SL-1674

POWER COST NORMALIZATION STUDIES CIVILIAN POWER REACTOR PROGRAM—1959

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Oak Ridge, Tennessee

REPORT SL-1674

POWER COST NORMALIZATION STUDIES

CIVILIAN POWER REACTOR PROGRAM - 1959

FOR

EVALUATION AND PLANNING BRANCH

DIVISION OF REACTOR DEVELOPMENT

UNITED STATES ATOMIC ENERGY COMMISSION

by

Sargent & Lundy

SEPTEMBER 1, 1959

TABLE OF CONTENTS

I - INTRODUCTION

In connection with the development of a comprehensive plan for a ten year civilian power reactor program, the Evaluation and Planning Branch, Division of Reactor Development, United States Atomic Energy Commision has had a series of status reports prepared to present a comprehensive review of the technical and economic status of various nuclear power reactor concepts. In as much as the economic data reported by the various contractors reflected different design philosophies, different estimating policies, and in some cases a technology not verified by the AEC definition of current status, Sargent and Lundy was requested on July 2, 1959 to review the aforementioned status reports and to prepare normalized cost estimates of each of eight reactor concepts for presentation to the AEC by August 20, 1959 for incorporation in their report Part I Summary Current Status of Reactor Concepts. This report presents the backup information associated with the aforementioned cost estimates.

II - SCOPE OF WORK

The objectives of the scope of work undertaken in these cost studies consisted of:

(1) Normalization of the capital cost estimates prepared by various contractors for a range of plant sizes by the use of comparative costs for similar equipment, with the same base for overhead and indirect costs.

(2) An evaluation of fuel costs consistent with the AEC specified fabrication costs and allowable irradiation levels.

(3) An evaluation of the operation and maintenance costs associated with each of the eight reactor concepts. The nuclear power reactor concepts studied in connection with the development of the 10-year civilian power reactors program have been categorized as follows:

A. Thermal Converter Reactors
   (1) Pressurized Water
   (2) Boiling Water
   (3) Organic Cooled
   (4) Sodium Graphite

B. Breeder Reactors
   (1) Liquid metal cooled, fast
   (2) Fluid fuel, aqueous homogeneous

C. Natural Uranium Fuel and Recycle Reactors
   (1) Heavy water moderated reactors
   (2) Gas cooled reactors

Capital cost estimates, fuel cost estimates, and operation and maintenance cost estimates, including nuclear insurance costs, were prepared for each of these reactor types over a range of plant sizes.

III - SUMMARY

In as much as the economic data reported by the various contractors in their Status Reports reflected varying design philosophies and different estimating policies, the overall objectives of the cost normalization were to:

(1) Use uniform costs throughout, with appropriate size differentials for those components of the plants which had the same design specifications, i.e. turbine generation, condensers, pumping equipment, heat exchangers, power transformers and buildings and structures.

(2) Incorporate provisions for service and auxiliary facilities on a common basis for all reactor concepts.

(3) Establish uniform construction periods for use in determining interest during construction.

(4) Assure that the cost estimates for all reactor types are prepared by the same estimating procedures.

In order to accomplish these objectives, each reactor concept was studied in three plant sizes. In general. the sizes selected for analysis were 75 MW(e) 200 MW(e), and 300 MW(e). Because of the time limitations of the study, a more detailed analysis was made for the 200 MW(e) plant size with less detailed extrapolation studies performed for the other plant sizes. In the case of the Organic Cooled and the Sodium Graphite reactor concepts the base size plants studied were 75 MW(e) with extrapolations to the larger sizes because of the availability of more definitive design information in these sizes. Likewise a base size of 150 MW(e) was selected for use with the Fast Breeder Reactor concept.

In general the areas in which the plant designs were normalized for cost estimating purposes were:

(1) site conditions
(2) property plat
(3) plant arrangement
(4) plant service requirements
(5) cost estimating

The site conditions utilized in all of the plant designs were as specified by the AEC. In general, the sites consisted of 1200 acres of grass covered level terrain adjacent to a river with adequate flow for the plant cooling water requirements. The plant is located approximately 40 feet above low water level and 20 feet above high water level. A limestone formation is located approximately 8 feet below grade level.

The arrangement of the plant structures for all concepts is essentially as indicated on Figure III-1. Slight variations in the placement of the fuel handling and waste disposal areas on the property exist in the normalized plant designs, however such variations have a relatively insignificant effect on the plant capital cost estimate.

The plant equipment arrangements were developed in as uniform a manner as possible. While the various reactor plant concepts dictate different reactor plant equipment arrangements, these differences were minimized wherever possible. In general, these differences arise from different philosophies of design associated with the various reactor concepts. The design philosophy and arrangement for such factors as containment, fuel handling, reactor control, shielding, and maintenance as reported in the various Status Reports was maintained in the reactor plant arrangement. The arrangements for the turbine plants, crib house, control rooms, machine shops, personnel facilities were

maintained as nearly uniform as possible in all cases. The plant requirements likewise were maintained constant whenever possible in the designs prepared for cost estimating.
The cost estimating for all plants was performed by the same group of estimators, thus alleviating to the maximum extent the differences in cost estimates which occur when the estimates are prepared by different groups. Likewise, the power cost evaluations were made with the same economic basis in all cases.
The fuel cost analysis were prepared by Argonne National Laboratory with the assistance of Sargent & Lundy. In this area cost studies were made for three core sizes with one exception. Sufficient information was not available for the gas cooled natural uranium concept to justify an attempt to cover a range of sizes. The cost estimates were based on the values for allowable burnup, fabrication costs, calculation procedure, fuel and cladding materials for the various concepts as specified by AEC.

Operation and maintenance costs were prepared for each of the various reactor plant concepts for a range of plant sizes. In preparing these cost estimates the complexity of station designs and the reactor complex were taken into account for each plant. The annual operating costs associated with coolant and moderator makeup has been incorporated when such items amount to a significant annual value. In addition, estimates were prepared for the nuclear insurance costs which would be associated with these plants under private ownership.

The power generation costs for the thermal converter reactors as related to plant size are indicated on Figure III-2. For comparison, a curve is indicated for the power generation cost of conventional coal fired plants based on an 80% load factor. Although single line curves are shown, it is fully understood that experience does not justify this practice.

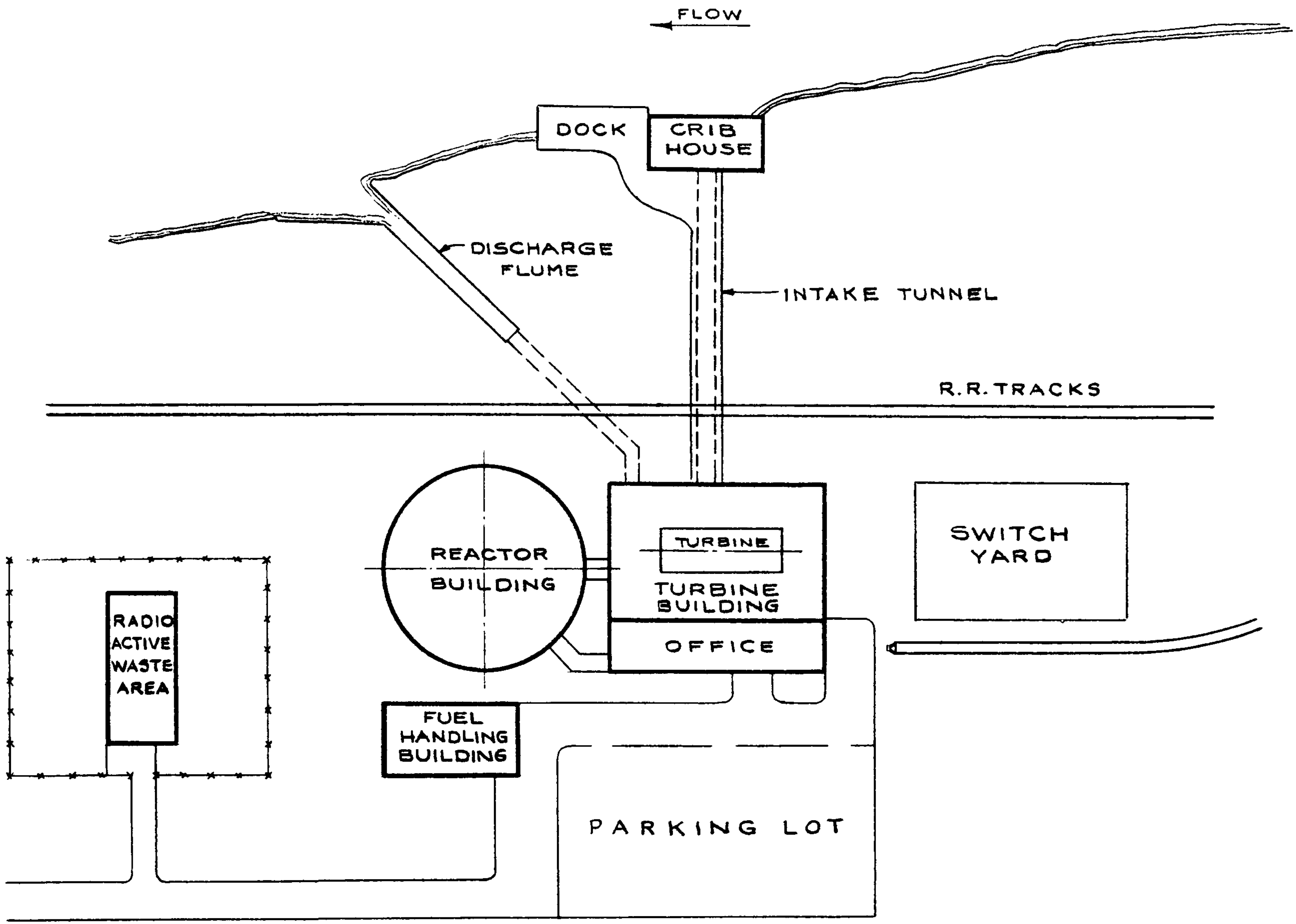
Although single line curves are shown, it is fully understood that experience does not justify this practice.
The power generation cost components including capital cost, fuel cost, operation and maintenance costs and nuclear insurance costs, have been shown separately on Figure III-3 through Figure III-6 for the pressurized water, boiling water, organic cooled, and sodium graphite reactors, respectively. Specific information relative to the economic basis utilized is indicated on the curves.
Similar curves of power generation costs and power generation cost component curves are presented for the breeder reactors on Figure III-7 through Figure III-9 and for the natural uranium fueled and recycle reactors on Figure III-10 through Figure III-12, respectively.
A summary table of the data utilized in plotting the aforementioned curves is presented on Table III-1, Summary of Normalized Power Generation Costs.

Table III-1
SL-1674

SUMMARY OF NORMALIZED POWER GENERATION COSTS

Reactor Type	Plant Capacity	Capital Costs: Total Capital Cost $	Capital Costs: Ann. Costs $/yr.	Capital Costs: Mills/kwh	Fuel Costs: Ann. Costs $/yr.	Fuel Costs: Mills/kwh	Oper. & Maint. Costs: Ann. Costs $/yr.	Oper. & Maint. Costs: Mills/kwh	Nuclear Insurance Costs: Ann. Costs $/yr.	Nuclear Insurance Costs: Mills/kwh	Total Power Costs: Ann. Costs $/yr.	Total Power Costs: Mills/kwh
Thermal Converter Reactors												
Pressurized Water	75	32,600,000	4,560,000	8.69	2,405,000	4.58	719,050	1.37	370,800	0.70	8,054,850	15.34
	200	56,400,000	7,900,000	5.64	5,490,000	3.92	1,091,300	0.78	481,700	0.34	14,963,000	10.68
	300	73,400,000	10,300,000	4.90	8,000,000	3.81	1,240,300	0.59	552,900	0.26	20,093,200	9.56
Boiling Water	75	35,200,000	4,930,000	9.40	2,190,000	4.17	728,050	1.38	369,000	0.71	8,217,050	15.66
	200	62,200,000	8,710,000	6.22	5,350,000	3.82	1,111,300	0.79	498,400	0.36	15,669,700	11.19
	300	78,900,000	11,050,000	5.26	7,300,000	3.47	1,270,300	0.61	565,250	0.27	20,185,550	9.61
Organic Cooled	75	26,200,000	3,670,000	6.98	3,320,000	6.33	985,800	1.88	336,400	0.64	8,312,200	15.83
	200	48,200,000	6,740,000	4.81	8,250,000	5.90	1,800,300	1.28	448,500	0.32	17,238,800	12.31
	300	66,000,000	9,225,000	4.39	12,020,000	5.72	2,293,300	1.09	525,600	0.25	24,063,900	11.45
Sodium Graphite	75	42,500,000	5,950,000	11.30	4,653,000	8.85	788,800	1.50	387,950	0.74	11,779,750	22.39
	200	72,000,000	10,090,000	7.20	11,174,000	7.97	1,251,300	0.89	531,500	0.38	23,046,800	16.44
	300	90,900,000	12,710,000	6.05	16,146,000	7.68	1,471,300	0.70	607,400	0.29	30,934,700	14.72
Breeder Reactors												
Fast, Sodium Cooled	75	34,100,000	4,770,000	9.10	4,150,000	7.90	849,550	1.61	351,950	0.67	10,121,500	19.28
	150	51,000,000	7,140,000	6.80	7,900,000	7.52	1,240,300	1.18	451,700	0.43	16,732,000	15.93
	200	60,000,000	8,400,000	6.00	10,370,000	7.40	1,391,300	0.99	488,950	0.35	20,650,250	14.74
	300	76,500,000	10,700,000	5.10	14,930,000	7.10	1,673,300	0.79	554,150	0.26	27,857,450	13.25
Thermal (Aqueous Homogeneous)	75	33,800,000	4,686,000	8.92	1,340,000	2.55	1,937,050	3.69	410,200	0.70	8,373,250	15.86
	200	72,300,000	10,000,000	7.15	3,010,000	2.15	3,907,300	2.79	535,850	0.38	17,453,150	12.47
	300	96,900,000	13,400,000	6.38	4,460,000	2.12	5,302,300	2.53	633,350	0.30	23,795,650	11.33
Natural Uranium & Recycle Reactors												
Heavy Water	75	48,000,000	6,620,000	12.60	2,420,000	4.61	956,300	1.82	426,500	0.81	10,422,800	19.84
	200	85,000,000	11,675,000	8.35	6,170,000	4.40	1,594,300	1.14	583,300	0.42	20,022,600	14.31
	300	108,000,000	14,800,000	7.05	8,870,000	4.22	1,924,300	0.91	676,700	0.32	26,271,000	12.50
Gas Cooled	75	50,600,000	7,090,000	13.50	2,020,000	3.85	728,050	1.38	432,900	0.82	10,270,950	19.55
	200	90,500,000	12,670,000	9.05	4,910,000	3.50	1,111,300	0.79	600,650	0.43	19,291,950	13.77
	300	114,000,000	15,960,000	7.60	7,040,000	3.35	1,270,300	0.61	696,500	0.33	24,966,800	11.89
Conventional Coal Fired Plants												
35¢/million Btu Fuel	60	13,254,000	1,855,600	4.41	1,628,700	3.88	317,200	0.75			3,801,500	9.04
	200	35,690,000	4,996,600	3.57	4,684,800	3.34	707,200	0.50	-	-	10,388,600	7.41
	325	53,795,000	7,531,300	3.31	7,549,900	3.32	832,000	0.36			15,913,200	6.99
25¢/million Btu Fuel	60	13,254,000	1,855,600	4.41	1,163,300	2.77	317,200	0.75			3,301,500	7.93
	200	35,690,000	4,996,600	3.57	3,346,300	2.39	707,200	0.50	-	-	9,050,100	6.46
	325	53,795,000	7,531,300	3.31	5,392,800	2.37	832,000	0.36			13,756,100	6.04

Note: Nuclear costs based on 80% Load Factor, 14% Fixed Charges, 4% Uranium Use Charge and $12.00/gm. Plutonium Credit.
Coal Fired costs based on 80% Load Factor and 14% Fixed Charges.



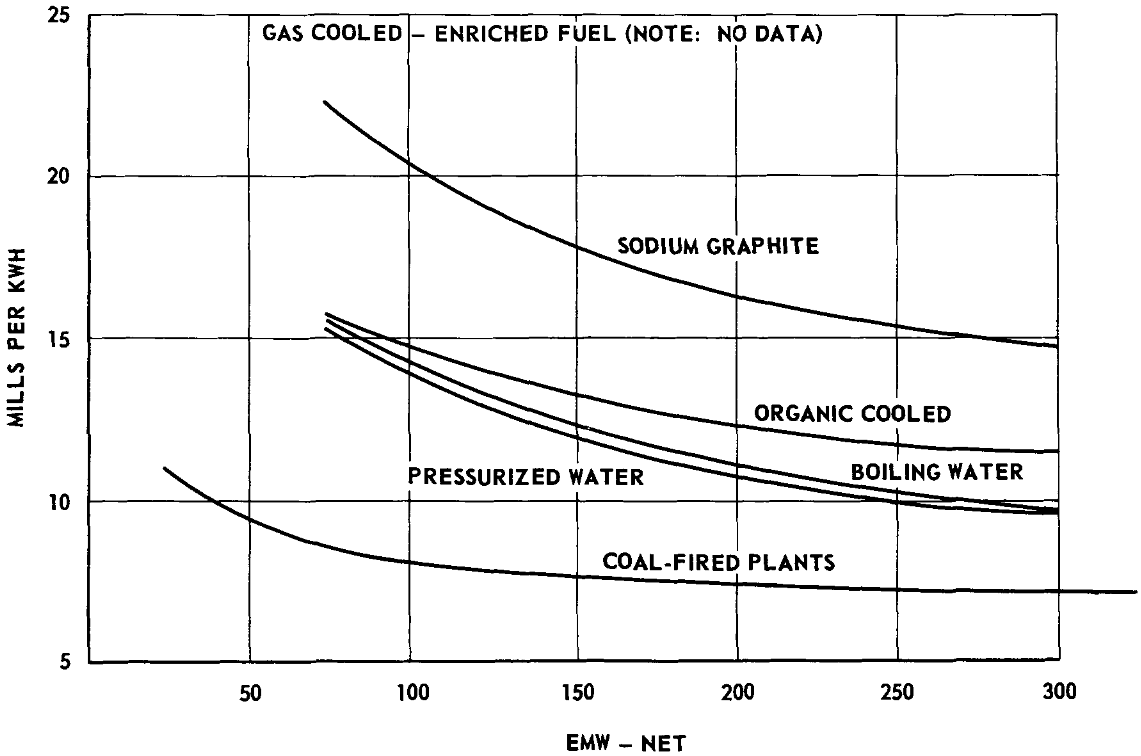
NORMALIZED PROPERTY PLAT

Figure III-1
SL-1674

POWER GENERATION COSTS

THERMAL CONVERTER REACTORS
vs
COAL-FIRED PLANTS

Single Unit Stations – 1959 Costs
Rating At 1½" Hg.



NOTES:

NUCLEAR –
BASED ON 1959 STATUS REPORT

LOAD FACTOR	80%
FIXED CHARGES	14%
URANIUM USE CHARGE	4%
PLUTONIUM CREDIT	$12/GM.

COAL – FIRED –
BASED ON SL – 1564 SUPP. 2

LOAD FACTOR	80%
FIXED CHARGES	14%
FUEL COST	35¢/10^6BTU

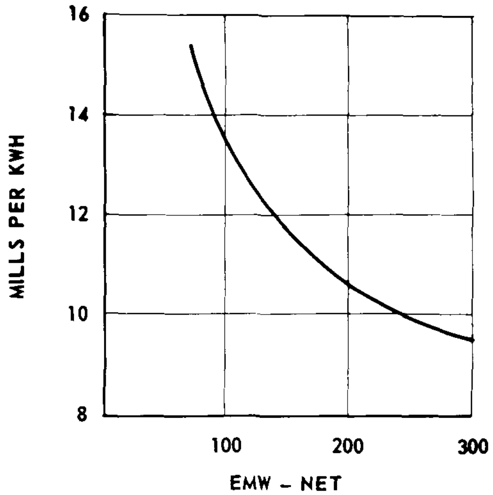
SEPT 1959

POWER GENERATION COSTS

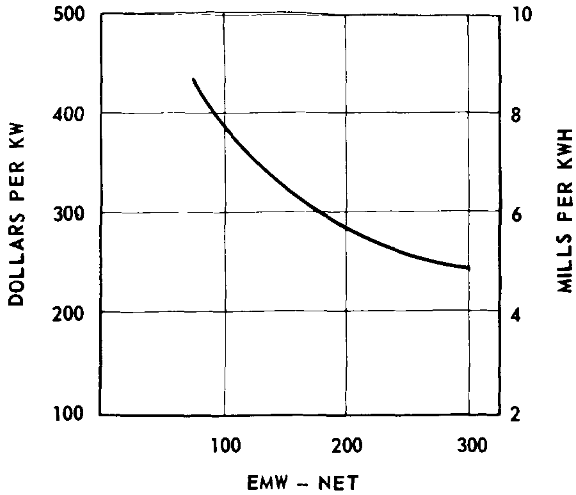
PRESSURIZED WATER REACTORS

Single Unit Stations – 1959 Costs
Rating At 1½" Hg.

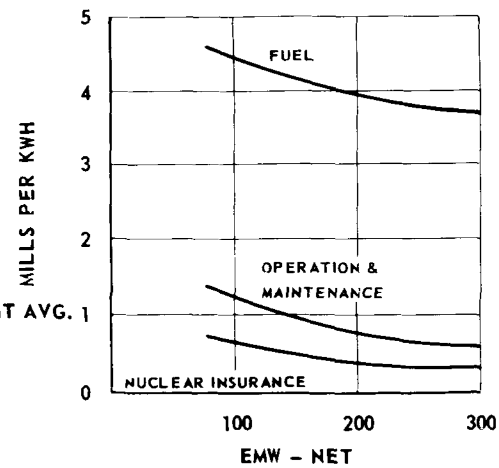
POWER GENERATION COSTS



CAPITAL COSTS



OPERATING COSTS



NOTES:

BASED ON 1959 STATUS REPORT

LOAD FACTOR	80%
FIXED CHARGES	14%
URANIUM USE CHARGE	4%
PLUTONIUM CREDIT	\$12/GM.
FUEL FABRICATION COST	
UO_2 – SS	\$110/KG.
FUEL EXPOSURE	13000 MWD/MT AVG.

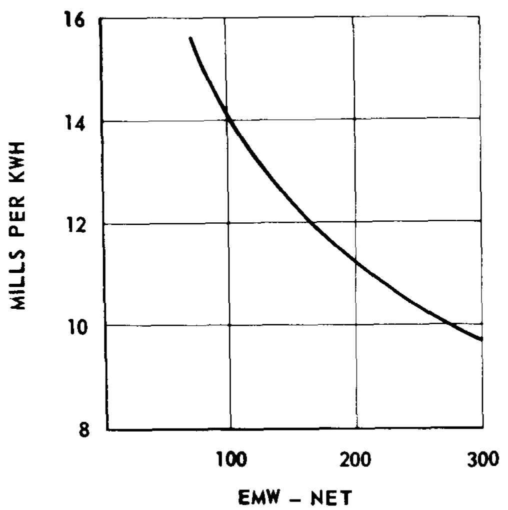
SEPT 1959

POWER GENERATION COSTS

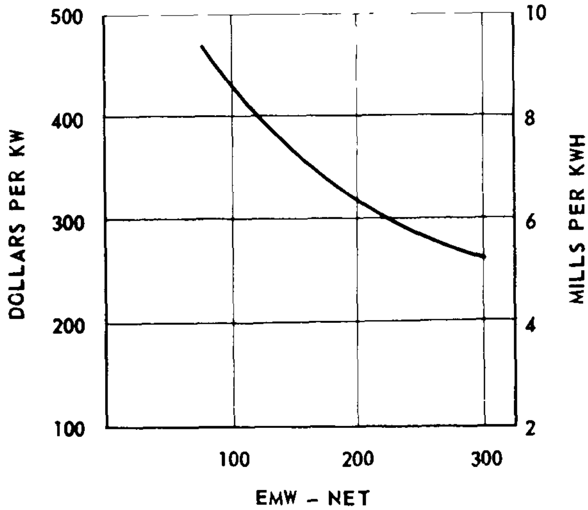
BOILING WATER REACTORS

Single Unit Stations – 1959 Costs
Rating At 1½" Hg.

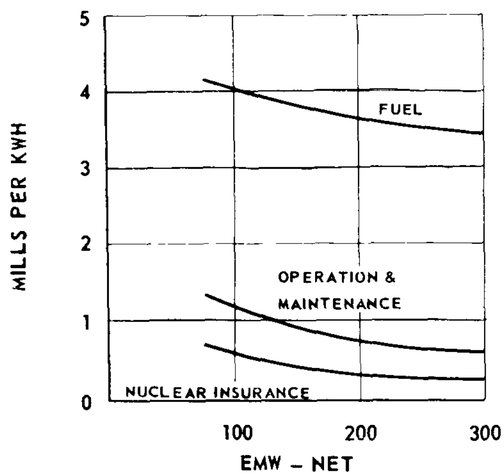
POWER GENERATION COSTS



CAPITAL COSTS



OPERATING COSTS



NOTES:

BASED ON 1959 STATUS REPORT

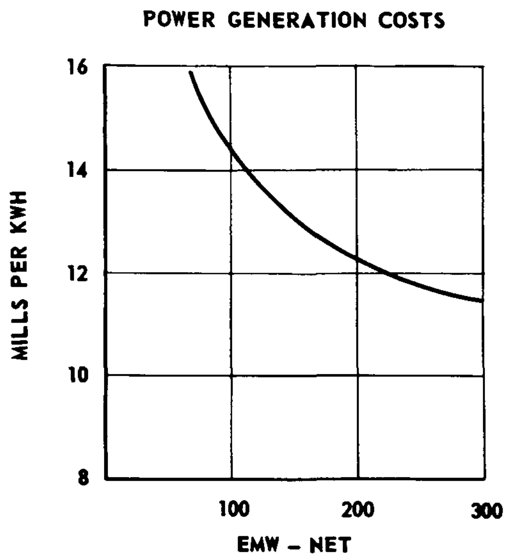
LOAD FACTOR	80%
FIXED CHARGES	14%
URANIUM USE CHARGE	4%
PLUTONIUM CREDIT	$12/GM.
FUEL FABRICATION COST	
UO_2 – ZR-2	$140/KG.
FUEL EXPOSURE	11000 MWD/MT AVG.

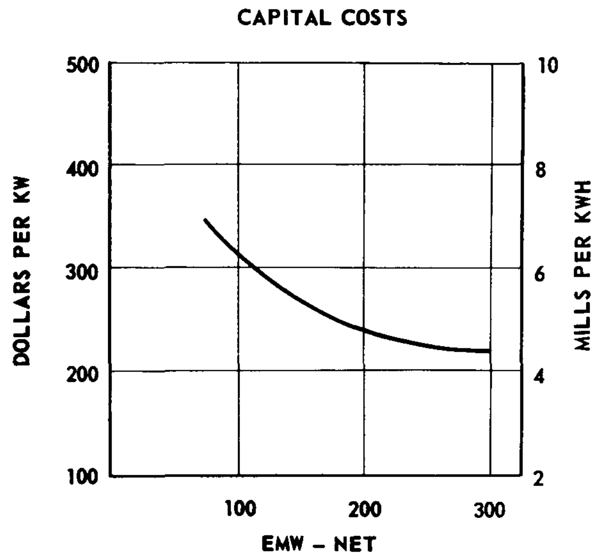
SEPT 1959

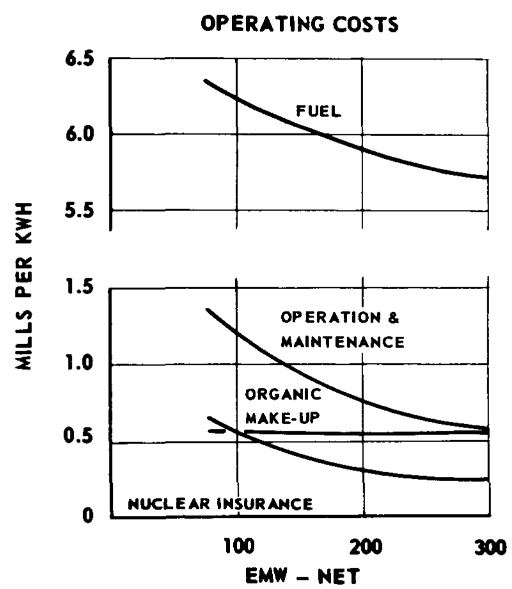
POWER GENERATION COSTS

ORGANIC COOLED REACTORS

Single Unit Stations – 1959 Costs
Rating At 1½" Hg.







NOTES:

BASED ON 1959 STATUS REPORT

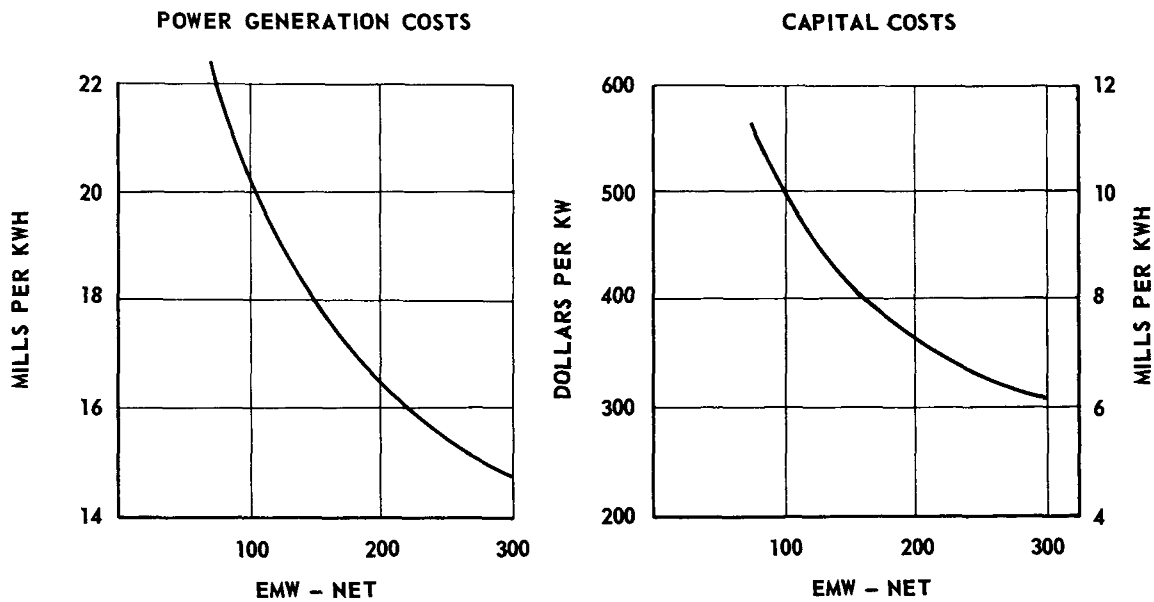
LOAD FACTOR	80%
FIXED CHARGES	14%
URANIUM USE CHARGE	4%
PLUTONIUM CREDIT	$12/GM.
FUEL FABRICATION COST	
U-3.5% MO – AL	$60/KG.
FUEL EXOPSURE	4500 MWD/MT AVG.

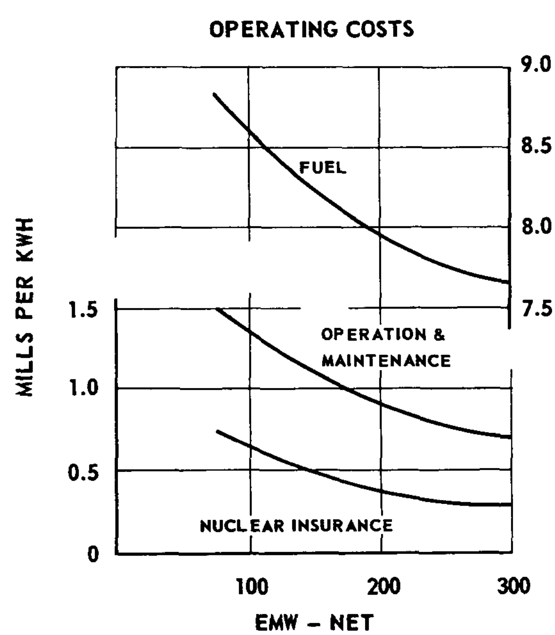
SEPT 1959

POWER GENERATION COSTS

SODIUM GRAPHITE REACTORS

Single Unit Stations – 1959 Costs
Rating At 1½" Hg.





NOTES:

BASED ON 1959 STATUS REPORT

LOAD FACTOR	80%
FIXED CHARGES	14%
URANIUM USE CHARGE	4%
PLUTONIUM CREDIT	$12/GM.
FUEL FABRICATION COST	
U-10% MO – SS	$80/KG.

SEPT 1959

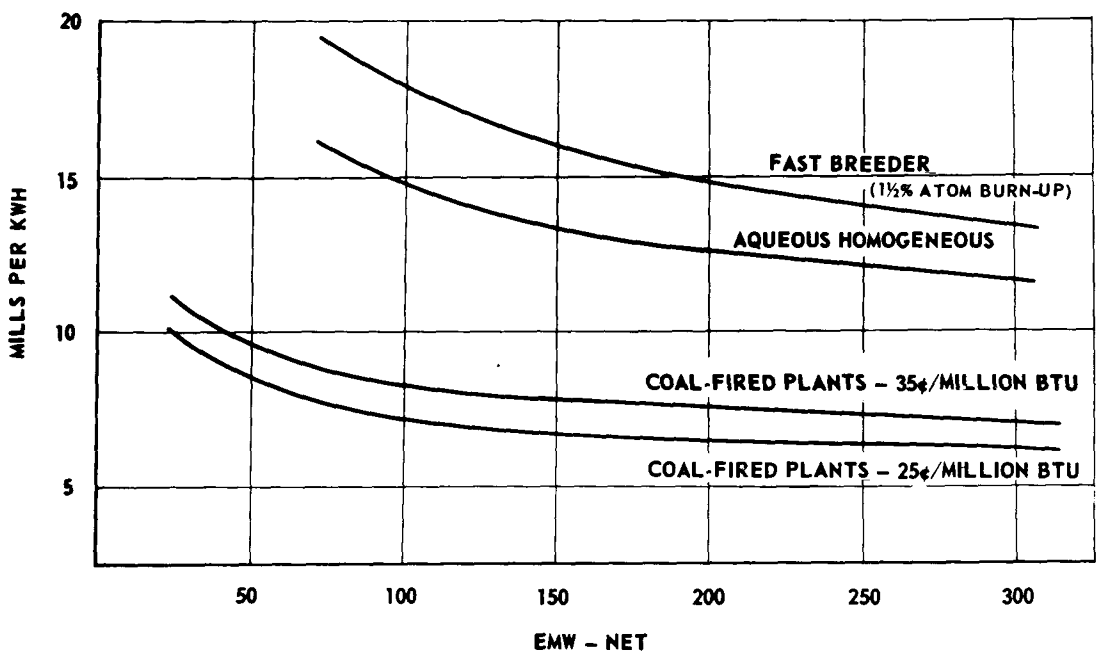
POWER GENERATION COSTS

BREEDER REACTORS

vs

COAL-FIRED PLANTS

Single Unit Stations – 1959 Costs
Rating At 1½" Hg.



NOTES:

NUCLEAR –
BASED ON 1959 STATUS REPORT

LOAD FACTOR	80%
FIXED CHARGES	14%
URANIUM USE CHARGE	4%
PLUTONIUM CREDIT	$12/GM.

COAL – FIRED –
BASED ON SL – 1564 SUPP. 2

LOAD FACTOR	80%
FIXED CHARGES	14%

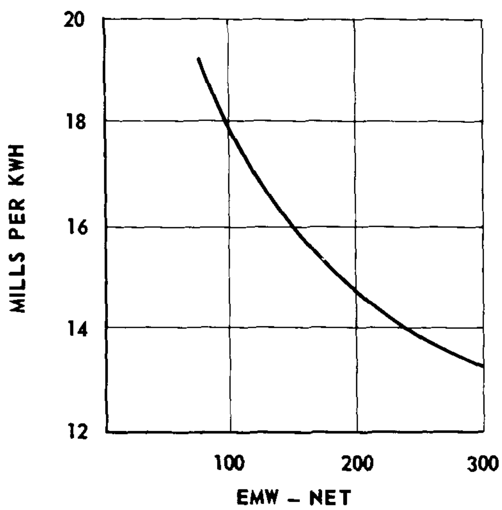
SEPT 1959

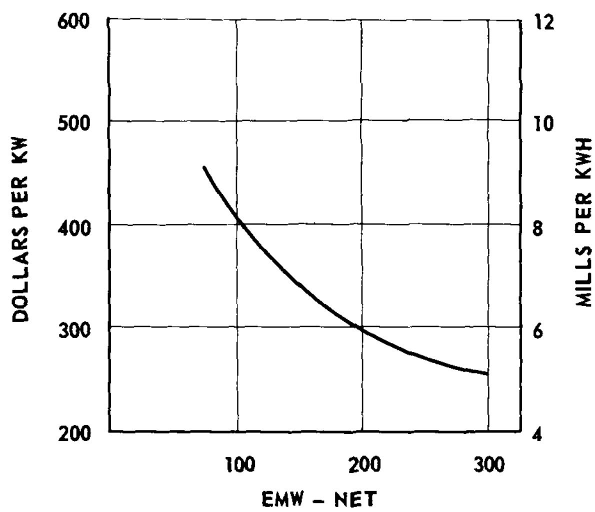
Figure III-8
SL-1674

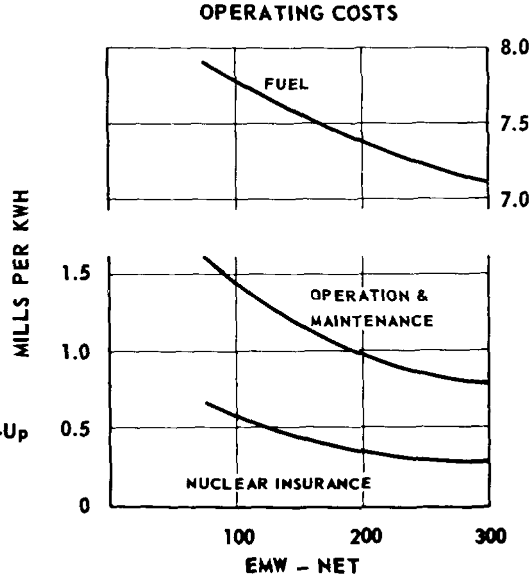
POWER GENERATION COSTS

FAST BREEDER REACTORS

Single Unit Stations – 1959 Costs
Rating At 1½" Hg.







NOTES:

BASED ON 1959 STATUS REPORT

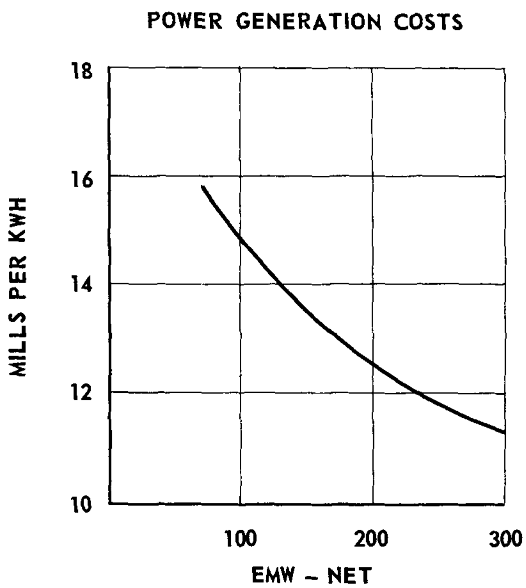
LOAD FACTOR	80%
FIXED CHARGES	14%
URANIUM USE CHARGE	4%
PLUTONIUM CREDIT	$12/GM.
FUEL FABRICATION COST	
U-10% MO – ZR	$480/KG.
FUEL EXPOSURE	1½% Atom Burn-Up

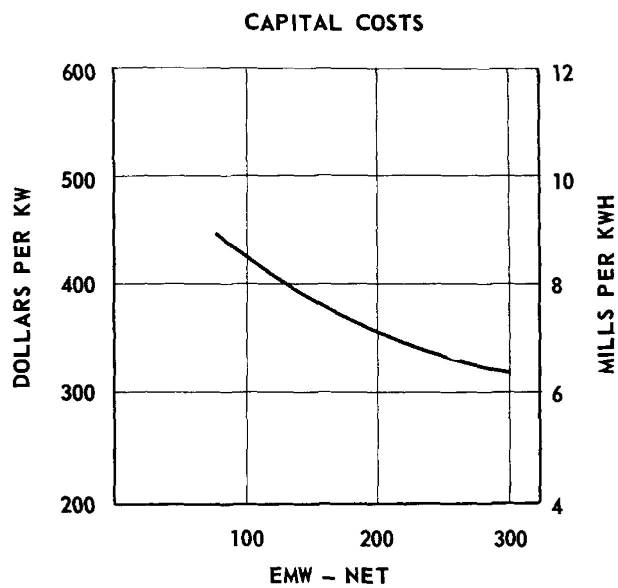
SEPT 1959

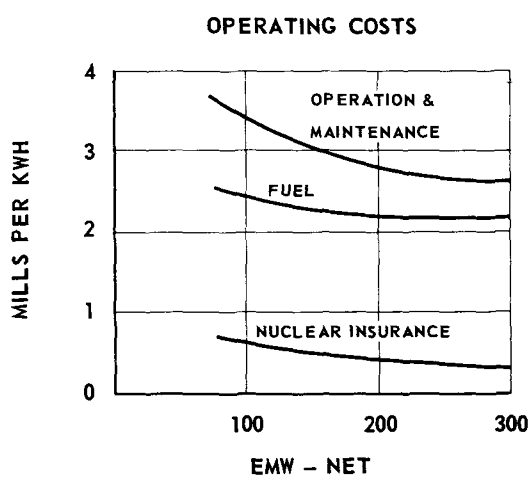
POWER GENERATION COSTS

AQUEOUS HOMOGENEOUS REACTORS

Single Unit Stations – 1959 Costs
Rating At 1½" Hg.







NOTES:

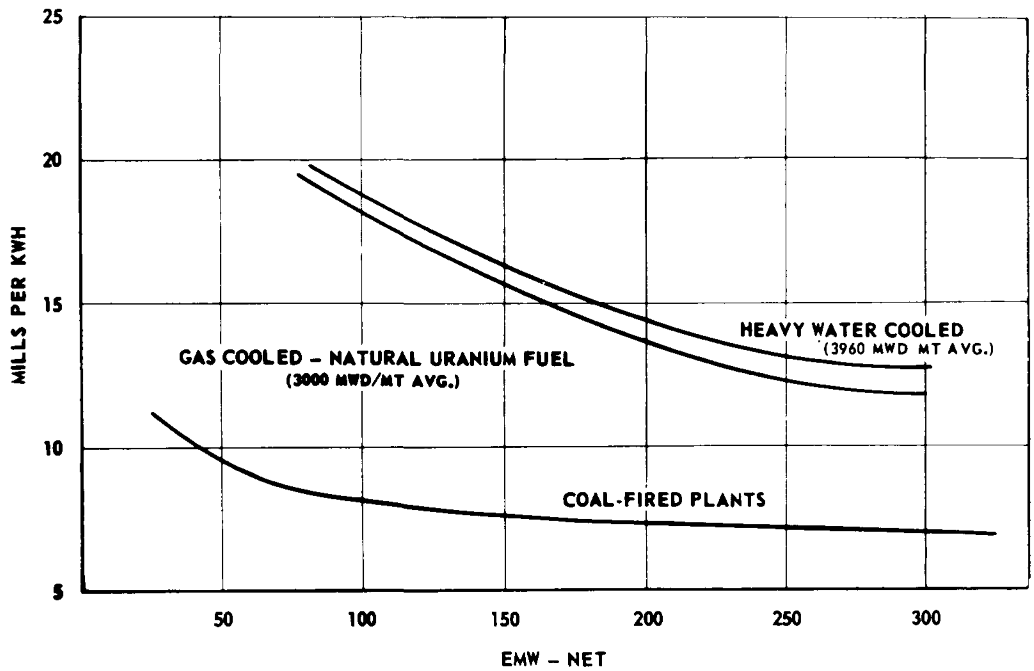
BASED ON 1959 STATUS REPORT

LOAD FACTOR	80%
FIXED CHARGES	14%
URANIUM USE CHARGE	4%
PLUTONIUM CREDIT	$12/GM.

POWER GENERATION COSTS

NATURAL URANIUM FUELED AND RECYCLE REACTORS vs COAL-FIRED PLANTS

Single Unit Stations – 1959 Costs
Rating At 1½" Hg.



NOTES:

NUCLEAR –
BASED ON 1959 STATUS REPORT

LOAD FACTOR	80%
FIXED CHARGES	14%
PLUTONIUM CREDIT	$12/GM.

COAL – FIRED –
BASED ON SL – 1564 SUPP. 2

LOAD FACTOR	80%
FIXED CHARGES	14%
FUEL COST	35¢/10^6BTU

SEPT 1959

Figure III-11
SL-1674

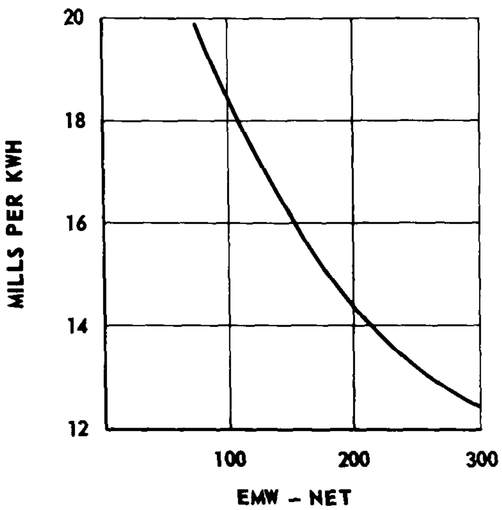
POWER GENERATION COSTS

HEAVY WATER MODERATED

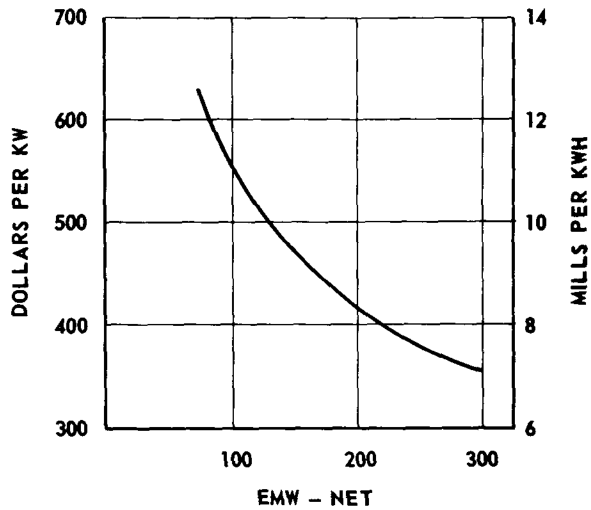
NATURAL URANIUM REACTORS

Single Unit Stations – 1959 Costs
Rating At 1½" Hg.

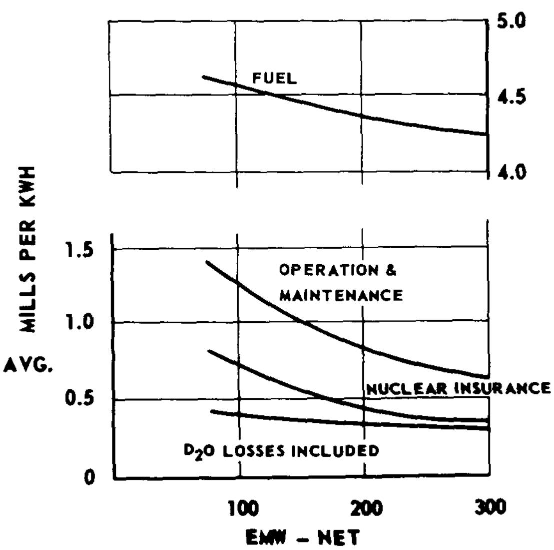
POWER GENERATION COSTS



CAPITAL COSTS



OPERATING COSTS



NOTES:

BASED ON 1959 STATUS REPORT

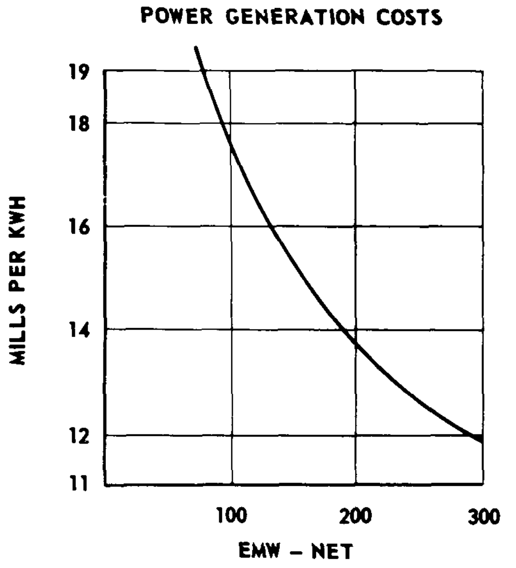
LOAD FACTOR	80%
FIXED CHARGES	14%
PLUTONIUM CREDIT	$12/GM.
FUEL FABRICATION COST U-ZR – ZR-2	$50/KG.
FUEL EXPOSURE	3960 MWD/MT AVG.

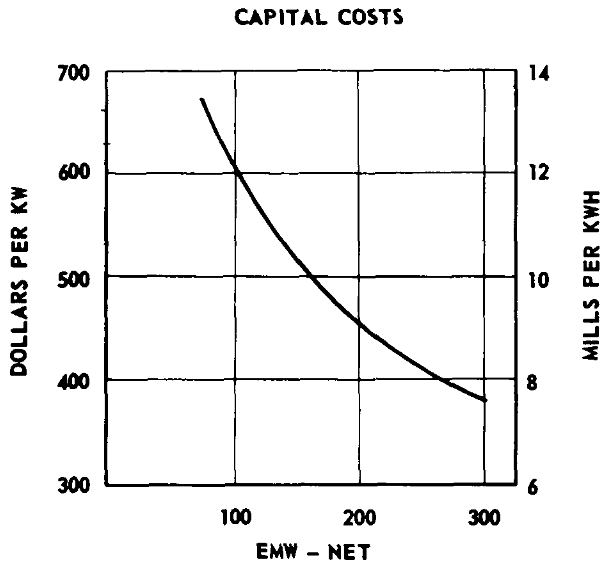
SEPT 1959

POWER GENERATION COSTS

GAS COOLED REACTORS – NATURAL URANIUM FUELED

Single Unit Stations – 1959 Costs
Rating At 1½" Hg.

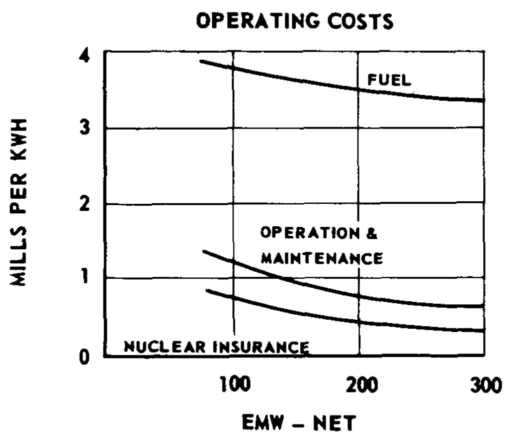




NOTES:

BASED ON 1959 STATUS REPORT

LOAD FACTOR	80%
FIXED CHARGES	14%
PLUTONIUM CREDIT	$12/GM.
FUEL CYCLE COST	
U – MAGNOX	$50/KG.
FUEL EXPOSURE	3000 MWD/MT AVG.



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IV- BASIC EVALUATION PARAMETERS

In preparing the normalized cost estimates presented in this report, a number of basic evaluation parameters or "ground rules" were established by the AEC. As stated previously, the objectives of the study were to normalize cost estimates by:

(1) Use of uniform costs with appropriate size differentials for those components of the power plants having common characteristics.
(2) To make provisions for service and auxiliary facilities on a common basis for the plants.
(3) Establish uniform construction periods for the computation of interest during construction.
(4) To assure that all cost estimates were prepared following the same estimating practices.

A. Plant Design Parameters

In developing the normalized plant designs, the information provided in the various status reports and additional information furnished by the AEC was utilized to the maximum extent possible. The technical limitations of the reactor plants have been treated in accordance with the technical information presented on Table IV-1, "Technical Status of Reactor Concepts", which was prepared by the AEC, and in accordance with the design descriptions furnished in the various status reports and other reports furnished by the AEC. These reports are delineated in the references listed at the end of this report.

In addition to the technical data relating to the reactor plant design, a description of site conditions prescribed for use in this study was furnished. The principal factors of the site conditions relating to the plant design are presented on Table IV-2, Site Data. It is noted that the site occupies approximately 1200 acres of grass covered level terrain with a grade elevation of approximately 40 ft. above low water level and approximately 20 ft. above high water level. The soil conditions for the site indicate alluvial soil and rockfill to a depth of 8 ft. over Brass field limestone.

Adequate water supply for the plant cooling water requirements are assumed.

B. Fuel Parameters

The methods of calculating fuel costs in connection with the fuel cost analysis are as described by the AEC and are indicated on Table IV-3. Likewise the values for enriched uranium, depleted uranium, fuel use charge, chemical processing charges and conversion charges utilized are indicated on Table IV-4. These costs agree with the values specified by the AEC for these materials and services. The values for fuel fabrication costs and the allowable fuel exposures for the materials and fuel compositions utilized in conjunction with this study are as specified by the AEC and are indicated on Table IV-5.

C. Capital Cost Parameters

1. AEC Code of Accounts

The capital cost estimates have been reported in accordance with the classification of accounts designed by the AEC for use in recording costs of nuclear power installations and related transmission and general plant facilities. These classifications of accounts are keyed to the electric plant accounts established by the Federal Power Commission and are based upon the revised FPC Uniform System of Accounts Described for Public Utilities and Licencees subject to provisions of the Federal Power Act to be effective January 1, 1961. In general, Table IV-6 shows the relationship between the AEC account numbers and the Federal Power Commission account numbers.

2. Interest During Construction.

Interest during construction applicable to various construction periods was established from an estimated accumulated expenditure curve developed by AEC, with an annual interest rate of 6%, simple interest. The cumulative expenditure curve and the interest graph are shown on Figure IV-1.

The following tabulation gives a summary of the interest for various construction periods.

Construction Period Months	Cumulative Interest at 6%
18	4.03%
24	5.38%
30	6.72%
36	8.06%
42	9.41%
48	10.75%
54	12.09%
60	13.44%

The following tabulation lists the data used in constructing the cumulative construction expenditure curve:

	Percentage Expenditure	
Percent of Time	Cumulative	Internal
5	0.25	.25
10	1.00	.75
15	2.25	1.25
20	3.75	1.50
25	6.00	2.25
30	8.60	2.6
35	12.00	3.4
40	16.25	4.25
45	22.50	6.25
50	31.50	9.0
55	44.50	13.0
60	58.00	13.5
65	71.5	13.5
70	84.25	12.75
75	91.5	7.25
80	95.5	4.0
85	97.75	2.25
90	99.00	1.25
95	99.75	0.75
100	100.00	0.25

3. Analysis of Indirect Construction Costs

Sargent & Lundy's normal estimating practices treat indirect construction costs in a somewhat different manner than the "ground rules" prescribed by AEC, but when applied to the direct costs the overall results are, for practical purposes, the same. Thus, the application of the AEC "ground rules" result, on a percentage basis, in an overall percentage of 153.2 for direct and indirect costs with a corresponding percentage figure of 153.3 obtained through the application of Sargent & Lundy's method. There is included in both methods the same dollar allowance for start-up costs, before the percentage for contingencies and interest during construction are applied. Sargent & Lundy's estimates normally include the construction Contractor's expense such as field expense, overhead, tools and fee or profit in the direct cost estimate, as these items would be so reflected in the usual bidding procedure. Contingencies, in nominal amounts are also included in the estimates of direct cost for conventional plants, but were set out separately in the preparation of the normalized cost estimates for nuclear power reactors. For nuclear plants then, Sargent & Lundy's practice results in a base for direct costs and Construction Contractor's expense, including fee or profit, of 112.5%. This figure compares with those derived under the AEC ground rules of 100% for direct labor and material plus 12% of this item for general and administrative expense. which also includes the Construction Contractor's expense, fee or profit, and administrative expense of owner, resulting in a comparable total of 112%. In applying the other items of indirect costs, engineering, design and inspection, the dollar amount for start-up costs, contingencies and interest during construction. Sargent & Lundy follows the same pattern as prescribed by the AEC "ground rules".

A comparison of the indirect construction cost percentage as set out in the AEC "ground rules" and as used by Sargent & Lundy is shown on the following tabulation:

COMPARISON OF INDIRECT CONSTRUCTION COST PERCENTAGES

AEC "Ground Rules"	% Accumulative
Base: Direct Labor & Material	100.00
General & Adm.Expense - including Const. Contractors field expense, overhead, fee, contractor's equipment & tools and adm. costs of owner at 12% of Direct Costs	12.00
Subtotal I	112.00
Engineering, Design & Inspection	
A/E services, Titles I, II, & III 15% of Subtotal I	16.8
	128.8
Start-up Costs 4.5 Month Oper. & Maint. Costs. Dollar Amt.	$
Subtotal II	> 128.8
Contingencies 10% Subtotal II	12.9
Subtotal III	> 141.7
Interest during Const. 6% for 36 mos. design & const. period 8.1% of Subtotal III	11.5
Total	> 153.2

S&L - Method Nuclear Cost Estimates	% Accumulative
Base: Direct Labor & Material, Incl. Const. Contractors field expense overheads, tools, & fee or profit, etc. at 12.5%	112.5
Engineering, Design & Inspection, incl. A/E services-7%, Field Expense-2.5%, purchasing 2%; Adm. Costs Client-2%, temporary const. facilities client-0.6%, taxes and insurance-0.5%, Total 14.6%	16.4
Subtotal I	128.9
Start-up Costs 4.5 months operating & maintenance costs Dollar Amt.	$
Subtotal II	> 128.9
Contingencies. 10% Subtotal II	12.9
Subtotal III	> 141.8
Interest During Const. 6% for 36 mos. design and const. period 8.1% of Subtotal III	11.5
Total	> 153.3

For the purposes of Report SL-1674 and in the interest of expediting the work, Sargent & Lundy percentage rates and method of application have been substituted for the percentages and method set forth in the AEC ground rules, since they are derived from Sargent & Lundy's actual experience and the overall results would be the same for either method. In arriving at the indirect charges, in conjunction with the normalized cost estimates for the several sizes of power reactors, from 75 MW(e) to 300 MW(e) for each reactor concept, the same percentages were applied to all plant sizes. The justification for this simplification in cost estimating is shown in Figure IV-2 which gives a break down of "top charges" for a small plant 25 MW(e) and for a large plant 325 MW(e) with the construction period being 30 months for the small plant and 36 months for the large plant. It should be noted the total percentages remain practically constant. Compared to the 8.1% interest for the larger plant, interest during construction (6.7%) is less for the smaller plant because of its shorter 30 month construction period, but this is off set by a higher rate for engineering, 8.5% as compared to 7.0% for the large plant.

4. Power Costs

Annual costs and power cost contributions in the areas of capital costs, fuel costs, and operation and maintenance costs were evaluated on the basis of 14% fixed charges and 80% load factor as specified by the AEC for use with the normalized nuclear power cost estimates.

Certain cost comparisons were made with conventional plants, based upon a 70% Load Factor. The conventional plant data was taken from SL Report 1564 - Supplement No. 2. As a matter of convenience in comparing this data, a conversion chart has been set up, Figure IV-3, which will enable conversions to be made between 70% and 80% Load Factors. Figure IV-3, also, includes a chart setting out the relationship between load factor and mills per KWh for $100 per KW of capital cost at 14% fixed charges. Representative loadings for 80% and 70%: Load Factors are given in the following tabulation:

Load Factor - 0.80

Hours Per Year	Per Cent Load	Product
4500	100	4500
2190	75	1645
1730	50	865
340	0	0
8760	(80)	7010

(8760 x 0.80 = 7008)

Load Factor - 0.70

Hours Per Year	Per Cent Load	Product
3800	100	3800
1800	75	1350
1400	50	700
1120	25	280
640	0	0
8760	(70)	6130

(8760 x 0.70 = 6132)

AEC SPECIFIED TECHNICAL STATUS OF REACTOR CONCEPTS

Note: The information in the following table represents the upper limits of Design Condition consistent with the technology already developed as of July 1, 1959. The parameters are based on parameter that could be used now for plant construction with no research and development. The figures in the table represent values that are based on sound results from research and development results and a combination of these figures listed under a single reactor concept do not necessarily represent a compatible set of design figures for a particular reactor:

Category Reactor Type Plant Cycle	Thermal Conv. PWR (Ind. 2-loop)	Thermal Conv. BWR Dual	Thermal Conv. OCR (Indir 2-loop)	Thermal Conv. SGR (Indir 3-loop)
A-General				
Max. Generating Capacity (EMW)	330	300	(	(
Limiting Factor	Press. Vessel	Press. Vessel	(Economics	(Economics
Nucleate/Bulk Boiling?	Yes/No	Yes	No/No	No/No
Fuel Material/Cladding	UO_2/SS(Zr2)	UO_2/Zr2(SS)	U-Mo3½/Al	U-10%MO/SS
Core Type	3-region	1-region	1-region	1-region
Coolant/Moderator	H_2O/H_2O	H_2O/H_2O	Santowax R	Na/Gr
Fuel Cycle	Batch-33%	Batch Id-20%	Batch-33%	Batch-30%
B-Reactor and Heat Transfer				
Max. Fuel Elem. and Temp. (°F)	5,000 (1)	5,000 (1)	1,100	1,260
Max. Fuel Elem. Surf. Temp. (°F)	650	650	750	1,000
Core Power Density (TKW/Liter)	55	30	20	5
Ave/Max. Burnup (TMWD/MTU)	13,000/27,500	11,000/27,500	7,000/11,000	3,000/7,000
Peak/Ave. Power Ratio	3.7(5.0 Uniform)	3.5	4.0	2.5

(1) Based on thermal conductivity of k = 1

Category Reactor Type Plant Cycle	Thermal Conv. PWR (Ind. 2-loop)	Thermal Conv. BWR Dual	Thermal Conv. OCR (Indir 2-loop)	Thermal Conv. SGR (Indir 3-loop)
Max. Initial Ex Reactivity (% ΔK/K)	20	20	7	5.5
Burnout Ht Flux (B/Ft^2-hr)	1.5 x 10^6	10^6 @ 5% exit qual	500,000	N.A.
Max. Core Ht Flux (B/Ft^2-hr)	470,000	400,000	140,000	800,000
Max. Organic Make-up Rate (B Ft^2-hr)	Na	Na	30% HBC (2)	Na
Max. Reactor Outlet Coolant Temp (°F)	544	544	575	950
Max. Reactor Coolant Press. (psig)	2,000	1,000	Na	Na
Moderator/Fuel Ratio	1.5	2.5	3.3	18
Control Method	Rods (3)	Rods	Rods	Rods
Voids	None	50%	None	None
C-Power Generating System				
Steam Pressure/Temp. (°F)	600/486 (Sat)	1015/546 (Sat)	600/550	800/850
Superheat	No	No	Yes	Yes
Condenser Vac.	1.5	1.5	1.5	1.5

(2) Based on 25#/TMWD make-up and 4% of gamma energy into moderator

(3) Based on T average control

Category Reactor Type Plant Cycle	Fast Breeder FBR (Indir 3-loop)	Nat. U HWCR - BWR (Ind 2-loop)	Gas Cooled Reactors Nat. U Indirect	 Th. Converter Enriched Indirect	Therm Breeder AHR
A-General					
Max. Generating Capacity (EMW)	((Economics	400	((Economics	((Economics	
Limiting Factor	(	Press. Vessel	(	(	
Nucleate/Bulk Boiling?	No/No	Yes/No	Na	Na	NO
Fuel Material/Cladding	U-10% Mo/SS	Nat U/Zr 2	Nat U/Magnox	UO_2/SS	CURRENT
Core Type	1-region & blkt	1-region	1-region	1-region	TECHNOLOGY
Coolant/Moderator	Na/None	D_2O/D_2O	CO_2/Graph	He/Graph	FOR LARGE CENTRAL
Fuel Cycle	Batch-10%	Batch-100%	Continuous reloading	Continuous reloading	STATION
B-Reactor and Heat Transfer					PLANTS
Max. Fuel Elem. Center Temp. (°F)	1150	880	1200	3000	
Max. Fuel Elem. Surf. Temp. (°F)	1000	575	750	1600	
Core Power Density (TKW/Liter)	850	26.3	0.75	2.5	
Ave/Max. Burnup (TMWD/MTU)	1.5/2.0 at. %	3,850/7,000	3,000/____	10,000/____	
Peak/Ave. Power Ratio	1.7	2.32	~ 2	~ 2	
Max. Initial Ex Reactivity (%Δ K/K)	3	3%	5-6	12	
Burnout Ht Flux (B/Ft^2-hr)	Na	1.32×10^6	--	--	
Max. Core Ht Flux (B/Ft^2-hr)	Na	881,000	?	150,000	

Category Reactor Type Plant Cycle	Fast Breeder FBR	Nat. U HWCR	Nat. U GCR	Th. Converter GCR	Therm Breeder AHR
Max Reactor Coolant Press/psig	Na	750	300	1400	NO
Moderator/Fuel Ratio	Na	25	--	19	CURRENT
Control Method	Rods	Rods	Rods	Rods	TECHNOLOGY
Coolant/Mod Leakage (%)		3 (Unrecoverable)		1% per day (He)	FOR LARGE
C-Power Generating System					CENTRAL
Steam Pressure/Temp (°F)	600/750	185/375	HP-550 LP-150	1400/950	STATION
Superheat	Yes	No	Yes	Yes	PLANTS
Condenser Vac.	1.5	1.5	1.5	1.5	

SITE DATA

1. Topography and General Characteristics

   a. Location and Total Area - The site is located on the east bank of the North River and 35 miles north of Middletown, the nearest city. It is 40 feet above the river minimum level and 20 feet above maximum river level. The site occupies approxi-maxtely 1,200 acres of level terrain and is grass covered.

   b. Access - The site is accessible by highway, railroad, air and water as follows:

      A 15-mile secondary road to State Highway No. 9 has been constructed and needs no additional improvements.

      A 5-mile spur to be constructed which will intersect the B & M Railroad.

      An airfield 3 miles from State Highway No. 9 and 15 miles from Middletown.

      The North River is navigable throughout the year for boats with up to 6 feet draft. All plant shipments will be made overland, except that heavy equipment such as reactor vessel and generator stator may be barged to site.

   c. Population - The site is near a large city (Middletown, 250,000 population) but in an area of low population density. Variation in population with distance from the site boundary is:

Miles	Population
0.25	0
0.5	60
1.0	200
5.0	2,700
10.0	8,000
20.0	40,000

   The nearest residence is 3/8 mile east of site on secondary road.

   d. Land Use in Surrounding Region - There are five industrial manufacturing plants within 15 miles of the site, but these are small plants employing less than 100 people each. Closely populated areas are found only in the centers of the small towns in the area, so the total land area used for housing is small. The remaining land, including that across the river, is used as forest or cultivated crop land, except for railroads,and highways.

e. Public Water Supplies - The North River provides an adequate source of raw make-up and condenser cooling water for the ultimate station capacity. The average maximum temperature is 75 F and the average minimum is 40 F.

2. Meteorology and Climatology

a. Prevailing Wind Variation - Prevailing surface winds in the region surrounding the site blow from the S through W quadrant at speeds varying from 4 to 15 miles per hour throughout the year. There are no large daily variations in wind speed or direction. Observations of wind velocities at altitude indicate a gradual increase in mean speed and a gradual shift in prevailing wind direction from southwest near the surface to westerly aloft.

b. Frequency of Temperature Inversions - Surface-based atmospheric inversions occur frequently during summer and early fall nights with clear skies and low wind speeds. These inversions are destroyed quickly by solar heating. Inversions occuring during winter or spring are more likely to extend into the daytime. Inversions occur most frequently when the winds blow from the south. Unstable weather conditions usually occur with winds from the north or west. Stagnation periods with steady light winds and a high frequency of inversions are most probable from August to October. A persistent inversion with its base between 1,000-4,000 feet, wind speeds less than 5 miles per hour below 5,000 feet, and clear skies which permit the formation of surface-based inversions at night are characteristic of these periods. Table IX-6 lists monthly percentages of time with inversions. The annual average is 48 per cent. A survey of U. S. climatology records summarized in WASH-740 indicates 50 per cent of total annual time with inversions as a representative national average.

c. Frequency and Severity of Disturbances - A maximum wind velocity of 100 mph has been recorded at the site.

d. Snow Load - 30 psf shall be used for snow loading.

3. Hydrology

a. Precipitation - Average annual rainfall at the site is over 27 in. per year.

b. Drainage - Natural drainage of the sites is provided by the land contours. The subterranean water travels toward the river at a velocity of 300 feet per year. The maximum temperature is 75 F with sufficient flow available to prevent exceeding the allowable temperature rise specified by the State.

c. Ground Water - Ground water in the region collects mostly in the weathered layer of the shale above the bedrock. Adequate ground water for sanitary supply and plant make-up is available within 50 feet below grade. Most wells in the region are drilled to the shale layer.

4. Geology and Seismology

a. Soil Profiles and Load Bearing Characteristics - Soil profiles for the site show alluvial soil and rock fill to a depth of 8 feet; Brassfield limestone to a depth of 30 feet; blue weathered shale and fossiliferous Richmond limestone to a depth of 50 feet; and bedrock over a depth of 50 feet. Allowable soil bearing is 6,000 psf and rock bearing characteristics are 18,000 psf and 15,000 psf for the Brassfield and Richmond strata, respectively. No underground cavities exist in the limestone.

b. Seismology - This is a Zone 1 site as designated by the Uniform Building Code based on the observation of three earthquakes of seismic intensities 6-8 on the Rossi-Forel scale in the period 1870-1958, causing minor damage to towns in the surrounding area.

5. Radioactive Waste Disposal

Sewerage: All sewerage must receive primary and secondary treatment prior to dumping into the North River.

Volatile Wastes: (Radioactive and Toxic Gas).

Maximum permissible concentrations or dosages shall be as prescribed in:

a. Standards for protection against radiation, AEC Regulation (10 CFR Part 20) Federal Register Doc. 57-511 files January 25, 1957.

b. National Bureau of Standards, Handbook 52, Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water.

c. In the event of conflict between items "a" and "b" above, Item "a" shall govern.

Liquid Waste: Maximum permissible activity of water entering the North River shall be as prescribed in the references listed under "volatile wastes" above. For the purpose of this study, the activity level of the liquid effluent shall be measured as it leaves the plant. No credit for dilution in the North River will be assumed.

Solid Waste: Storage on site for decay will be permissible but no ultimate disposal on site will be made. Assume commercial rates of sea disposal and plant located 500 miles from shipping site.

6. Other Site Information

   a. Disposition of Maximum Power Output - The site is located within the general distribution area of the Central Edison System. The system voltage is 230 kv. A 5-mile transmission line is required to connect the PWR to the system but the cost of this line will not be included in this study. Based on projections of load growth, the system will absorb the entire station output as it becomes available.

   b. Availability of Local Labor Force - Labor availability for plant construction and operation at this site is adequate although the distance of 35 miles to the nearest large center of population requires an additional transportation allowance in the wage rates for all classes of construction labor.

   c. Productivity - Assume productivity will be equivalent to western Massachusetts.

   d. Breakdown of the 14 Per Cent Capital Charges - The annual fixed charge based on capital cost is 14 per cent of the capital costs. The annual rate provides for amortization of the capital investment in 30 years.

	Per Cent
Cost of money	6.0
Income tax	4.6
Local taxes and insurance (not including third party liability)	2.1
Depreciation (sinking fund)	1.3
	14.0

   e. Construction and Emergency Power - Construction power is available at southeast corner of site boundary. Cost of this power is 15 mills per kilowatthour. Provision should be included in design for an emergency power source as the distribution system in the area is a single source transmission.

ADDENDUM TO SITE DATA AND ASSUMPTIONS

1. Natural gas service is available in town four miles from the site on the same side of the river.

2. Land valuation for cost estimating - $300 per acre. Land is generally available surrounding the site at the same cost.

3. Straight line depreciation will be assumed.

4. Spare parts of warehouse type will not be included in costs.

5. Materials and construction style of architecture, etc., will be in accordance with AEC Manual Chapter 6300 plus ASTM, ASME, and the National Board of Fire Underwriters' Codes and Standards where applicable.

6. Construction cost should be based on a 40-hour work week with no overtime.

7. Communication lines shall be furnished to be project boundaries at no cost. Cost for communication within the project boundaries will be in accordance with standard utility company practices.

8. The first core is not to be capitalized.

9. No land easement charge.

10. Sales tax same as western Massachusetts.

11. Include freight costs in estimates for western Massachusetts.

12. All site data not provided in this document shall be consistent with a western Massachusetts plant site, provided it does not conflict with information contained in this document.

13. For the purpose of this study, use the following power demand:

Hours Per Year	Per Cent Load	Product
4,500	100	4,500
2,190	75	1,645
1,730	50	865
340	0	0
8,760	80	7,010

The 80 per cent load factor is constant for each year of the 30 years of the economic life of the unit.

14. Cost estimate should not include equipment beyond high voltage side of transformer. Gateway structures, cable, switchyard, and high lines are not included in the cost estimates.

15. Cost of railroad siding from switch point on main line to plant property line shall be assumed to be $300,000.

16. Cost estimate should include cost of initial surveys to establish background radiation of air, water, and vegetation in vicinity of site. Cost of subsequent surveys during plant operation should be included in operating costs.

17. Assume qualified machine shops are available in Middletown. Furnish only minimum shop facilities at plant.

18. Cost estimates should include minimum equipment and operating personnel for health physics. Assume that available services, such as film badge processing, laundering of contaminated clothing, instrument calibration, and radiobiological analyses, will be performed by others under contract.

AEC Specification
Methods of Calculating Fuel Cycle Costs

A. Fuel Use Charge

Use Charge = .04 x value of fresh fuel[1]/batch (Yrs./batch in storage + 0.5 x Yrs./batch in core) + .04[2] x value of spent fuel/batch (0.5 x Yrs./batch in core + Yrs./batch in cooling and processing) batches/Yr.

= ________________ $/Yr.

B. Fabrication Costs[3]

1. Annual throughput = (Reactor Power in MW x 365 x L.F.)[3] / MWD/MT of U = _______ MTU

2. Core replacement (annual) ____________ MT

   = (throughput Kg (annual)) / (core loading (kg)) = __________ %

3. Annual fabrication cost __________ % annual core replacement x initial core cost = $__________

   (Initial core cost = kg of loading x ________ $/kg)[4]

4. Annual shipping cost of fresh fuel = annual throughput (kg) x $3.00/kg = _________________ $/Yr.

C. Depletion Cost

1 Original uranium value = ___________ throughput Kg/Yr. x ___________ $/Kg of U = ___________ $/Yr.

2. Final uranium value = _____________ throughput Kg/Yr. x ___________ $/Kg of U = ___________ $/Yr.

3. Loss in fabrication and processing = 1.5% of C1 = __________ $/Yr.

4. Fuel Depletion; (C1-C2 + C3) ____________ $/Yr.

5. Plutonium credit = _________________ (throughput in Kg/Yr.) x (__________ gm of Pu/Kg of U) x $12/gm Pu credit[5] = ______________ $/Yr.

6. Recovery Cost

a. Irradiated fuel shipment cost = (______throughput Kg) x

$12 45/Kg)[6]= $__________________

b. Recovery of nitrates (15,300 $/day) (T + metric ton/batch

of U)[7] =__________________$/batch

Annual cost = batches/Yr. x C6b =________________$/Yr.

c. Conversion of Uranium Nitrates to UF_3=______________KG

throughput x $5.60[8]/Kg = \_\_\_\_\_\_\_\_\_\_\_\_\_\_$/Yr.

d. Conversion of Pu nitrate to Pu metal = (_______________

gms of Pu/Yr.) x $1.50[8]/gm = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$/Yr.

e. Recovery Cost = C6(a) + (b) + (c) + (d) =_______________$/Yr.

Net Depletion Cost = (Fuel depletion) + (recovery cost)

\- (plutonium credit) = ____________$/Yr.

D. Interest on fabrication capital = .06 (fab. cost/batch x

$\frac{\text{fab. days/batch + 60)}}{365}$ x batches/Yr. + .03 (annual fab. cost x

$\frac{\text{in core time)}}{365}$ =______________$/Yr.

E. Total Fuel Cost

1. Fuel use charge =__________________$/Yr.

2. Capital charge__________________$/Yr.

3. Fabrication cost = _________________$/Yr.

4. Depletion cost___________________$/Yr.

Total fuel cost________________$/Yr.

Total Fuel Cost = $\left(\frac{\text{Total of E} \times 10^3}{\text{KWH/Yr.}}\right)$ =__________________Mills/KWH

Footnotes for Fuel Costs

(1) Cost of fresh UF_6 from AEC Schedule of Charges.

(2) Fuel use charge based on 4% per annum at following values of fuel:

a. Full value for initial enrichment from time of delivery of UF_6 until delivery to fresh fuel storage (assumed to be in cost of fabrication lump sum).

b. Full value for initial enrichment during fresh fuel storage time.

c. Average value of fuel during in-core residence. This is the average difference in value between fresh fuel and depleted.

d. Final value of depleted fuel during time from removal from core to return to AEC as UF_6.

This method of charge has not been officially approved by the AEC. However, since it is understood that periodic payments will be made out of operating capital for this cost, there is good probability that this method will be acceptable.

(3) L.F. = plant load factor which is the product of yearly plant availability factor and power generating rate in percent of full power operation (.9 x .9 = .80 L.F.). The L.F. has been placed at .8 rather than .6 or .7 which is customary for conventional fossil fired plants on the following basis:

Nuclear fuel cost must be lower than fossil fuel or plant can never be competitive because of inherently higher capital charges. If the fuel cost is lower for nuclear plants there will be the incentive to operate them as base load plants. Verification of this assumption can only be realized by extended plant operating experience.

(4) Cost of fabrication (in this summary) included the following:

a. Conversion of UF_3 to UO_2 for oxide cores (no charge for natural uranium cores).

b. Structural material required for cladding and supporting fuel material in assembly.

c. Labor of assembly.

d. Inspection, testing and quality control.

e. Material losses, cost of scrap recovery and rework.

f. Use charge for fissionable material during fabrication.

g. Packaging for shipment.

(5) AEC established value for post 1963 plutonium purchase price, based on total plutonium.

(6) Value assigned by AEC as a result of survey.

(7) (T) is startup and cleanup time, in days. For batch size in metric tons (W)

$W < 3$	$T = 3$
$3 < W < 8$	$T = W$
$8 < W$	$T = 8$

(8) AEC schedule of charges.

(9) Capital costs for money used for fabricating fuel are based on interest on money only, at 6%. This rate is charged against the full cost of fabrication for the period required for fabrication and storage, and against the average value of the cost of fabrication during the in-core period. The value of the fabrication capital is assumed to be zero when the fuel is removed from the core.

The values for initial and final enrichment, and plutonium production, will vary due to a number of factors, from one concept to another, and with size. Methods of calculation and fuel cycle management will vary with individual consideration. However, the average values used for the individual cycles will not vary significantly from those which might have been selected by others.

(10) Batch size in % refers to quantity of fresh fuel inserted in core at each rearrangement period. This quantity is also amount purchased on each order. The fabrication, processing, and capital charges are sensitive to this factor.

Optimization of batch size can be ascertained only after a rigorous physics analysis and correlation with cost of plant shutdowns and this effect on plant factor (P.F.). This factor will not be known until several plants have been operated at length.

MATERIAL COSTS AND CHARGES

(1) ENRICHED URANIUM
UF_6 (f.o.b. Oak Ridge)

Weight Fraction U^{235}	Official Charge Dollars per Kilogram of Uranium	Dollars per Gram of U^{235} Content
0.0072	40.50	5.62
0.0074	42.75	5.78
0.0076	45.25	5.95
0.0078	47.50	6.09
0.0080	50.00	6.25
0.0082	52.50	6.40
0.0084	55.00	6.55
0.0086	57.50	6.69
0.0088	60.00	6.82
0.0090	62.75	6.97
0.0092	65.25	7.09
0.0094	67.75	7.21
0.0096	70.50	7.34
0.0098	73.00	7.45
0.010	75.75	7.58
0.011	89.00	8.09
0.012	103.00	8.58
0.013	117.00	9.00
0.014	131.25	9.38
0.015	145.50	9.70
0.020	220.00	11.00
0.025	297.00	11.88
0.030	375.50	12.52
0.035	455.00	13.00
0.040	535.50	13.39
0.045	616.50	13.70
0.050	698.25	13.96

(The above schedule also provides the basis for use charges to be applied to leased fuel, as well as in calculating charges for uranium-235 consumption and isotopic depletion or dilution in leased fuel.)

(2) DEPLETED URANIUM
UF_6 (f.o.b. Paducah, Kentucky)

Weight Fraction U^{235}	Charge per Kg/U
.0036 and lower	$ 5.00
.0040	8.15
.0050	16.65
.0052	18.65
.0054	20.65
.0056	22.65
.0058	24.75
.0060	26.90
.0062	29.00
.0064	31.25
.0066	33.50
.0068	35.75
.0070	38.15

(3) $40 per kilogram of natural uranium metal
(4) $43 per kilogram of thorium
(5) $12 per gram of plutonium (equivalent fuel value of plutonium)
(6) $15 per gram of uranium-233 nitrate (equivalent fuel value of uranium-22)
(7) Prices for heavy water (currently $28 per pound)
(8) AEC fuel use charge 4%
(9) Chemical processing
$15,300 per day
No. days varies from 4 upward depending upon load
(10) Conversion charge
a. UNO_3 to UF_6 $ 5.60/kg
b. $PuNO_3$ to metal $ 1.50/gram
(11) Fuel shipping costs
a. Irradiated fuel $12.45 kg U
b. Non-irradiated fuel $ 1.50 lb.

AEC SPECIFIED FUEL FABRICATION COSTS AND ALLOWABLE FUEL EXPOSURES

Fuel fabrication costs:		
U-10 w/o MO-SS		\$80/kg U
U-2.75 w/o MO-SS		\$45/kg U
U-3 1/2 w/o MO-AL		\$60/kg U
UO - Zr-2		\$140/kg U
UO - SS		\$110/kg U
U - 10 w/o MO - Zr-2 (pins)		\$480/kg U
U-2% Zr-Zr-2		\$50/kg U
U - Magnox		\$50/kg U*
Exposures		
BWR	11,000	MWD/MT Ave.
PWR	13,000	MWD/MT Ave.
OCR	4,500	MWD/MT Ave.
SGR	3,000(11,000)	MWD/MT Ave.
D O	3,850	MWD/MT Ave.
Gas cooled - natural	3,000	MWD/MT Ave.
Fast Breeder	15,900	MWD/MT Ave.

* Total Fuel Cycle Cost except shipping.

AEC SYSTEM OF ACCOUNTS

AEC Key Account	NUCLEAR PRODUCTION PLANT	FPC Account
20	Land and Land Rights	320
21	Structures and Improvements	321
22	Reactor Plant Equipment	322
23	Turbo-Generator Units	323
24	Accessory Electric Equipment	324
25	Miscellaneous Power Plant Equipment	325
	TRANSMISSION PLANT	
52	Structures and Improvements	352
53	Station Equipment	353
	GENERAL PLANT	
397	Communication Equipment	397
71	INDIRECT CONSTRUCTION COSTS	-
81	UNDISTRIBUTED CONSTRUCTION COSTS	-
	CONTINGENCIES (For estimating only)	-

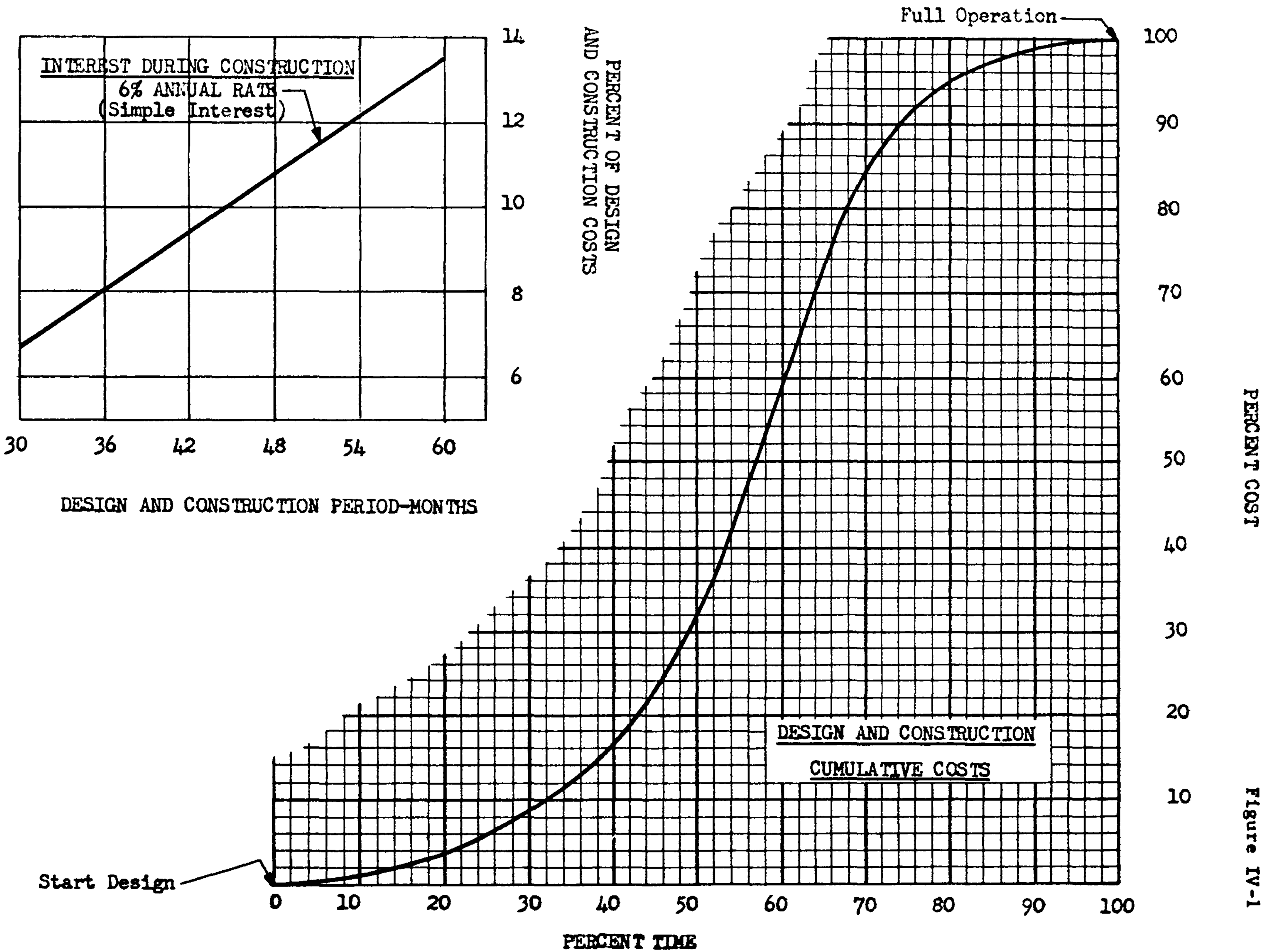

INTEREST DURING CONSTRUCTION
6% ANNUAL RATE
(Simple Interest)
14
12
10
8
6
PERCENT OF DESIGN AND CONSTRUCTION COSTS
30
36
42
48
54
60
DESIGN AND CONSTRUCTION PERIOD-MONTHS
Full Operation
100
90
80
70
60
50
40
30
20
10
PERCENT COST
DESIGN AND CONSTRUCTION
CUMULATIVE COSTS
Start Design
0
10
20
30
40
50
60
70
80
90
100
PERCENT TIME

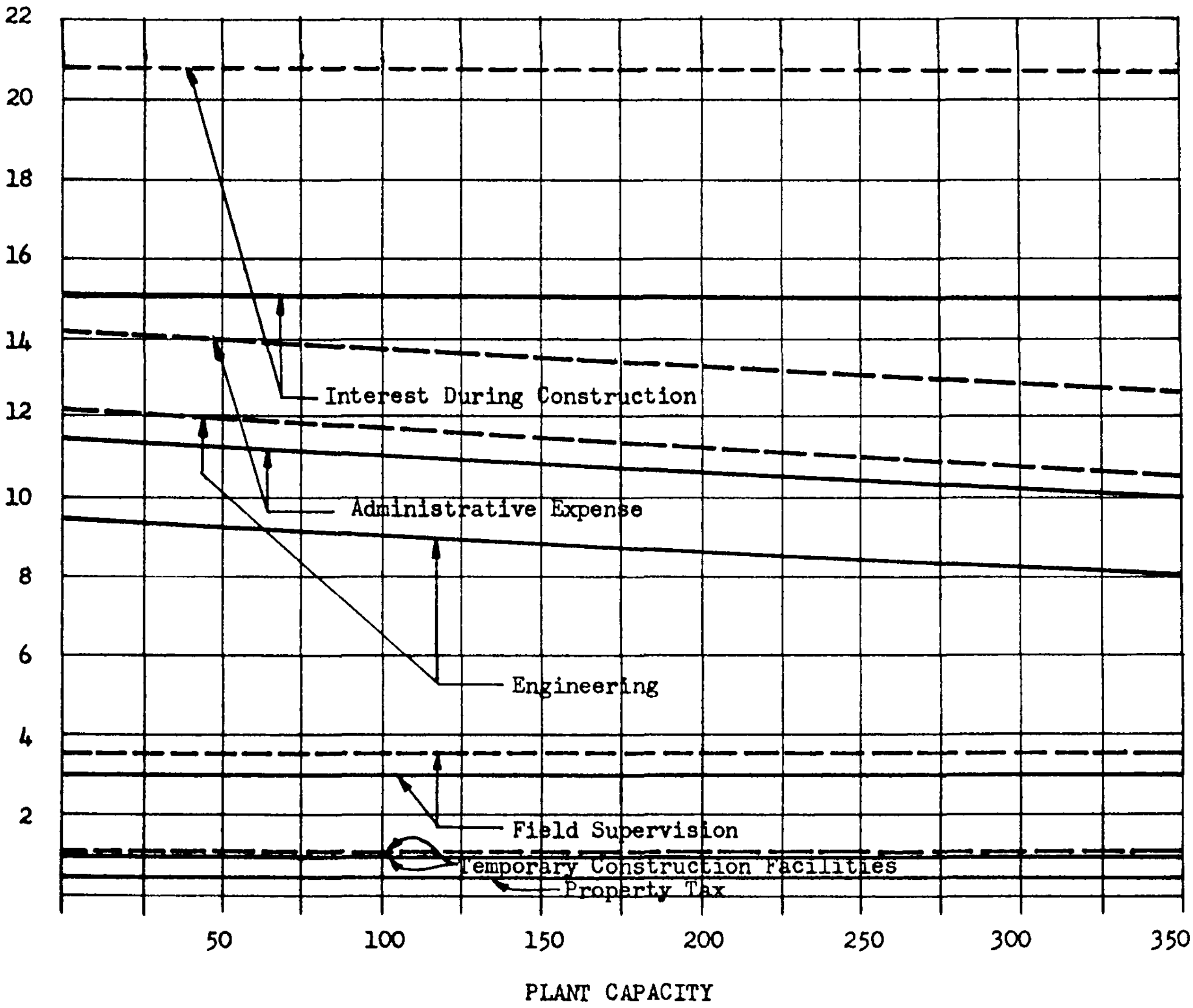
Figure IV-1

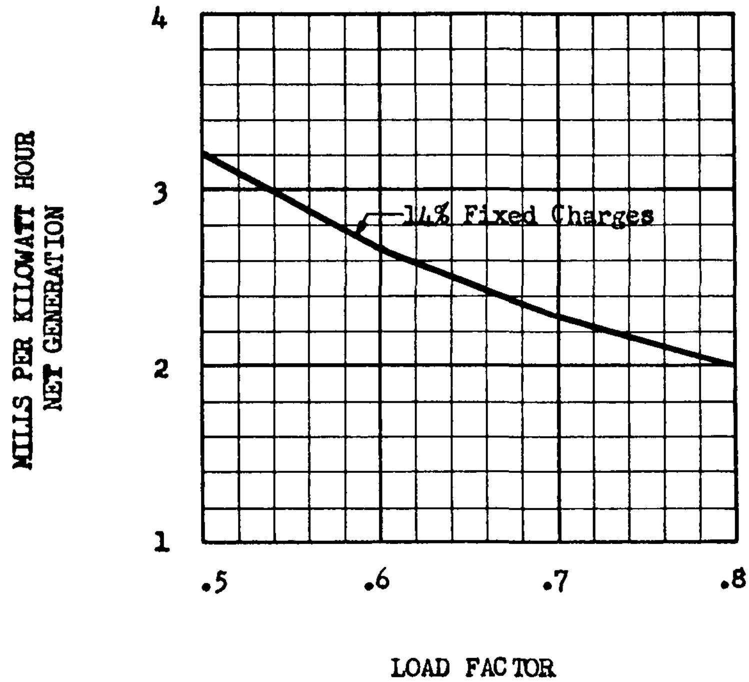
Figure IV-2

TOP CHARGE BREAKDOWN

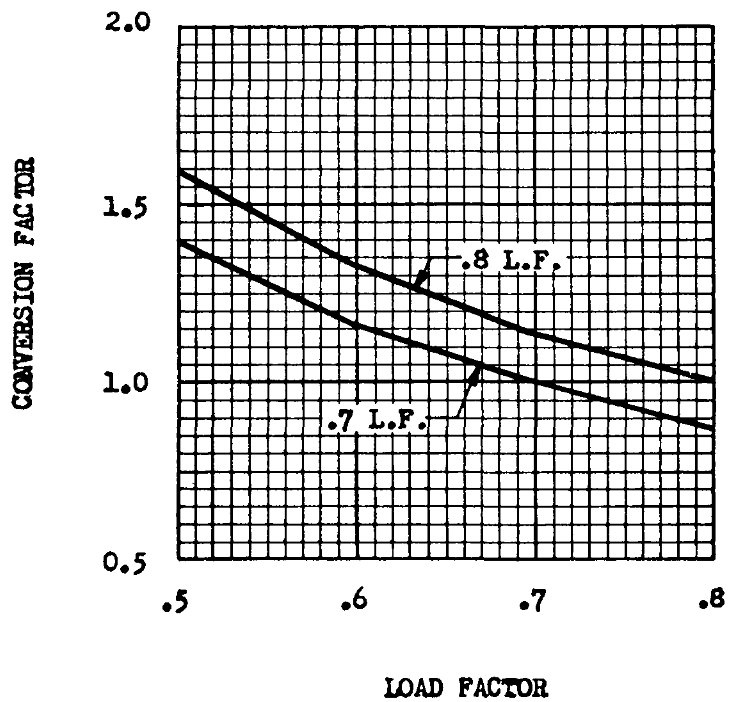
	Conventional ———		Nuclear - - -	
	25 MW	325 MW	25 MW	325 MW
Engineering	6.5%	5.0%	8.5%	7.0%
Field Supervision	2.0	2.0	2.5	2.5
Interest During Construction, 6%	4.0	5.4	6.7	8.1
Administrative Expense	2.0	2.0	2.0	2.0
Property Tax	0.5	0.5	0.5	0.5
Temporary Construction Facilities	0.5	0.5	0.6	0.6
	15.5%	15.4%	20.8%	20.7%
Construction period, months	18	24	30	36

(Does not include purchasing - 2% constant)





$100 Per KW Capital Cost
14% Fixed Charges
Mills Per KWH Net Ge neration



Conversion Factor
To Convert Power Costs at a Load Factor
to Costs at Other Load Factors

V - CAPITAL COST

This section of the report presents a description of the major features of the reactor plant concepts upon which the normalized cost estimates are based. The description and quantitative technical data presented here are for the base size unit of each concept only; however, the capital cost estimates are given for three plant sizes - 75, 200, and 300 MW(e). The technical data and plant arrangement for the plants, other than the base size plant, retain the same general features of the concept and differ only in equipment capacities, building size and number of components, from the base unit.

