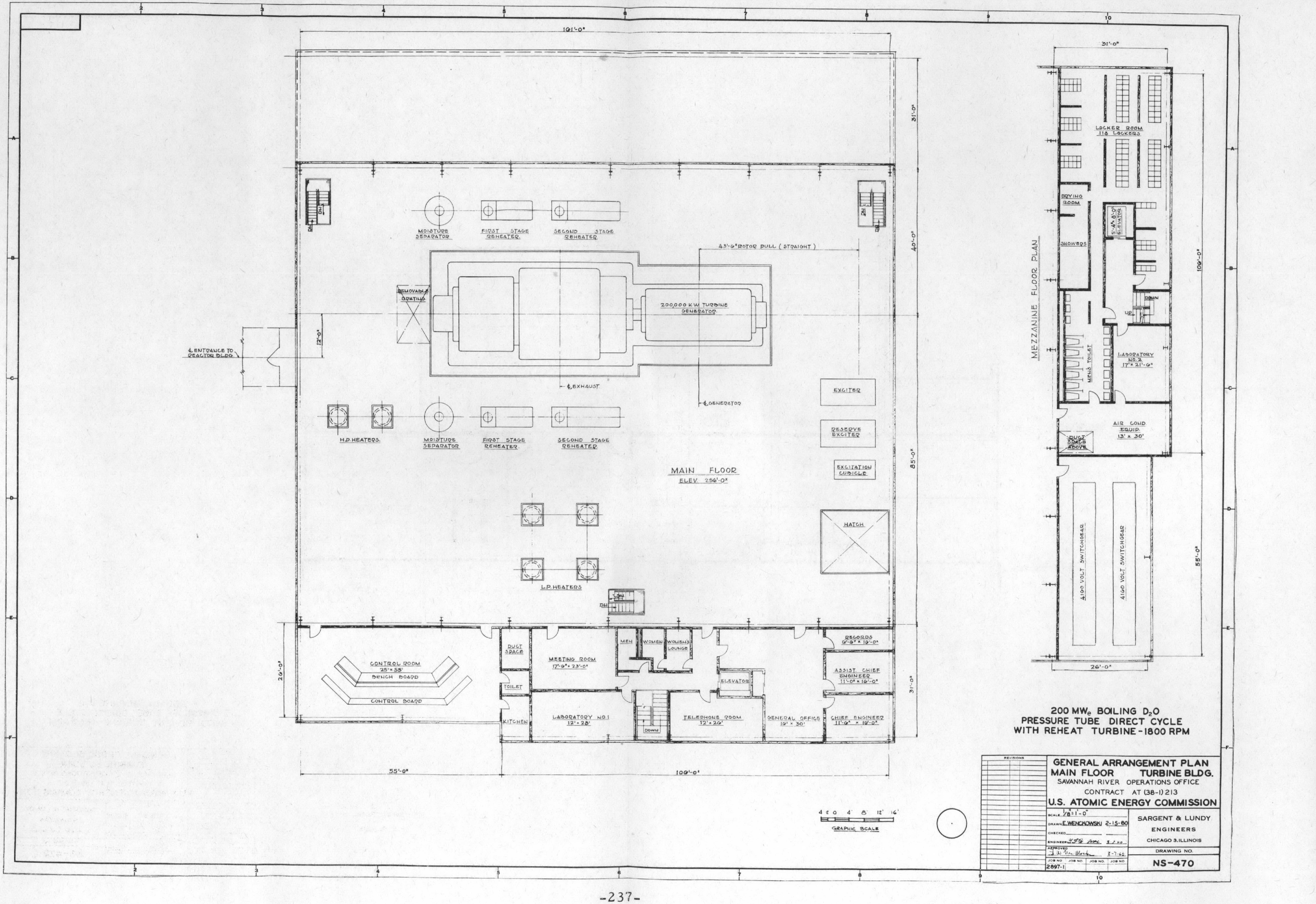
GENERAL CROSS SECTION "A-A" TURBINE BUILDING SAVANNAH RIVER OPERATIONS OFFICE CONTRACT AT (38-1) 213 U.S. ATOMIC ENERGY COMMISSION	
SCALE 1/8" = 1'-0"	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWN J. CANAVAN 2-15-60	
CHECKED	
ENGINEER CQH 3-7-60	
APPROVED 3-7-60	DRAWING NO.
JOB NO. 2897-1	NP-466



70 MWe PRESSURIZED D2O
PRESSURE TUBE
INDIRECT CYCLE PROTOTYPE
GRAPHIC SCALE
LONGITUDINAL SECTION "B-B"
TURBINE BUILDING
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN J. CANAVAN 2-15-60
CHECKED
ENGINEER
APPROVED
JOB NO.
2897-1
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-467
DEAERATOR
ELEV 282'-0"
TOP OF CRANE RAIL ELEV. 281'-0"
℄ TURBINE EXHAUST
MOISTURE SEPARATOR
℄ GENERATOR
PERSONNEL AIR LOCK
ELEV 251'-0"
MAIN FLOOR ELEV. 251'-0"
℄ 100'-0" DIA. REACTOR PLANT
EL. 241'-0"
EL. 231'-0"
STOP VALVE
TURBINE OIL TANK
℄ COND.
HOTWELL
BUS DUCT
MEZZANINE FL EL. 236'-0"
EL. 233'-0"
AUX. TRANSFORMER
MAIN TRANSFORMER
GROUND FLOOR EL. 221'-0"
GRADE EL. 220'-0"
℄ CONDENSATE PUMPS
30'-0"
20'-9"
11'-0"
1
2
3
4
5
6

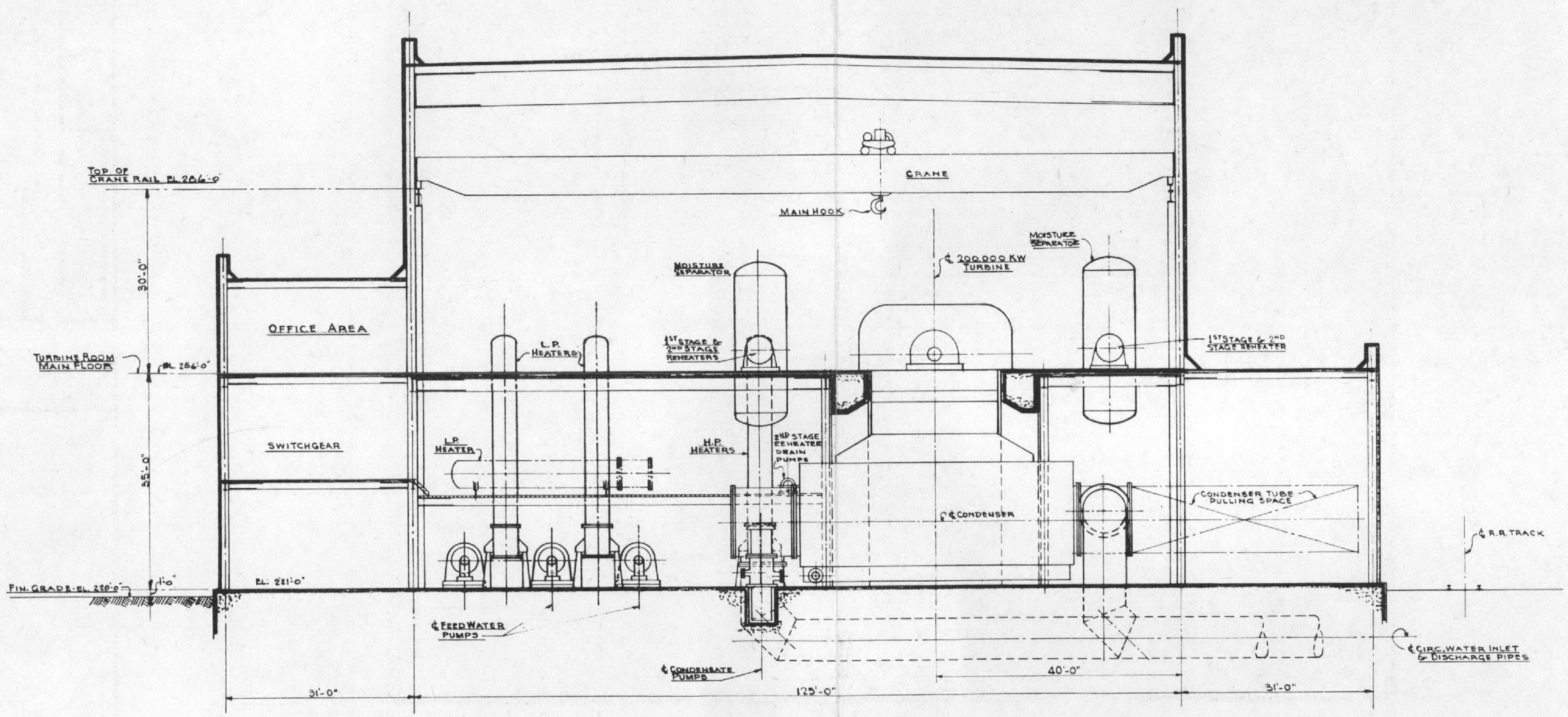

SERVICE AREA
FRESH ELEMENT STORAGE
CASK HANDLING & STORAGE
D_2O DISTILLATION EQUIPMENT
STORAGE POOL
MOVABLE BRIDGE
REMOVABLE HANDRAIL
16'x22' OVERHEAD DOOR
℄ RAILROAD
GATE FOR DEWATERING TUNNEL AND SPENT FUEL PORT.
℄ SPENT FUEL TUNNEL
℄ REACTOR AND CONTAINMENT VESSEL
℄ SPENT FUEL WELL
INSPECTION AND MAINTENANCE WELL
8'-8' OVERHEAD DOOR
TRUCK LOADING PLATFORM
CRANE
25 TON
5 TON
WATER LEVEL
FIN. GRADE EL. 220'-0"
LADDER
FUEL GATE
FUEL CONVEYOR CARRIAGE
SPENT FUEL TUNNEL
SECTION "A-A"
SERVICE HATCH
ESCAPE HATCH
FIN. ROOF SLAB ELEV. 221'-0"
8'-0"x8'-0" OVERHEAD DOOR
M.C.C.
PUMPS
ALPHA CELL FILL TANK
FIN. FLOOR ELEV. 221'-0"
5000 GAL. CAUSTIC TANK
5000 GAL. ACID TANK
DOWN
GRADE FLOOR PLAN
HATCHWAY
LADDER
SUMP PUMPS
FILTERS
MIXED BEDS
PUMPS
5000 GAL. WASTE TANK
1000 GAL. WASTE NEUT. TANK
NEW RESIN STORAGE TANK
BASEMENT FLOOR
CAUSTIC TANK
ACID TANK
ALPHA CELL FILL TANK
8'-0"x8'-0" OVERHEAD DOOR
MIXED BED WASTE & RESIN TANK
WASTE COLLECTING TANK
SECTION "A-A"
WASTE DISPOSAL BUILDING
TOP OF CRANE RAIL-EL. 253'-6"
FRESH ELEMENT STORAGE
SERVICE AREA
D_2O DISTILLATION EQUIPMENT ROOM
EL. 223'-6"
EL. 221'-0"
GRADE EL. 220'-0"
SECTION "B-B"
MOVABLE BRIDGE
HANDRAIL
℄ RAILROAD TRACK
GRADE
WATER LEVEL
STORAGE POOL
GRADE-EL. 220'-0"
℄ SPENT FUEL TUNNEL
℄ FUEL CONVEYING CARRIER
SECTION "C-C"
GRAPHIC SCALE
70 MWe PRESSURIZED D_2O
PRESSURE TUBE
INDIRECT CYCLE PROTOTYPE
REVISIONS
GENERAL ARRANGEMENT
FUEL HDLG & WASTE DISPOSAL BLDGS.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8"-1'-0"
DRAWN T. DENNEN 2-15-60
CHECKED
ENGINEER
APPROVED
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-468
JOB NO.
2897-1