The following discussion is divided into two major sections; first, a brief description of the features common to all of the plants and second, a brief description of each of the reactors and reactor plants, together with the cost estimates for each of the plants.

Complete sets of flow diagrams, electrical diagrams and building arrangement drawings appear at the end of the report for each of the base size plants. In addition general arrangement drawings indicating the major features of the extrapolated size plants for each concept also appear.

A. Features Common to All Plants

In several areas of the plant designs, normalization resulted in the use of similar components in all plants. Some of these 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 concept designs, it was possible to generalize on the yard features, such as fencing, outdoor fire protection equipment, gate houses, parking facilities, and oil storage tanks. Some slight variation of railroad track and roadway layout occurs between concepts because of a variation in reactor building, fuel handling building and waste disposal building arrangement, but these variations are slight and do not affect the capital costs appreciably

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

Except for the boiling water plant, all turbine-generators are supplied by nonradioactive secondary steam and are therefore of conventional construction. The turbines differ only in size and type due to varying steam conditions. In the case of the boiling water, direct cycle turbine-generator, an allowance has been made for the provision of decontamination facilities.

All of the main condensers are conventionally constructed of Admiralty tubes and carbon steel shell. All condensers are provided with single tube sheets, except for the boiling-direct cycle unit which has double tube sheets to preclude the uncontrolled admission of contaminated water into the primary system.

The circulating water systems for all plants consist of the requisite number of vertical circulating water pumps located in a insulated metal panel crib house. Conventional intake screens and screen washing equipment are used for all plants. All circulating water piping and discharge flumes are of conventional power plant construction arranged as shown on the drawings for each concept.

The condensate systems for all plants use two one-half capacity condensate pumps and two 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 all cascaded to the main condenser for deaeration. All of the feed water cycles are closed and have no deaerating type feed water heaters. Feed water treatment for each of the plants is conventional and identical in nature; however, in the boiling water plants only, full feed water flow demineralization equipment has been incorporated to prevent any impurity carry-over to the reactor where dissolved solids could become activated.

Conventional auxiliary plant power supply equipment has been provided for all plants. Normal heating, air conditioning, ventilation and plumbing services have also been provided in all cases.

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 power respectively. A diesel powered motor generator has been provided for all plants to supply emergency power in the event of normal power supply failure. Compressed air is supplied in all plants 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.

On site radioactive waste disposal facilities for solid, liquid and gaseous wastes have been provided for all plants. High activity solid and liquid wastes are permanently disposed 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 may 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.

B. Reactor Plant Descriptions and Cost Estimates

1. Pressurized Water Reactor Plant

The pressurized water reactor concept is similar, in general, to that being designed and constructed at the Yankee Atomic Plant and as reported in the AEC status report, reference (1). The principal characteristics of the plant are summarized in Table V-1 and on a simplified flow diagram for the plant shown in Fig. V-1. Table V-2 presents the capital cost breakdown for the 75, 200, and 300 MW(e) size plants.

Reactor

The reactor is a light water cooled and moderated type fueled with slightly enriched uranium dioxide contained in stainless steel tubes. The core assembly is contained within a stainless steel clad, carbon steel pressure vessel 11.75 ft. I.D. by 31 ft. high overall and has a wall thickness of 7.0 in., which corresponds to the design pressure of 2500 psig.

The reactor is controlled by control rods actuated from the top of the reactor vessel. A more complete description of the pressurized water reactor appears in the AEC status report, reference (1).

Primary System

Primary coolant leaves the reactor core at 544 F and is pumped through four steam generators where saturated steam at 555 psig is generated. From the steam generator the primary coolant is returned, by canned rotor pumps, to the reactor inlet at 503 F. A total of 53.6×10^6 lbs/hr. of primary coolant is circulated in order to generate 3.03×10^6 lbs/hr. of dry and saturated steam. Materials of construction for the primary piping and evaporator tubes is type 304 stainless steel. Primary system auxiliaries consist of a pressurizer and a bypass purification loop. Normal primary system operating pressure is 2200 psia.

Reactor Plant Arrangement and Buildings

The reactor, reactor auxiliary equipment and secondary steam generating facilities are all located in a steel spherical reactor building 135 ft. in diameter. Details of the building arrangements are shown in Drawings NS-102 through NS-112.

Adjacent to the reactor building, a fuel handling building equipped to store, ship and receive both spent and fresh fuel elements, has been provided.

Cost Estimates

Cost estimates for three pressurized water reactor plant sizes are presented in Table V-2. These estimated costs are modified from those appearing in reference (1) only insofar as was necessary as a result of normalizing the plant design and placing the estimates on a basis comparable to those presented for the other concepts.

2. Boiling Reactor Plant

The boiling reactor concept is a dual, direct cycle type similar to that being constructed at the Dresden Nuclear Power Station. The principal characteristics of the plant are summarized in Table V-3 and on a simplified flow diagram for the plant shown in Fig. V-2. Table V-4 presents the capital cost breakdown for the 75, 200, and 300 MW(e) size plants.

Addition to Page 5-3, paragraph headed

Cost Estimates

The pressurized water reactor plant cost data shown are based on a plant having an overall thermal efficiency of 25%. This plant includes a tandem-compound, four flow exhaust turbine with 35 in. long last-row blades, for the 300 MWe plant size. It would be possible, by increasing the last-row blade length to 43 in., to increase the net plant efficiency to 28%; however, an increase in capital expenditure of $1,455,000, exclusive of condenser and foundation cost increases, would be required.

Reactor

The reactor is a thermal neutron, light water cooled and moderated type fueled with slightly enriched uranium dioxide contained in Zr-2 tubes. The core assembly is contained within a stainless steel clad, carbon steel pressure vessel 12.25 ft. I.D. by 41 ft. high overall and has a wall thickness of 5.625 in., which corresponds to the design pressure of 1500 psig.

The reactor is controlled by bottom entering control rods, again similar to the Dresden Plant Design. A more complete description of the boiling reactor appears in the AEC status report, reference (2).

Primary System

Subcooled water enters at the bottom of the core and passes upward past the fuel elements where it is boiled at 950 psig. A mixture of steam and water then rises to a steam drum located above the reactor vessel where primary saturated steam is separated and passed directly to the high-pressure inlet of the turbine. The separated water is mixed with primary feed water being returned from the steam cycle and is circulated through secondary steam generators where secondary saturated steam is generated at 460 psig. The secondary steam is admitted to the turbine at an intermediate stage and the recirculated water is passed from the secondary steam generator outlet to the reactor inlet thereby completing the cycle. A simplified diagram of the principal system flows are shown in Fig. V-2.

Reactor Plant Arrangement and Buildings

The reactor, reactor auxiliary equipment and secondary steam generating facilities are located in a steel spherical reactor building 190 ft. in diameter. Details of the building arrangements are shown in Drawings NS-202 through NS-212.

In general, the reactor building arrangement is patterned closely to that of the Dresden design.

Adjacent to the reactor building a fuel handling building equipped to store, ship and receive both spent and fresh fuel elements has been provided.

Cost Estimates

Cost estimates for three boiling reactor plant sizes are presented in Table V-4. These estimated costs are modified from those appearing in reference (2) only insofar as was necessary as a result of normalizing the plant design and placing the estimates on a basis comparable to those presented for the other concepts.

3. Organic Cooled Reactor Plant

The organic cooled reactor concept is an indirect cycle type similar to that of Atomics International as discussed in reference (3). The base 75 MW(e) plant used here is similar to the plant design reported in TID-8501, Vol. IV, of the Organic Cooled Power Reactor Study, reference (4) except as it was modified to comply with the definition of "present day technology" used in this study; c.f. reference (3).

The principal characteristics of the plant are summarized in Table V-5 and on a simplified flow diagram for the plant shown in Fig. V-3. Table V-6 presents the capital cost breakdown for the 75, 200, and 300 MW(e) size plants.

Reactor

The reactor is a thermal neutron type cooled and moderated by a mixture of diphenyls commonly called Santowax-R. The core is made up of a number of slightly enriched - U-3.5 w/o Mo fuel alloy elements. The elements are cylindrical and clad completely with a helically finned aluminum jacket. Each fueled lattice position is made up of two of these elements mounted concentrically inside a stainless steel jacket used to channel the coolant flow, c.f. reference (3).

The core assembly is contained within an all carbon steel pressure vessel 11 ft. I.D. by 51 ft. high overall with a wall thickness of 3.5 in. corresponding to a design pressure of 300 psig.

Control of the reactor is effected by means of several control rods set in core lattice positions and actuated from above the core. A more complete discussion of the organic cooled reactor concept and its present day limitations appears in reference (3).

Primary System

The organic coolant exits at the reactor core at 575 F and is passed through three loops to superheater-evaporator units where 9.4×10^5 lbs/hr. of superheated steam at 550 F and 585 psig are generated. The 19.8×10^6 lbs/hr. of organic leaving the evaporators is pumped back to the core at 490 F. The entire primary coolant system is constructed of carbon steel with the exception of the fuel elements which are aluminum clad. The primary system operating pressure is 150 psia.

It may be noted that the current temperature limits of the fuel elements and the comparatively poor heat transfer characteristics of the organic coolant seriously handicap this concept, especially in the larger size plants. However, for consistency extrapolated designs were prepared for 200 and 300 MW(e) plants as well as for the 75 MW(e) base size unit.

Organics used for reactor coolants undergo radiation damage and result in the formation of high boiler concentrates. These high boiler products have been shown not to impair system operation up to concentrations of about 30%; however, they must be continuously removed from the system.

Provision has been made for primary coolant purification wherein the organic decomposition products are removed and fresh coolant make-up provided. Coolant make-up rates are approximately 25 lbs/MWD_t.

Reactor Plant Arrangement and Buildings

The reactor, reactor auxiliary equipment and secondary steam generating equipment are located in a 140 ft. diameter cylindrical concrete structure

60 ft. high. This concrete structure is covered with a 136 ft. diameter hemispherical carbon steel dome, providing complete reactor containment. Details of the building arrangements are shown in Drawings NS-302 through NS-312. Adjacent to the reactor building a fuel handling building equipped to store, ship and receive both spent and fresh fuel elements has been provided.

Cost Estimates

Cost estimates for three organic cooled reactor plant sizes are presented in Table V-6. These estimated costs are modified from those appearing in reference (3) only insofar as was necessary as a result of normalizing the plant design and placing the estimates on a basis comparable to those presented for the other concepts.

4. Sodium-Graphite Reactor Plant

The sodium cooled, graphite moderated reactor concept is an indirect cycle plant having three principal energy transport loops. The plant designs used for cost estimating in this study follow closely the Hallam Nuclear Power Plant being designed by Atomics International for installation at Hallam, Nebraska, reference (5).

The principal characteristics of the base 75 MW(e) plant are summarized in Table V-7 and on a simplified flow diagram for the plant shown in Fig. V-4. Table V-8 presents the capital cost breakdown for the 75, 200, and 300 MW(e) size plants.

Reactor

The reactor is a thermal neutron, sodium cooled, graphite moderated type. The fuel elements are composed of rods of slightly enriched U-10 w/o Mo alloy clad with stainless steel. The fuel elements are arranged in a regular hexagonal array in cylindrical channels cut through the stainless steel clad graphite "logs" which comprise the core structure. The core is contained within a 2 in. thick stainless steel cylindrical reactor vessel 19 ft. I.D. by 34 ft. high overall. Normal operating pressure within the reactor vessel is only slightly above atmospheric.

Reactor control is effected by a series of control rods actuated from above the core. A more detailed discussion of the sodium-graphite reactor concept can be found in reference (6).

Heat Transfer Systems

Primary, radioactive sodium leaves the reactor at 945 F and is passed to three intermediate heat exchangers where it is used to heat 8.44×10^6 lbs/hr. of secondary nonradioactive sodium from 557 F to 895 F. Primary sodium is returned to the reactor at 607 F.

The nonradioactive, secondary sodium is used, in three superheater-evaporator units, to generate 7.19×10^5 lbs/hr. of superheated steam at 850 F and 785 psig. Both primary and secondary sodium systems are constructed of stainless steel. The superheater-evaporator units are provided with double walled tubes to preclude any contact between sodium and water.

Provision has been made for sodium purification in both primary and secondary systems and all sodium piping is trace heated electrically. Facilities for washing radioactive sodium from fuel elements extracted from the core are also provided.

Reactor Plant Arrangement and Buildings

The reactor, reactor auxiliaries and secondary steam generating equipment are all located in an insulated metal panel rectangular building approximately 275 ft. long, 152 ft. wide and 75 ft. high. All primary system equipment is located below grade in completely shielded vaults. Details of the buildings and building arrangements are shown on Drawings NS-402 through NS-412. No separate fuel handling building has been provided in this design since adequate facilities were conveniently located as part of the reactor building.

Cost Estimates

Cost estimates for three sodium-graphite reactor plant sizes are presented in Table V-8. These estimated costs are modified from those appearing in reference (6) only insofar as was necessary as a result of normalizing the plant design and placing the estimates on a basis comparable to those presented for the other concepts.

5. Fast, Sodium Cooled Reactor Plants

The sodium cooled, fast breeder plant is an indirect cycle plant having three principal energy transport loops. The plant designs used for cost estimating in this study are basically similar to the Enrico Fermi Power Plant being constructed at Lagoona Beach, Michigan, reference (7).

The principal characteristics of the base 150 MW(e) plant are summarized in Table V-9 and on a simplified flow diagram for the plant shown in Fig. V-5. Table V-10 presents the capital cost breakdown for the 75, 150, and 300 MW(e) size plants.

Reactor

The reactor is a fast neutron, sodium cooled type fueled with highly enriched U-10 w/o Mo alloy, clad with Zr-2. Surrounding the closely packed core is a blanket formed of depleted U-10 w/o Mo alloy elements clad with stainless steel. The initial conversion ratio of the core and blanket is 1.10.

The core and blanket is contained within a stainless steel can comprising the reactor vessel. Surrounding the reactor vessel is a series of layers of graphite and boron-graphite neutron shield material which in turn is totally contained within a sealed primary shield tank. The control mechanisms, fuel handling mechanisms and primary spent and fresh fuel storage facilities are also contained within the primary shield tank.

For complete details on the reactor and primary structure see references (7) and (8).

Heat Transfer Systems

Primary, radioactive sodium leaves the reactor at 900 F and is passed to three intermediate heat exchangers where it is used to heat 16.4 x 10^6 lbs/hr. of secondary nonradioactive sodium from 550 F to 850 F. Primary sodium is returned to the reactor at 600 F.

The nonradioactive, secondary sodium is used, in three superheater-evaporator units, to generate 1.46 x 10^6 lbs/hr. of superheated steam at 780 F and 850 psig. Both primary and secondary sodium systems are constructed of stainless steel. The superheater-evaporator units are provided with double walled tubes to preclude any contact between sodium and water.

Provision has been made for sodium purification in both primary and secondary systems and all sodium piping is trace heated electrically. Facilities for washing radioactive sodium from fuel elements extracted from the core are also provided.

Reactor Plant Arrangement and Buildings

The reactor, reactor auxiliaries and intermediate heat exchangers are located within a cylindrical steel containment building 72 ft. diameter and 120 ft. high overall. The secondary steam generating equipment is located in a building attached to the turbine building and located between the turbine building and reactor building. Details of the buildings and building arrangements are shown on Drawings NS-702 through NS-708.

Cost Estimates

Cost estimates for three sodium fast breeder plant sizes are presented in Table V-10. These estimated costs are modified from those appearing in reference (8) only insofar as was necessary as a result of normalizing the plant design and placing the estimates on a basis comparable to those presented for the other concepts.

6. Thermal, Aqueous Homogeneous Reactor Plants

The aqueous homogeneous reactor plant concept has been considered as not within the scope of current technology. However, cost estimates were prepared for this concept in three plant sizes based on a plant conceptual design reported in reference (9). Although reference (10), the AEC status report, briefly discusses these plants no detailed design data is given.

The principal characteristics of the base 200 MW(e) plant are summarized in Table V-11 and on a simplified flow diagram Fig. V-6. Table V-12 presents the capital cost breakdown for the 75, 200, and 300 MW(e) size plants.

Reactor

The two reactors for the base 200 MW(e) plant are each composed of a two region spherical core. The core is made up of a solution of U_3SO_4 in D_2O and is contained within a spherical Zr-2 core vessel. The blanket, surrounding the core, is a ThO_2 slurry in D_2O and is contained within a stainless steel clad carbon steel spherical pressure vessel. None of these reactors require control rods, but are provided with gross control by means of fuel concentration regulation. The overall conversion ratio for these reactors is in excess of unity. Further detail on these reactors is presented in references (9) and (10).

Primary Systems

Both core and blanket systems operate at 1800 psi and are circulated through steam generators to produce a total of 3.1 x 10^6 lbs/hr. of saturated steam at 550 psig. The entire primary systems are constructed of stainless steel and all pumping equipment in contact with fuel solution is furnished with titanium impellers. Core fluid leaves the reactor at 572 F and returns at 497 F.

Complete systems for controlling fuel concentration and fuel and blanket storage are provided for each reactor.

No chemical fuel or blanket processing equipment have been included in the cost estimates or designs.

Reactor Plant Arrangement and Buildings

Each reactor and primary system is located within a steel cylindrical reactor building 66 ft. in diameter and 116 ft. high. The buildings are approximately one-half below grade and can be completely filled with water so that remote maintenance operations can be carried out on the primary systems. Details of the buildings and building arrangements are shown on Drawings NS-802 through NS-811.

Cost Estimates

Cost estimates for three aqueous homogeneous reactor plants are presented in Table V-12.

7. Heavy Water Reactor Plant

The heavy water reactor plant is a natural uranium fueled, pressurized water, indirect cycle type similar to those designed by the DuPont Company and as described in reference (11). The principal characteristics of the plant are summarized in Table V-13 and on a simplified flow diagram for the plant shown in Fig. V-7. Table V-14 presents the capital cost breakdown for the 75, 200, and 300 MW(e) size plants.

Reactor

The reactor is a thermal neutron, natural uranium fueled, hot D_2O cooled and moderated pressure vessel type. The core is composed of a lattice of natural uranium metal tubular fuel elements clad with Zr-2. The elements are spaced on a 6.5 in. triangular pitch and the whole of the core is contained within a 14.7 I.D. by 34 ft. high overall stainless steel clad carbon steel pressure vessel 4.5 in. thick, which corresponds to the 850 psia system design pressure.

The reactor is controlled by a bank of bottom entering control rods extending beneath the pressure vessel. More complete descriptive data on the reactor can be found in reference (11).

Primary System

Primary D_2O coolant enters the reactor at 414 F. In circulating through the core it is raised to a bulk outlet temperature of 480 F. The primary D_2O is circulated through an all stainless steel primary system by canned rotor pumps to four steam generators where a total of 3.03 x 10^6 lbs/hr. of 150 psig of dry and saturated steam are produced.

As part of the primary system a complete bypass purification system and pressurizing system to maintain a primary system operating pressure of 750 psig are provided.

All primary system equipment is located in sealed equipment cavities and allowance has been made throughout the design to minimize D_2O losses.

Reactor Plant Arrangement and Buildings

The reactor, reactor auxiliaries, and primary system are all located within a 164 ft. diameter spherical steel containment building. Details of the building arrangements are shown in Drawings NS-502 through NS-512.

Adjacent to the reactor building a fuel handling building equipped to store, ship and receive both spent and fresh fuel elements has been provided.

Cost Estimates

Cost estimates for three heavy water reactor plant sizes are presented in Table V-14. These estimated costs are modified from those appearing in reference (11) only insofar as was necessary as a result of normalizing the plant design and placing the estimates on a basis comparable to those presented for the other concepts.

8. Gas Cooled Reactor Plant

The gas cooled reactor plant is a natural uranium fueled, CO_2 cooled, graphite moderated indirect cycle unit similar to that designed by Kaiser Engineers in 1958, reference (13). The principal characteristics of the plant are summarized in Table V-15 and on a simplified flow diagram for the plant shown in Fig. V-8. Table V-16 presents the capital cost breakdown for the 75, 200, and 300 MW(e) size plants.

Reactor

The reactor is a thermal neutron, natural uranium metal fueled, graphite moderated type. The fuel elements are finned U-metal rods clad with Magnox. The elements are arranged in a square array forming an octagonal shaped core 13.4 ft. in equivalent diameter by 13.5 ft. high. The entire core is contained within a 70 ft. diameter spherical pressure vessel 3 in. thick of carbon steel. The vessel design pressure is 700 psia. Further detail on the reactor is presented in reference (13).

Primary System

CO_2 coolant leaves the reactor at 710 F and is circulated to eight steam generating units where 1.77 lbs/hr. of high-pressure steam at 650 F and 500 psig and 7.85 x 10^5 lbs/hr. of low-pressure steam at 450 F and 100 psig are generated. The gas returns to the reactor, via eight blowers, at a temperature of 323 F. Normal operating pressure of the primary system is 200 psia.

As part of the primary system, complete gas purifying and make-up and storage facilities are provided.

Reactor Plant Arrangement and Buildings

The gas cooled reactor, housed within a 12 ft. thick ordinary concrete shield comprises the principal reactor building. All eight steam generators are outdoors with the primary system blower equipment located in comparatively small enclosures attached to the main structure. Detail of the building arrangements are shown in Drawings NS-602 through NS-612.

Adjacent to and as a part of the reactor building, a fuel handling area equipped to store, ship and receive both spent and fresh fuel elements, has been provided.

Cost Estimates

Cost estimates for three gas cooled reactor plant sizes are presented in Table V-16. These estimated costs are modified from those appearing in reference [12] only insofar as was necessary as a result of normalizing the plant design and placing the estimates on a basis comparable to those presented for the other concepts.

REFERENCES

1. WCAP-1196, "Status of Pressurized Water Reactors", prepared by Westinghouse Electric Corp., June 26, 1959.

2. GNEC-100, "Boiling Water Reactor Evaluation", prepared by General Nuclear Engineering Corp., June 25, 1959.

3. NAA-SR-Memo-4076, "Organic Reactor Program Status Report", prepared by Atomics International, July 14, 1959.

4. TID-8501, "Organic Cooled Power Reactor Study" Part 4 - 75 MW Power Plant Conceptual Design, prepared by Bechtel Corp. & Atomics International, April, 1959.

5. NAA-SR-2960, "Preliminary Proposal for the Hallam Nuclear Power Facility", prepared by Atomics International.

6. NAA-SR-Memo-4156 "Status Report for Sodium Graphite Reactors", prepared by Atomics International, July, 1959.

7. APDA-124, "Enrico Fermi Atomic Power Plant", January, 1959.

8. "Data on Status of Fast Reactors", prepared by A. Amorosi and J. G. Yevick, July 13, 1959.

9. TID-7524 "HRP Civilian Power Reactor Conference Held at Oak Ridge, March 21-22, 1956, pp. 65-77.

10. ORNL-CF-59-7-129, "Thermal Breeder Reactor Program - Aqueous Homogeneous Reactors", prepared by Oak Ridge National Laboratory.

11. DPW-59-264, "Civilian Power Reactor Program Status of Heavy Water Moderated Power Reactors", prepared by E. I. DuPont de Nemours & Co., June 29, 1959.

12. "Status of Gas Cooled Reactor Program", prepared by Oak Ridge National Laboratory.

13. IDO-2022, "Gas Cooled Power Reactor, Feasibility Study, Optimum Natural Uranium Nuclear Power Plant, April 1, 1958, revision 1.

SUMMARY OF PLANT CHARACTERISTICS
PRESSURIZED WATER REACTOR PLANT

A. Heat Balance	
1. Total Reactor Power, MW(t)	810
2. Gross Turbine Power, MW(e)	213
3. Net Plant Power, MW(e)	200
4. Net Plant Efficiency, %	24.8
B. Turbine Cycle Conditions	
1. Throttle Temperature, F.	480
2. Throttle Pressure, psig	555
3. Steam Flow, lbs./hr.	3.03×10^6
4. Condenser Back-Pressure, in. HgA.	1.5
5. Final Feedwater Temperature, F.	340
C. Reactor Description	
1. Reactor Vessel	
a. Inside Diameter, ft.	11.75
b. Overall Height, ft.	31.0
c. Wall Thickness, in.	7.0
d. Material	SS Clad CS
e. Design Pressure, psia	2500
2. Reactor Core	
a. Active Diameter, ft.	8.6
b. Active Height, ft.	9.0
c. Active Core Volume, $ft.^3$	523
d. Lattice Arrangement	square
e. Lattice Spacing, in.	7.475
3. Reflector or Blanket	
a. Material	H_2O
b. Radial Thickness, ft.	1.5
4. Fuel Elements	
a. Fuel Material	UO_2
b. Clad Material	SS
c. Fuel Enrichment, %	3.34
d. Fuel Element Geometry	rods
e. Cladding Thickness, in.	0.029
5. Material Inventories	
a. Fuel, Metric tons	52
b. Uranium, Metric tons	41.7
c. U-235, initial-kg.	1390
6. Reactor Control	
a. Method of Control	rods
b. No. of Control Elements	36

D. Plant Performance Data

1. Primary Coolant Outlet Temp., F.	544
2. Primary Coolant Inlet Temp., F.	503
3. Reactor Temp. Drop., F.	41
4. Primary System Operating Pressure, psia.	2200
5. Primary Coolant Flow Rate, lbs/hr.	53.1×10^6
6. Avg. Core Heat Flux, Btu/hr.-ft.^{2}	86,180
7. Max. Core Heat Flux, Btu/hr.-ft.^{2}	395,000
8. Max. Cladding Surface Temp., F.	636
9. Max. Fuel Temp., F.	4500
10. Core Coolant Velocity, ft/sec.	14.1
11. Peak to Avg. Power Ratio	4.55
12. Core Power Density kw/ft.^{3}	1550
13. Core Specific Power kwt/metric ton-U	19,500
14. Fuel Burn-up MWD/metric ton-U	13,000

CAPITAL COST BREAKDOWN
PRESSURIZED WATER REACTOR PLANTS

Acct. No.	Account Description	75 MW.	200 MW.	300 MW.
20	Land & Land Rights			
	200 Land and Privilege Aquisitions	360,000	360,000	360,000
	Total (20)	360,000	360,000	360.000
21	Structures and Improvements			
	210 Access Roads for permanent use			
	211 General yard improvements	765,500	765,500	765.500
	212 Buildings	1,521,900	2,100,640	2,436 900
	213 Reactor Container Structures	2,480,000	2,540,825	3,100,000
	Total (21)	4,767,400	5,406,965	6,302.400
22	Reactor Plant Equipment			
	220 Reactor Equipment	3,612,000	5,562,200	6,349,600
	221 Heat Transfer Equipment	3,752,650	7,543,550	9,984 600
	222 Fuel Handling and storage facilities	744,150	811,150	886,300
	223 Fuel Reprocessing and Refabrication	-	-	-
	224 Waste Disposal	285,375	380,775	483,675
	225 Instrumentation and Control	995,000	1,190,000	1,330,000
	226 Feedwater Supply and Treatment	358,700	623,560	850,400
	227 Steam Cond. and Feedwater Piping	2,642,470	4,610,000	6,888,000
	Total (22)	12,390,345	20,721,235	26,772,575
23	Turbo-Generator Units			
	230 Turbo-Generators	3,568,200	9,275,200	13,048,200
	231 Circ. Water Systems	534,300	1,416,700	1,739,400
	232 Condensers	531,800	1,214,500	1,857,500
	234 Turb. Plant Inst'n and Control	91,000	102,000	115.000
	235 Turb. Plant Piping	Included	Included	Included
	236 Aux. Equipment for Generators	31,500	38,500	46.000
	237 Other Turb. Plant Equipment	12,000	20,000	25,000
	Total (23)	4,768,800	12,066,900	16,831,100
24	Accessory Electric Equipment			
	240 Generator Switchgear	18,000	22.500	26,000
	241 Switchboards and Aux. Sw. Gr.	260,000	405,000	465,000
	242 Protective Equipment	29,000	36,000	42,000
	243 Electrical Structure	46,000	79,000	101,000
	244 Conduit Work	70,000	106,500	141.000
	245 Power and Control Wiring	205,000	302,000	410,000
	246 Station Service Equipment	120,000	228,500	255,000
	Total (24)	748,000	1,179,500	1,440,000
25	Miscellaneous Power Plant Equipment			
	250 Cranes and Hoisting Equipment	127,000	207,000	255,000
	251 Compressed Air and Vacuum Cleaning	21,200	35,340	44,000
	252 Other Miscellaneous Equipment	258,300	381,500	483,500
	Total (25)	406,500	623,840	782.500

Acct. No.	Account Description		75 MW.	200 MW.	300 MW.
52-53	Main Power Transformer		283,000	679,500	991,000
	Total Direct Construction Costs *		23,724,045	41,037,940	53,479,575
	Indirect Construction Costs				
711	Professional Services A/E 7%)				
711	Field Expenses A/E 2.5%)				
712	Purchasing 2%)				
713	Admin. Costs - Client - 2%)				
713	Taxes and Ins. - Client 0.5%)	14.6%	3,460,000	6,000,000	7,800,000
812	Temporary Construction)				
	Facilities Client - 0.6%)				
	Sub-Total		27,184,045	47,037,940	61,279,575
	Start-Up Costs		270,000	410,000	465,000
	Sub-Total		27,454,045	47,447,940	61,744,575
	Contingencies 10%		2,745,400	4,744,794	6,174,460
	Sub-Total		30,199,445	52,192,734	67,919,035
	Coolant		-	-	-
	Sub-Total		30,199,445	52,192,734	67,919,035
715	Interest (6% Ann. Rate) 8.1%		2,445,000	4,220,000	5,500,00
	Total Capital Cost $		32,644,445	56,412,734	73,419,035
	Total Capital Cost $/KW(e)		435	282	242

*Direct Construction Cost Estimates incl. construction, contractors' field office expense, tools and construction equipment, overheads and profit.

SUMMARY OF PLANT CHARACTERISTICS
BOILING WATER REACTOR PLANT

	primary		secondary
A. Heat Balance			
1. Total Reactor Power, MW(t)		690	
2. Gross Turbine Power, MW(e)		212	
3. Net Plant Power, Mw(e)		200	
4. Net Plant Efficiency, %		29.0	
B. Turbine Cycle Conditions	primary		secondary
1. Throttle Temperature, F.	540		460
2. Throttle Pressure, psig	950		460
3. Steam Flow, lbs/hr.	1.44×10^6		1.21×10^6
4. Condenser Back-Pressure, in. Hg A.		1.5	
5. Final Feed Water Temperature, F.	565		405
C. Reactor Description			
1. Reactor Vessel			
a. Inside Diameter, ft.		12.25	
b. Overall Height, ft.		44.0	
c. Wall Thickness, in.		5.675	
d. Material		SS clad CS.	
e. Design Pressure, psia		1500	
2. Reactor Core			
a. Active Diameter, ft.		10.5	
b. Active Height, ft.		9.75	
c. Active Core Volume, ft^3		845	
d. Lattice Arrangement		square	
3. Reflector or Blanket			
a. Material		H_2O	
b. Radial Thickness, ft.		~1	
4. Fuel Elements			
a. Fuel Material		UO_2	
b. Clad Material		Zr-2	
c. Fuel Enrichment		1.5	
d. Fuel Element Geometry		rods	
e. Cladding Thickness		0.030	
5. Material Inventories			
a. Fuel, metric tons		66.5	
b. Uranium, metric tons		52.3	
c. U-235, initial-kg.		785	
6. Reactor Control			
a. Method of Control		rods	
b. No. of Control Elements		84	

D. Plant Performance Data

1. Primary Coolant Outlet Temp., F.	545.3
2. Primary Coolant Inlet Temp., F.	505
3. Reactor Temp. Drop., F.	40.3
4. Primary System Operating Pressure, psia	1015
5. Primary Coolant Flow Rate, lbs/hr.	1.43×10^6
6. Avg. Core Heat Flux, Btu/hr.-ft^2	97,700
7. Max. Core Heat Flux, Btu/hr.-ft^2	277,000
8. Max. Cladding Surface Temp., F.	585
9. Max. Fuel Temp., F.	4500
10. Core Coolant Velocity, ft/sec.	-
11. Peak to Avg. Power Ratio	2.92
12. Core Power Density kw/ft^3	817
13. Core Specific Power kwt/metric ton-U	13,200
14. Fuel Burn-up MWD/metric ton-U	11,000

CAPITAL COST BREAKDOWN
BOILING WATER REACTOR PLANTS

Acct. No.	Account Description	75 MW.	200 MW.	300 MW.
20	Land and Land Rights			
	200 Land and Privilege Acquisitions	360,000	360,000	360,000
	Total (20)	360,000	360,000	360,000
21	Structure and Improvements			
	210 Access Roads for Permanent Use	-	-	-
	211 General Yard Improvements	764,500	764,500	764,500
	212 Buildings	1,520,300	2,118,740	2,435,300
	213 Reactor Container Structures	3,000,000	5,865,100	7,050,000
	Total (21)	5,284,800	8,748,340	10,249,800
22	Reactor Plant Equipment			
	220 Reactor Equipment	4,350,400	5,884,500	7,043,800
	221 Heat Transfer Equipment	3,119,764	6,251,500	6.826,760
	222 Fuel Handling and Storage Facil.	763,000	846,000	984,000
	223 Fuel Reprocessing and Refabrication	-	-	-
	224 Waste Disposal	315,500	443,840	550,900
	225 Instrumentation and Control	1,490,000	1,690,000	1,890,000
	226 Feedwater Supply and Treatment	514,000	884,260	1,228,400
	227 Stm., Cond. and Feedwater Piping	2,850,000	5,284,000	7,800,000
	Total (22)	13,402,664	21,284,100	26,323,860
23	Turbo-Generator Units			
	230 Turbo-Generators	3,813,200	9,577,200	13,563,200
	231 Circ. Water Systems	538,500	1,406,700	1,714,200
	232 Condensers	635,200	1,321,200	2,000,200
	234 Turb. Plant Inst'n and Controls	91,000	102,000	115,000
	235 Turb. Plant Piping	Included	Included	Included
	236 Aux. Eqpt. for Generators	31,500	38,500	46,000
	237 Other Turb. Plant eqpt.	12,000	20,000	25,000
	Total (23)	5,121,400	12,465,600	17,463,600
24	Accessory Electric Equipment			
	240 Generator Switchgear	18,000	21,600	25,000
	241 Switchboards and Aux. Sw. Gr.	296,000	420,000	485,000
	242 Protective Eqpt.	29,000	36,000	42,000
	243 Electrical Structure	46,000	80,700	99,000
	244 Conduit Work	68,000	101,000	133,000
	245 Power and Control Wiring	208,000	284,300	390,000
	246 Station Service Eqpt.	112,000	210,500	239,000
	Total (24)	777,000	1,154,100	1,413,000
25	Miscellaneous Power Plant Eqpt.			
	250 Cranes and Hoisting Eqpt.	126,000	207,000	219,000
	251 Compressed Air and Vac. Cleaning	21,200	35,340	44,000
	252 Other Miscellaneous Eqpt.	246,300	341,500	439,500
	Total (25)	393,500	583,840	702,500

Acct. No.	Account Description		75 MW.	200 MW.	300 MW.
52-53	Main Power Transformer		283,000	679,500	991,000
	Total Direct Construction Costs *		25,622,364	45,275,480	57,503,760
	Indirect Construction Costs				
711	Professional Services - A/E - 7%	)			
711	Field Expense - A/E - 2.5%	)			
712	Purchasing 2.0%	)			
713	Admin. Costs - Client - 2.0%	)14.6%	3,745,000	6,610,000	8,400,000
713	Taxes and Ins. - Client - 0.5%	)			
812	Temporary Construction	)			
	Facilities Client - 0.6%	)			
	Sub-Total		29,367,364	51,885,480	65,903,760
	Start-Up Costs		273,000	417,000	476,000
	Sub-Total		29,640,364	52,302,480	66,379,760
	Contingencies - 10%		2,964,040	5,230,248	6,637,980
	Sub-Total		32,604,404	57,532,728	73,017,740
	Coolant		-	-	-
	Sub-Total		32,604,404	57,532,728	73,017,740
715	Interest (6% ann. rate) 8.1%		2,645,000	4,670,000	5,910,000
	Total Capital Cost $		35,249,404	62,202,728	78,927,740
	Total Capital Cost $/KW(e)		470	311	263

*Direct Construction Cost Estimates incl. construction, contractors' field office expense, tools and construction equipment, overheads and profit.

SUMMARY OF PLANT CHARACTERISTICS
ORGANIC COOLED REACTOR PLANT

A. Heat Balance	
1. Total Reactor Power, MW(t)	260
2. Gross Turbine Power, MW(e)	79
3. Net Plant Power, MW(e)	75
4. Net Plant Efficiency, %	28.5
B. Turbine Cycle Conditions	
1. Throttle Temperature, F.	550
2. Throttle Pressure, psig	585
3. Steam Flow, lbs/hr.	9.36×10^5
4. Condenser Back-Pressure, in. Hg A.	1.5
5. Final Feed Water Temperature, F.	360
C. Reactor Description	
1. Reactor Vessel	
a. Inside Diameter, ft.	11.0
b. Overall Height, ft.	51.0
c. Wall Thickness, in.	3.5
d. Material	CS
e. Design Pressure, psia	300
2. Reactor Core	
a. Active Diameter, ft.	9.5
b. Active Height, ft.	9.5
c. Active Core Volume, ft^3.	674
d. Lattice Arrangement	triangular
e. Lattice Spacing, in.	6
3. Reflector or Blanket	
a. Material	Santowax R
b. Axial Thickness, ft.	-
c. Radial Thickness, ft.	0.75
4. Fuel Elements	
a. Fuel Material	U-3.5 w/o Mo
b. Clad Material	AL.
c. Fuel Enrichment	1.6
d. Fuel Element Geometry	cylinder
e. Cladding Thickness	0.035
5. Material Inventories	
a. Fuel, metric tons	41.4
b. Uranium, metric tons	41
c. U-235, initial-kg.	656
6. Reactor Control	
a. Method of Control	rods
b. No. of Control Elements	19

D. Plant Performance Data

1.	Primary Coolant Outlet Temp., F.	575
2.	Primary Coolant Inlet Temp., F.	490
3.	Reactor Temp. Drop., F.	85
4.	Primary System Operating Pressure, psia	150
5.	Primary Coolant Flow Rate, lbs/hr.	19.8×10^6
6.	Avg. Core Heat Flux, Btu/hr. - ft^2.	28,000
7.	Max. Core Heat Flux, Btu/hr. - ft^2.	112,000
8.	Max. Cladding Surface Temp., F.	750
9.	Max. Fuel Temp., F.	-
10.	Core Coolant Velocity, ft/sec.	15 (max.)
11.	Peak to Avg. Power Ratio	4.0
12.	Core Power Density kw/ft^3.	386
13.	Core Specific Power kwt/metric ton - U	6340
14.	Fuel Burn-up MWD/metric ton - U	7000

CAPITAL COST BREAKDOWN
ORGANIC COOLED REACTOR PLANTS

Acct. No.	Account Description	75 MW	200 MW	300 MW
20	Land and Rights			
	200 Land and Privilege Acquisitions	360,000	360,000	360,000
	Total (20)	360,000	360,000	360,000
21	Structures and Improvements			
	210 Access Roads for Permanent Use	-	-	-
	211 Gen'l Yard Improvements	727,500	788,800	788,800
	212 Buildings	1,167,000	1,927,440	2,261,000
	213 Reactor Container Structures	2,302,700	3,961,450	4,104,450
	Total (21)	4,197,200	6,677,690	7,154,250
22	Reactor Plant Equipment			
	220 Reactor Equipment	2,439,680	4,459,300	6,442,600
	221 Heat Transfer Equipment	1,893,050	4,858,355	7,271,100
	222 Fuel Handling and Storage Facil.	605,570	7,771,675	1,104,960
	223 Fuel Reprocessing and Refab'n.	11,900	21,950	30,200
	224 Waste Disposal	189,225	255,000	326,000
	225 Instrumentation and Control	1,210,000	1,771,000	2,220,000
	226 Feed Water Supply and Treatment	291,820	483,700	703,300
	227 Stm. Cond. and Feed Water Piping	1,600,500	2,256,000	2,780,000
	Total (22)	8,241,745	14,876,980	20,878,160
23	Turbo-Generator Units			
	230 Turbo-Generators	3,443,200	7,795,200	12,598,200
	231 Circulating Water Systems	528,800	1,274,700	1,574,200
	232 Condensers	493,500	1,042,200	1,593,200
	234 Turb. Plant Inst'n and Controls	91,000	102,000	115,000
	235 Turbine Plant Piping	Included	-	-
	236 Aux. Equip. for Generators	31,500	38,500	46,000
	237 Other Turbine Plant Equipment	12,000	20,000	25,000
	Total (23)	4,600,000	10,272,600	15,951,600
24	Accessory Electric Equipment			
	240 Generator Switchgear	19,000	23,000	27,000
	241 Switchboards and Aux. Switchgear	284,000	423,000	485,000
	242 Protective Equipment	28,500	36,000	42,000
	243 Electrical Structure	48,000	85,000	102,000
	244 Conduit Work	95,500	133,000	160,000
	245 Power and Control Wiring	215,500	310,000	425,000
	246 Station Service Equipment	112,500	213,000	241,000
	Total (24)	803,000	1,223,000	1,482,000
25	Misc. Power Plant Equipment			
	250 Cranes and Hoisting Equipment	139,500	244,000	260,000
	251 Compressed Air and Vac. Cleaning	21,200	35,340	44,000
	252 Other Miscellaneous Equipment	272,140	385,500	474,500
	Total (25)	432,840	664,840	778,500

Acct. No.	Account Description		75 MW	200 MW	300 MW
52-53	Main Power Transformer		283,000	679,500	991,000
	Total Direct Construction Costs*		18,917,785	34,754,610	47,595,510
	Indirect Construction Costs				
711	Professional Services - A/E-7%	)			
711	Field Expense - A/E-2.5%	)			
712	Purchasing - 2.0%	)	2,760,000	5,070,000	6,950,000
713	Admin. Costs - Client-2.0%	) 14.6			
713	Taxes and Insurance - Client-0.5%	) %			
812	Temporary Construction	)			
	Facilities - Client-0.6%	)			
	Sub Total		21,677,785	39,824,610	54,545,510
	Start-Up Costs		266,000	402,000	455,000
	Sub Total		21,943,785	40,226,610	55,000,510
	Contingencies - 10%		2,194,378	4,022,661	5,500,051
	Sub Total		24,138,163	44,249,271	60,500,561
	Coolant		133,400	355,800	533,600
	Sub Total		24,271,563	44,605,071	61,034,161
715	Interest (6% ann. rate) 8.1%		1,966,000	3,613,000	4,944,000
	Total Capital Cost $		26,237,563	48,218,071	65,978,161
	Total Capital Costs $/KW (e)		350	241	220

*Direct Construction Cost Estimates incl. construction, contractors' field office expense, tools and construction equipment, overheads and profit.

SUMMARY OF PLANT CHARACTERISTICS
SODIUM GRAPHITE REACTOR PLANT

A. Heat Balance	
1. Total Reactor Power, MW(t)	240
2. Gross Turbine Power, MW(e)	80
3. Net Plant Power, MW(e)	75
4. Net Plant Efficiency, %	30.8
B. Turbine Cycle Conditions	
1. Throttle Temperature, F.	850
2. Throttle Pressure, psig	785
3. Steam Flow, lbs./hr.	7.19×10^6
4. Condenser Back-Pressure, in. Hg A.	1.5
5. Final Feed Water Temperature, F.	300
C. Reactor Description	
1. Reactor Vessel	
a. Inside Diameter, ft.	19.0
b. Overall Height, ft.	34.0
c. Wall Thickness, in.	0.75
d. Material	SS
e. Design Pressure, psia	50
2. Reactor Core.	
a. Active Diameter, ft.	13.4
b. Active Height, ft.	13.5
c. Active Core Volume, ft^3	1930
d. Lattice Arrangement	hex.
3. Reflector or Blanket	
a. Material	Graphite
b. Axial Thickness; Ft.	2
c. Radial Thickness, Ft.	2
4. Fuel Elements	
a. Fuel Material	U-10 w/o Mo
b. Clad Material	SS
c. Fuel Enrichment	2.85
d. Fuel Element Geometry	rods
5. Material Inventories	
a. Fuel, metric tons	36.7
b. Uranium, metric tons	33
c. U-235, initial-kg.	940
6. Reactor Control	
a. Method of Control	rods
b. No. of Control Elements	31

D. Plant Performance Data

1. Primary Coolant Outlet Temp., F.	945
2. Primary Coolant Inlet Temp., F.	607
3. Reactor Temp. Drop., F.	338
4. Primary System Operating Pressure, psia.	atmos.
5. Primary Coolant Flow Rate, lbs./hr.	8.44×10^6
6. Avg. Core Heat Flux, Btu/hr.-ft.^{2}	121,000
7. Max. Core Heat Flux, Btu/hr.-ft.^{2}	302,000
8. Max. Cladding Surface Temp., F.	1000
9. Max. Fuel Temp., F.	1260
10. Core Coolant Velocity, ft/sec.	11.4 max.
11. Peak to Avg. Power Ratio	2.5
12. Core Power Density kw/ft^3	124
13. Core Specific Power kwt/metric ton-U	7270
14. Secondary Sodium Outlet Temp., F.	895
15. Secondary Sodium Inlet Temp., F.	557
16. Secondary Sodium Flow Rate, lbs./hr.	8.01×10^6
17. Fuel Burn-up MWD/metric ton-U	3000

CAPITAL COST BREAKDOWN
SODIUM COOLED, GRAPHITE MODERATED REACTOR PLANTS

Acct. No.	Account Description	75 MW	200 MW	300 MW
20	Land and Land Rights			
	200 Land and Privilege Aquisitions	360,000	360,000	360,000
	Total (20)	360,000	360,000	360.000
21	Structures and Improvements			
	210 Access Roads for Permanent Use	-	-	-
	211 Gen'l Yard Improvements	729,500	729,500	729,500
	212 Buildings	1,169,000	1,746,200	2,082,200
	213 Reactor Container Structures	4,568,200	7,350,000	9,300,000
	Total (21)	6,466,700	9,825,700	12,111,700
22	Reactor Plant Equipment			
	220 Reactor Equipment	7,135,980	8,465,850	9,684,110
	221 Heat Transfer Equipment	4,665,550	9,635,900	11,907,610
	222 Fuel Handling and Storage Facil's	865,150	967,050	1,069,700
	223 Fuel Reprocessing and Refabrication	-	-	-
	224 Waste Disposal	170,800	212,100	260,700
	225 Instrumentation and Control	1,195,000	1,675,000	1,861,000
	226 Feed Water Supply and Treatment	288,500	544,100	750,900
	227 Stm. Cond. and Feed Water Piping	3,569,000	8,199,396	9,512,000
	Total (22)	17,889,980	29,699,396	35,046,020
23	Turbo-Generator Units			
	230 Turbo-Generators	3,300,200	7,493,200	12,203,200
	231 Circulating Water Systems	504,300	1,032,500	1,285,500
	232 Condensers	383,300	805,500	1,218,000
	234 Turb. Plant Inst'n and Control	91,000	102,000	115,000
	235 Turbine Plant Piping	Included	Included	Included
	236 Aux. Equipment for Generators	31,500	38,500	46,000
	237 Other Turbine Plant Equipment	12,000	20,000	25,000
	Total (23)	4,322,300	9,491,700	14,892,700
24	Accessory Electric Equipment			
	240 Generator Switchgear	19,000	23,000	27,000
	241 Switchboards and Aux. Switchgear	326,000	485,000	520,000
	242 Protective Equipment	30,500	40,000	47,000
	243 Electrical Structure	58,000	83,000	115,000
	244 Conduit Work	101,500	135,000	165,000
	245 Power and Control Wiring	245,500	340,000	440,000
	246 Station Service Equipment	103,000	210,000	245,000
	Total (24)	883,500	1,316,000	1,559,000
25	Misc. Power Plant Equipment			
	250 Cranes and Hoisting Equipment	220,000	262,000	284,000
	251 Compressed Air and Vac. Cleaning	21,200	35,340	44,000
	252 Other Miscellaneous Equipment	279,300	419,000	550,000
	Total (25)	520,500	716,340	878,000

Acct. No.	Account Description		75 MW	200 MW	300 MW
52-53	Main Power Transformer		283,000	679,500	991,000
	Total Direct Construction Costs *		30,725,980	52,088,636	65,838,420
	Indirect Construction Costs				
711	Professional Services - A/E-7%	)			
711	Field Expenses - A/E-2.5%	)			
712	Purchasing - 2%	)			
713	Admin. Costs - Client-2%	)14.6	4,480,000	7,600,000	9,610,000
713	Taxes and Insurance - Client-0.5%	) %			
812	Temporary Construction Facilities - Client-0.6%	)			
	Sub Total		35,205,980	59,688,636	75,448,420
	Start-Up Costs		296,000	470,000	552,000
	Sub Total		35,501,980	60,158,636	76,000,420
	Contingencies - 10%		3,550,198	6,015,860	7,600,042
	Sub Total		39,052,178	66,174,496	83,600,462
	Coolant		234,000	420,000	500,000
	Sub Total		39,286,178	66,594,496	84,100,462
715	Interest (6% ann. rate) 8.1%		3,180,000	5,400,000	6,810,000
	Total Capital Cost $		42,466,178	71,994,496	90,910,462
	Total Capital Cost $/KW(e)		565	360	303

*Direct Construction Cost Estimates incl. construction, contractors' field office expense, tools and construction equipment, overheads and profit.

SUMMARY OF PLANT CHARACTERISTICS
FAST, SODIUM COOLED REACTOR PLANT

A. Heat Balance	
1. Total Reactor Power, MW(t)	440
2. Gross Turbine Power, MW(e)	160
3. Net Plant Power, MW(e)	150
4. Net Plant Efficiency, %	34.2
B. Turbine Cycle Conditions	
1. Throttle Temperature, F	780
2. Throttle Pressure, psig	850
3. Steam Flow, lbs/hr.	1.46×10^6
4. Condenser Back-Pressure, in. Hg A.	1.5
5. Final Feed Water Temperature, F	380
C. Reactor Description	
1. Reactor Vessel	
a. Inside Diameter, ft.	14.5
b. Overall Height, ft.	36.2
c. Wall Thickness, in.	2
d. Material	SS
e. Design Pressure, psia	6000
2. Reactor Core	
a. Active Diameter, ft.	3.0
b. Active Height, ft.	2.54
c. Active Core Volume, $ft.^3$	17.75
d. Lattice Arrangement	square
e. Lattice Spacing, in.	2.693
3. Reflector or Blanket	
a. Material	dep. U-10 w/o Mo
b. Axial Thickness, ft.	1.17
c. Radial Thickness, ft.	2.4
4. Fuel Elements	
a. Fuel Material	U-10 w/o Mo
b. Clad Material	SS
c. Fuel Enrichment	93
d. Fuel Element Geometry	rods
5. Material Inventories	
a. Fuel, metric tons	0.509
b. Uranium, metric tons	0.463
c. U-235, initial-kg.	430
6. Reactor Control	
a. Method of Control	rods
b. No. of Control Elements	10

D. Plant Performance Data

1. Primary Coolant Outlet Temp., F	900
2. Primary Coolant Inlet Temp., F	600
3. Reactor Temp. Drop, F	300
4. Primary System Operating Pressure, psia	atmos.
5. Primary Coolant Flow Rate, lbs/hr.	16.4×10^6
6. Avg. Core Heat Flux, Btu/hr.-ft^2.	675,000
7. Max. Core Heat Flux, Btu/hr.-ft^2.	1,167,000
8. Max. Cladding Surface Temp., F	1000
9. Max. Fuel Temp., F	1050
10. Core Coolant Velocity, ft/sec.	31.2
11. Peak to Avg. Power Ratio	1.44
12. Core Power Density, kw/ft^3.	21,500
13. Core Specific Power, kwt/metric ton- U	947,000
14. Secondary Sodium Outlet Temp., F	850
15. Secondary Sodium Inlet Temp., F	550
16. Secondary Sodium Flow Rate, lbs/hr.	16.4×10^6
17. Fuel Burnup	2 w/o

CAPITAL COST BREAKDOWN
FAST, SODIUM COOLED REACTOR PLANTS

Acct. No.	Account Description	75 MW	150 MW	300 MW
20	Land and Land Rights			
	200 Land and Privilege Acquisitions	360,000	360,000	360,000
	Total (20)	360,000	360,000	360,000
21	Structures and Improvements			
	210 Access Roads for Permanent Use	-	-	-
	211 General Yard Improvements	762,000	762,000	762,000
	212 Buildings	1,169,900	1,439,500	2,084,900
	213 Reactor Container Structure	2,138,700	4,138,700	4,658,700
	Total (21)	4,070,600	6,340,200	7,505,600
22	Reactor Plant Equipment			
	220 Reactor Equipment	2,613,700	3,105,770	3,522,700
	221 Heat Transfer Equipment	5,139,980	7,282,925	13,203,764
	222 Fuel Handling and Storage Facil's	1,605,000	1,755,000	1,955,000
	223 Fuel Reprocessing and Refabrication	-	-	-
	224 Waste Disposal	208,250	248,690	298,400
	225 Instrumentation and Control	890,000	1,155,000	1,460,000
	226 Feed Water Supply and Treatment	323,000	432,920	771,400
	227 Stm. Cond. and Feed Water Piping	3,200,000	5,461,500	7,100,000
	Total (22)	13,979,930	19,441,805	28,311,264
23	Turbo-Generator Units			
	230 Turbo-Generators	3,552,200	6,567,200	12,549,200
	231 Circ. Water Systems	524,900	1,005,500	1,559,400
	232 Condensers	470,800	746,700	1,491,500
	234 Turb. Plant Inst'n and Control	91,000	102,000	115,000
	235 Turb. Plant Piping	Included	Included	Included
	236 Aux. Equip. for Generators	31,500	35,000	46,000
	237 Other Turb. Plant Equip.	12,000	17,000	25,000
	Total (23)	4,682,400	8,473,400	15,785,100
24	Accessory Electric Equipment			
	240 Generator Switchgear	19,000	22,500	26,000
	241 Switchboards and Aux. Sw. Gr.	290,000	381,000	490,000
	242 Protective Equipment	30,000	38,000	47,000
	243 Electrical Structure	55,000	67,000	102,000
	244 Conduit Work	90,000	108,500	140,000
	245 Power and Control Wiring	235,000	312,500	428,000
	246 Station Service Equip.	110,000	189,500	225,000
	Total (24)	829,000	1,119,000	1,458,000

Acct. No.	Account Description		75 MW	150 MW	300 MW
25	Misc. Power Plant Equipt.				
	250 Cranes and Hoisting Equip.		197,000	298,000	375,000
	251 Compressed Air and Vac. Cleaning		21,200	29,600	44,000
	252 Other Misc. Equipt.		271,800	364,000	547,500
	Total (25)		490,000	691,600	966,500
52-53	Main Power Transformer		283,000	476,500	991,000
	Total Direct Construction Costs *		24,694,930	36,902,505	55,377,464
	Indirect Construction Costs				
711	Professional Services A/E 7%	)			
711	Field Expenses A/E 2.5%	)			
712	Purchasing 2%	)			
713	Admin. Costs - Client 2%	) 14.6%	3,610,000	5,400,000	8,080,000
713	Taxes and Ins.-Client 0.5%	)			
812	Temporary Construction	)			
	Facilities Client 0.6%	)			
	Sub-Total		28,304,930	42,302,505	63,457,464
	Start-Up Costs		318,000	466,000	628,000
	Sub-Total		28,622,930	42,768,505	64,085,464
	Contingencies 10%		2,862,290	4,276,851	6,408,550
	Sub-Total		31,485,220	47,045,356	70,494,014
	Coolant		67,000	133,000	266,000
	Sub-Total		31,552,220	47,178,356	70,760,014
715	Interest (6% Ann. Rate) 8.1%		2,550,000	3,820,000	5,725,000
	Total Capital Cost $		34,102,220	50,998,356	76,485,014
	Total Capital Cost $/KW(e)		455	340	255

*Direct Construction Cost Estimates Incl. Construction, Contractors' Field Office Expense, Tools and Construction Equipment, Overheads and Profit.

SUMMARY OF PLANT CHARACTERISTICS
AQUEOUS HOMOGENEOUS REACTOR PLANT

A. Heat Balance	
1. Total Reactor Power, MW(t)	760
2. Gross Turbine Power, MW(e)	212
3. Net Plant Power, MW(e)	200
4. Net Plant Efficiency, %	26.3
B. Turbine Cycle Conditions	
1. Throttle Temperature, F.	479
2. Throttle Pressure, psig	550
3. Steam Flow, lbs/hr.	3.10×10^6
4. Condenser Back-Pressure, in. Hg A.	1.5
5. Final Feed Water Temperature, F.	405
C. Reactor Description	
1. Reactor Vessel	
a. Inside Diameter, ft.	11.33
b. Overall Height, ft.	-
c. Wall Thickness, in.	6.5
d. Material	SS clad CS.
e. Design Pressure, psia	2500
2. Reactor Core.	
a. Active Diameter, ft.	6
b. Active Height, ft.	-
c. Active Core Volume, ft^3	113
3. Reflector or Blanket	
a. Material	D_2O-Th O_2 Slurry
b. Axial Thickness, ft.	-
c. Radial Thickness, ft.	2.5
4. Fuel Elements	
Fuel Material	U_3SO_4 in D_2O
5. Reactor Control	
Method of Control	fuel concentration
D. Plant Performance Data	
1. Primary Coolant Outlet Temp., F.	572
2. Primary Coolant Inlet Temp., F.	497
3. Reactor Temp. Drop., F.	75
4. Primary System Operating Pressure, psia	1800
5. Primary Coolant Flow Rate, lbs/hr.	31.3×10^6
6. Core Power Density kw/ft^3	6720

CAPITAL COST BREAKDOWN
AQUEOUS HOMOGENEOUS REACTOR PLANTS

Acct. No.	Account Description	75 MW.	200 MW.	300 MW.
20	Land & Land Rights			
	200 Land and Privilege Aquisitions	360,000	360,000	360,000
	Total (20)	360,000	360,000	360,000
21	Structures and Improvements			
	210 Access Roads for permanent use	-	-	-
	211 General yard improvements	767,000	767,000	767,000
	212 Buildings	1,382,200	1,960,440	2,297,200
	213 Reactor Container Structures	3,700,000	8,349,200	10,845,000
	Total (21)	5,849,200	11,076,640	13,909,200
22	Reactor Plant Equipment			
	220 Reactor Equipment	2,219,200	4,526,000	6,131,000
	221 Heat Transfer Equipment	3,370,700	8,660,400	11,556,000
	222 Fuel Handling and Storage Facilities	-	-	-
	223 Fuel Reprocessing and Refabrication	-	-	-
	224 Waste Disposal	6,000	9,800	16,000
	225 Instrumentation and Control	500,000	690,000	800,000
	226 Feedwater Supply and Treatment	332,700	615,960	815,500
	227 Steam Cond. and Feedwater Piping	3,000,000	6,155,000	8,200,000
	Total (22)	9,428,600	20,657,160	27,518,500
23	Turbo-Generator Units			
	230 Turbo-Generators	3,568,200	9,275,200	13,047,200
	231 Circ. Water Systems	537,300	1,422,700	1,855,400
	232 Condensers	552,800	1,270,500	1,948,500
	234 Turb. Plant Inst'n and Control	91,000	102,000	115,000
	235 Turb. Plant Piping	Included	Included	Included
	236 Aux. Equipment for Generators	31,500	38,500	46,000
	237 Other Turb. Plant Equipment	12,000	20,000	25,000
	Total (23)	4,792,800	12,128,900	17,037,100
24	Accessory Electric Equipment			
	240 Generator Switchgear	19,000	22,500	26,000
	241 Switchboards and Aux. Sw. Gr.	260,000	385,000	460,000
	242 Protective Equipment	31,000	41,000	48,000
	243 Electrical Structure	52,000	70,000	99,000
	244 Conduit Work	95,000	123,000	145,000
	245 Power and Control Wiring	240,000	338,000	440,000
	246 Station Service Equipment	115,000	210,500	245,000
	Total (24)	812,000	1,190,000	1,463,000
25	Miscellaneous Power Plant Equipment			
	250 Cranes and Hoisting Equipment	152,000	238,000	240,000
	251 Compressed Air and Vacuum Cleaning	21,200	35,340	44,000
	252 Other Misc. Equipment	274,300	417,500	548,500
	Total (25)	447,500	690,840	832,500

Acct. No.	Account Description		75 MW.	200 MW.	300 MW.
52-53	Main Power Transformer		283,000	679,500	991,000
	Total Direct Construction		21,973,100	46,783,040	62,111,300
	Indirect Construction Costs				
711	Professional Services A/E 7%)				
711	Field Expenses A/E 2.5%)				
712	Purchasing 2.0%)				
713	Admin. Costs - Client - 2.0%)	14.6%	3,210,000	6,840,000	9,070,000
713	Taxes and Ins. - Client 0.5%)				
812	Temporary Construction)				
	Facilities Client - 0.6%)				
	Sub-Total		25,183,100	53,623,040	71,181,300
	Start-Up Costs		340,000	657,000	821,000
	Sub-Total		25,523,100	54,280,040	72,002,300
	Contingencies 10%		2,552,310	5,428,004	7,200,230
	Sub-Total		28,075,410	59,708,044	79,202,530
	Coolant		3,170,000	7,180,000	10,400,000
	Sub-Total		31,245,410	66,888,044	89,602,530
715	Interest (6% Ann. Rate) 8.1%		2,530,000	5,410,000	7,260,000
	Total Capital Cost $		33,775,410	72,298,044	96,862,530
	Total Capital Cost $/KW(e)		450	362	323

*Direct Construction Cost Estimates incl. construction, contractors' field office expense, tools and construction equipment, overheads and profit.

SUMMARY OF PLANT CHARACTERISTICS
HEAVY WATER REACTOR PLANT

A. Heat Balance	
1. Total Reactor Power, MW(t)	860
2. Gross Turbine Power, MW(e)	214
3. Net Plant Power, MW(e)	200
4. Net Plant Efficiency, %	23.2
B. Turbine Cycle Conditions	
1. Throttle Temperature, F.	366
2. Throttle Pressure, psig	150
3. Steam Flow, lbs./hr.	3.03×10^6
4. Condenser Back-Pressure, in. Hg A.	1.5
5. Final Feed Water Temperature, F.	251
C. Reactor Description	
1. Reactor Vessel	
a. Inside Diameter, ft.	14.7
b. Overall Height, ft.	34.0
c. Wall Thickness, in.	4.5
d. Material	SS clad CS
e. Design Pressure, psia	850
2. Reactor Core	
a. Active Diameter, ft.	12
b. Active Height, ft.	15
c. Active Core Volume, ft^3	1700
d. Lattice Arrangement	Triangular
e. Lattice Spacing, in.	6.5
3. Reflector or Blanket	
a. Material	D_2O
b. Axial Thickness, ft.	1
c. Radial Thickness, ft.	1
4. Fuel Elements	
a. Fuel Material	nat. U metal
b. Clad Material	Zr-2
c. Fuel Enrichment	nat.
d. Fuel Element Geometry	cylinders
e. Cladding Thickness	0.030
5. Material Inventories	
a. Fuel, metric tons	27.2
b. Uranium, metric tons	27.2
c. U-235, initial-kg.	188
d. Moderator, lbs. (incl. coolant)	5.5×10^5
6. Reactor Control	
a. Method of Control	rods
b. No. of Control Elements	26

D. Plant Performance Data

1. Primary Coolant Outlet Temp., F.	480
2. Primary Coolant Inlet Temp., F.	414
3. Reactor Temp. Drop., F.	66
4. Primary System Operating Pressure, psia.	750
5. Primary Coolant Flow Rate, lbs/hr.	39.6×10^6
6. Avg. Core Heat Flux, Btu/hr.-ft^2.	335,000
7. Max. Core Heat Flux, Btu/hr.-ft^2.	777,000
8. Max. Cladding Surface Temp., F.	575
9. Max. Fuel Temp., F.	880
10. Core Coolant Velocity, ft/sec.	15
11. Peak to Avg. Power Ratio	2.32
12. Core Power Density kw/ft^3.	506
13. Core Specific Power kwt/metric ton-U	31,600
14. Fuel Burn-up MWD/metric ton-U	3960

CAPITAL COST BREAKDOWN
HEAVY WATER MODERATED REACTOR PLANTS

Acct. No.	Account Description	75 MW	200 MW	300 MW
20	Land and Land Rights			
	200 Land and Privilege Acquisitions	360,000	360,000	360,000
	Total (20)	360,000	360,000	360,000
21	Structures and Improvements			
	210 Access Roads for Permanent Use	-	-	-
	211 Gen'l Yard Improvements	765,500	765,500	765,500
	212 Buildings	1,515,300	2,126,740	2,430,300
	213 Reactor Container Structures	4,250,200	4,878,600	5,134,000
	Total (21)	6,531,000	7,770,840	8,329,800
22	Reactor Plant Equipment			
	220 Reactor Equipment	7,701,990	10,417,850	11,567,650
	221 Heat Transfer Equipment	3,570,070	8,142,000	11,766,620
	222 Fuel Handling and Storage Facilities	940,650	940,650	940,650
	223 Fuel Reprocessing and Refabrication	-	-	-
	224 Waste Disposal	328,000	356,390	394,000
	225 Instrumentation and Control	1,100,000	1,290,000	1,395,000
	226 Feedwater Supply and Treatment.	247,920	440,300	595,600
	227 Stm., Cond and Feedwater Piping	2,410,000	4,664,000	5,660,000
	Total (22)	16,298,630	26,251,190	32,319,520
23	Turbo - Generator Units			
	230 Turbo - Generators	3,848,200	9,395,200	13,290,200
	231 Circ. Water Systems	598,500	1,714,200	2,174,600
	232 Condensers	752,300	1,587,500	2,433,500
	234 Turb. Plant Inst'n and Control	91,000	102,000	115,000
	235 Turb Plant Piping	Included	Included	Included
	236 Aux. Eqpt for Generators	31,500	38,500	46,000
	237 Other Turb. Plant Eqpt.	12,000	20,000	25,000
	Total (23)	5,333,500	12,857,400	18,084,300
24	Accessory Electric Equipment			
	240 Generator Switchgear	18,000	21,600	26,000
	241 Switchboards and Aux. Sw. Gr.	265,000	416,000	480,000
	242 Protective Eqpt.	29,000	36,000	42,000
	243 Electrical Structure	46,000	74,700	100,000
	244 Conduit Work	70,000	106,000	140,000
	245 Power and Control Wiring	205,000	305,300	415,000
	246 Station Service Eqpt	115,000	227,500	250,000
	Total (24)	748,000	1,187,100	1,453,000
25	Misc. Power Plant Eqpt.			
	250 Cranes and Hoisting Eqpt.	117,000	253,000	255,000
	251 Compressed Air and Vac. Cleaning	21,200	35,340	44,000
	252 Other Misc. Eqpt.	257,800	381,000	483,500
	Total (25)	396,000	669,340	782,500

Acct. No.	Account Description		75 MW	200 MW	300 MW
52-53	**Main Power Transformer**		283,000	679,500	991,000
	Total Direct Construction Cost *		29,950,130	49,775,370	62,320,120
	Indirect Construction Costs				
711	Professional Services A/E-7%)				
711	Field Expenses A/E 2.5%)				
712	Purchasing 2%)				
713	Admin. Costs-Client-2%)	14.6%	4,370,000	7,270,000	9,100,000
713	Taxes and Ins.- Client-0.5%)				
812	Temporary Construction)				
	Facilities Client-0.6%)				
	Sub-Total		34,320,130	57,045,370	71,420,120
	Start-Up Costs		276,000	425,000	498,000
	Sub-Total		34,596,130	57,470,370	71,918,120
	Contingencies 10%		3,459,610	5,747,037	7,191,810
	Sub-Total		38,055,740	63,217,407	79,109,930
	Coolant		6,340,000	15,400,000	20,800,000
	Sub-Total		44,395,740	78,617,407	99,909,930
715	Interest (6% Ann. rate) 8.1%		3,600,000	6,380,000	8,090,000
	Total Capital Cost	$	47,995,740	84,997,407	107,999,930
	Total Capital Cost KW(e)	$	640	425	360

* Direct Construction Cost Estimates incl. construction, contractors' field office expense, tools and construction equipment, overheads and profit

SUMMARY OF PLANT CHARACTERISTICS
GAS COOLED REACTOR PLANT

	High-Pressure		Low-Pressure
A. Heat Balance			
1. Total Reactor Power, MW(t)		830	
2. Gross Turbine Power, MW(e)		240	
3. Net Plant Power, MW(e)		200	
4. Net Plant Efficiency, %		24.1	
B. Turbine Cycle Conditions			
1. Throttle Temperature, F.	650		450
2. Throttle Pressure, psig	500		100
3. Steam Flow, lbs/hr.	1.77×10^6		7.85×10^5
4. Condenser Back-Pressure, in. Hg A.		1.5	
5. Final Feed Water Temperature, F.		2.60	
C. Reactor Description			
1. Reactor Vessel			
a. Inside Diameter, ft.		70	
b. Overall Height, ft.		-	
c. Wall Thickness		3.0	
d. Material		c.s.	
e. Design Pressure, psia		500	
2. Reactor Core			
a. Active Diameter, ft.		50	
b. Active Height, ft.		29	
c. Active Core Volume, ft.		57,000	
d. Lattice Arrangement		square	
e. Lattice Spacing, in.		8	
3. Reflector or Blanket			
a. Material		Graphite	
4. Fuel Elements			
a. Fuel Material		U-metal	
b. Clad Material		Magnox	
c. Fuel Enrichment		nat.	
d. Fuel Element Geometry		finned rods	
e. Cladding Thickness		0.020	
5. Material Inventories			
a. Fuel, metric tons		274	
b. Uranium, metric tons		274	
c. U-235, initial-kg.		1970	
6. Reactor Control			
a. Method of Control		rods	
b. No. of Control Elements		100	

D. Plant Performance Data

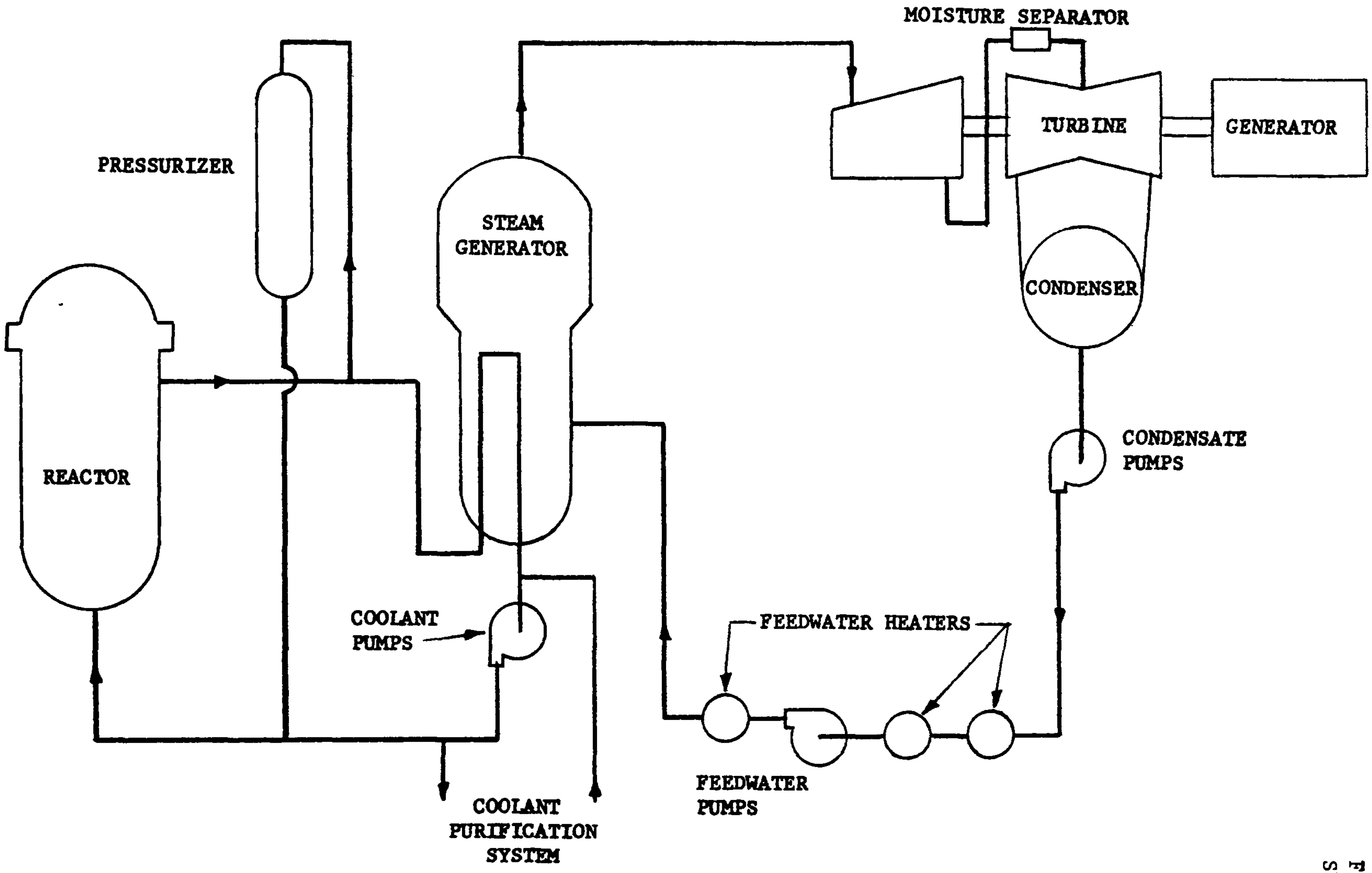
1.	Primary Coolant Outlet Temp., F.	710
2.	Primary Coolant Inlet Temp., F.	323
3.	Reactor Temp. Drop., F.	387
4.	Primary System Operating Pressure, psia	200
5.	Primary Coolant Flow Rate, lbs/hr.	28.3×10^6
6.	Avg. Core Heat Flux, Btu/hr. - ft^2	56,000
7.	Max. Core Heat Flux, Btu/hr. - ft^2	96,000
8.	Max. Cladding Surface Temp., F.	730
9.	Max. Fuel Temp., F.	1200
10.	Core Coolant Velocity, ft/sec.	-
11.	Peak to Avg. Power Ratio	1.72
12.	Core Power Density kw/ft^3	14.6
13.	Core Specific Power kwt/metric ton - U	3030
14.	Fuel Burn-up MWD/metric ton - U	3000

CAPITAL COST BREAKDOWN
GAS COOLED REACTOR PLANTS

Acct. No	Account Description	75 MW	200 MW	300 MW
20	Land and Land Rights			
	200 Land and Privilege Aquisition	360,000	360,000	360,000
	Total (20)	360,000	360,000	360,000
21	Structures and Improvements			
	210 Access Road for Permanent use	-	-	-
	211 General Yard Improvements	808,000	808,000	808,000
	212 Buildings	940,500	1,520,100	1,855,500
	213 Reactor Container Structures	4,930,000	5,804,800	6,680,000
	Total (21)	6,678,500	8,132,900	9,343,500
22	Reactor Plant Equipment			
	220 Reactor Equipment	6,935,000	15,452,000	19,210,000
	221 Heat Transfer Equipment	7,641,500	15,267,800	17,805,400
	222 Fuel Handling and Storage Facilities	1,446,000	1,610,000	1,771,000
	223 Fuel Reprocessing and Refabrication	-	-	-
	224 Waste Disposal	152,000	255,000	434,000
	225 Instrumentation and Control	2,735,000	3,145,000	3,650,000
	226 Feedwater Supply and Treatment	282,100	463,760	684,500
	227 Stm Cond , and Feedwater Piping	4,112,455	7,730,000	9,230,891
	Total (22)	23,304,055	43,923,560	52,785,791
23	Turbo - Generator Units			
	230 Turbo - Generators	3,571 200	7,963,200	13,303,200
	231 Circ. Water Systems	582,900	1,429,700	1,870,600
	232 Condensers	622,300	1,325,700	2,004.500
	234 Turb. Plant Inst'n and Control	91,000	102,000	115,000
	235 Turb. Plant Piping	Included	Included	Included
	236 Aux Equip. for Generators	31,500	38,500	46,000
	237 Other Turb Plant Equipment	12,000	20,000	25,000
	Total (23)	4,910,900	10,879,100	17,364,300
24	Accessory Electric Equipment			
	240 Generator Switchgear	19,000	22,500	26,000
	241 Switchboards and Aux Sw Gr	300,000	484,000	520,000
	242 Protective Equipment	31,000	39,000	45,000
	243 Electrical Structure	60,000	86,500	120,000
	244 Conduit Work	90,000	97,000	125,000
	245 Power and Control Wiring	260,000	367,500	460,000
	246 Station Service Equipment	200,000	345,000	430,000
	Total (24)	960,000	1,441,500	1,726,000
25	Misc. Power Plant Equipment			
	250 Cranes and Hoisting Equipment	86,000	169,000	170,000
	251 Compressed Air and Vac Cleaning	21,200	35,340	44,000
	252 Other Misc. Equipment	274,800	417,500	548,500
	Total (25)	382,000	621,840	762,500

Acct. No.	Account Description		75 MW	200 MW	300 MW
52-53	Main Power Transformer		283,000	679,500	991,000
	Total Direct Construction Costs *		36,878,455	66,038,400	83,333,091
	Indirect Construction Costs				
711	Professional Services A/E 7%	)			
711	Field Expenses A/E 2.5%	)			
712	Purchasing 2%	)			
713	Admin. Costs - Client 2%	) 14.6%	5,390,000	9,645,000	12,170,000
713	Taxes and Ins. - Client 0.5%	)			
812	Temporary Construction	)			
	Facilities Client - 0 6%	)			
	Sub - Total		42,268,455	75,683,400	95,503,091
	Start-Up Costs		273,000	417,000	476,000
	Sub - Total		42,541,455	76,100,400	95,979,091
	Contingencies 10%		4,254,150	7,610,040	9,597,910
	Sub - Total		46,795,605	83,710,440	105,577,001
	Coolant		-	-	-
	Sub - Total		46,795,605	83,710,440	105,577,001
715	Interest (6% Ann. Rate) 8.1%		3,790,000	6,790,000	8,550,000
	Total Capital Cost		$ 50,585,605	90,500,440	114,127,001
	Total Capital Cost $/KW(e)		$ 675	452	380

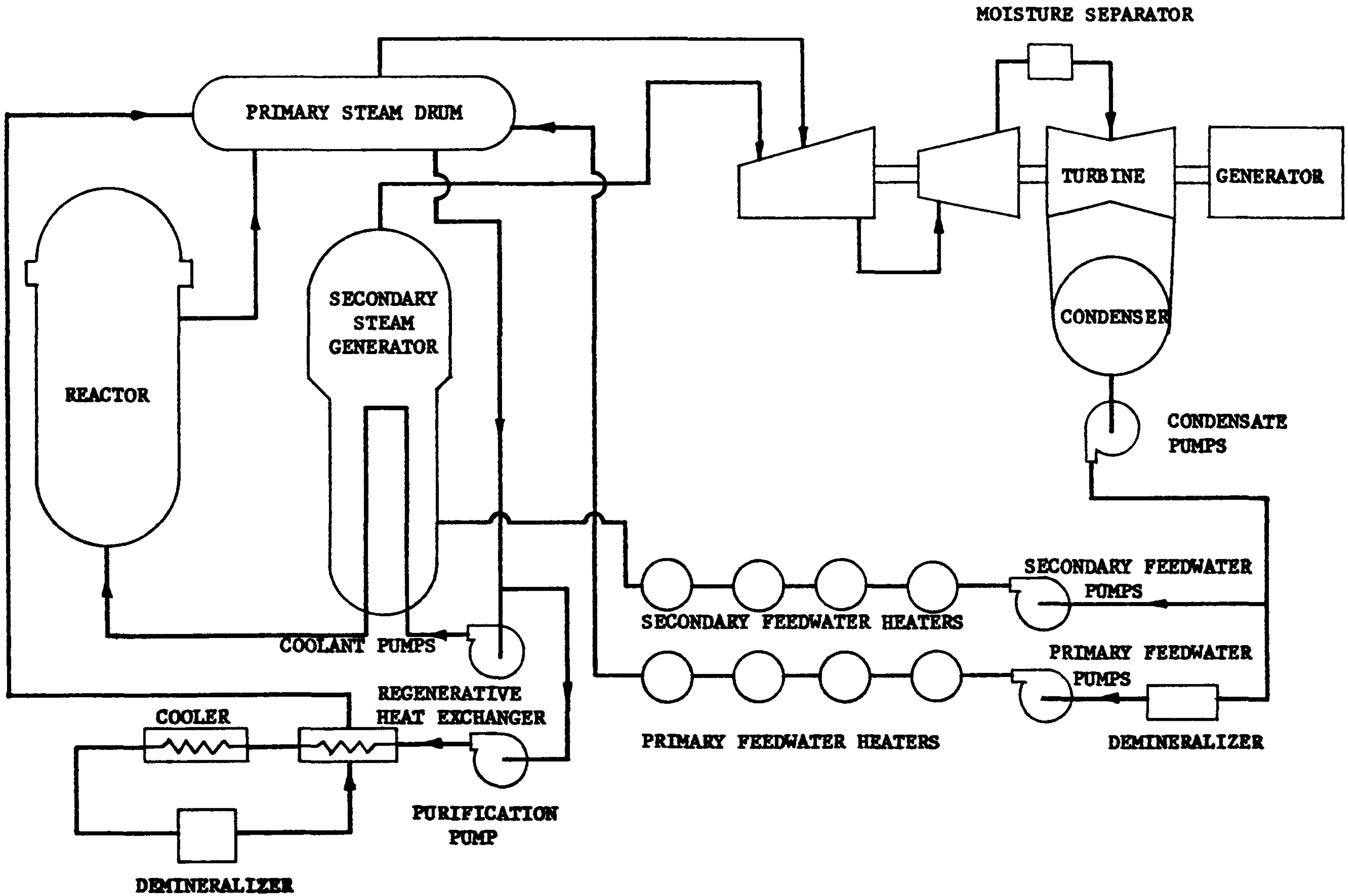
* Direct Construction Cost Estimates include Construction, Contractors' Field Office Expense, Tools and Construction Equipment, Overheads, and Profits.



SIMPLIFIED FLOW DIAGRAM
PRESSURIZED WATER REACTOR PLANT

Figure V-1
SL-1674

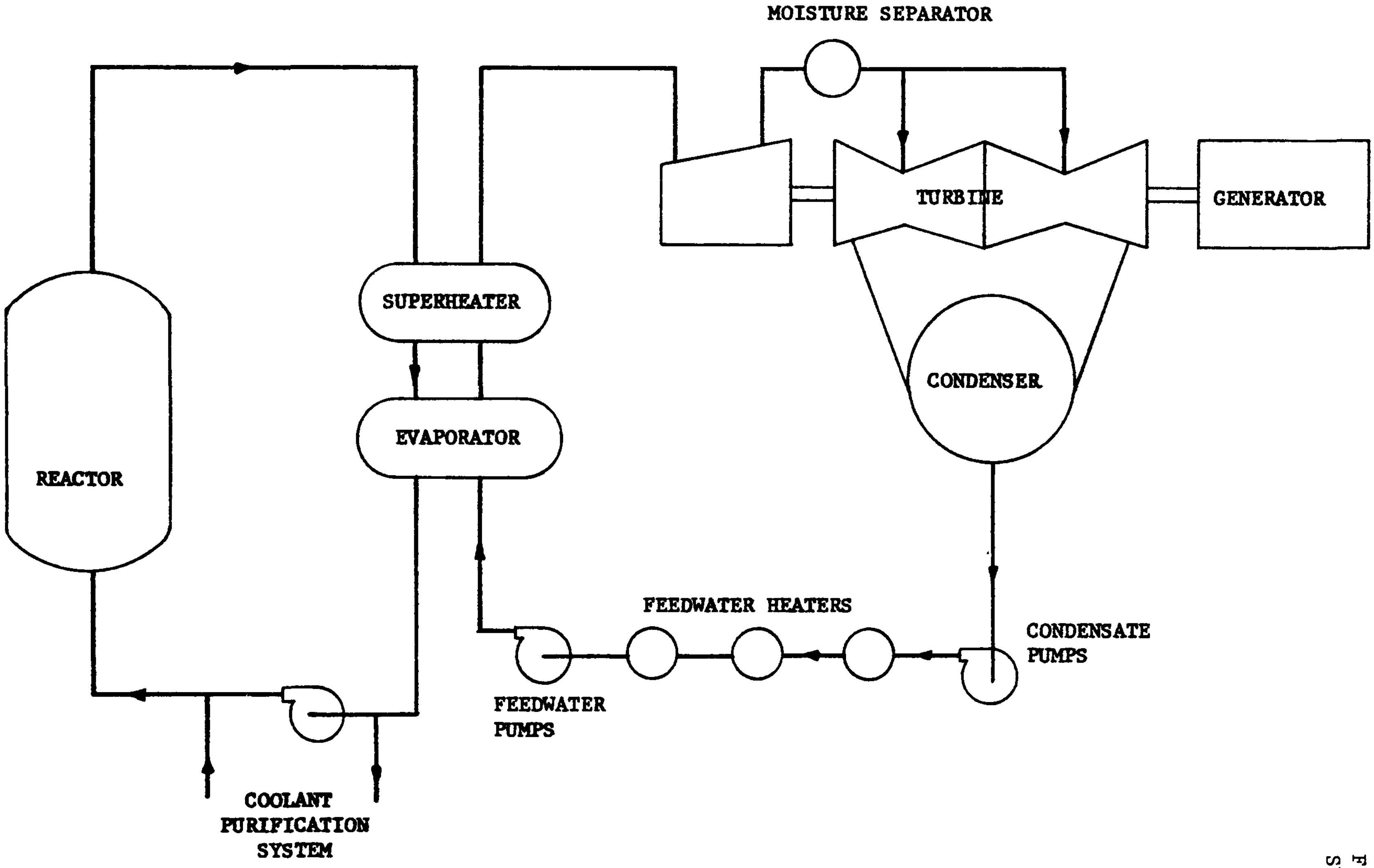
SEPT 1959



SIMPLIFIED FLOW DIAGRAM
BOILING WATER REACTOR PLANT

SEPT 1959

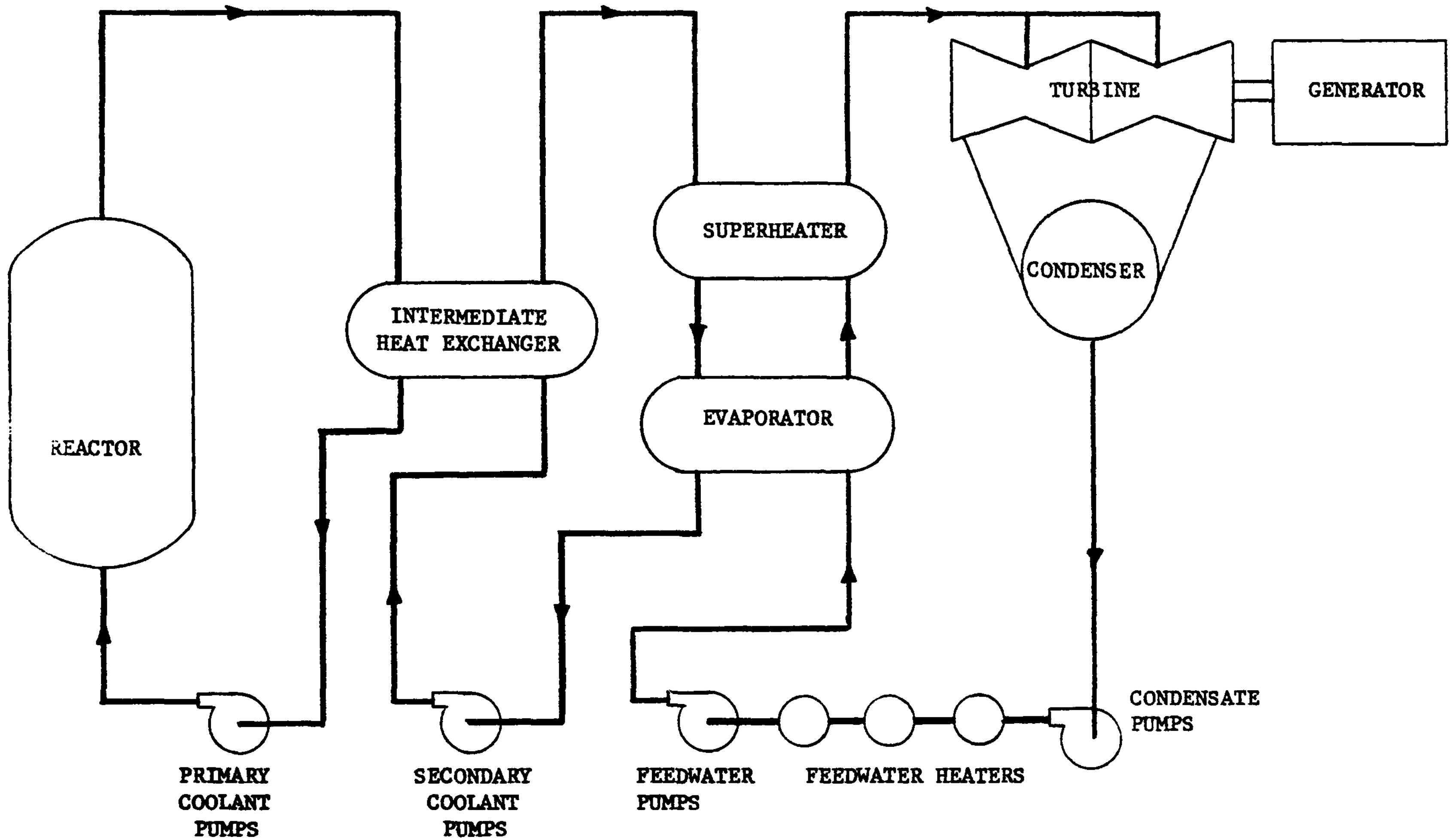
Figure V-2
SL-1674



SIMPLIFIED FLOW DIAGRAM
ORGANIC COOLED REACTOR PLANT

SEPT 1959

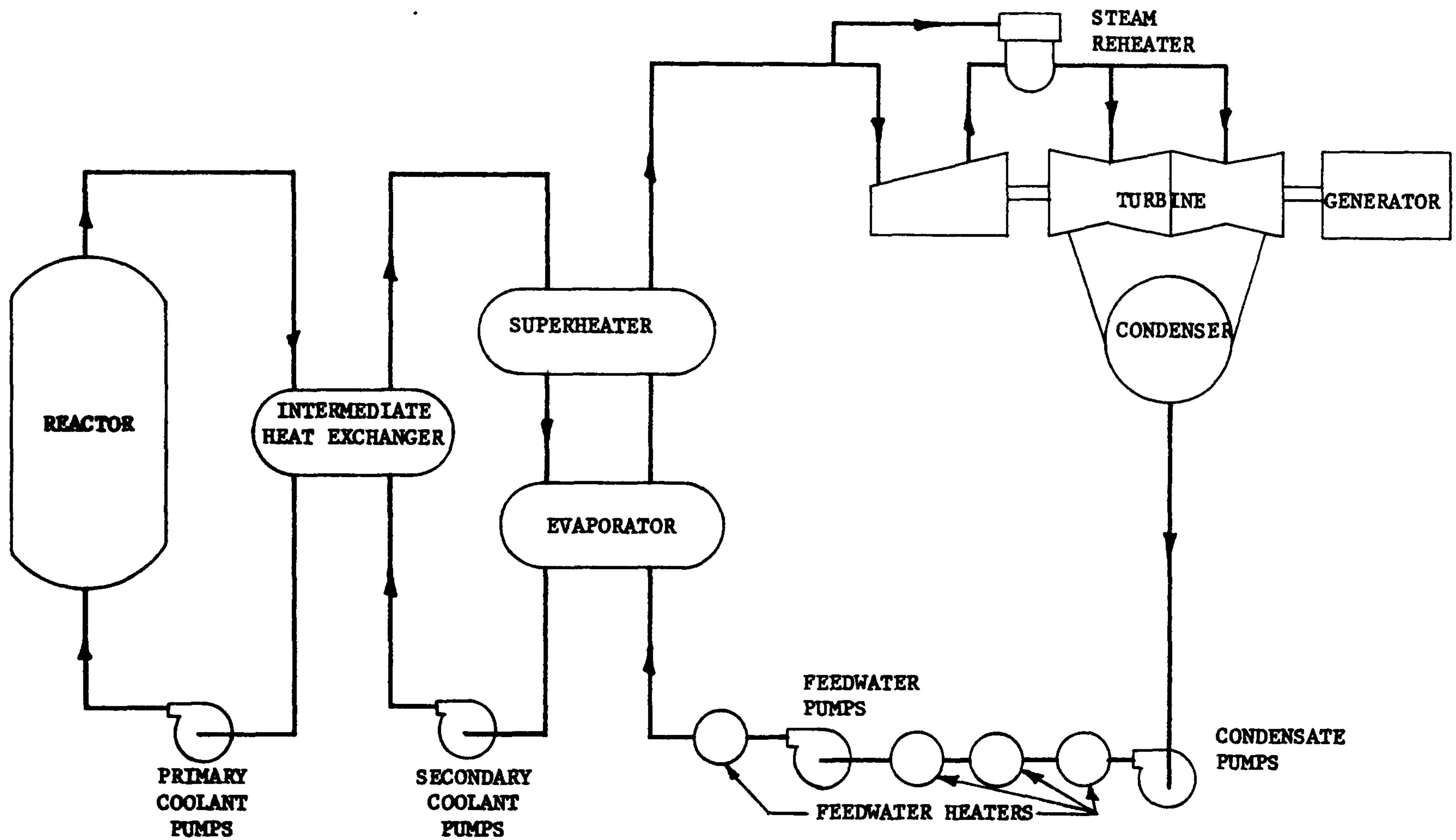
Figure V-3
SL-1674



SIMPLIFIED FLOW DIAGRAM
SODIUM COOLED - GRAPHITE MODERATED REACTOR PLANT

SEPT 1959

Figure V-4
SL-1674



SIMPLIFIED FLOW DIAGRAM

FAST REACTOR - SODIUM COOLED
REACTOR PLANT

SEPT 1959

Figure V-5
SL-1674

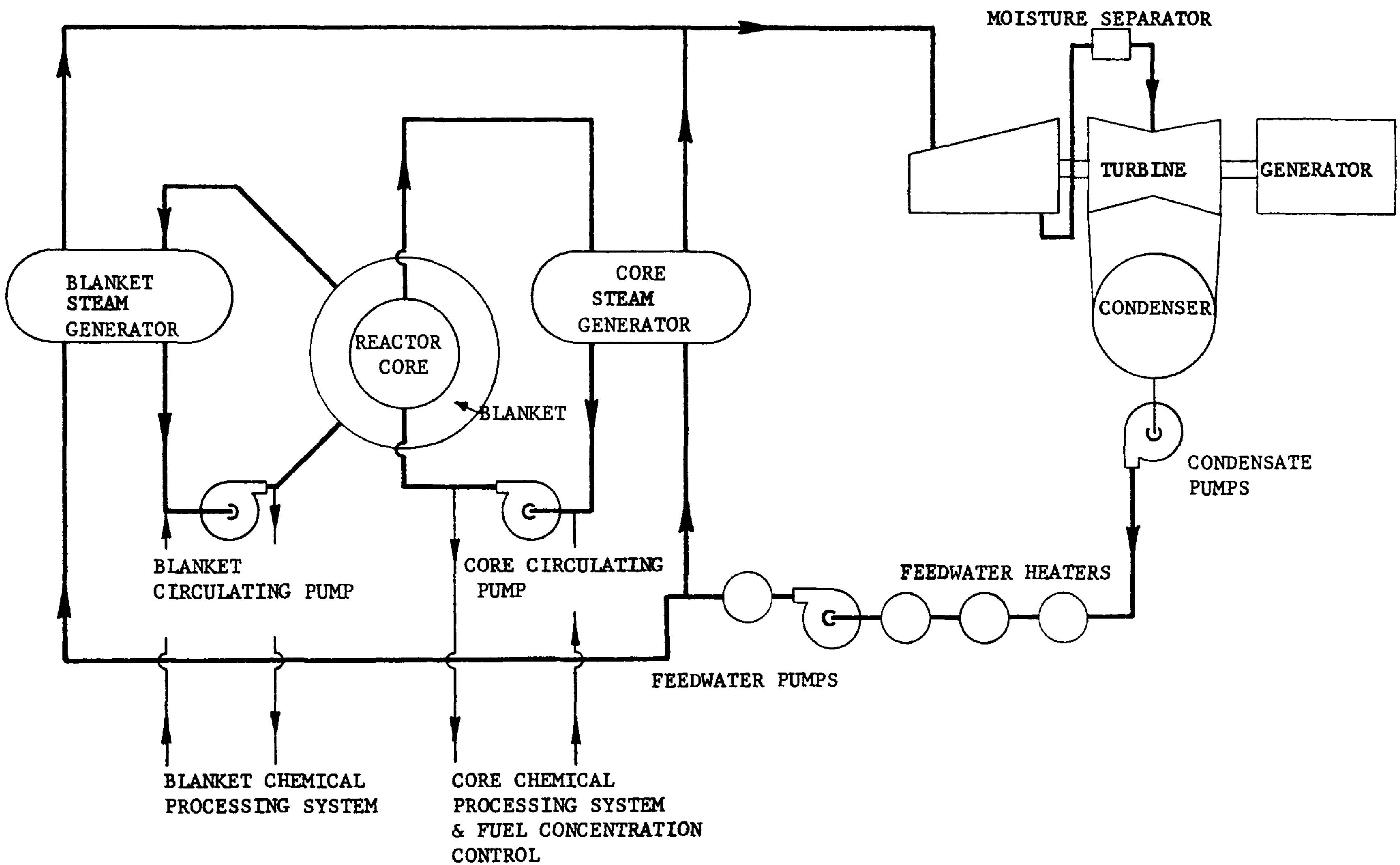
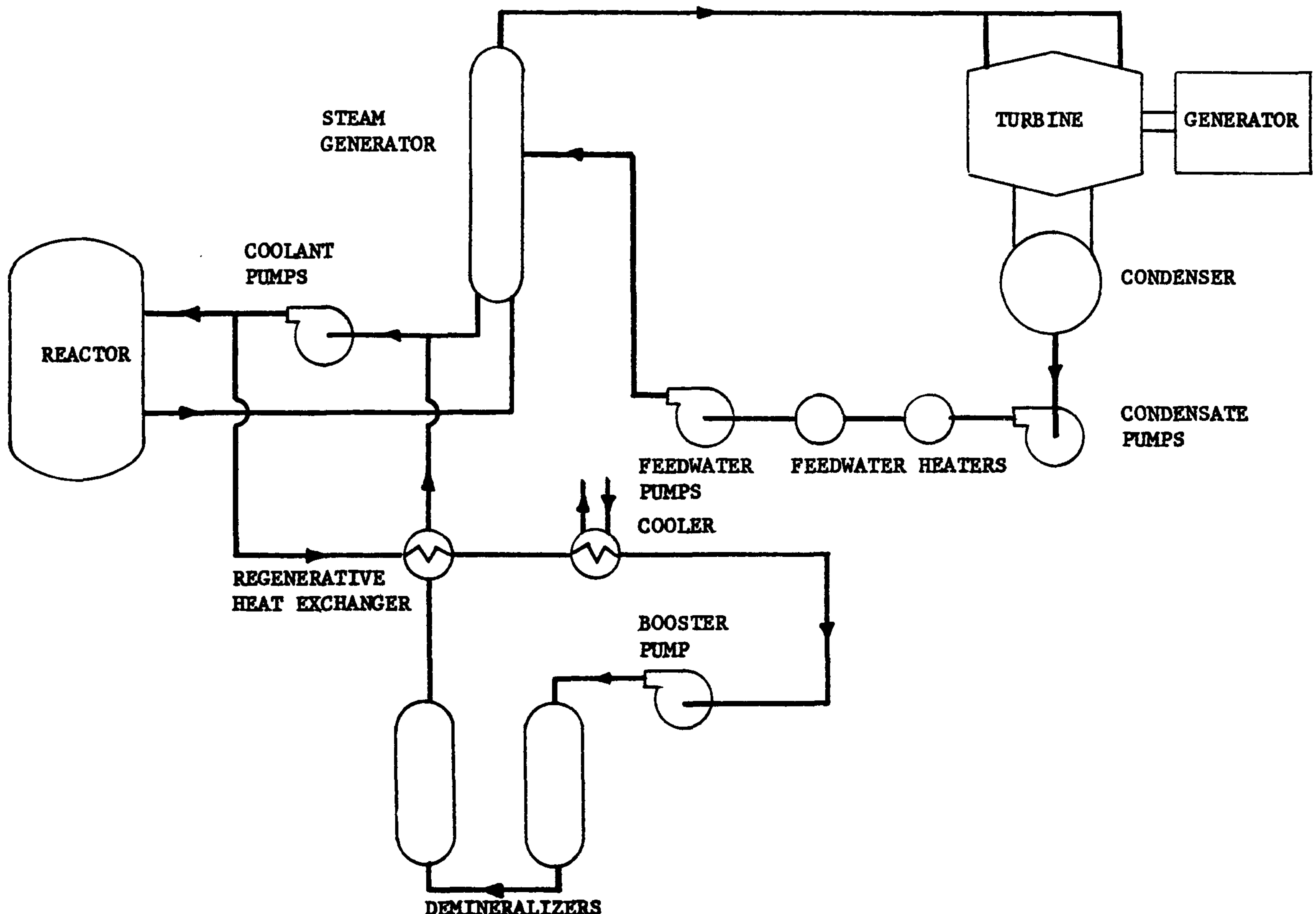


Figure V-6
SL-1674

SIMPLIFIED FLOW DIAGRAM
AQUEOUS HOMOGENEOUS REACTOR PLANT

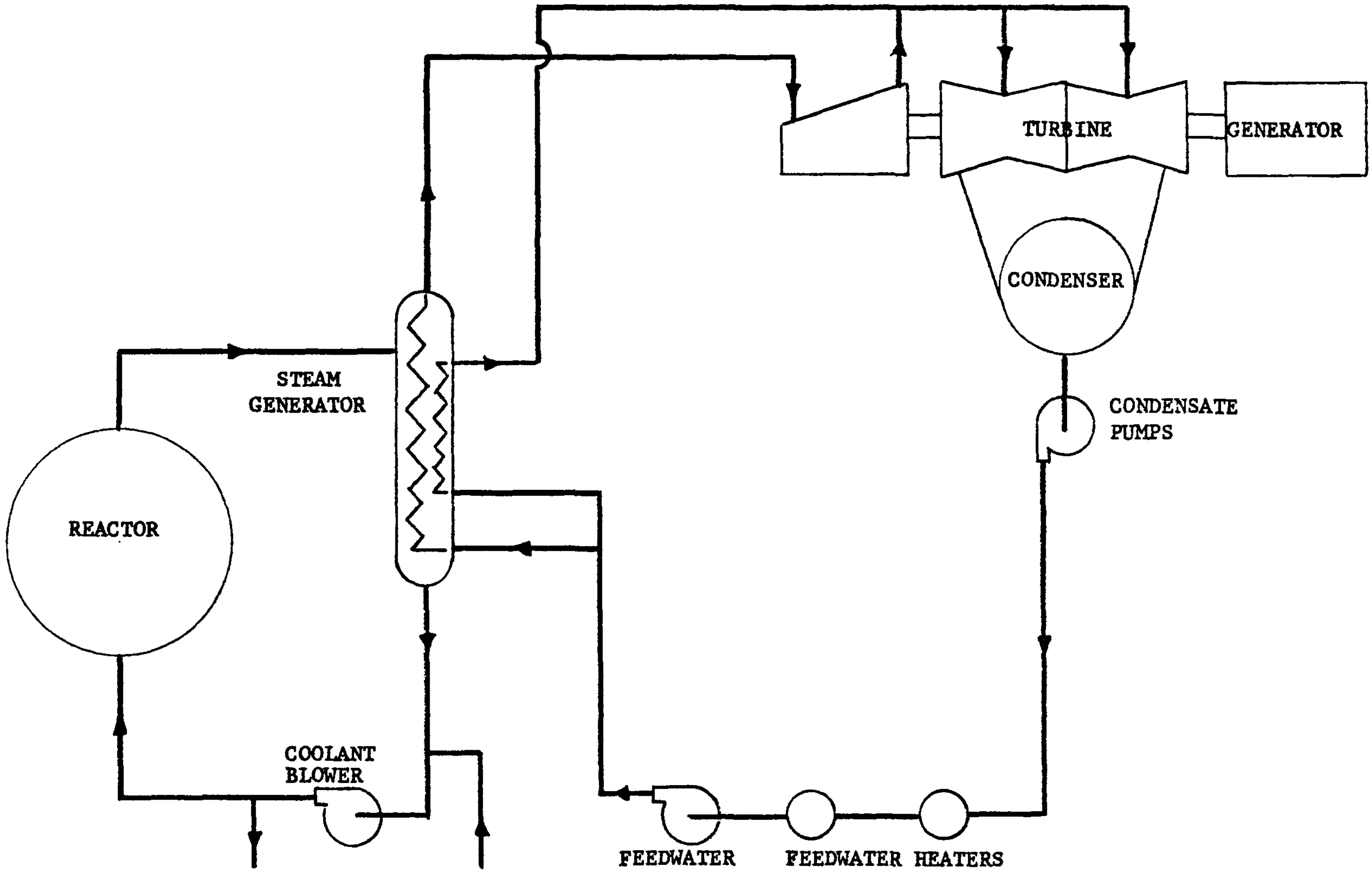
SEPT 1959



SIMPLIFIED FLOW DIAGRAM
HEAVY WATER MODERATED AND COOLED NATURAL URANIUM REACTOR PLANT

SEPT 1959

Figure V-7
SL-1674



SEPT 1959

SIMPLIFIED FLOW DIAGRAM
GAS COOLED - GRAPHITE MODERATED REACTOR PLANT

Figure V-8
SL-1674

VI - FUEL CYCLE COST EVALUATION

A. Introduction

The fuel cycle cost evaluation and normalization has been performed as a companion work to the plant cost normalization and was conducted by Argonne National Laboratory with the assistance of Sargent & Lundy.

The object of the task was to estimate fuel cycle costs based upon a common method of calculation and inclusion of all costs likely to be incurred in actual operation. As a result of the rationalization, almost all of the fuel cycle costs are higher than those presented in the various status reports.

Cost studies have been made for three core sizes to provide cost vs. size curves, with one exception. Sufficient information was not available on the gas cooled-natural uranium design to justify an attempt to cover a range of sizes.

Confidence in the evaluation results parallels the state of development of each concept. The position in time, and amount of accurate information available has also influenced the emphasis on relative quantity of discussion devoted to each type. The state of the art for aqueous homogeneous and gas cooled-natural uranium reactors is limited in the United States. Thus, prognostigations concerning these two concepts are of questionable validity.

1. Adjustments

The changes in total fuel costs occured as a result of adjustments in each of the following items.

a. Direct Costs

(1) Fabrication

Adjustments were made in this item to correspond more closely with actual contract prices for fuel element fabrication rather than "preliminary estimates." The costs used are admittedly subject to variation for any specific application when purchase specifications are submitted for fixed cost bids. There is just as much probability that the purchase price will be higher as there is that it will be lower. Adjusted fabrication costs are shown in Table VI-1.

(2) Depletion

This charge is a function of initial enrichment vs. final enrichment and plutonium production. Enrichment is in turn affected by choice of cladding materials, geometry, moderator to material ratios, design lifetime, reactivity control considerations, etc.

Changes in burnup values have been made for this study. These, affect enrichment and indirectly, fabrication capital interest through changes in inventory time. These values are shown in Table VI-2. Only test data is available to justify selection of values used.

b. Capital Costs

The interest on fuel element fabrication capital while normally listed in operating costs has been included as a separate cost item. The value of fuel material has been taken on a depreciating scale rather than full value for computing the AEC 4% lease charge. It is understood that periodic payments will be made against this charge, making this philosophy valid. The cost of money for the fuel cycle is a function of enrichment, burnup, fabrication costs, inventory, and length of cycle.

This inclusion of interest on fabrication capital has added about 0.25 mill/kw hr for low cost fuel cycles to about 1.0 mill/kw hr for higher cost fuel cycles.

B. Parameters Affecting Costs

Just as in technical areas, optimization requires compromise and detailed study of all parameters simultaneously. The cost estimates in this evaluation have not been optimized for obvious reasons.

The detailed cost estimates prepared for this evaluation use specific values for all areas. These are generalized values. This procedure is necessary to secure a nominal total projected power cost for each of the reactor concepts. Costs for a specifically designed fuel cycle will obviously vary, to some extent at least, from those included here.

1. Fixed

Many factors are included in the makeup of fuel cycle costs. Some of these are fixed such as AEC published charges for enriched uranium, depleted uranium, plutonium credit, use charges, conversion charges and chemical processing charges as tabulated previously in Section IV.

2. Variable

Although single line curves are usually shown for fuel cycle costs, there is not enough actual fabrication and operating experience to justify such action.

The variables which contribute to the possible wide spread in cost estimates include:

a. Physics

(1) Methods of Calculation.
(2) Constants Selected.
(3) Optimism and Judgment of Calculations.

Although sufficient nuclear parameters can be selected on the basis of experience for preliminary estimates, rigorous physics calculations are required for establishment of final values. Considerable time and effort are still required to improve the accuracy of both steps.

b. Design Parameters (not necessarily in order of importance)

(1) Fuel Material and Cladding
(2) Geometry
(3) Moderator/Fuel Ratio
(4) Operating Conditions
(5) Coolant
(6) Maximum Fuel Temperature
(7) Maximum Fuel Element Surface Temperature
(8) Moderator
(9) Core Power Density (kw per liter)
(10) Specific Power (kw/kg U)
(11) Max./Avg. Burnup
(12) Max. Initial Excess Reactivity Required
(13) Peak/Avg. Power Ratio
(14) Burnout Heat Flux
(15) Reactor Coolant Pressure
(16) Control Methods
(17) Plant Operating Conditions
(18) Plant Thermal Efficiency

c. Fabrication and Processing

The total fuel cycle cost period extends from the time UF_6, in the case of enriched fuel, (uranium metal in the case of natural uranium), is released from shipment at Oak Ridge. Tennessee until the time spent fuel in the form of UF_6 is returned for credit. A flow chart of fuel flow is shown in Fig. VI-1. During this period costs are incurred in the following steps:

1. Direct Costs

(a) Fabrication
(b) Shipping and Storage
(c) In-core Residence or Depletion
(d) Post core Cooling and Shipping
(e) Reprocessing

2. Use and Interest Charges

(a) AEC lease charge of 4% per annum on value of fuel rented.
(b) Interest on operating capital required to pay for fabrication costs.

Each of the aforementioned cost factors may be discussed in more detail as follows:

1. Direct Costs

(a) Fabrication

Items included in fabrication cost in this evaluation are:

(i) Conversion of UF_6 to UO_2 or metal (this cost does not apply to natural uranium cores). Although cost of conversion and shipment of UO_2 to fabricator of pellets is included in the gross price used, it may or may not be included in fixed price contracts for domestic cores. Prices for conversion have ranged from $5 to $9 per kilogram per percent enrichment, depending upon quantity.

(2) Labor - fabrication of parts, assembly, inspection, testing, packing for shipment.

(3) Structural Materials - tubing or plate material for cladding fuel; intermediate spacers or separators; end fittings, etc.

At the present time it is not possible to predict that the greater volume of material and labor associated with large cores will result in lower costs than for smaller sizes. Factors involved are:

Batch size or quantity fabricated in each order.

Complexity of larger size assemblies, including material integrity, assembly problems, and inspection and testing procedures.

Inventory time (not a large factor)

The $140.00 per kilogram of contained uranium metal cost of fuel clad in Zircaloy-II is an AEC guaranteed price for Euratom contracts. No commercial fuel has been fabricated for this price to date, in which all the cost items shown here are included.

Some factors which may affect fabrication costs include:

a) Choice of structural materials (the following discussion is qualitative only).

1) Stainless Steel Considerations

a) Low first cost.
b) Fabrication and assembly in air by welding or brazing.
c) Material integrity established.
d) Ample source of vendors.
e) Both seamless and welded tubes available.
f) High neutron capture cross section requires increased enrichment to provide sufficient final reactivity.
g) Increased initial reactivity control requirements add to total power costs and neutron wastage.
h) Increasing evidence of release of corrosion product activity from stainless cladding surface with subsequent transport and deposit throughout primary system may result in maintenance problems. This problem would not be as serious in an integrated unit such as the BWR direct cycle internal circulation and separation type.
i) Good corrosion resistance under most conditions.

2) Zircaloy-II Considerations

a) High first cost.
b) Rate of rejection of fabricated shapes is high, due to imperfections in material Rates of rejection of 33 to 50% are current.
c) Requires fabrication in inert atmosphere with close quality control. (Properly welded joints have excellent integrity).
d) Lack of established brazing techniques make assembly of large, multi-piece units difficult.
e) Low neutron absorption allows minimum enrichment.
f) Satisfactory strength and corrosion resistance in most water environments up to 650 F.
g) Effects of hydriding due to presence of free hydrogen in coolant not clearly established. May influence costs through reduction in length of in-core time.

3) Aluminum

This material does not have satisfactory physical properties and performance characteristics for operation in water reactors at operating conditions of interest. In various forms it is of interest for use in organic cooled reactors for cladding uranium metal alloys or oxide fuel material.

b) Geometry

Every heterogeneous fuel element design is a compromise between the ideal physics requirements and practical mechanical design, fabricating, and operating considerations. These include:

1) Nuclear Requirements

a) Moderator to material ratio: This parameter (for hydrogeneous reactors in particular) affects conversion ratio, stability, initial enrichment, burnout, etc. Low moderator to material ratios, while possibly desirable, require close packing of fuel rods or plates. Use of close packed fuel rods complicates assembly problem with resulting high cost. Close packed rod assemblies, with water channels of practical clearance width between fuel elements, produces aggravated flux peaks. This condition necessitates the reduction of average flux values to prevent damage to fuel during transient conditions.

b) Rod diameter: Large (.5 in. to .8 in.) UO_2 or metal fuel rods serve to:

Reduce volume of structural material to fuel ratio.

Reduce fabrication costs because of fewer total number of rods required.

Reduce number of intermediate spacers or stiffeners required for structural stability in long assemblies.

Increase plutonium production.

Balanced against the desirable features of neutron economy are:

2) Heat Transfer Requirements

Water reactor considerations require use of small diameter rods (.25 in. to .45 in.) for high power density. This feature adds structural material; requires more frequent use of spacers; raises costs. The requirement for good heat transfer from the pellet to clad influences cost to some extent. Opinions vary as to amount of gap tolerable and method of treatment. Some designers require centerless ground pellets with .5 mil clearance while others allow use of unground pellets with 2, 3, or 5 mil clearance. Fortunately, grinding of pellets is not a significant factor in overall cost. However, its cost is additive.

Considerable success has been achieved in manufacture of fuel rods by the "hot-swage" process. Fuel densities of 90-92% have been secured. This is equivalent to the averaged density of a sintered pellet with nominal 1 mil gap type rod. This process promises to reduce fuel fabrication costs appreciably. However, before gaining widespread acceptance, this type must pass conclusive irradiation tests under operating conditions.

3) Mechanical Design and Fabrication Consideration

a) Large Bundle Designs - As higher power reactors are designed which require large cores, the mechanical design and fabricability problems become more acute. Individual fuel bundles containing greater numbers of individual rods become necessary. However, when oxide is used as a fuel, the rod diameter must not increase because of the poor heat transfer characteristics of the UO_2. As total length increases, more frequent spacers or ties between rods are required to overcome distortion caused by non-uniform flux distribution and heating; vibration from flow, etc.

The factors of increased complexity of the larger elements, coupled with greatly increased weight and difficulty of handling, more difficult inspection and testing procedures, etc., do not contribute to reduce the cost for large cores as compared to small, at the present state of the art.

In considering methods of extending fuel burnup to utilize fissionable material at the axial ends of the core, a divided element has been proposed. In this scheme the bottom and top halves can be interchanged to place unburned fuel in the high flux center of the core at the proper time in the cycle. This plan, when coupled with radial rearrangement and low water/to material ratios reduces fuel costs by about 20%. However, the mechanical design is complicated and increased fabrication costs may be expected for this type of element, to offset some of the gain. In addition the cost and time required for handling elements will be increased.

b) Losses - waste, inspection rejects, etc. This item should not exceed about 0.5% total after costs of reprocessing recoverable scrap are included. The 1% figure sometimes quoted cannot be tolerated.

c) Fuel Use Charge to Time of Shipment - normally figured at 4% of original value during this period. This cost is a function of length of time required for fabrication. It is advantageous to reduce this period to the shortest practical length. The fuel use charge cost for the fabrication period may or may not be included in the contract price. The method of handling the fuel use charge and interest on fabrication capital, where these items are separated and not included in lump sum, is discussed later under Use and Interest Charges.

(b) Shipping and Storage - A figure of $3 per kilogram was allowed for transportation of fresh fuel. The actual cost of shipping can only be determined by experience.

Storage - The storage time of fresh fuel at the reactor site must be kept as short as possible to minimize inventory charges. 60 days time was allowed in this evaluation.

(c) In-core Residence or Depletion - In-core residence time is a function of fissile material atom consumption in conjunction with plutonium production and amount consumed in place, etc.

Factors to be considered in securing optimum in-core time include:

1. Material Integrity

a. Cladding Sheath

Stainless steel and Zircaloy-II materials have performed satisfactorily to date. There is no statistical data to prove that these materials will or will not be satisfactory at irradiation levels of 12-18,000 MWD/MT. The search for substitute materials has not been fruitful. Therefore, until proven otherwise, it can only be assumed that the high level of irradiation can be achieved.

b. Fuel Stability

As in the case of cladding material, there is no statistical evidence on performance of UO_2 at burnup levels of 9-15,000 MWD/MT. Samples have been irradiated successfully to rates of 50,000 MWD/MT, in in-pile test loops only. However, results have been sufficiently favorable to justify the placing of guarantees of burnups of 10,000 MWD/MT, average. Present indications are that reactivity lifetime will be a more limiting factor than irradiation damage to UO_2 fuel material. Uranium metal alloys have performed as predicted. Temperature and burnup limitations of metal fuels prevent serious consideration for economical fuel cycles.

2. Power Density (kw/liter)

Stability considerations place an upper limit on the core power density. Optimum power density has been found to be considerably below maximum. Although core size variation directly affects pressure vessel size and surrounding structure, capital cost differentials are not great between maximum and optimum power density sizes.

3. Specific Power (tMW/MT)

Working the fuel in the core at maximum efficiency permits operation with a minimum inventory. This arrangement is satisfactory if geometry does not result in excess neutron leakage which makes increased enrichment necessary.

4. Feasibility Limitations

a. Reactivity Lifetime

Variable parameters which affect reactivity lifetime and not previously mentioned, include:

1. Length to diameter ratio of core.
2. Moderator density and variations.
3. Fuel management program.

The fuel management parameter offers several methods of extending reactivity lifetime for a given enrichment, such as:

a) Uniform radial and axial enrichment with periodic radial shifting through predetermined zones. The benefits of outside to center flow core arrangement with self flattening characteristics must be weighed against center to outside flow with accompanying high flux and power producing region in center of core. Radial shifting only does not utilize fuel at extreme ends of core.

b) Zone core loadings with different enrichment for each of 2 or 3 radial zones. Normally the zones decrease progressively from outer to center to provide self flattening power distribution. The complete core is changed in this concept and remains in place for 2 or 3 years per cycle. This arrangement places a higher requirement on fuel element integrity but requires less frequent plant shutdowns for reloading.

Fuel fabrication costs may be slightly higher due to bookeeping and handling problems in the vendor's shop.

Fuel at ends of elements is not used efficiently in this arrangement.

c) Radially zoned core as in (a) above with variation in enrichment over length of element to secure a more desirable axial flux distribution. While this approach will provide more efficient use of available fuel, fabrication costs will be increased again due to complex handling and bookkeeping requirements. One loading per cycle as in (b).

d) Uniform enrichment in divided fuel elements arranged in radial zones. Top and bottom halves of a fuel assembly may be interchanged at a predetermined stage in cycle to secure burnup of normally unused fuel at axial extremities. The merits of this scheme with problems of making fuel elements in halves and introduction of structural material in the center of the core must be weighed against problems of (c). In addition this scheme requires more frequent fuel changes.

e) Uniform enrichment in single batch per cycle loading arrangement. This method has some merit for small, high leakage cores but is not favored for large units.

Schemes (c) and (d) offer promise, when coupled with other optimized parameters listed above, to extend reactivity lifetime approximately 20%.

b. Enrichment

1. Initial enrichment varies considerably with cladding material, moderator/material ratios, and methods of making physics calculations. Variations in enrichment for a given loading requirement may be .3 to 1.0%.

2. High initial enrichment has some adverse effect upon plutonium production/kg U.

3. High initial enrichment requires excess poison to hold down reactivity at the start of a fuel cycle. This poison may be in the form of strips discreetly located throughout the core, chemical dispersed in the coolant, burnable poison dispersed in the fuel or cladding, or in control rods. All methods contribute an incremental cost which must be substracted from the gain of increased fuel in-core lifetime.

(d) Post-core Cooling and Shipping - Length of decay or cool down of irradiated fuel elements is governed by the cost of shielding and cooling in shipment. The cost of the shielded casks and weight must be compared to use charges incurred during this period. One hundred days storage is considered adequate at the present time.

Shipping of Irradiated Fuel - A price of $12.45 per kilogram has been established for this series of studies. This value may vary in actual practice. High specific power cores will obviously have a cost advantage in this area.

(e) Reprocessing - Reprocessing costs are given in the table of AEC schedule of charges listed in Section IV.

2. Depletion, Use, and Interest Charges -

a. Fuel Material Use and Depletion

Factors which affect this portion of cost are:

1. Burnup of fissile material and resulting depletion cost. This item is affected by:

   (a) Initial enrichment requirement due to neutron loss ratio, core poisons, and self poisoning effects due to fission product buildup over core lifetime. Values for each of these factors are subject to wide variations at the present time.

2. Percent of power from fertile material to extend core lifetime. This factor is a function of conversion ratio due to:

   (a) Initial enrichment.
   (b) Geometry L/D ratio; moderator/material ratio; rod diameter and spacing; etc.

3. Fuel management methods - core life can be extended by proper combination of (1) and (2) above with proper fuel management program.

b. Use and Interest Charges

1. Use Charge

   The AEC fuel rental charge of 4% per year is used in all calculations, and is paid on the following values for each stage:

(a) UF_6 purchase to installation in reactor	Full value
(b) In-core residence time	Average value
(c) After-core to return to AEC as UF_6	Depleted value

   Note: The use charges for material during fabrication is included in the fabrication costs and is not accounted for separately in this study. However, this condition may not always apply in actual contracts. This number, while not significant for lower enrichment cores, becomes an appreciable factor for high enrichment, long fabrication time cores.

2. Interest on Fabrication Capital

   (a) Pre-core period - (time for fabrication, shipping, and storing) full cost at 6% per year
   (b) In-core period (full depreciation at end of time) 50% of full cost at 6% per year

As in the case of use charges, some saving can be affected by decreasing pre-core time by improving fabrication techniques. High specific power will reduce the amount of fuel inventory and resulting interest charges. This gain will be offset somewhat by more frequently incurred direct fabrication costs of the higher throughput rate. For the purposes of this study, the time required to fabricate fuel has been assumed to vary with the batch size only, as shown in Fig. VI-2. A pre-core shipping and storage time of 90 days has been used for all cases. The time required to cool and ship spent fuel has been assumed to be 120 days.

C. Concept Cost Estimates

1. General Comments

As stated previously, fuel cost estimates vary widely due to a number of factors. The chief factor is lack of valid operating experience data. This situation cannot be remedied before about 1965 Another series of factors include:

a. Fabrication cost variation
b. Methods of preparing core calculations
c. Judgment of design personnel

"Back-of-the-envelope" calculations and generalized curves can present a "ballpark" picture only. Rigorous calculations, taking into account definite values for a specific case may reveal answers considerably outside original expectations.

Certain nuclear and economic parameters differ from values proposed in the individual status reports. All cycles have been treated on a comparable basis. These values are listed in the tabulation given in each specific type cost detail breakdown. These parameters are established, as stated previously, on the basis of immediate feasibility without necessity for additional basic research and development. Engineering development will always be required to some degree and will be considered as part of the engineering and design cost item.

The uniformly enriched, partial loaded or "batch" type fuel management scheme with movement of portions of the core through zones is gaining favor. This method promises to extend core lifetime and reduce fuel cycle costs. The periodic shutdowns required for fuel shuffling must be of short duration when not coupled with regular maintenance outages. Otherwise it may become difficult to achieve the 0.8 load factor considered necessary for nuclear plant operation

All types require extensive development if necessary cost reduction are to be achieved.

2. Comments on Various Concepts

At the present time, in general terms, there does not appear to be any significant difference in fuel cycle costs between the pressurized and boiling water reactor concepts. Their current lowest cost position is due primarily to their ability to use available materials to advantage, and to the amount of past development effort. Future cost reductions may be at a slow rate and difficult to achieve.

The value and practicability of superheating steam from a direct cycle boiling water reactor either in an integral core or in a separate reactor cannot be assessed at this time.

The organic moderated fuel cycle costs are relatively high because of temperature and heat transfer limitations. Better materials and increased heat transfer rates must be developed or this concept can never achieve a competitive position. Conversely, the successful development of suitable fuel and clad materials and methods of operating with nucleate boiling in the core may place it in the most competitive position.

The sodium graphite fuel cycle costs are at such a high level at the present time that there is little hope of reaching a competitive position with present materials.

The natural uranium - D_2O and natural uranium - gas cooled fuel cycles, because of disproportionate fabrication costs and present low burnup are not competitive with slightly enriched systems. However, if increased burnup is proved to be feasible the competitive position of the natural uranium fuel cycle will improve.

The fast breeder sodium cooled reactor fuel cycle position is dependent upon reduction of fabrication costs, achievement of satisfactory breeding ratios, and development of fuel materials. Additional operating experience must be gained before it is possible to determine if this concept can ever become competitive.

In event costs cannot be reduced, it will be necessary to re-examine the coupling of power and plutonium production in one concept.

The aqueous homogeneous reactors are not developed to the stage where valid predictions can be made of their potential worth.

Detailed breakdowns of fuel cycle estimates for the various concepts are given in the following Tables and Figures.

Table VI-3 -Summary of Annual Fuel Costs - Pressurized Water Reactors.

Figure VI-3 -Fuel Costs - Pressurized Water Reactors.

Table VI-4 -Summary of Annual Fuel Costs - Boiling Water Reactors.

Figure VI-4 -Fuel Costs - Boiling Water Reactors.

Table VI-5 -Summary of Annual Fuel Costs - Organic Cooled Reactors.

Figure VI-5 -Fuel Costs - Organic Cooled Reactors.

Table VI-6 -Summary of Annual Fuel Costs - Sodium Graphite Reactors.

Figure VI-6 -Fuel Costs - Sodium Graphite Reactors.

Table VI-7 -Summary of Annual Fuel Costs - Fast Breeder Reactors.

Figure VI-7 -Fuel Costs - Fast Breeder Reactors.

ADJUSTED FUEL FABRICATION COSTS

Type of Reactor	Contractor's Status Report $/kg U	AEC Specified $/kg U
1. Pressurized Water	$96.00 to $172.00	$110.00
2. Boiling Water	$140.00	$140.00
3. Organic Moderated	50.00	60.00
4. Sodium Graphite	50.00 to 70.00	80.00
5. Heavy Water-Natural U	13.00 to 22.00	50.00
6. Gas Cooled-Natural U	-	-
7. Aqueous Homogeneous	-	-
8. Fast Breeder Seed	-	480.00
9. Fast Breeder Blanket	-	45.00

FUEL BURNUP

Type of Reactor	Burnup MWD/MT: Contractor's Status Report	Burnup MWD/MT: AEC Specified
1. Pressurized Water	14,700	13,000
2. Boiling Water	10,000	11,000
3. Organic Moderated	4,500	4,500
4. Sodium Graphite	3,000	3,000 (11,000)
5. Heavy Water-Natural U	3580-3960	3,850
6. Gas Cooled-Natural U	-	3,000
7. Fast Breeder	2 a/o	15,900 (1.5 a/o)

SUMMARY OF ANNUAL FUEL COSTS
(Pressurized Water Reactors)

	Units			
1. Gross Power[a]	MW(e)	22	147	249
2. Net Power	MW(e)	20	135	231
3. Reactor Power	MW(t)	85	555	925
4. Annual Generation[b]	kwh	0.140×10^9	0.945×10^9	1.61×10^9
5. Specific Power	MW(t)/MTU	12.7	16.9	16.6
6. Core Loading	MTU	6.68	32.76	55.38
7. Total Fuel Inventory[c]	MTU	9.06	55.2	85.5
	Cores	1.355	1.68	1.55
8. Type Fuel		UO_2	UO_2	UO_2
9. Type Clad		SS	SS	SS
10. Burnup[d]	MWD/MTU	13,000	13,000	13,000
11. Initial Enrichment	%	3.3	3.1	3.2
12. Final Enrichment	%	2.05	2.1	2.22
13. Plutonium Production	gPu/KgU	5.0	6.5	7.0
14. Fuel Management		100%	50%	25%
15. Fabrication Unit Cost[e]	$/KgU	110	110	110
16. Direct Costs				
a. Fabrication	Mills/kwh	1.51	1.45	1.43
b. Shipping	Mills/kwh	0.21	0.20	0.20
c. Depletion	Mills/kwh	2.82	2.13	2.05
d. Reprocessing	Mills/kwh	0.49	0.38	0.38
e. Plutonium Credit	Mills/kwh	0.70	0.89	0.94
f. AEC Lease Charge	Mills/kwh	0.73	0.55	0.57
17. Indirect Costs				
a. Use of Fabrication Capital	Mills/kwh	0.23	0.20	0.19
18. Total Fuel Costs	Mills/kwh	5.29	4.02	3.88

Pressurized Water Footnotes

a. Plant size from status report.

b. Annual power generation based on .8 P.F.

c. Total inventory is sensitive to fabrication, storage, in-core and reprocessing time; fuel management, and batch size. This combination of variables has significant effect on total fuel cycle cost.

d. 13,000 MWD/MT burnup value represents limit of confidence of fuel life due to lack of operating experience.

e. $110 per kilogram contained uranium metal used for stainless clad fuel is an average value of several cost "estimates." Although this is an AEC guaranteed price for Euratom Contracts, there is no assurance that a domestic core can be purchased for this price, once the specifications are down in writing.

The complexity of mechanical design coupled with rigidity of specifications has a severe impact upon the fabrication cost.

SUMMARY OF ANNUAL FUEL COSTS
(Boiling Water Reactors)

	Units			
1. Gross Power[a]	MW(e)	20.0	155	320
2. Net Power	MW(e)	18.5	146	306
3. Reactor Power	MW(t)	64.8	508	980
4. Annual Generation[b]	kwh	$0.1295x10^9$	$1.023x10^9$	$2.144x10^9$
5. Specific Power	MW(t)/MTU	12.25	12.2	15.3
6. Core Loading	MTU	5.326	41.4	56.377
7. Total Fuel Inventory[c]	MTU	6.88	64.8	94.0
	Cores	1.29	1.56	1.67
8. Type Fuel		UO_2	UO_2	UO_2
9. Type Clad		Zr-2	Zr-2	Zr-2
10. Burnup[d]	MWD/MTU	11,000	11,000	11,000
11. Initial Enrichment	%	2.20	1.90	1.70
12. Final Enrichment	%	1.28	0.98	0.80
13. Plutonium Production	$_gPu/K_gU$	5.0	5.3	5.45
14. Fuel Management		100% batch	50% batch	25% batch
15. Fabrication Unit Cost[e]	$/K$_g$U	140	140	140
16. Direct Costs				
a. Fabrication	Mills/kwh	1.86	1.85	1.71
b. Shipping	Mills/kwh	0.23	0.20	0.19
c. Depletion	Mills/kwh	1.87	1.78	1.56
d. Reprocessing	Mills/kwh	0.58	0.50	0.41
e. Plutonium Credit	Mills/kwh	0.80	0.84	0.79
f. AEC Lease Charge	Mills/kwh	0.38	0.28	0.15
17. Indirect Costs				
a. Use of Fabrication Capital	Mills/kwh	0.26	0.30	0.21
18. Total Fuel Costs	Mills/kwh	4.38	4.07	3.44

Boiling Water Footnotes

a. Plant size choice from status report.

b. Annual power generation based on .8 P.F.

c. Total fuel inventory is sensitive to fabrication, storage, in-core and reprocessing time; fuel management and batch size. This combination of variables has significant effect on total fuel cycle cost.

d. 11,000 MWD/MT burnup value represents limit of confidence of fuel life, due to lack of operating experience.

e. $140.00/kilogram of contained uranium metal used for zircaloy clad fuel is the AEC guaranteed price for Euratom Contracts. There is no assurance that a domestic core for a particular concept can be purchased for this price. Rigidity of specifications and complexity of fuel element have severe effect upon final cost.

SUMMARY OF ANNUAL FUEL COSTS
(Organic Cooled Reactors)

		Units			
1.	Gross Power[a]	MW(e)	25	183	365
2.	Net Power	MW(e)	22.6	174	350
3.	Reactor Power	MW(t)	80	600	1180
4.	Annual Generation[b]	kwh	0.158×10^9	1.22×10^9	2.44×10^9
5.	Specific Power	MW(t)/MTU	6.2	6.2	6.2
6.	Core Loading	MTU	12.9	96.5	191
7.	Total Fuel Inventory[c]	MTU	20.31	178.04	350.68
		Cores	1.57	1.85	1.84
8.	Type Fuel[d]		U-3.5 Mo	U-3.5 Mo	U-3.5 Mo
9.	Type Clad		Al	Al	Al
10.	Burnup[e]	MWD/MTU	4500	4500	4500
11.	Initial Enrichment	%	1.90	1.72	1.72
12.	Final Enrichment	%	1.28	1.14	1.14
13.	Plutonium Production	gPu/KgU	2.55	2.55	2.55
14.	Fuel Management		100% batch	50% batch	25% batch
15.	Fabrication Unit Cost	$/KgU	60	60	60
16.	Direct Costs				
	a. Fabrication	Mills/kwh	1.98	1.93	1.87
	b. Shipping	Mills/kwh	.51	.49	.48
	c. Depletion	Mills/kwh	3.09	2.71	2.61
	d. Processing	Mills/kwh	1.00	0.75	0.74
	e. Plutonium Credit	Mills/kwh	0.87	0.84	0.83
	f. AEC Lease Charge	Mills/kwh	.67	.57	.56
17.	Indirect Costs				
	a. Use of Fabrication Capital	Mills/kwh	.26	.31	.30
18.	Total Fuel Costs	Mills/kwh	6.64	5.92	5.73

Organic Moderated Footnotes

a. Plant size from status report.

b. Annual power generation based on .8 P.F.

c. Total fuel inventory is sensitive to fabrication, storage, in-core, and reprocessing time; fuel management, and batch size. This combination of variables has significant effect on total fuel cycle cost.

d. The finned aluminum clad uranium-moly alloy fuel element in either flat plate or tubular shape represents the extent of current organic moderated and cooled reactor technology. This type element has not been contemplated for use in core sizes above 80-100 MW(t) output. Above this size the use of UO_2 clad in aluminum powdered material with nucleate boiling in the channels has been proposed to secure low power costs. Consequently the fuel cycle, and also capital,costs as presented here have no possible chance of becoming competitive. This is a case in point to illustrate the necessity for achieving objectives of research and development programs.

e. 4500 MWD/MT burnup value represents limit of confidence on average fuel life, due to lack of operating experience.

SUMMARY OF ANNUAL FUEL COSTS
(Sodium Graphite Reactors)

	Units				
1. Gross Power[a]	MW(e)	80.5	165	317	315
2. Net Power	MW(e)	76	156	300	300
3. Reactor Power	MW(t)	240	480	884	884
4. Annual Generation[b]	kwh	0.53×10^9	1.09×10^9	2.1×10^9	2.1×10^9
5. Specific Power	MW(t)MTU	7.3	11.0	17.2	13.5
6. Core Loading	MTU	33	43.5	51.6	65.3
7. Total Fuel Inventory[c]	MTU	68.37	120	200	-
	Cores	2.07	2.76	3.88	-
8. Type Fuel		U-10 Mo	U-10 Mo	U-10 Mo	U-10 Mo
9. Type Clad		SS	SS	SS	SS
10. Burnup[d]	MWD/MTU	3,000	3,000	3,000	11,000
11. Initial Enrichment	%	2.81	2.9	3.11	3.84
12. Final Enrichment	%	2.44	2.5	2.78	2.64
13. Plutonium Production	gPu/KgU	1.73	1.7	1.70	4.55
14. Fuel Management		50% batch	50% batch	50% batch	20% batch
15. Fabrication Unit Cost	$/KgU	80	80	80	102
16. Direct Costs					
a. Fabrication	Mills/kwh	3.54	3.45	3.27	1.14
b. Shipping	Mills/kwh	0.68	0.67	0.63	0.17
c. Depletion	Mills/kwh	2.63	2.89	2.33	2.17
d. Processing	Mills/kwh	1.39	1.27	1.15	0.35
e. Plutonium Credit	Mills/kwh	0.92	0.88	0.83	0.52
f. AEC Lease Charge	Mills/kwh	1.19	0.95	0.83	0.69
17. Indirect Costs					
a. Use of Fabrication Capital	Mills/kwh	0.36	0.32	0.30	0.12
18. Total Fuel Costs	Mills/kwh	8.87	8.67	7.68	4.12

Sodium Graphite Footnotes

a. Plant size from status report.

b. Annual power generation based on .8 P.F.

c. Total fuel inventory is sensitive to fabrication, storage, in-core, and reprocessing time; fuel management, and batch size.

d. This material has burnup limited to 3000 MWD/MT due to irradiation damage, which is accelerated because of operation at high temperature. Due to the dispreportionate fabrication cost factor in short lived fuel, this type has little potential attractiveness for development. However, it is the fuel of current technology.

SUMMARY OF ANNUAL FUEL COSTS
(Fast Breeder Reactors)

	Units		
1. Gross Power	MW(e)	153	347
2. Net Power	MW(e)	143	324
3. Reactor Power	MW(t)	430	900
4. Annual Generation x 10^9	kwh	1.002	2.270
5. Specific Power (core at 90%)	MW(t)/MTU	51.46	60.23
6. Loading	MTU	58.694	73.398
7. Total Fuel Inventory	MTU	25.0	58.5
	Cores	3.33	4.35
8. Type Fuel		U-10% Mo	U-10% Mo
9. Type Clad		Zr	Zr
10. Burnup[a]	MWD/MTU	15,900	15,900
11. Initial Enrichment (Core)	%	21	21
12. Final Enrichment (Core)	%	19.55	19.55
13. Plutonium Production	Pu/Yr. (Kg)	138.5	269.2
14. Fuel Management (Core and Axial and Radial Blk. yr.)		.0384	.0384
15. Fabrication Unit Costs, $/kgU			
a. Core		$480	$480
b. Axial and Radial Blanket		$45	$45
16. Direct Costs			
a. Fabrication	Mills/kwh	3.95	3.63
b. Shipping	Mills/kwh	0.29	0.31
c. Depletion	Mills/kwh	2.19	1.96
d. Processing	Mills/kwh	1.54	1.35
e. Plutonium Credit	Mills/kwh	1.66	1.42
f. AEC Lease Charge	Mills/kwh	1.00	0.91
17. Indirect Costs			
a. Use of Fabrication Capital	Mills/kwh	0.23	0.24
18. Total Fuel Costs	Mills/kwh	7.54	6.98

Fast Sodium Cooled Footnotes

For \$480	Cost due to complexity of finely divided fuel pins and assembly problems.
For \$45	Low cost due to large diameter fuel rods and uncomplicated assembly.
a.	Converted to MWD/MTU for comparison only.

SUMMARY OF ANNUAL FUEL COSTS
(Aqueous Homogeneous Reactors)

	Units	PAR-150	PAR-315	AHR
1. Net Power	MW(e)	150	315	316
2. Annual Generation	kwh	1.051×10^9	2.208×10^9	2.215×10^9
3. Type Fuel		ThO_2-UO_2	ThO_2-UO_2	$UO_2(SO_4)$
4. Fuel Management		Cont.	Cont.	Cont.
5. Direct Costs				
a. Depletion(net)[1]	Mills/kwh	0.49	0.32	-0.22
b. Reprocessing[2]	Mills/kwh	1.49	1.05	1.94
c. AEC Lease Charge	Mills/kwh	0.26	0.20	0.24
d. Thorium Inventory[3]	Mills/kwh	0.03	0.06	0.16
6. Total Fuel Cycle Costs	Mills/kwh	2.27	1.63	2.12

These costs are based on conceptual designs as follows:

PAR-150. Single-region, thorium oxide-uranium oxide slurry reactor, 150MW(e) net, with a single turbine-generator. Design study by Westinghouse-Pennsylvania Power and Light.

PAR-315. A single reactor, 315 MW(e) net, scaled-up by Westinghouse from the PAR-150. Single turbine-generator.

AHR-. A three-reactor station, 316MW(e) net for the station. Each reactor is a two-region breader, with uranyl sulfate solution as fuel and a thorium oxide slurry blanket. Single turbine-generator for the station.

Footnotes

1. Includes cost of burnup and credit for plutonium.
2. Reprocessing costs include capital, operating, and maintenance costs of on-site reprocessing plant. Plants are valued at $\$5.4 \times 10^6$ for the 150 MW(e) plant, $\$8.0 \times 10^6$ for the 315 MW(e) plant, and $\$14.8 \times 10^6$ for the 316 MW(e) plant.
3. Capital costs of thorium inventory are evaluated at 12% of the total inventory.

SUMMARY OF ANNUAL FUEL COSTS
(Heavy Water Reactors)

	Units			
1. Gross Power[a]	MW(e)	106	212	318
2. Net Power	MW(e)	100	200	300
3. Reactor Power	MW(t)	435	870	1304
4. Annual Generation[b]	kwh	701×10^9	1.402×10^9	2.103×10^9
5. Specific Power	MW(t)/MTU	16.4	32.0	40.8
6. Core Loading	MTU	26.5	27.2	32.0
7. Total Fuel Inventory[c]	MTU	84.19	143.9	215.7
	Cores	3.177	5.29	6.74
8. Type Fuel		U-Zr	U-Zr	U-Zr
9. Type Clad		Zr-2	Zr-2	Zr-2
10. Burnup[d]	MWD/MTU	3850	3850	3850
11. Initial Enrichment	%	0.71	0.71	0.71
12. Final Enrichment	%	0.46	0.47	0.47
13. Plutonium Production	gPu/KgU	2.4	2.5	2.7
14. Fuel Management		100% batch	100% batch	100% batch
15. Fabrication Unit Cost[e]	$/KgU	$50.00	$50.00	$50.00
16. Direct Costs				
a. Fabrication	Mills/kwh	2.36	2.37	2.36
b. Shipping	Mills/kwh	73	.73	.72
c. Depletion	Mills/kwh	1.29	1.24	1 24
d. Reprocessing	Mills/kwh	1.20	1.19	1.16
e. Plutonium Credit	Mills/kwh	1.36	1.41	1.53
f. AEC Lease Charge	Mills/kwh	.07	.05	.05
17. Indirect Costs				
a. Use of Fabrication Capital	Mills/kwh	.28	.23	.22
18. Total Fuel Costs	Mills/kwh	4.57	4.40	4.22

Heavy Water Footnotes

a. Plant size from status report. Small sizes obviously not competitive in this concept.

b. Annual power generation based on .8 P.F.

c. Total inventory is sensitive to fabrication, storage, in-core, and reprocessing time; fuel management, and batch size. Both inventory time and fabrication costs have severe impact upon over-all fuel cycle costs due to short burnup lifetime and low fuel depletion costs.

d. 3850 MWD/MT burnup limiting factor is loss of reactivity.

e. $50.00 per kilogram contained natural uranium is considered to be a possible fabrication cost. However, the utilization of this type of fuel rod at the specified operating temperature may not be considered current technology in a true sense. In addition, the probability is remote that a metallic fuel element will be commercially acceptable for use in high temperature water. In event that metal elements are not used, the prevailing fabrication prices for UO_2-Zircaloy will apply. Short lived fuel elements can not be made competitive if fabrication costs are $140.00 per kilogram.

SUMMARY OF ANNUAL FUEL COSTS
(Gas Cooled Reactors)

	Units		Possible Breakdown of Fuel Cost
1. Gross Power[a]	MW(e)		
2. Net Power	MW(e)	230	
3. Reactor Power	MW(t)	966	
4. Annual Generation[b]	kwh	$1.61x10^9$	
5. Specific Power	MW(t)/MTU	2.6	
6. Core Loading	MTU	370	
7. Total Fuel Inventory[c]	MTU	501	
	Cores	1.37	
8. Type Fuel		U metal	
9. Type Clad		Magnox	
10. Burnup[d]	MWD/MTU	3,000	
11. Initial Enrichment	%	Natural	
12. Final Enrichment	%	Depleted	
13. Plutonium Production	gPu/KgU	2.01	
14. Fuel Management		25% batch	
15. Complete Fuel Cycle Cost Except Shipping[e]	$/KgU Mills/kwh	$50 2.92	
16. Direct Costs			
a. Fabrication	Mills/kwh		0.89
b. Shipping, @ $9/KgU	Mills/kwh	0.53	0.53
c. Depletion	Mills/kwh		1.75
d. Processing	Mills/kwh		1.15
e. Plutonium Credit	Mills/kwh		1.41
f. Charge for Privately Owned Inventory, @ 12%	Mills/kwh		0.45
17. Indirect Costs			
a. Use of Fabrication Capital	Mills/kwh		0.09
18. Total Fuel Costs	Mills/kwh	3.45	3.45

Gas Cooled-Natural Uranium Footnotes

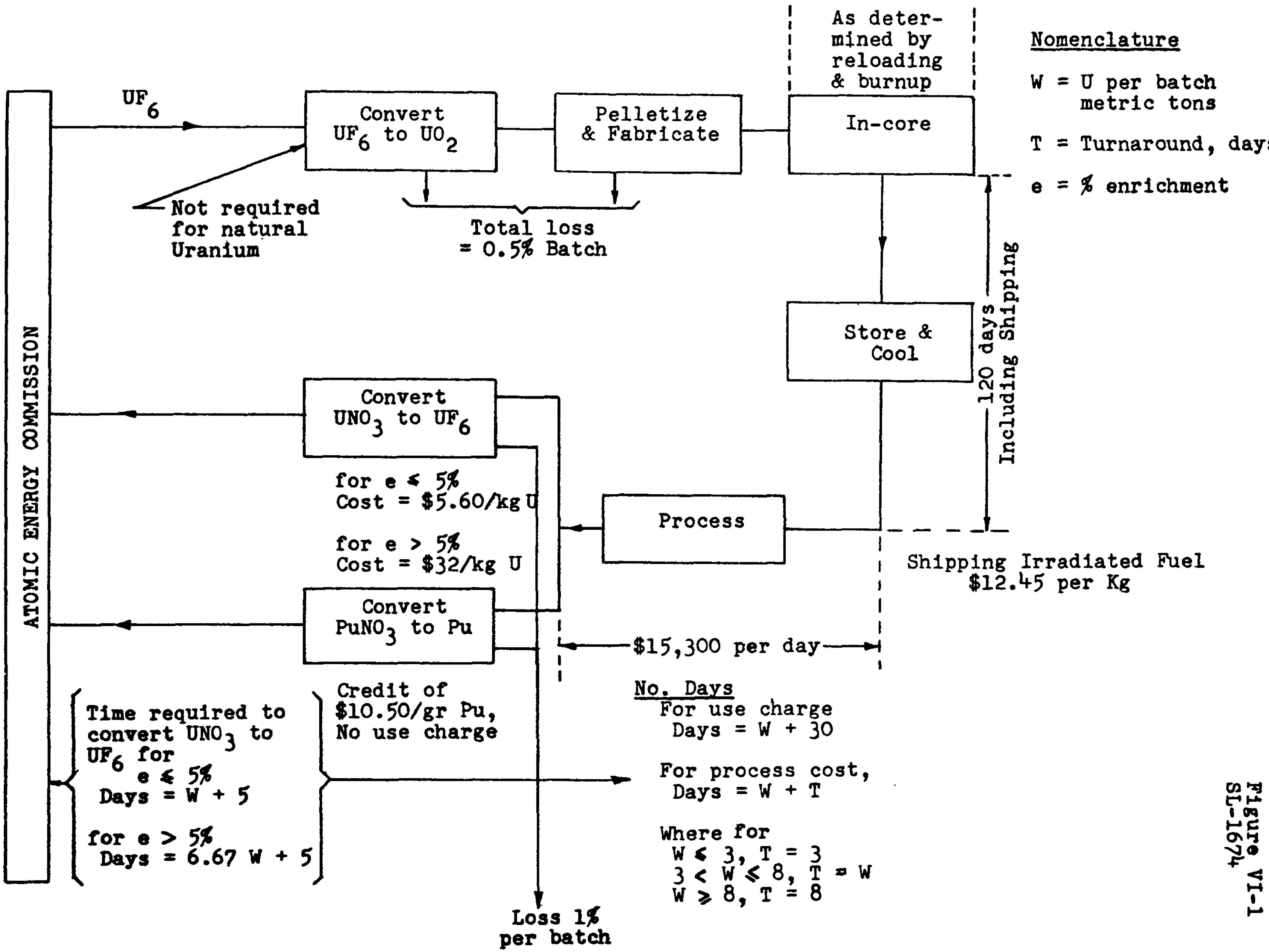
a. Only one plant size available for actual cost comparison (Hinkley Point) other sizes used are interpolations.

b. Annual power generation based on .8 P.F.

c. Total inventory is sensitive to fabrication, storage, in-core, and reprocessing time; fuel management, and batch size. Continuous refueling is a necessity for this concept. Due to short lifetime of natural uranium, out-of-core inventory capital charges and fabrication costs and capital charges are major factors in total fuel costs.

d. 3,000 MWD/MT burnup limiting factor is loss of reactivity.

e. $50.00 per kilogram of contained natural uranium metal in "magnox" cost is derived by interpolation of English price data with adjustments for labor and other cost differentials.



FUEL CYCLE FLOW CHART

Figure VI-1
SL-1674

FUEL FABRICATION TIME

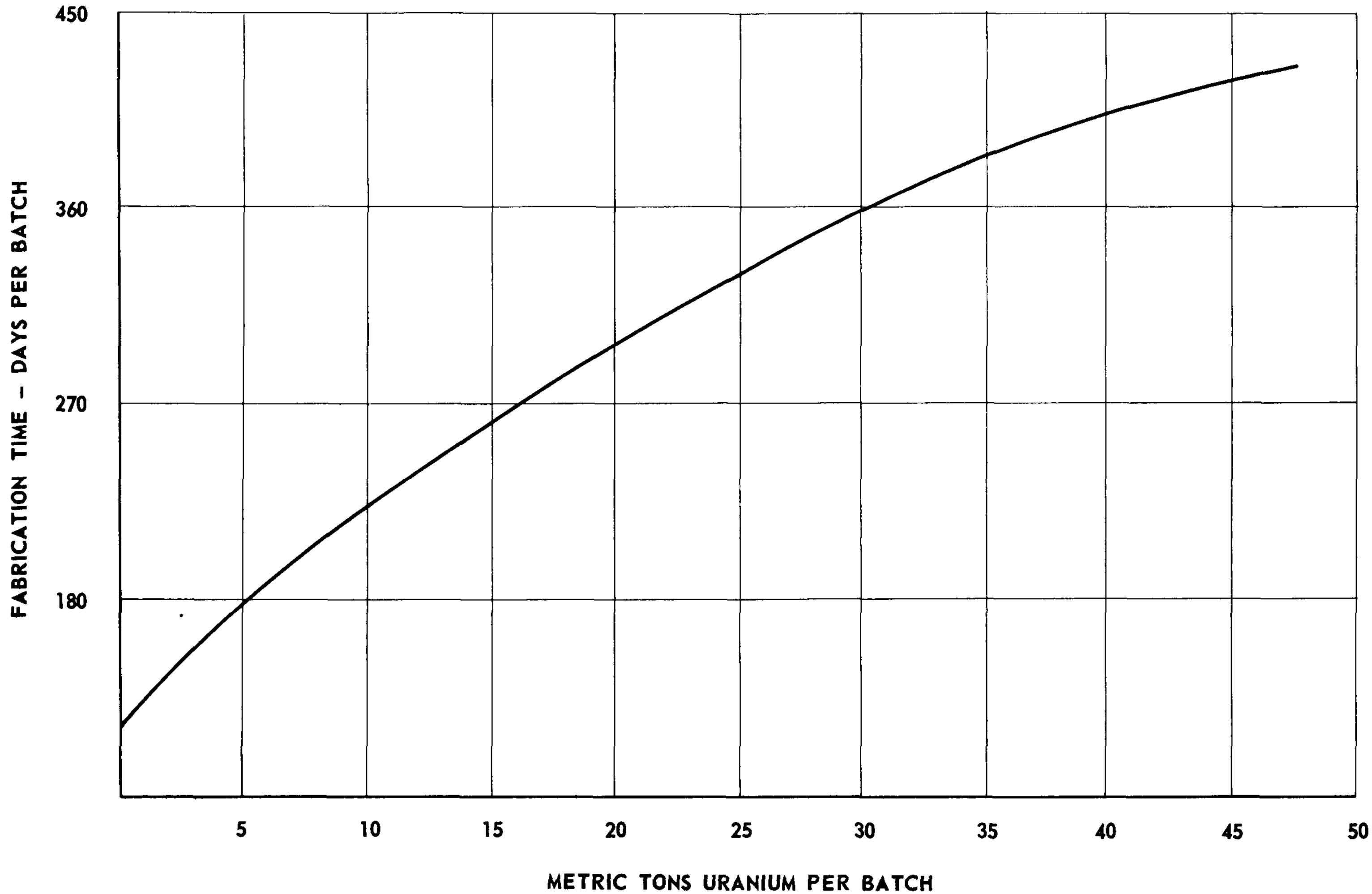


Figure VI-2
SL-1674

FUEL COSTS – PRESSURIZED WATER REACTORS

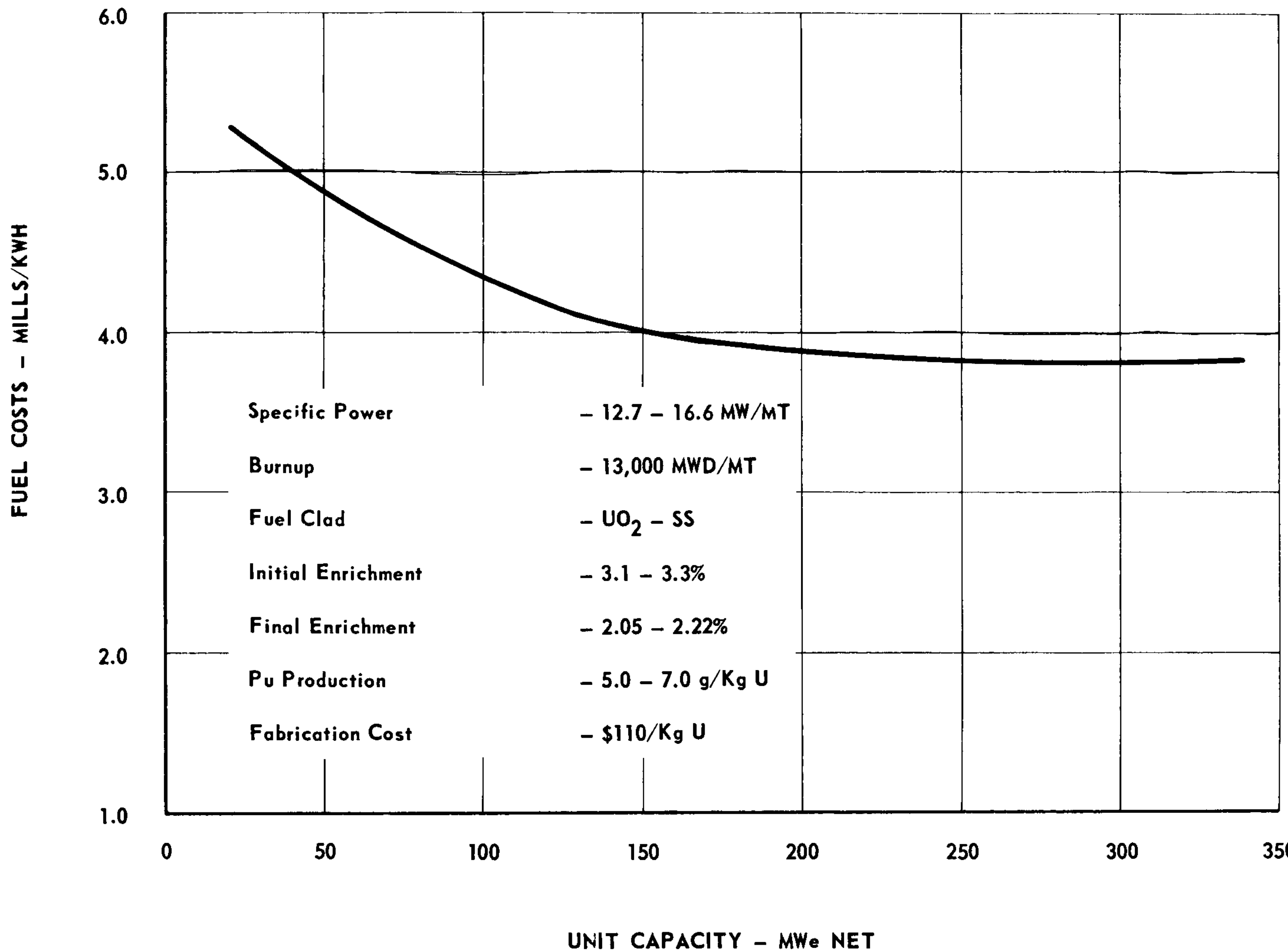


Figure VI-3
SL-1674

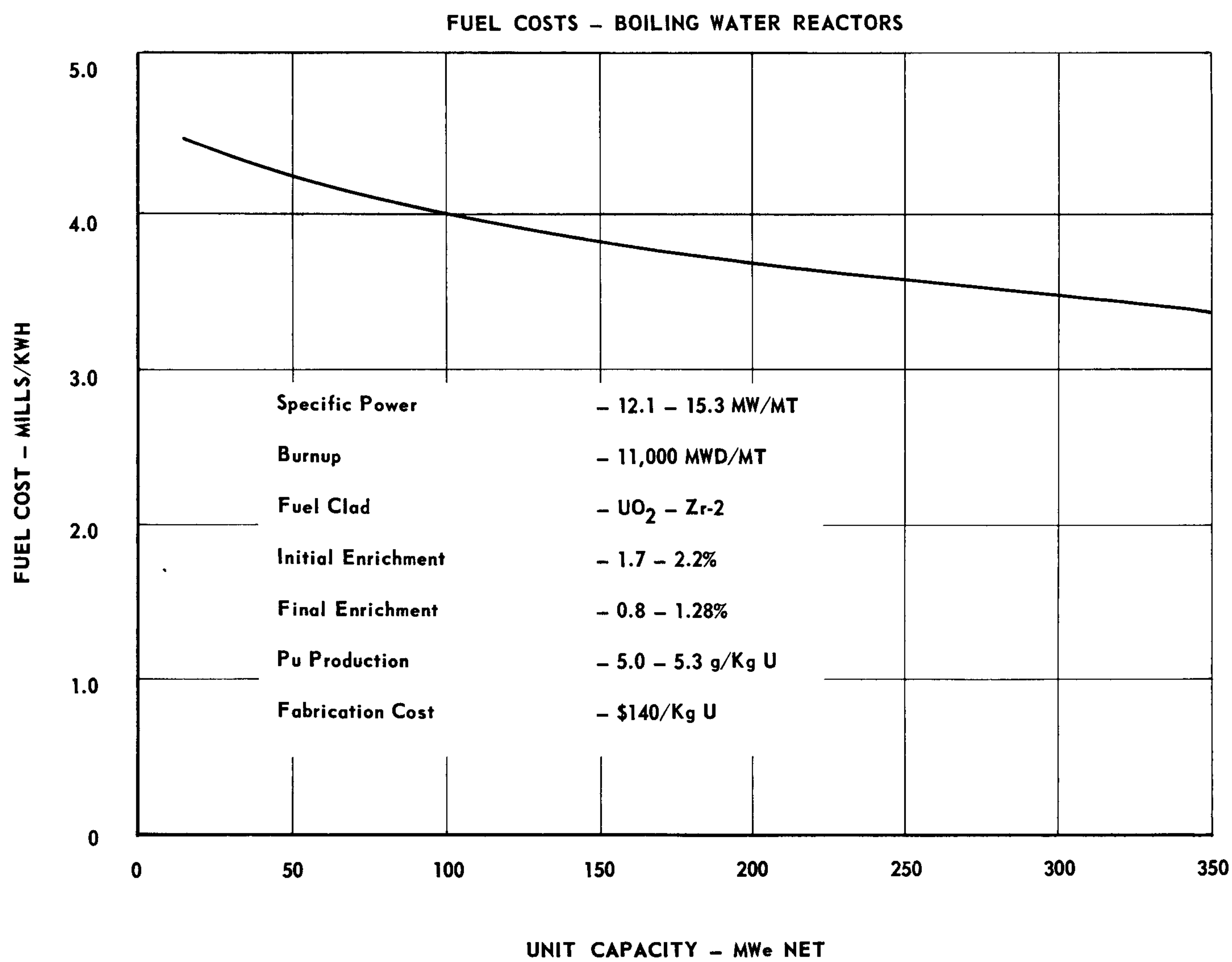


Figure VI-4
SL-1674

FUEL COSTS – ORGANIC COOLED REACTORS

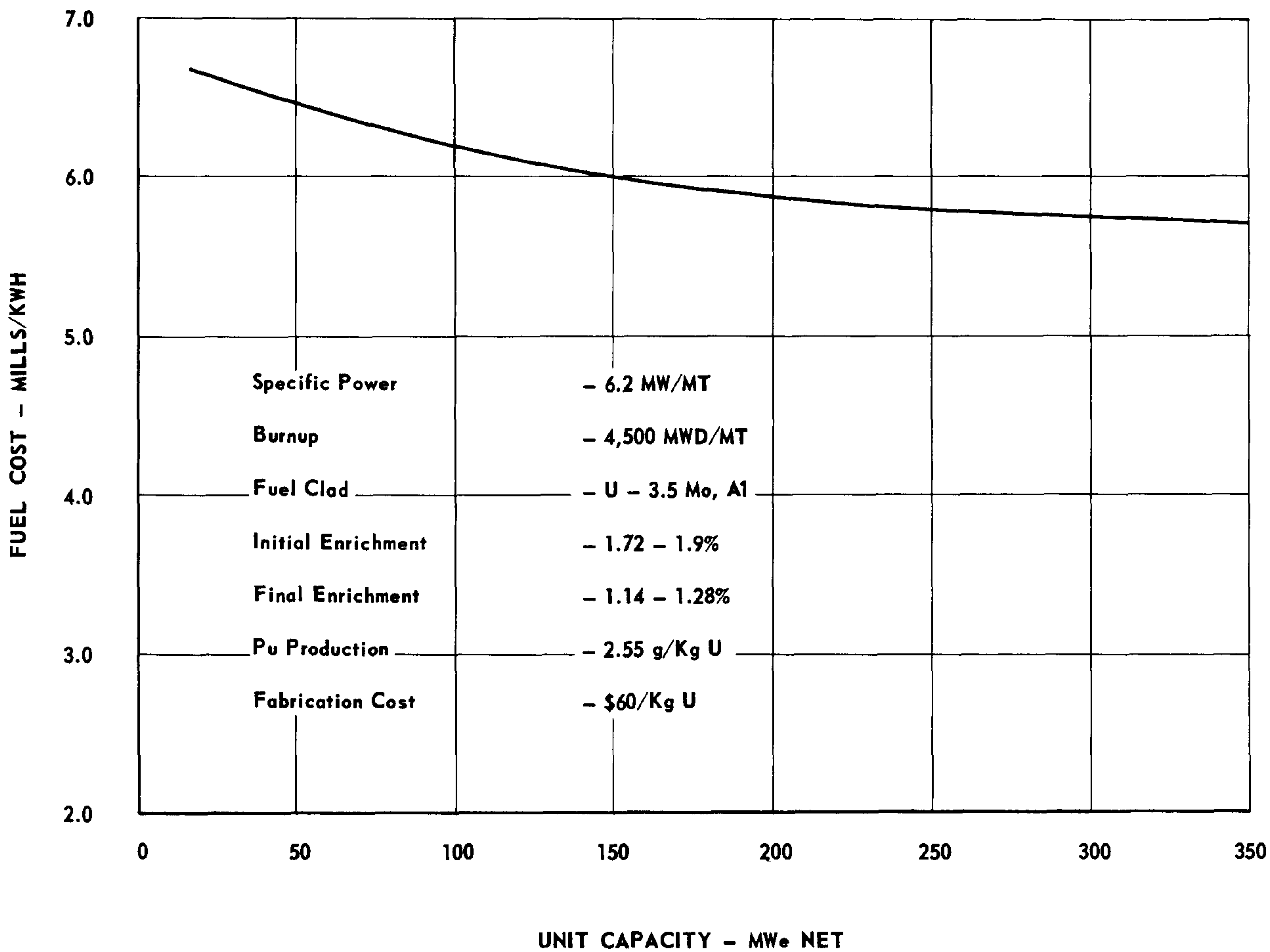


Figure VI-5
SL-1674

FUEL COSTS – SODIUM GRAPHITE REACTORS

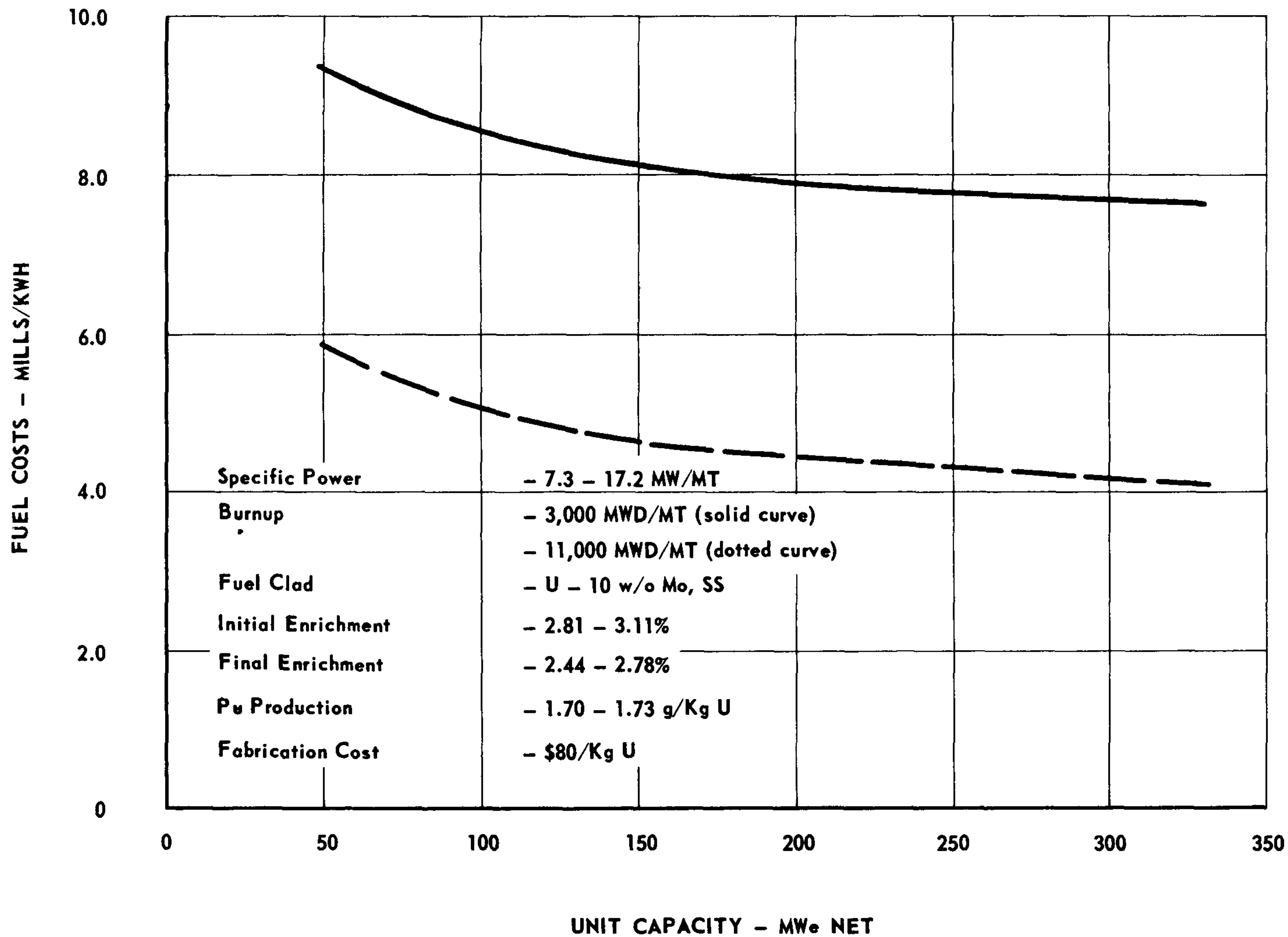


Figure VI-6
SL-1674

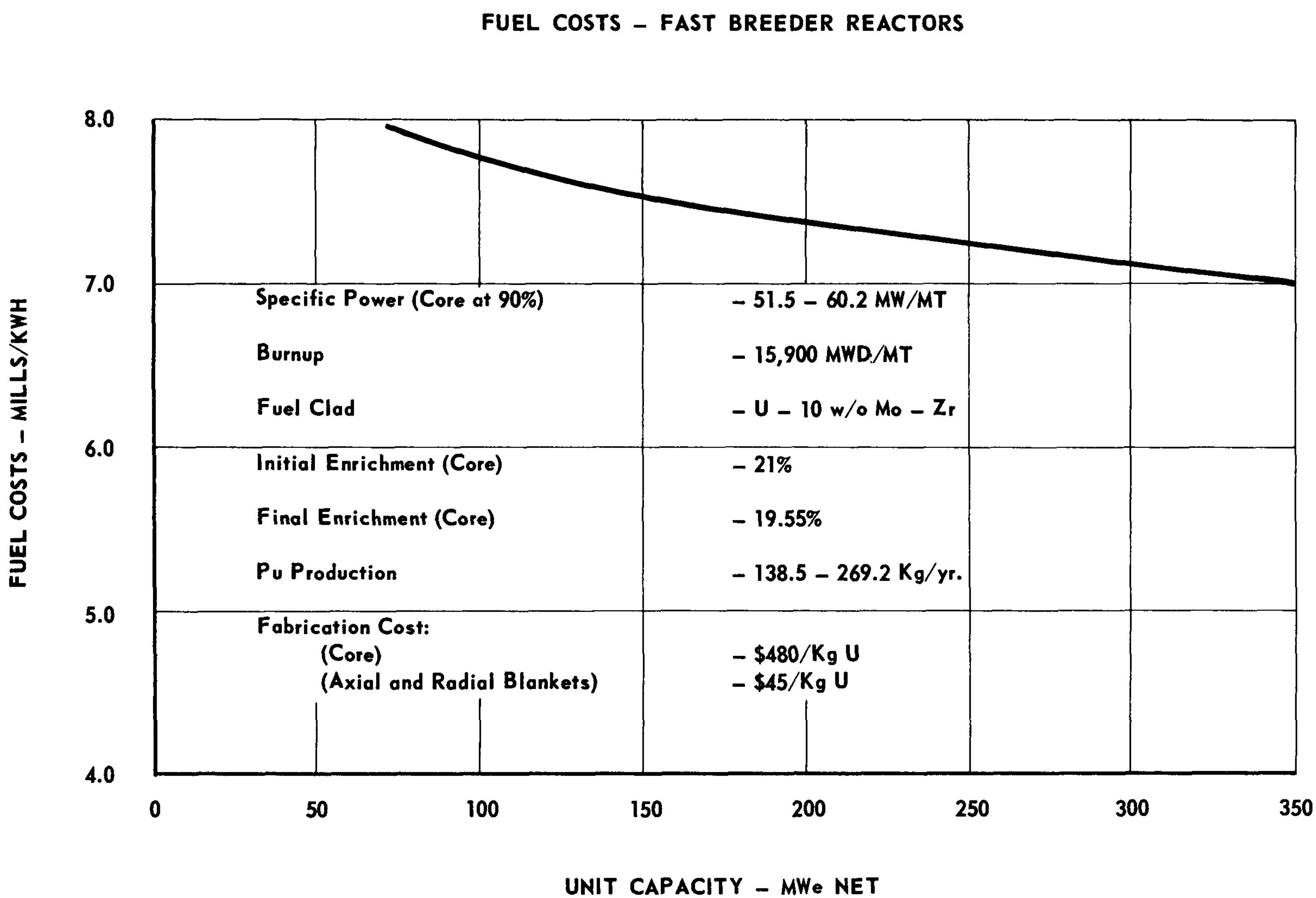


Figure VI-7
SL-1674

FUEL COSTS – AQUEOUS HOMOGENEOUS REACTORS

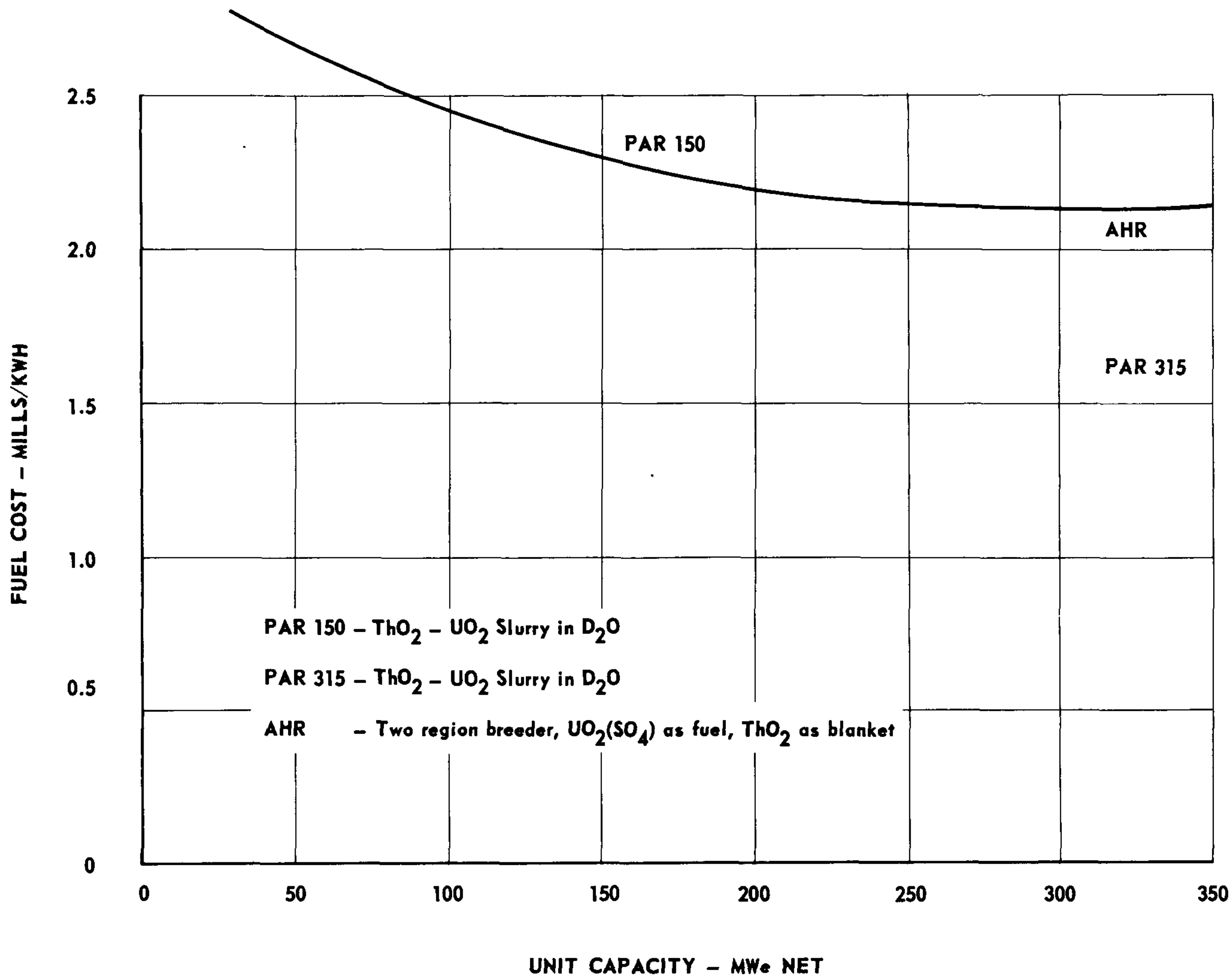


Figure VI-8
SL-1674

FUEL COSTS – D_2O NATURAL URANIUM REACTORS

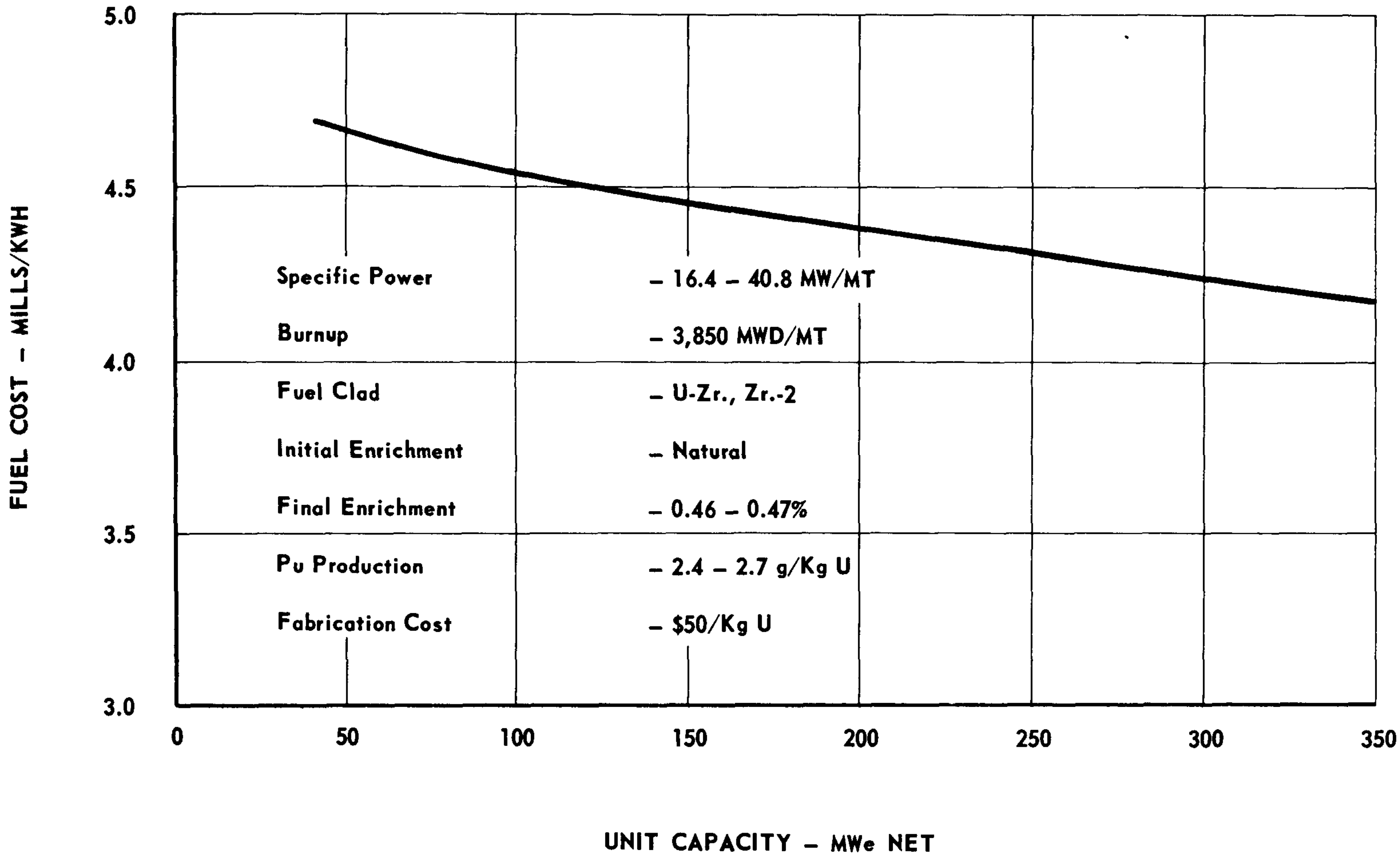


Figure VI-9
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FUEL COSTS – GAS COOLED REACTORS

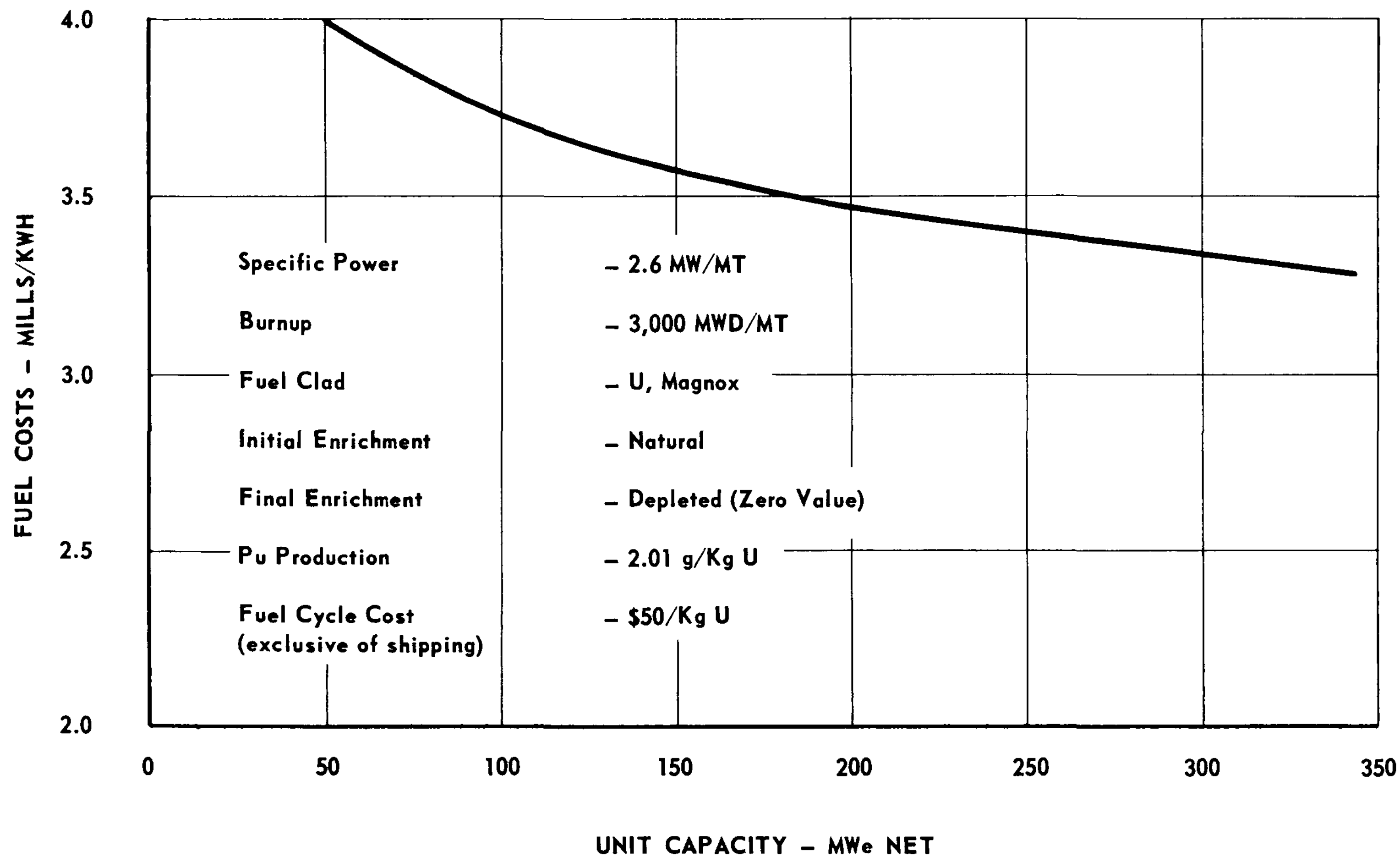


Figure VI-10
SL-1674

VII - NORMALIZATION STUDY OF OPERATING AND MAINTENANCE COSTS FOR NUCLEAR POWER REACTORS

This Section VII of Report SL-1674 covers the development and determination of normalized cost estimates for operating and maintenance for eight nuclear power reactor concepts listed in the Atomic Energy Commission's "Ten-Year Plan - Civilian Reactor Development".