115 KV BUS
O.C.B.
O.C.B.
L.A.
MAIN POWER TRANSFORMER 13.2-115 KV 75,000 KVA
UNIT AUXILIARY TRANSFORMER 13.2-2.4 KV 6,000/7,500 KVA
13.8 KV 88,235 KVA @ 30 PSI H2
MAIN EXCITER
RESERVE EXCITER
VR
VR
GROUND TRANS. 13,800-240V. 25 KVA
RESERVE AUX. TRANSFORMER 115-2.4 KV 6,000/7,500 KVA
BUS P.T.S.
2300 V. SW. GR. 1
2300 V. SW. GR. 2
AUXILIARY TRANS. 1 2400-480V. 750/1000 KVA
AUXILIARY TRANS. 2 2400-480V. 750/1000 KVA
MAIN EXCITER
CIRC. WATER PUMP 1
TURB. AUX. OIL PUMP
SERVICE WATER PUMP 1
COOLANT PUMP 1
STEAM GEN. FEED PUMP 1
CONDENSATE PUMP 1
MODERATOR CIRC. PUMP 1
RESERVE EXCITER
CIRC. WATER PUMP 2
SERVICE WATER PUMP 2
COOLANT PUMP 2
STEAM GEN. FEED PUMP 2
CONDENSATE PUMP 2
MODERATOR CIRC. PUMP 2
SERVICE WATER PUMP 3
TURBINE 480V. SW. GR. 11
REACTOR 480V. SW. GR. 12
TURB. PLANT M.C.C. 1
TURB. PLANT M.C.C. 2
CRIB HOUSE M.C.C.
WASTE BLD'G. M.C.C.
TURB. PLANT LTG. BUS 1
TURB. PLANT CRANE
480V. EMG. BUS FEED
FIRE PUMP 1
TURB. PLANT CHILLED WATER GEN.
STATION AIR COMPRESSOR
TURB. PLANT M.C.C. 3
TURB. PLANT M.C.C. 4
FUEL HDL'G. BLDG. M.C.C.
MACHINE SHOP PANEL
440V. RECEPT'S.
REACTOR CHILLED WATER GEN.
REACTOR M.C.C. 1
REACTOR M.C.C. 2
REACTOR LTG. BUS 1
440V RECEPT'S
REACTOR M.C.C. 3
FIRE PUMP 2
SERVICE CRANE
125V. D.C. BUS REACTOR PLANT
125 V. D.C. BUS TURBINE PLANT
115 V. A.C. INSTRUMENT BUS
480V EMERG. BUS
REACTOR PLANT 125 V. D.C. DISTR. PANEL
125 V. 160 A.H.
REACTOR BATT. CHGR.
TURB. PLANT 125 V. D.C. M.C.C.
125 V. 500 A.H.
TURBINE BATT. CHGR.
15 H.P.
7.5 KW.
INVERTER
INSTRUMENT TRANS. 480-120V. 10 KVA
SHUTDOWN COOLANT PUMP
SHUTDOWN COOLING WTR. PUMP
TURB. PLANT EMERG. M.C.C.
REACTOR PLANT EMERG. M.C.C.
CONTROL ROD M.C.C. 1
CONTROL ROD M.C.C. 2
DIESEL GEN. 200 KW 480V
START MOTOR
70 MWe PRESSURIZED D2O
PRESSURE TUBE
INDIRECT CYCLE PROTOTYPE
REVISIONS
ELECTRICAL DIAGRAM
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE NONE
DRAWN J. RODRIGUEZ 2-15-60
CHECKED
ENGINEER
APPROVED
JOB NO
2897-1
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-469



200 MW$_e$ BOILING D_2O PRESSURE TUBE DIRECT CYCLE WITH REHEAT TURBINE - 1800 RPM

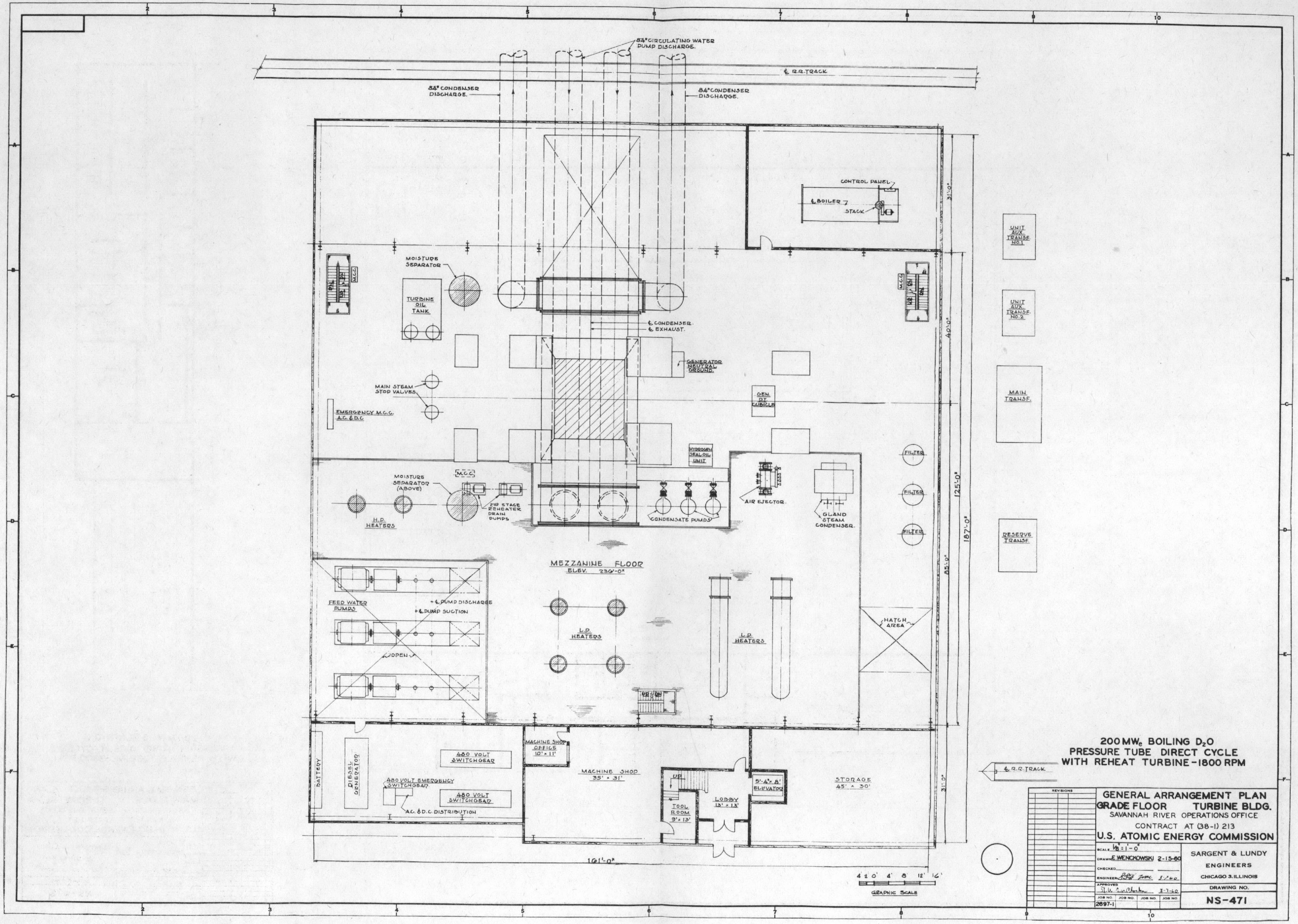
REVISIONS	GENERAL ARRANGEMENT PLAN MAIN FLOOR TURBINE BLDG. SAVANNAH RIVER OPERATIONS OFFICE CONTRACT AT (38-1) 213 U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWN E. WENCKOWSKI 2-15-60	
CHECKED	
ENGINEER	
APPROVED	DRAWING NO.
JOB NO. 2897-1	NS-470



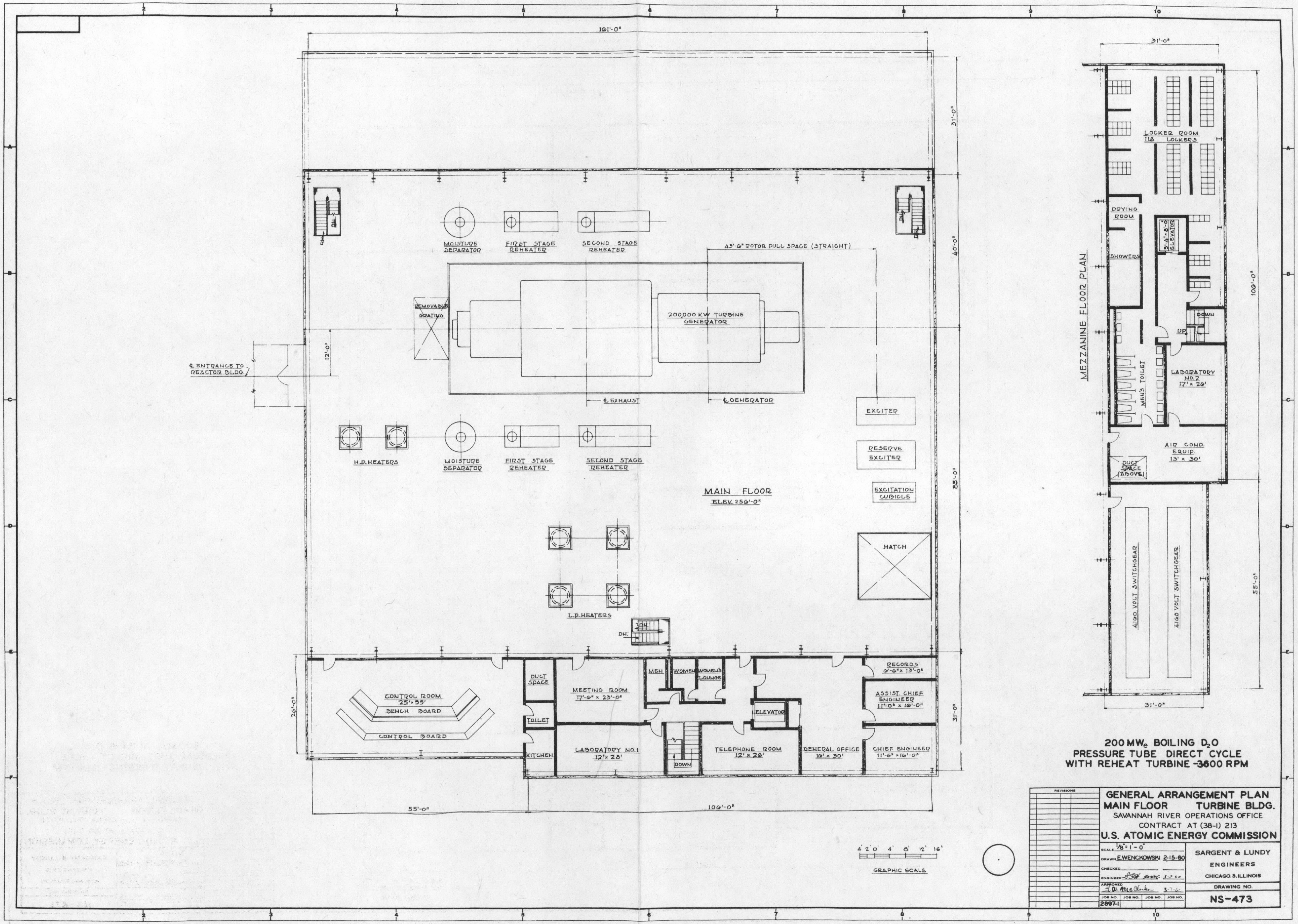
200MW$_e$ BOILING D_2O
PRESSURE TUBE DIRECT CYCLE
WITH REHEAT TURBINE - 1800 RPM