A study and evaluation were made of the subject material in the status reports pertaining to operating and maintenance costs. Other reports and material on this subject were also studied, including nuclear insurance covering nuclear property, third party liability, and indemnity insurance.

The status reports as a whole gave insufficient data on which to base normalized cost estimates for all the reactor concepts being considered. Also, these reports contained little or no data on nuclear insurance costs. Therefore, in order to arrive at normalized cost estimates, cost estimates of operation and maintenance were prepared for nuclear power reactors in capacities of 75 MW(e), 200 MW(e), and 300 MW(e) for each of eight reactor concepts. From this data, tables and curves have been developed which should enable the user to arrive at a reasonable comparative cost estimate, bearing in mind the present limited experience in this field, for operating and maintenance applicable to single unit nuclear power reactors ranging in capacity from 50 MW(e) to 100 MW(e) and from 150 MW(e) to 350 MW(e), with nominal extrapolation possible beyond this range. Corresponding estimates were made for nuclear insurance.

A. Summary - Operating and Maintenance Cost, Nuclear Power Stations

There is little operating experience to draw upon to base operating and maintenance cost estimates for full scale nuclear power stations. The first full scale nuclear plant to be placed in operation, Britain's Calder Hall, a dual purpose 184,000 kilowatt, two reactor plant, has a complement of some 250 operating people; while for their Hinkley Point Station, a 500,000 kilowatt, two reactor station now under construction, the designers estimate that an operating staff of 325 will be required. In this country, Shippingport (60/100 MW(e)) is the only full scale plant now in operation. The total operating personnel at Shippingport was originally set at 127 people. This has been increased substantially to about 165 due to the fact that many test operations are being carried out at the plant. Other sources of information on the operation and maintenance of full scale plants are the estimates for those plants that are now under construction, such as Yankee, Indian Point, Enrico Fermi, and Dresden, all of which should be in operation within the next year or two. The personnel schedule for the Enrico Fermi plant (100 MW(e)) is 59 for the reactor section only while the Dresden station (180 MW(e)) operating setup provides for 95 people for the complete station operation. Because of this limited background of operating experience, the operating organization setup for a nuclear plant and the estimated cost of operating such a plant must be based to a large extent on an analysis of the operating requirements for each particular plant concept, tempered with the operating and maintenance experience associated with conventional plants.

Normalized operating and maintenance cost estimates together with nuclear insurance estimates have been set up for a one unit 75,000 KW(e), 200,000 KW(e), and 300,000 KW(e) plant for each of the following reactor concepts:

a. Thermal Converters

(1) Pressurized water reactor.
(2) Boiling water reactor.
(3) Organic cooled reactor.
(4) Sodium cooled, thermal neutron reactor.

b. Breeder Reactors

(1) Liquid metal cooled, fast neutron reactor.
(2) Fluid fuel, aqueous homogeneous reactor. (Not considered current technology.)

c. Natural Uranium Fueled Reactors

(1) D_2O moderated, natural uranium reactor.
(2) Gas cooled, natural uranium reactor.

The results of these estimates are shown on Tables VII-1 to VII-8, inclusive, and Chart VII-3 which shows a comparison of operating and maintenance costs with conventional plants.

B. Method of Approach to Normalized Estimates

The following discussion outlines the approach to setting up normalized cost estimates for the operating and maintenance of the several types of nuclear plants listed above.

a. At this stage of development, operating and maintenance costs for nuclear plants will be higher than for conventional plants of corresponding net kilowatt capacity. This is due essentially to the radiological and biological aspects of nuclear plants with their attendant safety problems together with lack of any extended operating experience on which to base judgment to achieve operating economics.

b. In considering the items making up the total cost per kilowatt hour of a nuclear plant, viz., plant investment charges, fuel costs, and operating and maintenance costs, the latter item of operating and maintenance represents a relatively small proportion of the total cost, being approximately 10%. This cost relationship merits a somewhat simplified approach in normalizing operating and maintenance cost estimates.

c. Operating and maintenance costs were broken down into:

(1) Supervision and engineering labor.
(2) Station labor.
(3) Fringe benefits, applicable to payroll.
(4) Operating supplies, maintenance materials, and services.

(5) Allowance for special items. These are items applicable to a particular type of reactor such as the make-up of heavy water in a D_2O moderated reactor, organic liquid in an organic cooled reactor, helium in a gas cooled reactor or special maintenance and operating techniques associated with certain reactor concepts, such as the aqueous homogeneous.

C. Outline of General Approach

Before commenting on each of the above operating and maintenance cost items, a discussion of the general approach to normalized cost estimates for these items is pertinent. In considering total operating costs of a nuclear or conventional plant, the total fuel costs vary with the kilowatt-hour output, the charges on plant investment sometimes referred to as fixed charges, once the rate is set, vary in accordance with plant capacity or investment while the other operating costs - operating payroll, operating supplies, maintenance materials and services - tend to vary in accordance with plant capacity and are sometimes referred to as fixed operating expense. In normalizing cost estimates, it has been assumed that an operating organization setup for a particular type nuclear plant would be adequate to take care of the operating requirements of several other types of reactor plants, also covering a range of plant capacities. Thus, the operating organization for a 200,000 kilowatt nuclear power station would be applicable to plants using any of the several hetrogeneous reactor types employing such coolants as light or heavy water, organic fluids, gases or liquid metals. Further, it has been assumed that this operating organization providing for 95 people for a 200,000 kw station would be adequate, as far as personnel is concerned, to take care of the operating requirements of a one unit-single reactor and turbine-generator unit-nuclear plant in sizes ranging from 150,000 kw to 350,000 kw. Likewise the operating organization setup providing for 70 people for a 75,000 kw nuclear plant would be adequate for a one unit plant ranging in capacity from 50,000 to 100,000 kw.

Cost of operating supplies, maintenance materials, and services and allowance for special items have been estimated for each size and type of reactor plant. They will tend to vary in accordance with the type of reactor, size of plant, complexity of operations, arrangement of facilities and the extent to which maintenance work can be carried on by direct contact or remote methods.

a. Supervision and Engineering

A nuclear plant will require more engineering or technical personnel than a conventional plant, hence a correspondingly higher cost. This is because at the present development of nuclear plant operations, many of the operating functions and plant results require engineering and technical personnel which in a conventional plant are performed in many instances by non-technical people or staff people whose services extend over the several generating stations in the particular system.

b. Station Labor

Again because of the radiological and biological aspects, the newness of nuclear operations and the operating licensing and other requirements that are set up by governmental regulations, the operating organization as a whole will contain a greater percentage of higher paid jobs together with more personnel than that involved in a comparable conventional plant.

c. Fringe Benefits

Twenty percent has been added to the estimated supervision, engineering, and station labor payroll to reflect the cost of such fringe items as vacations, hospitalization and sick benefits, insurance, pensions, payroll taxes and other employee benefits. The 20% figure is conservatively low for the Electric Utility Industry. No overtime has been included in the payroll estimates, which also tend to make these estimates conservatively low. The operating payroll rates and estimates and the personnel requirements are shown on Tables VII-9 to VII-12, inclusive.

d. Operating Supplies, Maintenance Materials and Services

In determining the item of cost for operating supplies, maintenance materials and service, an estimate was made for each size of plant and adjusted to reflect applicability to each type of reactor concept. This item includes, in addition to the usual items, maintenance work required beyond the normal crew, services for monitoring surveys on site and off site, testing and calibrating dosimeters, etc.

e. Allowance for Special Items

As covered above, these items cover make-up of coolant or special maintenance and operating techniques associated with specific reactor concepts. Tables VII-13 and VII-14 set out the data for organic make-up and heavy water losses, respectively. Figures VII-1 and VII-2 present this data in graph form.

D. Insurance

Insurance costs for nuclear plants represent a significant cost item and are substantially higher than for conventional plants. For example, the nuclear insurance premium for a nominal 200 MW(e) nuclear plant would be approximately $500,000 per year, which is several times the cost of a comparable size conventional plant. This higher cost is due essentially to lack of insurance experience and the liability potential, both on site and off site, to property, personnel and the general public resulting from a nuclear incident which conceivably could release radioactive contaminates.

Nuclear insurance coverage falls into three categories:

a. An all-risk nuclear property insurance for which the rate is approximately 35¢ per $100 of insurance coverage.

b. Nuclear liability insurance for which an insurance pool of $60,000,000 has been set up by mutually-owned and stockholder-owned insurance companies. This type of insurance coverage is required before the plant is eligible for government indemnity insurance. The maximum amount of insurance coverage is $60,000,000 at an annual premium of $260,000. The rates for this nuclear liability, or so-called third party liability insurance, is as follows:

Amount		Rate/Million	Annual Premium
First	$ 1,000,000	$40,000	$ 40,000
Next	4,000,000	20,000	80,000
Next	5,000,000	8,000	40,000
Next	10,000,000	4,000	40,000
Next	20,000,000	2,000	40,000
Next	20,000,000	1,000	20,000
	$60,000,000		$260,000

c. Government indemnity insurance at the rate of $30 per MW thermal with a maximum coverage of $500,000,000.

In the normalized cost estimates, one year's insurance premium has been shown for each of the three plant sizes under each reactor concept. It should be recognized that nuclear insurance coverage will also be required before the plant begins regular operation. This coverage starts when the first nuclear fuel is withdrawn from a government warehouse and continues in varying amounts through fuel processing, fuel storage on the plant site, preliminary operation, critical testing, and test operation until the plant is ready for regular operation. Such insurance coverage, which has not been included in the normalized cost estimates, may extend over a period of nearly three years, with a total premium being approximately one-half of the premium for a year's regular operation.

It is expected that insurance for nuclear plants will continue to be high until actual experience with a reasonable number of plants demonstrates specifically that this type of insurance risk is lower than now assumed. This experience demonstration could take many years.

E. Start-Up, Training and Operating License Procedure Costs

There are certain interrelationships between the activities covered by start-up, training and compliance with operating licensing procedure as they relate to nuclear power stations. The following brief outline of each of these activities brings out this interrelationship.

a. Start-Up

On the job training and breaking in of operators, preoperational testing and coordinating of equipment until the plant is placed in regular operation are considered start-up costs. Start-up costs are considered as part of the initial plant investment and under the AEC ground rules have been assumed to be 4.5 months of the normal annual operating and maintenance expenses, exclusive of fuel. While the 4.5 months' cost has been used in the normalized cost estimates, consideration should be given to increasing the amount to at least six months for full scale nuclear plants built in the immediate future.

b. Training

Because there are no full scale nuclear plants in operation (Shippingport excepted) from which to select experienced operating personnel, training of personnel for nuclear plant operations must start well ahead of the plant's in-service date, usually two or more years. The training consists generally of:

(1) Orientation courses in nuclear theory and technology together with applied courses, the text of which are designed to cover the nuclear technology and operating features of the particular nuclear power station in question.

(2) Special courses and instruction in health physics, water technology, maintenance methods, etc.

(3) Actual operating training and practice on an available reactor such as EBWR and VBWR and qualifying certain personnel for an operator's license.

(4) Preparation of operating manuals and procedures.

(5) Following up construction progress and preoperational tests.

The general training pattern is for the supervisory force to receive sufficient advance training so as to enable them to direct the training of the nonsupervisory force and have substantially the entire operating force participate in the start-up work.

c. Operating License Procedure

This activity covers two broad areas: the first area covers the obtaining of a construction permit for the plant which is in effect pending the engineering plans becoming finalized, construction progressing to substantial completion, and the plant being ready for the first fuel loading when the construction permit is supplanted by an operating license. This entire action in time parallels the engineering and construction of the plant and is also subject to public hearings and favorable findings by the AEC's Licensing Division, the Advisory Committee on Reactor Safeguards, and the Inspection Division; the second area covers the training and qualifying for an operator's license for some 20 to 30% of the plant personnel.

To date, no nongovernment-owned full scale nuclear power station has received an operating license in this country. The major nuclear plants now under construction, such as Enrico Fermi, Yankee, Indian Point, and Dresden are in various stages of the licensing procedure.

In determining the allocation of cost for these activities, start-up costs have been included as part of the initial plant investment while training and licensing costs have not as yet been as clearly defined as between operating and investment and these latter two items have not been included in the normalized estimates.

In summarizing start-up, training, and licensing activities it can be stated that, at the present stage of development, they involve a long and costly procedure. Because of the interrelationships and overlapping aspects, it is difficult to set a separate dollar value for each of these activities but in total cost they are about one and one-half to twice the normal annual operating and maintenance costs, exclusive of fuel, for the particular reactor plant in question. This estimate of cost for a particular reactor project would be substantially higher if there were any material opposition to the granting of either a construction permit or operating license for that project. These relatively high costs involved in present licensing procedures can be attributed, for the most part, to the safety requirement aspects of nuclear energy utilization, lack of operating experience with full scale plants, and the newness of the whole procedure. One could expect simplification and hence a less costly overall licensing procedure as the field of nuclear power generation develops.

In closing this Section VII of Report SL-1674, on normalized operating and maintenance costs including nuclear insurance, it is well to point out that the data developed herein will provide a basis for determining a reasonable comparative cost estimate of operating and maintenance for the several reactor concepts in a wide range of capacities. However, it should be recognized that such a derived comparative estimate would not necessarily substitute for the requirements of a specific cost estimate for a particular reactor installation where all the local factors, such as company policy, local labor rates, union agreements and practices, etc., are known that would be reflected into the specific cost estimate.

LIST OF EXHIBITS - SECTION VII

Table VII-1
SL-1674

NORMALIZED OPERATING AND MAINTENANCE COST ESTIMATE
PRESSURIZED WATER COOLED AND MODERATED POWER REACTOR

A. GENERAL DATA						
Reactor Type	Pressurized Water		Pressurized Water		Pressurized Water	
Megawatts - Thermal	315		810		1200	
Megawatts - Net Electrical	75		200		300	
Kilowatt-Hour Output Net $(10)^6$ 80% Load Factor	525.6		1401.6		2102.4	
Est. Plant Investment Cost $(10)^3$	32,600		56,400		73,400	
B. OPERATING AND MAINTENANCE COST EST.	Cost Est.	No. Emp.	Cost Est.	No. Emp.	Cost Est.	No. Emp.
Supervision and Engineering	$166,500	18	$216,000	24	$216,000	24
Station Labor	309,600	52	410,100	71	410,100	71
Total	$476,100	70	$626,100	95	$626,100	95
Plus 20% Fringe Benefits	95,200	Mills/kwh	125,200	Mills/kwh	125,200	Mills/kwh
Total	$571,300		$751,300		$751,300	
Operating Supplies, Maintenance Materials and Services	147,750		340,000		489,000	
Total	$719,050	1.37	$1,091,300	.78	$1,240,300	.59
C. NUCLEAR INSURANCE PREMIUM						
All Risk Property Insurance	$114,100		$197,400		$256,900	
Nuclear Liability Insurance	247,250		260,000		260,000	
Government Indemnity	9,450		24,300		36,000	
Total	$370,800	.70	$481,700	.34	$552,900	.26

Table VII-2
SL-1674

NORMALIZED OPERATING AND MAINTENANCE COST ESTIMATE
BOILING WATER COOLED AND MODERATED POWER REACTOR

A. GENERAL DATA						
Reactor Type	Boiling Water		Boiling Water		Boiling Water	
Megawatts - Thermal	260		690		970	
Megawatts - Net Electrical	75		200		300	
Kilowatt-Hour Output Net $(10)^6$ 80% Load Factor	525.6		1401.6		2102.4	
Est. Plant Investment Cost $(10)^3$	35,200		62,200		78,900	
B. OPERATING AND MAINTENANCE COST EST.	Cost Est.	No. Emp.	Cost Est.	No. Emp.	Cost Est.	No. Emp.
Supervision and Engineering	$166,500	18	$216,000	24	$216,000	24
Station Labor	309,600	52	410,100	71	410,100	71
Total	$476,100	70	$626,100	95	$626,100	95
Plus 20% fringe Benefits	95,200	Mills/kwh	125,200	Mills/kwh	125,200	Mills/kwh
Total	$571,300		$751,300		$751,300	
Operating Supplies, Maintenance Materials and Services	156,750		360,000		519,000	
Total	$728,050	1.38	$1,111,300	.79	$1,270,300	.61
C. NUCLEAR INSURANCE PREMIUM						
All Risk Property Insurance	$123,200		$217,700		$276,150	
Nuclear Liability Insurance	238,000		260,000		260,000	
Government Indemnity	7,800		20,700		29,100	
Total	$369,000	.71	$498,400	.36	$565,250	.27

NORMALIZED OPERATING AND MAINTENANCE COST ESTIMATE
ORGANIC COOLED AND MODERATED POWER REACTOR

A. GENERAL DATA						
Reactor Type	Organic Cooled		Organic Cooled		Organic Cooled	
Megawatts - Thermal	260		700		1050	
Megawatts - Net Electrical	75		200		300	
Kilowatt-Hour Output Net $(10)^6$ 80% Load Factor	525.6		1401.6		2102.4	
Est. Plant Investment Cost $\$(10)^3$	26,200		48,200		66,000	
B. OPERATING AND MAINTENANCE COST EST.	Cost Est.	No. Emp.	Cost Est.	No. Emp.	Cost Est.	No. Emp.
Supervision and Engineering	$166,500	18	$216,000	24	$216,000	24
Station Labor	309,600	52	410,100	71	410,100	71
Total	$476,100	70	$626,100	95	$626,100	95
Plus 20% Fringe Benefits	95,200	Mills/kwh	125,200	Mills/kwh	125,200	Mills/kwh
Total	$571,300		$751,300		$751,300	
Operating Supplies, Maintenance Materials and Services	139,500		320,000		462,000	
Total	$710,800	1.35	$1,071,300	.76	$1,213,300	.58
*Organic Make-Up	275,000	.53	729,000	.52	1,080,000	.51
Total Oper. and Maint.	$985,800	1.88	$1,800,300	1.28	$2,293,300	1.09
*Note: Make-Up at rate of 25#/MW day thermal at 13.5¢ per pound.						
C. NUCLEAR INSURANCE PREMIUM						
All Risk Property Insurance	$ 92,050		$169,050		$231,350	
Nuclear Liability Insurance	238,000		260,000		260,000	
Government Indemnity	7,800		21,000		31,500	
Total	$337,850	0.64	$450,050	0.32	$522,850	0.25

Table VII-3
SL-1674

NORMALIZED OPERATING AND MAINTENANCE COST ESTIMATE
SODIUM COOLED, GRAPHITE MODERATED, POWER REACTOR

A. GENERAL DATA						
Reactor Type	Sodium Graphite		Sodium Graphite		Sodium Graphite	
Megawatts - Thermal	240		650		975	
Megawatts - Net Electrical	75		200		300	
Kilowatt-Hour Output Net $(10)^6$ 80% Load Factor	525.6		1401.6		2102.4	
Est. Plant Investment Cost $(10)^3$	42,500		72,000		90,900	
B. OPERATING AND MAINTENANCE COST EST.	Cost Est.	No. Emp.	Cost Est.	No. Emp.	Cost Est.	No. Emp.
Supervision and Engineering	$166,500	18	$216,000	24	$216,000	24
Station Labor	309,600	52	410,100	71	410,100	71
Total	$476,100	70	$626,100	95	$626,100	95
Plus 20% Fringe Benefits	95,200	Mills/kwh	125,200	Mills/kwh	125,200	Mills/kwh
Total	$571,300		$751,300		$751,300	
Operating Supplies, Maintenance Materials and Services	217,500		500,000		720,000	
Total	$788,800	1.50	$1,251,300	.89	$1,471,300	.70
C. NUCLEAR INSURANCE PREMIUM						
All Risk Property Insurance	$148,750		$252,000		$318,150	
Nuclear Liability Insurance	232,000		260,000		260,000	
Government Indemnity	7,200		19,500		29,250	
Total	$387,950	.74	$531,500	.38	$607,400	.29

NORMALIZED OPERATING AND MAINTENANCE COST ESTIMATE
FAST BREEDER POWER REACTOR

A. GENERAL DATA								
Reactor Type	Fast Breeder		Fast Breeder		Fast Breeder		Fast Breeder	
Megawatts - Thermal	220		440		585		880	
Megawatts Net Electrical	75		150		200		300	
Kilowatt-Hour Output Net $(10)^6$ 80% Load Factor	525.6		1051.2		1401.6		2102.4	
Est. Plant Investment Cost $(10)^3$	34,100		51,000		60,400		76,500	
B. OPERATING AND MAINTENANCE COST EST.	Cost Est.	No. Emp.	Cost Est.	No. Emp.	Cost Est.	No. Emp.	Cost Est.	No. Emp.
Supervision and Engineering	$166,500	18	$216,000	24	$216,000	24	$216,000	24
Station Labor	309,600	52	410,100	71	410,100	71	410,100	71
Total	476,100	70	626,100	95	626,100	95	626,100	95
Plus 20% Fringe Benefits	95,200	Mills/kwh	125,200	Mills/kwh	125,200	Mills/kwh	125,200	Mills/kwh
Total	$571,300		$751,300		$751,300		$751,300	
Operating Supplies, Maintenance Materials and Services	278,250		489,000		640,000		921,000	
Total	$849,550	1.61	$1,240,300	1.18	$1,391,300	.99	$1,672,300	.79
C. NUCLEAR INSURANCE PREMIUM								
All Risk Property Insurance	$119,350		$178,500		$211,400		$267,750	
Nuclear Liability Insurance	226,000		260,000		260,000		260,000	
Government Indemnity	6,600		13,200		17,550		26,400	
Total	$351,950	.67	$451,700	.43	$488,950	.35	$554,150	.26

Table VIII-5
SL-1674

NORMALIZED OPERATING AND MAINTENANCE COST ESTIMATE
AQUEOUS HOMOGENEOUS, THERMAL, POWER REACTOR
(NOT CURRENT TECHNOLOGY)

A. GENERAL DATA						
Reactor Type	Aqueous Homogeneous		Aqueous Homogeneous		Aqueous Homogeneous	
Megawatts - Thermal	285		760		1140	
Megawatts Net Electrical	75		200		300	
Kilowatt-Hour Output Net $(10)^6$ 80% Load Factor	525.6		1401.6		2103.4	
Est. Plant Investment Cost $(10)^3$	33,800		72,300		96,900	
B. OPERATING AND MAINTENANCE COST EST.	Cost Est.	No. Emp.	Cost Est.	No. Emp.	Cost Est.	No. Emp.
Supervision and Engineering	$166,500	18	$216,000	24	$216,000	24
Station Labor	309,600	52	410,100	71	410,100	71
Total	476,100	70	626,100	95	626,100	95
Plus 20% Fringe Benefits	95,200	Mills/kwh	125,200	Mills/kwh	125,200	Mills/kwh
Total	$571,300		$751,300		$751,300	
Operating Supplies, Maintenance Materials and Services	435,000		1,000,000		1,440,000	
Total	$1,006,300		$1,751,300		$2,191,300	
Allowance for Special Maintenance	870,000		2,000,000		2,880,000	
Heavy Water Make-Up Fuel	60,750		156,000		231,000	
Total	$1,937,050	3.69	$3,907,300	2.79	$5,302,300	2.53
C. NUCLEAR INSURANCE PREMIUM						
All Risk Property Insurance	$118,300		$253,050		$339,150	
Nuclear Liability Insurance	242,750		260,000		260,000	
Government Indemnity	8,550		22,800		34,200	
Total	$368,600	.70	$535,850	.38	$633,350	.30

NORMALIZED OPERATING AND MAINTENANCE COST ESTIMATE
HEAVY WATER (D_2O) MODERATED, NATURAL URANIUM, POWER REACTOR

A. GENERAL DATA						
Reactor Type	Heavy Water-Natural		Heavy Water-Natural		Heavy Water-Natural	
Megawatts - Thermal	325		860		1290	
Megawatts -Net Electrical	75		200		300	
Kilowatt-Hour Output Net $(10)^6$ 80% Load Factor	525.6		1401.6		2102.4	
Est. Plant Investment Cost $(10)^3$	48,000		85,000		108,000	
B. OPERATING AND MAINTENANCE COST EST.	Cost Est.	No. Emp.	Cost Est.	No. Emp.	Cost Est.	No. Emp.
Supervision and Engineering	$166,500	18	$216,000	24	$216,000	24
Station Labor	309,600	52	410,100	71	410,100	71
Total	476,100	70	626,100	95	626,100	95
Plus 20% Fringe Benefits	95,200	Mills/kwh	125,200	Mills/kwh	125,200	Mills/kwh
Total	$571,300		$751,300		$751,300	
Operating Supplies, Maintenance Materials and Services	165,000		380,000		546,000	
Total	$736,300		$1,131,300		$1,297,300	
Heavy Water Make-Up	220,000		463,000		627,000	
Total	$956,300	1.82	$1,594,300	1.14	$1,924,300	.91

Note: D_2O loss rate equivalent to 3% per year of Total Inventory. D_2O cost at $28.00/#

C. NUCLEAR INSURANCE PREMIUM						
All Risk Property Insurance	$168,000		$297,500		$378,000	
Nuclear Liability Insurance	248,750		260,000		260,000	
Government Indemnity	9,750		25,800		38,700	
Total	$426,500	.81	$583,300	.42	$676,700	.32

Table VII-7
SL-1674

NORMALIZED OPERATING AND MAINTENANCE COST ESTIMATE
GAS COOLED, GRAPHITE MODERATED, NATURAL URANIUM, POWER REACTOR

A. GENERAL DATA						
Reactor Type	Gas Cooled (Nat.)		Gas Cooled (Nat.)		Gas Cooled (Nat.)	
Megawatts - Thermal	310		830		1250	
Megawatts-Net Electrical	75		200		300	
Kilowatt-Hour Output Net $(10)^6$ 80% Load Factor	525.6		1401.6		2102.4	
Est. Plant Investment Cost $(10)^3$	50,600		90,500		114,000	
B. OPERATING AND MAINTENANCE COST EST.	Cost Est.	No. Emp.	Cost Est.	No. Emp.	Cost Est.	No. Emp.
Supervision and Engineering	$166,500	18	$216,000	24	$216,000	24
Station Labor	309,600	52	410,100	71	410,100	71
Total	476,100	70	626,100	95	626,100	95
Plus 20% Fringe Benefits	95,200	Mills/kwh	125,200	Mills/kwh	125,200	Mills/kwh
Total	$571,300		$751,300		$751,300	
Operating Supplies, Maintenance Materials and Service	156,750		360,000		519,000	
Total	$728,050	1.38	$1,111,300	.79	$1,270,300	.61
C. NUCLEAR INSURANCE PREMIUM						
All Risk Property Insurance	$177,100		$315,750		$399,000	
Nuclear Liability Insurance	246,500		260,000		260,000	
Government Indemnity	9,300		24,900		37,500	
Total	$432,900	.82	$600,650	.43	$696,500	.33

Table VIII-8
SL-1674

OPERATING PAYROLL ESTIMATE
FOR 200 MW(e) NUCLEAR POWER STATION
(Applicable to a 150 to 350 MW(e) Plant Range)

Position	Number	Rate	Annual Cost
A. Supervision and Engineering			
Station Superintendent	1	$15,000/Yr.	$15,000.00
Asst. Station Superintendent	1	12,000/Yr.	12,000.00
Electrical Superintendent	1	10,800/Yr.	10,800.00
Maintenance Superintendent	1	10,800/Yr.	10,800.00
Shift Superintendent	5	10,800/Yr.	54,000.00
Supervising Engineer	1	10,800/Yr.	10,800.00
Nuclear Engineer	1	9,600/Yr.	9,600.00
Thermal Engineer	1	8,400/Yr.	8,400.00
Instrument Engineer	1	8,400/Yr.	8,400.00
Chemistry Engineer	1	8,400/Yr.	8,400.00
Radiation Protection Engineer	1	8,400/Yr.	8,400.00
Engineer	2	7,500/Yr.	15,000.00
Engineer Assistant	4	6,000/Yr.	24,000.00
Office Supervisor	1	6,000/Yr.	6,000.00
Foreman	2	7,200/Yr.	14,400.00
Total Supervision & Technical	24		$216,000.00
B. Station Labor			
Senior Control Operator*	5	3.48 hr.	36,192.00
Control Operator*	5	3.35 hr.	34,840.00
Equipment Operator*	4	3.23 hr.	26,873.60
Equipment Attendant*	5	2.81 hr.	29,224.00
Auxiliary Operator*	9	2.51 hr.	46,987.20
Station Man*	5	2.36 hr.	24,544.00
Radiation Protection Man*	5	3.23 hr.	33,592.00
Laboratory Man*	5	2.81 hr.	29,224.00
Instrument Mechanic A *	2	3.23 hr.	13,436.80
Instrument Mechanic B *	2	2.81 hr.	11,689.60
Mechanic A	5	3.13 hr.	32,552.00
Mechanic B	3	2.71 hr.	16,910.40
Helper	2	2.26 hr.	9,401.80
General Clerk	1	2.39 hr.	4,971.20
Clerk-Stenographer	1	2.16 hr.	4,492.80
Clerk	1	2.01 hr.	4,180.80
Storekeeper	1	2.71 hr.	5,636.80
Janitor	4	2.10 hr.	17,472.00
Watchman*	5	2.20 hr.	22,880.00
Total Station Labor	71		$410,113.80

* These rates increase 10¢ per hour for shift work.

C. Total Station Costs			
Supervision & Engineering	24		216,000.00
Station Labor	71		410,113.00
Total	95		$626,100.00
Plus 20% Fringe Benefits			125,200.00
Total Cost			$751,300.00

PERSONNEL REQUIREMENTS
FOR TYPICAL 200 MW(e) SINGLE UNIT NUCLEAR POWER PLANT
(Applicable to a capacity range of 150 MW(e) to 350 MW(e))

Job Title	Personnel Per Shift Night	Days	Middle	Total
Plant Management				
Station Superintendent		1		1
Assistant Station Superintendent L.		1		1
Station Electrical Supervisor		1		1
Operating				
Shift Superintendent L.	1	1	1	5
Senior Control Operator L.	1	1	1	5
Control Operator L.	1	1	1	5
Equipment Operator L.	1	1	1	4
Equipment Attendant	1	1	1	5
Auxiliary Operator	2	2	2	9
Station Man	1	1	1	5
Technical Staff				
Supervising Engineer L.		1		1
Radiation Protection Engineer		1		1
Chemical Engineer		1		1
Thermal Engineer		1		1
Nuclear Engineer L.		1		1
Instrument Engineer		1		1
Engineer		4		4
Engineer Assistant		2		2
Laboratory Man	1	1	1	5
Mechanic A (Instrument)		2		2
Mechanic B (Instrument)		2		2
Radiation Protection Man	1	1	1	5
Maintenance				
Master Mechanic		1		1
Foreman		2		2
Mechanic A		5		5
Mechanic B		3		3
Helper		2		2
Office Service				
Office Supervisor		1		1
Clerical				
General Clerk I		1		1
General Clerk III		1		1
Clerk		1		1
Security				
Watchman	1	1	1	5
Service				
Janitor		4		4
Stores				
Storekeeper		1		1
Stockman I		1		1
	11	53	11	95

L. - A.E.C. License Required

OPERATING PAYROLL ESTIMATE FOR A 75 MW(e) NUCLEAR POWER STATION (Applicable to a 50 to 100 MW(e) Plant Range)

Position	Number	Rate	Annual Cost
A. Supervision and Engineering			
Station Superintendent	1	$15,000/Yr.	$15,000.00
Asst. Station Superintendent	1	12,000/Yr.	12,000.00
Maintenance Superintendent	1	10,800/Yr.	10,800.00
Shift Superintendent	4	10,800/Yr.	43,200.00
Supervising Engineer	1	10,800/Yr.	10,800.00
Nuclear-Thermal Engineer	1	9,600/Yr.	9,600.00
Instrument Engineer	1	8,400/Yr.	8,400.00
Chemical Engineer	1	8,400/Yr.	8,400.00
Radiation Protection Engineer	1	8,400/Yr.	8,400.00
Engineer	1	7,500/Yr.	7,500.00
Engineer Assistant	2	6,000/Yr.	12,000.00
Office Supervisor	1	6,000/Yr.	6,000.00
Foreman	2	7,200/Yr.	14,400.00
	18		$166,500.00
B. Station Labor			
Senior Control Operator*	5	3.48 hr.	$ 36,192.00
Control Operator*	5	3.35 hr.	34,840.00
Equipment Operator*	4	3.23 hr.	26,873.60
Equipment Attendant*	5	2.81 hr.	29,224.00
Station Man*	4	2.36 hr.	19,635.20
Instrument Mechanic*	2	3.23 hr.	13,436.80
Radiation Protection Man*	5	3.23 hr.	33,592.00
Laboratory Man*	3	2.81 hr.	17,534.40
Mechanic A	4	3.13 hr.	26,041.60
Mechanic B	3	2.71 hr.	16,910.40
Helper	2	2.26 hr.	9,410.60
General Clerk	1	2.39 hr.	4,971.20
Clerk-Stenographer	1	2.16 hr.	4,492.80
Stockman	1	2.41 hr.	5,012.80
Janitor	3	2.10 hr.	13,104.00
Watchman*	4	2.20 hr.	18,304.00
	52		$309,575.40

* These rates increased 10¢ per hour for shift work.

C. Total Station Costs		
Supervision and Engineering	18	$166,500.00
Station Labor	52	309,575.40
Total	70	$476,075.40
Plus 20% Fringe Benefits		95,215.08
Total Cost		$571,290.48

PERSONNEL REQUIREMENTS FOR TYPICAL 75 MW (e) SINGLE UNIT NUCLEAR POWER PLANT
(Applicable to a capacity range of 50 MW(e) to 100 MW(e)

Job Title	Personnel Per Shift Night	Days	Middle	Total
PLANT MANAGEMENT				
Station Superintendent		1		1
Assistant Station Superintendent L.		1		1
OPERATING				
Shift Superintendent L.	1	1	1	4
Senior Control Operator L.	1	1	1	5
Control Operator L.	1	1	1	5
Equipment Operator L.	1	1	1	4
Equipment Attendant	1	1	1	5
Station Man	1	1	1	4
TECHNICAL STAFF				
Supervising Engineer L.		1		1
Radiation Protection Engineer		1		1
Chemical Engineer		1		1
Nuclear Engineer L.		1		1
Instrument Engineer		1		1
Engineer		2		2
Engineer Assistant		1		1
Laboratory Man	1	1	1	3
Mechanic A (Instrument)		2		2
Radiation Protection Man	1	1	1	5
MAINTENANCE				
Maintenance Superintendent		1		1
Foreman		2		2
Mechanic A		4		4
Mechanic B		3		3
Helper		2		2
OFFICE SERVICE				
Office Supervisor		1		1
Clerical				
Clerk		2		2
SECURITY				
Watchman	1	1	1	4
SERVICE				
Janitor		3		3
STORES				
Stockman I		1		1
	9	39	9	70

L. - A.E.C. License Required

ORGANIC MAKE-UP-COSTS

Nominal Plant Size MW(e)	Thermal Power MW(e)	MWDth/yr. at 0.8 L.F.	Make-Up Rate at 25 lb/MWDth (lb/yr.)	Annual Cost at $0.135/lb. ($/yr.)
75	280	8.17×10^4	2.04×10^6	2.75×10^5
100	370	1.08×10^5	2.7×10^6	3.65×10^5
150	560	1.64×10^5	4.1×10^6	5.54×10^5
200	740	2.16×10^5	5.4×10^6	7.29×10^5
300	1100	3.2×10^5	8.0×10^6	10.8×10^5
400	1500	4.38×10^5	11.0×10^6	14.85×10^5

Assumptions:

(a) Thermal Efficiency = 0.27.

(b) Load Factor = 0.8.

(c) Make-up Rate = 25 lb/MWDth.

(d) Cost of Santowax R = $0.135/lb.

HEAVY WATER (D_2O) MAKE-UP COSTS

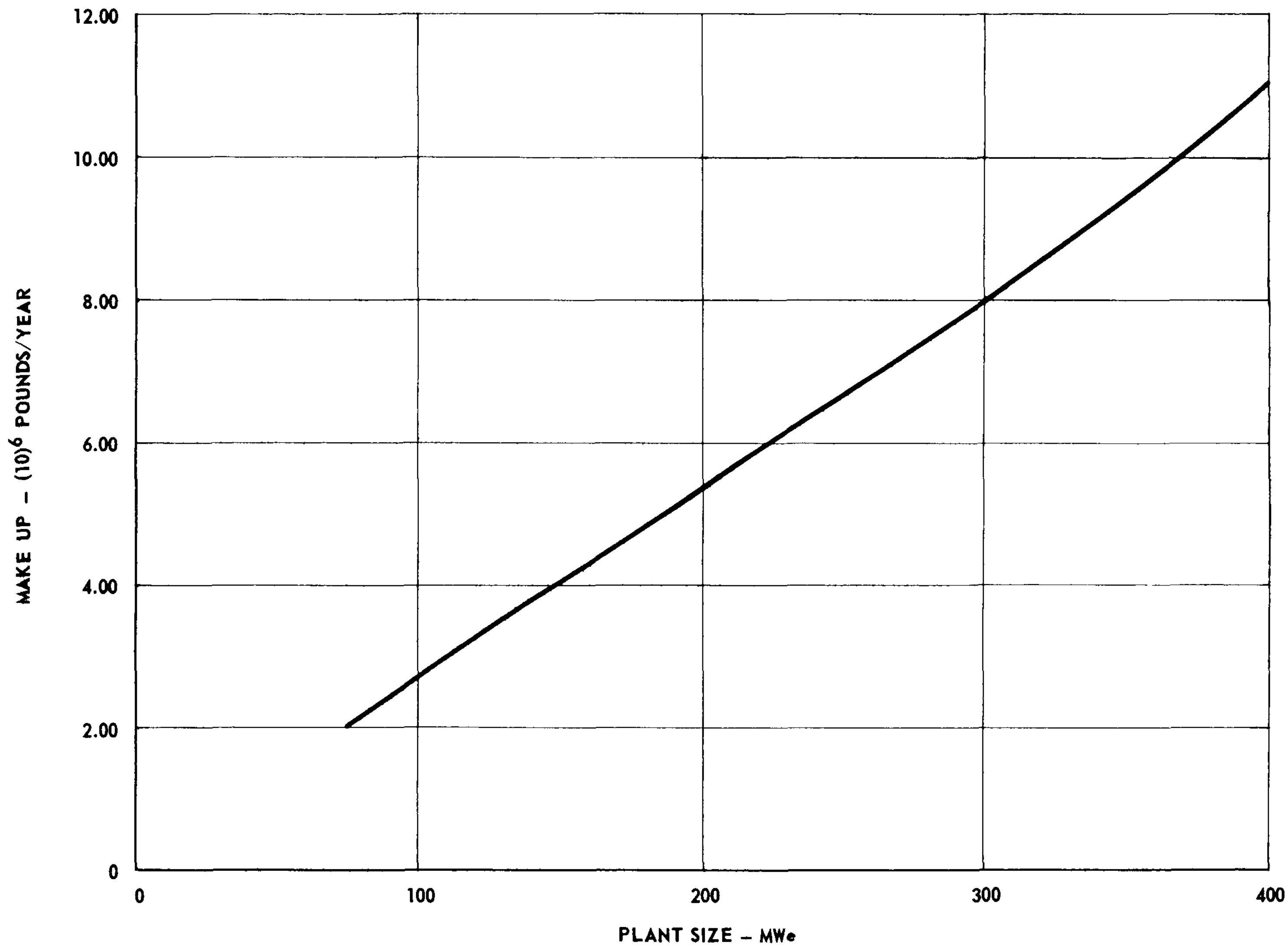
Nominal Plant Size MW(e)	Inventory Metric Ton Per MW(e)	Total D_2O Inventory (Metric Tons)	Total D_2O Inventory Pounds	D_2O Annual Loss at 3% 1 lbs/yr.	Annual D_2O Make-Up Cost at $28/lb.
75	1.58	119	$2.6\ (10)^5$	$7.9\ (10)^3$	$2.2\ (10)^5$
100	1.50	150	$3.3\ (10)^5$	$9.9\ (10)^3$	$2.77\ (10)^5$
150	1.35	202	$4.5\ (10)^5$	$13.5\ (10)^3$	$3.8\ (10)^5$
200	1.24	248	$5.5\ (10)^5$	$16.5\ (10)^3$	$4.63\ (10)^5$
221	1.20	266	$5.9\ (10)^5$	$17.6\ (10)^3$	$4.93\ (10)^5$
300	1.12	336	$7.5\ (10)^5$	$22.4\ (10)^3$	$6.27\ (10)^5$
400	1.06	424	$9.2\ (10)^5$	$27.6\ (10)^3$	$7.8\ (10)^5$

Assumptions: (a) D_2O total inventory varies as shown on attached curve VII-2 .

(b) D_2O loss rate = 3%/yr. of total inventory.

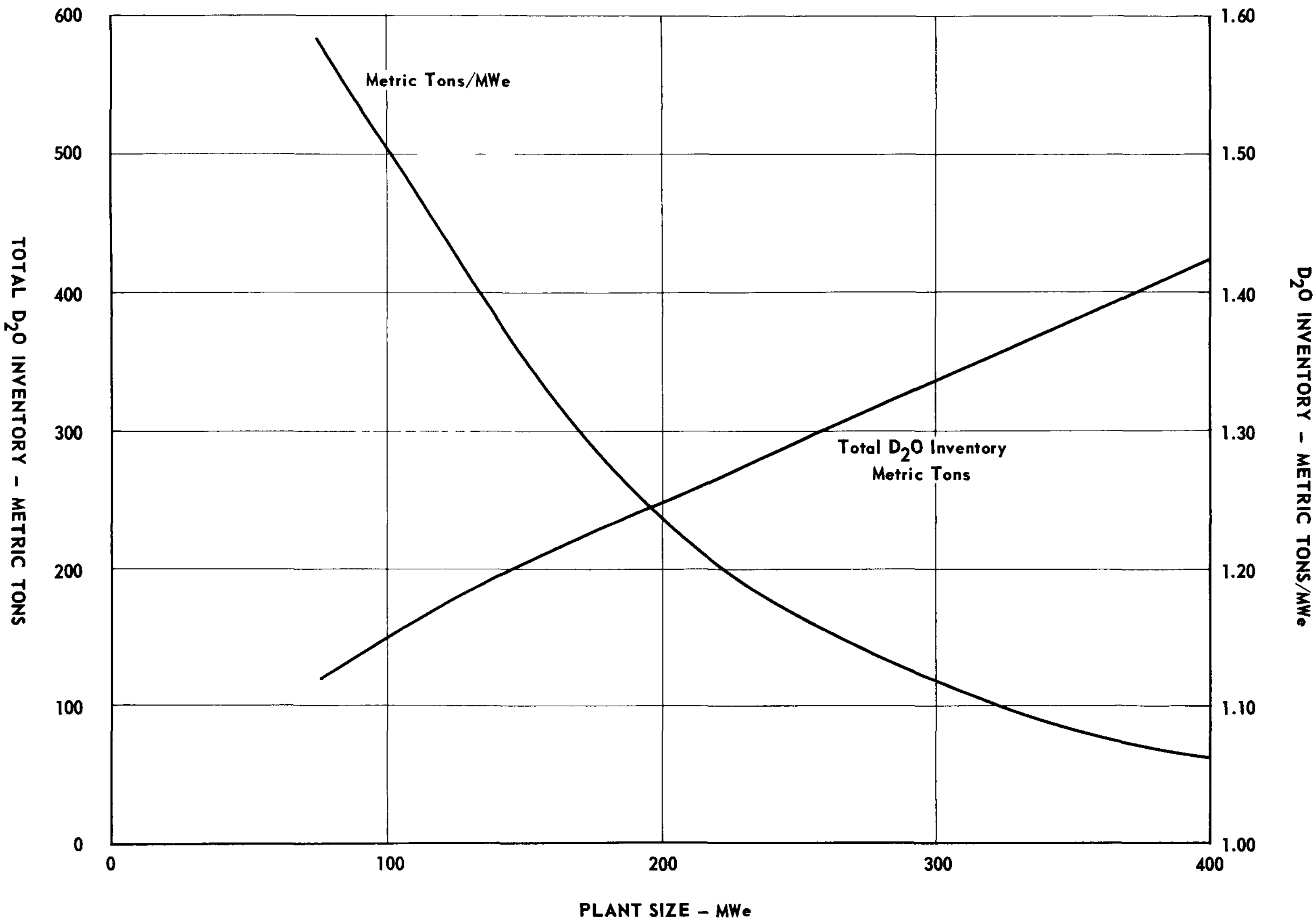
(c) D_2O cost = $28.00/lb.

Table VII-14
SL-1674



ORGANIC COOLANT MAKE UP AT 25#/MWD thermal/YEAR

Figure VII-1
SL-1674



HEAVY WATER (D_2O) INVENTORY

Figure VII-2
SL-1674

COMPARISON OF OPERATING AND MAINTENANCE COSTS FOR CONVENTIONAL AND NUCLEAR ONE UNIT PLANTS

(Excludes make-up and losses of fluids, special maintenance and operating techniques)

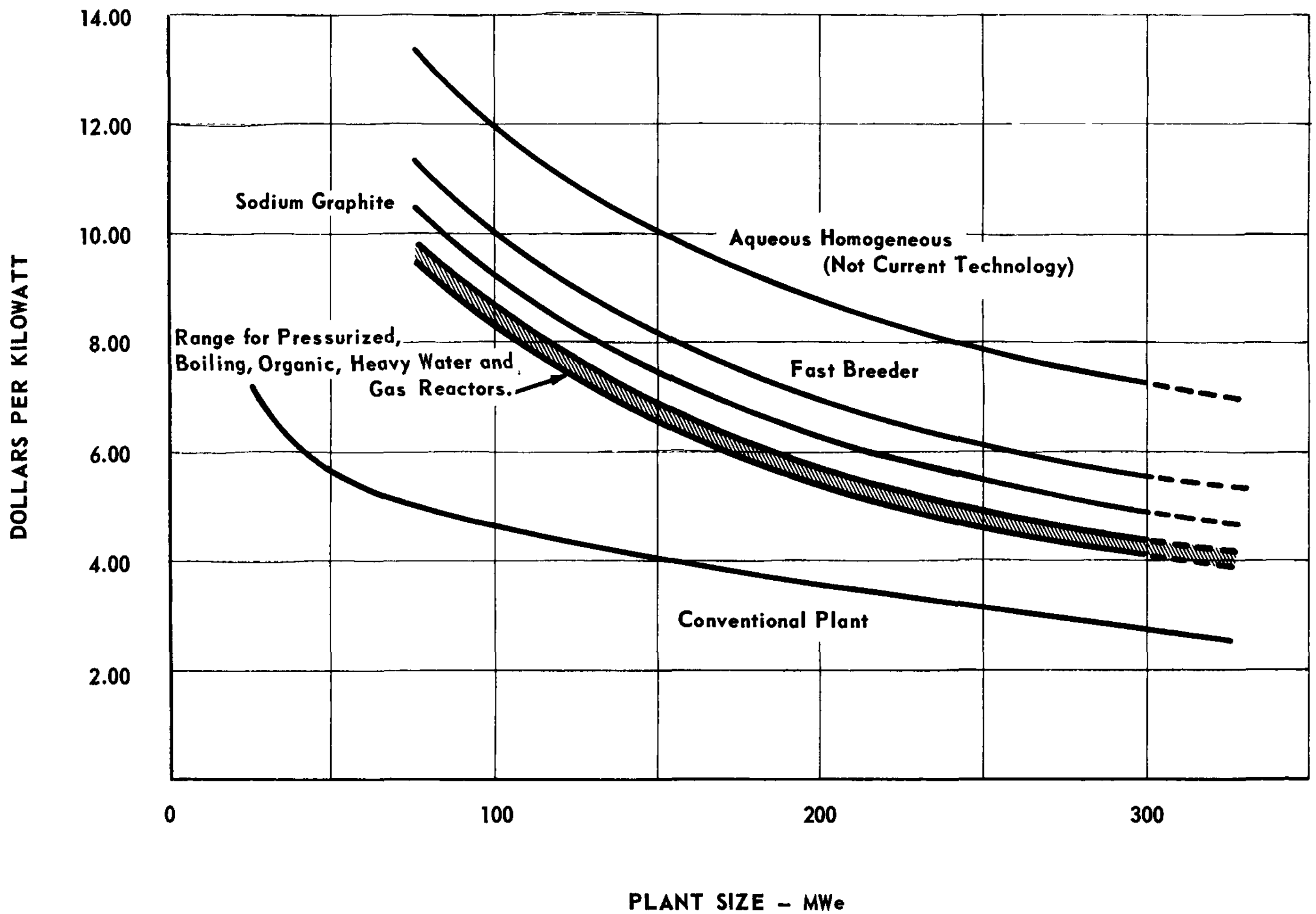


Figure VII-3
SL-1674

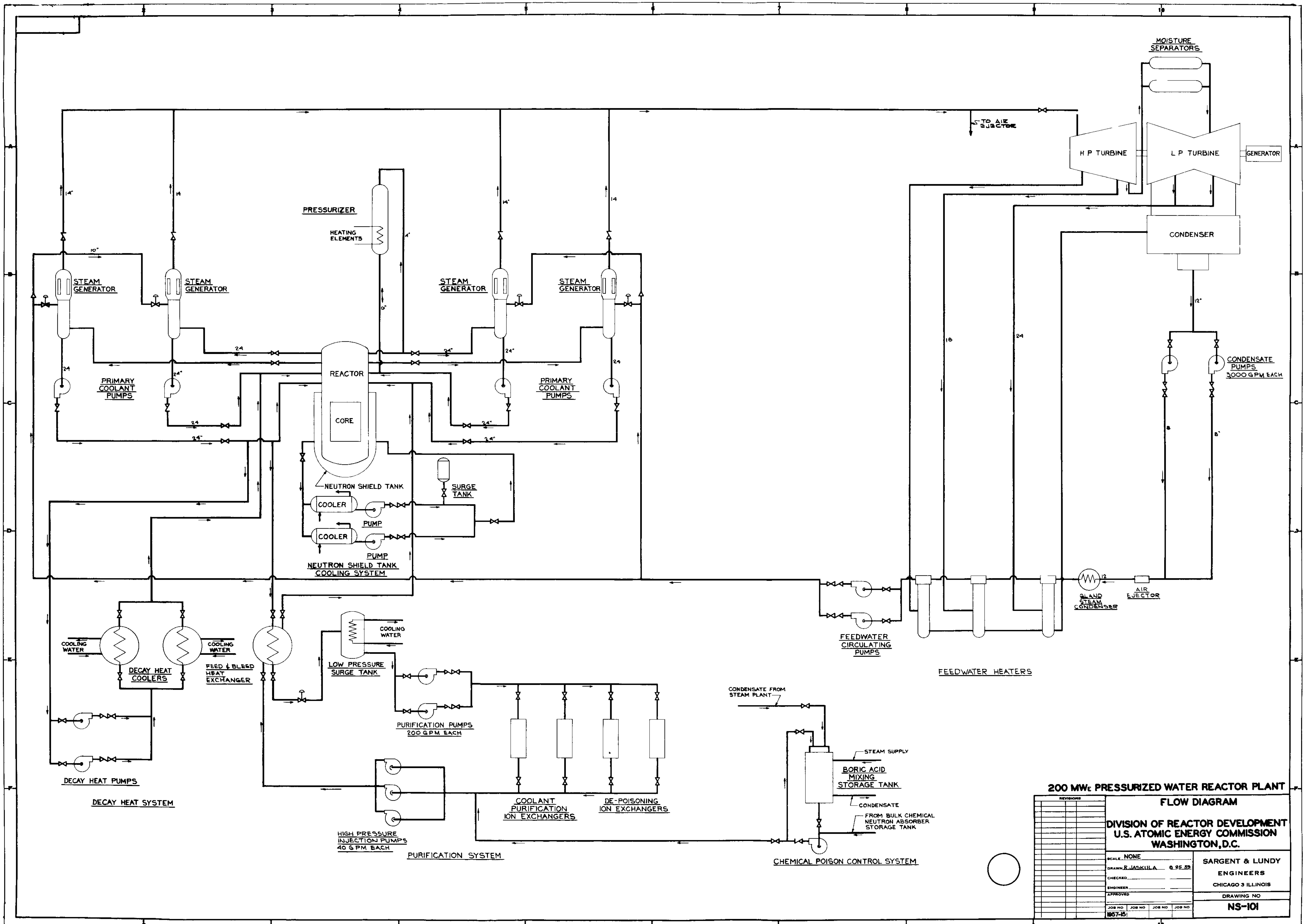
DRAWING LIST

Drawing Number	Drawing Title
	200 MW(e) Pressurized Water Reactor Plant
NS-101	Flow Diagram
NS-102	Property Plat
NS-103	General Arrangement Plan Upper Floor "A-A" Reactor Building
NS-104	General Arrangement Plan Upper Floor "B-B" Reactor Building
NS-105	General Cross Section "C-C" Reactor Building
NS-106	General Cross Section "D-D" Reactor Building
NS-107	General Arrangement Plan Main Floor Turbine Building
NS-108	General Arrangement Plan Mezz. & Basement Floor Turbine Building
NS-109	General Cross Section "A-A" Turbine Building
NS-110	Longitudinal Section "B-B" Turbine Building
ES-101	Electrical Diagram
	75 MW(e) Pressurized Water Reactor Plant
NS-111	General Arrangement Plan & Section
	300 MW(e) Pressurized Water Reactor Plant
NS-112	General Arrangement Plan & Section
	200 MW(e) Boiling Water Reactor Plant
NS-201	Flow Diagram
NS-202	Property Plat
NS-203	General Arrangement Plan Upper Floor "A-A" Reactor Building
NS-204	General Arrangement Plan Lower Floor "B-B" Reactor Building
NS-205	General Cross Section "C-C" Reactor Building
NS-206	General Cross Section "D-D" Reactor Building
NS-207	General Arrangement Plan Main Floor Turbine Building
NS-208	General Arrangement Plan Basement & Mezz. Floor Turbine Building
NS-209	General Cross Section "A-A" Turbine Building
NS-210	Longitudinal Section "B-B" Turbine Building
ES-201	Electrical Diagram
	75 MW(e) Boiling Water Reactor Plant
NS-211	General Arrangement Plan & Section
	300 MW(e) Boiling Water Reactor Plant
NS-212	General Arrangement Plan & Section
	75 MW(e) Organic Cooled Reactor Plant
NS-301	Flow Diagram
NS-302	Property Plat
NS-303	General Arrangement Plans Upper Floors "A-A" & "B-B" Reactor Building

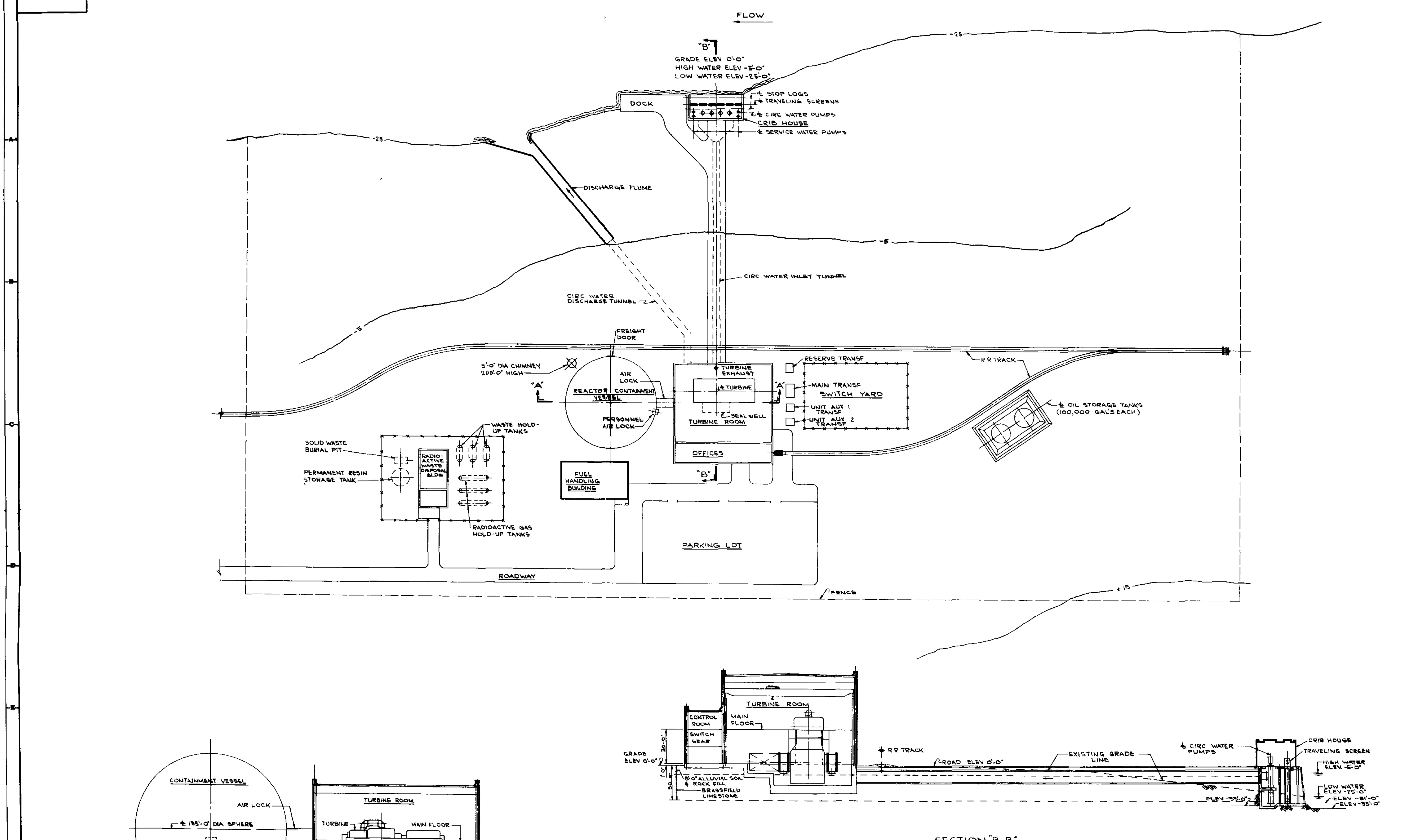
Drawing Number	Drawing Title
	75 MW(e) Boiling Water Reactor Plant (Cont.)
NS-304	General Arrangement Plan Lower Floor "C-C" Reactor Building
NS-305	General Cross Section "D-D" Reactor Building
NS-306	General Cross Section "E-E" Reactor Building
NS-307	General Arrangement Plan Main Floor Turbine Building
NS-308	General Arrangement Plan Mezz. & Basement Floors Turbine Building
NS-309	General Cross Section "A-A" Turbine Building
NS-310	Longitudinal Section "B-B" Turbine Building
ES-301	Electrical Diagram
	200 MW(e) Organic Cooled Reactor Plant
NS-311	General Arrangement Plan & Section
	300 MW(e) Organic Cooled Reactor Plant
NS-312	General Arrangement Plan & Section
	75 MW(e) Sodium Graphite Reactor Plant
NS-401	Flow Diagram
NS-402	Property Plat
NS-403	General Arrangement Plan Upper Floor "A-A" Reactor Building
NS-404	General Arrangement Plan Lower Floor "B-B" Reactor Building
NS-405	General Cross Section "C-C" Reactor Building
NS-406	General Cross Sections "D-D" & "C-C" Reactor Building
NS-407	General Arrangement Plan Main Floor Turbine Building
NS-408	General Arrangement Plan Mezz. & Basement Floors Turbine Building
NS-409	General Cross Section "A-A" Turbine Building
NS-410	Longitudinal Section "B-B" Turbine Building
ES-401	Electrical Diagram
	300 MW(e) Sodium Graphite Reactor Plant
NS-411	General Arrangement Plan & Section
	300 MW(e) Sodium Graphite Reactor Plant
NS-412	General Arrangement Plan & Section
	200 MW(e) Heavy Water Moderated Reactor Plant
NS-501	Flow Diagram
NS-502	Property Plat
NS-503	General Arrangement Plan Upper Floor "A-A" Reactor Building
NS-504	General Arrangement Plan Lower Floors "B-B" & "C-C" Reactor Building
NS-505	General Cross Section "D-D" Reactor Building
NS-506	General Cross Section "E-E" Reactor Building
NS-507	General Arrangement Plan Main Floor Turbine Building

Drawing Number	Drawing Title
	200 MW(e) Heavy Water Moderated Reactor Plant (Cont.)
NS-508	General Arrangement Plan Mezz. & Basement Floors Turbine Building
NS-509	General Cross Section "A-A" Turbine Building
NS-510	Longitudinal Section "B-B" Turbine Building
ES-501	Electrical Diagram
	75 MW(e) Heavy Water Moderated Reactor Plant
NS-511	General Arrangement Plan & Section
	300 MW(e) Heavy Water Moderated Reactor Plant
NS-512	General Arrangement Plan & Section
	200 MW(e) Gas Cooled Reactor Plant
NS-601	Flow Diagram
NS-602	Property Plat
NS-603	General Arrangement Plan Upper Floor "A-A" Reactor Building
NS-604	General Arrangement Plan Lower Floor "B-B" Reactor Building
NS-605	General Cross Section "C-C" Reactor Building
NS-606	General Cross Section "D-D" Reactor Building
NS-607	General Arrangement Plan Main Floor Turbine Building
NS-608	General Arrangement Plan Basement & Mezz. Floors Turbine Building
NS-609	General Cross Section "A-A Turbine Building
NS-610	Longitudinal Section "B-B" Turbine Building
ES-601	Electrical Diagram
	75 MW(e) Gas Cooled Reactor Plant
NS-611	General Arrangement Plan & Section
	300 MW(e) Gas Cooled Reactor Plant
NS-612	General Arrangement Plan & Section
	150 MW(e) Fast Breeder Reactor Plant
NS-701	Flow Diagram
NS-702	Property Plat
NS-703	General Arrangement Plans "A-A" & "B-B" Reactor Building
NS-704	General Cross Sections "C-C" & "D-D" Reactor Building
NS-705	General Arrangement Plans Main & Basement Floors Turbine Building
NS-706	General Cross Sections "A-A & "B-B" Turbine Building
ES-701	Electrical Diagram
	75 MW(e) Fast Breeder Reactor Plant
NS-707	General Arrangement Plan & Section
	300 MW(e) Fast Breeder Reactor Plant
NS-708	General Arrangement Plan & Section

Drawing Number	Drawing Title
	200 MW(e) Aqueous Homogeneous Reactor Plant
NS-801	Flow Diagram
NS-802	Property Plat
NS-803	General Arrangement Plan Turbine Building & Reactor Building
NS-804	General Arrangement Plan Upper Floor Reactor Building
NS-805	General Cross Section "A-A" Reactor Building
NS-806	General Arrangement Plan Main Floor Turbine Building
NS-807	General Arrangement Plan Mezz. & Basement Floors Turbine Building
NS-808	General Cross Section "A-A" Turbine Building
NS-809	Longitudinal Section "B-B" Turbine Building
ES-801	Electrical Diagram
	75 MW(e) Aqueous Homogeneous Reactor Plant
NS-810	General Arrangement Plan & Section
	300 MW(e) Aqueous Homogeneous Reactor Plant
NS-811	General Arrangement Plan & Section



MOISTURE SEPARATORS
TO AIR EJECTOR
H P TURBINE
L P TURBINE
GENERATOR
CONDENSER
PRESSURIZER
HEATING ELEMENTS
STEAM GENERATOR
STEAM GENERATOR
STEAM GENERATOR
STEAM GENERATOR
REACTOR
CORE
PRIMARY COOLANT PUMPS
PRIMARY COOLANT PUMPS
NEUTRON SHIELD TANK
SURGE TANK
COOLER
COOLER
PUMP
PUMP
NEUTRON SHIELD TANK COOLING SYSTEM
CONDENSATE PUMPS 3000 GPM EACH
GLAND STEAM CONDENSER
AIR EJECTOR
FEEDWATER CIRCULATING PUMPS
FEEDWATER HEATERS
COOLING WATER
COOLING WATER
COOLING WATER
DECAY HEAT COOLERS
FEED & BLEED HEAT EXCHANGER
LOW PRESSURE SURGE TANK
PURIFICATION PUMPS 200 GPM EACH
DECAY HEAT PUMPS
DECAY HEAT SYSTEM
HIGH PRESSURE INJECTION PUMPS 40 GPM EACH
PURIFICATION SYSTEM
COOLANT PURIFICATION ION EXCHANGERS
DE-POISONING ION EXCHANGERS
CONDENSATE FROM STEAM PLANT
STEAM SUPPLY
BORIC ACID MIXING STORAGE TANK
CONDENSATE
FROM BULK CHEMICAL NEUTRON ABSORBER STORAGE TANK
CHEMICAL POISON CONTROL SYSTEM
200 MWe PRESSURIZED WATER REACTOR PLANT
FLOW DIAGRAM
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.
SCALE NONE
DRAWN R. JASKULA
CHECKED
ENGINEER
APPROVED
SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS
DRAWING NO
NS-101
JOB NO
1857-151



200 MWE PRESSURIZED WATER REACTOR PLANT

REVISIONS	

PROPERTY PLAT

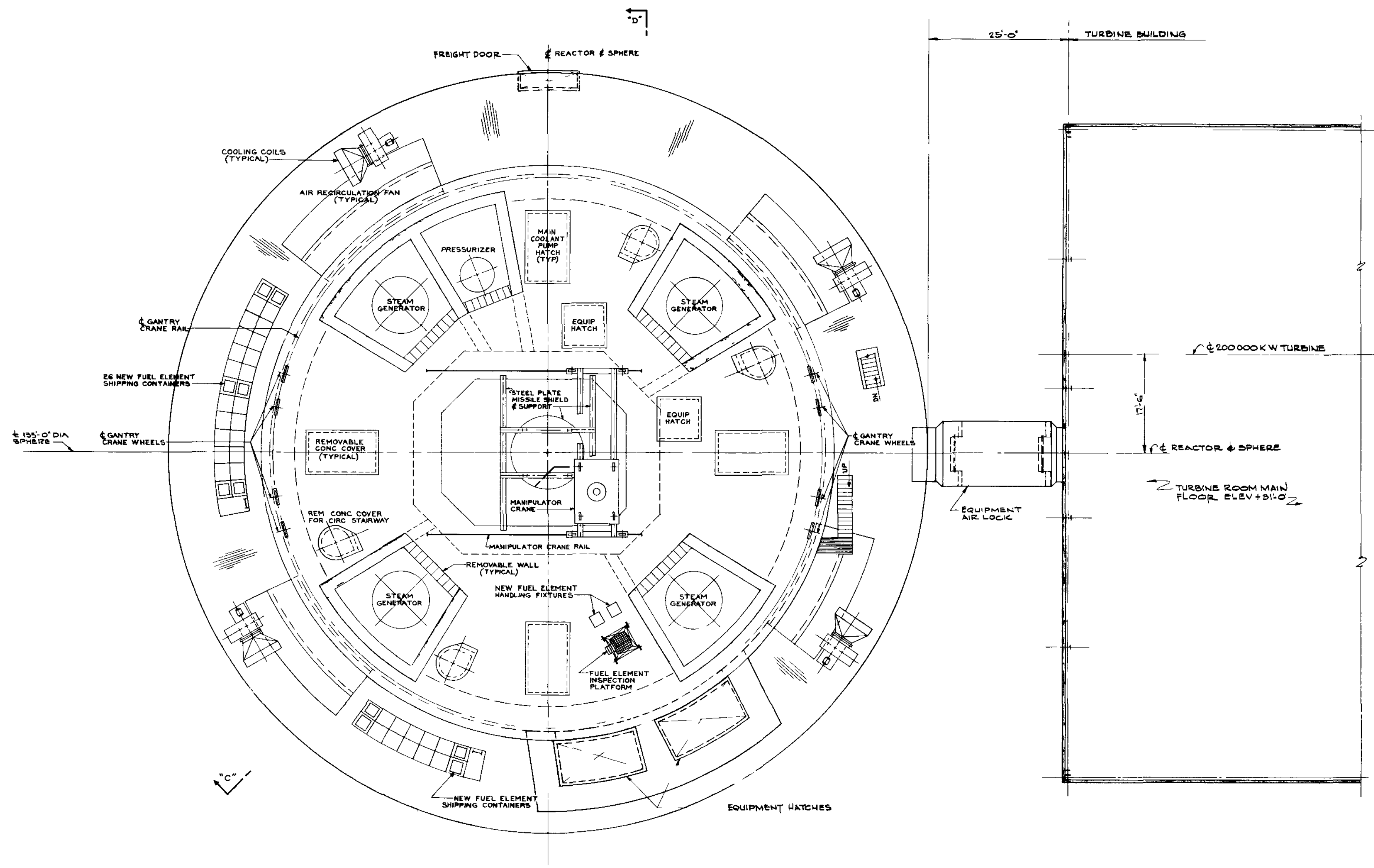
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1" = 50'-0" & AS NOTED
DRAWN R. JASKULA 8-25-59
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO	JOB NO
1957-15			

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-102



MAIN FLOOR
PLAN "A-A"

"D"

200 MWE PRESSURIZED WATER REACTOR PLANT

REVISIONS

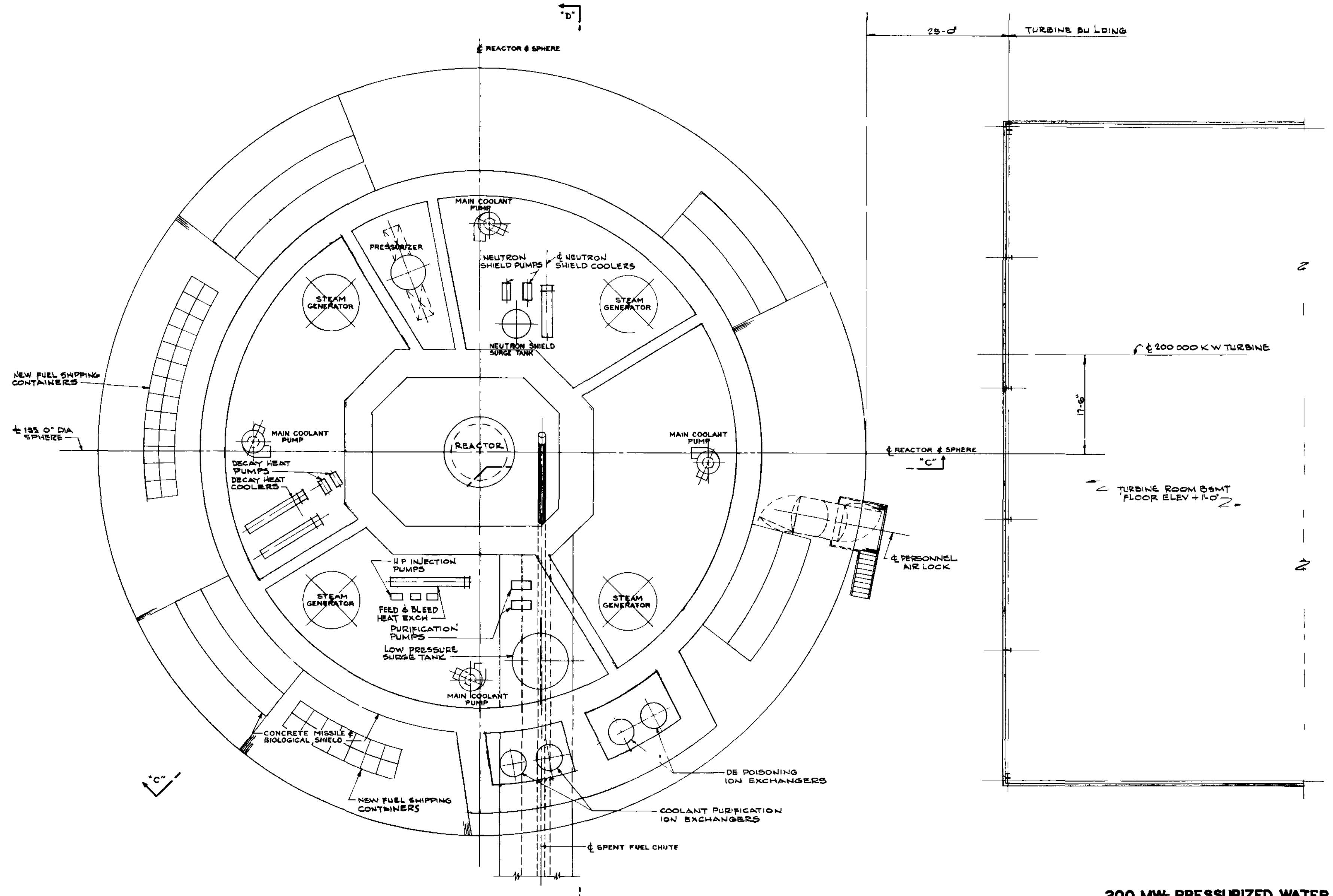
GENERAL ARRANGEMENT PLAN
UPPER FLOOR "A-A" REACTOR BLD'G
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN W.R. DEEHRING 8-25-59
CHECKED
ENGINEER
APPROVED

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

JOB NO 1957-15

DRAWING NO
NS-103



PLAN "B-B"

200 MWe PRESSURIZED WATER REACTOR PLANT

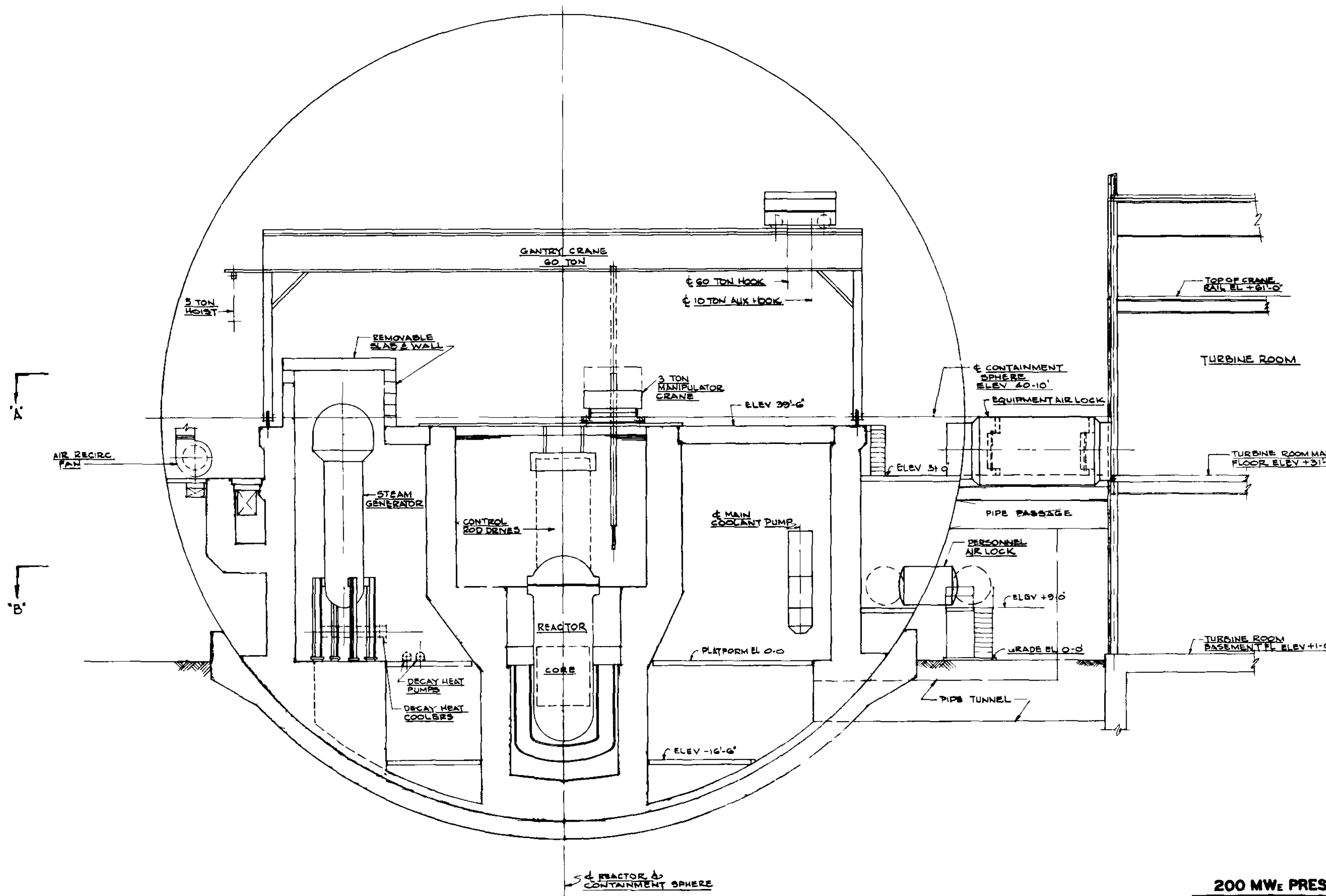
GENERAL ARRANGEMENT PLAN
LOWER FLOOR "B-B" REACTOR BLD'G
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

REVISIONS

SCALE	1/8"=1'-0"
DRAWN	W R DEEHRING 8-25-55
CHECKED	
ENGINEER	
APPROVED	
JOB NO	1957-B

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-104



SECTION "C-C"

200 MWe PRESSURIZED WATER REACTOR PLANT

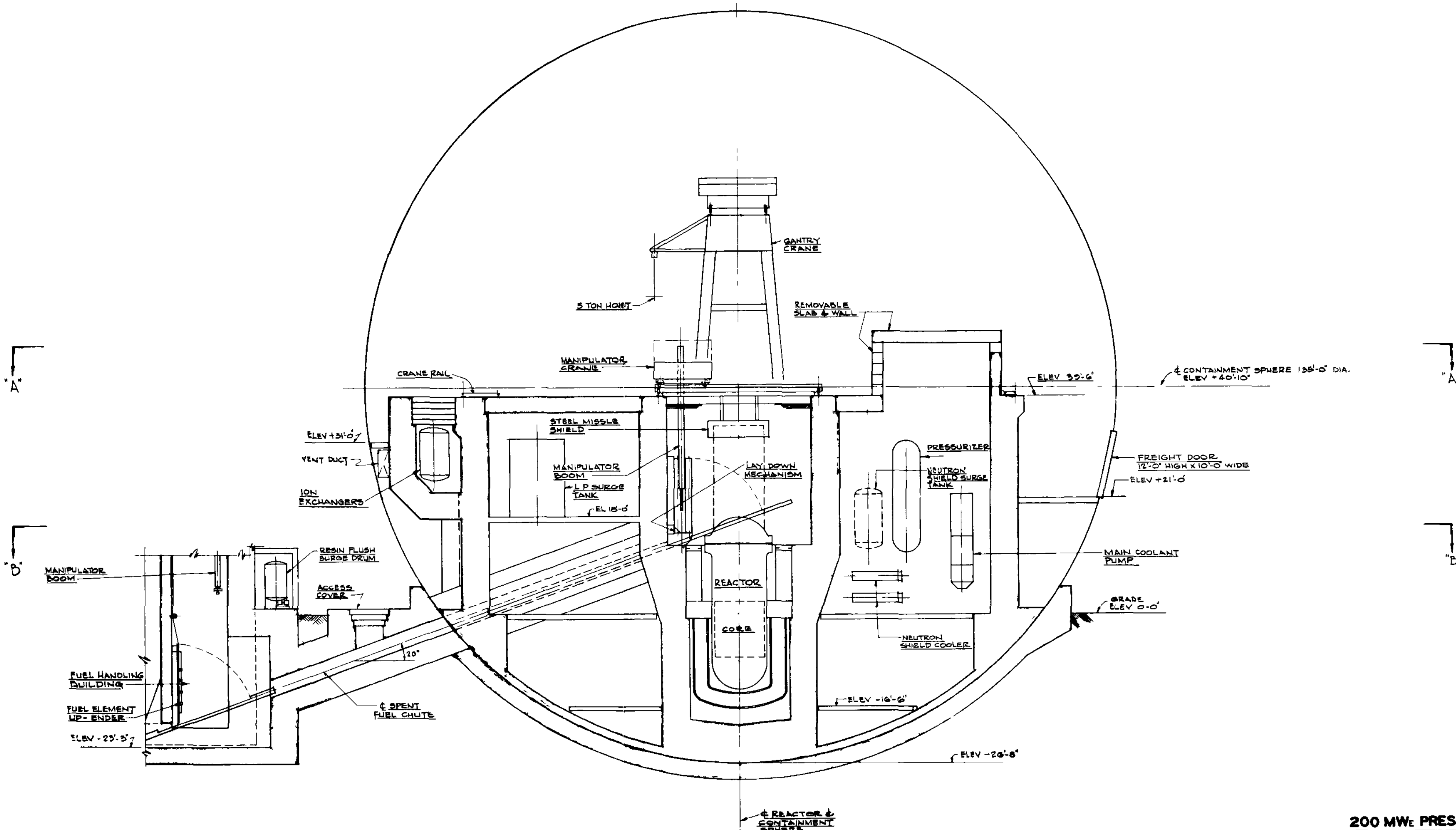
GENERAL CROSS SECTION "C-C"
REACTOR BLD'G
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

REVISIONS

SCALE 1/8"=1'-0"
DRAWN F.J. FILIP 6-25-59
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

DRAWING NO
NS-105



SECTION "D-D"

200 MWe PRESSURIZED WATER REACTOR PLANT

REVISIONS

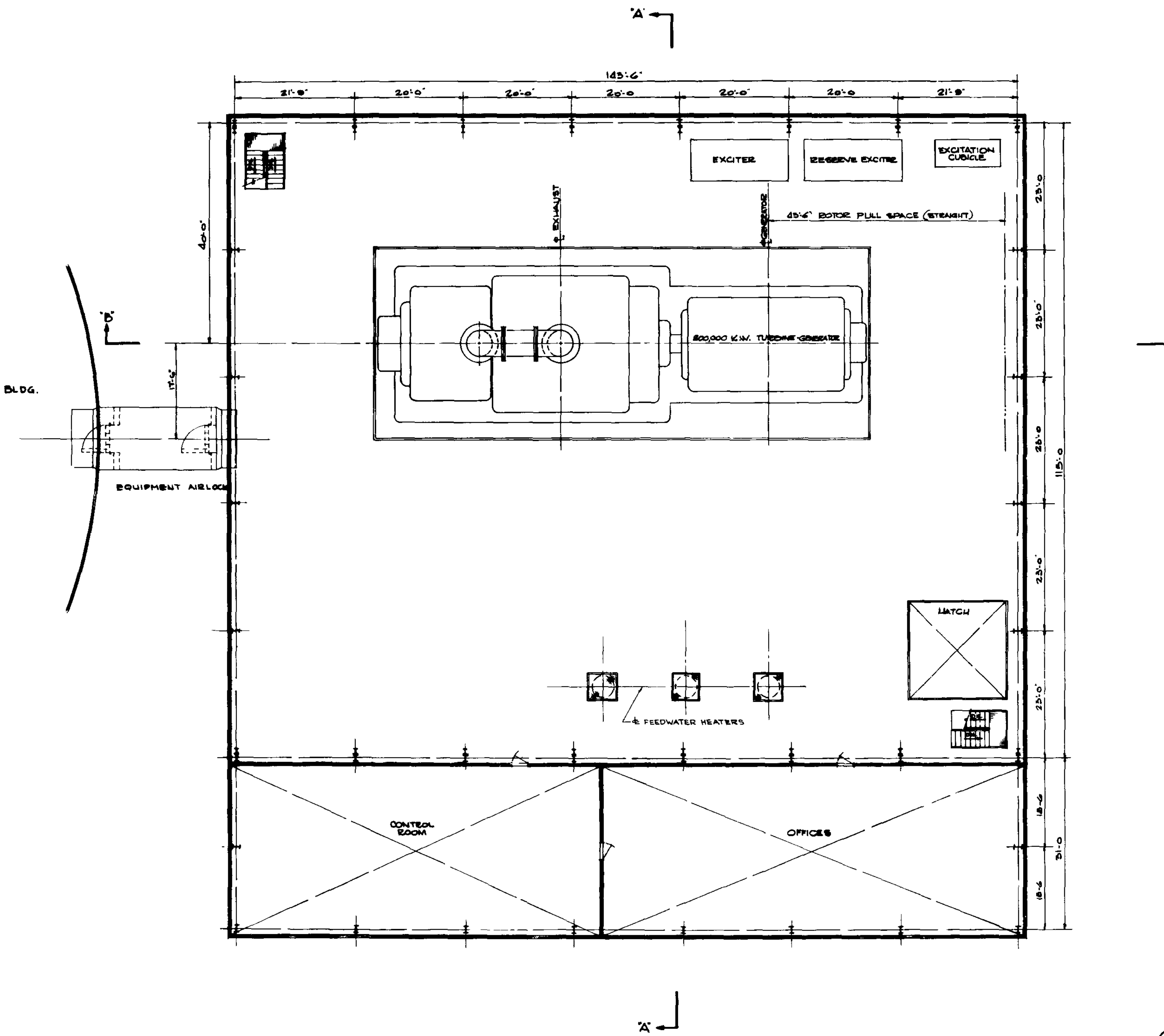
GENERAL CROSS SECTION "D-D"
REACTOR BLD'G
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN F.J.FILIP 6-25-59
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO	JOB NO
2857-15			

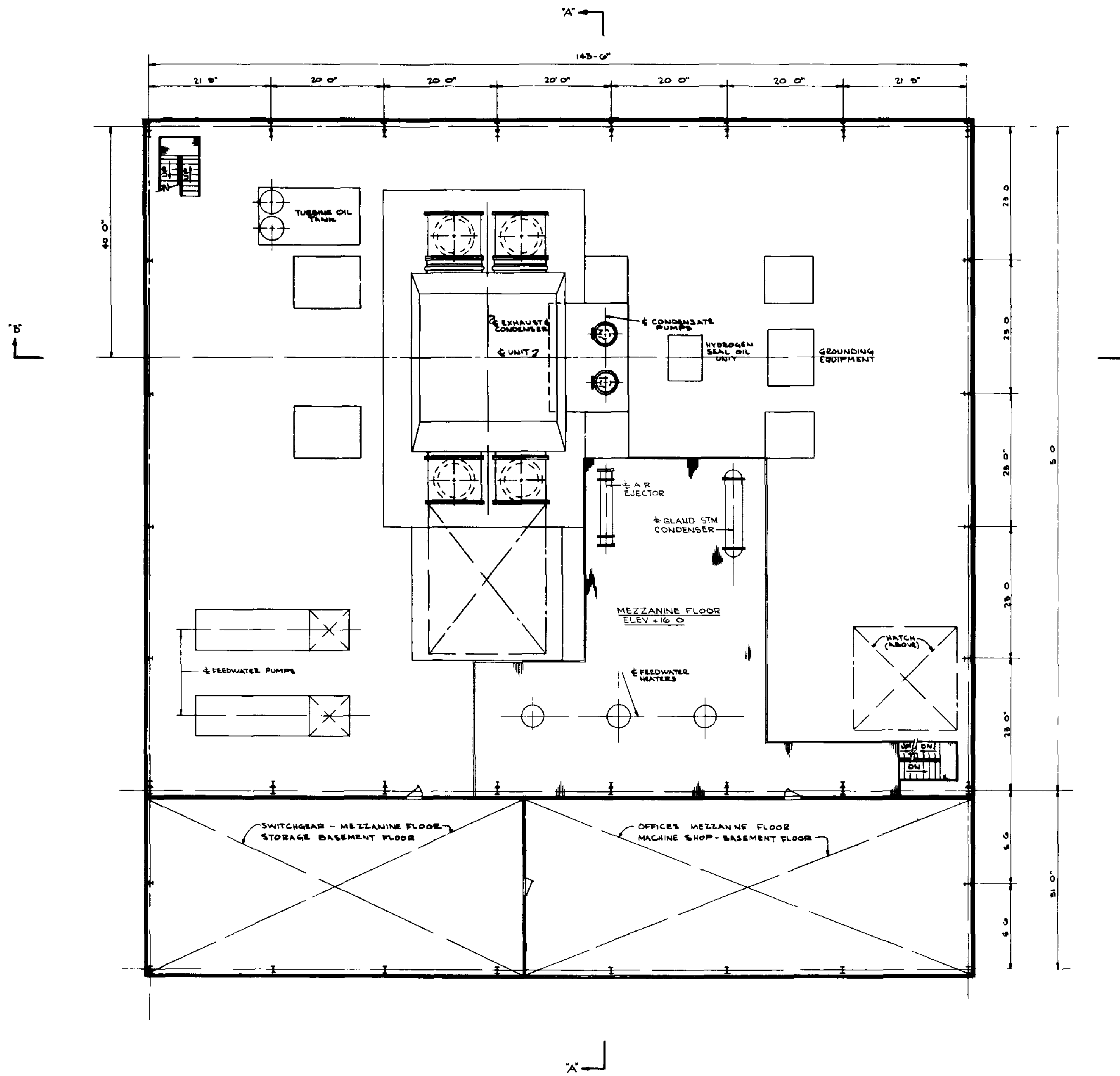
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO.
NS-106



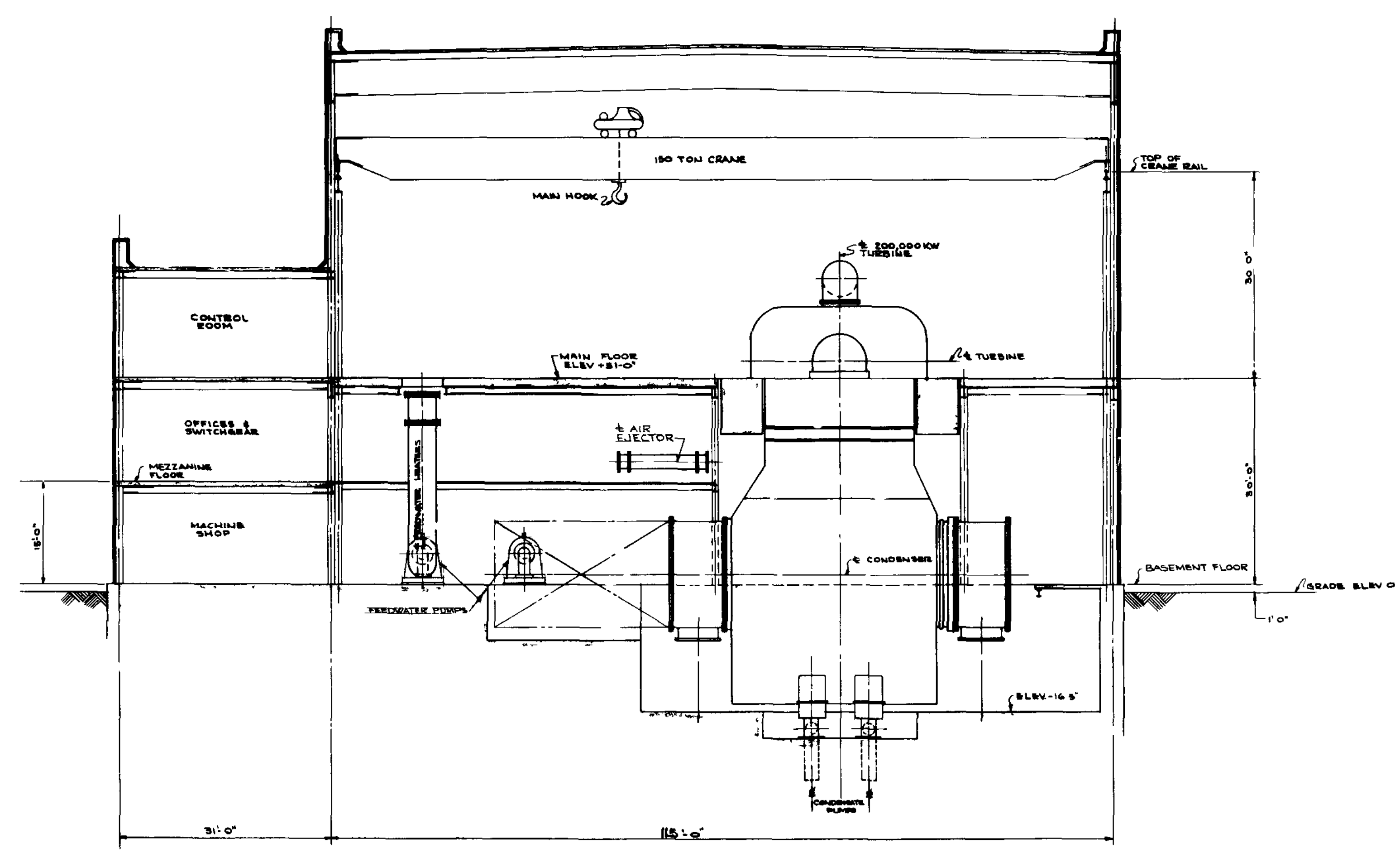
200 MWE PRESSURIZED WATER REACTOR PLANT

REVISIONS	GENERAL ARRANGEMENT PLAN MAIN FLOOR TURBINE BLD'G DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.	
	SCALE 1/8"=1'-0" DRAWN A J SCHALL 8-25-55 CHECKED ENGINEER	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
	APPROVED	DRAWING NO
	JOB NO 1957-15 · JOB NO · JOB NO · JOB NO	NS-107



200 MWe PRESSURIZED WATER REACTOR PLANT

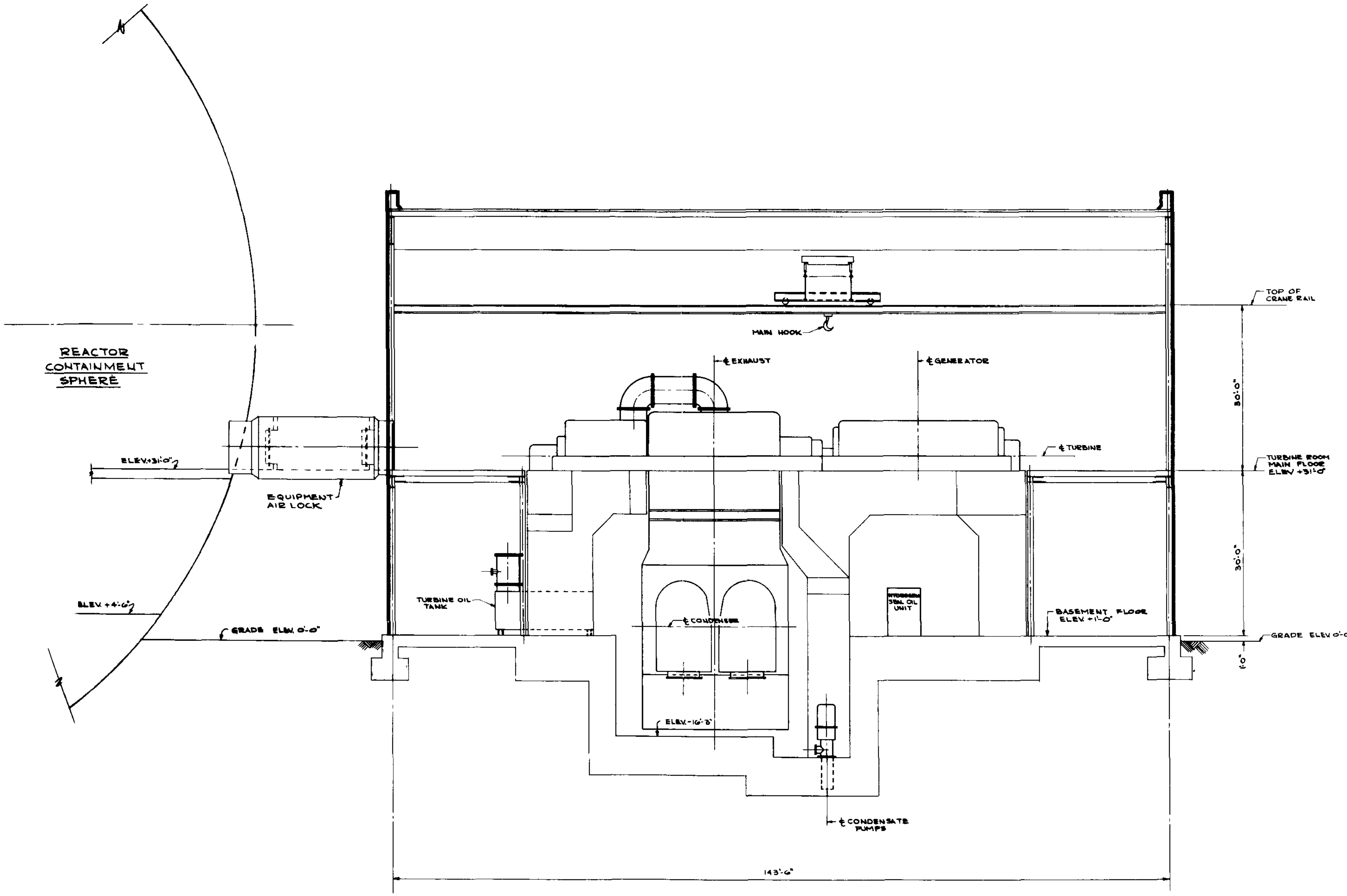
REVISIONS	GENERAL ARRANGEMENT PLAN MEZZ. & BASEMENT FL. TURBINE BLD'G DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.
SCALE 1/8"=1'-0" DRAWN A.J. SCHALL 6-25-55 CHECKED ENGINEER APPROVED	SARGENT & LUNDY ENGINEERS CHICAGO 3 ILLINOIS
JOB NO 1957-15	DRAWING NO NS-108



SECTION "A-A"

200 MWe PRESSURIZED WATER REACTOR PLANT

REVISIONS	GENERAL CROSS SECTION "A-A" TURBINE BLD'G DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.
SCALE 1/8"=1'-0"	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWN A J SCHALL 8-25-59	
CHECKED	
ENGINEER	
APPROVED	DRAWING NO
JOB NO 1957-15	NS-109



SECTION "B-B"

200 MWe PRESSURIZED WATER REACTOR PLANT

LONGITUDINAL SECTION "B-B"
TURBINE BLD'G
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

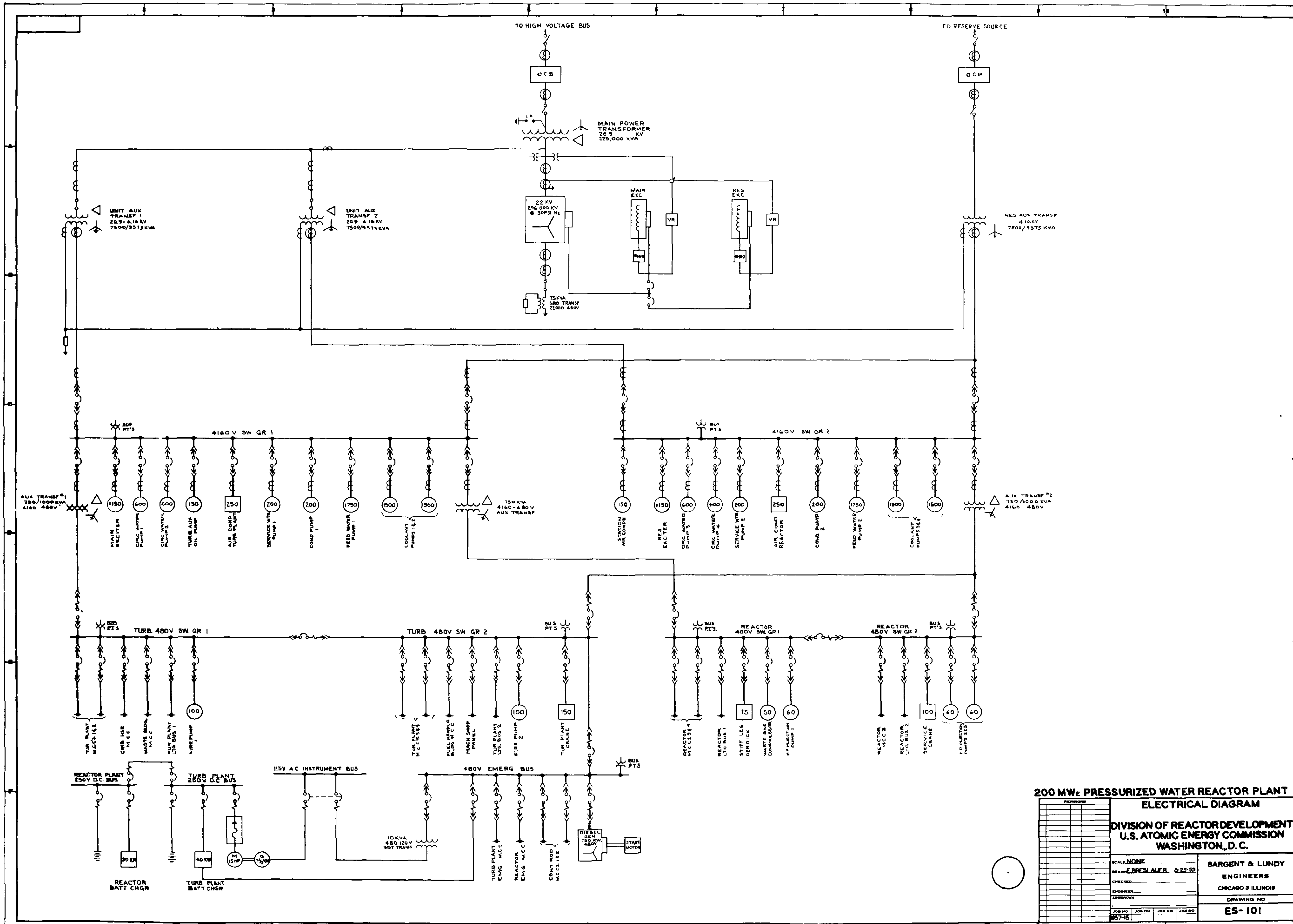
REVISIONS

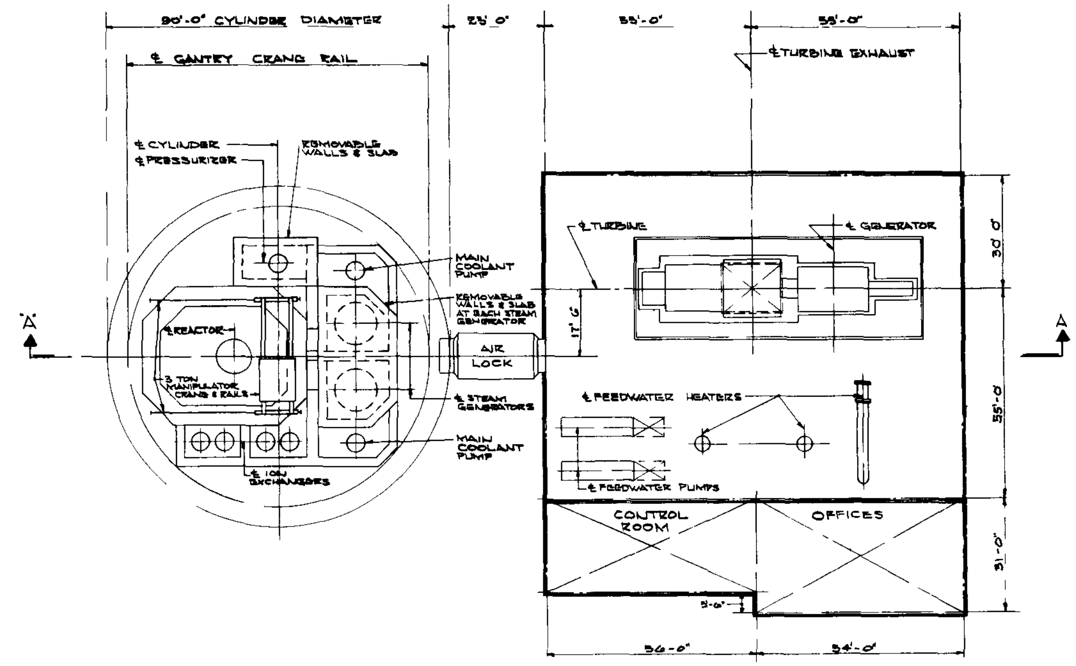
SCALE 1/8"=1'-0"
DRAWN A J SCHALL 8-25-59
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO	JOB NO
1957-15			

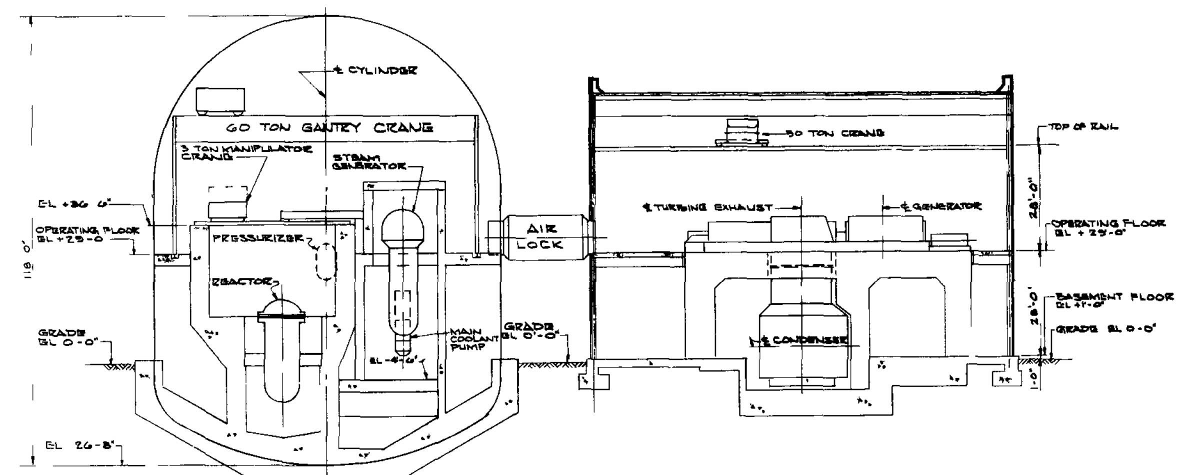
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-110


TO HIGH VOLTAGE BUS
TO RESERVE SOURCE
OCB
OCB
MAIN POWER TRANSFORMER 20.9 KV 225,000 KVA
UNIT AUX TRANSF 1 20.9-4.16KV 7500/9375KVA
UNIT AUX TRANSF 2 20.9-4.16KV 7500/9375KVA
RES AUX TRANSF 4.16KV 7500/9375 KVA
MAIN EXC
RES EXC
VR
VR
RHEO
RHEO
75KVA GRD TRANSF 22000-480V
4160V SW GR 1
4160V SW GR 2
BUS PT'S
AUX TRANSF #1 750/1000 KVA 4160-480V
750 KVA 4160-480V AUX TRANSF
AUX TRANSF #2 750/1000 KVA 4160-480V
MAIN EXCITER
CIRC WATER PUMP 1
CIRC WATER PUMP 2
TURB AUX OIL PUMP
AIR COND TURB PLANT
SERVICE WTR PUMP 1
COND PUMP 1
FEED WATER PUMP 1
COOLANT PUMPS 1 & 2
STATION AIR COMPR
RES EXCITER
CIRC WATER PUMP 3
CIRC WATER PUMP 4
SERVICE WTR PUMP 2
AIR COND REACTOR
COND PUMP 2
FEED WATER PUMP 2
COOLANT PUMPS 3 & 4
TURB 480V SW GR 1
TURB 480V SW GR 2
REACTOR 480V SW GR 1
REACTOR 480V SW GR 2
TUR PLANT MCC'S 1 & 2
CRIB HSE MCC
WASTE BLDG MCC
TUR PLANT LTG BUS 1
FIRE PUMP 1
TUR PLANT MCC'S 3 & 4
FUEL HANDLING BLDG MCC
MACH SHOP PANEL
TUR PLANT LTG BUS 2
FIRE PUMP 2
TUR PLANT CRANE
REACTOR MCC'S 3 & 4
REACTOR LTG BUS 1
STIFF LEG DERRICK
WASTE GAS COMPRESSOR
HP INJECTION PUMP 1
REACTOR MCC 3
REACTOR LTG BUS 2
SERVICE CRANE
HP INJECTION PUMPS 2 & 3
REACTOR PLANT 250V D.C. BUS
TURB PLANT 250V D.C. BUS
115V AC INSTRUMENT BUS
480V EMERG BUS
10 KVA 480-120V INST TRANS
REACTOR BATT CHGR
TURB PLANT BATT CHGR
TURB PLANT EMERG MCC
REACTOR EMERG MCC
CONT ROD MCC'S 1 & 2
DIESEL GEN 750 KW 480V
START MOTOR
200 MWE PRESSURIZED WATER REACTOR PLANT
ELECTRICAL DIAGRAM
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.
SCALE NONE
DRAWN E BRESLAUER 8-25-53
SARGENT & LUNDY ENGINEERS
CHICAGO 3 ILLINOIS
DRAWING NO
ES-101



PLAN



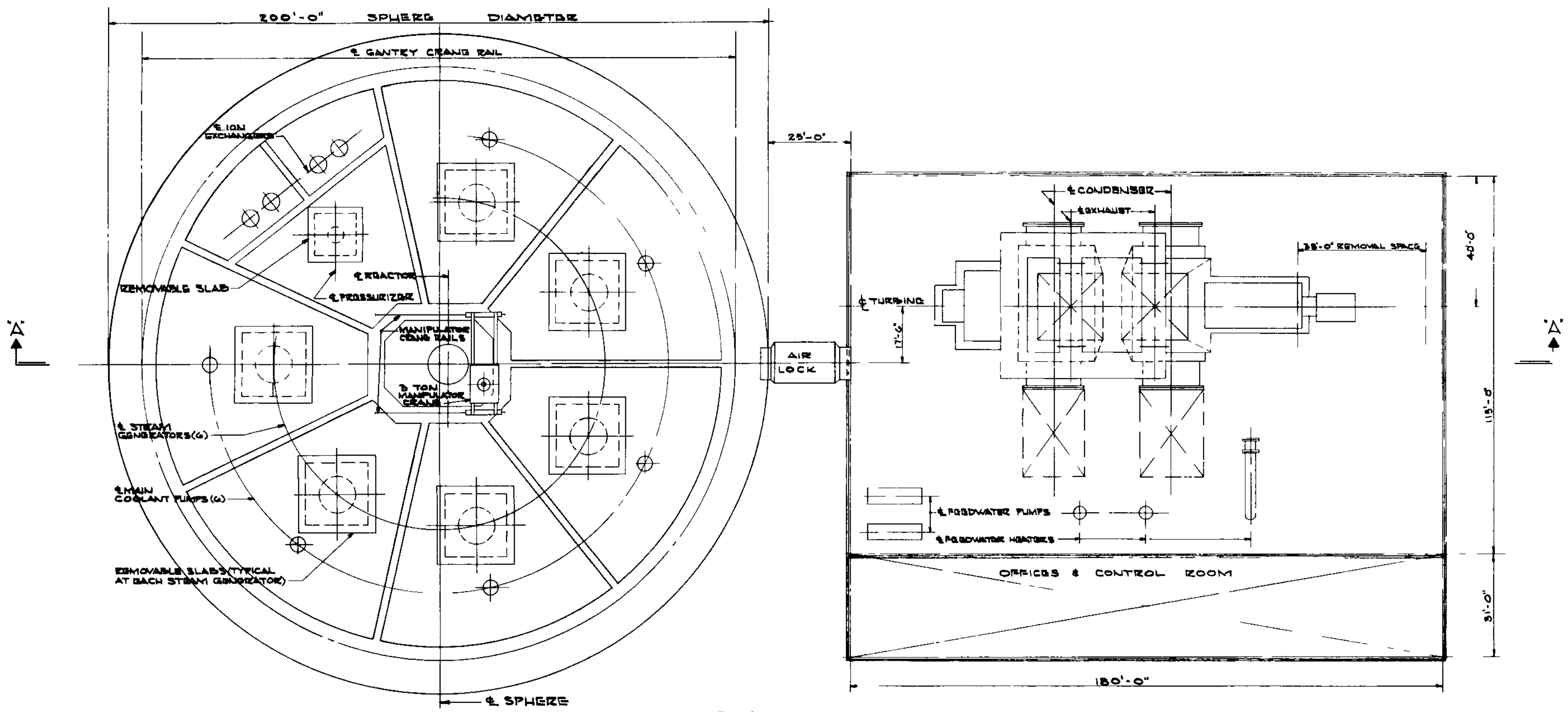
SECTION "A-A"

75 MWe PRESSURIZED WATER REACTOR PLANT

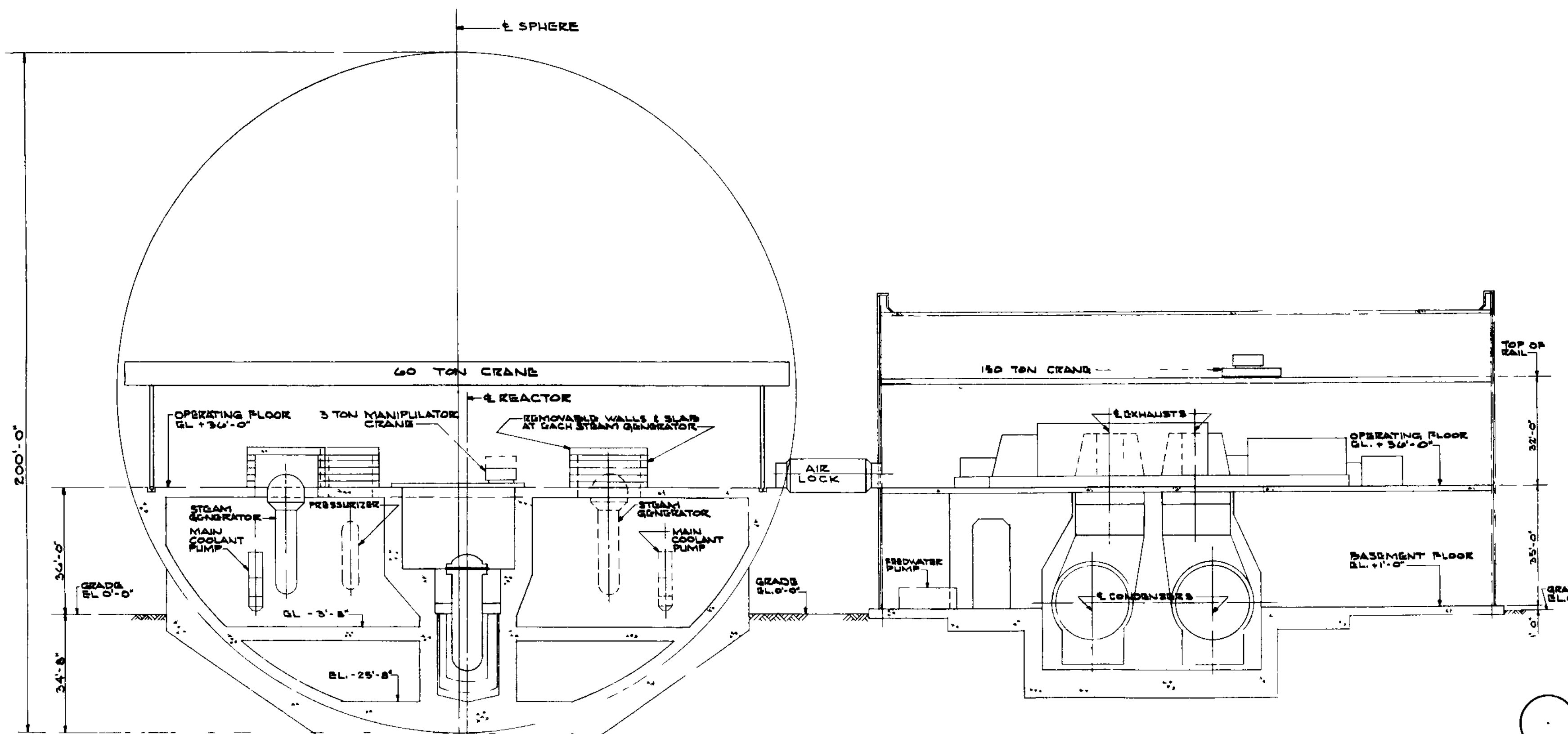
GENERAL ARRANGEMENT PLAN & SECTION

DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

REVISIONS	
SCALE 1/16" = 1'-0"	SARGENT & LUNDY
DRAWN A E JOHNSEN 8-25-57	ENGINEERS
CHECKED	CHICAGO 3 ILLINOIS
ENGINEER	
APPROVED	DRAWING NO
JOB NO 1957-15	NS-111



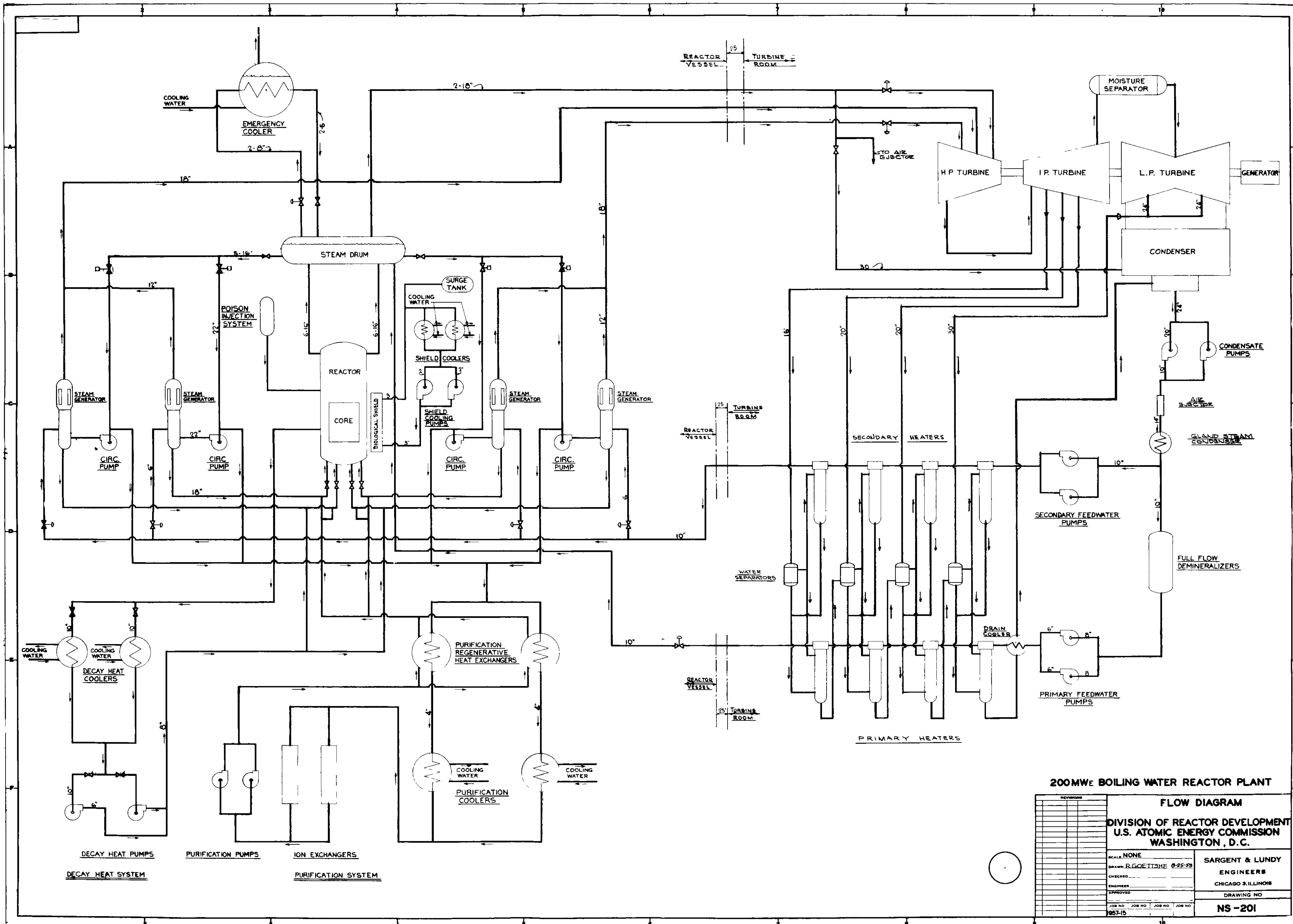
PLAN

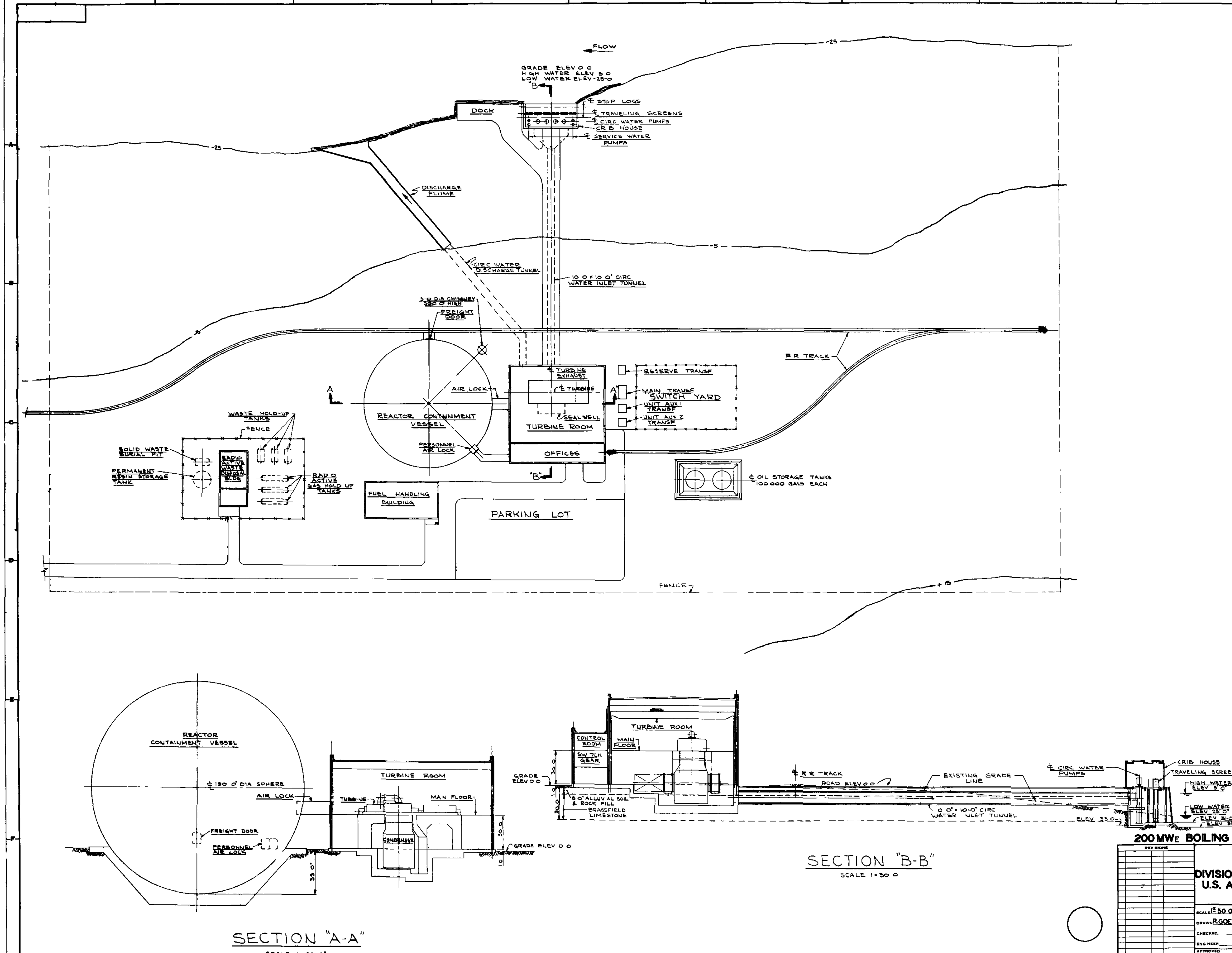


SECTION "A-A"

300 MWe PRESSURIZED WATER REACTOR PLANT

REVISIONS	GENERAL ARRANGEMENT PLAN & SECTION DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.
SCALE 1/16"=1'-0" DRAWN A E JOHNSEN 8-25-57 CHECKED ENGINEER APPROVED	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
JOB NO 1957-15	DRAWING NO NS-112


200 MWe BOILING WATER REACTOR PLANT
FLOW DIAGRAM
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
SCALE NONE
DRAWN R.GOETTSHE 8-25-59
DRAWING NO
NS-201
REVISIONS
CHECKED
ENGINEER
APPROVED
JOB NO
1957-15
EMERGENCY COOLER
COOLING WATER
STEAM DRUM
REACTOR
CORE
BIOLOGICAL SHIELD
POISON INJECTION SYSTEM
SURGE TANK
SHIELD COOLERS
SHIELD COOLING PUMPS
STEAM GENERATOR
CIRC. PUMP
REACTOR VESSEL
TURBINE ROOM
MOISTURE SEPARATOR
H.P. TURBINE
I.P. TURBINE
L.P. TURBINE
GENERATOR
TO AIR EJECTOR
CONDENSER
CONDENSATE PUMPS
AIR EJECTOR
GLAND STEAM CONDENSER
SECONDARY HEATERS
WATER SEPARATORS
SECONDARY FEEDWATER PUMPS
FULL FLOW DEMINERALIZERS
DRAIN COOLER
PRIMARY FEEDWATER PUMPS
PRIMARY HEATERS
DECAY HEAT COOLERS
DECAY HEAT PUMPS
DECAY HEAT SYSTEM
PURIFICATION REGENERATIVE HEAT EXCHANGERS
PURIFICATION COOLERS
PURIFICATION PUMPS
ION EXCHANGERS
PURIFICATION SYSTEM



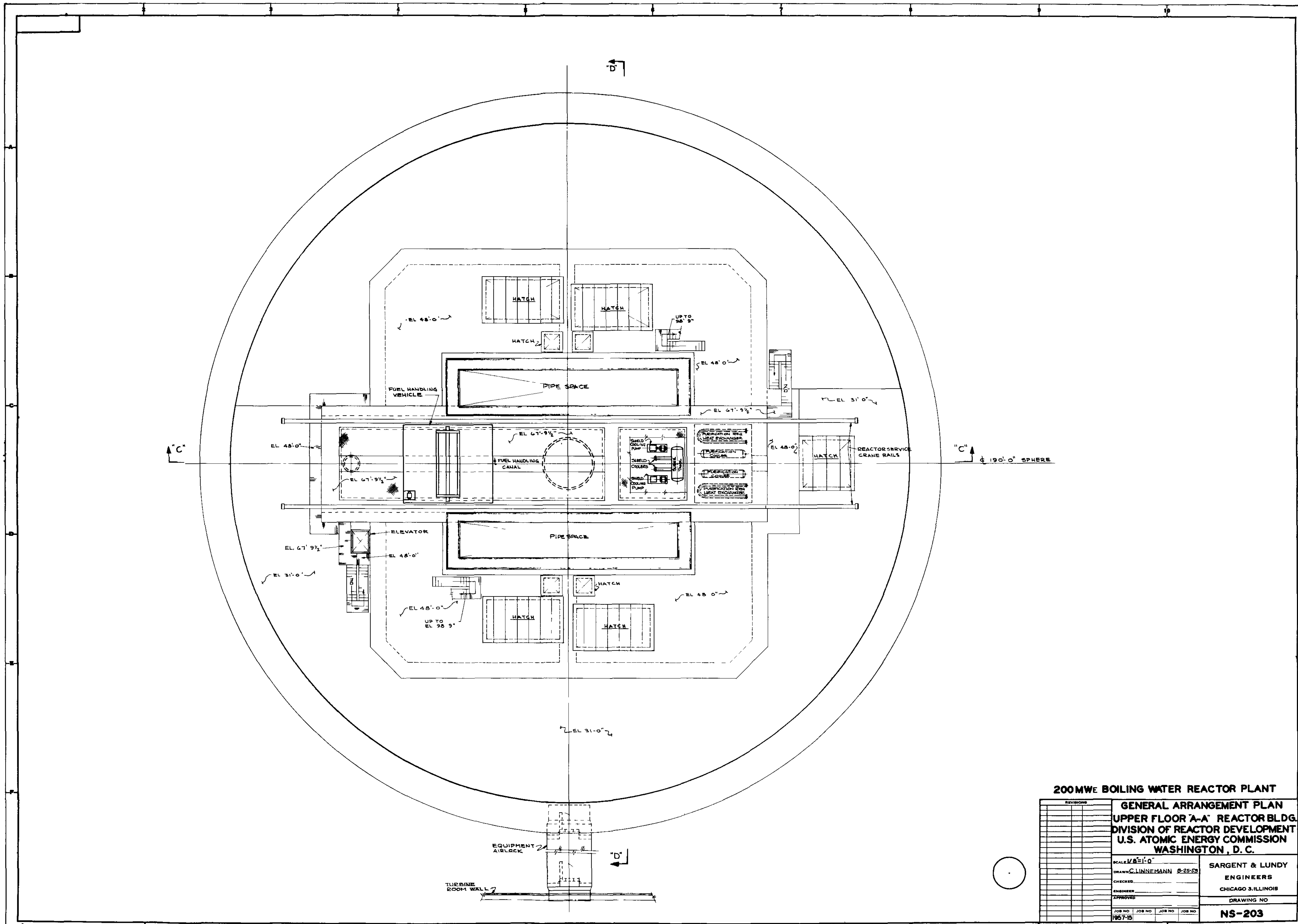
200 MWe BOILING WATER REACTOR PLANT

PROPERTY PLAT

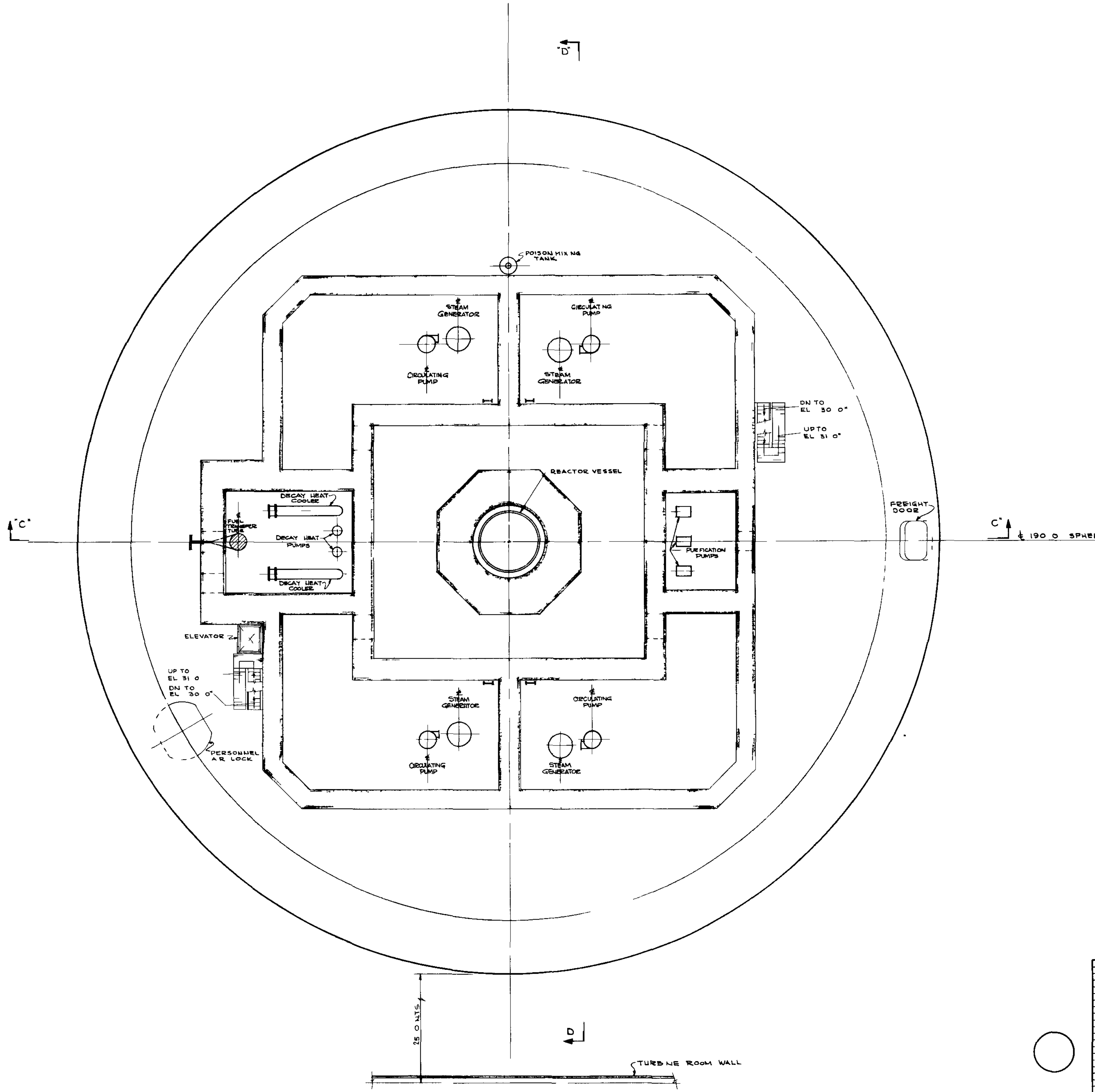
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D. C.

SCALE 1" = 50 0" & AS NOTED	SARGENT & LUNDY ENGINEERS CHICAGO 3 ILLINOIS
DRAWN R.GOETTSCHE 8 25-59	
CHECKED	
ENGINEER	
APPROVED	DRAWING NO
JOB NO 1957-15	NS-202

REVISIONS

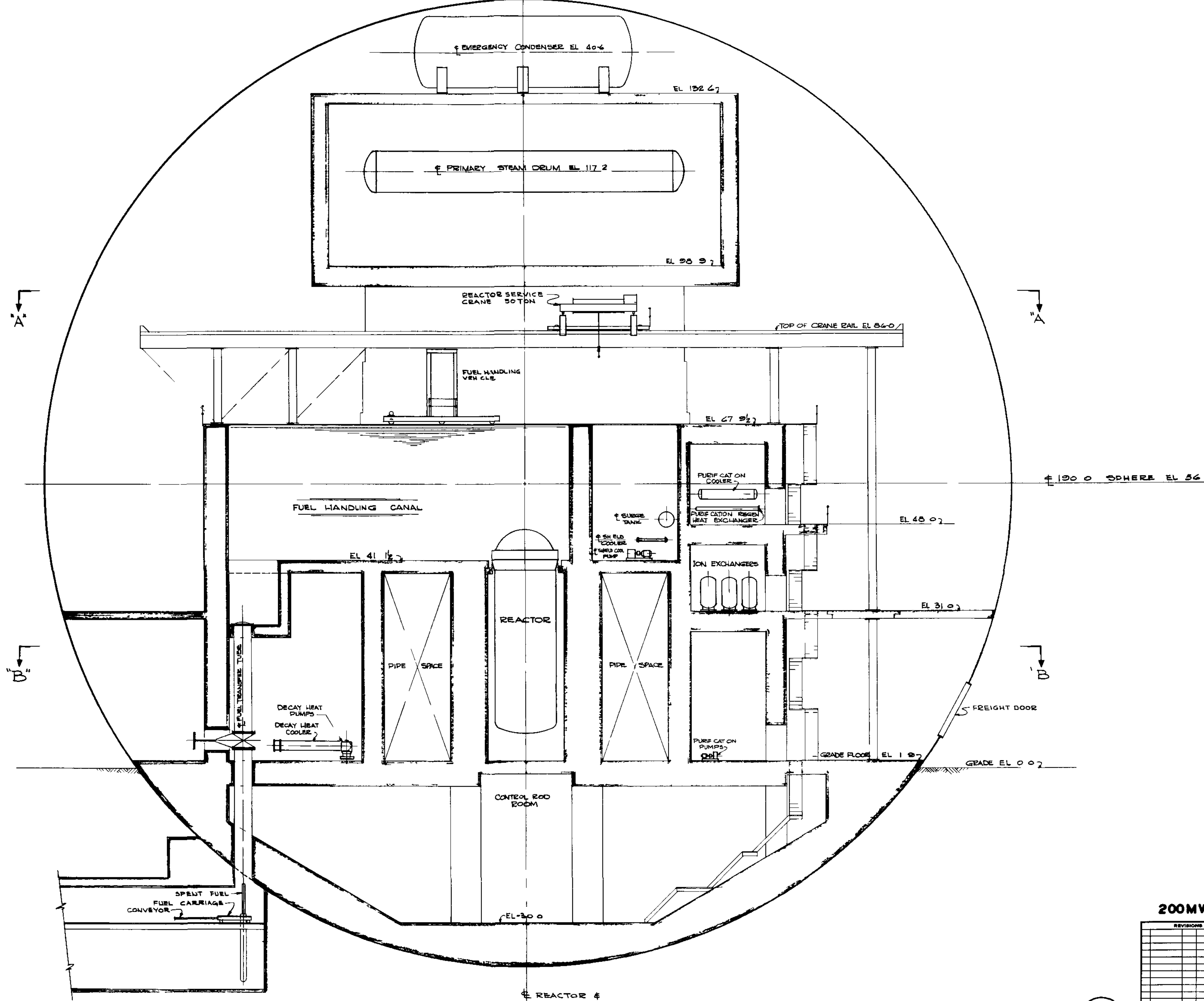


"D"
HATCH
HATCH
HATCH
HATCH
HATCH
HATCH
UP TO 98' 9"
EL 48'-0"
PIPE SPACE
PIPE SPACE
FUEL HANDLING VEHICLE
EL 67'-9½"
EL 31'-0"
"C"
EL 48'-0"
FUEL HANDLING CANAL
SHIELD COOLING PUMP
SHIELD COOLERS
PURIFICATION HEAT EXCHANGER
PURIFICATION COOLER
REACTOR SERVICE CRANE RAILS
℄ 190'-0" SPHERE
ELEVATOR
EL 67' 9½"
UP TO EL 98' 9"
EQUIPMENT AIRLOCK
TURBINE ROOM WALL
200 MWE BOILING WATER REACTOR PLANT
REVISIONS
GENERAL ARRANGEMENT PLAN
UPPER FLOOR "A-A" REACTOR BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D. C.
SCALE 1/8"=1'-0"
DRAWN C. LINNEMANN 8-25-59
CHECKED
ENGINEER
APPROVED
JOB NO
1957-15
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO
NS-203



200MWe BOILING WATER REACTOR PLANT

REVISIONS	GENERAL ARRANGEMENT PLAN LOWER FLOOR "B-B" REACTOR BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D. C.	
	SCALE 1/8"=1' 0" DRAWN A. SCHALL 8-25 59 CHECKED ENGINEER APPROVED	SARGENT & LUNDY ENGINEERS CHICAGO 3 ILLINOIS
	JOB NO 1957 15 · JOB NO · JOB NO · JOB NO	DRAWING NO NS-204



200 MWe BOILING WATER REACTOR PLANT

GENERAL CROSS SECTION "C-C"
REACTOR BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

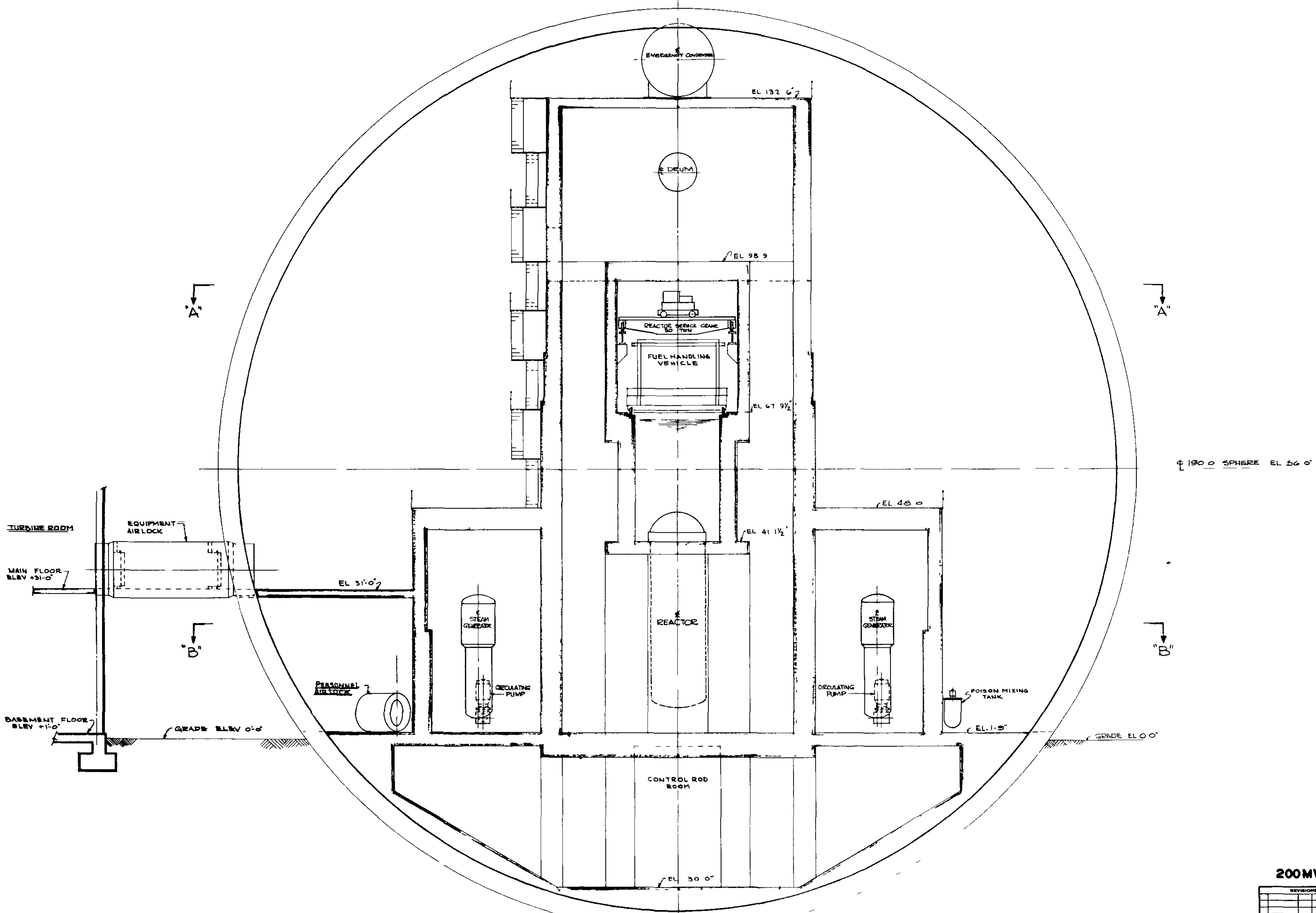
REVISIONS

SCALE 1/8" = 1'-0"
DRAWN A SCHALL 8-25-57
CHECKED
ENGINEER
APPROVED

SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

JOB NO 1957-15

DRAWING NO
NS-205



200 MWe BOILING WATER REACTOR PLANT

REVISIONS			

GENERAL CROSS SECTION "D-D"
REACTOR BLDG.

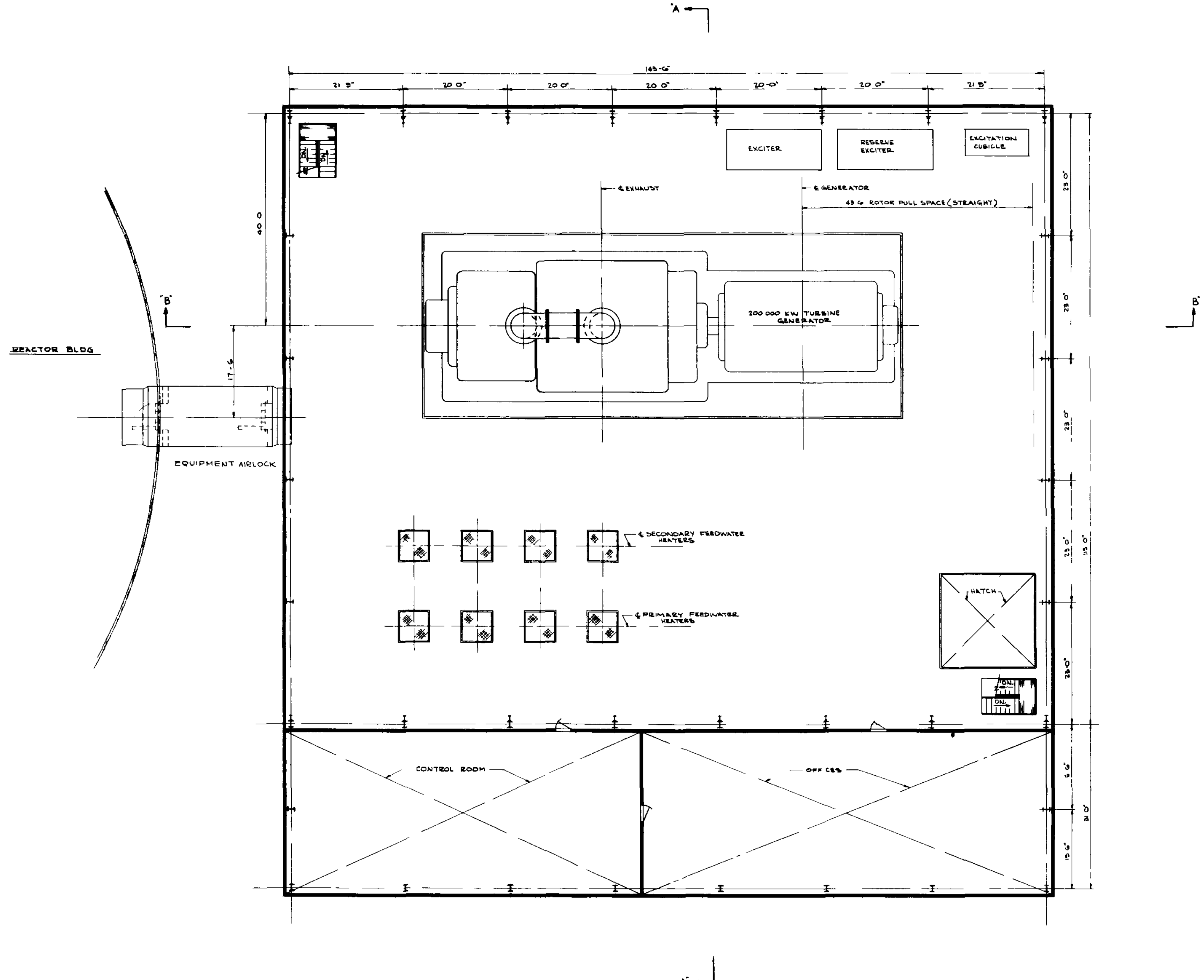
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8" = 1'-0"
DRAWN R. JASKULA 8-25-59
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO	JOB NO
1957-15			

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-206



200 MWe BOILING WATER REACTOR PLANT

REVISIONS			

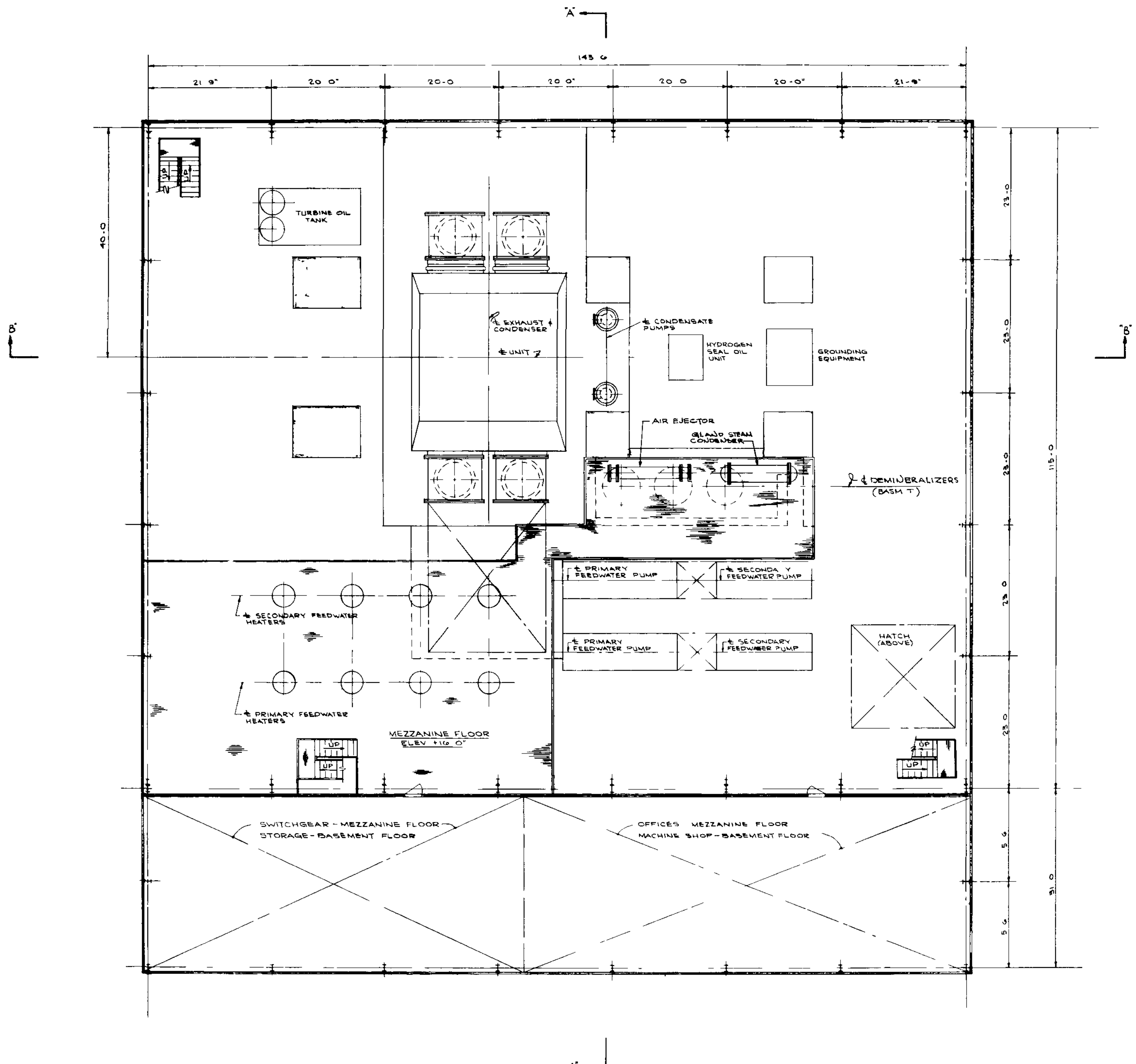
GENERAL ARRANGEMENT PLAN
MAIN FLOOR TURBINE BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN F.P. RUSSO 8-25-59
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO	JOB NO
1957-15			

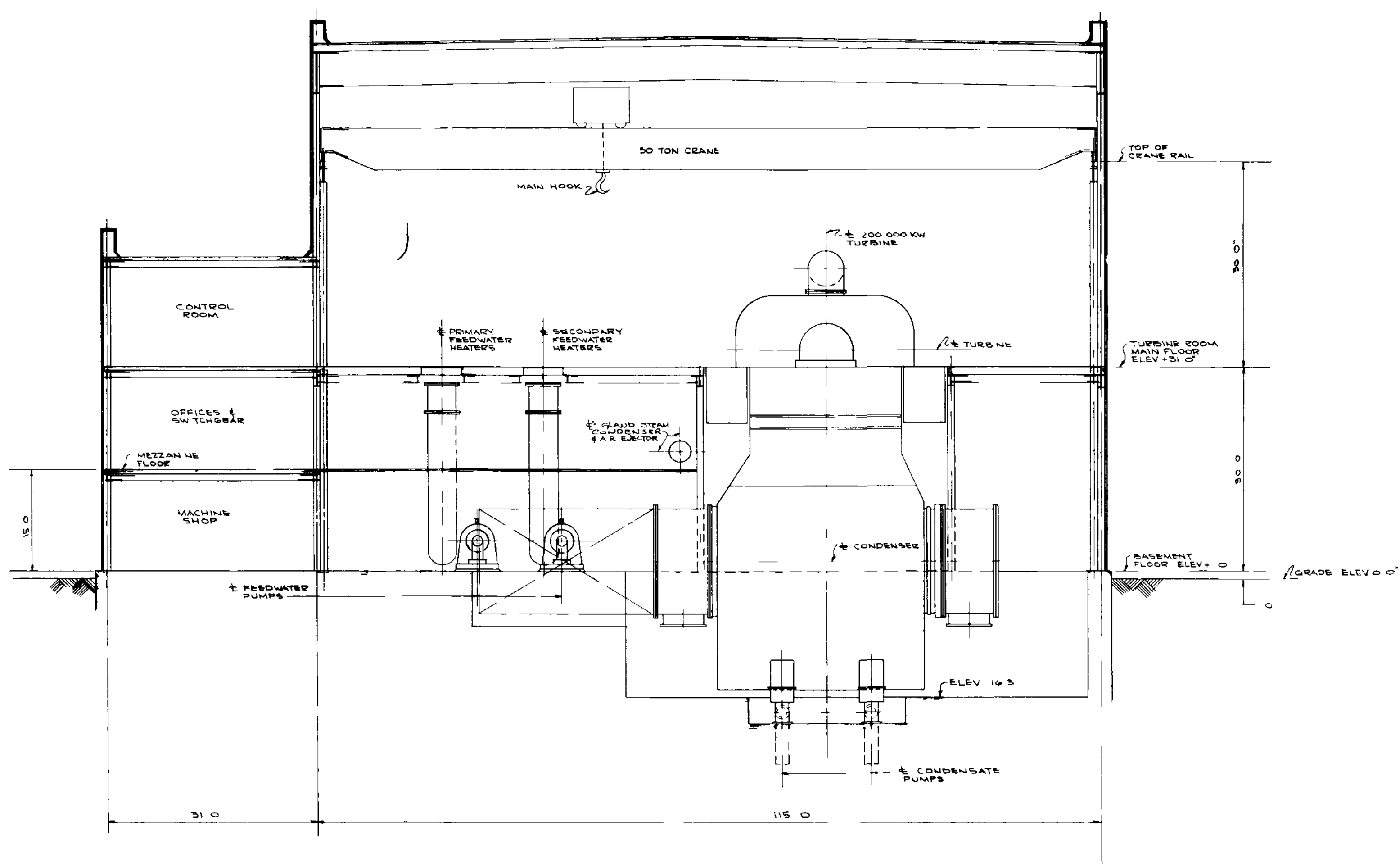
SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

DRAWING NO
NS-207



200 MWe BOILING WATER REACTOR PLANT

REVISIONS	GENERAL ARRANGEMENT PLAN BSMT. & MEZZ. FLR. TURBINE BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.	
	SCALE 1/8"=1'-0"	SARGENT & LUNDY ENGINEERS
	DRAWN F P RUSSO 8-25 57	CHICAGO 3 ILLINOIS
	CHECKED	
	ENGINEER	DRAWING NO
	APPROVED	
	JOB NO 1957-15	NS-208



200 MWe BOILING WATER REACTOR PLANT

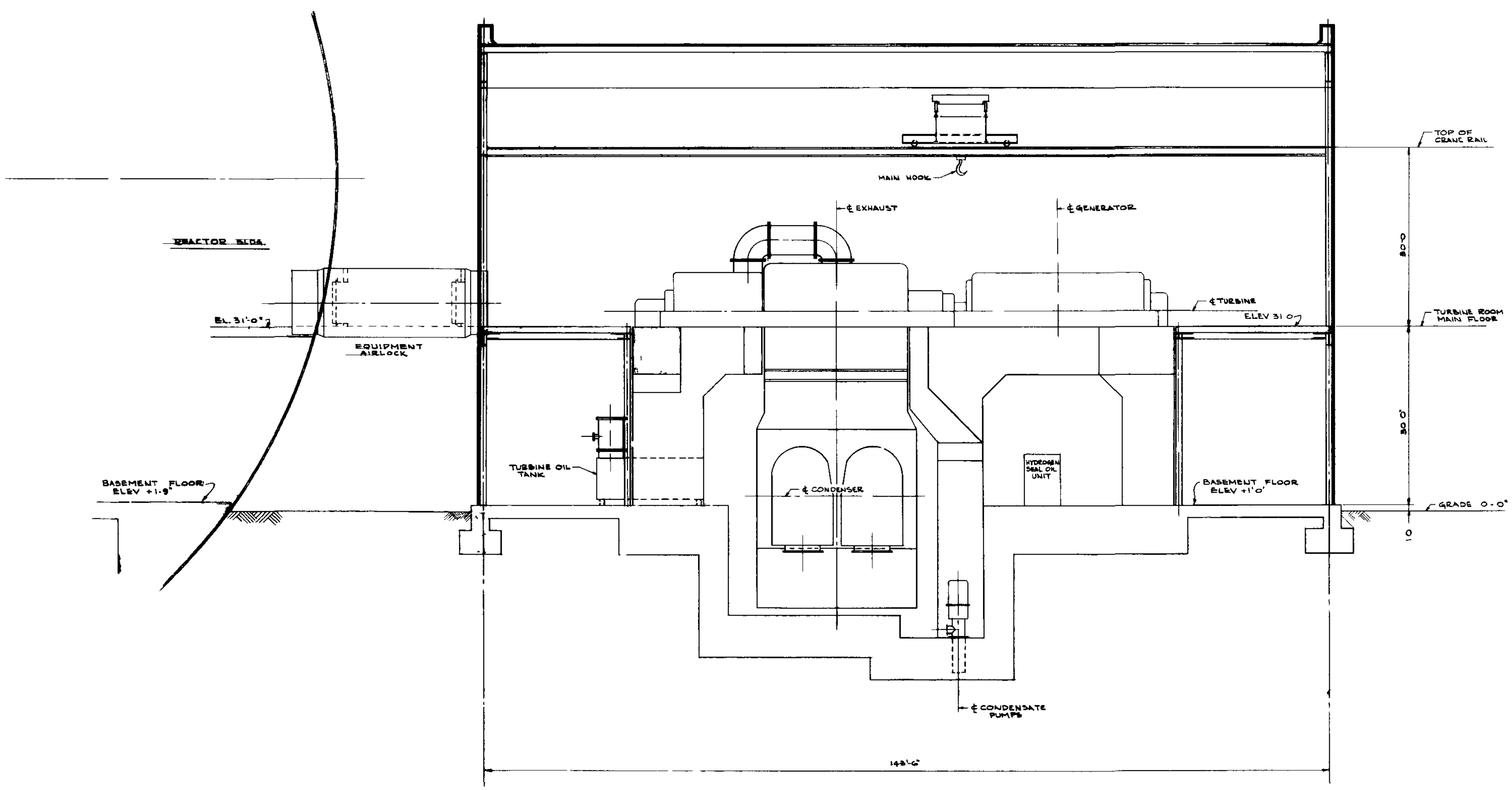
REVISIONS

GENERAL CROSS SECTION "A-A"
TURBINE BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN F P RUSSO 8 25-59
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15 | JOB NO | JOB NO | JOB NO

SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

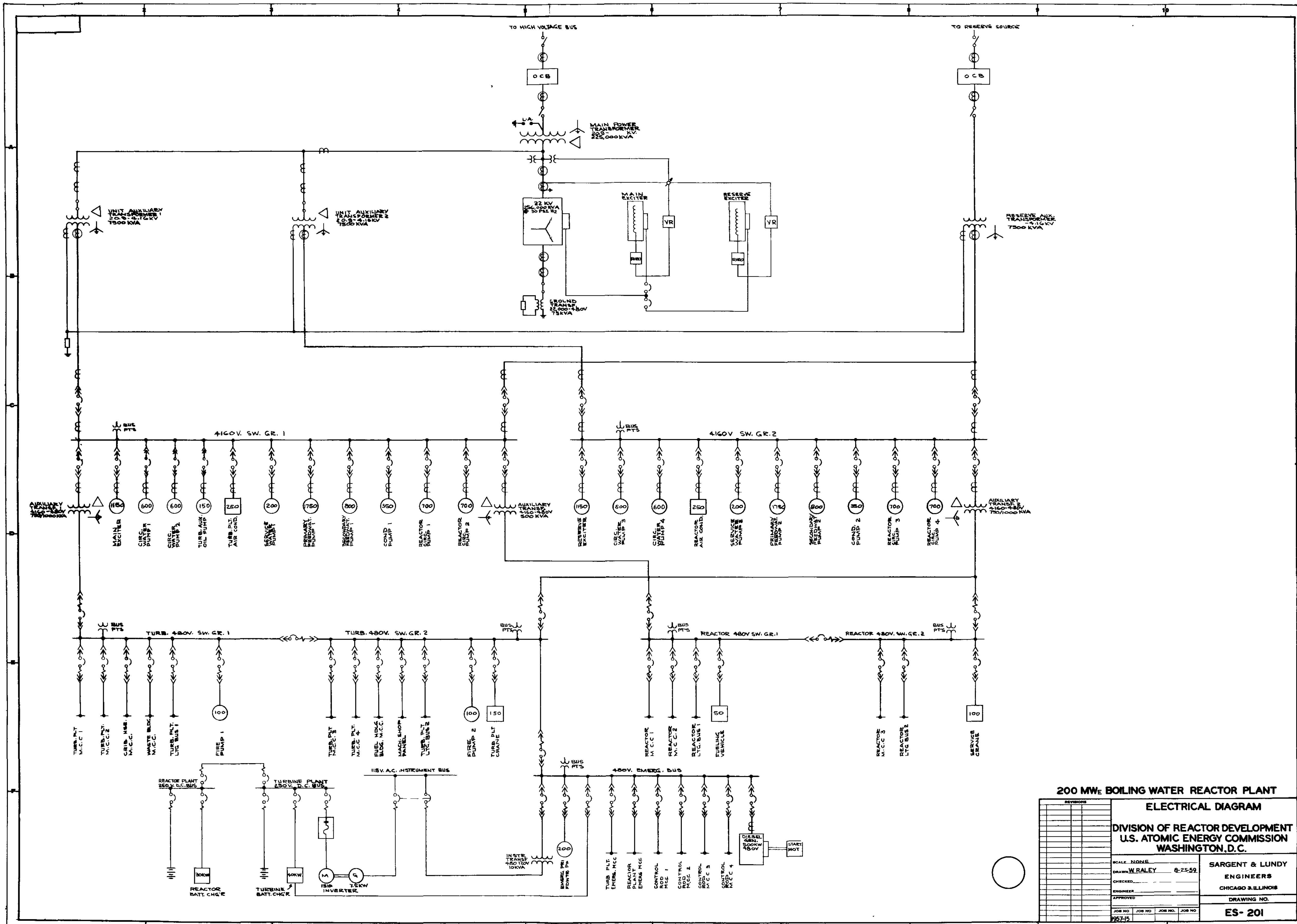
DRAWING NO
NS-209



200 MWe BOILING WATER REACTOR PLANT

REVISIONS	LONGITUDINAL SECTION "B-B" TURBINE BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.

SCALE 1/8" = 1'-0"	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWN F.P RUSSO 8-25-59	
CHECKED	
ENGINEER	
APPROVED	DRAWING NO
JOB NO 1957-15	NS-210



200 MWE BOILING WATER REACTOR PLANT

REVISIONS

ELECTRICAL DIAGRAM

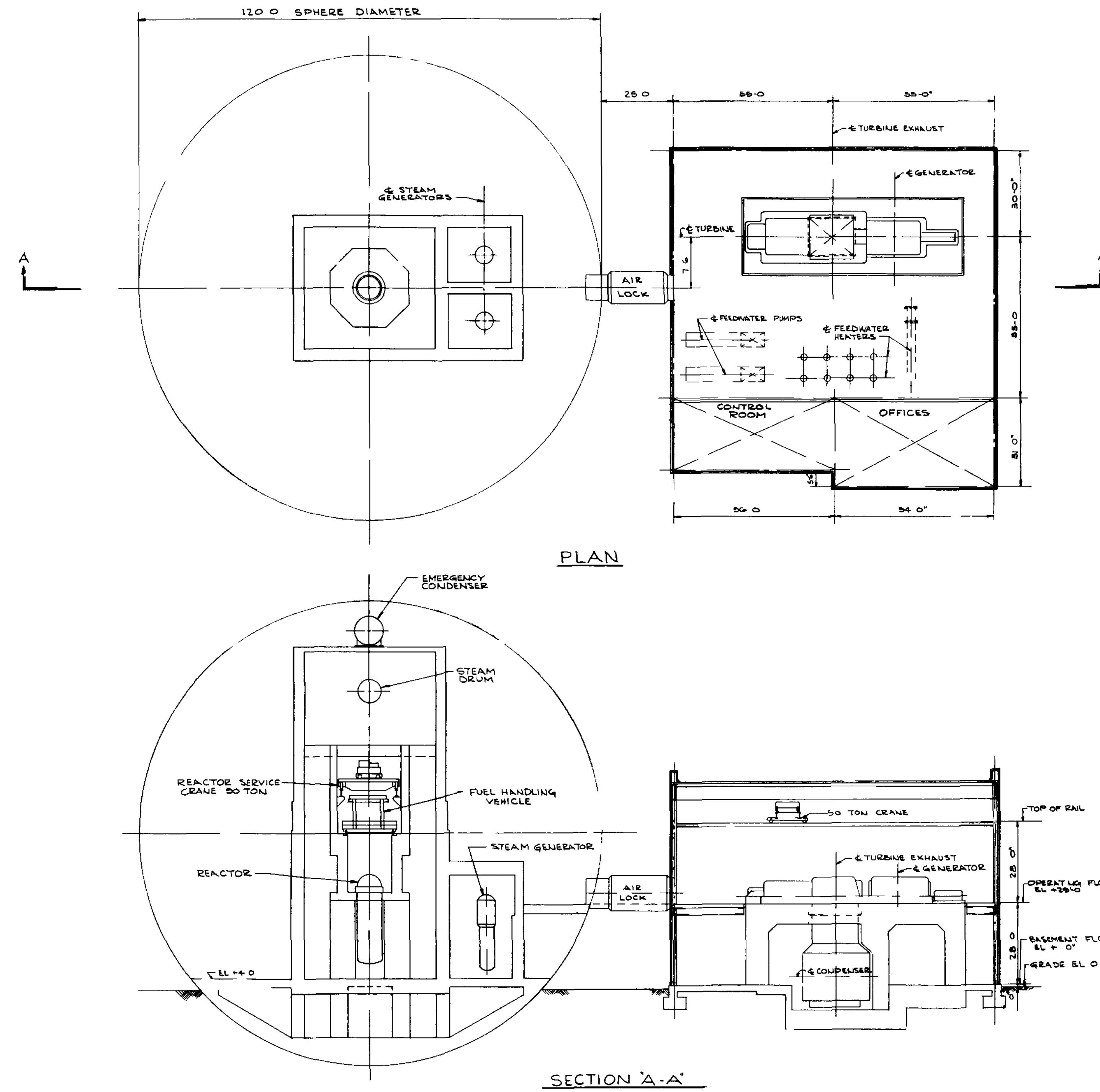
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE NONE
DRAWN W RALEY 8-25-59
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO.	JOB NO
1957-15			

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO.
ES- 201



75 MWe BOILING WATER REACTOR PLANT

REVISIONS

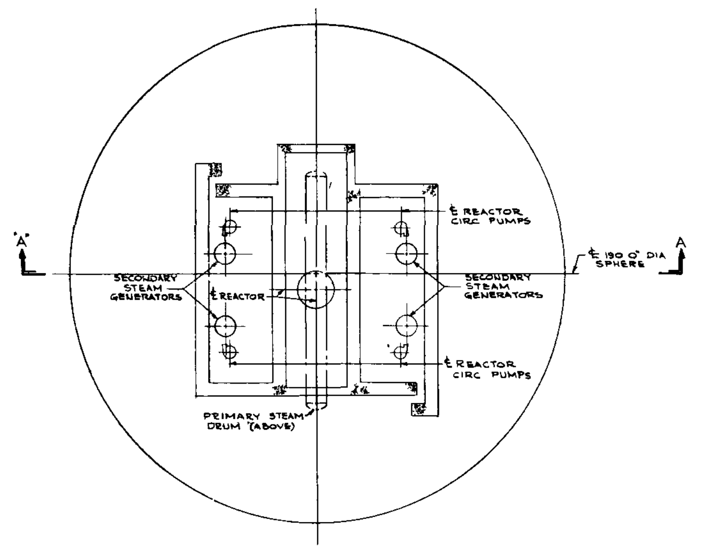
GENERAL ARRANGEMENT PLAN & SECTION
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/16" = 1-0"
DRAWN F.P. RUSSO 8-25-59
CHECKED
ENGINEER
APPROVED

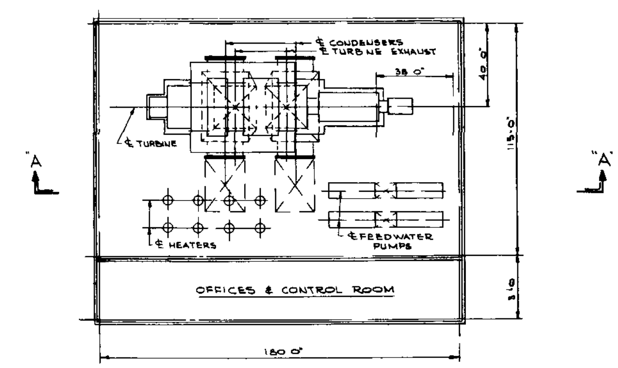
JOB NO	JOB NO	JOB NO	JOB NO
1957-15			

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

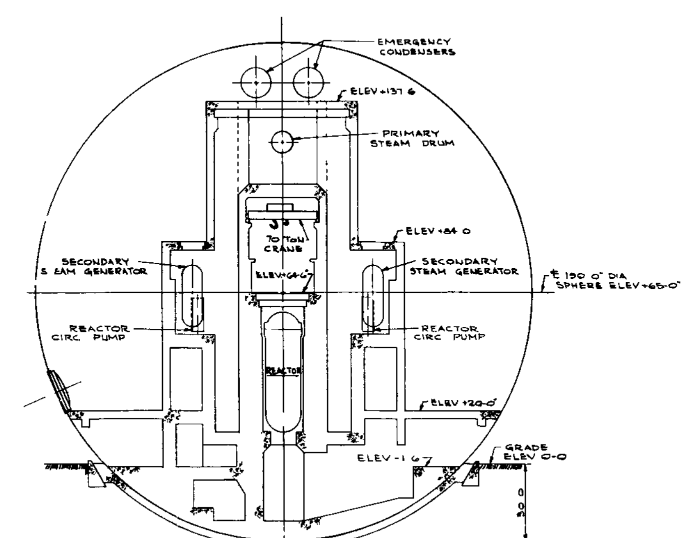
DRAWING NO
NS-211



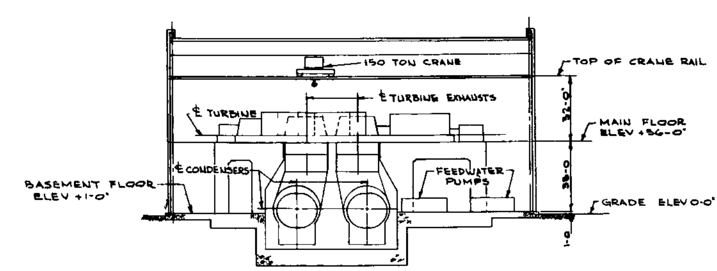
PLAN
REACTOR PLANT



PLAN
TURBINE PLANT



SECTION "A-A"



SECTION "A-A"

300 MWe BOILING WATER REACTOR PLANT

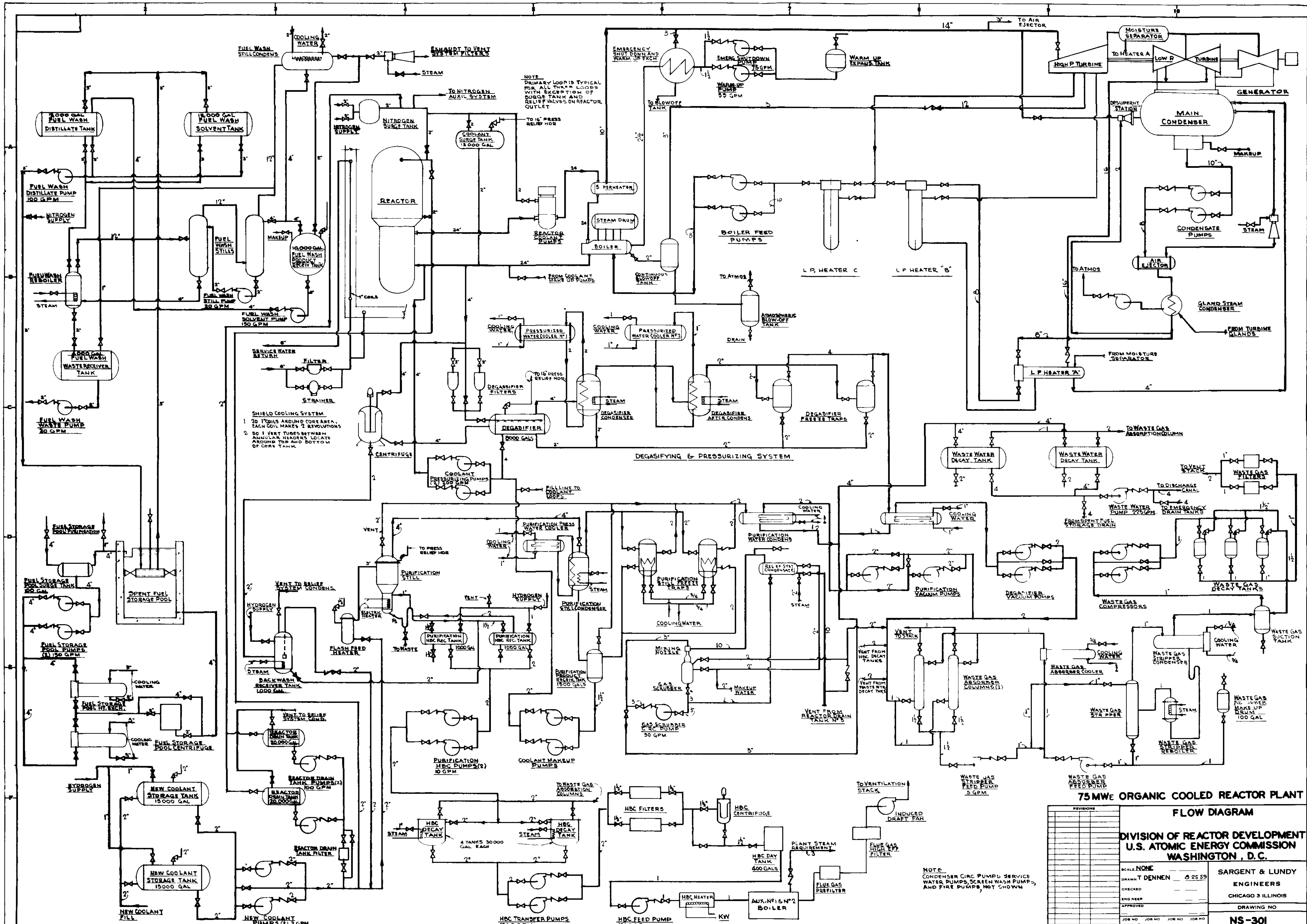
GENERAL ARRANGEMENT PLAN & SECTION
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

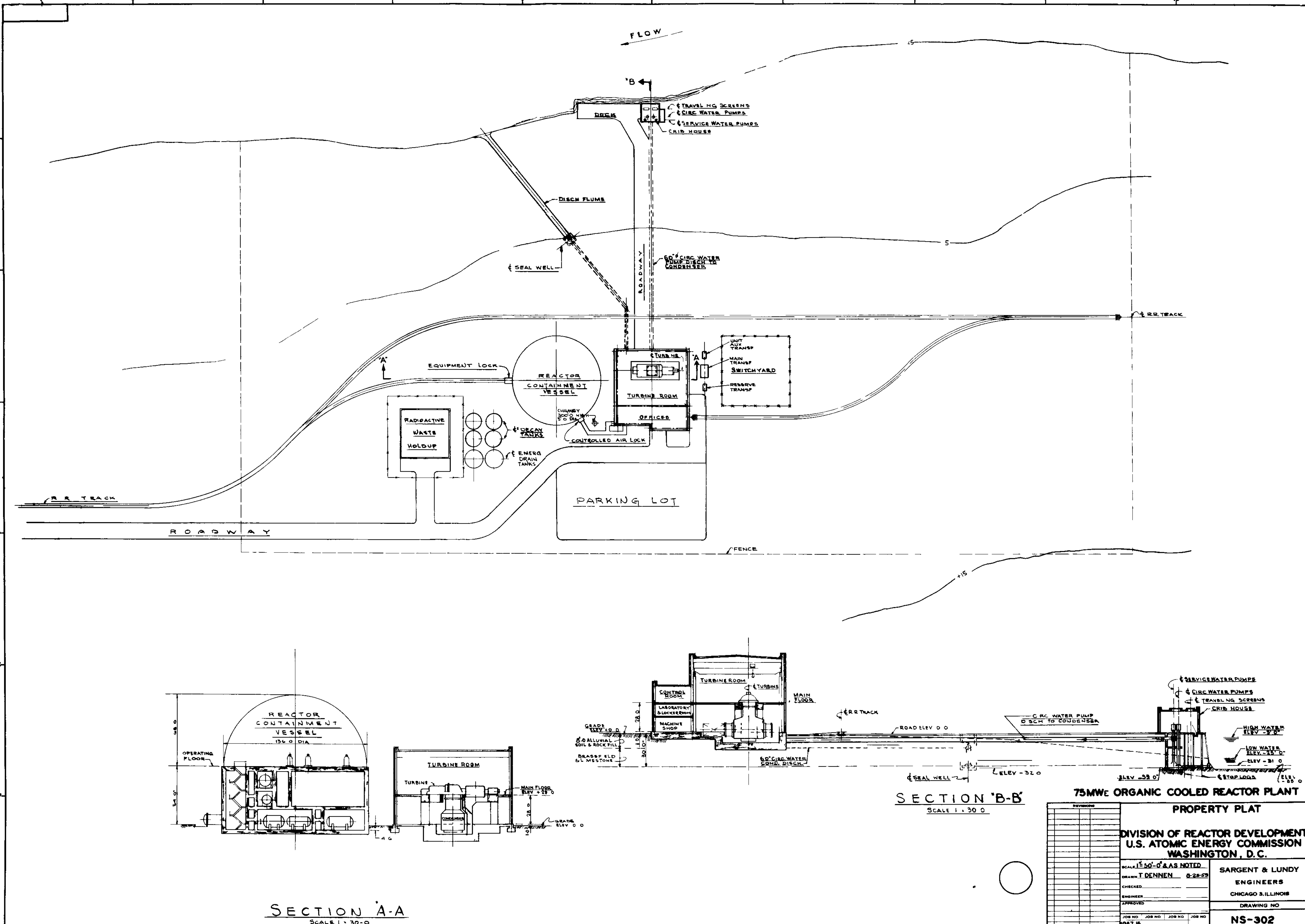
REVISIONS

SCALE 1" = 30'-0"
DRAWN R GOETTSCHE 8-25-53
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-212


75 MWe ORGANIC COOLED REACTOR PLANT
FLOW DIAGRAM
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.
SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS
NS-301
REACTOR
NITROGEN SURGE TANK
COOLANT SURGE TANK
REACTOR COOLANT PUMPS
BOILER
STEAM DRUM
S. PERHEATER
EMERGENCY SHUT DOWN AND WARM UP EXCH
EMERG SHUTDOWN PUMP
WARM UP EXPANS TANK
HIGH P TURBINE
LOW P TURBINE
MOISTURE SEPARATOR
GENERATOR
MAIN CONDENSER
CONDENSATE PUMPS
AIR EJECTOR
GLAND STEAM CONDENSER
BOILER FEED PUMPS
L.P. HEATER C
L.P. HEATER "B"
L P HEATER "A"
ATMOSPHERIC BLOW-OFF TANK
CONTINUOUS BLOWOFF TANK
FUEL WASH DISTILLATE TANK
FUEL WASH SOLVENT TANK
FUEL WASH STILLS
FUEL WASH PRODUCT RECEIV TANK
FUEL WASH REBOILER
FUEL WASH WASTE RECEIVER TANK
FUEL WASH WASTE PUMP
SHIELD COOLING SYSTEM
DEGASIFIER
DEGASIFIER FILTERS
DEGASIFIER CONDENSER
DEGASIFIER AFTER CONDENS
DEGASIFIER FREEZE TRAPS
PRESSURIZED WATER COOLER No 1
PRESSURIZED WATER COOLER No 2
DEGASIFYING & PRESSURIZING SYSTEM
CENTRIFUGE
COOLANT PRESSURIZING PUMPS
SPENT FUEL STORAGE POOL
FUEL STORAGE POOL PUMPS
FUEL STORAGE POOL CENTRIFUGE
PURIFICATION STILL
PURIFICATION STILL CONDENSER
PURIFICATION STILL FREEZE TRAPS
PURIFICATION VACUUM PUMPS
PURIFICATION HBC PUMPS (2) 10 GPM
COOLANT MAKEUP PUMPS
BACKWASH RECEIVER TANK 1000 GAL
GAS SCRUBBER
WASTE WATER DECAY TANK
WASTE GAS FILTERS
WASTE GAS DECAY TANKS
WASTE GAS COMPRESSORS
WASTE GAS ABSORBER COLUMNS (2)
WASTE GAS STRIPPER
WASTE GAS STRIPPER REBOILER
NEW COOLANT STORAGE TANK 15000 GAL
NEW COOLANT PUMPS (2) 2 GPM
REACTOR DRAIN TANK
REACTOR DRAIN TANK PUMPS (2)
HBC DECAY TANK
HBC TRANSFER PUMPS (2) 2 GPM
HBC FILTERS
HBC CENTRIFUGE
HBC DAY TANK 400 GALS
HBC FEED PUMP (2) 1 GPM
HBC HEATER
AUX. No 1 & No 2 BOILER
FLUE GAS PREFILTER
FLUE GAS HIGH EFF FILTER
INDUCED DRAFT FAN
NOTE
CONDENSER CIRC PUMPS, SERVICE WATER PUMPS, SCREEN WASH PUMPS AND FIRE PUMPS NOT SHOWN
NOTE
PRIMARY LOOP IS TYPICAL FOR ALL THREE LOOPS WITH EXCEPTION OF SURGE TANK AND RELIEF VALVES ON REACTOR OUTLET
DRAWN T DENNEN 8-25-59
SCALE NONE