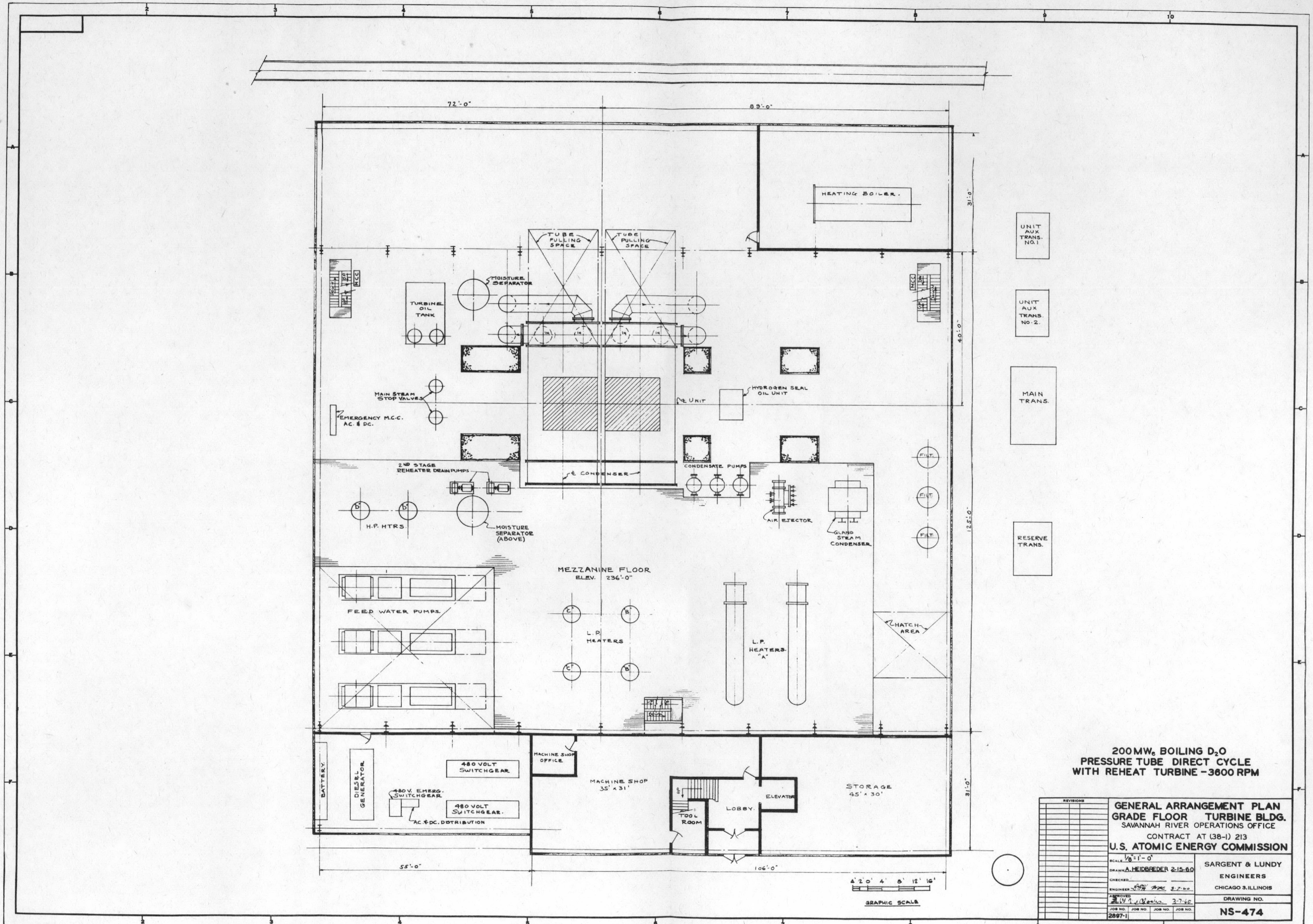
4 2 0 4 8 12' 16'
GRAPHIC SCALE

REVISIONS	GENERAL CROSS SECTION TURBINE BUILDING SAVANNAH RIVER OPERATIONS OFFICE CONTRACT AT (38-1) 213 U.S. ATOMIC ENERGY COMMISSION	
	SCALE 1/8" = 1'-0" DRAWN T. DENNEN 2-15-60 CHECKED ENGINEER [illegible] 3-2-60 APPROVED [illegible] 3-7-60 JOB NO. 2897-1	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS DRAWING NO. NS-472

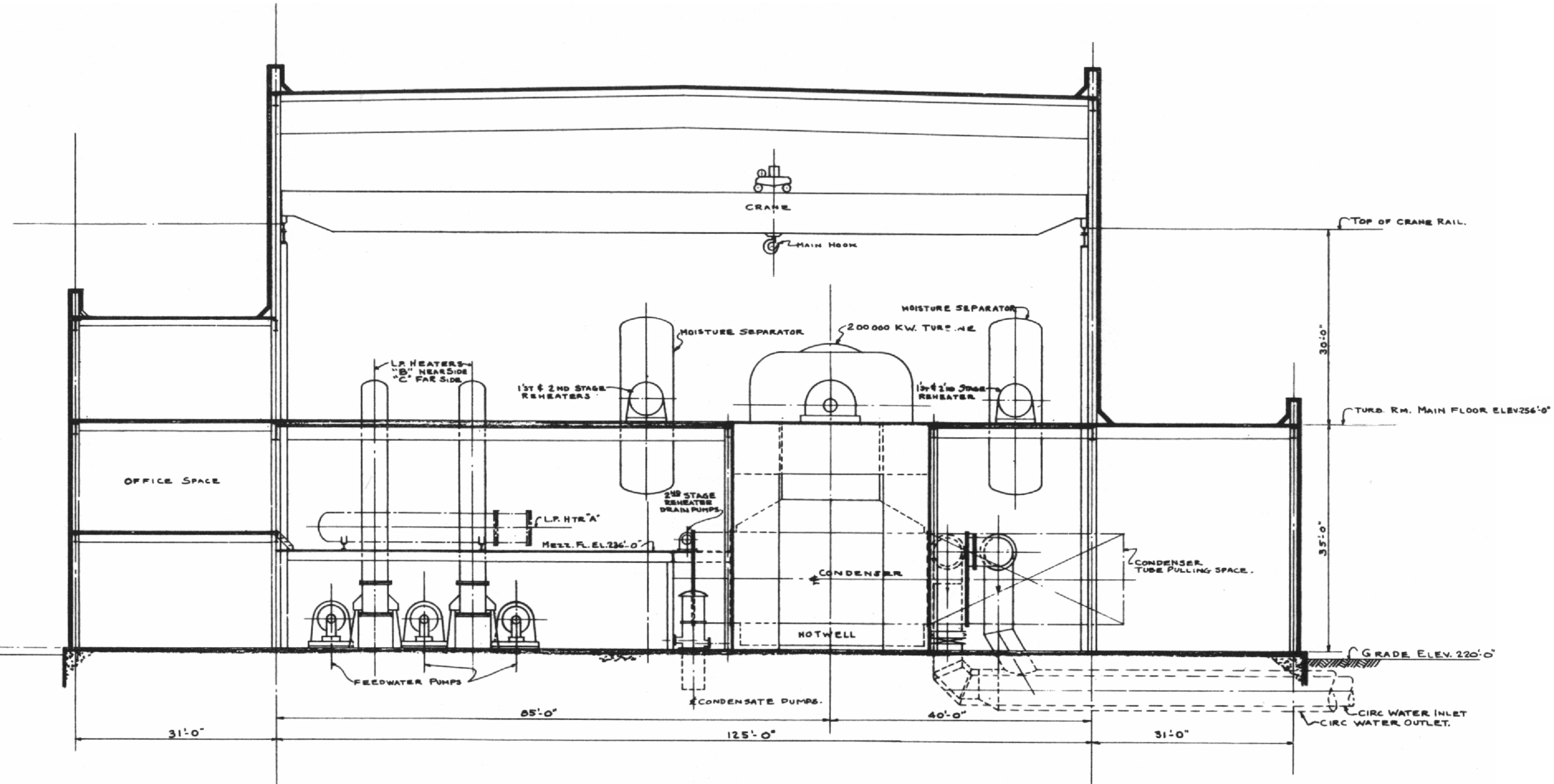


84" CIRCULATING WATER PUMP DISCHARGE.
℄ R.R. TRACK
84" CONDENSER DISCHARGE.
84" CONDENSER DISCHARGE.
CONTROL PANEL
℄ BOILER
STACK
UNIT AUX. TRANSF. NO.1
UNIT AUX. TRANSF. NO.2
MAIN TRANSF.
RESERVE TRANSF.
MOISTURE SEPARATOR
TURBINE OIL TANK
M.C.C.
℄ CONDENSER
℄ EXHAUST
GENERATOR NEUTRAL GROUND
MAIN STEAM STOP VALVES
EMERGENCY M.C.C. A.C. & D.C.
GEN. P.T. CUBICLE
HYDROGEN SEAL OIL UNIT
MOISTURE SEPARATOR (ABOVE)
M.C.C.
2ND STAGE REHEATER DRAIN PUMPS
H.P. HEATERS
CONDENSATE PUMPS
AIR EJECTOR
GLAND STEAM CONDENSER
FILTER
FILTER
FILTER
MEZZANINE FLOOR
ELEV. 239'-0"
FEED WATER PUMPS
℄ PUMP DISCHARGE
℄ PUMP SUCTION
OPEN
L.P. HEATERS
L.P. HEATERS
HATCH AREA
31'-0"
40'-0"
125'-0"
187'-0"
85'-0"
31'-0"
161'-0"
BATTERY
DIESEL GENERATOR
480 VOLT SWITCHGEAR
480 VOLT EMERGENCY SWITCHGEAR
480 VOLT SWITCHGEAR
A.C. & D.C. DISTRIBUTION
MACHINE SHOP OFFICE 10' × 11'
MACHINE SHOP 35' × 31'
UP
TOOL ROOM 9' × 13'
LOBBY 13' × 13'
5'-4" × 8' ELEVATOR
STORAGE 45' × 30'
℄ R.R. TRACK
4 2 0 4' 8 12' 16'
GRAPHIC SCALE
200 MWe BOILING D2O
PRESSURE TUBE DIRECT CYCLE
WITH REHEAT TURBINE - 1800 RPM
REVISIONS
GENERAL ARRANGEMENT PLAN
GRADE FLOOR TURBINE BLDG.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN E. WENCKOWSKI 2-15-60
CHECKED
ENGINEER 3-7-60
APPROVED 3-7-60
JOB NO. JOB NO. JOB NO. JOB NO.
2897-1
SARGENT & LUNDY
ENGINEERS
CHICAGO 3. ILLINOIS
DRAWING NO.
NS-471

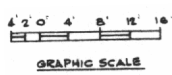

101'-0"
31'-0"
40'-0"
85'-0"
MOISTURE SEPARATOR
FIRST STAGE REHEATER
SECOND STAGE REHEATER
43'-6" ROTOR PULL SPACE (STRAIGHT)
REMOVABLE GRATING
200,000 KW TURBINE GENERATOR
℄ ENTRANCE TO REACTOR BLDG.
12'-0"
℄ EXHAUST
℄ GENERATOR
EXCITER
RESERVE EXCITER
EXCITATION CUBICLE
H.P. HEATERS
MAIN FLOOR
ELEV. 256'-0"
HATCH
L.P. HEATERS
DN.
CONTROL ROOM
25' x 55'
BENCH BOARD
CONTROL BOARD
DUCT SPACE
MEETING ROOM
17'-6" x 23'-0"
TOILET
KITCHEN
LABORATORY NO. 1
12' x 28'
MEN
WOMEN
WOMEN'S LOUNGE
ELEVATOR
DOWN
TELEPHONE ROOM
12' x 28'
GENERAL OFFICE
19' x 30'
RECORDS
9'-6" x 13'-0"
ASSIST. CHIEF ENGINEER
11'-0" x 10'-0"
CHIEF ENGINEER
11'-6" x 16'-0"
20'-0"
55'-0"
106'-0"
MEZZANINE FLOOR PLAN
LOCKER ROOM
118 LOCKERS
DRYING ROOM
SHOWERS
ELEVATOR
DOWN
UP
MEN'S TOILET
LABORATORY NO. 2
17' x 29'
AIR COND. EQUIP
13' x 30'
DUCT SPACE (ABOVE)
4160 VOLT SWITCHGEAR
4160 VOLT SWITCHGEAR
100'-0"
55'-0"
31'-0"
200 MWe BOILING D2O
PRESSURE TUBE DIRECT CYCLE
WITH REHEAT TURBINE - 3600 RPM
GRAPHIC SCALE
REVISIONS
GENERAL ARRANGEMENT PLAN
MAIN FLOOR TURBINE BLDG.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN E. WENCKOWSKI 2-15-60
CHECKED
ENGINEER
APPROVED
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NS-473
JOB NO.
2697-1



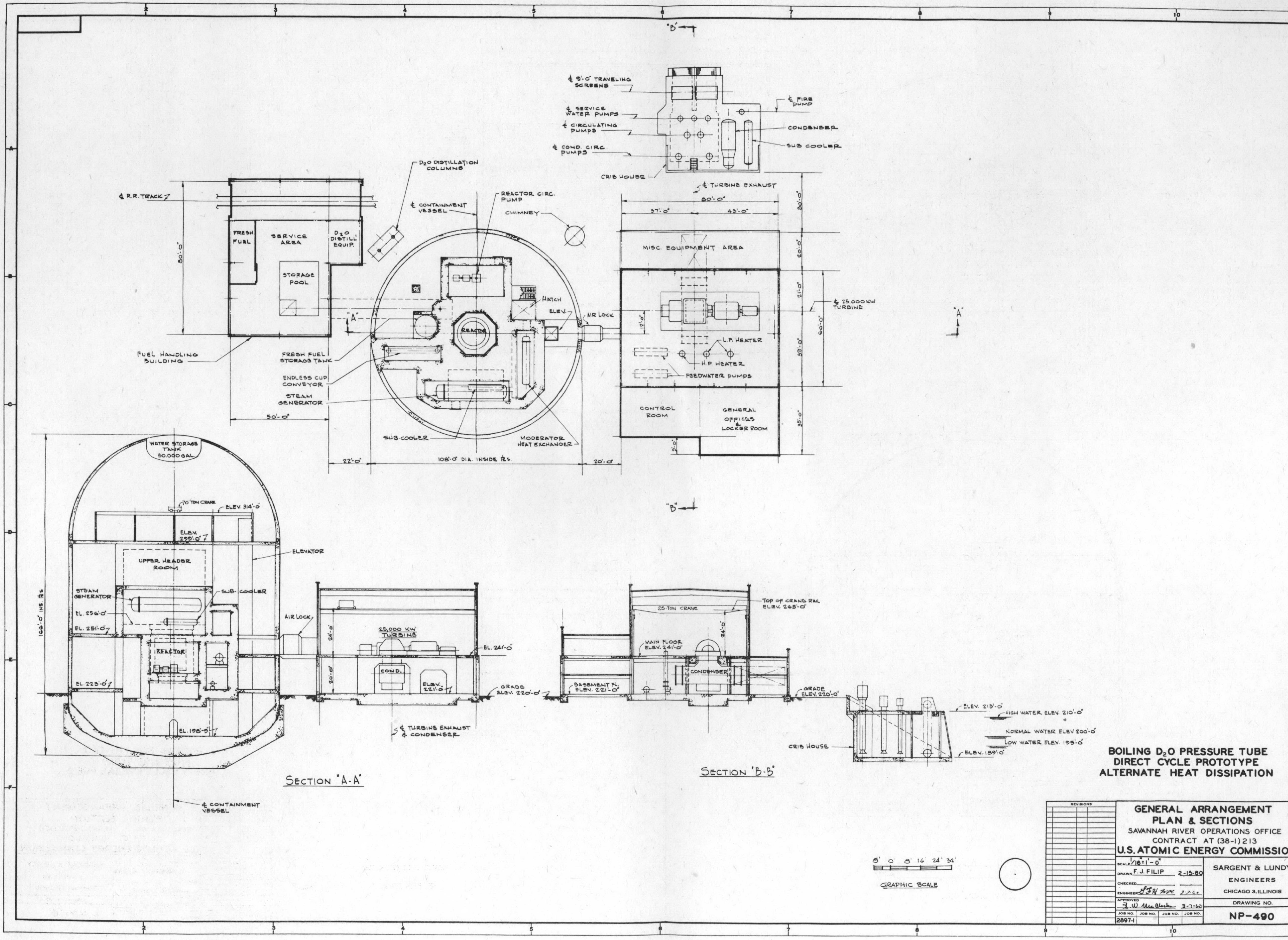
72'-0"
83'-0"
HEATING BOILER.
31'-0"
UNIT AUX TRANS. NO. 1
UNIT AUX TRANS. NO. 2.
MAIN TRANS.
RESERVE TRANS.
TUBE PULLING SPACE
TUBE PULLING SPACE
MOISTURE SEPARATOR
TURBINE OIL TANK
MCC
40'-0"
MAIN STEAM STOP VALVES
EMERGENCY M.C.C. AC. & DC.
HYDROGEN SEAL OIL UNIT
℄ UNIT
2ND STAGE REHEATER DRAIN PUMPS
℄ CONDENSER
CONDENSATE PUMPS
AIR EJECTOR
GLAND STEAM CONDENSER
FILT.
FILT.
FILT.
H.P. HTRS
MOISTURE SEPARATOR (ABOVE)
125'-0"
MEZZANINE FLOOR ELEV. 236'-0"
FEED WATER PUMPS
L.P. HEATERS
L.P. HEATERS "A"
HATCH AREA
BATTERY
DIESEL GENERATOR
480 VOLT SWITCHGEAR
480V. EMERG. SWITCHGEAR
480 VOLT SWITCHGEAR
AC & DC. DISTRIBUTION
MACHINE SHOP OFFICE
MACHINE SHOP 35' x 31'
TOOL ROOM
LOBBY
ELEVATOR
STORAGE 45' x 30'
55'-0"
106'-0"
4 2 0 4 8 12 16
GRAPHIC SCALE
200MWe BOILING D_2O
PRESSURE TUBE DIRECT CYCLE
WITH REHEAT TURBINE - 3600 RPM
REVISIONS
GENERAL ARRANGEMENT PLAN
GRADE FLOOR TURBINE BLDG.
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/8" = 1'-0"
DRAWN A. HEIDBREDER 2-15-60
CHECKED
ENGINEER 3-7-60
APPROVED 3-7-60
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
JOB NO. 2897-1
NS-474



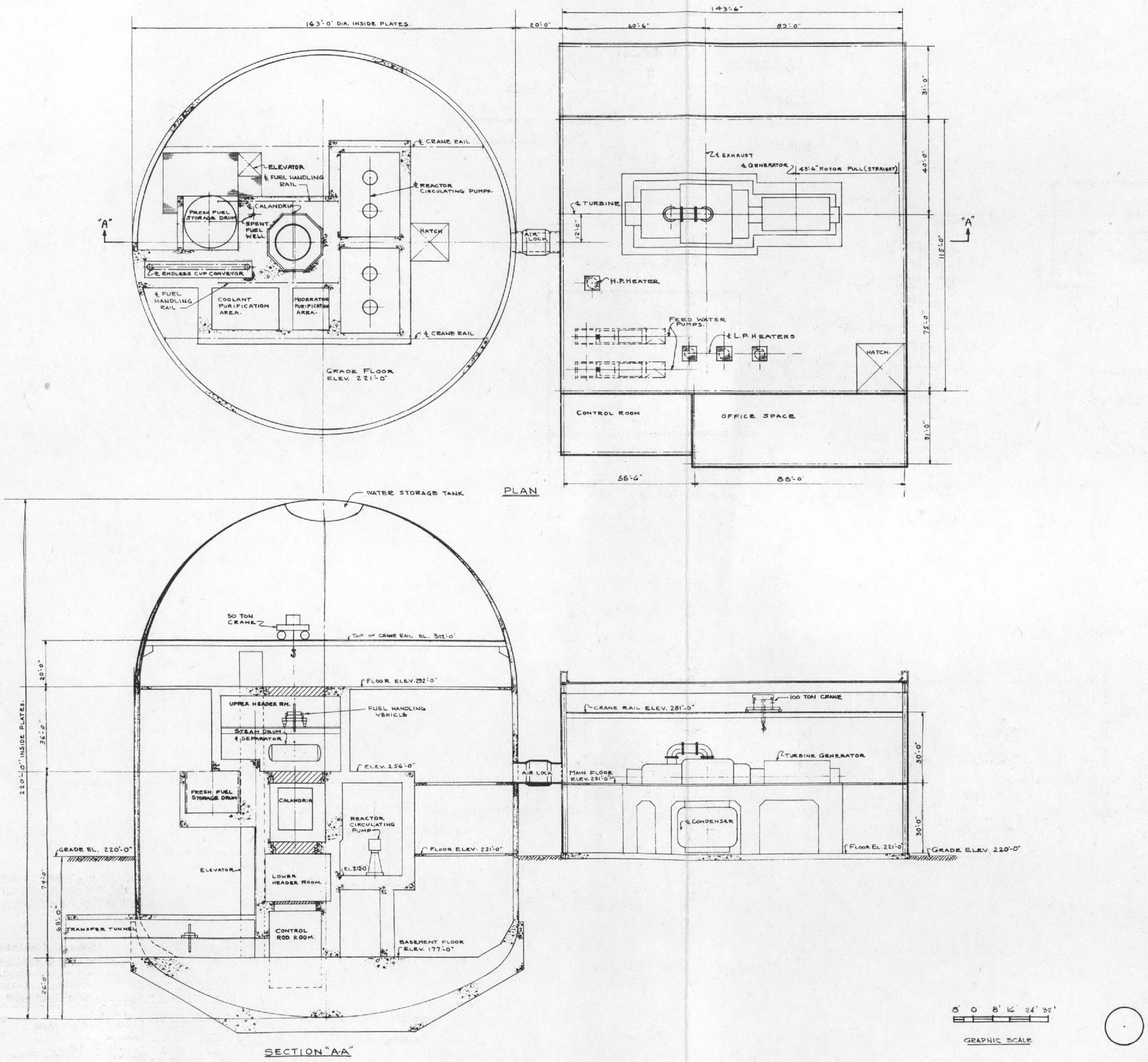
200 MW$_e$ BOILING D_2O
PRESSURE TUBE DIRECT CYCLE
WITH REHEAT TURBINE - 3600 RPM



GENERAL CROSS SECTION TURBINE BUILDING SAVANNAH RIVER OPERATIONS OFFICE CONTRACT AT (38-1) 213 U.S. ATOMIC ENERGY COMMISSION				
SCALE 1/8" = 1'-0"				SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWN A. HEIDBREDER 2.15.60				
CHECKED				
ENGINEER [illegible] 3-7-60				
APPROVED [illegible] 3-7-60				DRAWING NO.
JOB NO. 2897-1	JOB NO.	JOB NO.	JOB NO.	NS-475