75MWe ORGANIC COOLED REACTOR PLANT

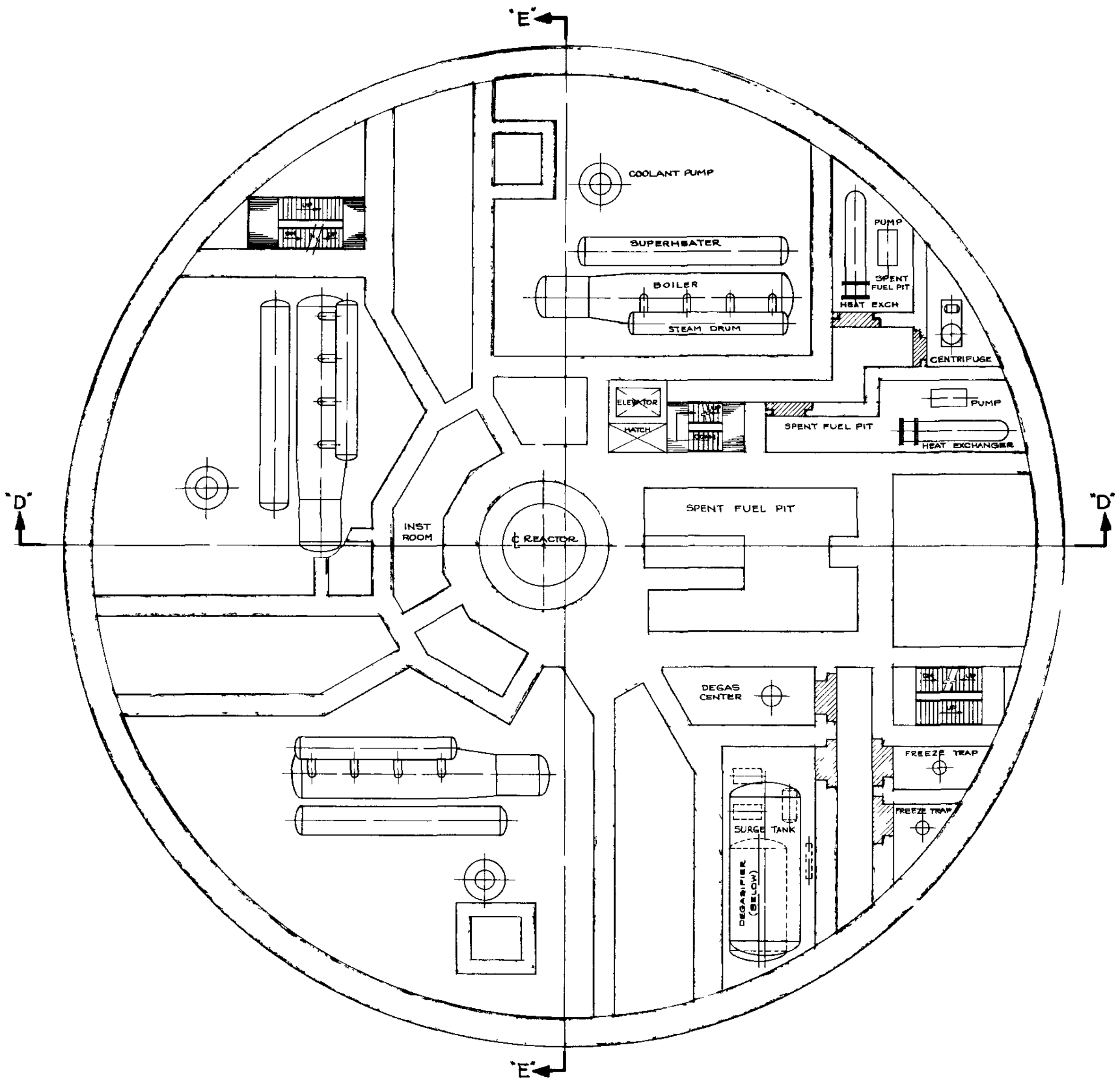
PROPERTY PLAT

DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

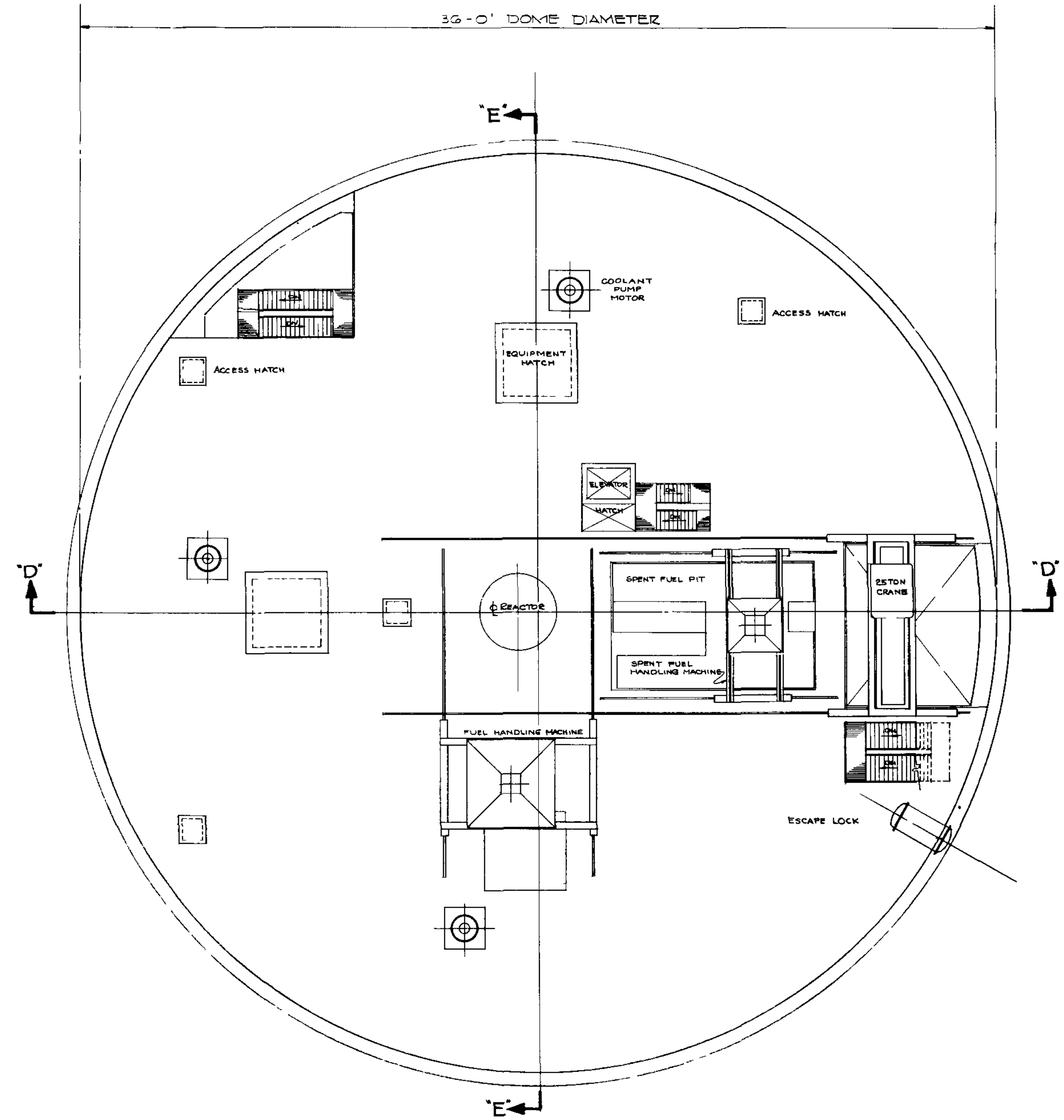
SCALE 1" = 50'-0" & AS NOTED
DRAWN T DENNEN 8-25-59
CHECKED
ENGINEER
APPROVED
JOB NO 1957 15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-302



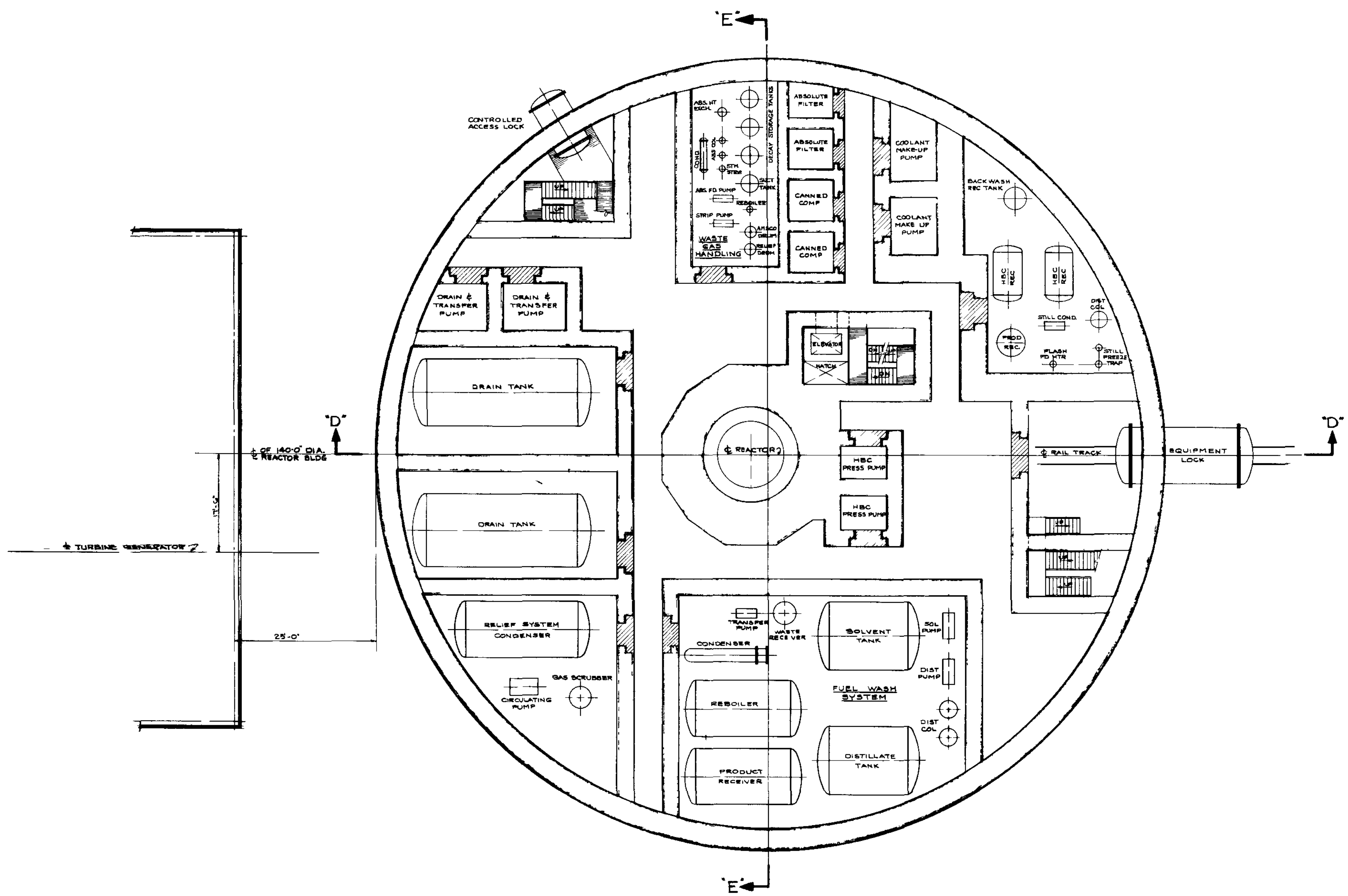
PLAN AT "B-B"



PLAN AT "A-A"

75 MWE ORGANIC COOLED REACTOR PLANT

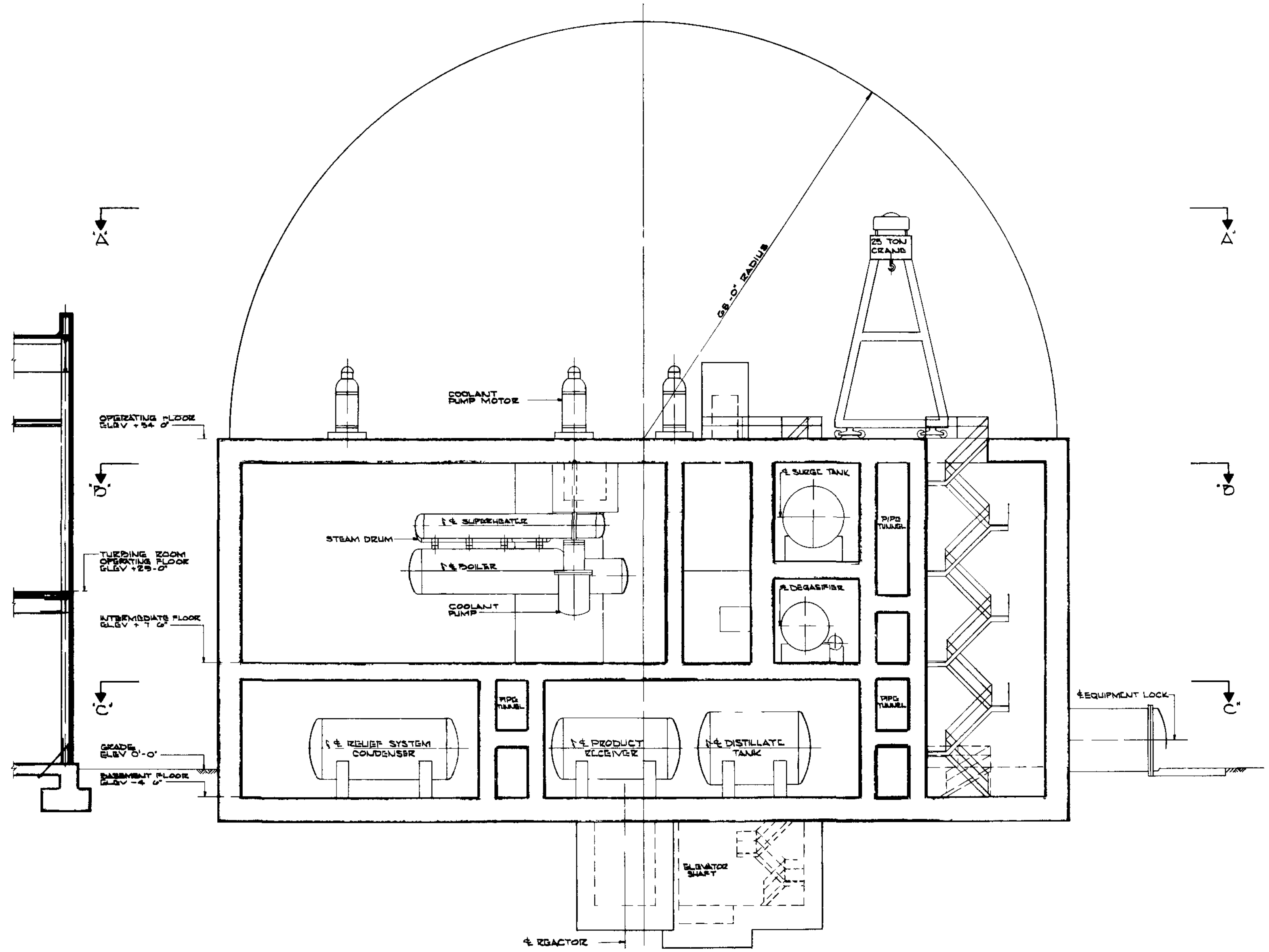
REVISIONS	GENERAL ARRANGEMENT PLANS UPPER FLRS. "A-A" & "B-B" REACTOR BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.	
	SCALE 1/8=1-0 DRAWN C.L.INNEMANN 8-25-59 DATE CHECKED APPROVED	SARGENT & LUNDY ENGINEERS CHICAGO, ILLINOIS
	JOB NO 1957-15 | JOB NO | JOB NO | JOB NO	DRAWING NO NS-303



PLAN AT "C-C"

75 MWe ORGANIC COOLED REACTOR PLANT

REVISIONS	GENERAL ARRANGEMENT PLAN LOWER FLR. "C-C" REACTOR BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.
SCALE 1/8"=1'-0" DRAWN C. LINNEMANN 8-25-59 DATE CHECKED APPROVED JOB NO 1957-13	SARGENT & LUNDY ENGINEERS CHICAGO, ILLINOIS DRAWING NO. NS-304



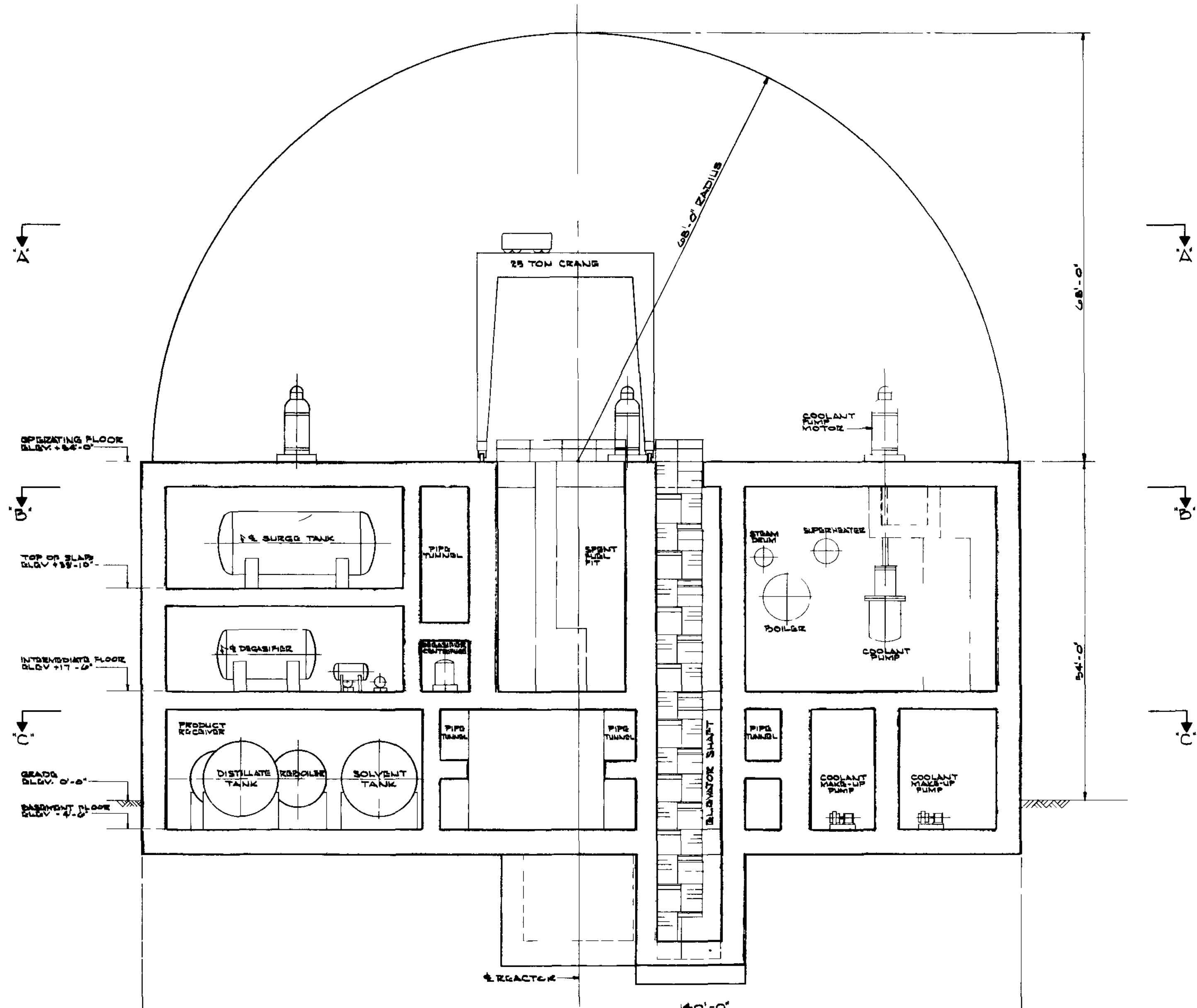
SECTION 'D-D'

75 MWe ORGANIC COOLED REACTOR PLANT

REVISIONS	GENERAL CROSS SECTION "D-D" REACTOR BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.
	SCALE 1/8=1-0
	DRAWN A.E. JOHNSEN 8-25-59
	CHECKED
	ENGINEER
	APPROVED
	JOB NO 1957-15 / JOB NO / JOB NO / JOB NO

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-305



SECTION "E-E"

75 MWe ORGANIC COOLED REACTOR PLANT

REVISIONS

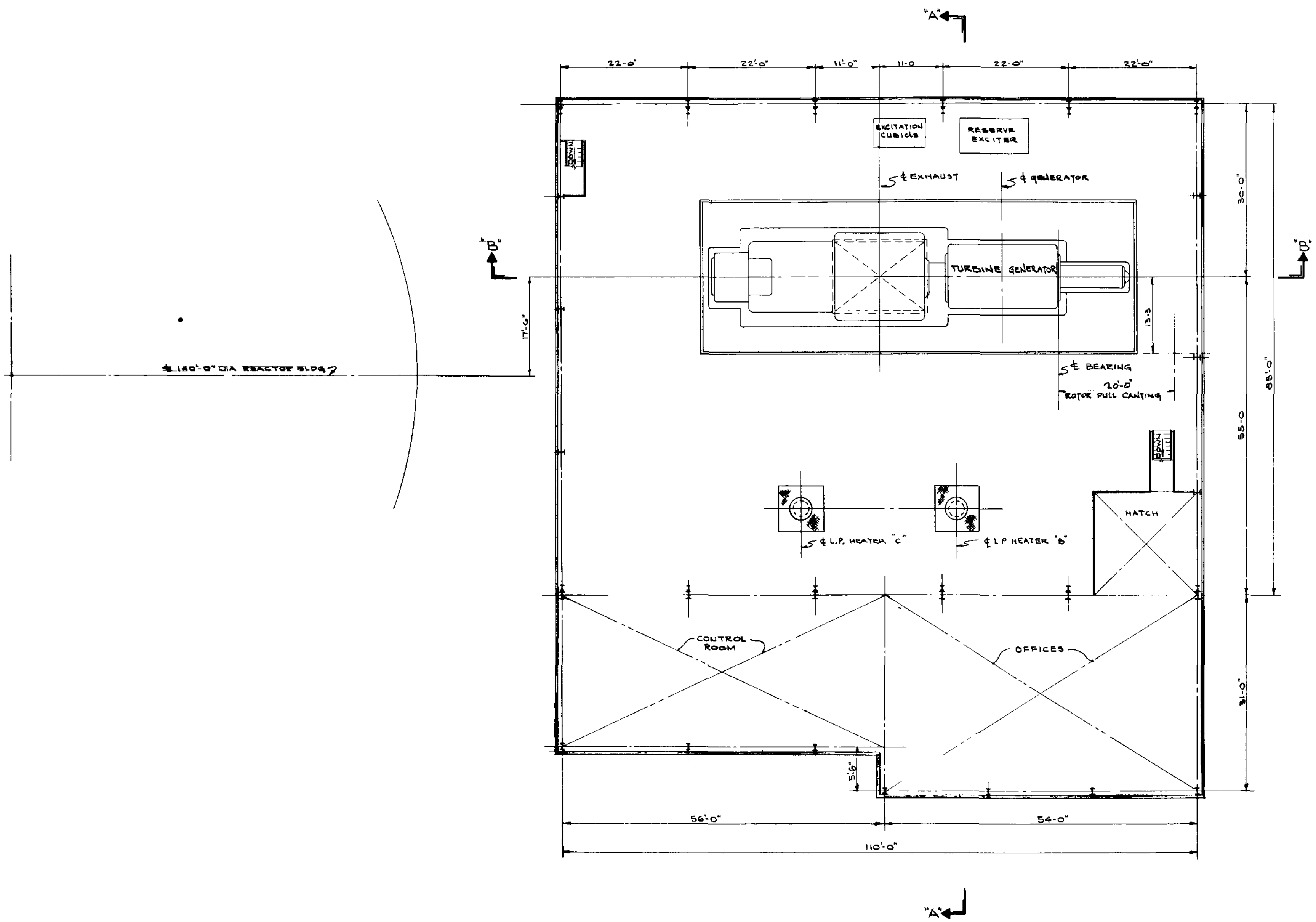
GENERAL CROSS SECTION "E-E"
REACTOR BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN A.E. JOHNSEN 8-25-59
CHECKED
ENGINEER
APPROVED

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

JOB NO	JOB NO	JOB NO	JOB NO
1957-15			

DRAWING NO
NS-306



75 MWe ORGANIC COOLED REACTOR PLANT

GENERAL ARRANGEMENT PLAN
MAIN FLOOR TURBINE BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

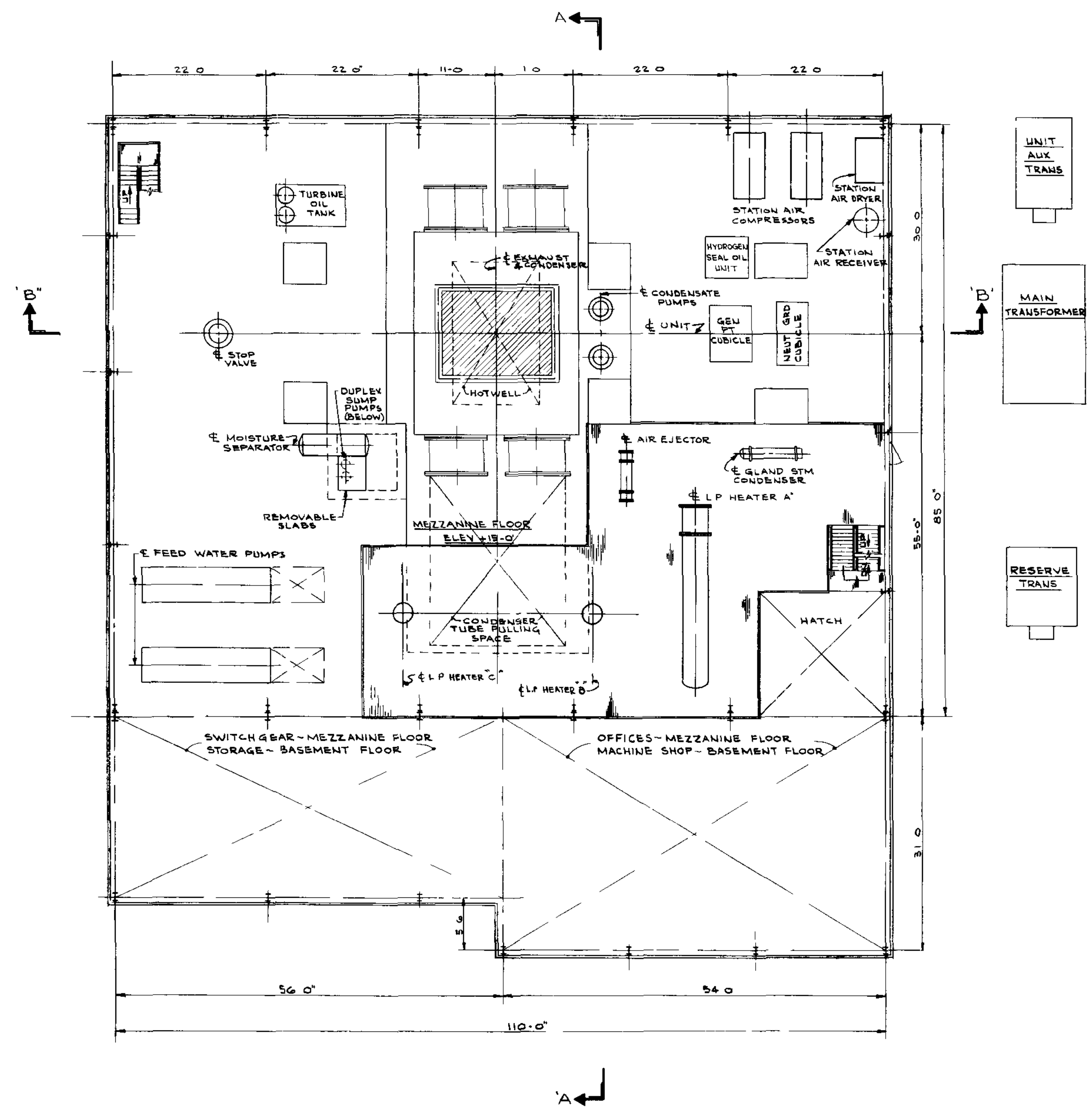
REVISIONS

SCALE 1/8" = 1'-0"
DRAWN R. GOETTSCHE 8-25-59
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO	JOB NO
1957-15			

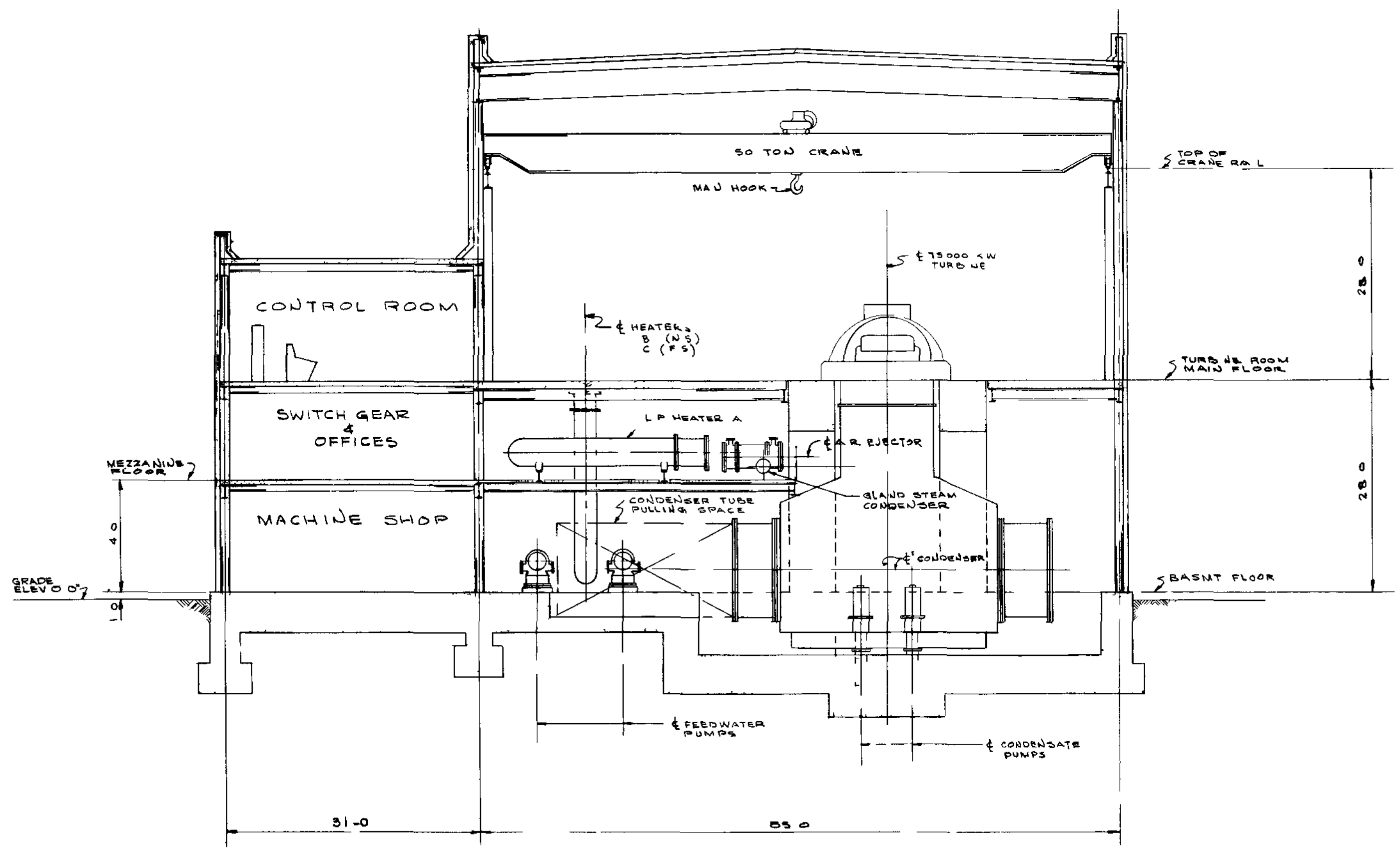
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-307



75MWE ORGANIC COOLED REACTOR PLANT

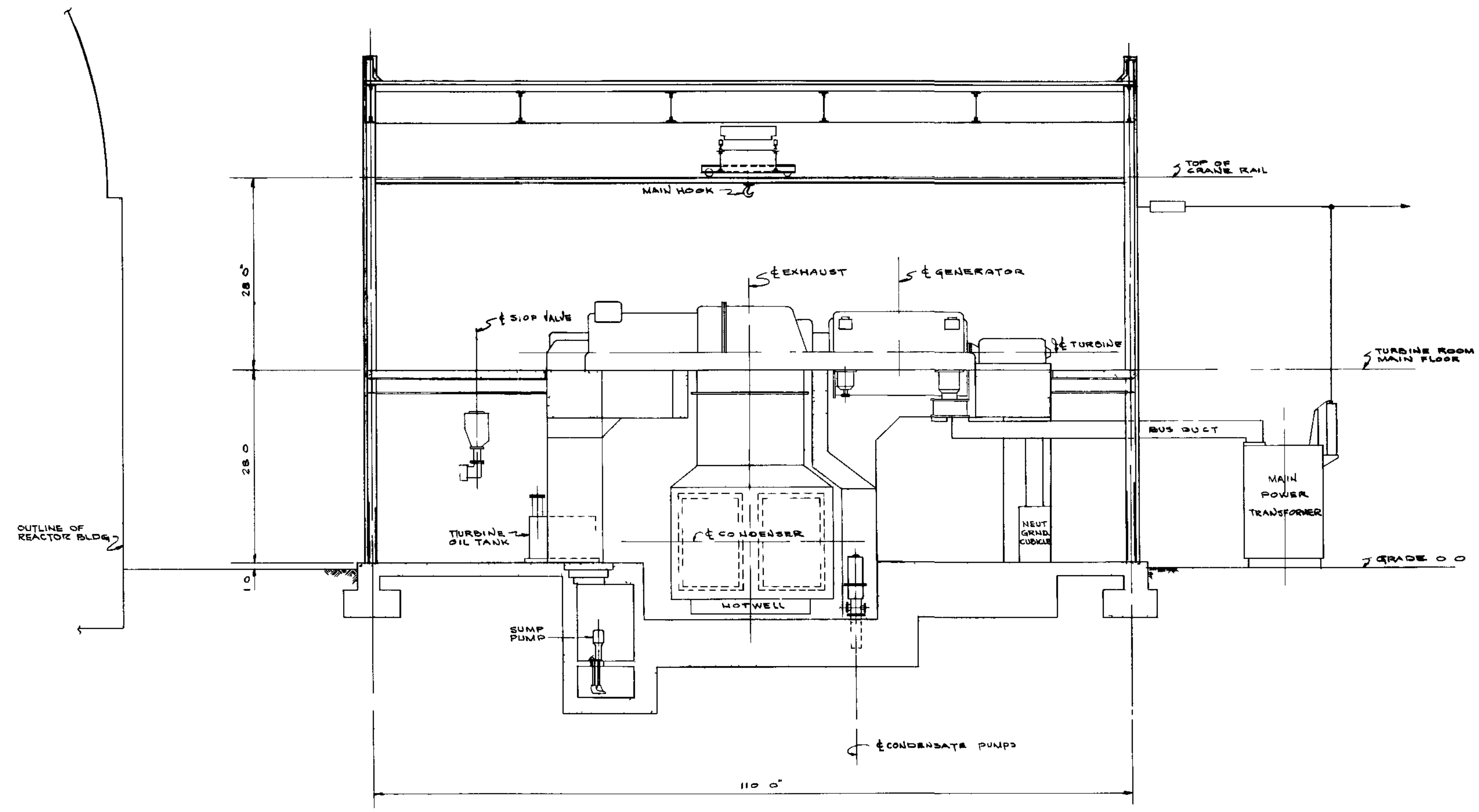
REVISIONS	
	GENERAL ARRANGEMENT PLAN **MEZZ. & BSMT. FLRS TURBINE BLDG.** **DIVISION OF REACTOR DEVELOPMENT** **U.S. ATOMIC ENERGY COMMISSION** **WASHINGTON, D.C.**
SCALE 1/8" = 1'-0" DRAWN R GOETTSCHE 8-25-59 CHECKED ENGINEER APPROVED	SARGENT & LUNDY ENGINEERS CHICAGO 3 ILLINOIS
JOB NO 1957-15	DRAWING NO NS-308



SECTION "A-A"

75 MWe ORGANIC COOLED REACTOR PLANT

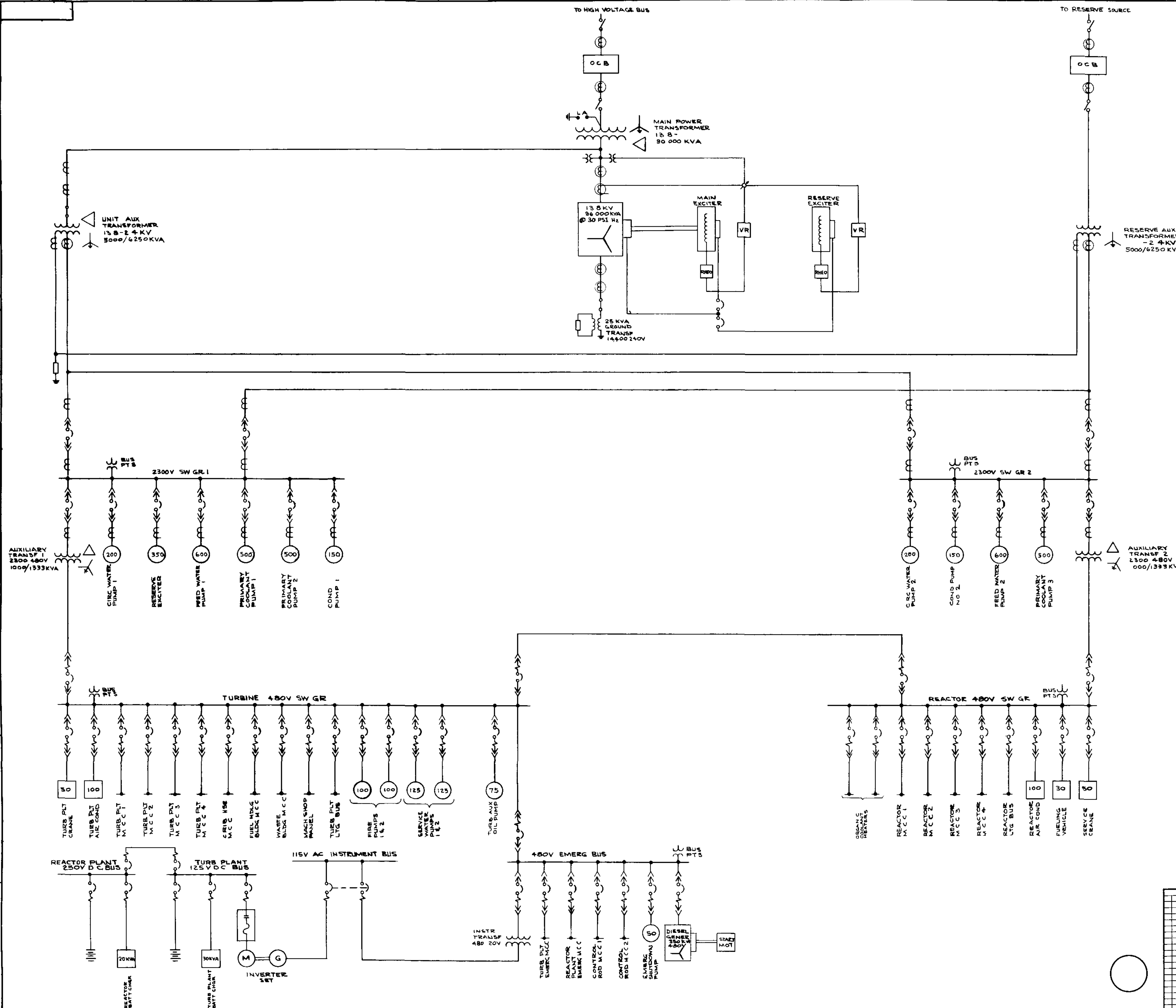
REVISIONS	
	GENERAL CROSS SECTION "A-A" TURBINE BLDG. DIVISION OF REACTOR DEVELOPMENT U.S ATOMIC ENERGY COMMISSION WASHINGTON, D.C.
	SCALE 1/8"= 1-0" DRAWN E. VICTORINE 8 25-59 CHECKED ENGINEER APPROVED
	SARGENT & LUNDY ENGINEERS CHICAGO 3 ILLINOIS
	OB NO 1957-15
	DRAWING NO NS-309



SECTION 'B-B'

75MWe ORGANIC COOLED REACTOR PLANT

REVISIONS	LONGITUDINAL SECTION 'B-B' TURBINE BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.
SCALE 1/8"=1-0	SARGENT & LUNDY ENGINEERS CHICAGO 3 ILLINOIS
DRAWN E VICTORINE 8-25 59	
CHECKED	
ENG NEER	
APPROVED	DRAWING NO
JOB NO 1957-B	NS-310



75 MWe ORGANIC COOLED REACTOR PLANT

ELECTRICAL DIAGRAM

DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

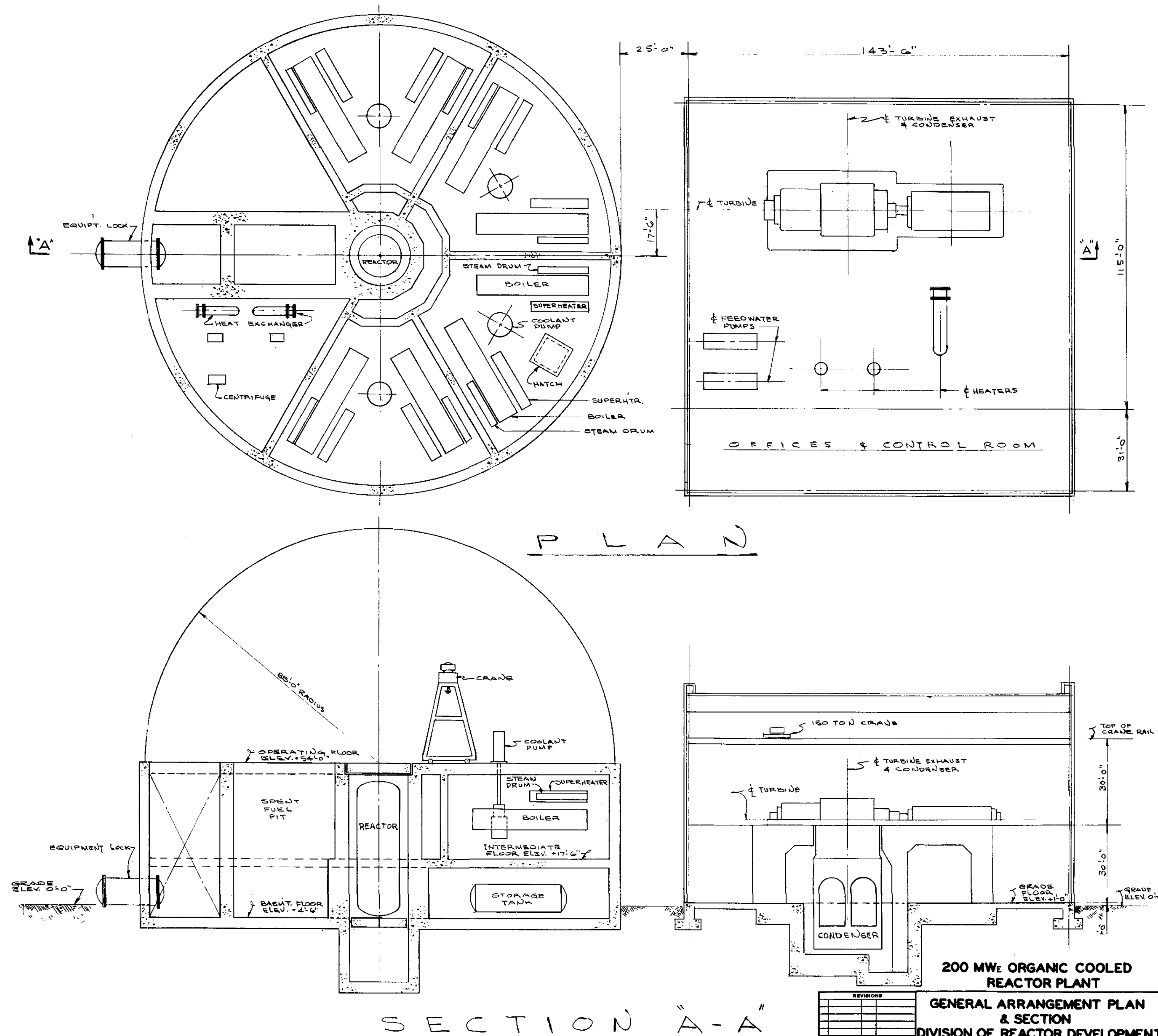
REVISIONS

SCALE NONE
DRAWN W RALEY 8-25-59
CHECKED
ENGINEER
APPROVED

JOB NO 1957 15 | JOB NO | JOB NO | JOB NO

SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

DRAWING NO
ES-301



200 MWe ORGANIC COOLED REACTOR PLANT

REVISIONS

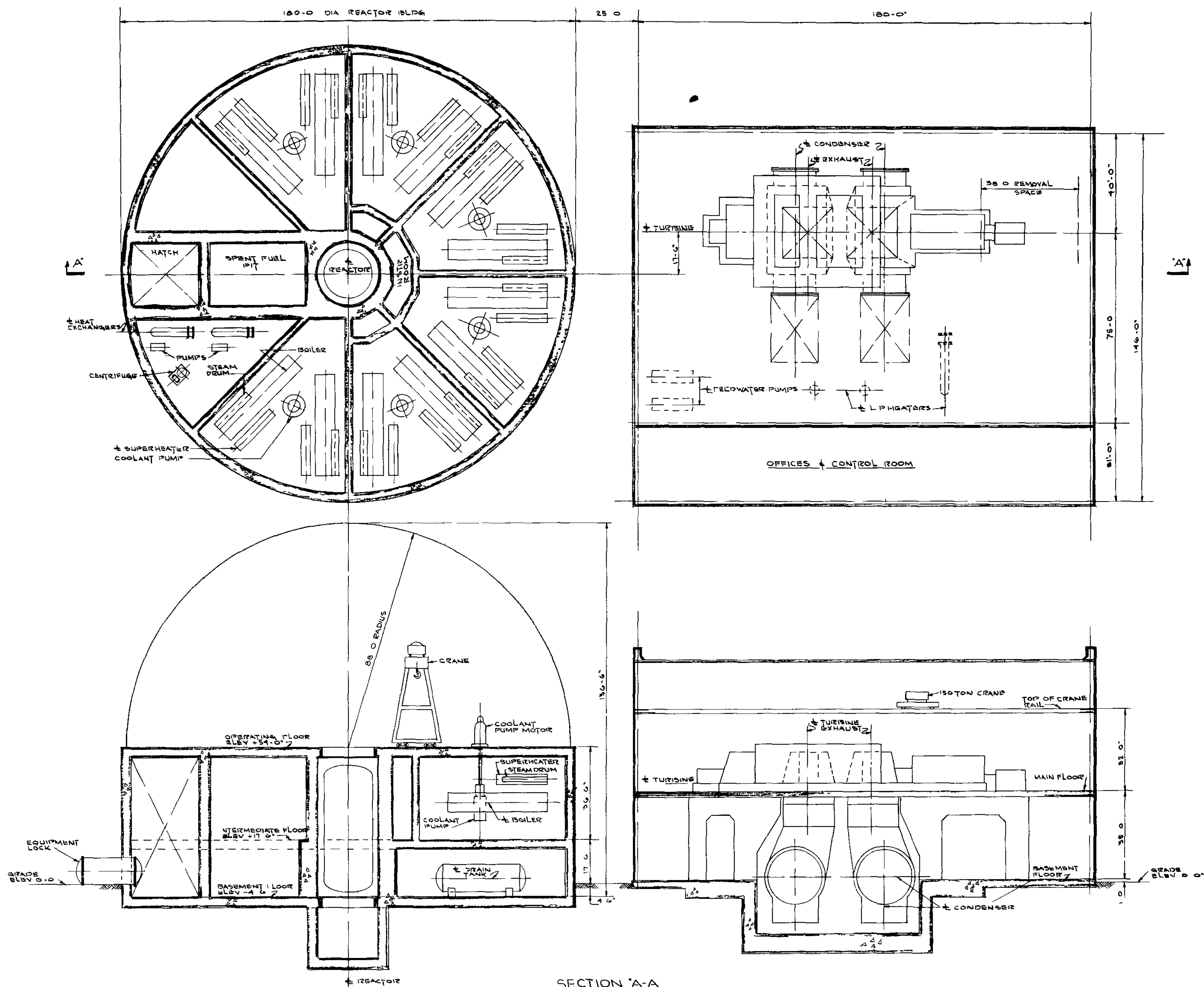
GENERAL ARRANGEMENT PLAN & SECTION
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/16"=1'-0"
DRAWN E.J. VICTORINE 8-25-59
CHECKED
ENGINEER
APPROVED

SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS

JOB NO.	JOB NO.	JOB NO.	JOB NO.
1957-15			

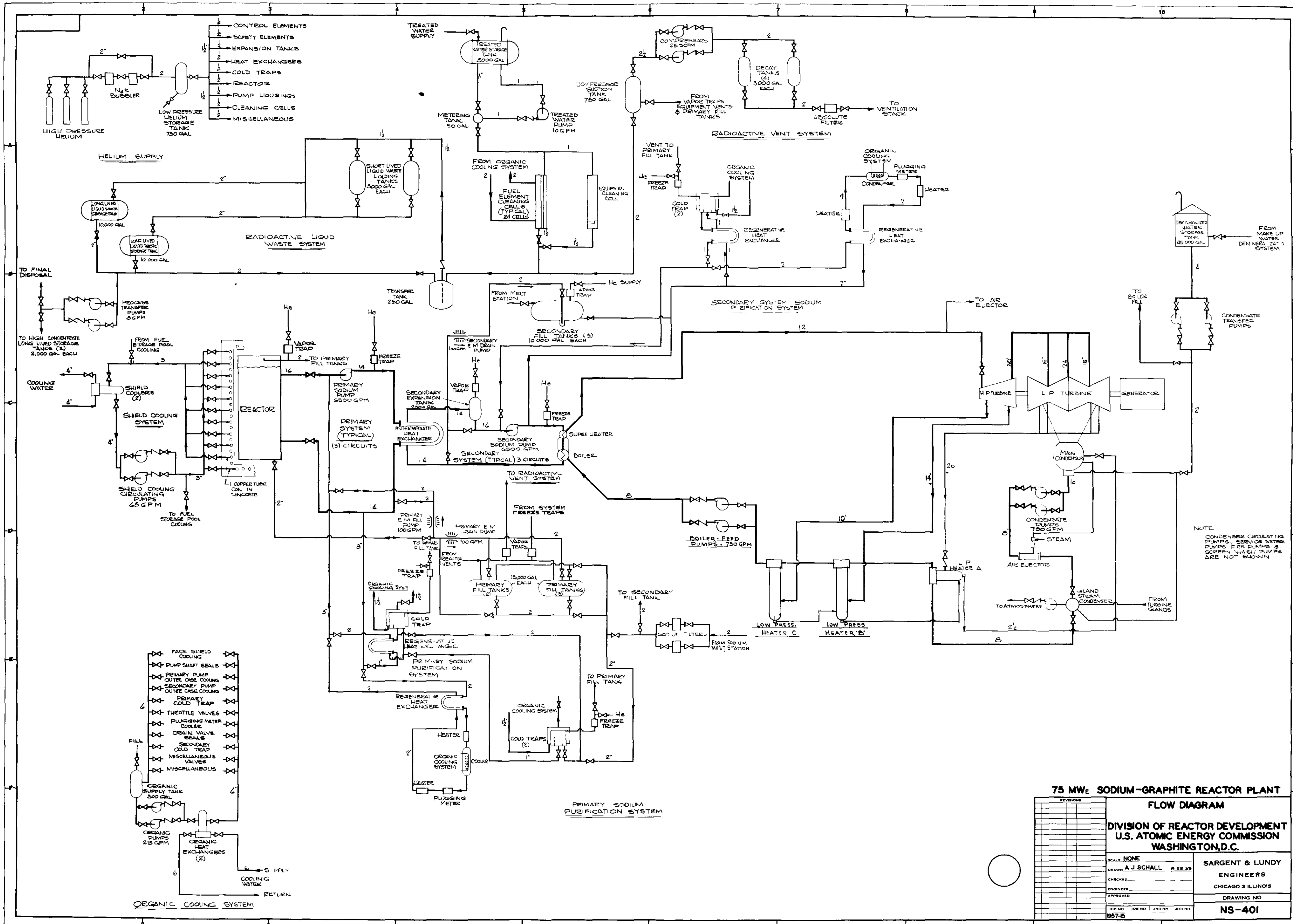
DRAWING NO. **NS-311**



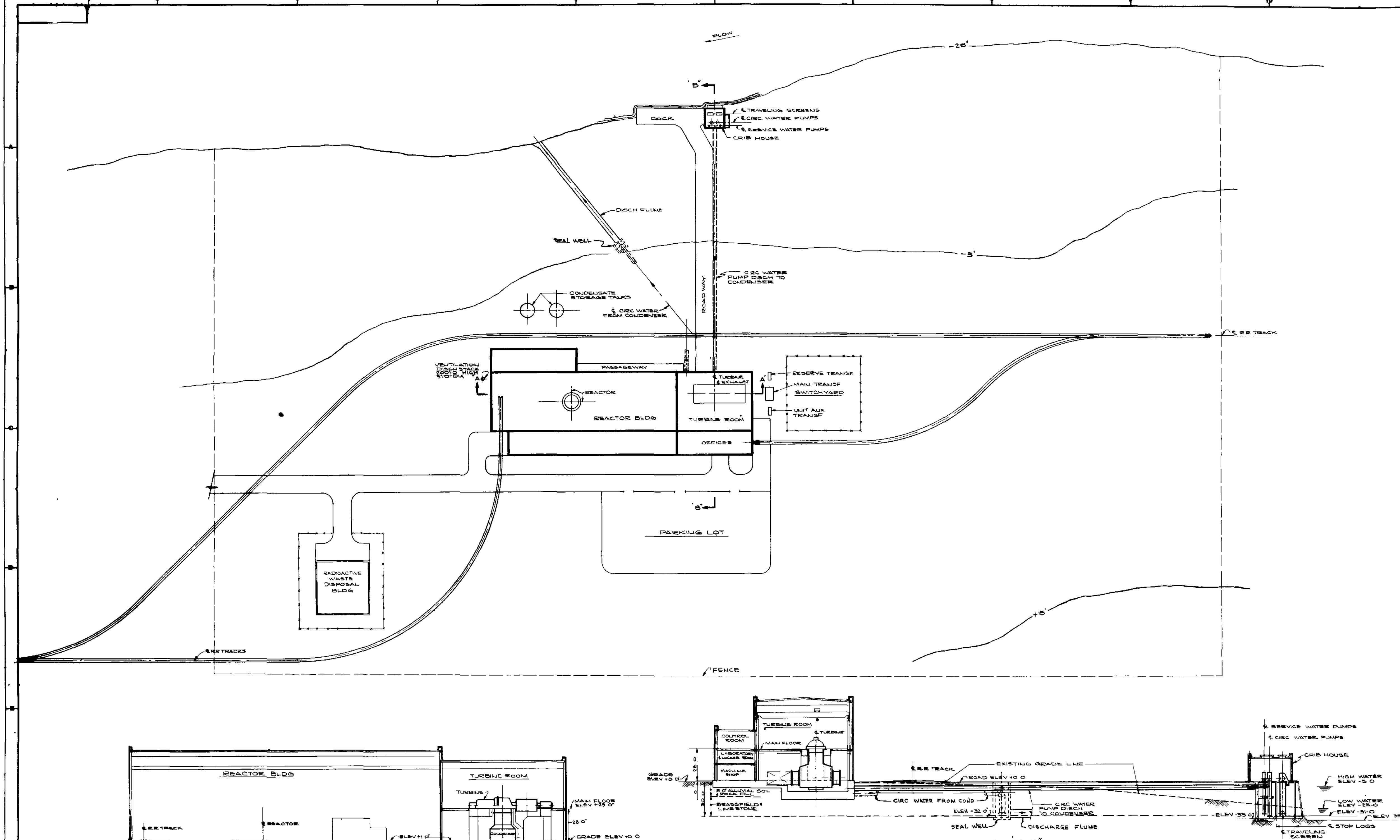
300 MWE ORGANIC COOLED REACTOR PLANT

REVISIONS	GENERAL ARRANGEMENT PLAN & SECTION DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.

SCALE 1/16"=1'-0"	SARGENT & LUNDY
DRAWN R. JASKULA 8-25-59	ENGINEERS
CHECKED	CHICAGO 3 ILLINOIS
ENGINEER	
APPROVED	DRAWING NO
JOB NO 2957-15	NS-312

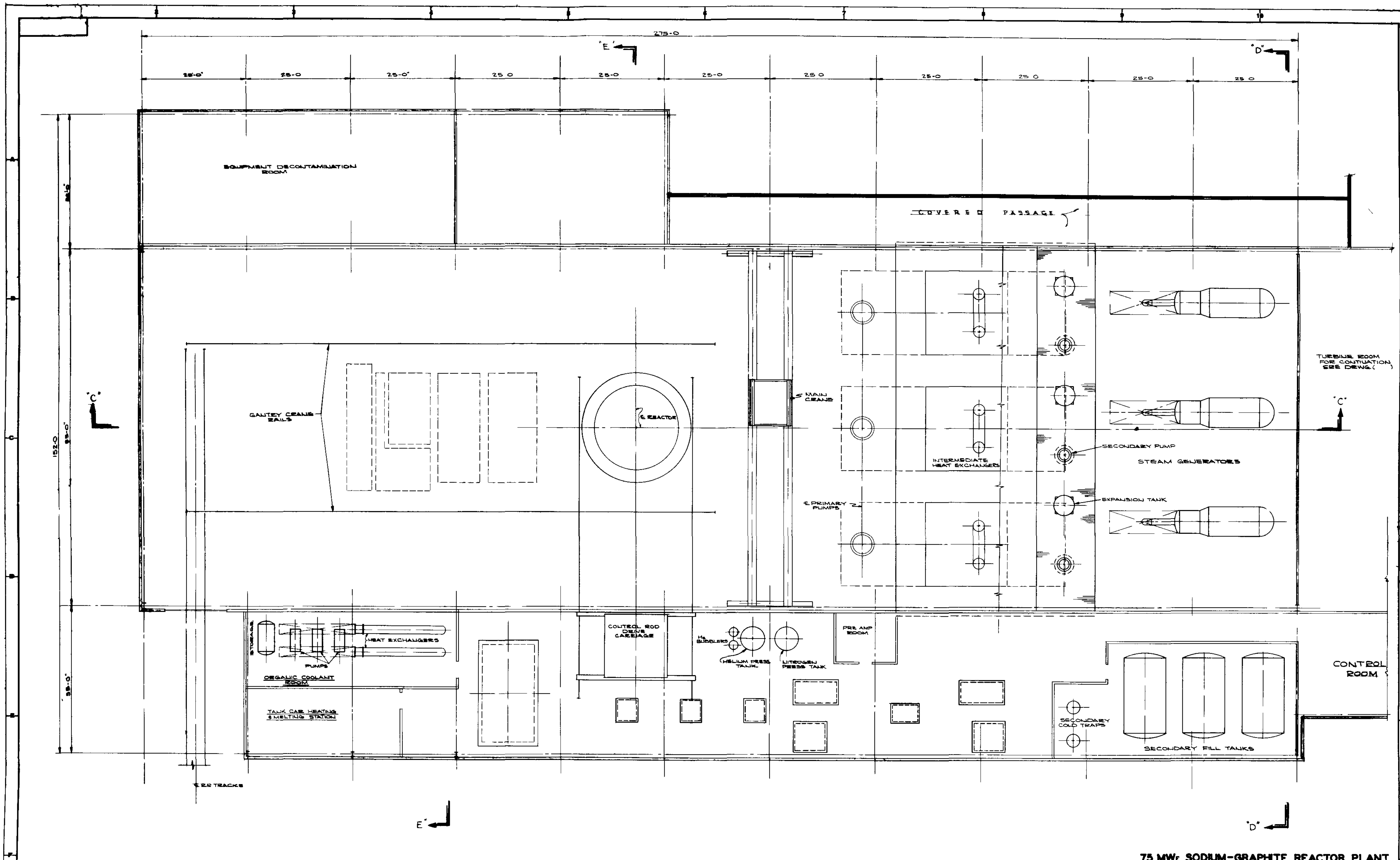


75 MWe SODIUM-GRAPHITE REACTOR PLANT
FLOW DIAGRAM
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.
SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS
SCALE NONE
DRAWN A J SCHALL
DRAWING NO
NS-401
REVISIONS
CHECKED
ENGINEER
APPROVED
JOB NO
1957-15
HELIUM SUPPLY
HIGH PRESSURE HELIUM
NaK BUBBLER
LOW PRESSURE HELIUM STORAGE TANK 750 GAL
CONTROL ELEMENTS
SAFETY ELEMENTS
EXPANSION TANKS
HEAT EXCHANGERS
COLD TRAPS
REACTOR
PUMP HOUSINGS
CLEANING CELLS
MISCELLANEOUS
TREATED WATER SUPPLY
TREATED WATER STORAGE TANK 5000 GAL
METERING TANK 50 GAL
TREATED WATER PUMP 10 GPM
FROM ORGANIC COOLING SYSTEM
FUEL ELEMENT CLEANING CELLS (TYPICAL) 24 CELLS
EQUIPMENT CLEANING CELL
COMPRESSORS 25 SCFM
COMPRESSOR SUCTION TANK 750 GAL
DECAY TANKS (4) 3000 GAL EACH
FROM VAPOR TRAPS EQUIPMENT VENTS & PRIMARY FILL TANKS
ABSOLUTE FILTER
TO VENTILATION STACK
RADIOACTIVE VENT SYSTEM
SHORT LIVED LIQUID WASTE HOLDING TANKS 5000 GAL EACH
LONG LIVED LIQUID WASTE STORAGE TANK 10,000 GAL
RADIOACTIVE LIQUID WASTE SYSTEM
TRANSFER TANK 250 GAL
TO FINAL DISPOSAL
PROCESS TRANSFER PUMPS 5 GPM
TO HIGH CONCENTRATE LONG LIVED STORAGE TANKS (2) 2,000 GAL EACH
VENT TO PRIMARY FILL TANK
FREEZE TRAP
COLD TRAP (2)
ORGANIC COOLING SYSTEM
REGENERATIVE HEAT EXCHANGER
PLUGGING METER
CONDENSER
HEATER
SECONDARY SYSTEM SODIUM PURIFICATION SYSTEM
He SUPPLY
FROM MELT STATION
SECONDARY FILL TANKS (3) 10,000 GAL EACH
DEMINERALIZED WATER STORAGE TANK 45,000 GAL
FROM MAKE UP WATER DEMINERALIZER SYSTEM
TO BOILER FILL
CONDENSATE TRANSFER PUMPS
FROM FUEL STORAGE POOL COOLING
COOLING WATER
SHIELD COOLERS (2)
SHIELD COOLING SYSTEM
SHIELD COOLING CIRCULATING PUMPS 65 GPM
TO FUEL STORAGE POOL COOLING
COPPER TUBE COIL IN CONCRETE
REACTOR
VAPOR TRAP
TO PRIMARY FILL TANKS
PRIMARY SODIUM PUMP 6500 GPM
PRIMARY SYSTEM (TYPICAL) (3) CIRCUITS
INTERMEDIATE HEAT EXCHANGER
SECONDARY E M DRAIN PUMP
SECONDARY EXPANSION TANK 2500 GAL
SECONDARY SODIUM PUMP 6500 GPM
SECONDARY SYSTEM (TYPICAL) 3 CIRCUITS
SUPER HEATER
BOILER
TO AIR EJECTOR
H P TURBINE
L P TURBINE
GENERATOR
MAIN CONDENSER
CONDENSATE PUMPS 750 GPM
STEAM
AIR EJECTOR
GLAND STEAM CONDENSER
FROM TURBINE GLANDS
TO ATMOSPHERE
H P HEATER A
LOW PRESS. HEATER C
LOW PRESS. HEATER B
BOILER-FEED PUMPS - 750 GPM
NOTE
CONDENSER CIRCULATING PUMPS, SERVICE WATER PUMPS, FIRE PUMPS & SCREEN WASH PUMPS ARE NOT SHOWN
TO RADIOACTIVE VENT SYSTEM
FROM SYSTEM FREEZE TRAPS
PRIMARY E M FILL PUMP 100 GPM
PRIMARY E M DRAIN PUMP 100 GPM
FROM REACTOR VENTS
VAPOR TRAPS
PRIMARY FILL TANKS (2) 15,000 GAL EACH
TO SECONDARY FILL TANK
SODIUM FILTER
FROM SODIUM MELT STATION
COLD TRAP
REGENERATIVE HEAT EXCHANGER
PRIMARY SODIUM PURIFICATION SYSTEM
TO PRIMARY FILL TANK
COLD TRAPS (2)
COOLER
PRIMARY SODIUM PURIFICATION SYSTEM
FACE SHIELD COOLING
PUMP SHAFT SEALS
PRIMARY PUMP OUTER CASE COOLING
SECONDARY PUMP OUTER CASE COOLING
PRIMARY COLD TRAP
THROTTLE VALVES
PLUGGING METER COOLER
DRAIN VALVE SEALS
SECONDARY COLD TRAP
MISCELLANEOUS VALVES
MISCELLANEOUS
FILL
ORGANIC SUPPLY TANK 500 GAL
ORGANIC PUMPS 215 GPM
ORGANIC HEAT EXCHANGERS (2)
COOLING WATER
SUPPLY
RETURN
ORGANIC COOLING SYSTEM



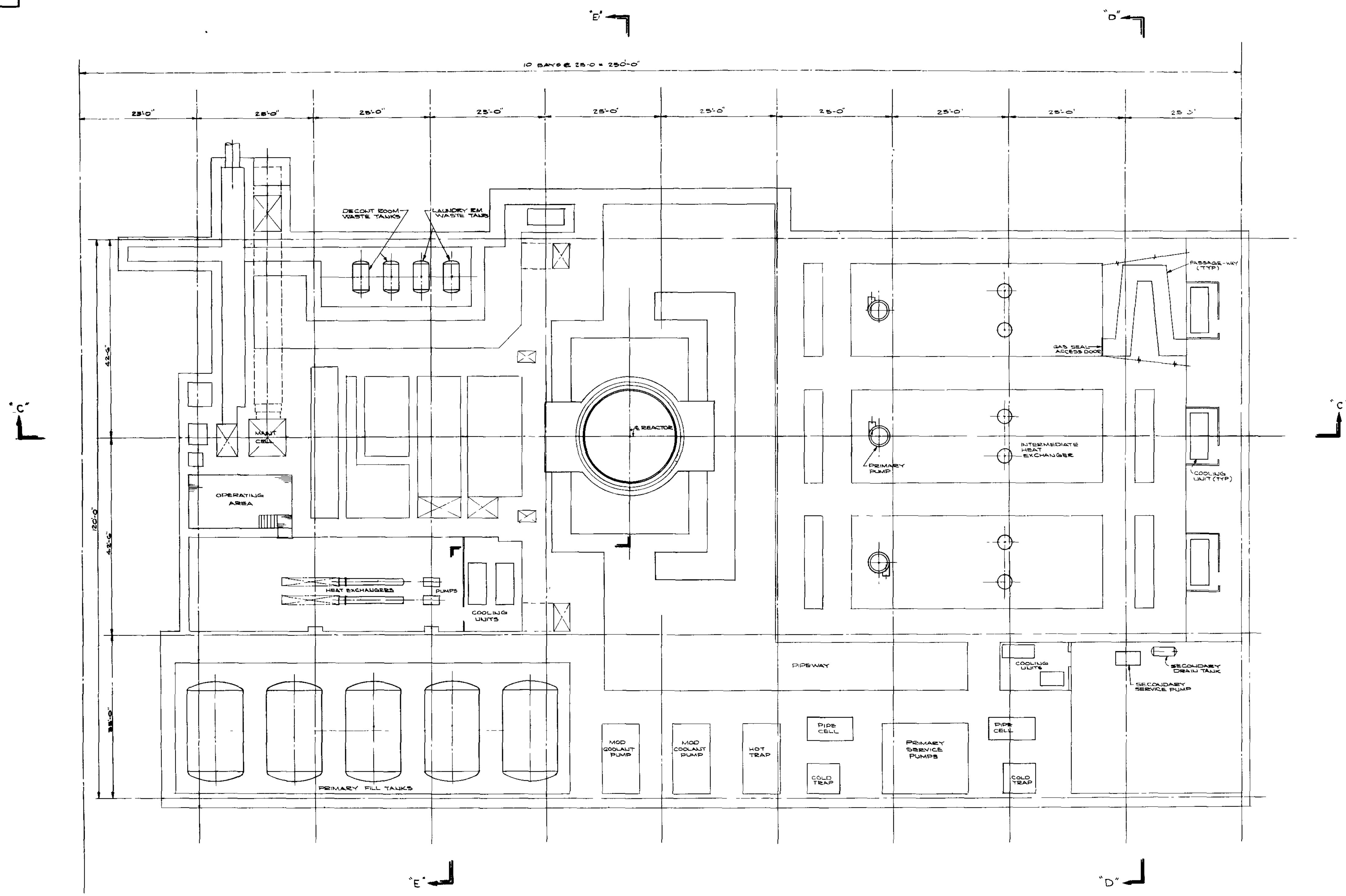
75 MWe SODIUM-GRAPHITE REACTOR PLANT

REVISIONS	PROPERTY PLAT DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.	
	SCALE 1"=50'-0" & AS NOTED DRAWN R R MAYERLE 8-25-59 CHECKED ENGINEER	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
	APPROVED	DRAWING NO
	JOB NO 1957-15 / JOB NO / JOB NO / JOB NO	NS-402



75 MWe SODIUM-GRAPHITE REACTOR PLANT

REVISIONS	GENERAL ARRANGEMENT PLAN UPPER FLOOR "A-A" REACTOR BLD'G DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.
SCALE 1/8"=1'-0" DRAWN R R MAYERLE 8-25-59 CHECKED ENGINEER APPROVED	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
JOB NO 1957-15	DRAWING NO NS-403



75 MWe SODIUM-GRAPHITE REACTOR PLANT

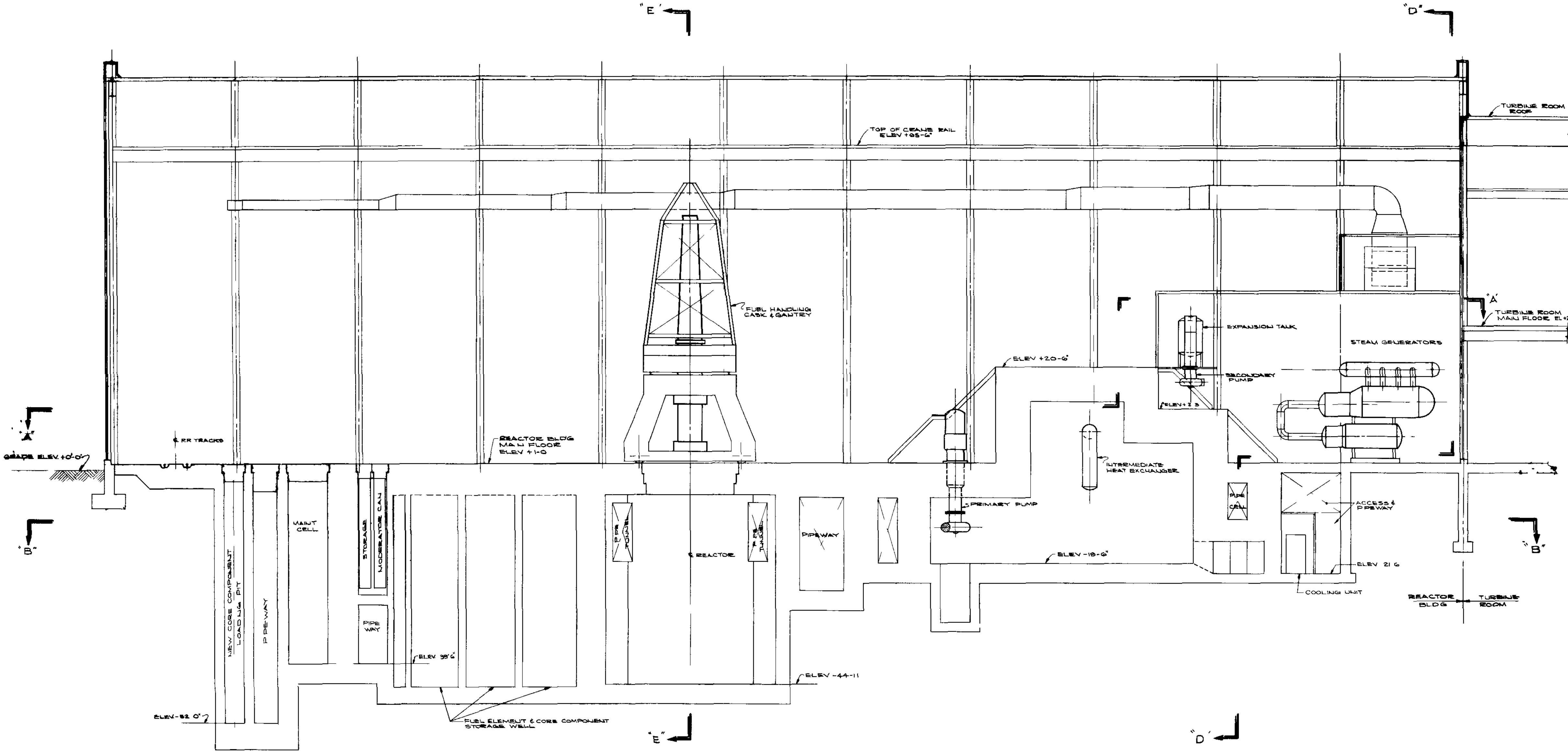
GENERAL ARRANGEMENT PLAN
LOWER FLOOR "B-B" REACTOR BLD'G
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

REVISIONS

SCALE 1/8"=1'-0"
DRAWN E.J.S. 8-25-59
CHECKED
ENGINEER
APPROVED
JOB NO 1867-15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO.
NS-404



75 MWe SODIUM–GRAPHITE REACTOR PLANT

REVISIONS

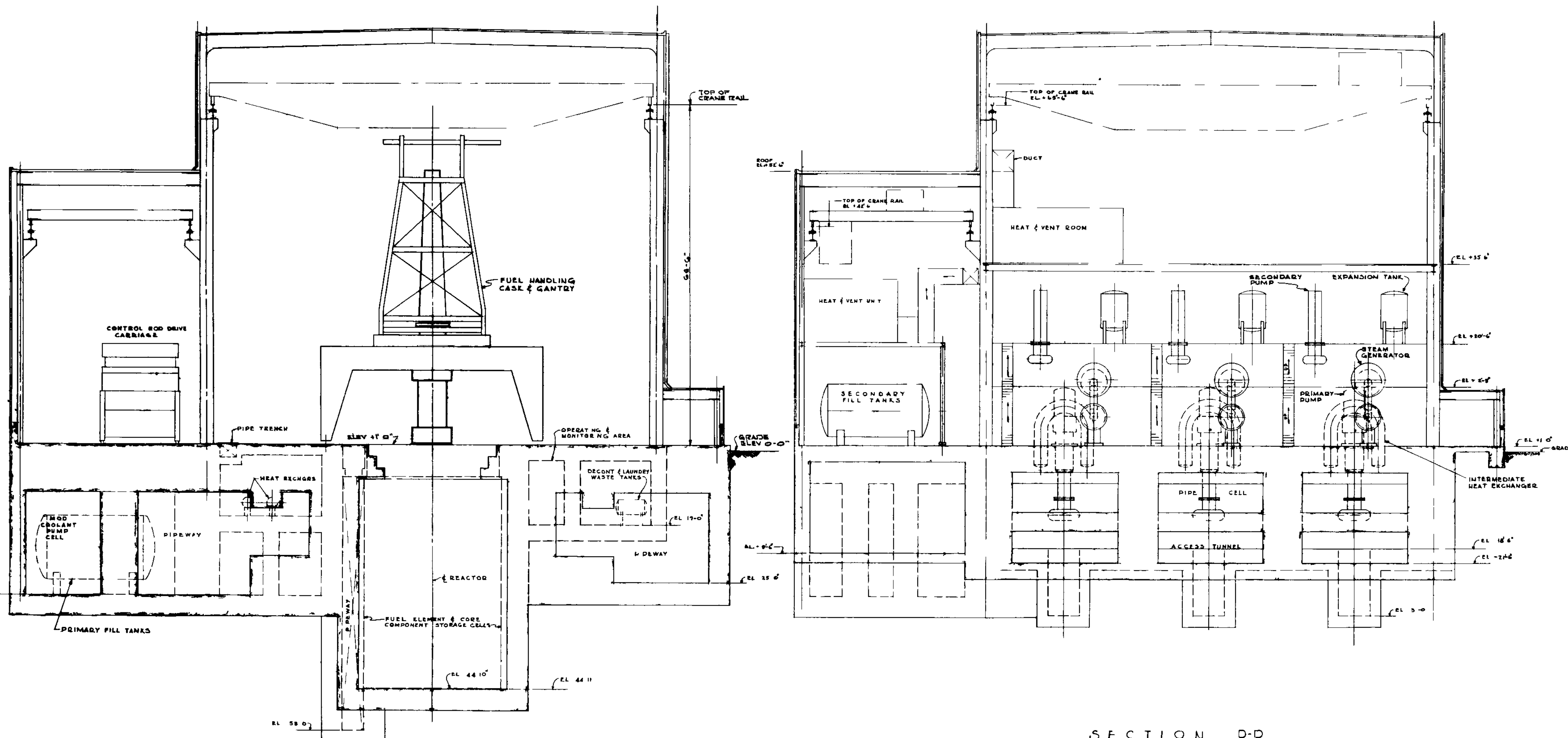
GENERAL CROSS SECTION "C-C"
REACTOR BLD'G.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8" = 1'-0"
DRAWN R R MAYERLE 8 25 59
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO	JOB NO
1957-15			

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-405



SECTION E-E

SECTION D-D

75 MWe SODIUM-GRAPHITE REACTOR PLANT

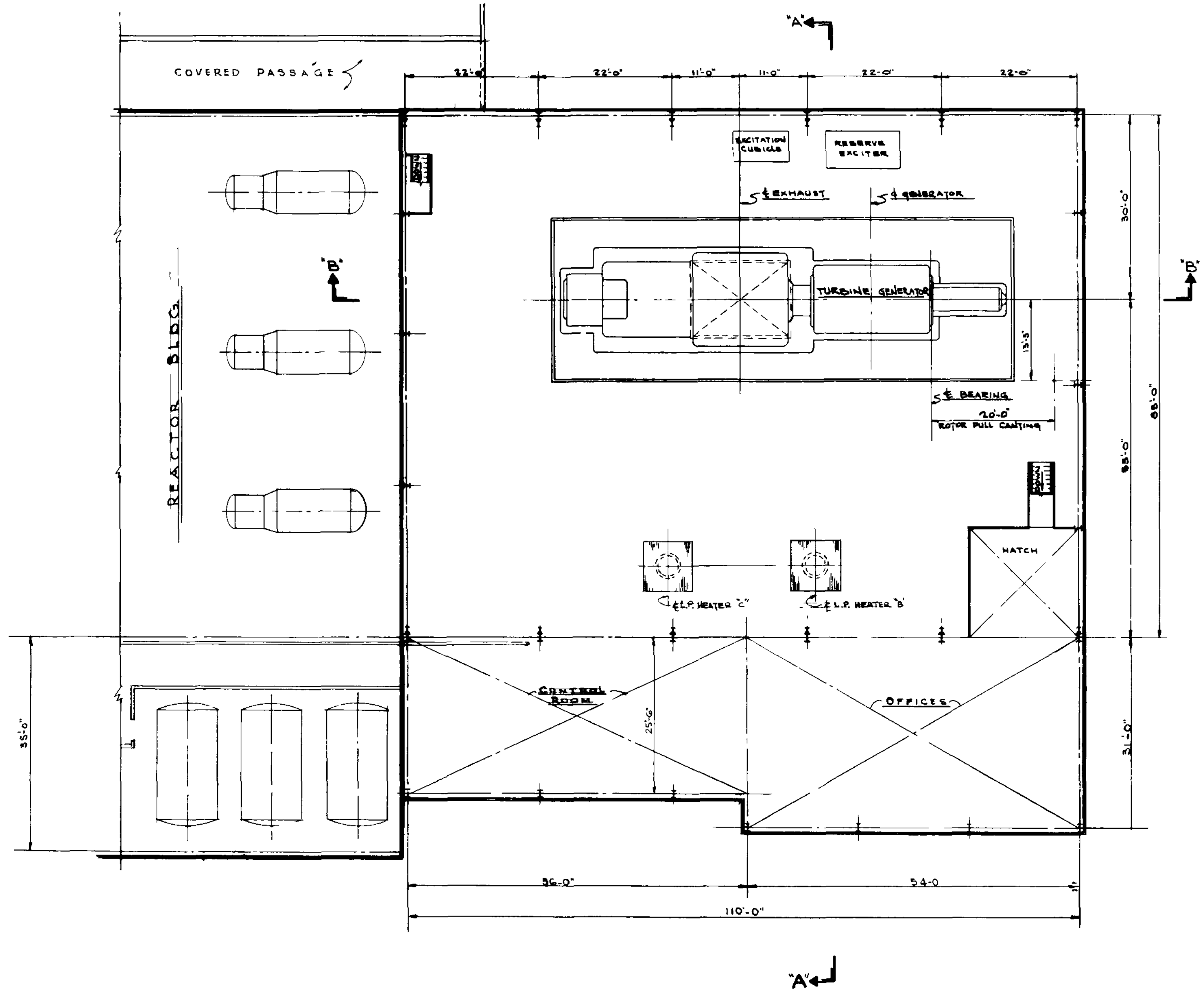
GENERAL CROSS SECTIONS D-D & C-C REACTOR BLDG

DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN F P RUSSO
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15

SARGENT & LUNDY ENGINEERS
CHICAGO 3 ILLINOIS

DRAWING NO
NS-406



75 MWe SODIUM-GRAPHITE REACTOR PLANT

REVISIONS		

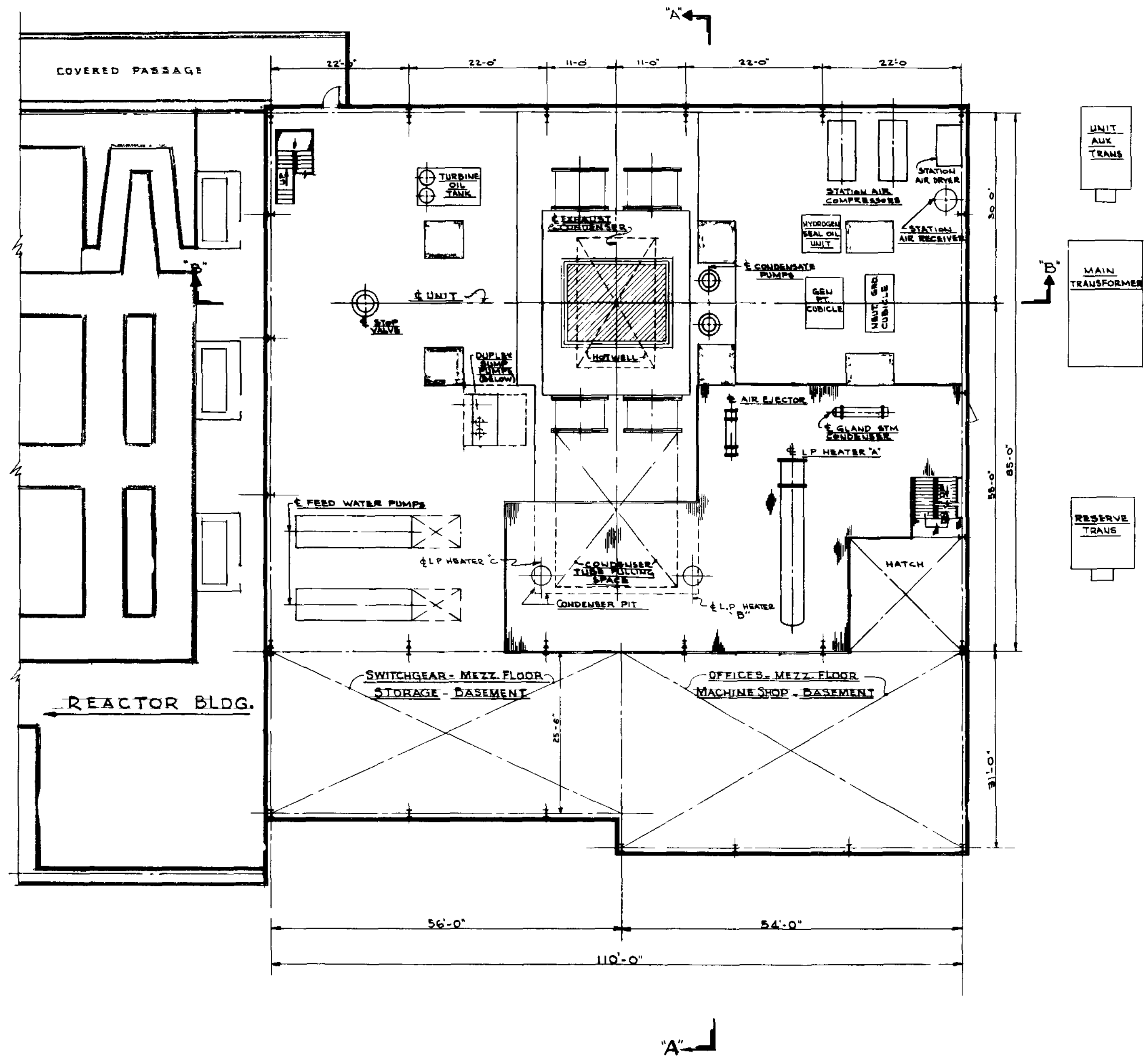
GENERAL ARRANGEMENT PLAN
MAIN FLOOR TURBINE BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN T DENNEN 8-25-59
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO.	JOB NO
1957-15			

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO.
NS-407



75 MWE SODIUM-GRAPHITE REACTOR PLANT

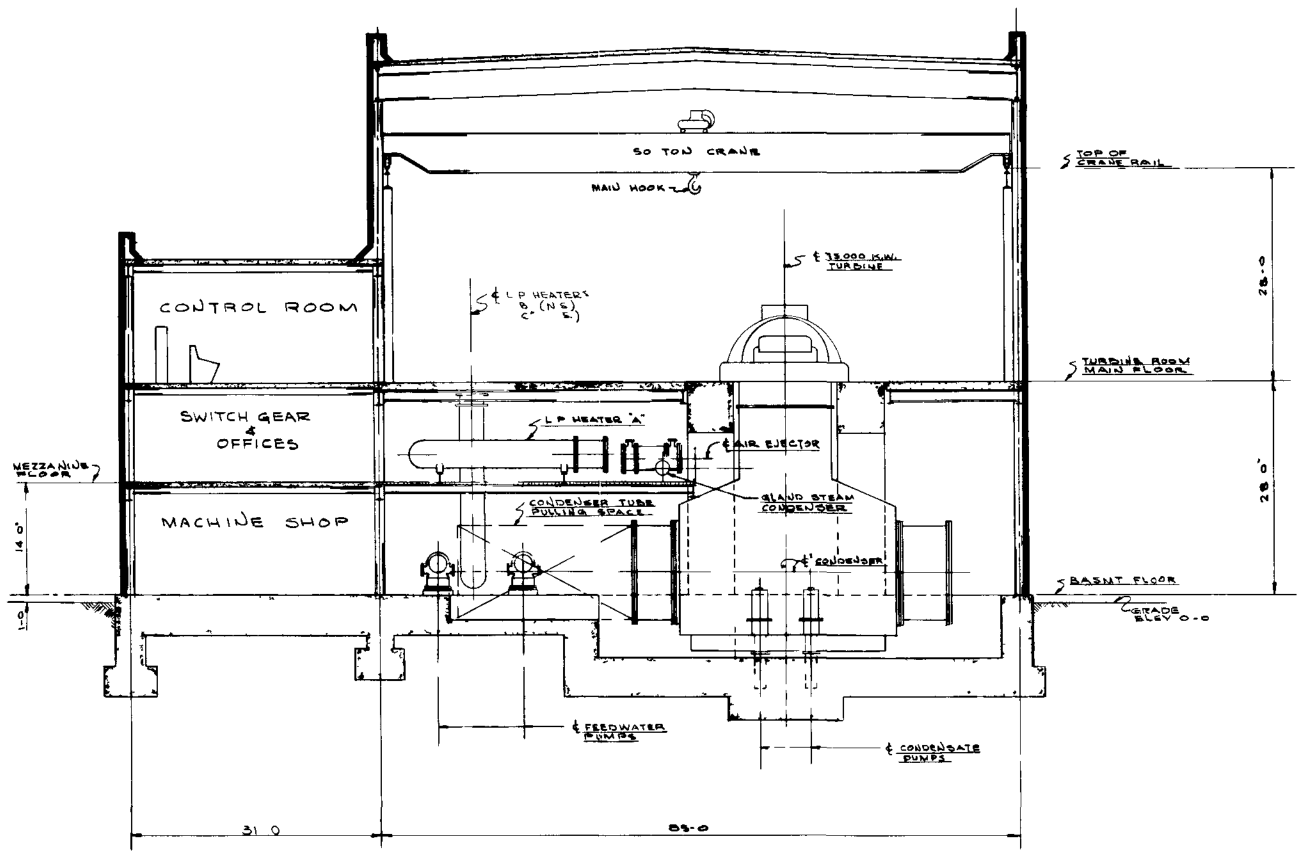
REVISIONS	GENERAL ARRANGEMENT PLAN MEZZ. & BASEMENT FLR. TURBINE BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN T DENNEN 8-25-59
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO	JOB NO
1957-15			

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-408

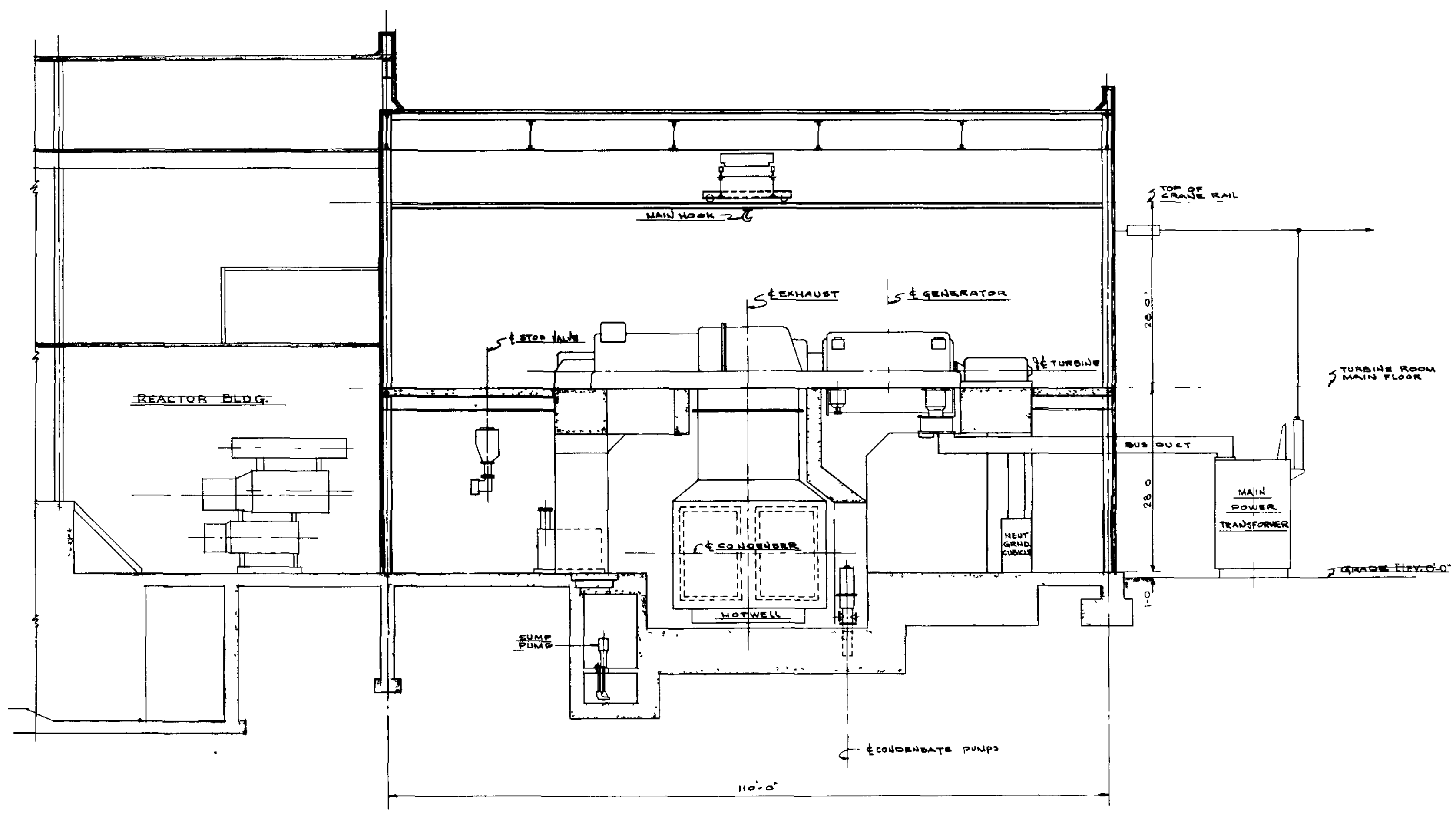


SECTION A-A

75 MWe SODIUM-GRAPHITE REACTOR PLANT

GENERAL CROSS SECTION "A-A"
TURBINE BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