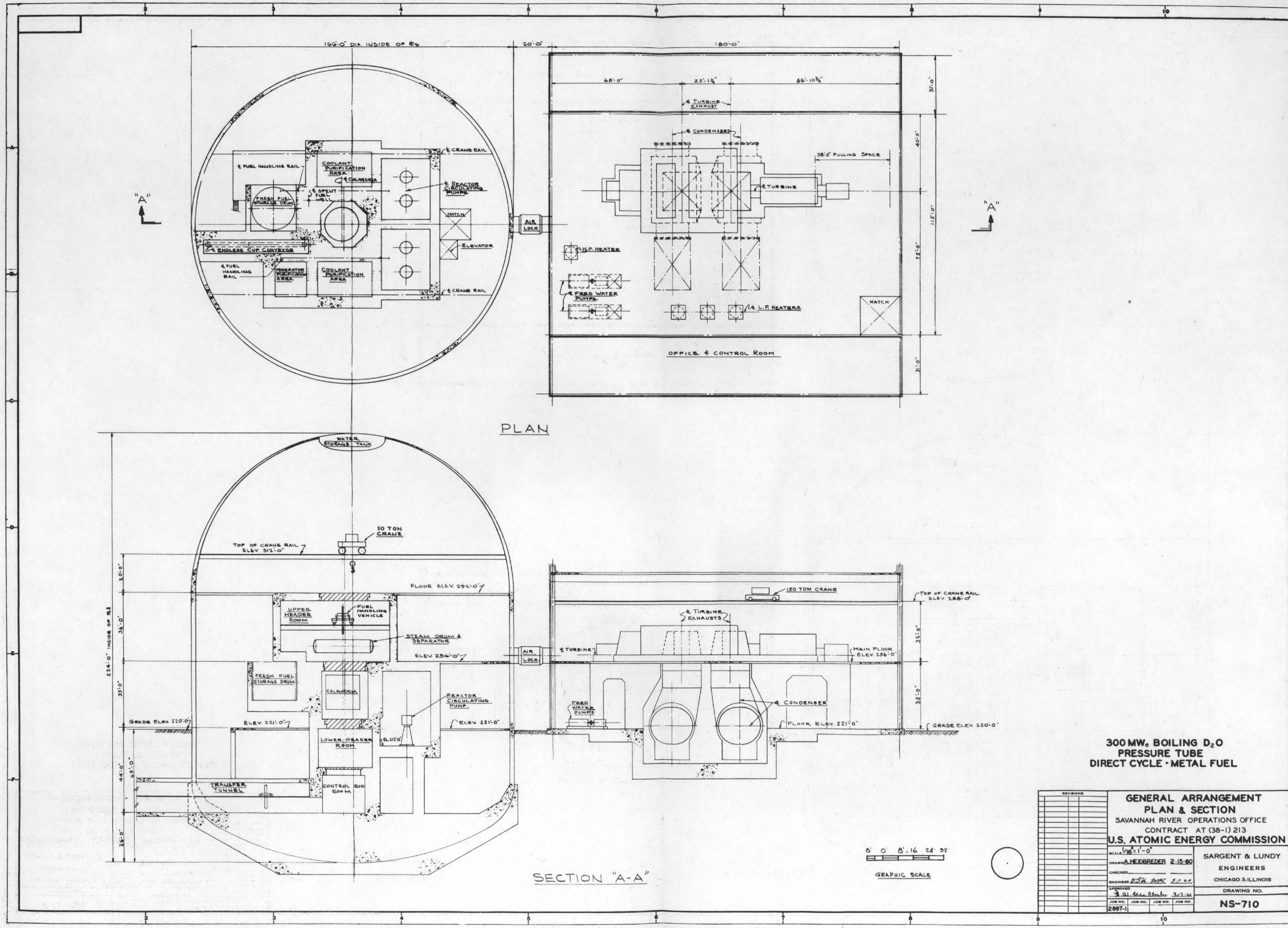


BOILING D_2O PRESSURE TUBE
DIRECT CYCLE PROTOTYPE
ALTERNATE HEAT DISSIPATION
GENERAL ARRANGEMENT
PLAN & SECTIONS
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NP-490
DRAWN F. J. FILIP 2-15-60
JOB NO. 2897-1
REVISIONS
GRAPHIC SCALE
SECTION "A-A"
SECTION "B-B"
℄ 9'-0" TRAVELING SCREENS
℄ SERVICE WATER PUMPS
℄ CIRCULATING PUMPS
℄ COND. CIRC. PUMPS
CRIB HOUSE
℄ FIRE PUMP
CONDENSER
SUB COOLER
℄ TURBINE EXHAUST
℄ R.R. TRACK
FRESH FUEL
SERVICE AREA
D_2O DISTILL. EQUIP.
STORAGE POOL
FUEL HANDLING BUILDING
D_2O DISTILLATION COLUMNS
℄ CONTAINMENT VESSEL
REACTOR CIRC. PUMP
CHIMNEY
HATCH
ELEV.
AIR LOCK
REACTOR
FRESH FUEL STORAGE TANK
ENDLESS CUP CONVEYOR
STEAM GENERATOR
SUB COOLER
MODERATOR HEAT EXCHANGER
108'-0" DIA. INSIDE ℄S
MISC. EQUIPMENT AREA
℄ 25,000 KW TURBINE
L.P. HEATER
H.P. HEATER
FEEDWATER PUMPS
CONTROL ROOM
GENERAL OFFICES & LOCKER ROOM
WATER STORAGE TANK 50,000 GAL.
70 TON CRANE
ELEV. 314'-0"
UPPER HEADER ROOM
ELEVATOR
STEAM GENERATOR
SUB-COOLER
AIR LOCK
REACTOR
25,000 KW TURBINE
COND.
EL. 241'-0"
GRADE ELEV. 220'-0"
℄ TURBINE EXHAUST & CONDENSER
℄ CONTAINMENT VESSEL
25 TON CRANE
TOP OF CRANE RAIL ELEV. 265'-0"
MAIN FLOOR ELEV. 241'-0"
BASEMENT FL. ELEV. 221'-0"
CONDENSER
GRADE ELEV. 220'-0"
ELEV. 213'-0"
HIGH WATER ELEV. 210'-0"
NORMAL WATER ELEV. 200'-0"
LOW WATER ELEV. 195'-0"
ELEV. 189'-0"
CRIB HOUSE

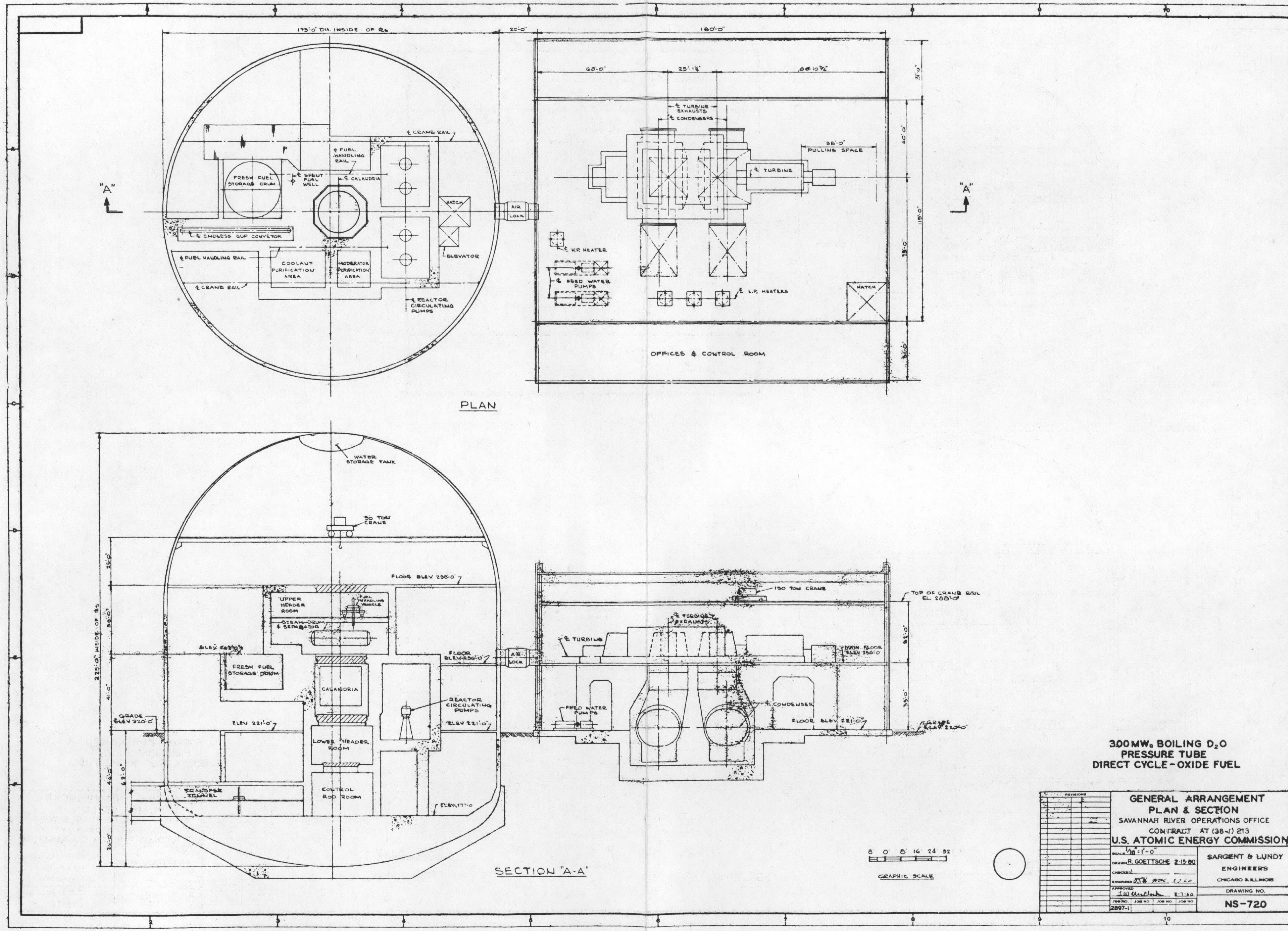


200 MW$_e$ BOILING D_2O
PRESSURE TUBE
DIRECT CYCLE - METAL FUEL

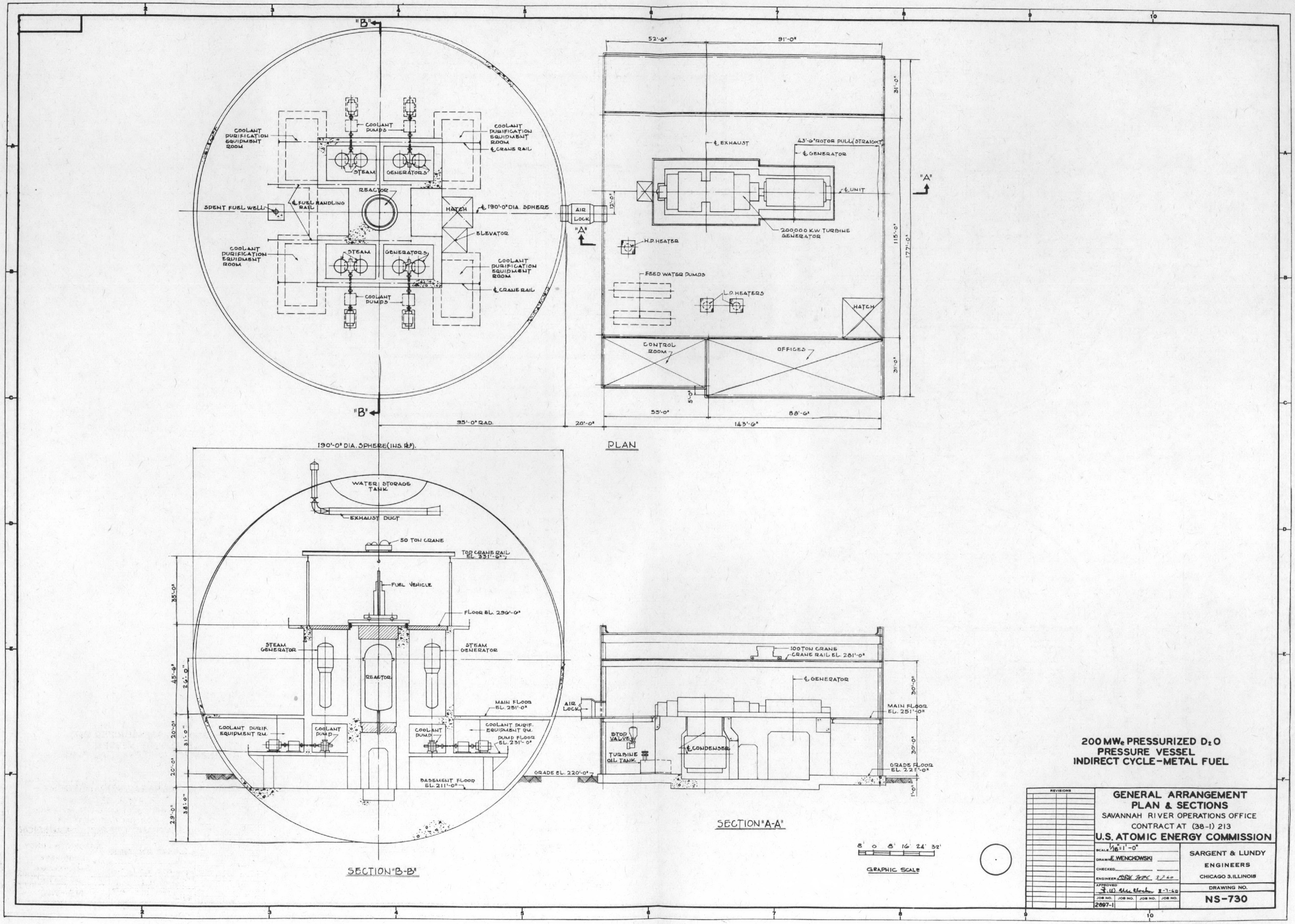
REVISIONS	GENERAL ARRANGEMENT PLAN & SECTION SAVANNAH RIVER OPERATIONS OFFICE CONTRACT AT (38-1) 213 U.S. ATOMIC ENERGY COMMISSION	
	SCALE 1/16" = 1'-0" DRAWN A. HEIDBREDER 2-15-60 CHECKED ENGINEER [illegible] 3-7-60	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
	APPROVED [illegible] 3-7-60	DRAWING NO.
	JOB NO. 2897-1	NS-700



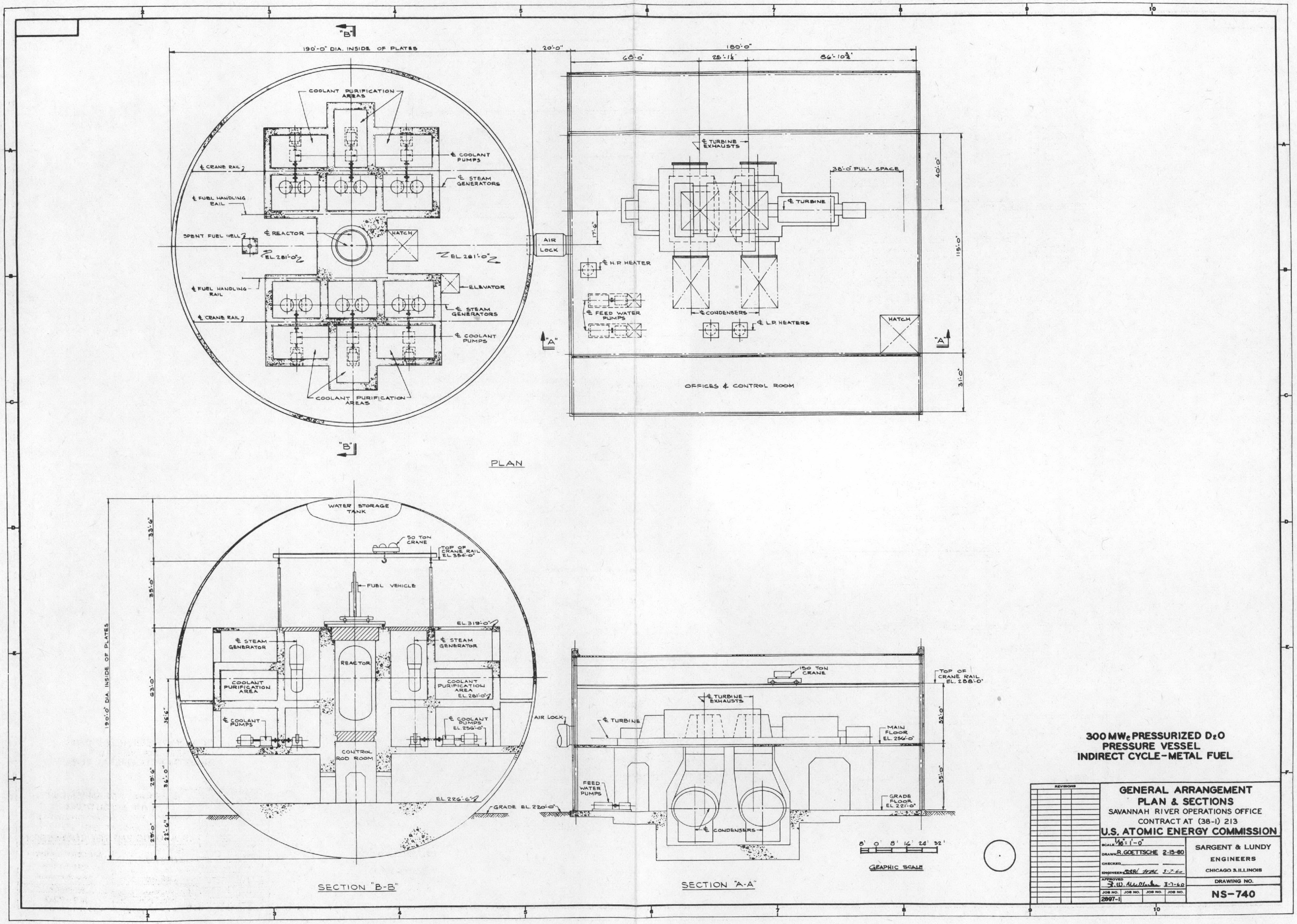
PLAN
SECTION "A-A"
"A"
166'-0" DIA INSIDE OF R's
20'-0"
180'-0"
68'-0"
25'-1¼"
86'-10¾"
℄ FUEL HANDLING RAIL
COOLANT PURIFICATION AREA
℄ CALANDRIA
℄ SPENT FUEL WELL
FRESH FUEL STORAGE DRUM
℄ CRANE RAIL
℄ REACTOR CIRCULATING PUMPS
HATCH
ELEVATOR
AIR LOCK
ENDLESS CUP CONVEYOR
℄ FUEL HANDLING RAIL
MODERATOR PURIFICATION AREA
COOLANT PURIFICATION AREA
℄ TURBINE EXHAUST
℄ CONDENSERS
38'-0" PULLING SPACE
℄ TURBINE
℄ H.P. HEATERS
℄ FEED WATER PUMPS
℄ L.P. HEATERS
HATCH
OFFICE & CONTROL ROOM
31'-0"
40'-0"
115'-0"
75'-0"
31'-0"
WATER STORAGE TANK
50 TON CRANE
TOP OF CRANE RAIL ELEV. 312'-0"
FLOOR ELEV. 292'-0"
UPPER HEADER ROOM
FUEL HANDLING VEHICLE
STEAM DRUM & SEPARATOR
ELEV. 256'-0"
FRESH FUEL STORAGE DRUM
CALANDRIA
REACTOR CIRCULATING PUMP
GRADE ELEV. 220'-0"
ELEV. 221'-0"
ELEV. 221'-0"
LOWER HEADER ROOM
CONTROL ROD ROOM
TRANSFER TUNNEL
224'-0" INSIDE OF R's
20'-0"
36'-0"
35'-0"
44'-0"
26'-0"
150 TON CRANE
TOP OF CRANE RAIL ELEV. 288'-0"
℄ TURBINE EXHAUSTS
℄ TURBINE
AIR LOCK
MAIN FLOOR ELEV. 256'-0"
33'-0"
35'-0"
FEED WATER PUMPS
℄ CONDENSER
FLOOR ELEV. 221'-0"
GRADE ELEV. 220'-0"
GRAPHIC SCALE
300 MWe BOILING D_2O
PRESSURE TUBE
DIRECT CYCLE - METAL FUEL
REVISIONS
GENERAL ARRANGEMENT
PLAN & SECTION
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/16" = 1'-0"
DRAWN A. HEIDBREDER 2-15-60
CHECKED
ENGINEER
APPROVED
JOB NO.
2897-1
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NS-710



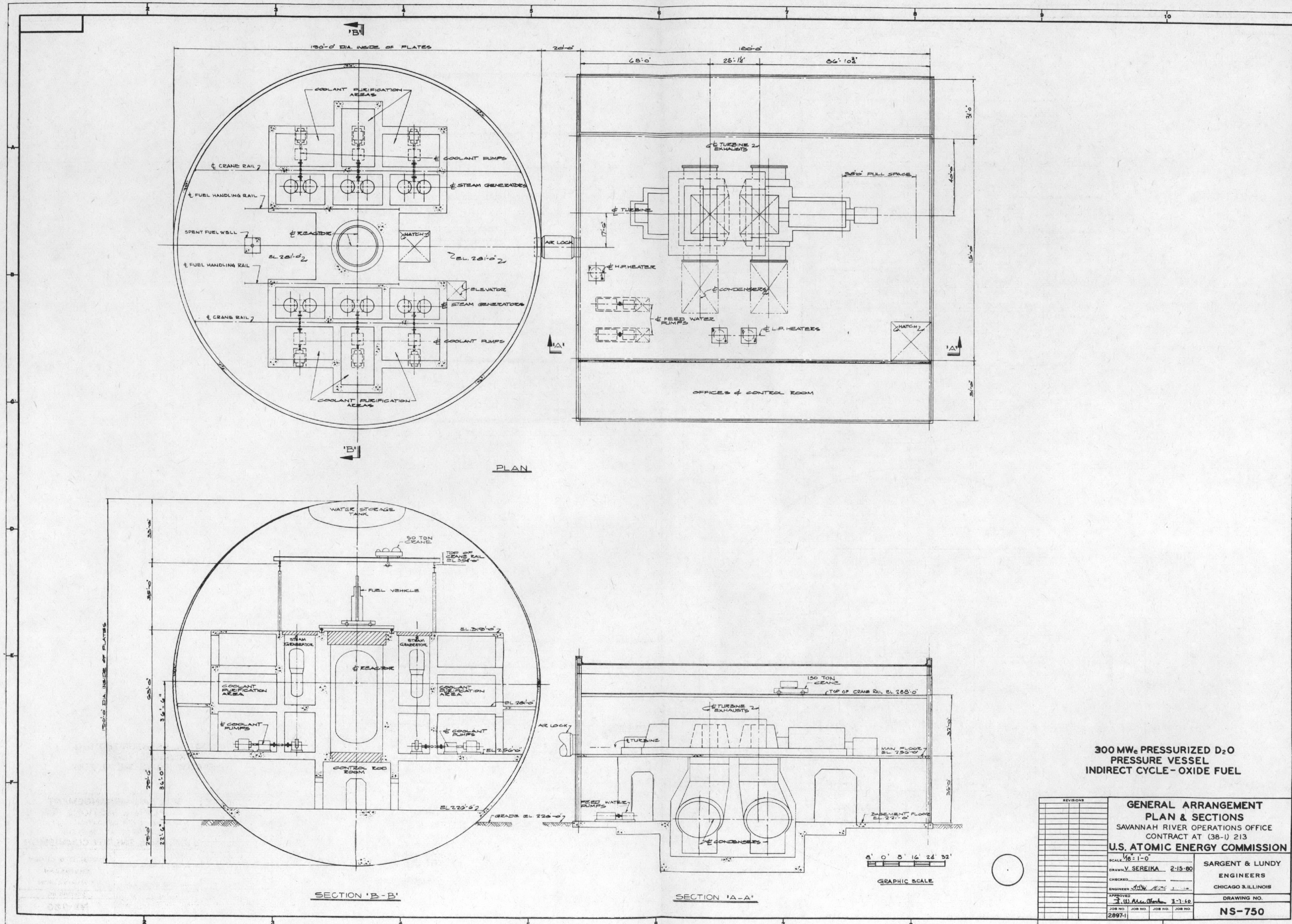
PLAN
SECTION "A-A"
173'-0" DIA. INSIDE OF ℄
FRESH FUEL STORAGE DRUM
SPENT FUEL WELL
FUEL HANDLING RAIL
℄ CALANDRIA
℄ CRANE RAIL
HATCH
AIR LOCK
ELEVATOR
℄ ENDLESS CUP CONVEYOR
℄ FUEL HANDLING RAIL
COOLANT PURIFICATION AREA
MODERATOR PURIFICATION AREA
℄ CRANE RAIL
℄ REACTOR CIRCULATING PUMPS
℄ TURBINE EXHAUSTS
℄ CONDENSERS
PULLING SPACE
℄ TURBINE
℄ H.P. HEATER
℄ FEED WATER PUMPS
℄ L.P. HEATERS
OFFICES & CONTROL ROOM
WATER STORAGE TANK
30 TON CRANE
FLOOR ELEV 298'-0"
UPPER HEADER ROOM
FUEL HANDLING VEHICLE
STEAM DRUM & SEPARATOR
FRESH FUEL STORAGE DRUM
CALANDRIA
REACTOR CIRCULATING PUMPS
LOWER HEADER ROOM
CONTROL ROD ROOM
TRANSFER TUNNEL
GRADE ELEV 220'-0"
ELEV 221'-0"
ELEV 177'-0
150 TON CRANE
TOP OF CRANE RAIL EL. 268'-0"
℄ TURBINE EXHAUSTS
℄ TURBINE
MAIN FLOOR ELEV 256'-0"
FEED WATER PUMPS
℄ CONDENSER
FLOOR ELEV 221'-0"
300 MWe BOILING D_2O
PRESSURE TUBE
DIRECT CYCLE - OXIDE FUEL
GENERAL ARRANGEMENT
PLAN & SECTION
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NS-720
R. GOETTSCHE 2-15-60
GRAPHIC SCALE