REVISIONS	
SCALE 1/8"=1'-0"	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWN T. DENNEN 8-25-58	
CHECKED	
ENGINEER	
APPROVED	DRAWING NO
JOB NO 1957-15	NS-409



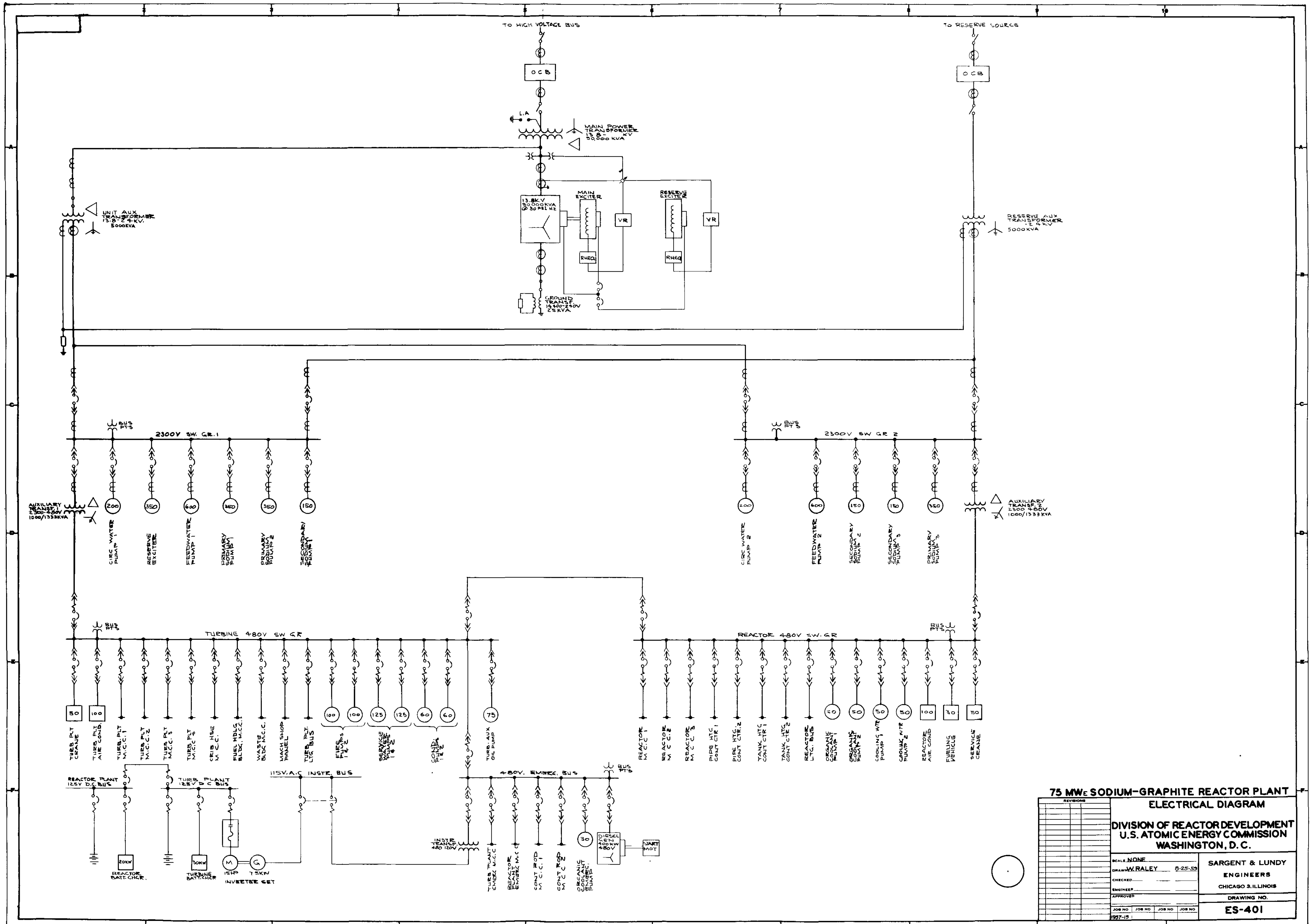
SECTION "B-B"

75 MWE SODIUM-GRAPHITE REACTOR PLANT

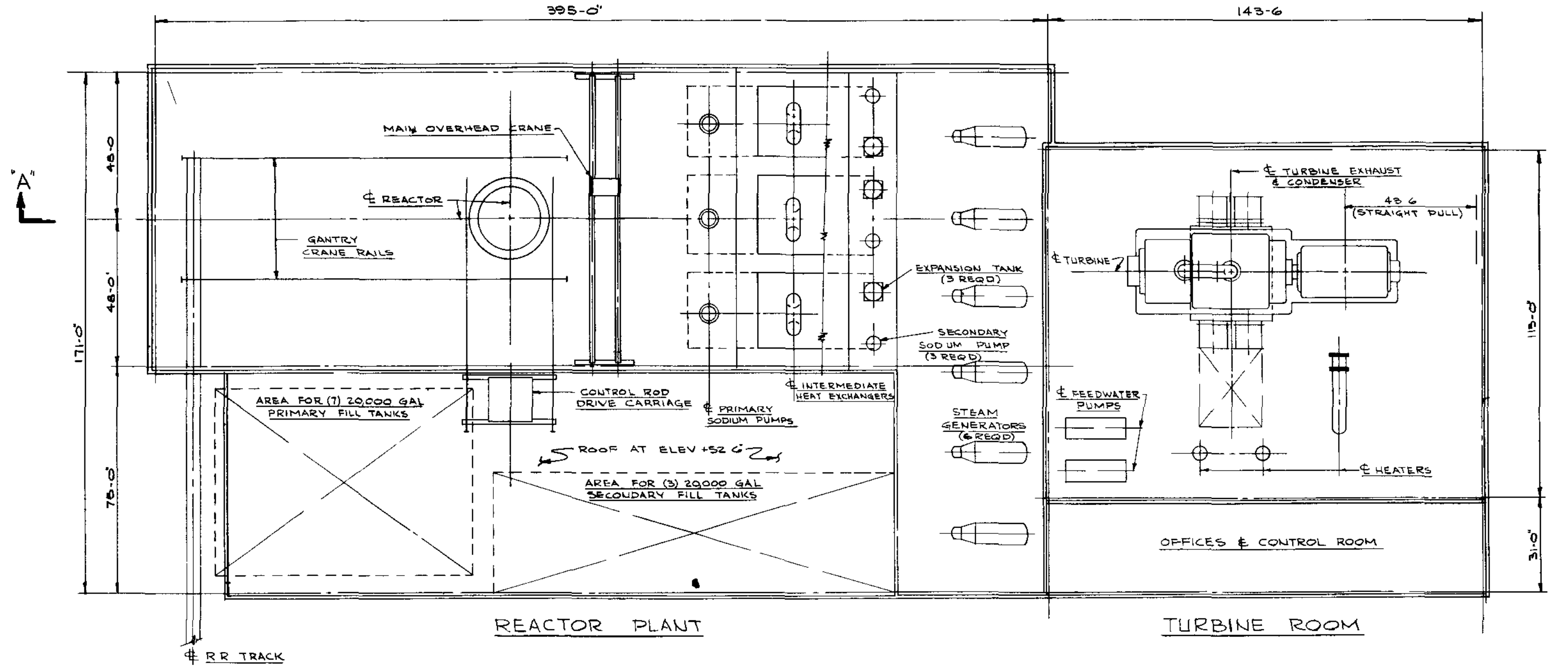
REVISIONS	LONGITUDINAL SECTION "B-B" TURBINE BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.
	SCALE 1/8"=1'-0"
	DRAWN T. DENNEN 8 25 59
	CHECKED
	ENGINEER
	APPROVED
	JOB NO 1957-15

SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS

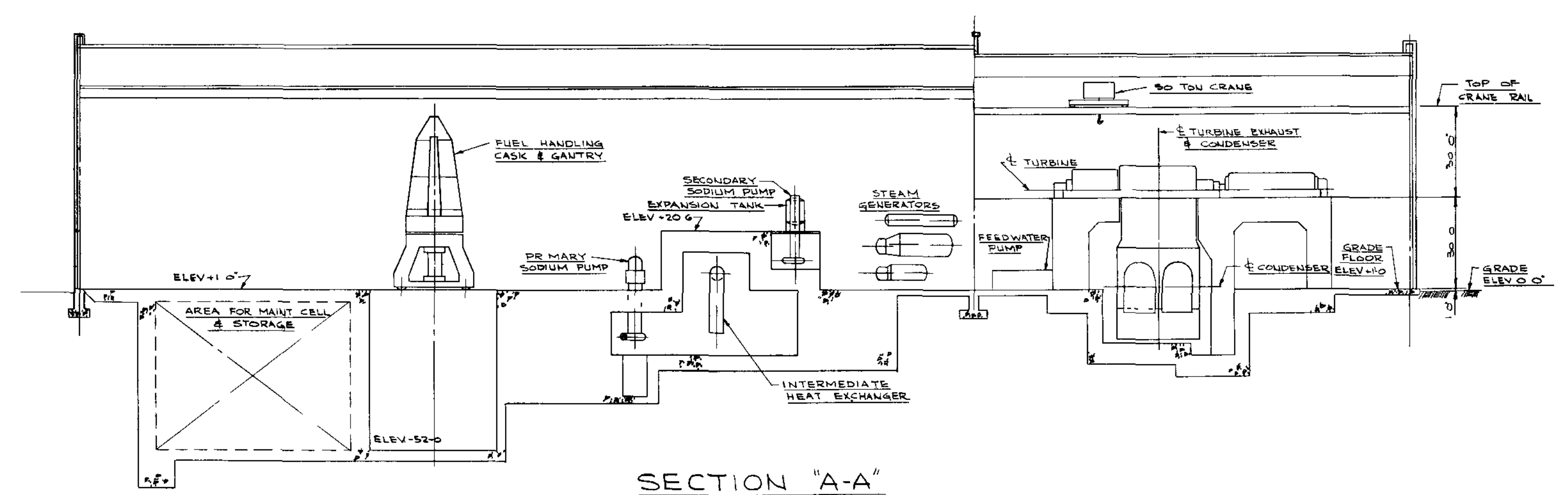
DRAWING NO NS-410



TO HIGH VOLTAGE BUS
TO RESERVE SOURCE
OCB
OCB
L.A.
MAIN POWER TRANSFORMER 13.8 - KV 50,000 KVA
UNIT AUX TRANSFORMER 13.8-2.4 KV. 5000KVA
RESERVE AUX TRANSFORMER 13.8-2.4 KV 5000KVA
13.8KV 50,000KVA
MAIN EXCITER
RESERVE EXCITER
VR
VR
RHEO.
RHEO.
GROUND TRANSF. 14,400-240V 25KVA
BUS PT'S
2300V SW. GR. 1
2300V SW GR 2
AUXILIARY TRANSF. 1 2300-480V 1000/1333KVA
AUXILIARY TRANSF. 2 2300-480V 1000/1333KVA
200
350
600
350
350
150
600
600
150
150
350
CIRC WATER PUMP 1
RESERVE EXCITER
FEEDWATER PUMP 1
PRIMARY SODIUM PUMP 1
PRIMARY SODIUM PUMP 2
SECONDARY SODIUM PUMP 1
CIRC WATER PUMP 2
FEEDWATER PUMP 2
SECONDARY SODIUM PUMP 2
SECONDARY SODIUM PUMP 3
PRIMARY SODIUM PUMP 3
TURBINE 480V SW GR
REACTOR 480V SW. GR
50
100
100
100
125
125
60
60
75
50
50
50
50
100
30
50
TURB. PLT CRANE
TURB. PLT AIR COND.
TURB. PLT M.C.C. 1
TURB. PLT M.C.C. 2
TURB. PLT M.C.C. 3
TURB. PLT M.C.C. 4
CRIB HSE M.C.C.
FUEL HDLG BLDG. M.C.C.
WASTE BLDG M.C.C.
MACH SHOP PANEL
TURB. PLT LTG. BUS
FIRE PUMPS 1 & 2
SERVICE WATER PUMPS 1 & 2
COND. PUMPS 1 & 2
TURB. AUX OIL PUMP
REACTOR M.C.C. 1
REACTOR M.C.C. 2
REACTOR M.C.C. 3
PIPE HTG CONT CTR 1
PIPE HTG CONT CTR 2
TANK HTG CONT CTR 1
TANK HTG CONT CTR 2
REACTOR LTG. BUS
ORGANIC COOLANT PUMP 1
ORGANIC COOLANT PUMP 2
COOLING WTR PUMP
COOLING WTR PUMP 2
REACTOR AIR COND
FUELING VEHICLE
SERVICE CRANE
REACTOR PLANT 125V D.C. BUS
TURB. PLANT 125V D.C. BUS
115V. A.C. INSTR. BUS
480V. EMERG. BUS
20KW
30KW
REACTOR BATT. CHGR.
TURBINE BATT. CHGR.
M
G
15HP
7.5KW
INVERTER SET
INSTR. TRANSF. 480-120V
30
DIESEL GEN 400KW 480V
START MOT
TURB. PLANT EMERG. M.C.C.
REACTOR EMERG. M.C.C.
CONT ROD M.C.C. 1
CONT ROD M.C.C.
ORGANIC COOLANT EMERG. PUMP
75 MWe SODIUM-GRAPHITE REACTOR PLANT
ELECTRICAL DIAGRAM
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.
REVISIONS
SCALE NONE
DRAWN W. RALEY 8-25-55
CHECKED
ENGINEER
APPROVED
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
ES-401
JOB NO.
1957-15



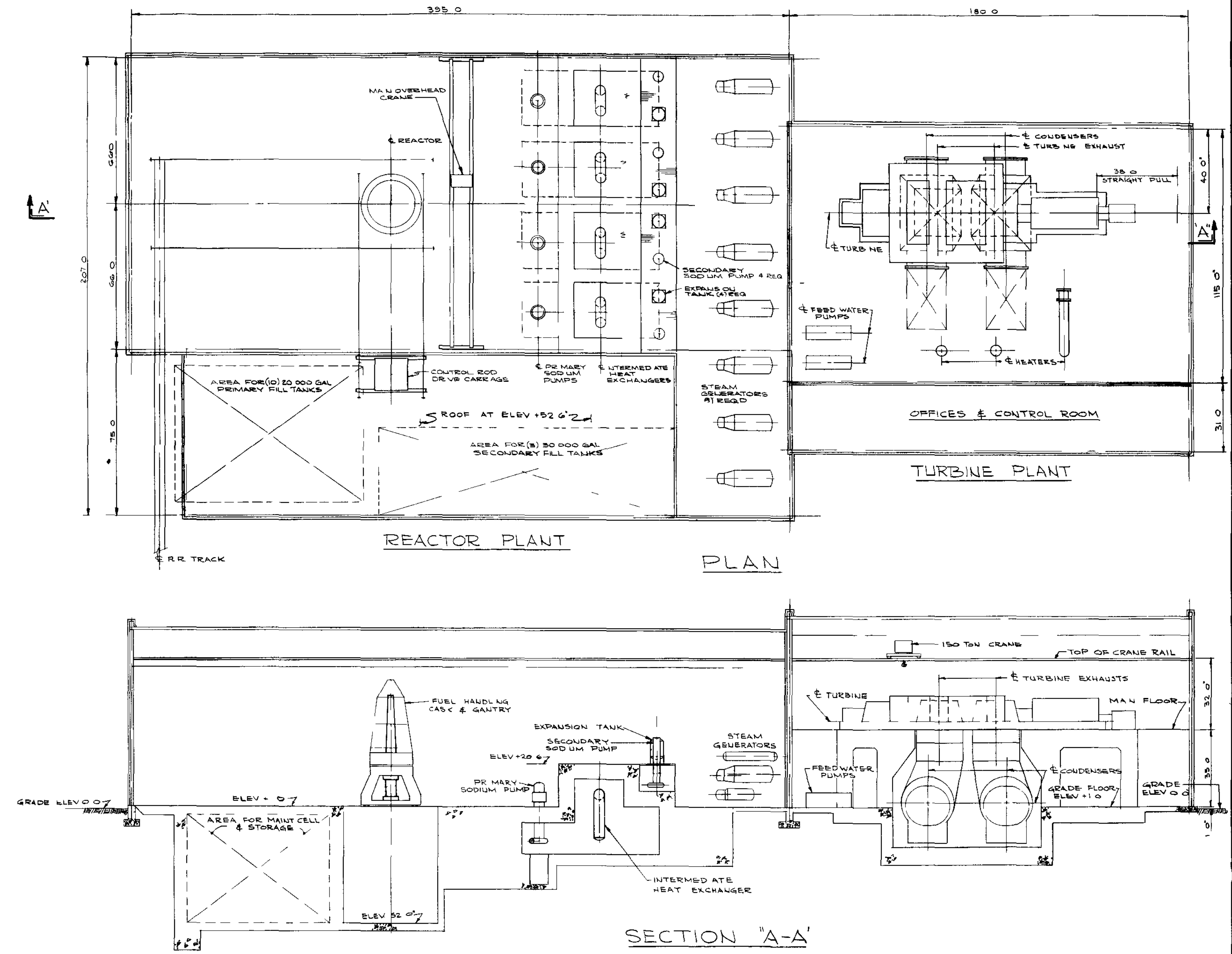
PLAN



SECTION "A-A"

200 MWe SODIUM-GRAPHITE REACTOR PLANT

REVISIONS	
GENERAL ARRANGEMENT PLAN & SECTION DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.	
SCALE 1"=20-0" DRAWN R GOETTSCHE 8 25 59 CHECKED ENGINEER APPROVED	SARGENT & LUNDY ENGINEERS CHICAGO 3 ILLINOIS
JOB NO 1957-15	DRAWING NO NS-411



300MWe SODIUM-GRAPHITE REACTOR PLANT

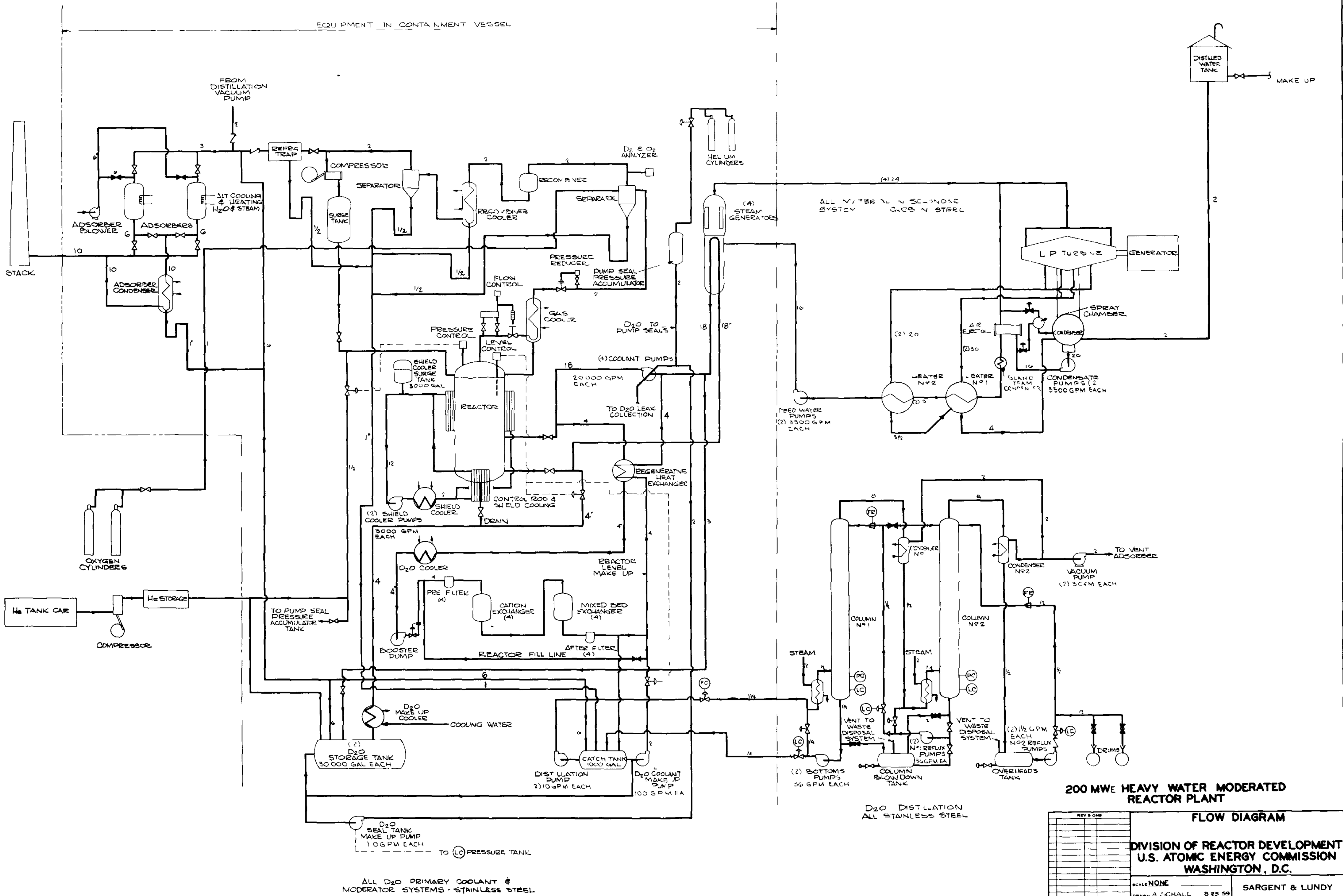
GENERAL ARRANGEMENT PLAN & SECTION
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

REVISIONS

SCALE 1"=20'-0"
DRAWN R.R. MAYERLE 8-25-59
CHECKED
ENGINEER
APPROVED
JOB NO 1957 15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-412



200 MWe HEAVY WATER MODERATED REACTOR PLANT

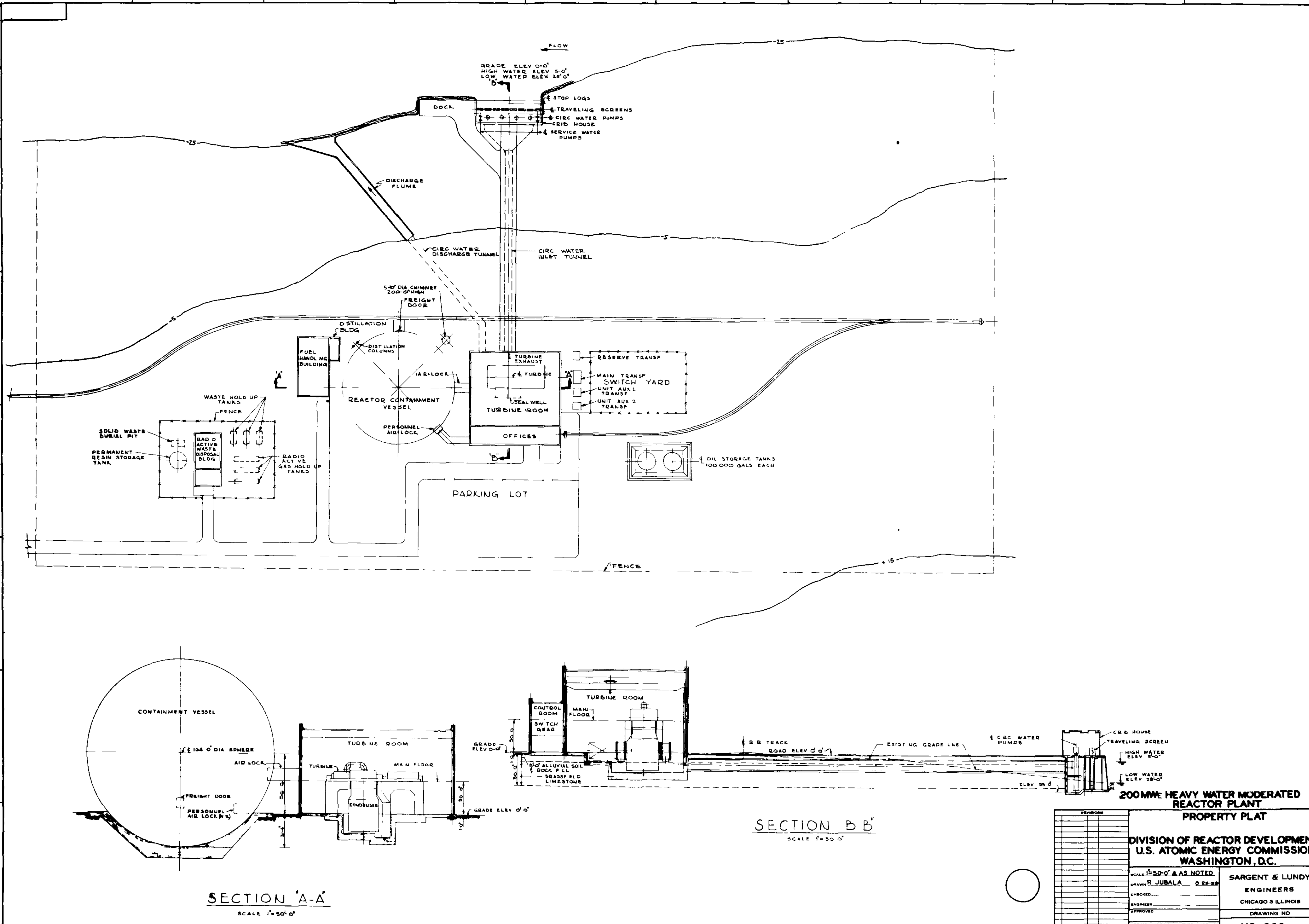
FLOW DIAGRAM

DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE NONE
DRAWN A. SCHALL 8-25-59
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

DRAWING NO
NS-501



200 MWE HEAVY WATER MODERATED REACTOR PLANT

PROPERTY PLAT

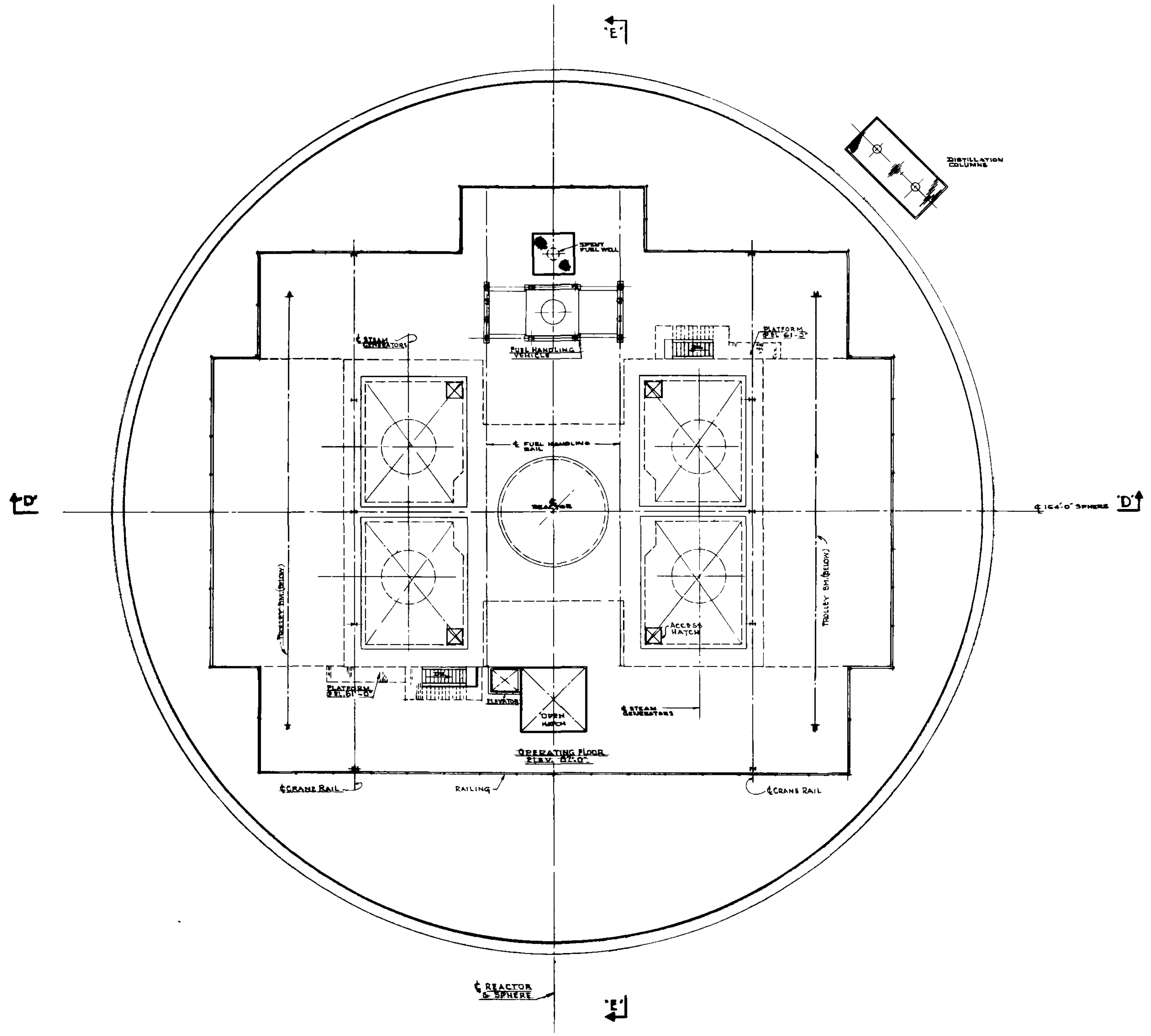
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1"=50'-0" & AS NOTED
DRAWN R JUBALA 6-25-59
CHECKED
ENGINEER
APPROVED

SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

DRAWING NO
NS-502

1957-13



200 MWe HEAVY WATER MODERATED REACTOR PLANT

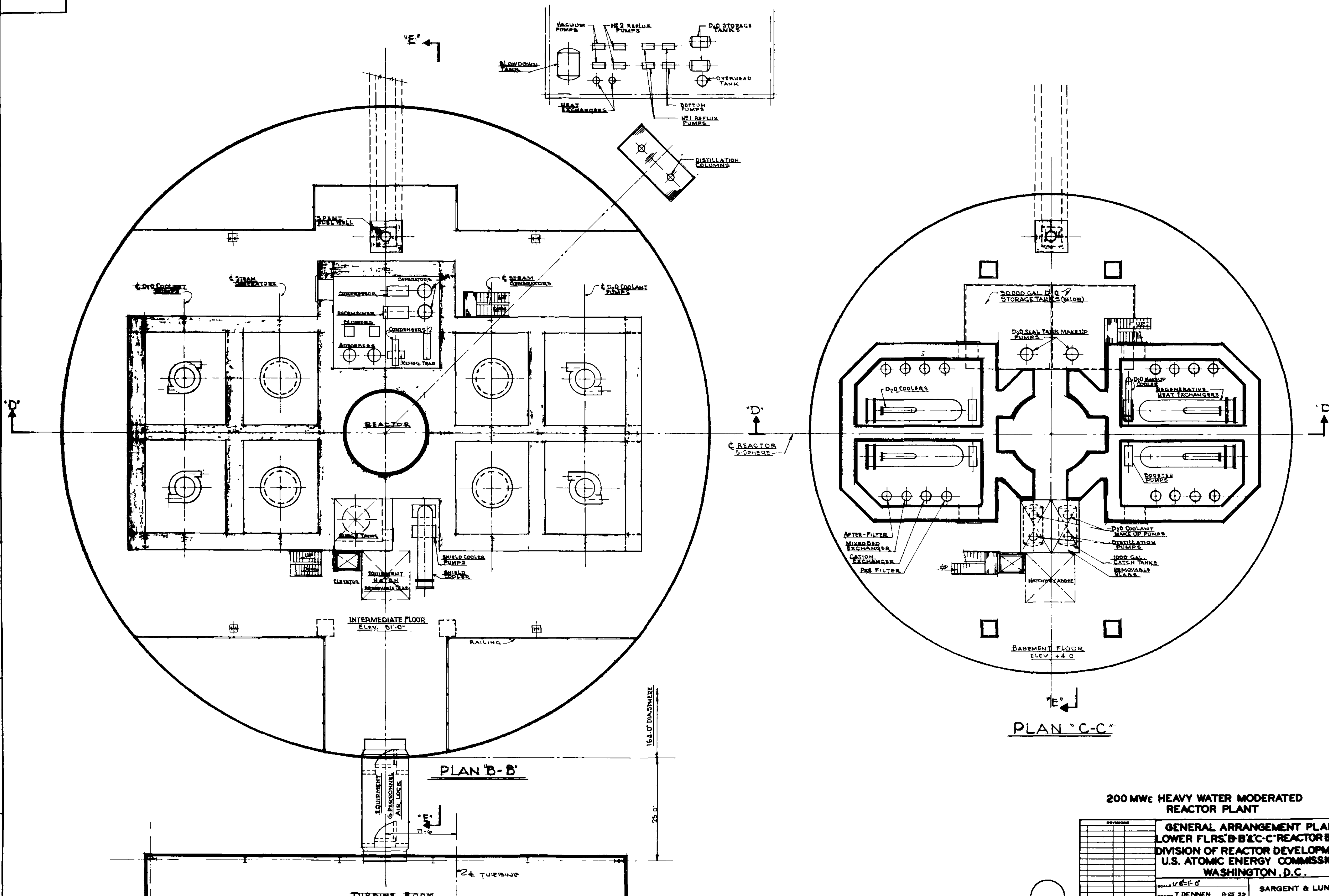
REVISIONS

GENERAL ARRANGEMENT PLAN
UPPER FLOOR "A-A" REACTOR BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN T DENNEN 8-25-59
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-503



200 MWe HEAVY WATER MODERATED REACTOR PLANT

REVISIONS			

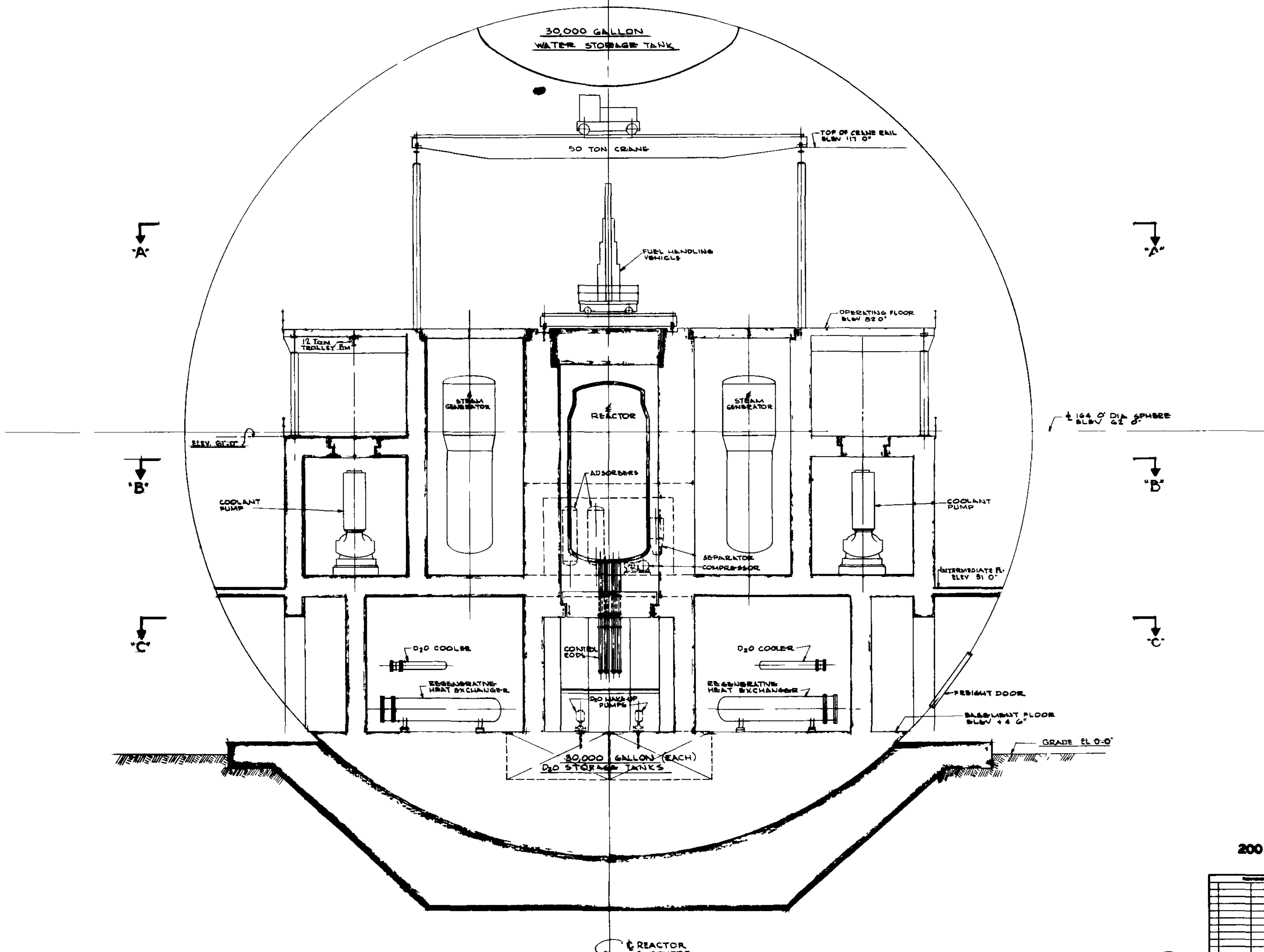
GENERAL ARRANGEMENT PLAN
LOWER FLRS."B-B"&"C-C" REACTOR BLDG
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN T DENNEN 8-25 59
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO	JOB NO
1657-15		-	

SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

DRAWING NO
NS-504



200 MWe HEAVY WATER MODERATED REACTOR PLANT

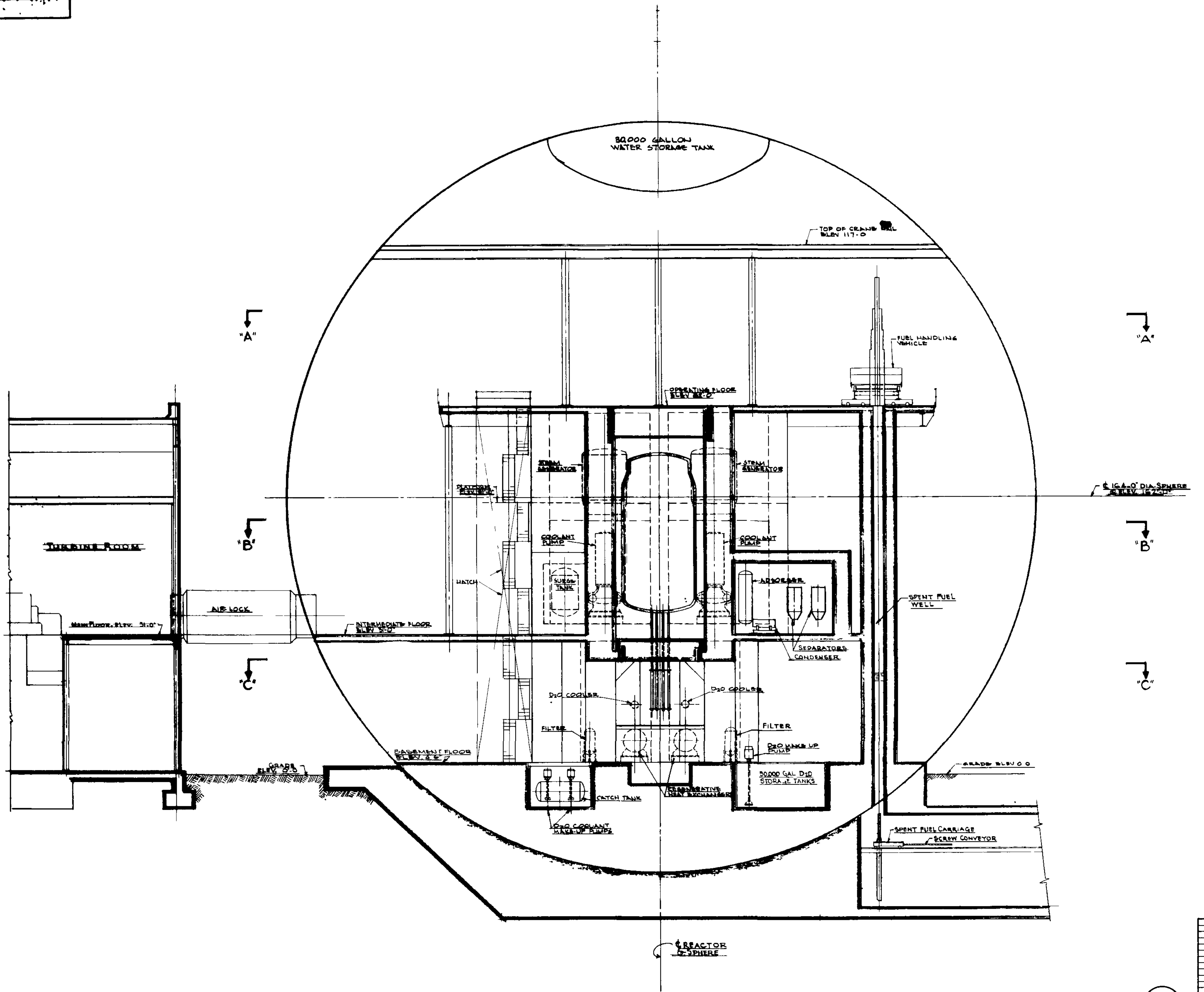
GENERAL CROSS SECTION "D-D"
REACTOR BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN E.J. SLOWINSKI 8 25
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO	JOB NO
1867-15			

SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

DRAWING NO
NS-505

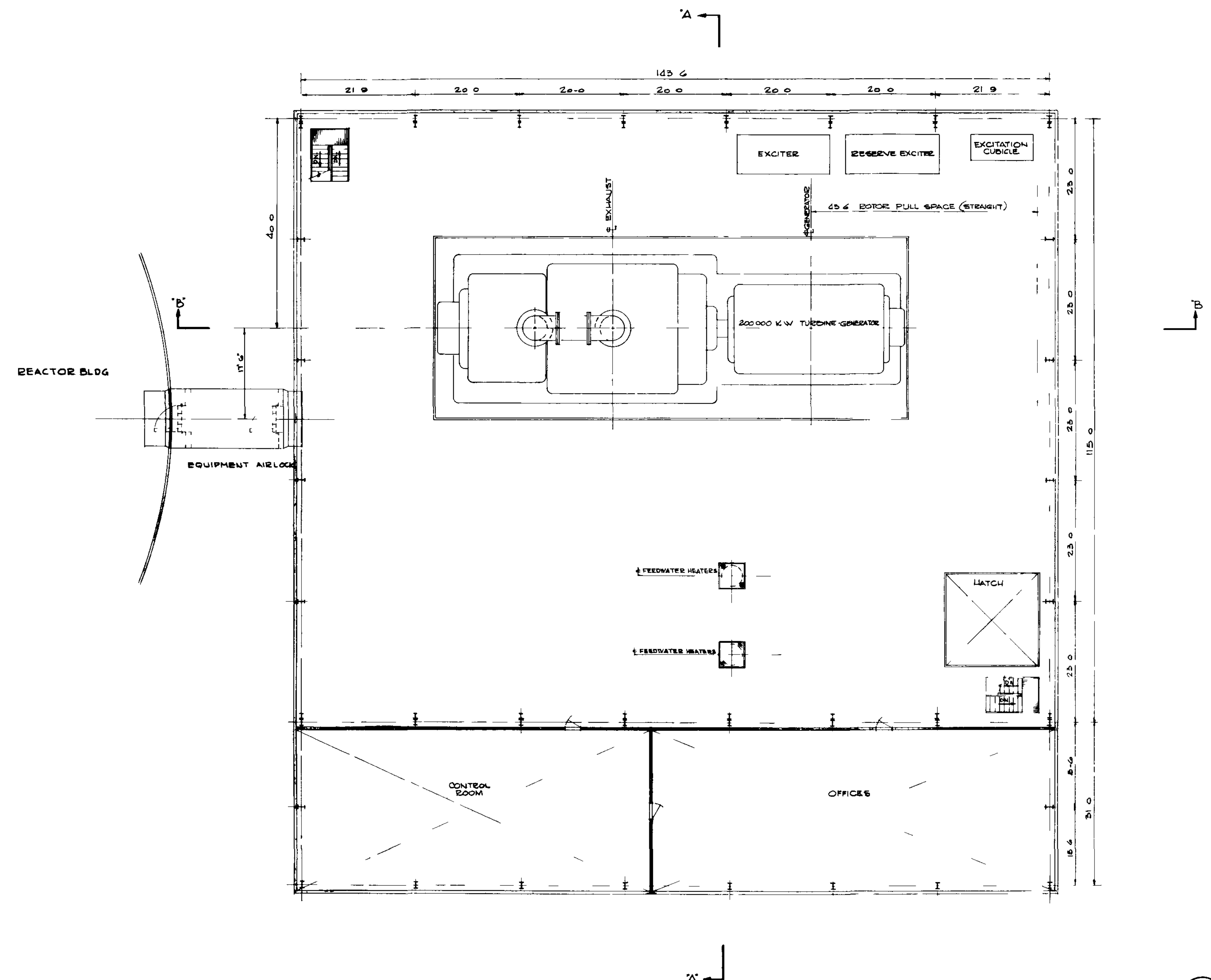


200 MWe HEAVY WATER MODERATED REACTOR PLANT

REVISIONS	GENERAL CROSS SECTION "E-E" REACTOR BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.
	SCALE 1/8" = 1'-0"
	DRAWN T DENNEN 6-25-59
	CHECKED
	ENGINEER
	APPROVED
	JOB NO 1957-15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

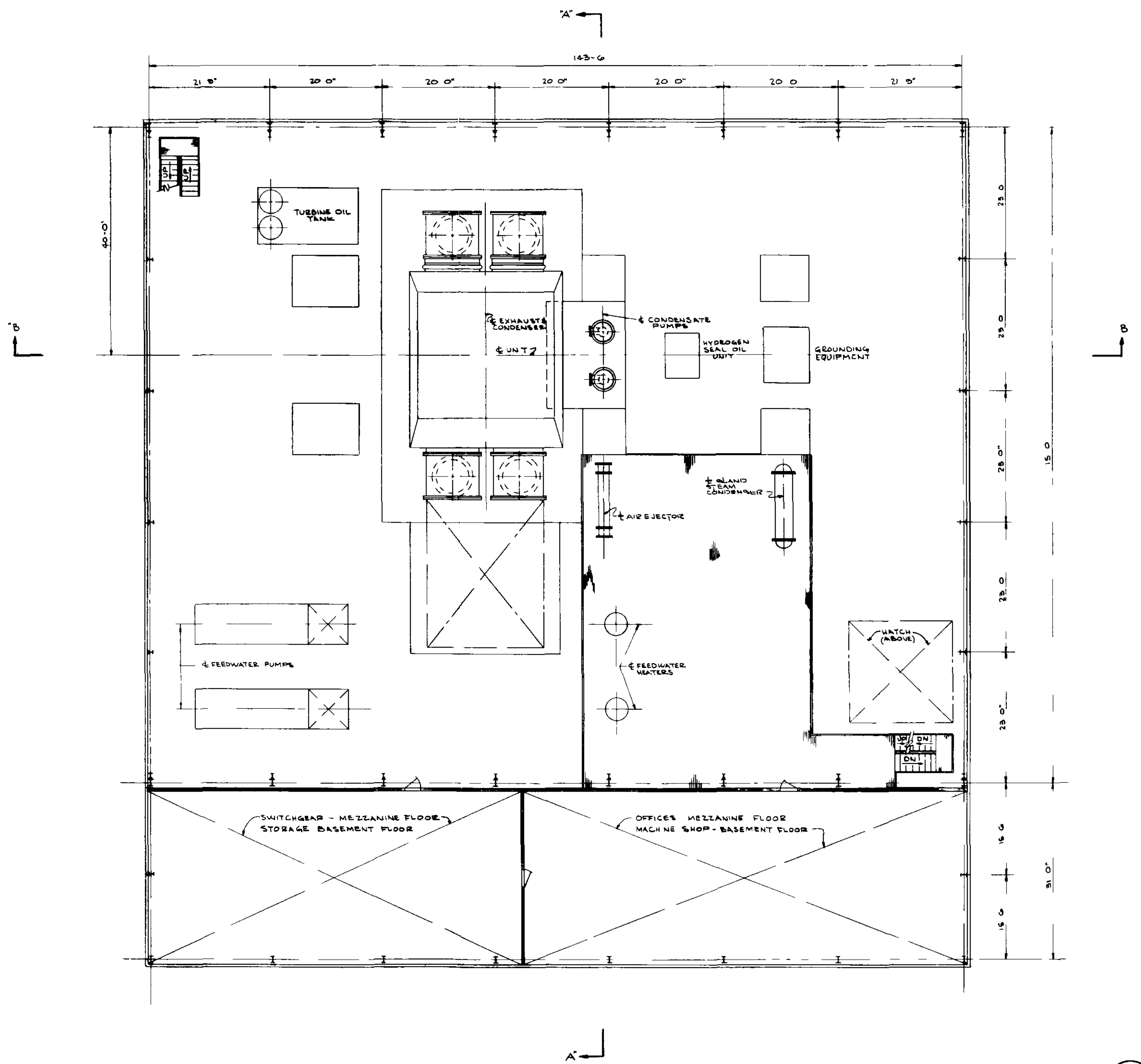
DRAWING NO
NS-506



200MWe HEAVY WATER MODERATED REACTOR PLANT

GENERAL ARRANGEMENT PLAN
MAIN FLOOR TURBINE BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1-0"	SARGENT & LUNDY ENGINEERS CHICAGO 3 ILLINOIS
DRAWN A J SCHALL 8 25 59	
CHECKED	
ENGINEER	
APPROVED	DRAWING NO
JOB NO 1957-15	NS-507



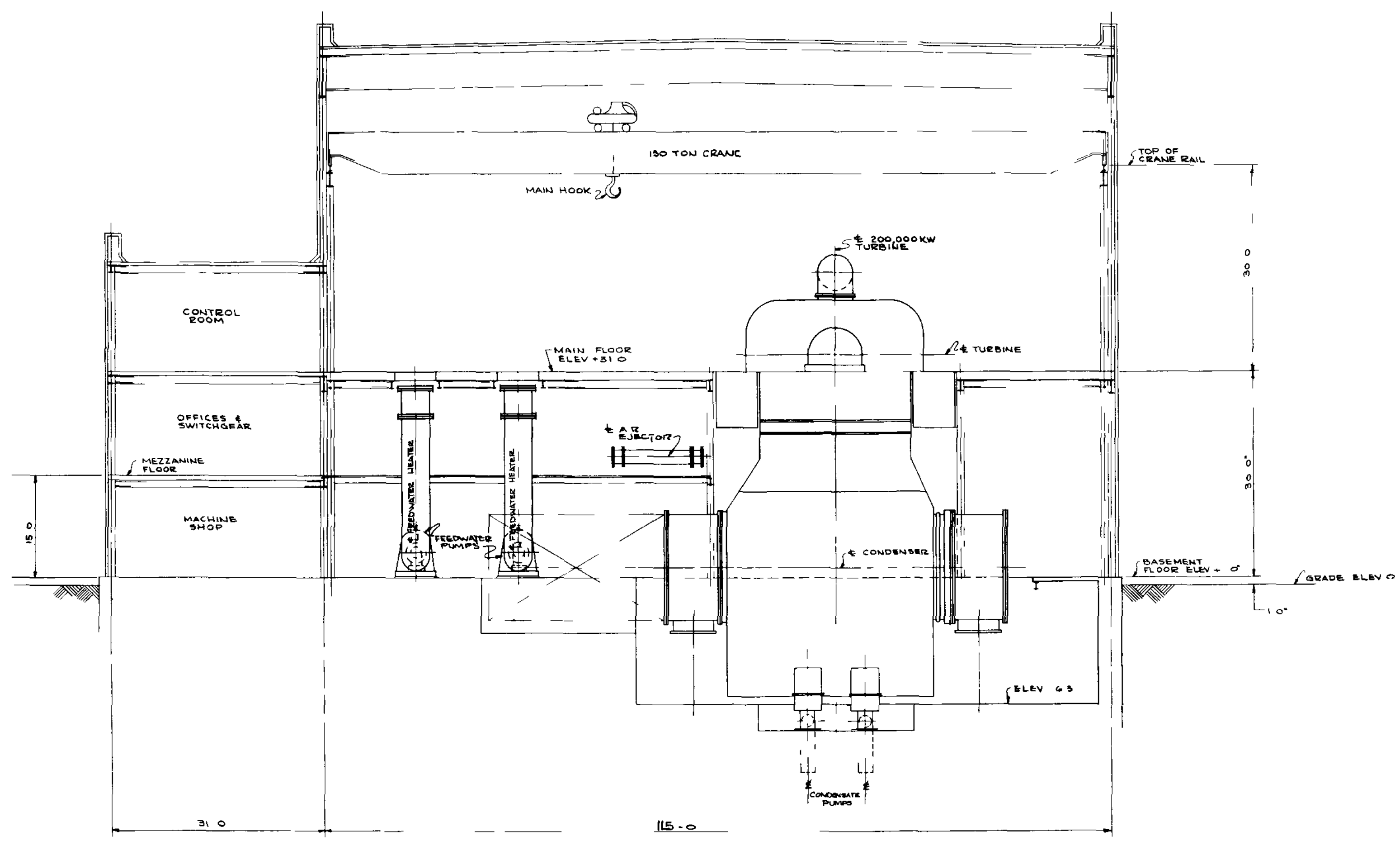
200 MWe HEAVY WATER MODERATED REACTOR PLANT

GENERAL ARRANGEMENT PLAN
MEZZ. & BSMT. FLRS. TURBINE BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN C. KUSZYNSKI 8-25-59
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15

SARGENT & LUNDY ENGINEERS
CHICAGO 3 ILLINOIS

DRAWING NO
NS-508



SECTION A-A"

200MWe HEAVY WATER MODERATED REACTOR PLANT

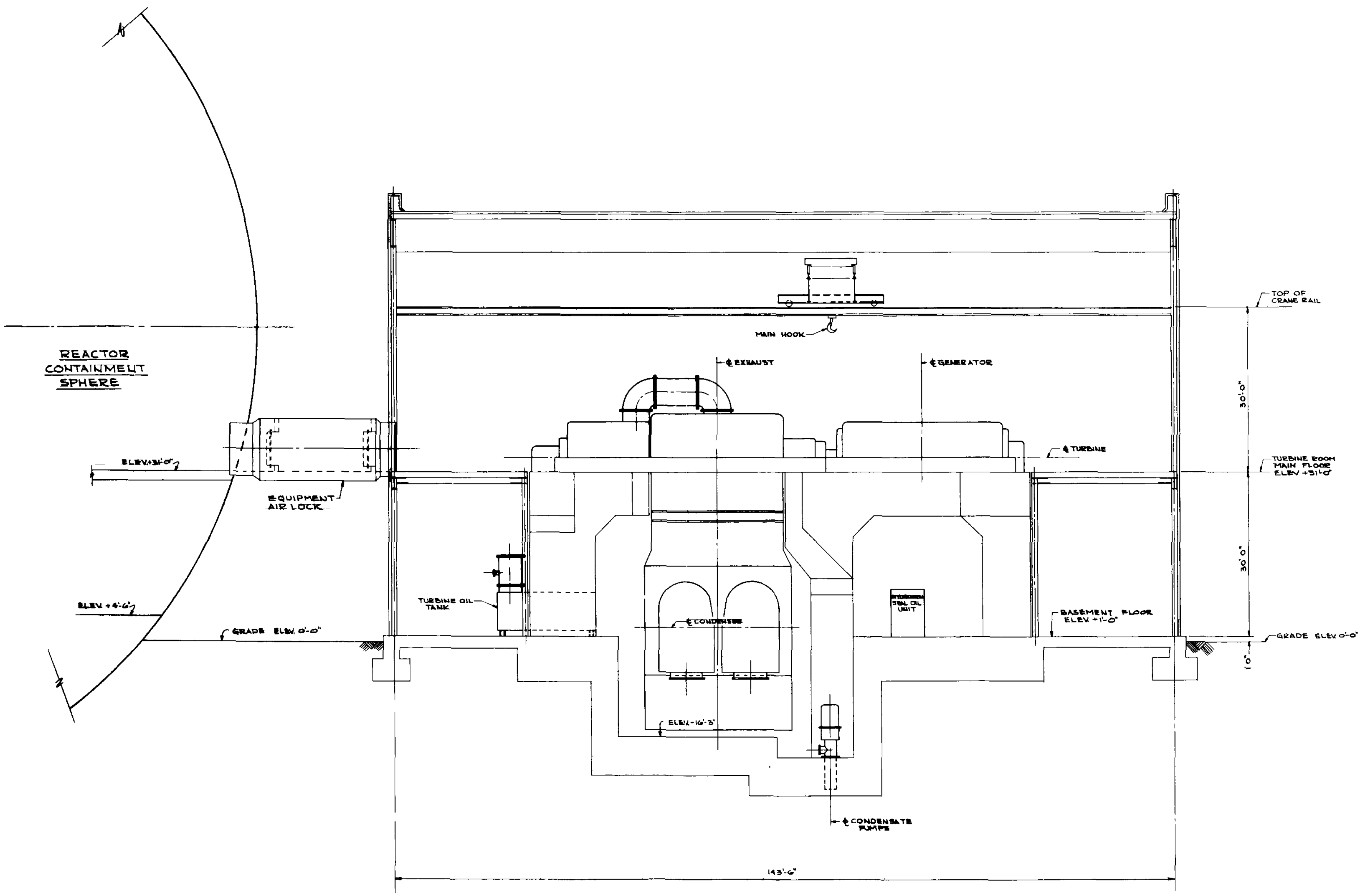
GENERAL CROSS SECTION "A-A"
TURBINE BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

REVISIONS

SCALE 1/8=1-0
DRAWN C KUSZYNSKI 8 25 59
CHECKED
ENG NEER
APPROVED
JOB NO 1957-15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

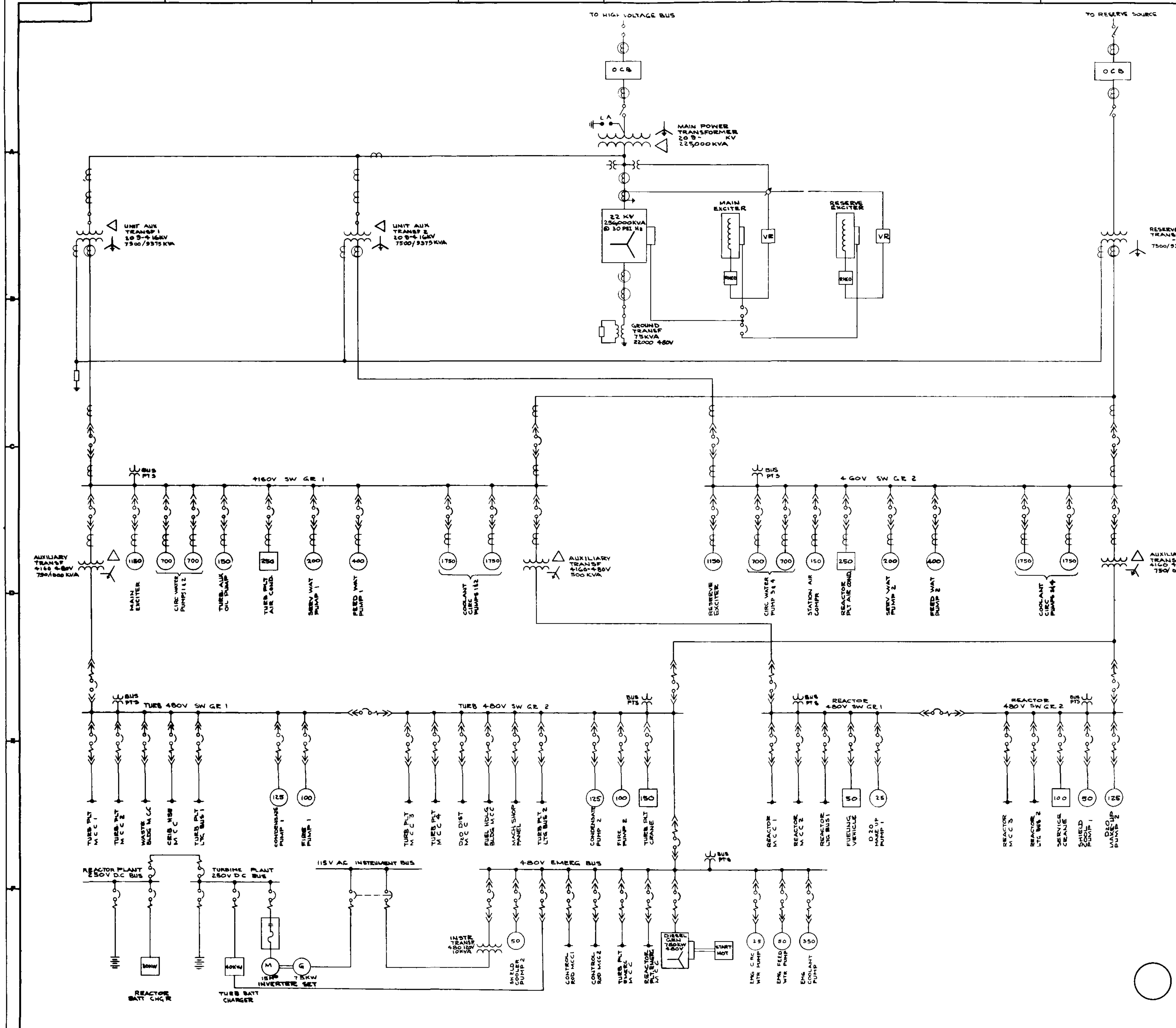
DRAWING NO
NS-509



SECTION "B-B"

200 MWe HEAVY WATER MODERATED REACTOR PLANT

REVISIONS	LONGITUDINAL SECTION "B-B" TURBINE BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.	
	SCALE 1/8"=1'-0"	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
	DRAWN C KUSZYNSKI 8-25-59	
	CHECKED	
	ENGINEER	
	APPROVED	DRAWING NO
	JOB NO 1957-15	NS-510



200 MWe HEAVY WATER MODERATED REACTOR PL'T.

REVISIONS

ELECTRICAL DIAGRAM

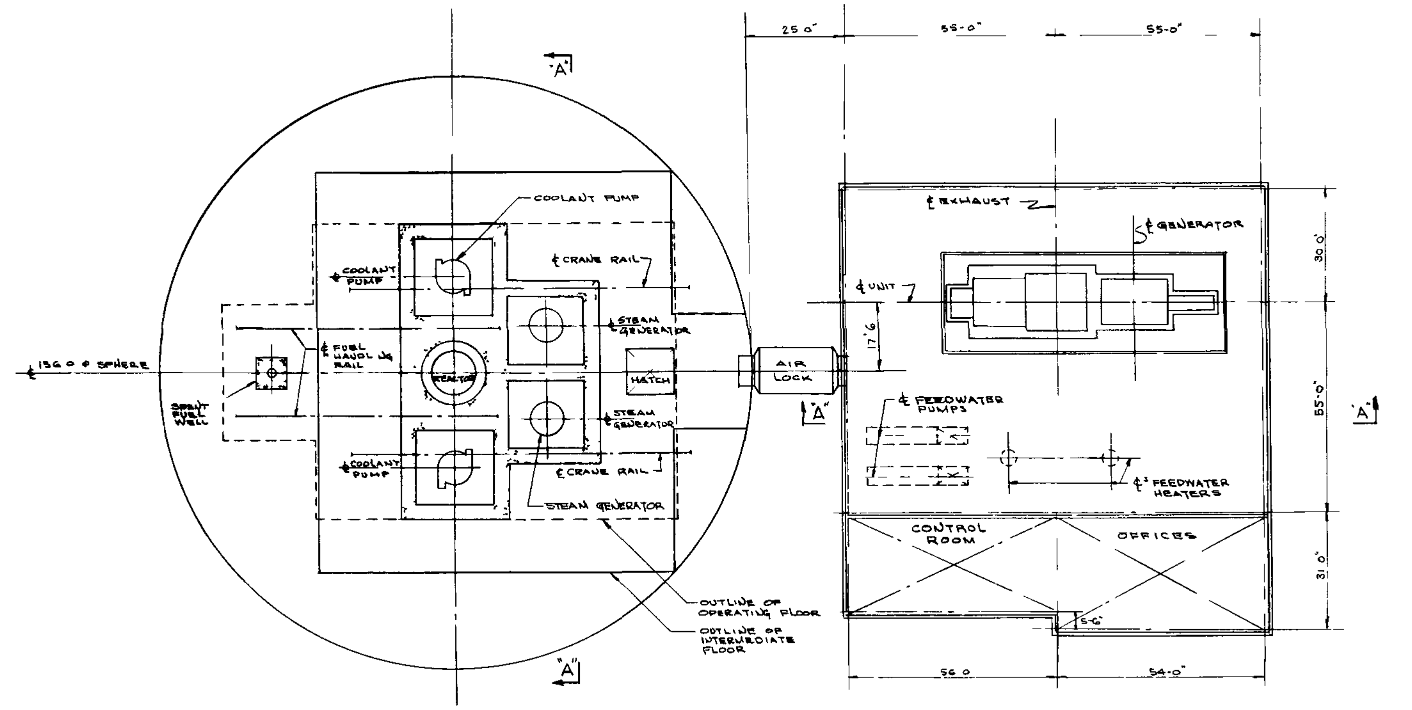
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE NONE
DRAWN W. RALEY 8-25-59
CHECKED
ENGINEER
APPROVED

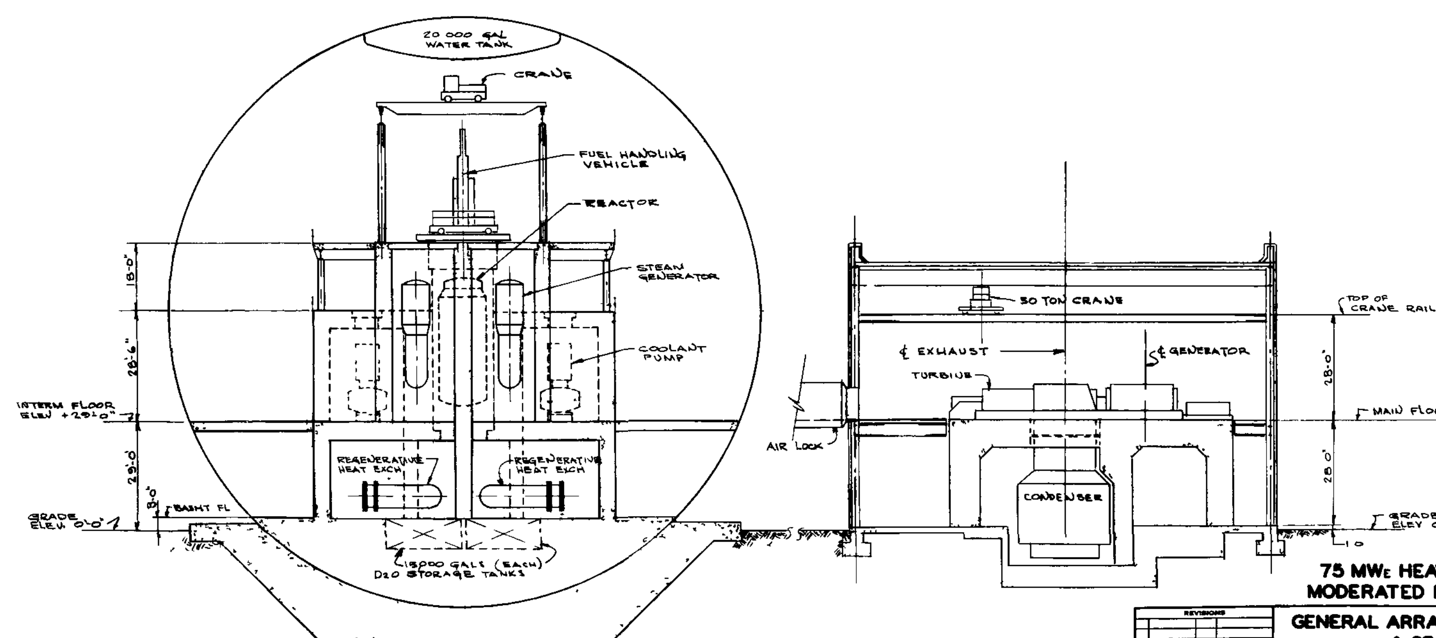
JOB NO	JOB NO	JOB NO.	JOB NO
1957-15			

SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

DRAWING NO
ES- 501



P L A N



SECTION "A-A"

75 MWe HEAVY WATER MODERATED REACTOR PLANT

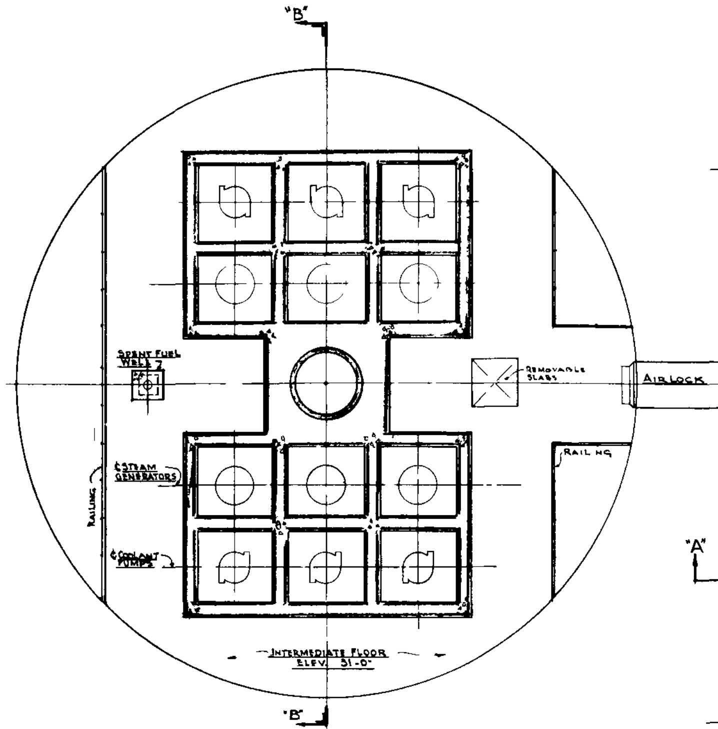
GENERAL ARRANGEMENT PLAN & SECTION
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D. C.

REVISIONS

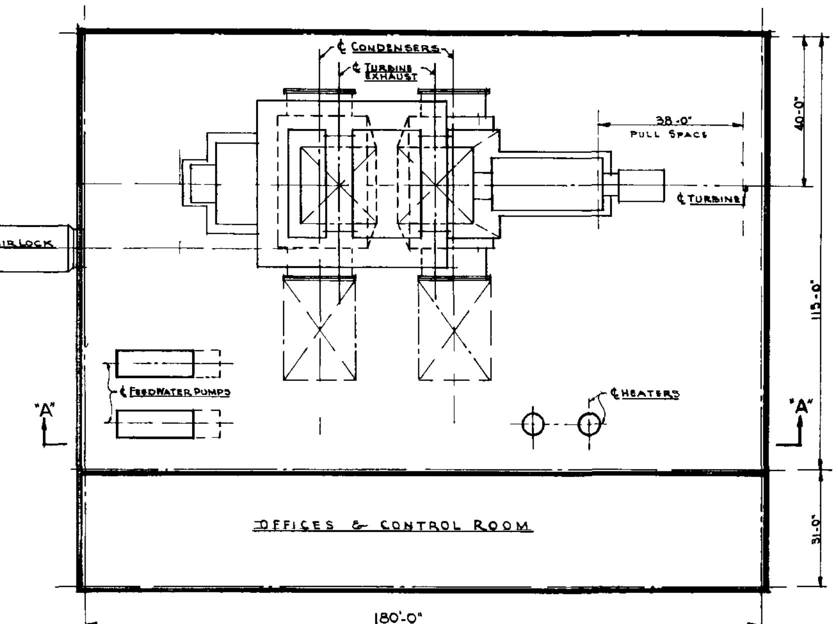
SCALE 1/16"=1'-0"
DRAWN E. VICTORINE 8-25-59
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-511

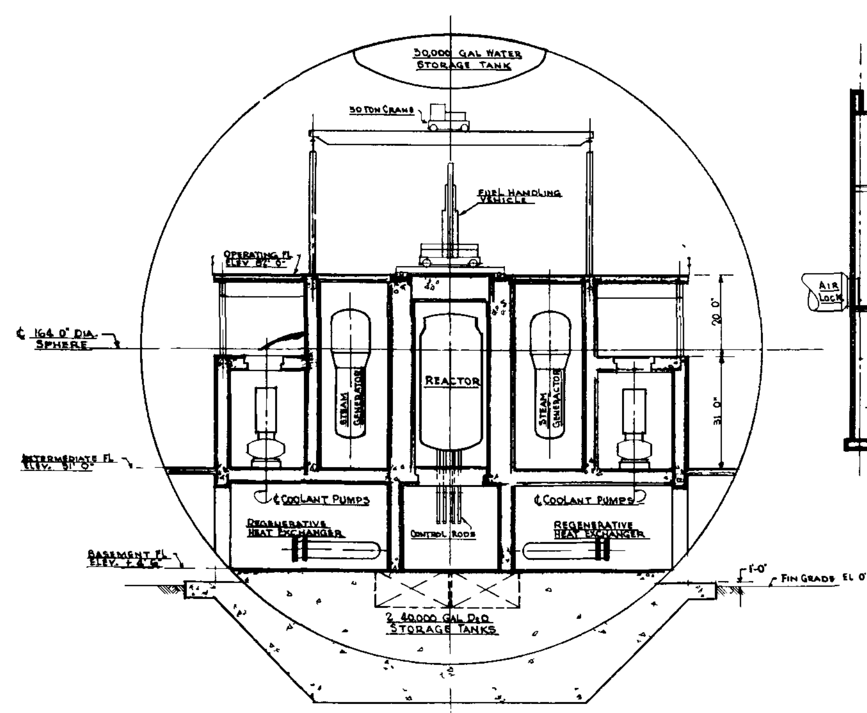


REACTOR PLANT



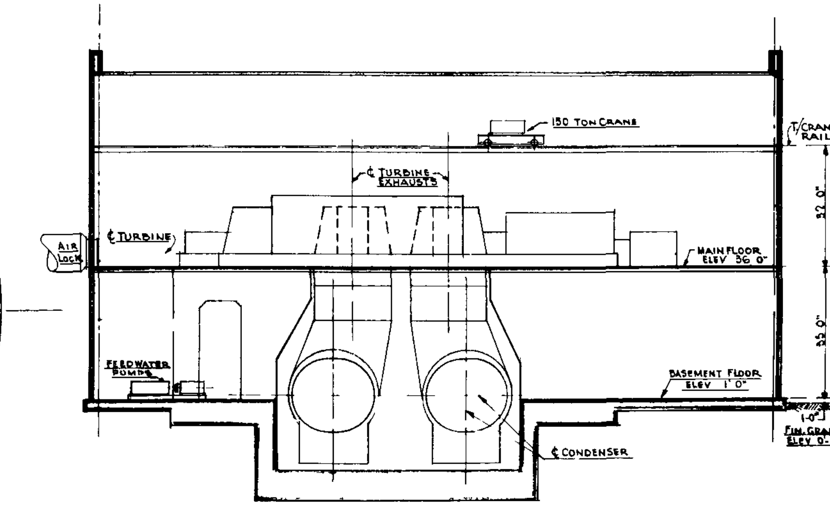
TURBINE ROOM

PLAN



SECTION "B-B"

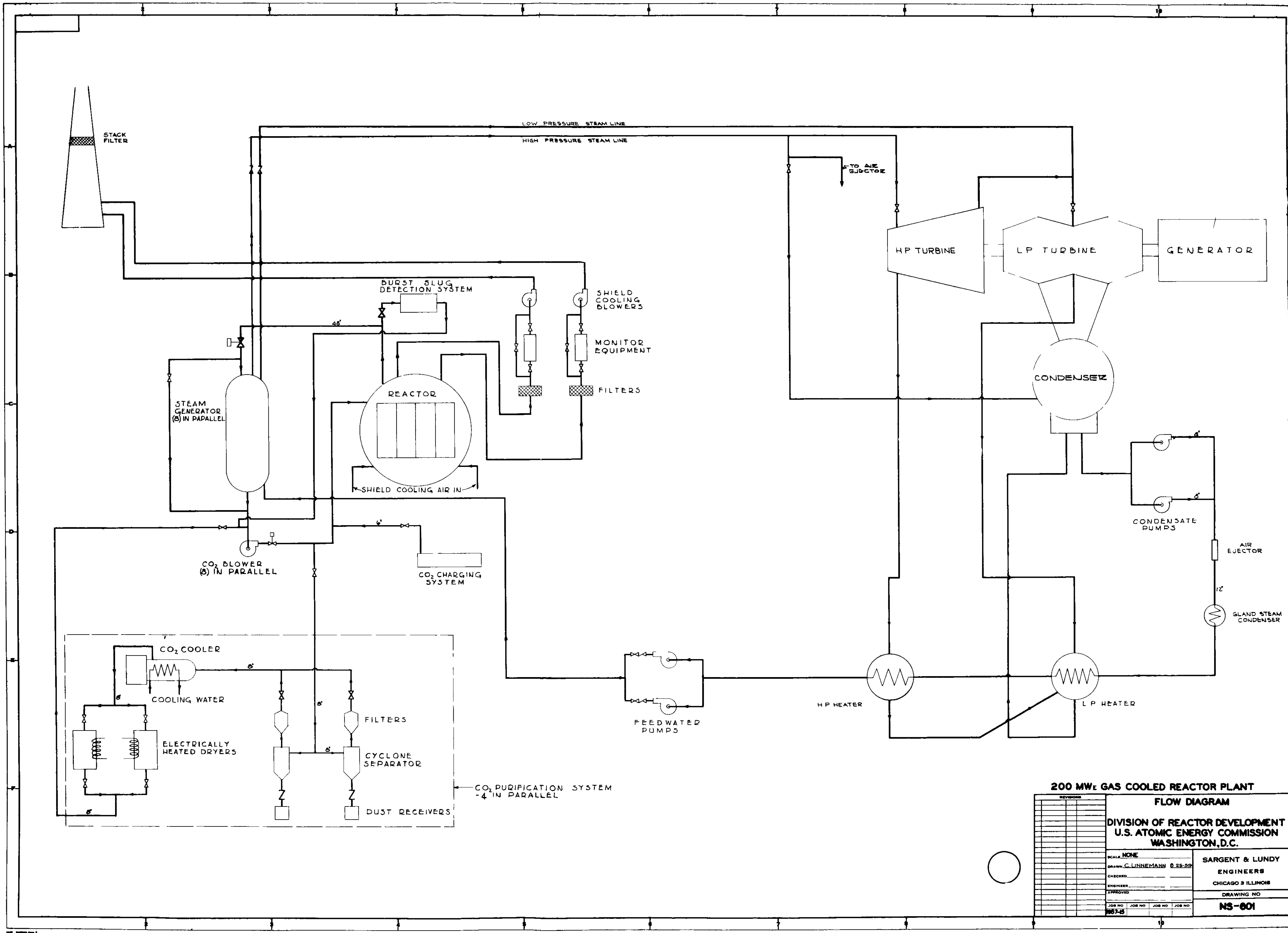
CONTAINMENT VESSEL

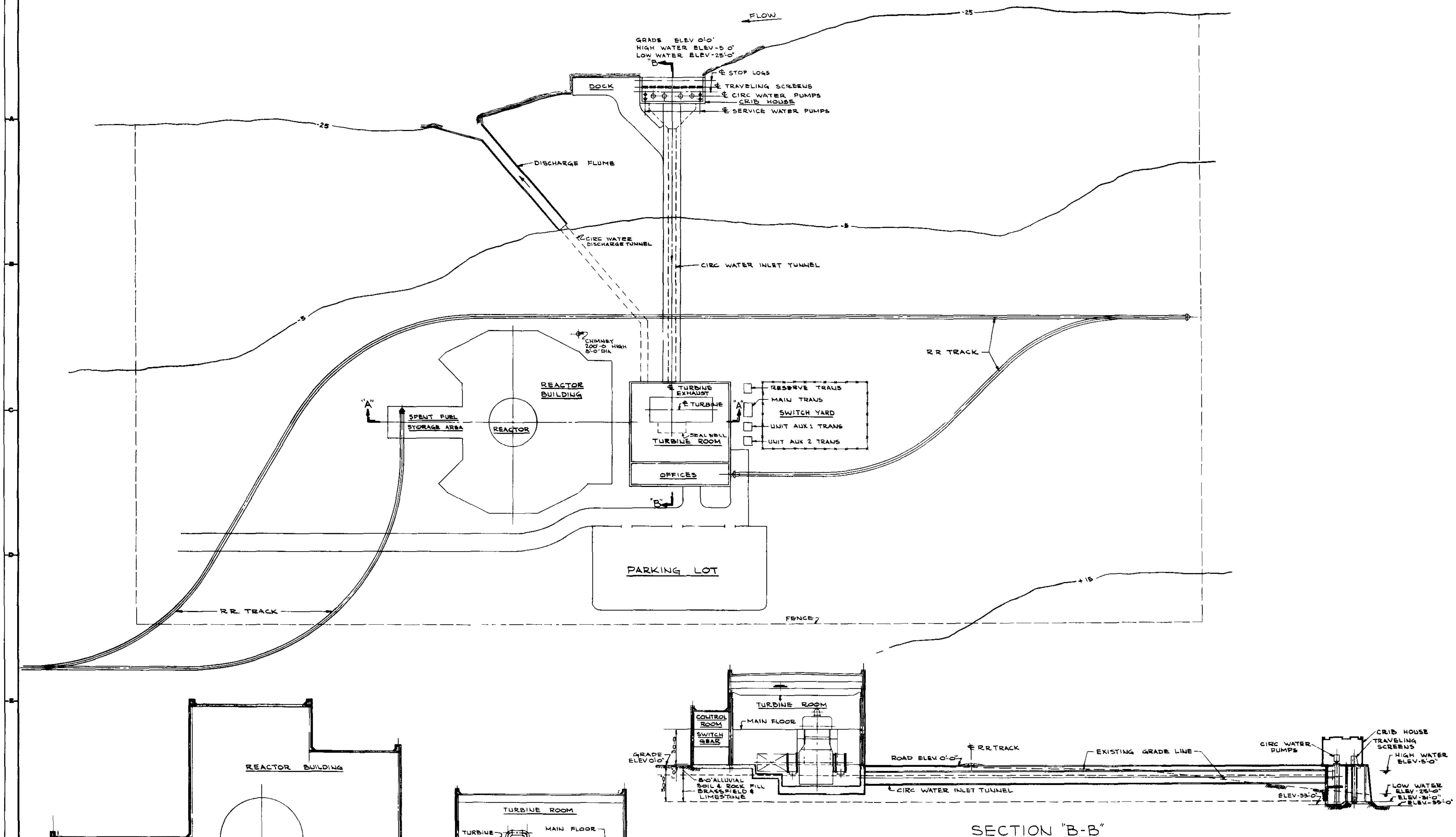


SECTION "A-A"

300 MWe HEAVY WATER MODERATED REACTOR PLANT

REVISIONS	
	GENERAL ARRANGEMENT PLAN & SECTION **DIVISION OF REACTOR DEVELOPMENT** **U.S. ATOMIC ENERGY COMMISSION** **WASHINGTON, D. C.**
SCALE 1/16" = 1'-0" DRAWN T DENNEN 6 25 59 CHECKED ENGINEER APPROVED	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
JOB NO 1957-15	DRAWING NO NS-512


STACK FILTER
LOW PRESSURE STEAM LINE
HIGH PRESSURE STEAM LINE
TO AIR EJECTOR
HP TURBINE
LP TURBINE
GENERATOR
BURST SLUG DETECTION SYSTEM
48"
SHIELD COOLING BLOWERS
MONITOR EQUIPMENT
FILTERS
STEAM GENERATOR (8) IN PARALLEL
REACTOR
SHIELD COOLING AIR IN
CONDENSER
CONDENSATE PUMPS
AIR EJECTOR
12"
GLAND STEAM CONDENSER
6"
CO_2 BLOWER (8) IN PARALLEL
CO_2 CHARGING SYSTEM
CO_2 COOLER
COOLING WATER
ELECTRICALLY HEATED DRYERS
FILTERS
CYCLONE SEPARATOR
DUST RECEIVERS
CO_2 PURIFICATION SYSTEM - 4 IN PARALLEL
FEEDWATER PUMPS
HP HEATER
L P HEATER
200 MWE GAS COOLED REACTOR PLANT
FLOW DIAGRAM
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.
SCALE NONE
DRAWN C. LINNEMANN 8-25-59
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15
SARGENT & LUNDY ENGINEERS
CHICAGO 3 ILLINOIS
DRAWING NO
NS-601



200 MWE GAS COOLED REACTOR PLANT

PROPERTY PLAT

DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

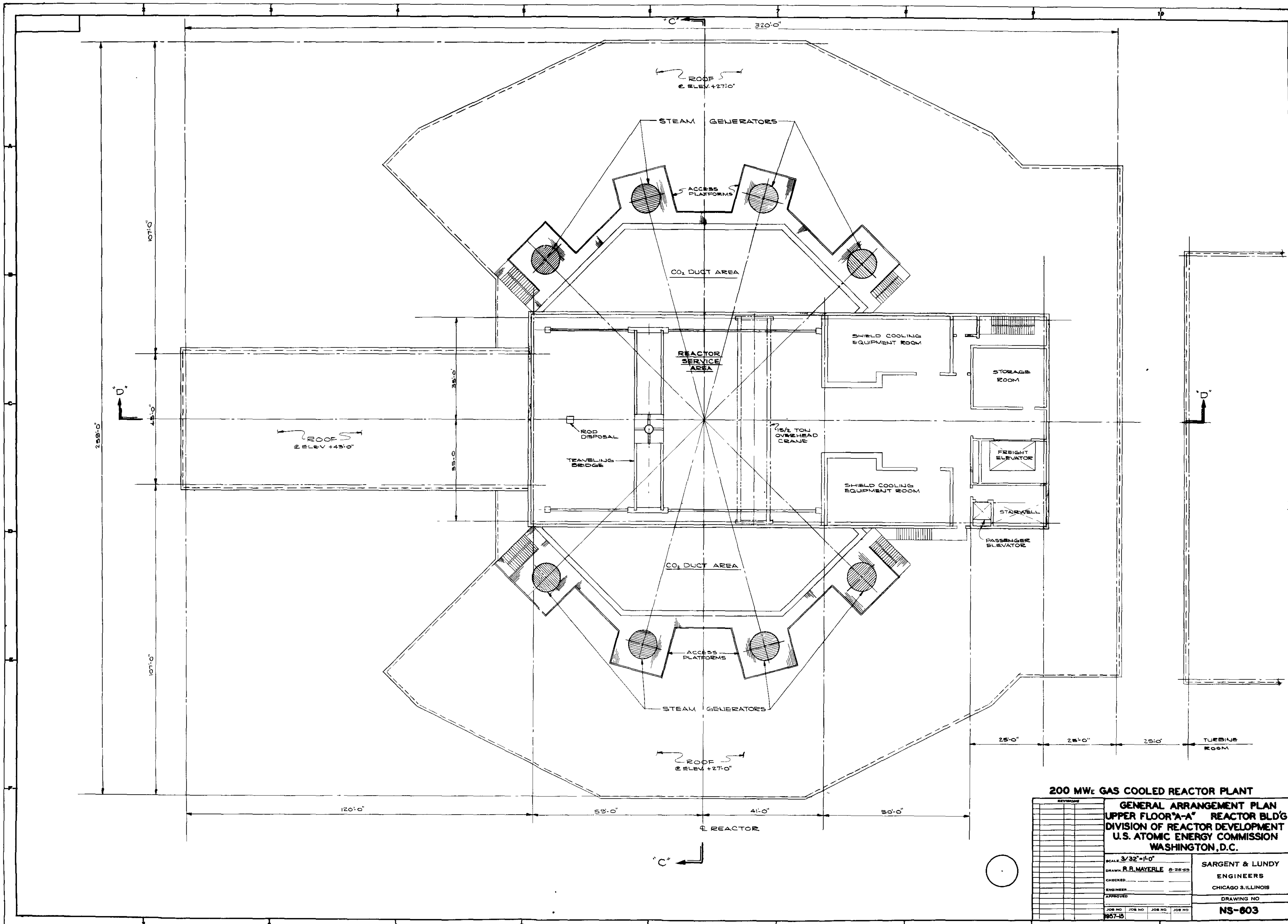
REVISIONS

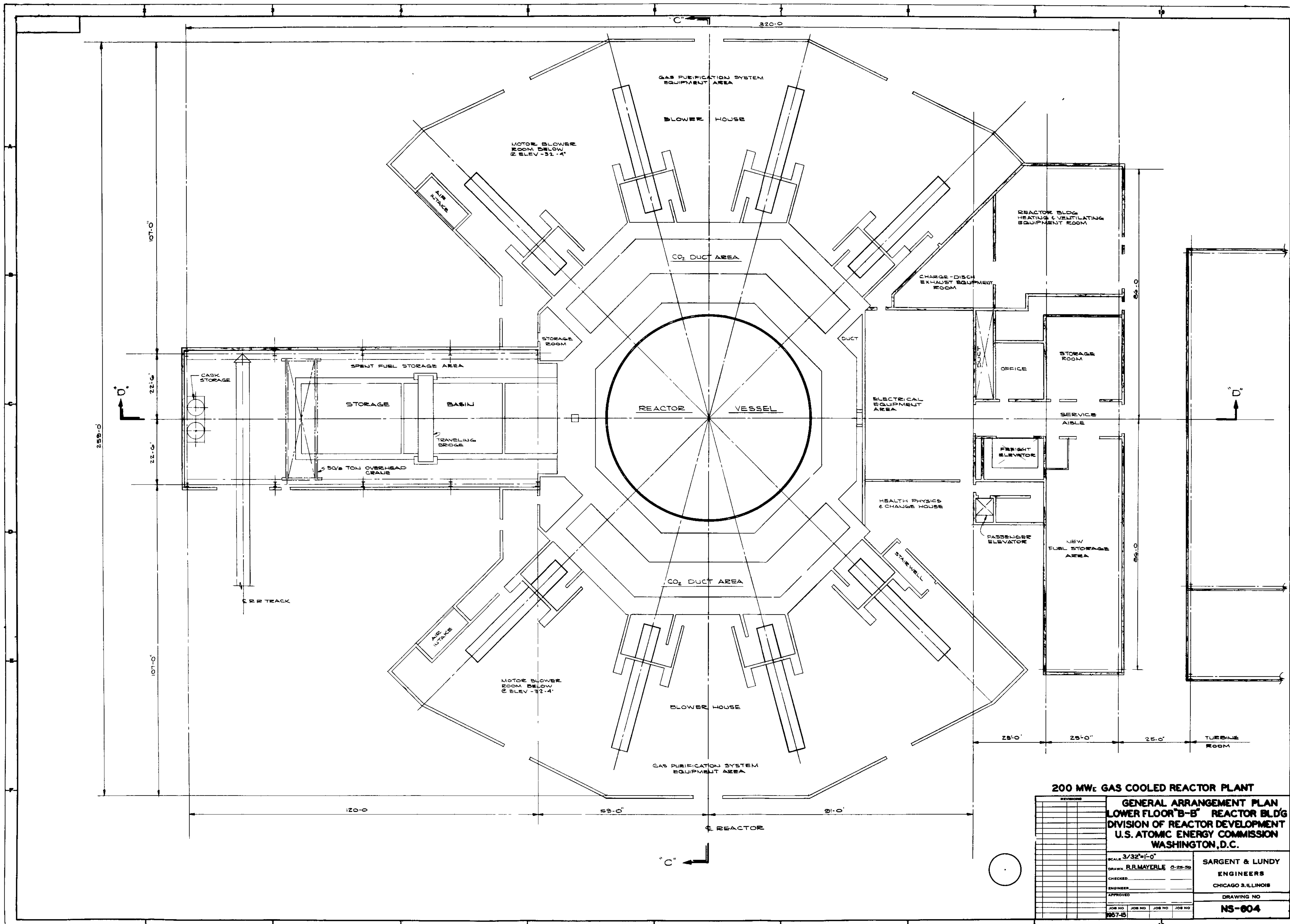
SCALE 1"=50'-0" & AS NOTED
DRAWN R GOETTSCHE 8-25-59
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO	JOB NO
1957-15			