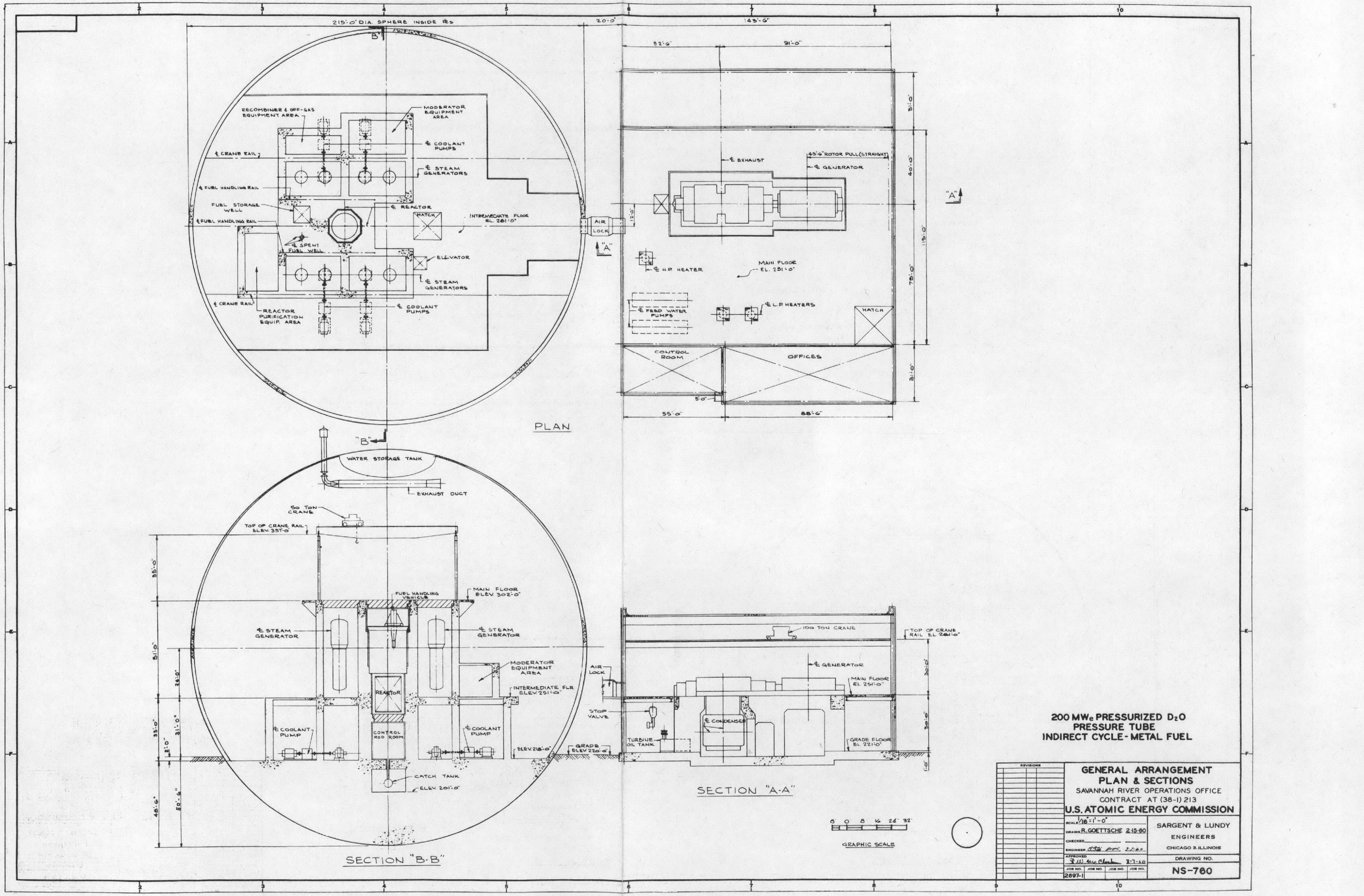


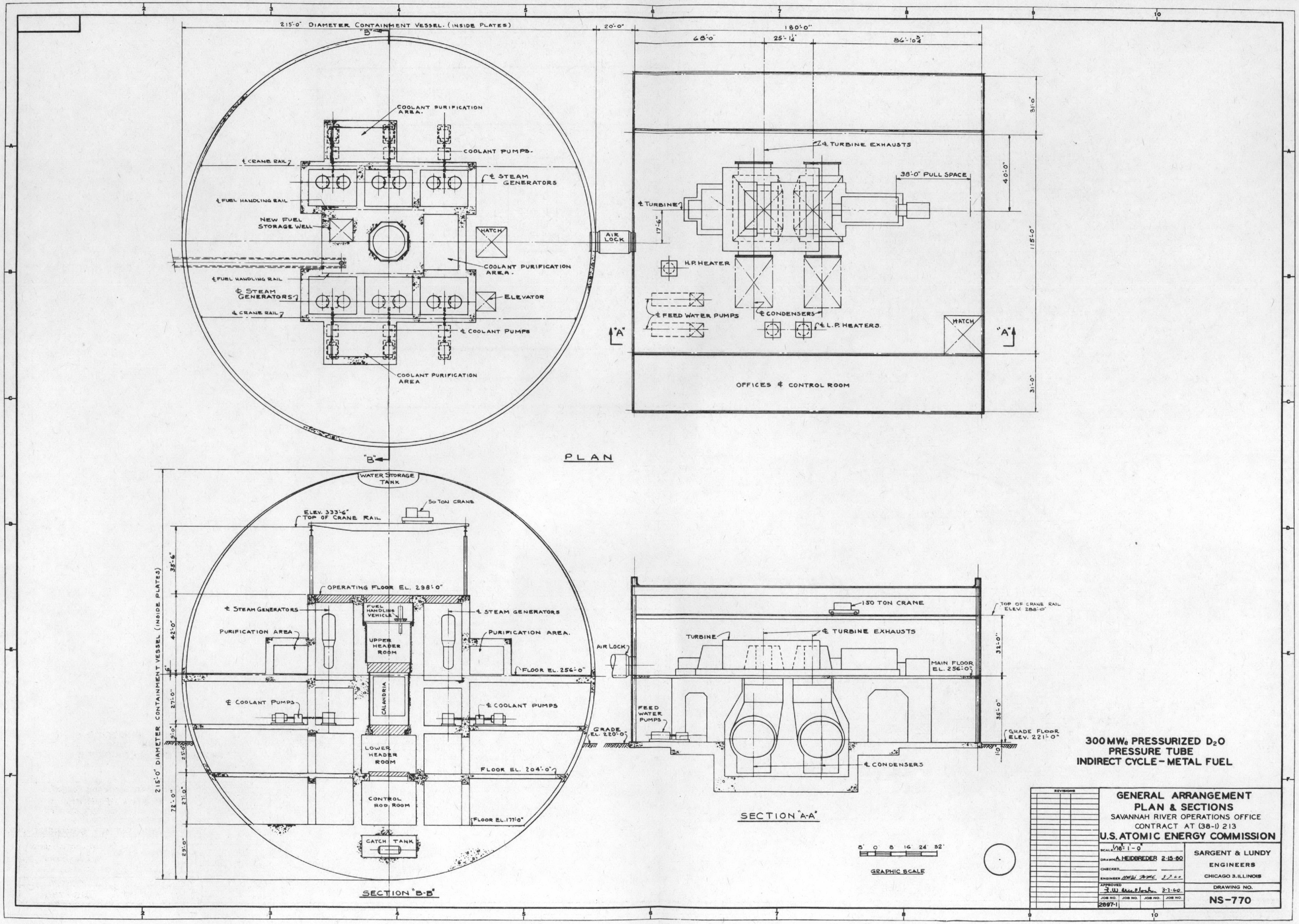
PLAN
SECTION "B-B"
SECTION "A-A"
COOLANT PURIFICATION EQUIPMENT ROOM
COOLANT PUMPS
STEAM GENERATORS
REACTOR
SPENT FUEL WELL
FUEL HANDLING RAIL
HATCH
190'-0" DIA. SPHERE
ELEVATOR
CRANE RAIL
AIR LOCK
EXHAUST
43'-0" ROTOR PULL (STRAIGHT)
GENERATOR
UNIT
200,000 K.W TURBINE GENERATOR
H.P. HEATER
FEED WATER PUMPS
L.P. HEATERS
CONTROL ROOM
OFFICES
95'-0" RAD.
190'-0" DIA. SPHERE (INS. R)
WATER STORAGE TANK
EXHAUST DUCT
50 TON CRANE
TOP CRANE RAIL EL. 331'-6"
FUEL VEHICLE
FLOOR EL. 296'-0"
STEAM GENERATOR
MAIN FLOOR EL. 251'-0"
COOLANT PURIF. EQUIPMENT RM.
COOLANT PUMP
PUMP FLOOR EL. 231'-0"
BASEMENT FLOOR EL. 211'-0"
GRADE EL. 220'-0"
100 TON CRANE
CRANE RAIL EL. 281'-0"
STOP VALVE
TURBINE OIL TANK
CONDENSER
GRADE FLOOR EL. 221'-0"
GRAPHIC SCALE
200 MWe PRESSURIZED D_2O PRESSURE VESSEL INDIRECT CYCLE-METAL FUEL
GENERAL ARRANGEMENT PLAN & SECTIONS
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/16"=1'-0"
DRAWN E. WENCHOWSKI
SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWING NO. NS-730

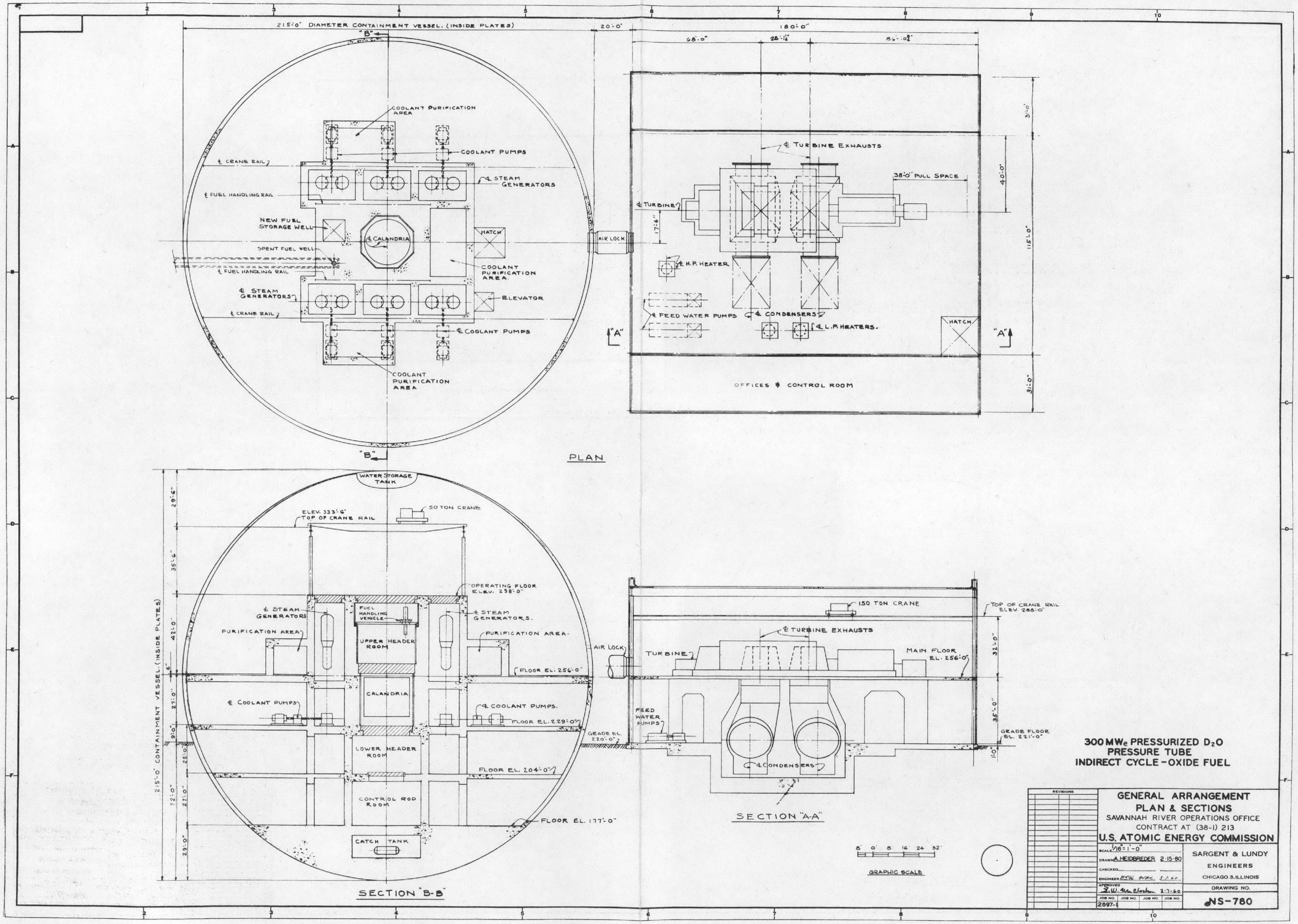


190'-0" DIA. INSIDE OF PLATES
COOLANT PURIFICATION AREAS
℄ COOLANT PUMPS
℄ STEAM GENERATORS
℄ CRANE RAIL
℄ FUEL HANDLING RAIL
℄ REACTOR
SPENT FUEL WELL
EL. 281'-0"
HATCH
AIR LOCK
℄ ELEVATOR
180'-0"
68'-0"
86'-10¾"
℄ TURBINE EXHAUSTS
38'-0" PULL SPACE
℄ TURBINE
℄ H.P. HEATER
℄ FEED WATER PUMPS
℄ CONDENSERS
℄ L.P. HEATERS
OFFICES & CONTROL ROOM
PLAN
WATER STORAGE TANK
50 TON CRANE
TOP OF CRANE RAIL EL. 354'-0"
FUEL VEHICLE
EL. 319'-0"
REACTOR
CONTROL ROD ROOM
EL. 256'-0"
EL. 226'-6"
GRADE EL. 220'-0"
190'-0" DIA. INSIDE OF PLATES
150 TON CRANE
TOP OF CRANE RAIL EL. 288'-0"
MAIN FLOOR EL. 256'-0"
GRADE FLOOR EL. 221'-0"
FEED WATER PUMPS
SECTION "B-B"
SECTION "A-A"
GRAPHIC SCALE
300 MWe PRESSURIZED D2O
PRESSURE VESSEL
INDIRECT CYCLE-METAL FUEL
REVISIONS
GENERAL ARRANGEMENT
PLAN & SECTIONS
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/16" = 1'-0"
DRAWN R. GOETTSCHE 2-15-60
CHECKED
ENGINEER 3-7-60
APPROVED 3-7-60
JOB NO. 2897-1
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NS-740


PLAN
SECTION 'B-B'
SECTION 'A-A'
GRAPHIC SCALE
COOLANT PURIFICATION AREAS
COOLANT PUMPS
STEAM GENERATORS
CRANE RAIL
FUEL HANDLING RAIL
SPENT FUEL WELL
REACTOR
HATCH
ELEVATOR
AIR LOCK
TURBINE
TURBINE 2 EXHAUSTS
H.P. HEATER
CONDENSERS
FEED WATER PUMPS
L.P. HEATERS
OFFICES & CONTROL ROOM
WATER STORAGE TANK
50 TON CRANE
FUEL VEHICLE
CONTROL ROD ROOM
150 TON CRANE
MAIN FLOOR
BASEMENT FLOOR
300 MWe PRESSURIZED D2O
PRESSURE VESSEL
INDIRECT CYCLE - OXIDE FUEL
GENERAL ARRANGEMENT
PLAN & SECTIONS
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWN V. SEREIKA 2-15-60
DRAWING NO.
NS-750


215'-0" DIA. SPHERE INSIDE
20'-0"
143'-6"
32'-6"
91'-0"
RECOMBINER & OFF-GAS EQUIPMENT AREA
MODERATOR EQUIPMENT AREA
℄ CRANE RAIL
℄ COOLANT PUMPS
℄ STEAM GENERATORS
℄ FUEL HANDLING RAIL
FUEL STORAGE WELL
℄ REACTOR
HATCH
INTERMEDIATE FLOOR EL. 281'-0"
℄ FUEL HANDLING RAIL
℄ SPENT FUEL WELL
ELEVATOR
℄ STEAM GENERATORS
℄ CRANE RAIL
REACTOR PURIFICATION EQUIP. AREA
℄ COOLANT PUMPS
AIR LOCK
℄ EXHAUST
45'-6" ROTOR PULL (STRAIGHT)
℄ GENERATOR
℄ H.P. HEATER
MAIN FLOOR EL. 251'-0"
℄ FEED WATER PUMPS
℄ L.P. HEATERS
HATCH
CONTROL ROOM
OFFICES
55'-0"
88'-6"
PLAN
WATER STORAGE TANK
EXHAUST DUCT
50 TON CRANE
TOP OF CRANE RAIL ELEV. 357'-0"
FUEL HANDLING VEHICLE
MAIN FLOOR ELEV. 302'-0"
℄ STEAM GENERATOR
℄ STEAM GENERATOR
MODERATOR EQUIPMENT AREA
REACTOR
INTERMEDIATE FLR ELEV. 251'-0"
℄ COOLANT PUMP
℄ COOLANT PUMP
CONTROL ROD ROOM
ELEV. 218'-0"
GRADE ELEV. 220'-0"
CATCH TANK
ELEV. 201'-0"
SECTION "B-B"
100 TON CRANE
TOP OF CRANE RAIL EL. 281'-0"
℄ GENERATOR
AIR LOCK
MAIN FLOOR EL. 251'-0"
STOP VALVE
℄ CONDENSER
TURBINE OIL TANK
GRADE FLOOR EL. 221'-0"
SECTION "A-A"
GRAPHIC SCALE
200 MWe PRESSURIZED D2O PRESSURE TUBE INDIRECT CYCLE - METAL FUEL
GENERAL ARRANGEMENT PLAN & SECTIONS
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/16" = 1'-0"
DRAWN R. GOETTSCHE 2-15-60
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NS-760
2897-1


215'-0" DIAMETER CONTAINMENT VESSEL. (INSIDE PLATES)
"B"
20'-0"
180'-0"
68'-0"
25'-1 1/4"
86'-10 3/4"
COOLANT PURIFICATION AREA.
COOLANT PUMPS.
℄ CRANE RAIL
℄ STEAM GENERATORS
℄ FUEL HANDLING RAIL
NEW FUEL STORAGE WELL
HATCH
AIR LOCK
COOLANT PURIFICATION AREA.
℄ FUEL HANDLING RAIL
℄ STEAM GENERATORS
ELEVATOR
℄ CRANE RAIL
℄ COOLANT PUMPS
COOLANT PURIFICATION AREA
2-℄ TURBINE EXHAUSTS
38'-0" PULL SPACE
℄ TURBINE
17'-6"
H.P. HEATER
℄ FEED WATER PUMPS
℄ CONDENSERS
℄ L.P. HEATERS
HATCH
"A"
"A"
OFFICES & CONTROL ROOM
31'-0"
40'-0"
115'-0"
31'-0"
PLAN
WATER STORAGE TANK
50 TON CRANE
ELEV. 333'-6" TOP OF CRANE RAIL
OPERATING FLOOR EL. 298'-0"
℄ STEAM GENERATORS
FUEL HANDLING VEHICLE
℄ STEAM GENERATORS
PURIFICATION AREA
UPPER HEADER ROOM
PURIFICATION AREA.
FLOOR EL. 256'-0"
CALANDRIA
℄ COOLANT PUMPS
℄ COOLANT PUMPS
LOWER HEADER ROOM
FLOOR EL. 204'-0"
CONTROL ROD ROOM
FLOOR EL. 177'-0"
CATCH TANK
215'-0" DIAMETER CONTAINMENT VESSEL (INSIDE PLATES)
35'-6"
42'-0"
27'-0"
27'-0"
72'-0"
29'-0"
SECTION "B-B"
150 TON CRANE
TOP OF CRANE RAIL ELEV. 288'-0"
TURBINE
℄ TURBINE EXHAUSTS
AIR LOCK
MAIN FLOOR EL. 256'-0"
32'-0"
35'-0"
FEED WATER PUMPS
GRADE EL. 220'-0"
GRADE FLOOR ELEV. 221'-0"
℄ CONDENSERS
SECTION "A-A"
GRAPHIC SCALE
300 MWe PRESSURIZED D_2O
PRESSURE TUBE
INDIRECT CYCLE - METAL FUEL
REVISIONS
GENERAL ARRANGEMENT
PLAN & SECTIONS
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/16" = 1'-0"
DRAWN A. HEIDBREDER 2-15-60
CHECKED
ENGINEER
APPROVED
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NS-770
JOB NO. 2897-1


215'-0" DIAMETER CONTAINMENT VESSEL. (INSIDE PLATES)
20'-0"
180'-0"
68'-0"
85'-0"
COOLANT PURIFICATION AREA
COOLANT PUMPS
℄ CRANE RAIL
℄ STEAM GENERATORS
℄ FUEL HANDLING RAIL
NEW FUEL STORAGE WELL
℄ CALANDRIA
HATCH
SPENT FUEL WELL
COOLANT PURIFICATION AREA.
ELEVATOR
℄ COOLANT PUMPS
AIR LOCK
℄ TURBINE EXHAUSTS
38'-0" PULL SPACE
℄ TURBINE
17'-6"
℄ H.P. HEATER
℄ FEED WATER PUMPS
℄ CONDENSERS
℄ L.P. HEATERS.
"A"
OFFICES & CONTROL ROOM
31'-0"
40'-0"
115'-0"
"B"
PLAN
WATER STORAGE TANK
50 TON CRANE
ELEV. 333'-6" TOP OF CRANE RAIL
OPERATING FLOOR ELEV. 298'-0"
FUEL HANDLING VEHICLE
UPPER HEADER ROOM
PURIFICATION AREA
FLOOR EL. 256'-0"
CALANDRIA
FLOOR EL. 229'-0"
GRADE EL. 220'-0"
LOWER HEADER ROOM
FLOOR EL. 204'-0"
CONTROL ROD ROOM
FLOOR EL. 177'-0"
CATCH TANK
215'-0" CONTAINMENT VESSEL. (INSIDE PLATES)
SECTION "B-B"
150 TON CRANE
TOP OF CRANE RAIL ELEV. 288'-0"
MAIN FLOOR EL. 256'-0"
FEED WATER PUMPS
GRADE FLOOR EL. 221'-0"
SECTION "A-A"
GRAPHIC SCALE
300 MWe PRESSURIZED D₂O PRESSURE TUBE INDIRECT CYCLE - OXIDE FUEL
GENERAL ARRANGEMENT
PLAN & SECTIONS
SAVANNAH RIVER OPERATIONS OFFICE
CONTRACT AT (38-1) 213
U.S. ATOMIC ENERGY COMMISSION
SCALE 1/16" = 1'-0"
DRAWN A. HEIDBREDER 2-15-60
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NS-780