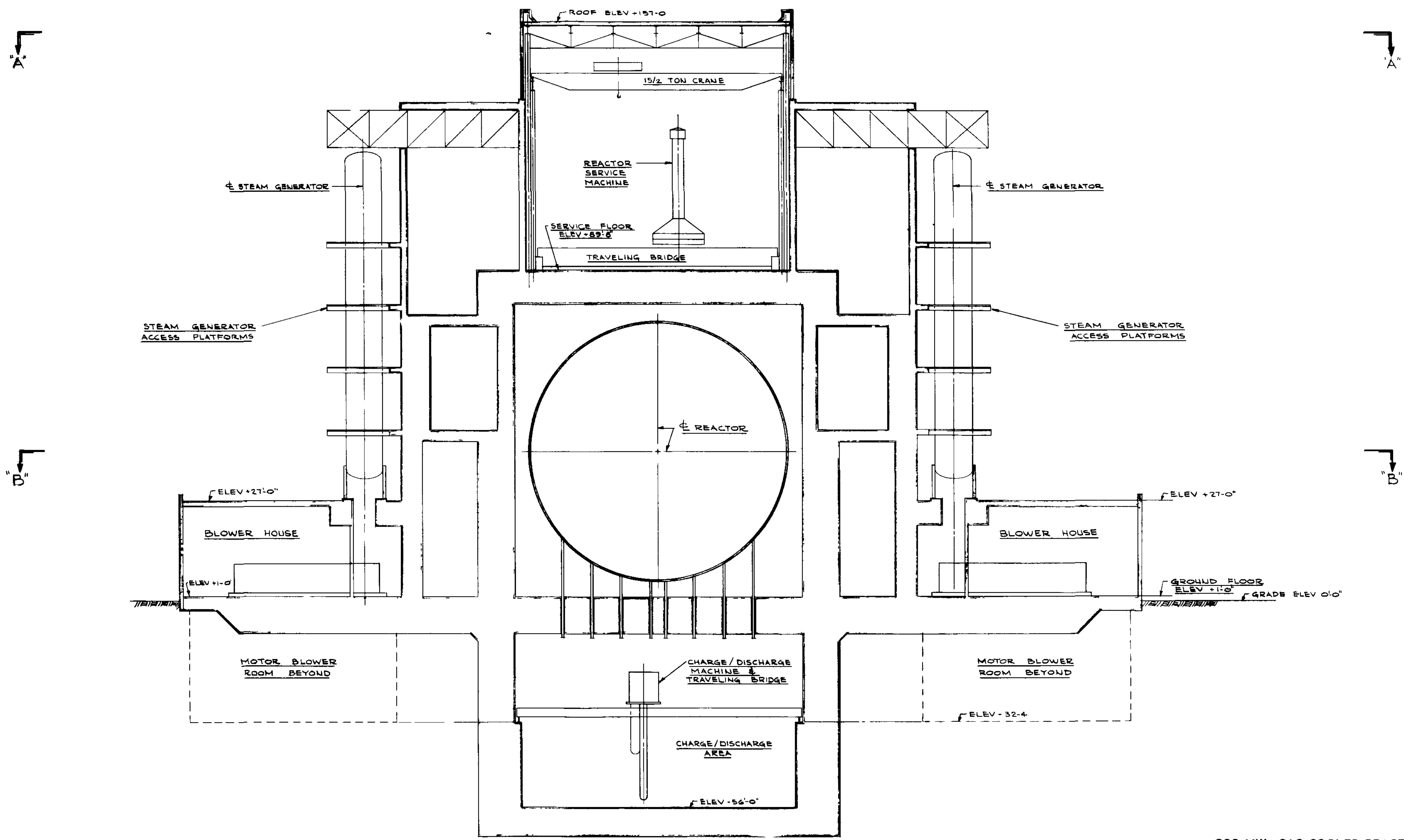
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-802


320'-0"
ROOF
℄ ELEV. +27'-0"
STEAM GENERATORS
ACCESS PLATFORMS
CO₂ DUCT AREA
REACTOR SERVICE AREA
SHIELD COOLING EQUIPMENT ROOM
STORAGE ROOM
ROD DISPOSAL
TRAVELING BRIDGE
15/2 TON OVERHEAD CRANE
FREIGHT ELEVATOR
STAIRWELL
PASSENGER ELEVATOR
ROOF
℄ ELEV. +43'-0"
"C"
"D"
107'-0"
258'-0"
35'-0"
45'-0"
25'-0"
TURBINE ROOM
120'-0"
55'-0"
41'-0"
50'-0"
℄ REACTOR
200 MWE GAS COOLED REACTOR PLANT
REVISIONS
GENERAL ARRANGEMENT PLAN
UPPER FLOOR "A-A" REACTOR BLD'G
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.
SCALE 3/32"=1'-0"
DRAWN R.R. MAYERLE 8-25-59
CHECKED
ENGINEER
APPROVED
JOB NO
1957-15
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO
NS-603



"C"
320-0
GAS PURIFICATION SYSTEM EQUIPMENT AREA
BLOWER HOUSE
MOTOR BLOWER ROOM BELOW @ ELEV -32-4"
AIR INTAKE
REACTOR BLDG HEATING & VENTILATING EQUIPMENT ROOM
CO_2 DUCT AREA
CHARGE-DISCH EXHAUST EQUIPMENT ROOM
STORAGE ROOM
DUCT
SPENT FUEL STORAGE AREA
CASK STORAGE
STORAGE BASIN
TRAVELING BRIDGE
50/8 TON OVERHEAD CRANE
REACTOR VESSEL
ELECTRICAL EQUIPMENT AREA
OFFICE
STORAGE ROOM
SERVICE AISLE
FREIGHT ELEVATOR
PASSENGER ELEVATOR
HEALTH PHYSICS & CHANGE HOUSE
NEW FUEL STORAGE AREA
STAIRWELL
CO_2 DUCT AREA
℄ R.R. TRACK
"D"
107-0"
22-6"
259-0
86-0
28-0"
25-0"
25-0"
TURBINE ROOM
120-0
59-0"
91-0"
℄ REACTOR
"C"
200 MWe GAS COOLED REACTOR PLANT
GENERAL ARRANGEMENT PLAN
LOWER FLOOR "B-B" REACTOR BLD'G
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.
SCALE 3/32"=1'-0"
DRAWN R.R.MAYERLE 6-25-59
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15
SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWING NO NS-604



200 MWE GAS COOLED REACTOR PLANT

REVISIONS	

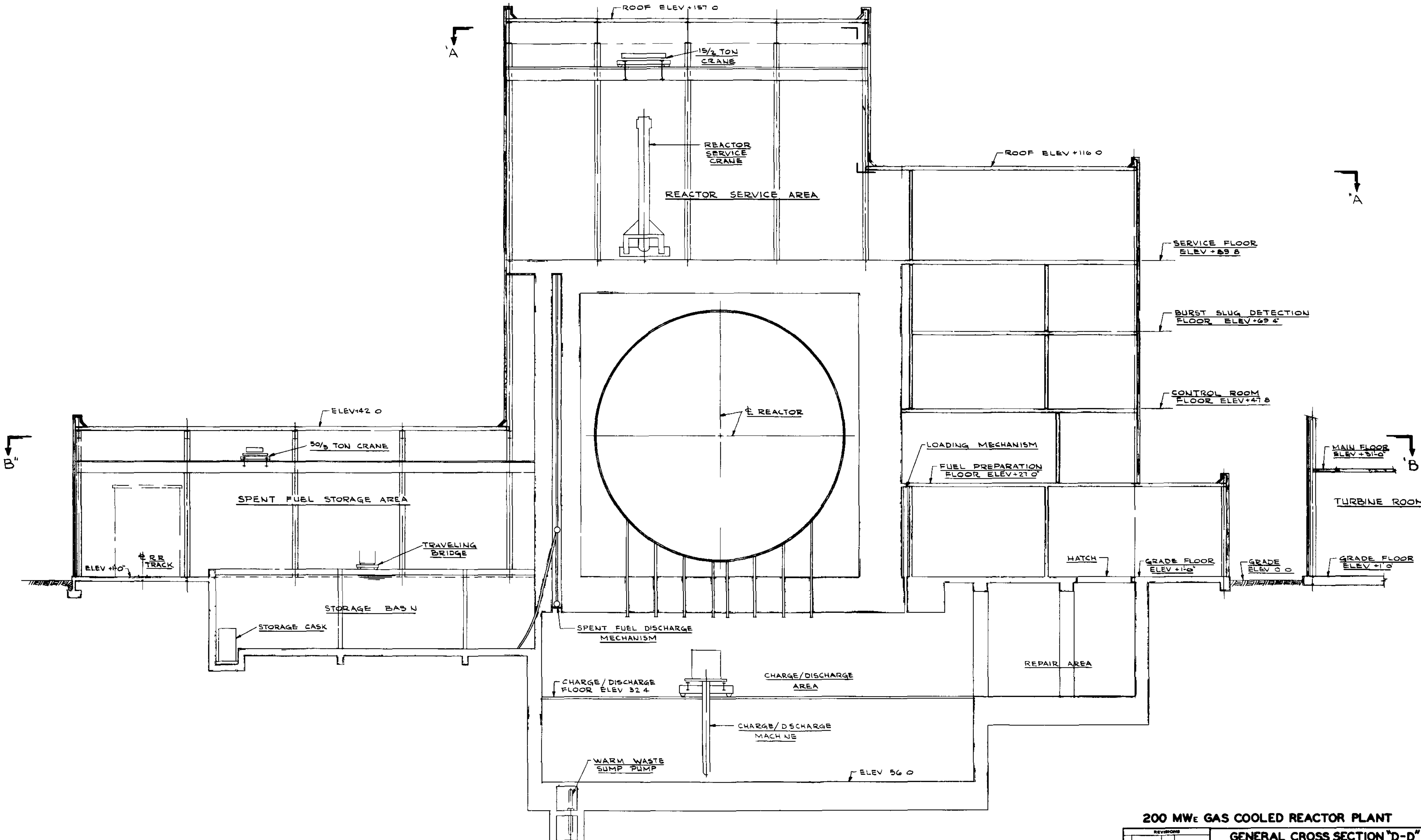
GENERAL CROSS SECTION "C-C"
REACTOR BLD'G
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 3/32"=1'-0"
DRAWN R GOETTSCHE 8-25-59
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO	JOB NO
1957-15			

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-605



200 MWe GAS COOLED REACTOR PLANT

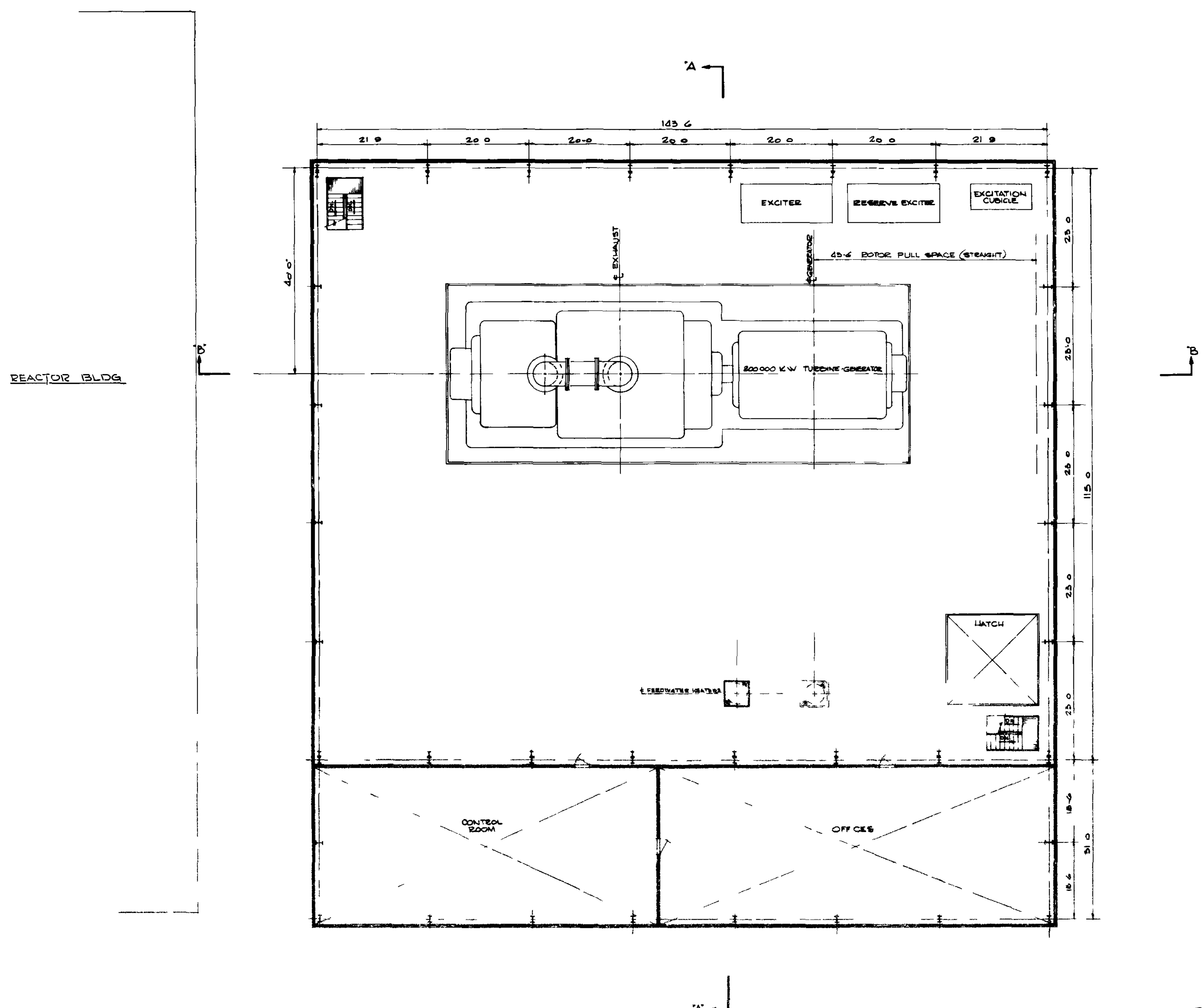
GENERAL CROSS SECTION "D-D"
REACTOR BLD'G
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

REVISIONS

SCALE 3/32"=1'-0"
DRAWN R GOETTSCHE 8 28 58
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

DRAWING NO
NS-606



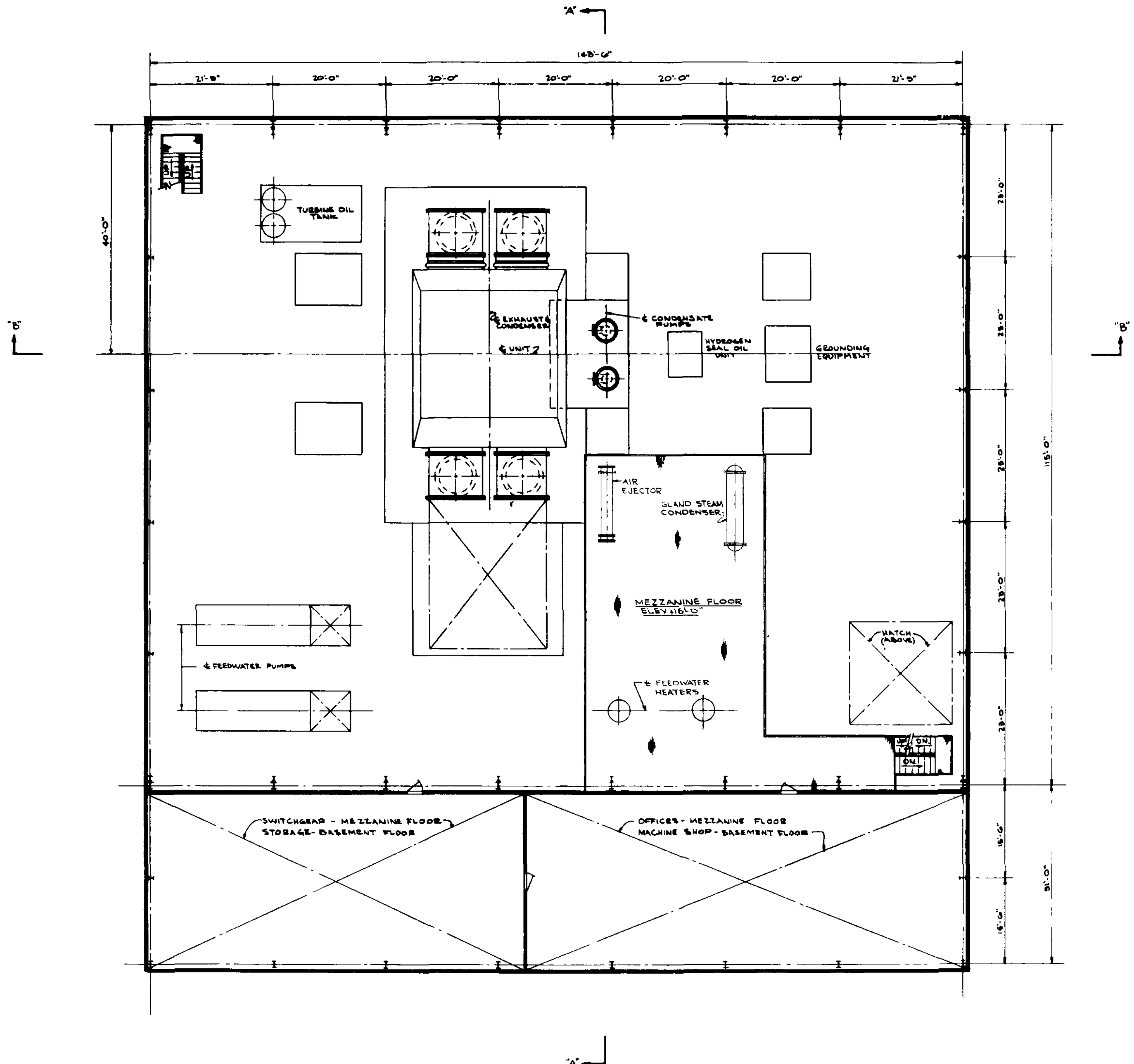
200 MWe GAS COOLED REACTOR PLANT

GENERAL ARRANGEMENT PLAN
MAIN FLOOR TURBINE BLDG
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8" = 1'-0"
DRAWN F RUSSO 6 25 59
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-607



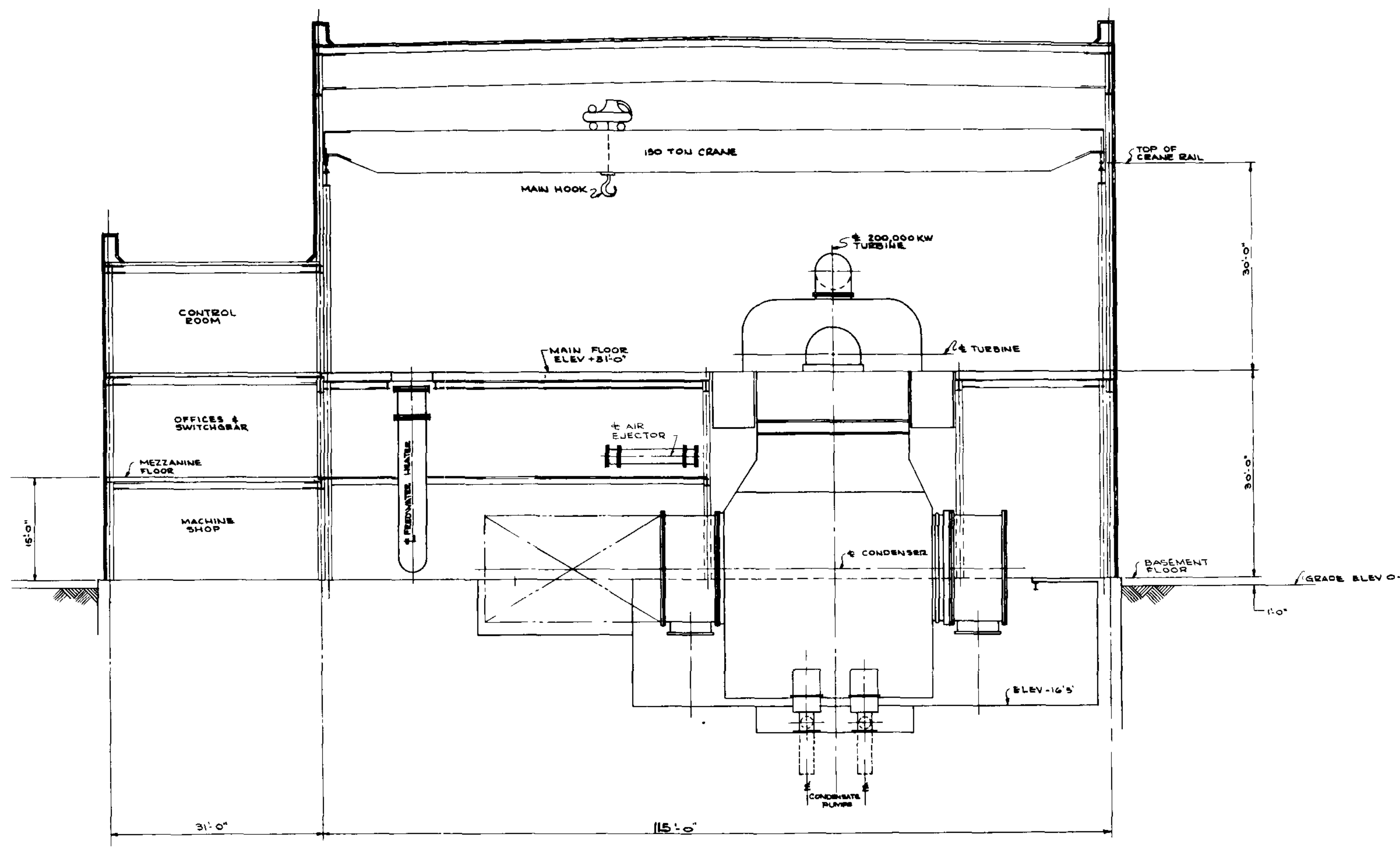
200 MWe GAS COOLED REACTOR PLANT

GENERAL ARRANGEMENT PLAN
BASEMENT & MEZZ. FL. TURBINE BLD'G
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN F. RUSSO 6-25-59
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO.
NS-608

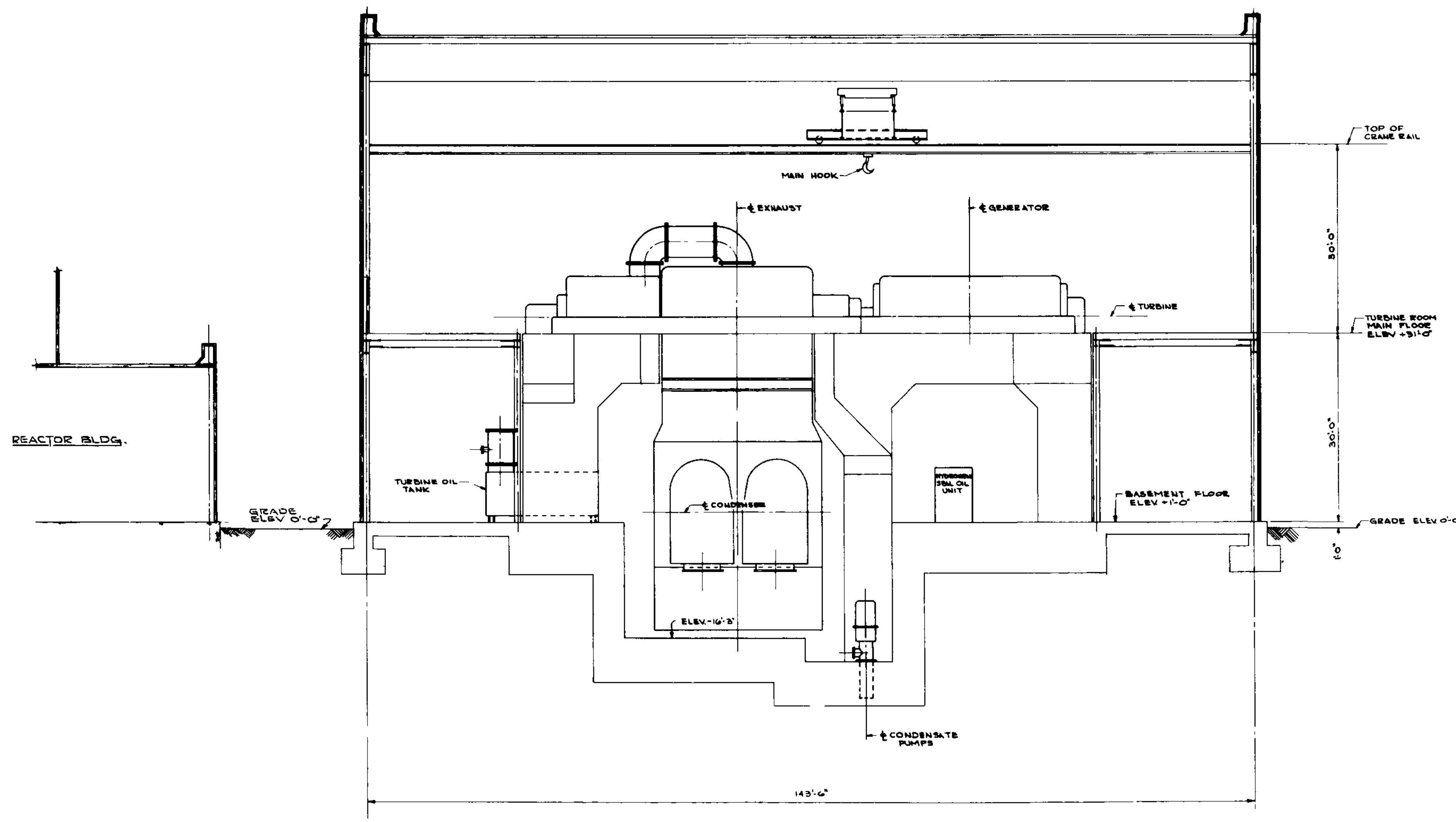


SECTION "A-A"

200 MWE GAS COOLED REACTOR PLANT

GENERAL CROSS SECTION "A-A"
TURBINE BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

REVISIONS	
SCALE 1/8"=1'-0"	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWN A JOHNSEN 8-25-59	
CHECKED	
ENGINEER	
APPROVED	DRAWING NO
JOB NO 1957-15	NS-609



SECTION "B-B"

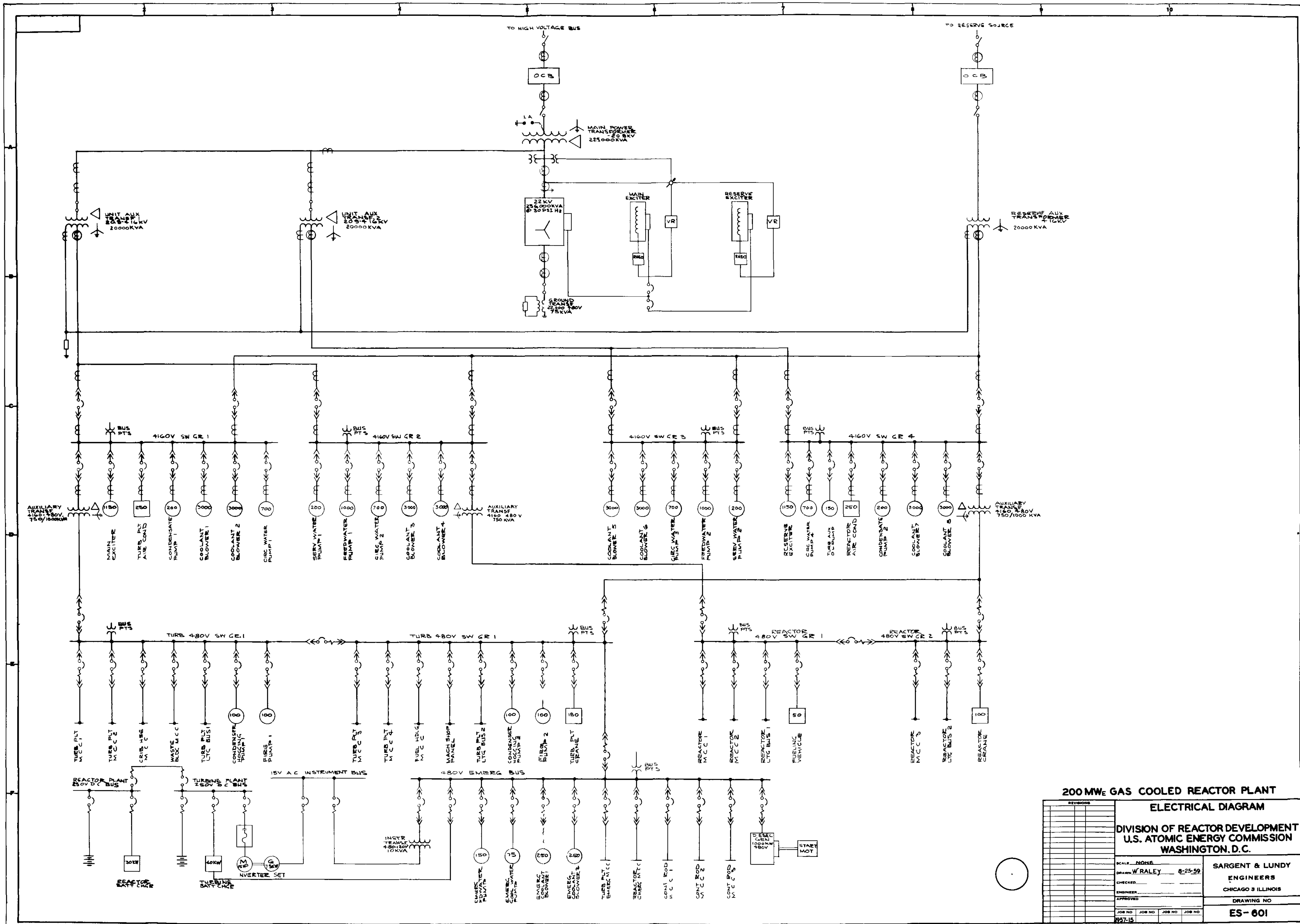
200 MWe GAS COOLED REACTOR PLANT

LONGITUDINAL SECTION "B-B"
TURBINE BLDG
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN A. JOHNSEN 6-26-59
CHECKED
ENGINEER
APPROVED
JOB NO 5957-15

SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO. NS-610



200 MWe GAS COOLED REACTOR PLANT

ELECTRICAL DIAGRAM

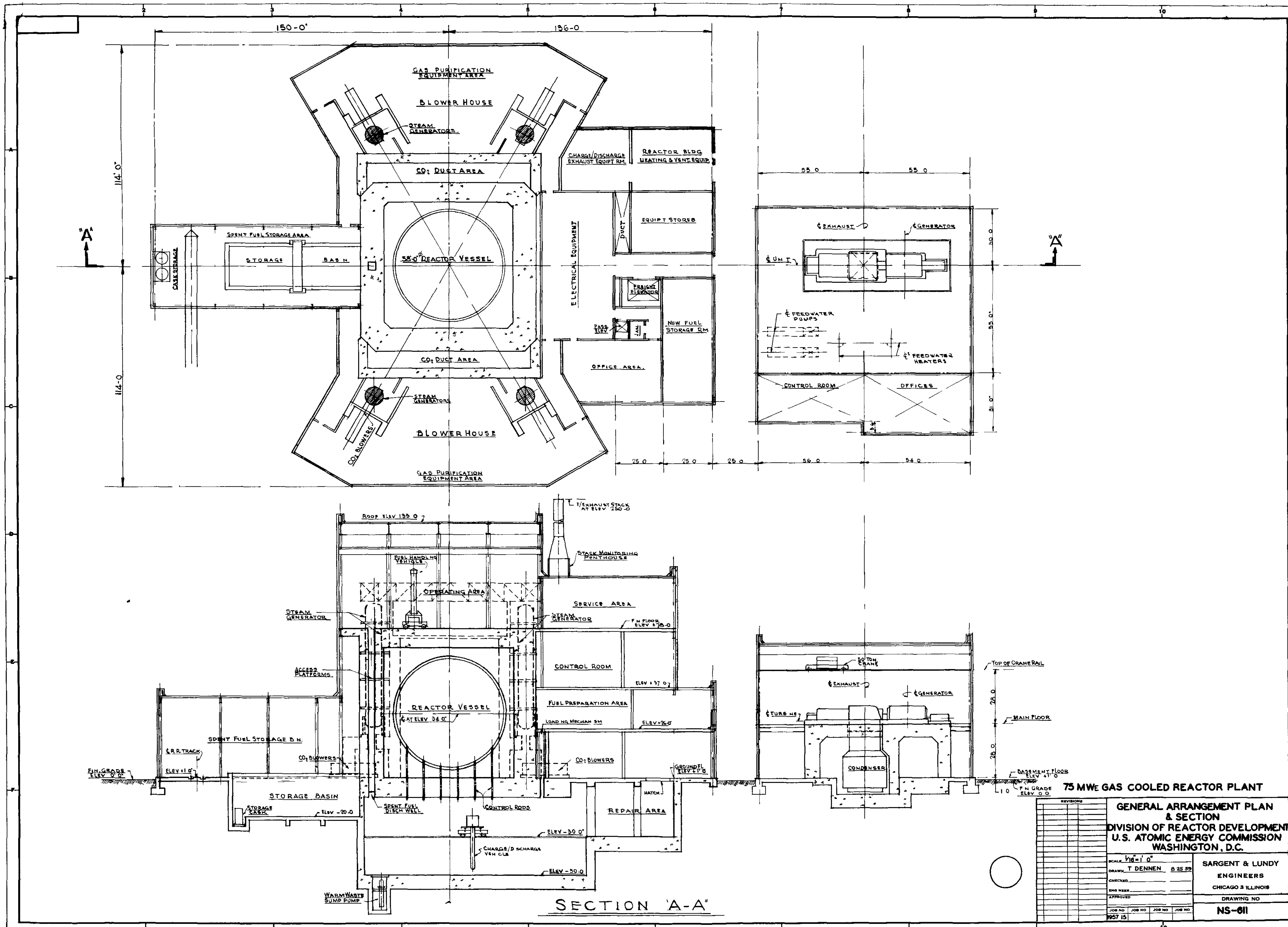
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

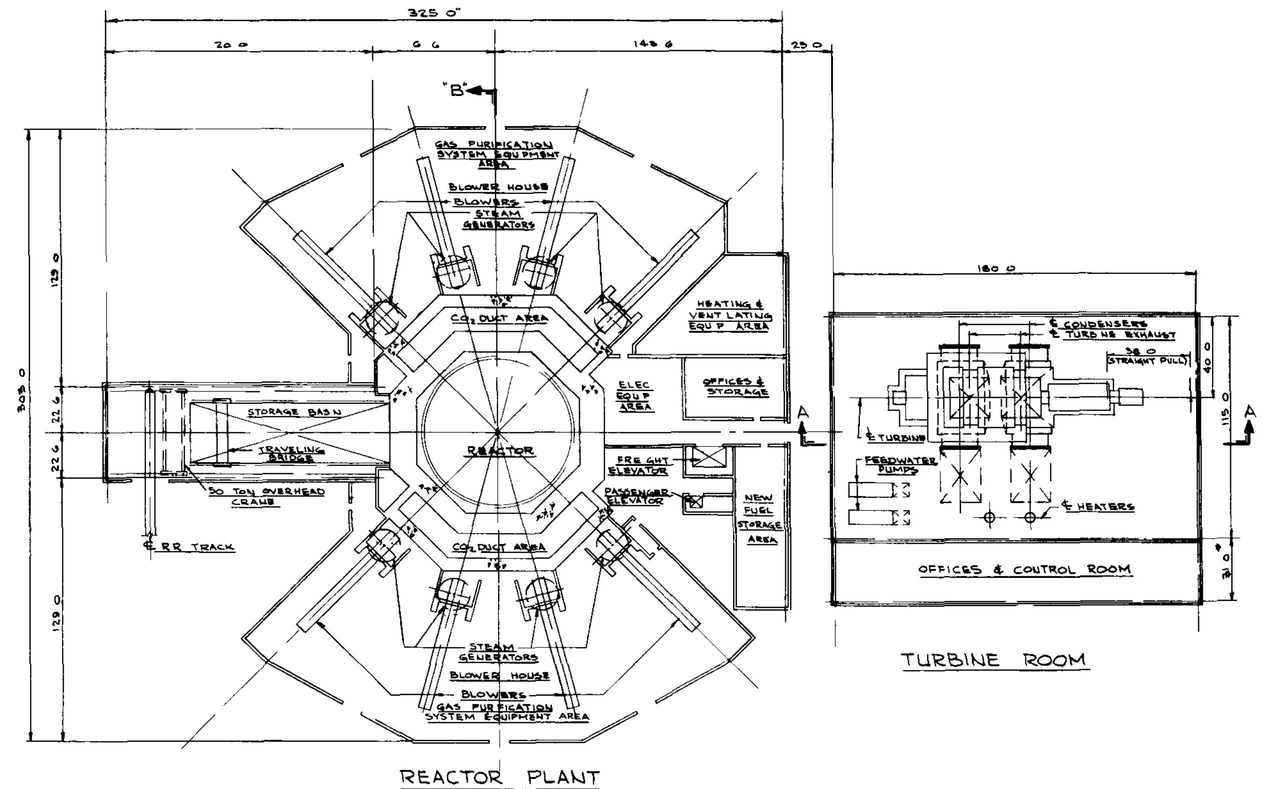
SCALE: NONE
DRAWN: W RALEY 8-25-59
CHECKED
ENGINEER
APPROVED

SARGENT & LUNDY ENGINEERS
CHICAGO 3 ILLINOIS

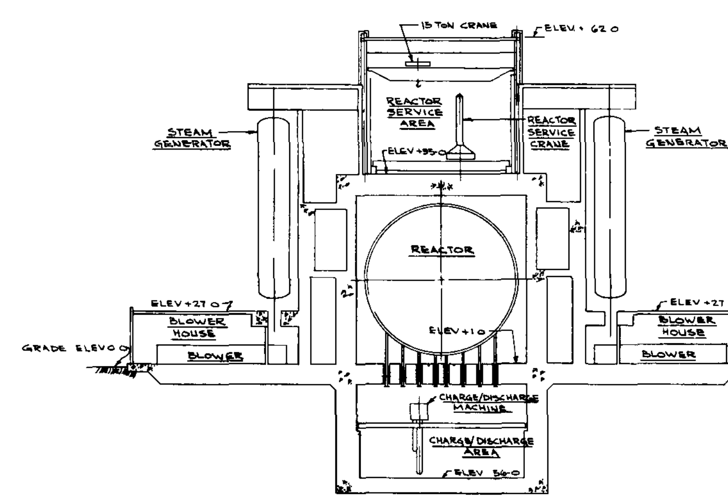
JOB NO 1957-15

DRAWING NO
ES-601

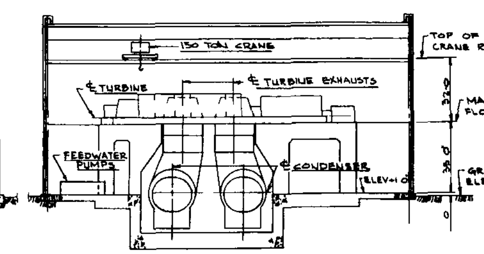

150-0"
136-0
114'-0"
114-0
GAS PURIFICATION EQUIPMENT AREA
BLOWER HOUSE
STEAM GENERATORS
CO_2 DUCT AREA
CHARGE/DISCHARGE EXHAUST EQUIPT RM.
REACTOR BLDG HEATING & VENT. EQUIP.
EQUIPT STORES
DUCT
"A"
SPENT FUEL STORAGE AREA
STORAGE BASIN
CASK STORAGE
58'-0" REACTOR VESSEL
ELECTRICAL EQUIPMENT
FREIGHT ELEVATOR
PASS ELEV
NEW FUEL STORAGE RM
OFFICE AREA
CO_2 BLOWERS
55 0
¢ EXHAUST
¢ GENERATOR
¢ UNIT
¢ FEEDWATER PUMPS
¢ FEEDWATER HEATERS
CONTROL ROOM
OFFICES
25 0
56 0
54 0
T/EXHAUST STACK AT ELEV 250-0
ROOF ELEV 135 0
STACK MONITORING PENTHOUSE
FUEL HANDLING VEHICLE
OPERATING AREA
STEAM GENERATOR
SERVICE AREA
F.H. FLOOR ELEV +78-0
ACCESS PLATFORMS
CONTROL ROOM
ELEV +37 0
REACTOR VESSEL
¢ AT ELEV 56 0"
FUEL PREPARATION AREA
LOADING MECHAN SM
ELEV +26-0
SPENT FUEL STORAGE B.N.
¢ R.R. TRACK
FIN. GRADE ELEV 0'-0"
ELEV +1'-0"
CO_2 BLOWERS
GROUND FL ELEV +1'-0
STORAGE BASIN
STORAGE CASK
ELEV -20-0
SPENT FUEL DISCH WELL
CONTROL RODS
HATCH
REPAIR AREA
ELEV -30 0"
CHARGE/DISCHARGE VEH CLE
ELEV -50-0
WARM WASTE SUMP PUMP
SECTION 'A-A'
50 TON CRANE
TOP OF CRANE RAIL
MAIN FLOOR
TURB NE
CONDENSER
BASEMENT FLOOR ELEV +1'-0
F.N. GRADE ELEV 0 0
75 MWE GAS COOLED REACTOR PLANT
REVISIONS
GENERAL ARRANGEMENT PLAN
& SECTION
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.
SCALE 1/16"=1' 0"
DRAWN T DENNEN 8 25 59
CHECKED
ENGINEER
APPROVED
JOB NO
1957 15
SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS
DRAWING NO
NS-611



PLAN



SECTION B-B

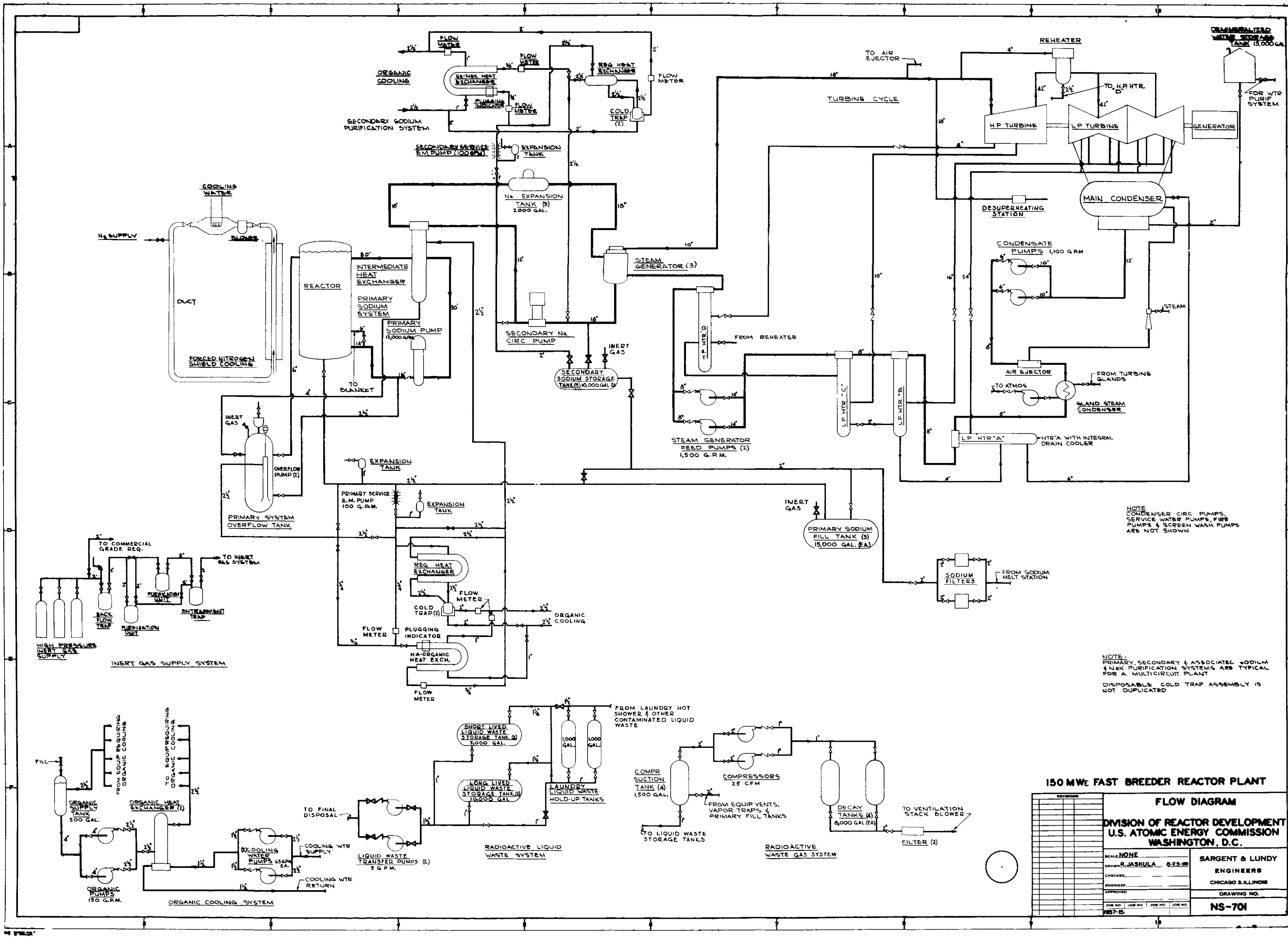


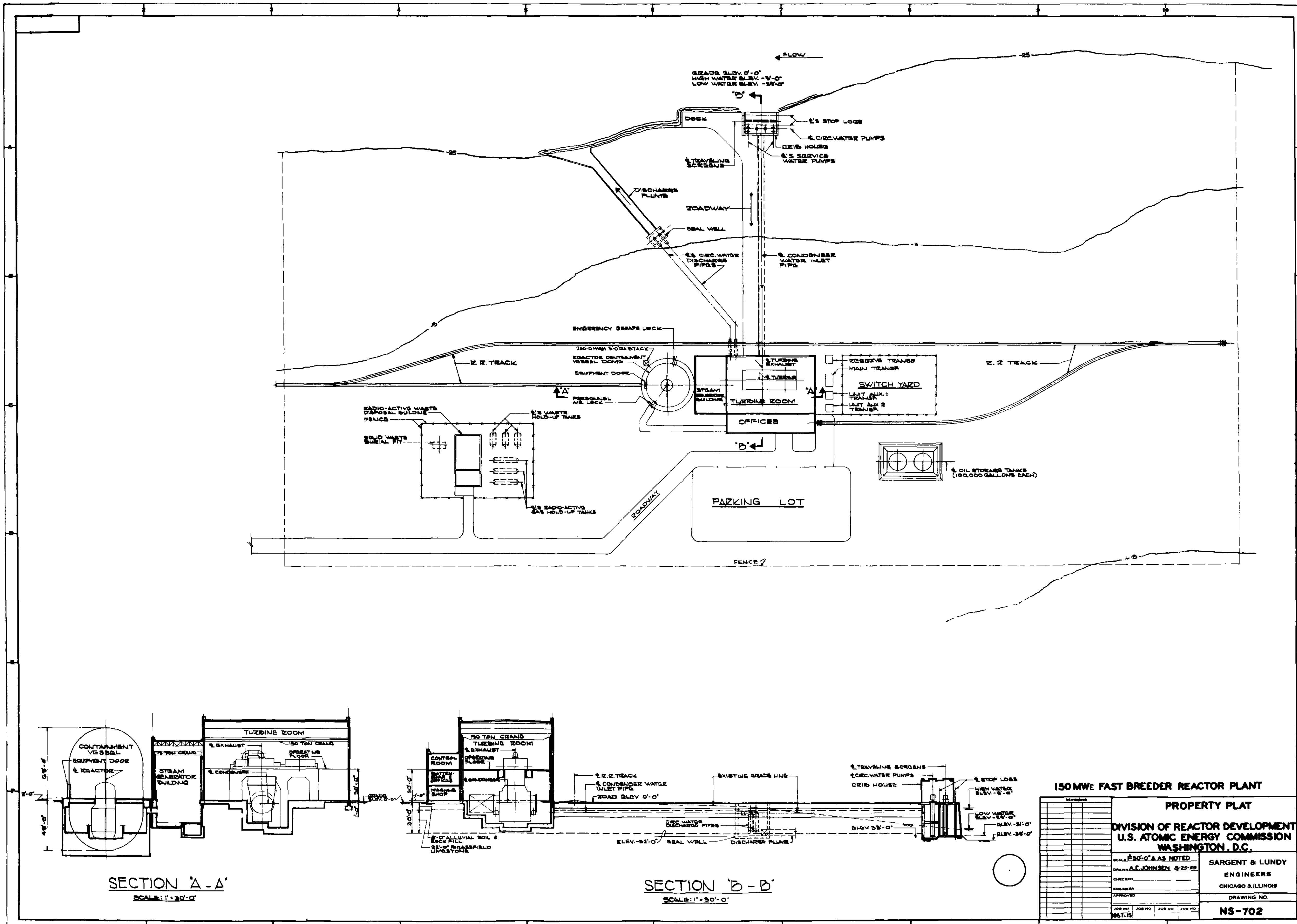
SECTION A A

300MWe GAS COOLED REACTOR PLANT

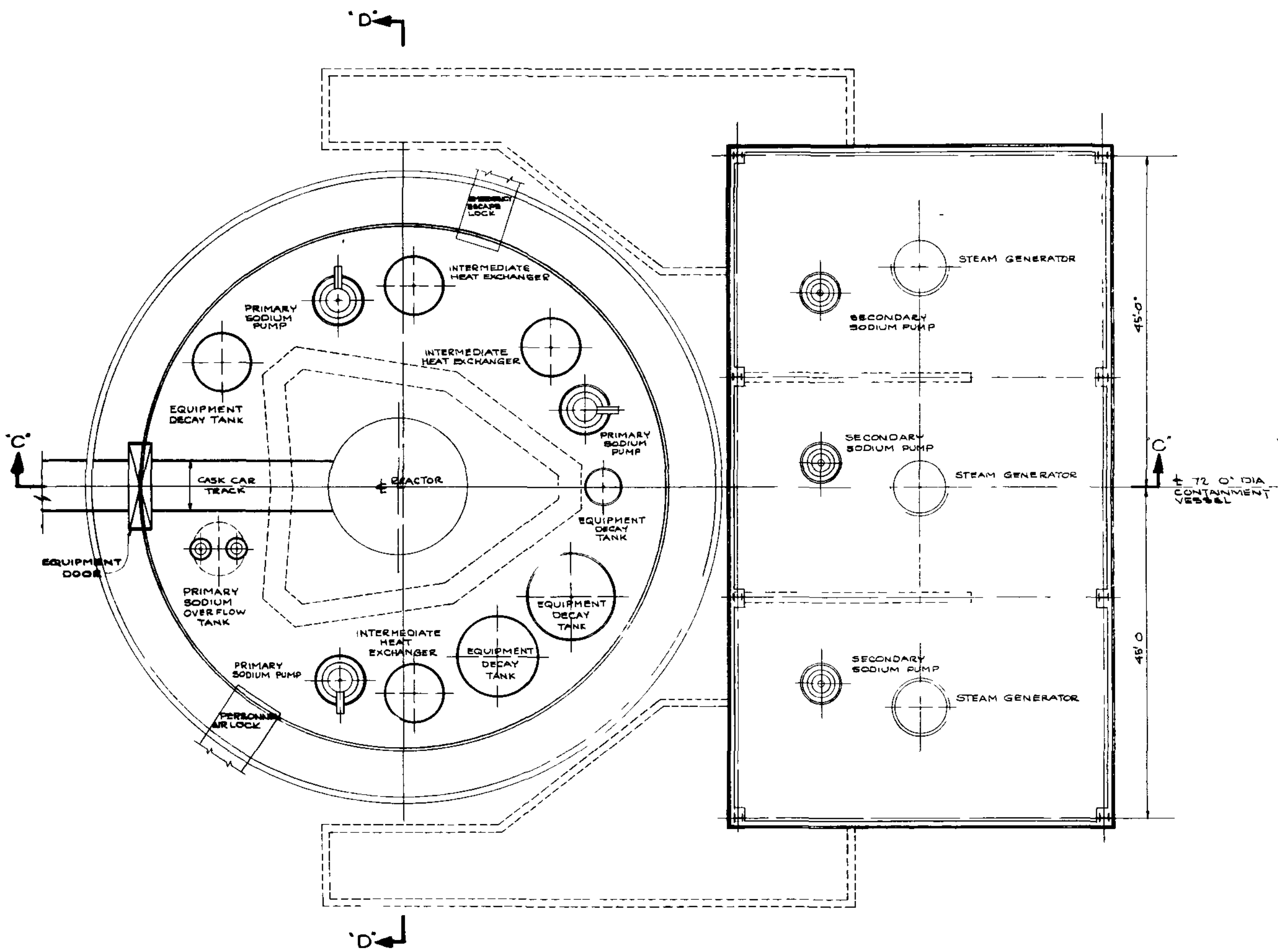
GENERAL ARRANGEMENT PLAN & SECTION
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

REVISIONS	
SCALE 1" = 30'-0"	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
DRAWN R GOETTSCHE 8-25-59	
CHECKED	
ENGINEER	
APPROVED	DRAWING NO.
JOB NO 1957-15	NS-612

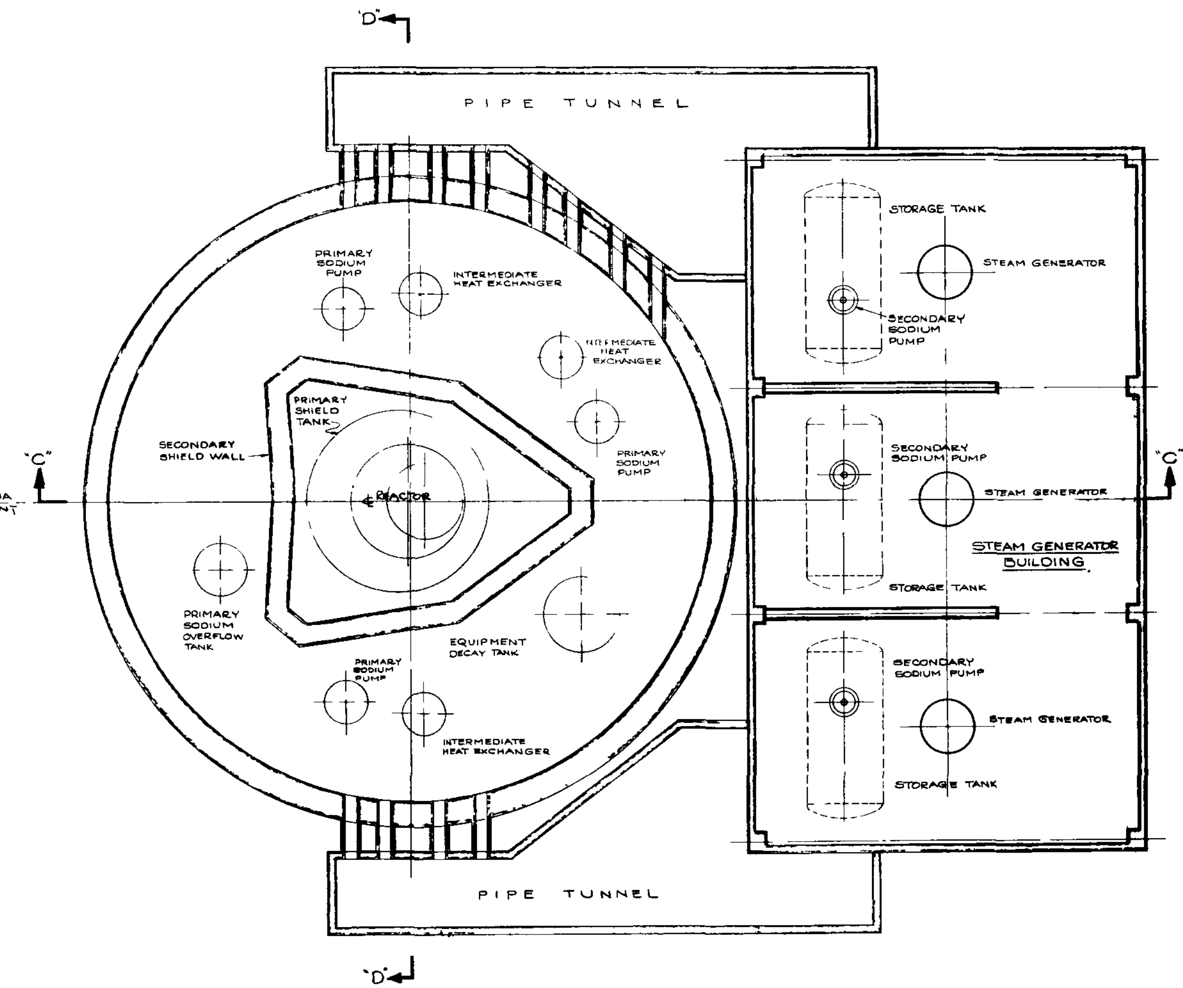

150 MWe FAST BREEDER REACTOR PLANT
FLOW DIAGRAM
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
SCALE NONE
DRAWN R. JASKULA
CHECKED
ENGINEER
APPROVED
DRAWING NO.
NS-701
JOB NO 1857-15
REVISIONS
REACTOR
INTERMEDIATE HEAT EXCHANGER
PRIMARY SODIUM SYSTEM
PRIMARY SODIUM PUMP 12,000 G.P.M.
TO BLANKET
DUCT
COOLING WATER
BLOWER
N2 SUPPLY
FORCED NITROGEN SHIELD COOLING
INERT GAS
OVERFLOW PUMP (2)
PRIMARY SYSTEM OVERFLOW TANK
EXPANSION TANK
PRIMARY SERVICE E.M. PUMP 100 G.P.M.
REG. HEAT EXCHANGER
COLD TRAP (2)
FLOW METER
PLUGGING INDICATOR
NA-ORGANIC HEAT EXCH.
ORGANIC COOLING
Na EXPANSION TANK (3) 2000 GAL.
SECONDARY SERVICE E.M. PUMP (100 GPM)
SECONDARY Na CIRC PUMP
SECONDARY SODIUM STORAGE TANK (3) 10,000 GAL EA
STEAM GENERATOR (3)
SECONDARY SODIUM PURIFICATION SYSTEM
Na-NaK HEAT EXCHANGER
ORGANIC COOLING
PRIMARY SODIUM FILL TANK (3) 15,000 GAL. (EA.)
SODIUM FILTERS
FROM SODIUM MELT STATION
TO AIR EJECTOR
TURBINE CYCLE
REHEATER
TO H.P. HTR. D
H.P. TURBINE
L.P. TURBINE
GENERATOR
DEMINERALIZED WATER STORAGE TANK 15,000 GAL.
FOR WTR PURIF SYSTEM
MAIN CONDENSER
DESUPERHEATING STATION
CONDENSATE PUMPS 1,100 G.P.M.
STEAM
AIR EJECTOR
TO ATMOS
FROM TURBINE GLANDS
GLAND STEAM CONDENSER
H.P. HTR. D
FROM REHEATER
LP HTR "C"
LP HTR "B"
LP HTR "A"
HTR "A" WITH INTEGRAL DRAIN COOLER
STEAM GENERATOR FEED PUMPS (2) 1,500 G.P.M.
NOTE
CONDENSER CIRC PUMPS, SERVICE WATER PUMPS, FIRE PUMPS & SCREEN WASH PUMPS ARE NOT SHOWN
NOTE:
PRIMARY, SECONDARY & ASSOCIATED SODIUM & NaK PURIFICATION SYSTEMS ARE TYPICAL FOR A MULTICIRCUIT PLANT
DISPOSABLE COLD TRAP ASSEMBLY IS NOT DUPLICATED
TO COMMERCIAL GRADE REQ.
TO INERT GAS SYSTEM
BACK FLOW TRAP
PURIFICATION UNIT
ENTRAINMENT TRAP
HIGH PRESSURE INERT GAS SUPPLY
INERT GAS SUPPLY SYSTEM
FILL
ORGANIC SUPPLY TANK 500 GAL.
FROM EQUIP REQUIRING ORGANIC COOLING
TO EQUIP REQUIRING ORGANIC COOLING
ORGANIC HEAT EXCHANGER (2)
ORGANIC PUMPS 150 G.P.M.
ORGANIC COOLING SYSTEM
(2) COOLING WATER PUMPS 65 GPM EA.
COOLING WTR SUPPLY
COOLING WTR RETURN
TO FINAL DISPOSAL
LIQUID WASTE TRANSFER PUMPS (2) 5 G.P.M.
SHORT LIVED LIQUID WASTE STORAGE TANK (2) 5,000 GAL.
LONG LIVED LIQUID WASTE STORAGE TANK (2) 10,000 GAL.
LAUNDRY LIQUID WASTE HOLD-UP TANKS
1,000 GAL.
FROM LAUNDRY HOT SHOWER & OTHER CONTAMINATED LIQUID WASTE
RADIOACTIVE LIQUID WASTE SYSTEM
COMPR SUCTION TANK (4) 1,500 GAL.
COMPRESSORS 25 CFM
FROM EQUIP VENTS, VAPOR TRAPS & PRIMARY FILL TANKS
TO LIQUID WASTE STORAGE TANKS
DECAY TANKS (4) 8,000 GAL (EA.)
TO VENTILATION STACK BLOWER
FILTER (2)
RADIOACTIVE WASTE GAS SYSTEM



FLOW
GRADE ELEV. 0'-0"
DOCK
STOP LOGS
CIRC. WATER PUMPS
CRIB HOUSE
SERVICE WATER PUMPS
TRAVELING SCREENS
DISCHARGE FLUME
ROADWAY
SEAL WELL
CIRC. WATER DISCHARGE PIPES
CONDENSER WATER INLET PIPE
EMERGENCY ESCAPE LOCK
R.R. TRACK
EQUIPMENT DOOR
STEAM GENERATOR BUILDING
TURBINE ROOM
OFFICES
RESERVE TRANSF.
MAIN TRANSF.
SWITCH YARD
UNIT AUX. 1 TRANSF.
UNIT AUX. 2 TRANSF.
RADIO-ACTIVE WASTE DISPOSAL BUILDING
FENCE
SOLID WASTE BURIAL PIT
WASTE HOLD-UP TANKS
RADIO-ACTIVE GAS HOLD-UP TANKS
OIL STORAGE TANKS (100,000 GALLONS EACH)
PARKING LOT
ROADWAY
FENCE
CONTAINMENT VESSEL
EQUIPMENT DOOR
REACTOR
STEAM GENERATOR BUILDING
TURBINE ROOM
150 TON CRANE
CONDENSER
OPERATING FLOOR
SECTION 'A-A'
SCALE: 1" = 30'-0"
CONTROL ROOM
OFFICES
WASHING SHOP
R.R. TRACK
CONDENSER WATER INLET PIPE
ROAD ELEV. 0'-0"
EXISTING GRADE LINE
TRAVELING SCREENS
CIRC. WATER PUMPS
CRIB HOUSE
STOP LOGS
SEAL WELL
DISCHARGE FLUME
SECTION 'B-B'
SCALE: 1" = 30'-0"
150 MWe FAST BREEDER REACTOR PLANT
REVISIONS
PROPERTY PLAT
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.
SCALE 1"=50'-0" & AS NOTED
DRAWN A.E. JOHNSEN 8-25-59
CHECKED
ENGINEER
APPROVED
JOB NO
1867-15
SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NS-702



UPPER PLAN AT 'A-A'



LOWER PLAN AT 'B-B'

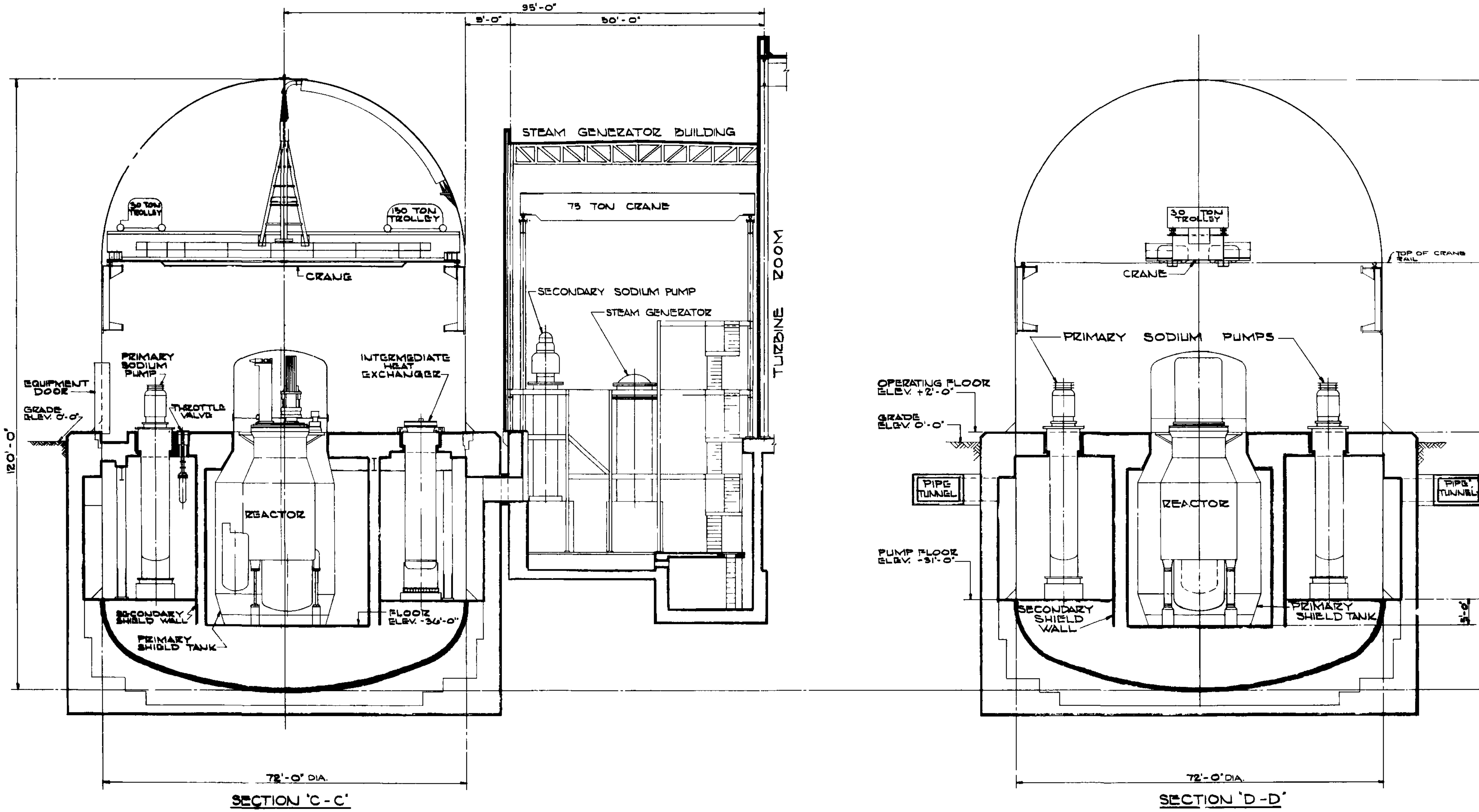
150 MWe FAST BREEDER REACTOR PLANT

GENERAL ARRANGEMENT PLANS
'A-A' & 'B-B' REACTOR BLDG
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8" = 1'-0"
DRAWN C. LINNEMANN 8-25-59
CHECKED
ENGINEER
APPROVED
JOB NO 1857-15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-703



150 MWe FAST BREEDER REACTOR PLANT

REVISIONS	

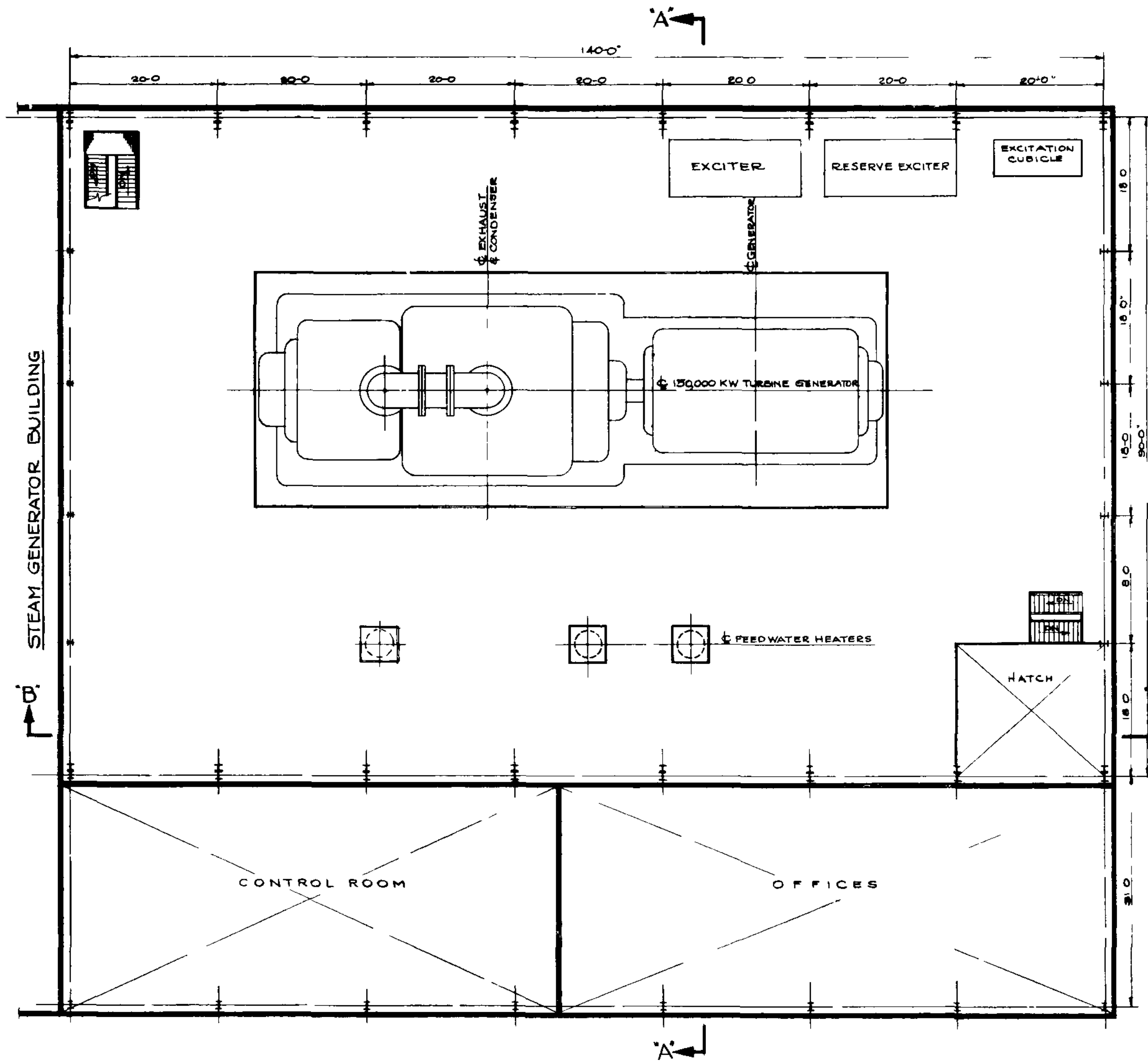
GENERAL CROSS SECTIONS
"C-C" & "D-D" REACTOR BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN A.E. JOHNSEN 6-23-59
CHECKED
ENGINEER
APPROVED

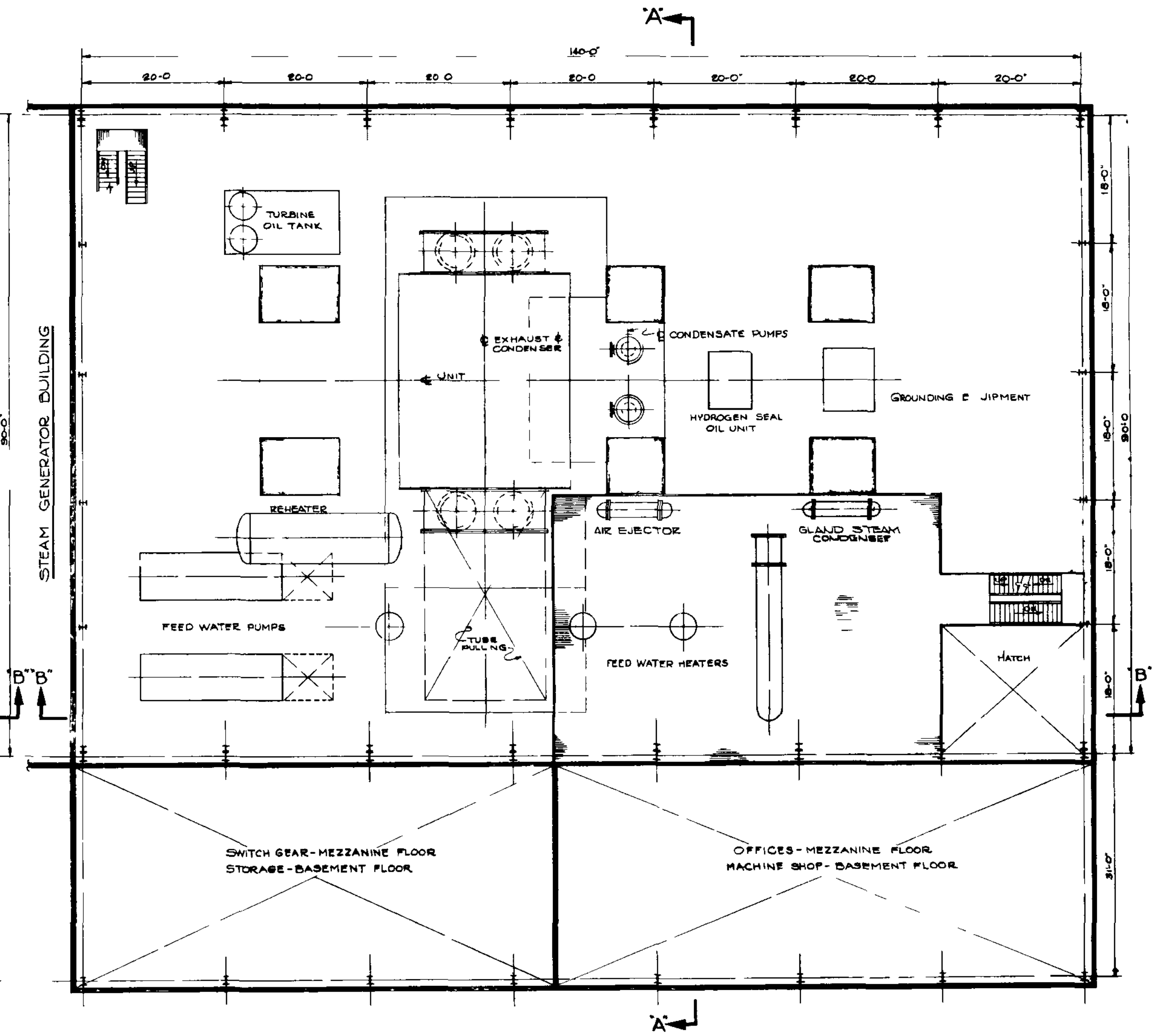
JOB NO	JOB NO	JOB NO	JOB NO
1857-15			

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO.
NS-704



MAIN FLOOR PLAN



BASEMENT FLOOR PLAN

150 MWe FAST BREEDER REACTOR PLANT

REVISIONS

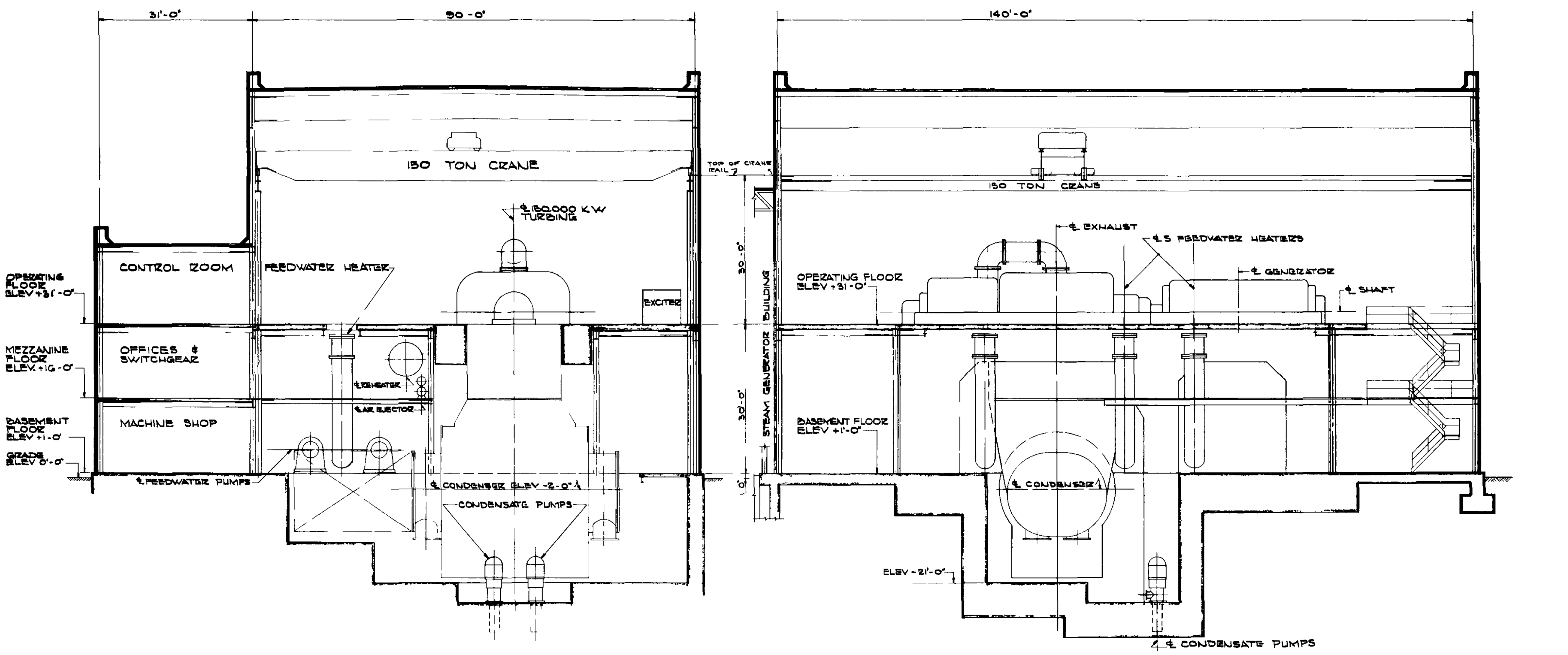
GENERAL ARRANGEMENT PLANS
MAIN & BSMT. FLRS. TURBINE BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8" = 1'-0"
DRAWN C. LINNEMANN 8-25-59
CHECKED
ENGINEER
APPROVED

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

JOB NO. 1187-5

DRAWING NO.
NS-705



SECTION 'A-A'

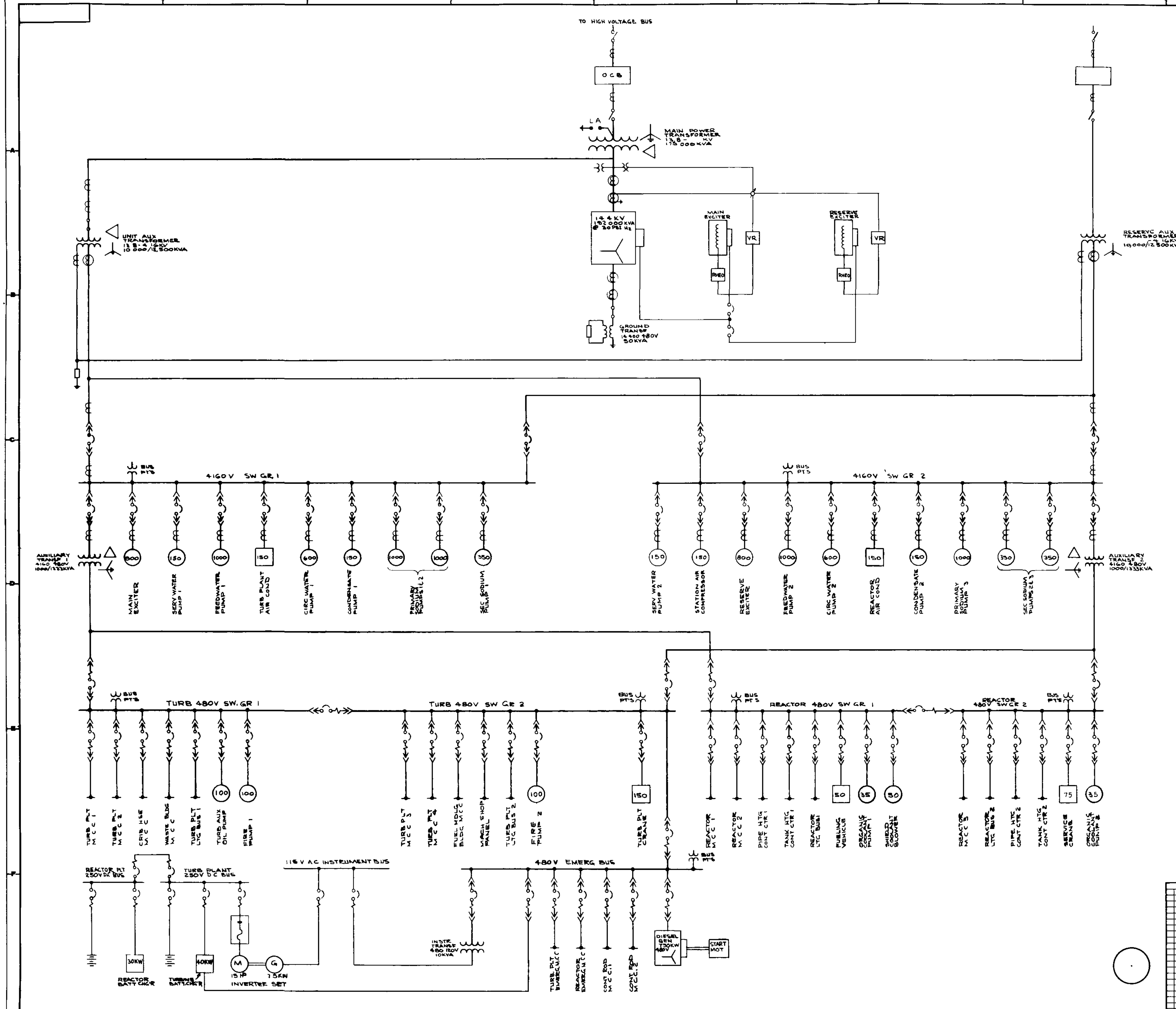
SECTION 'B-B'

150MWe FAST BREEDER REACTOR PLANT

REVISIONS	GENERAL CROSS SECTIONS 'A-A' & 'B-B' TURBINE BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.
	SCALE 1/8"=1'-0"
	DRAWN A.E. JOHNSEN 8-25-59
	CHECKED
	ENGINEER
	APPROVED
	JOB NO 1957-15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

DRAWING NO
NS-706

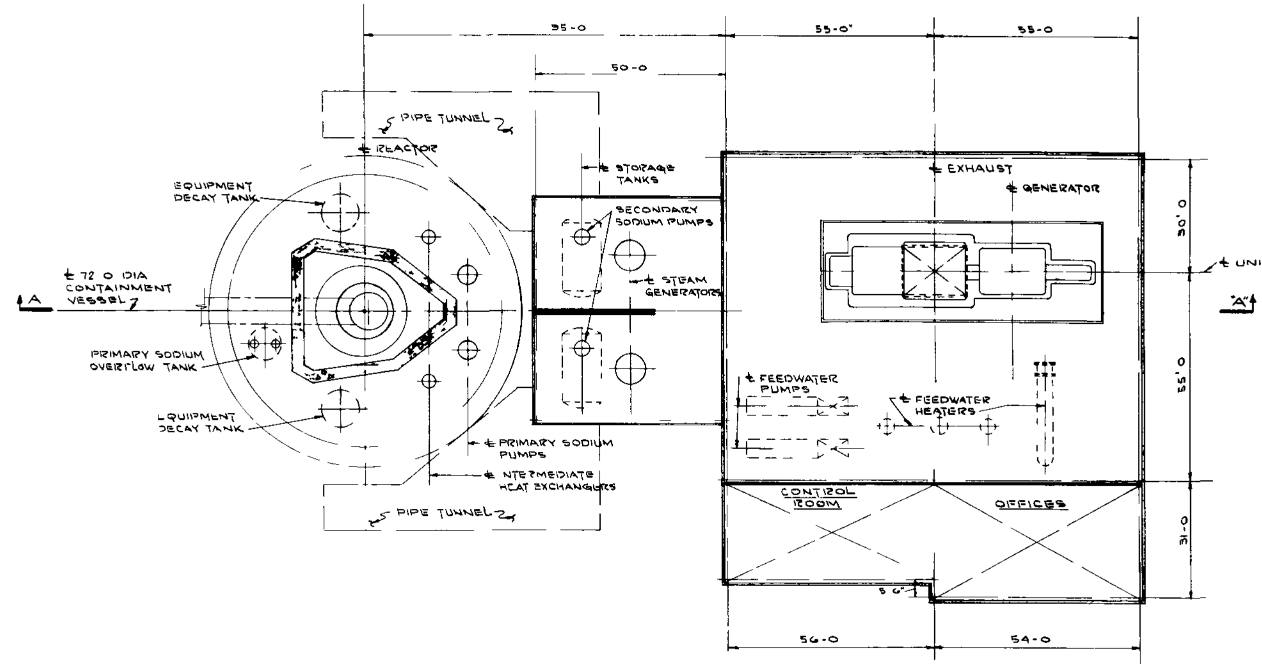


150 MWE FAST BREEDER REACTOR PLANT

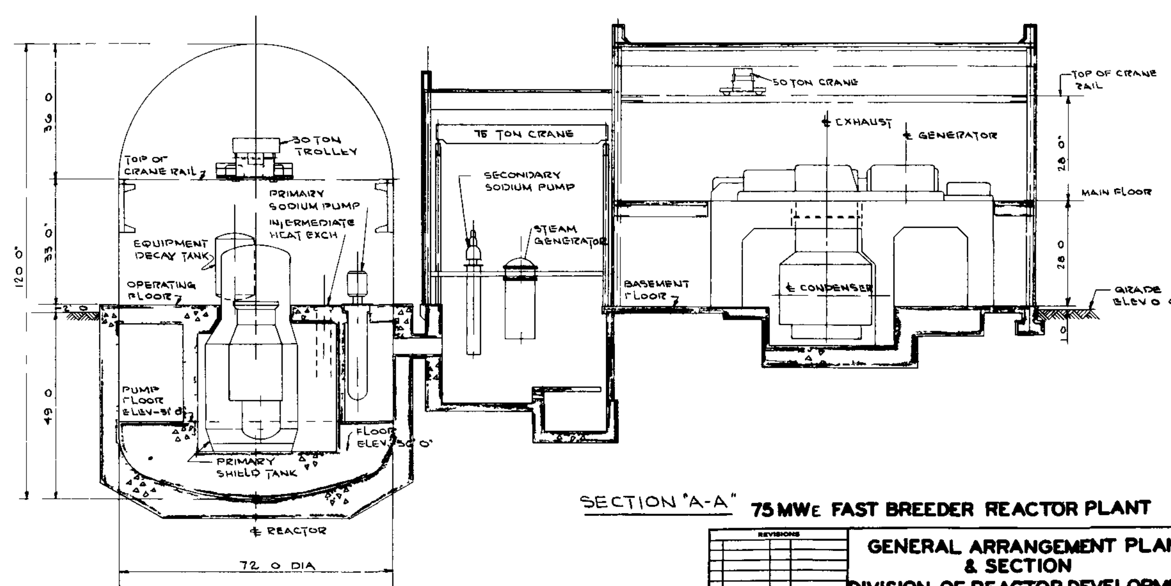
ELECTRICAL DIAGRAM

DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE NONE	SARGENT & LUNDY ENGINEERS CHICAGO 3 ILLINOIS
DRAWN W. RALEY 8-25-63	
CHECKED	
ENGINEER	
APPROVED	DRAWING NO
JOB NO 1957-15	ES-701



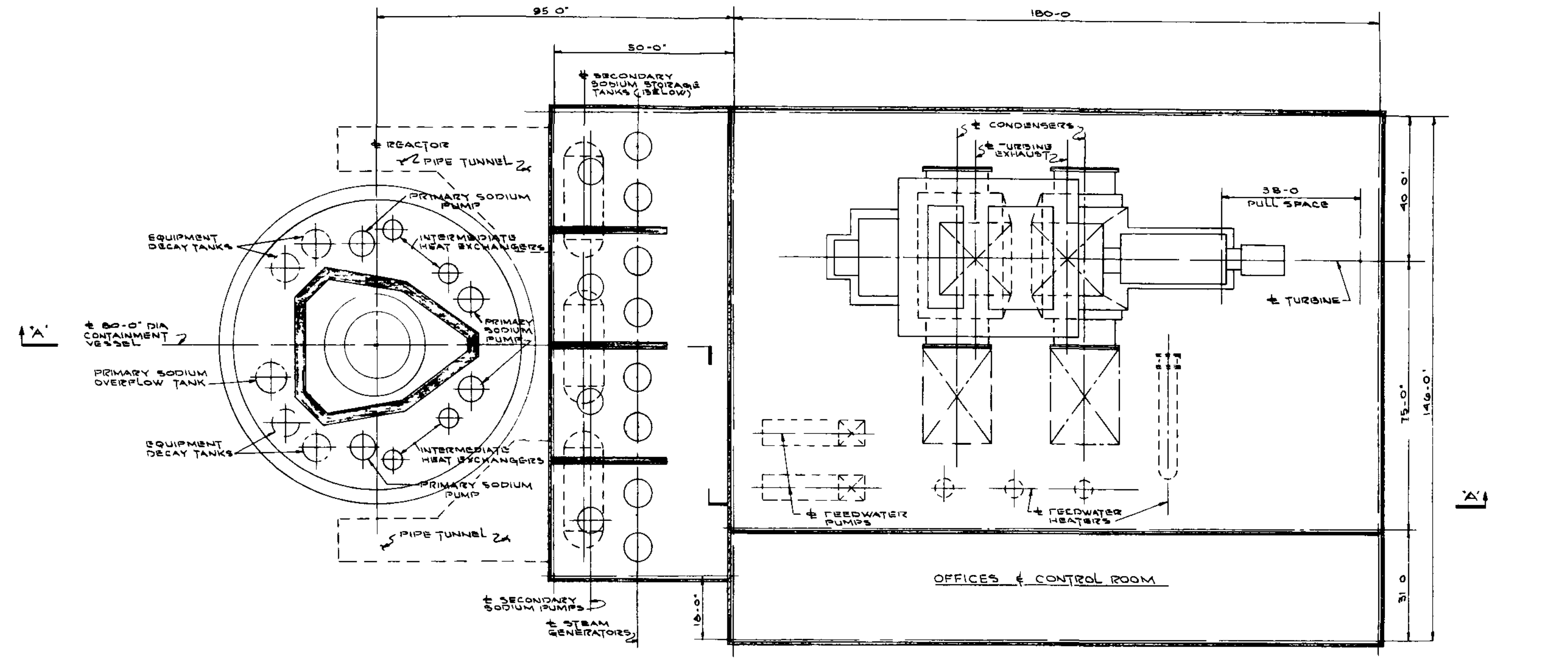
PLAN



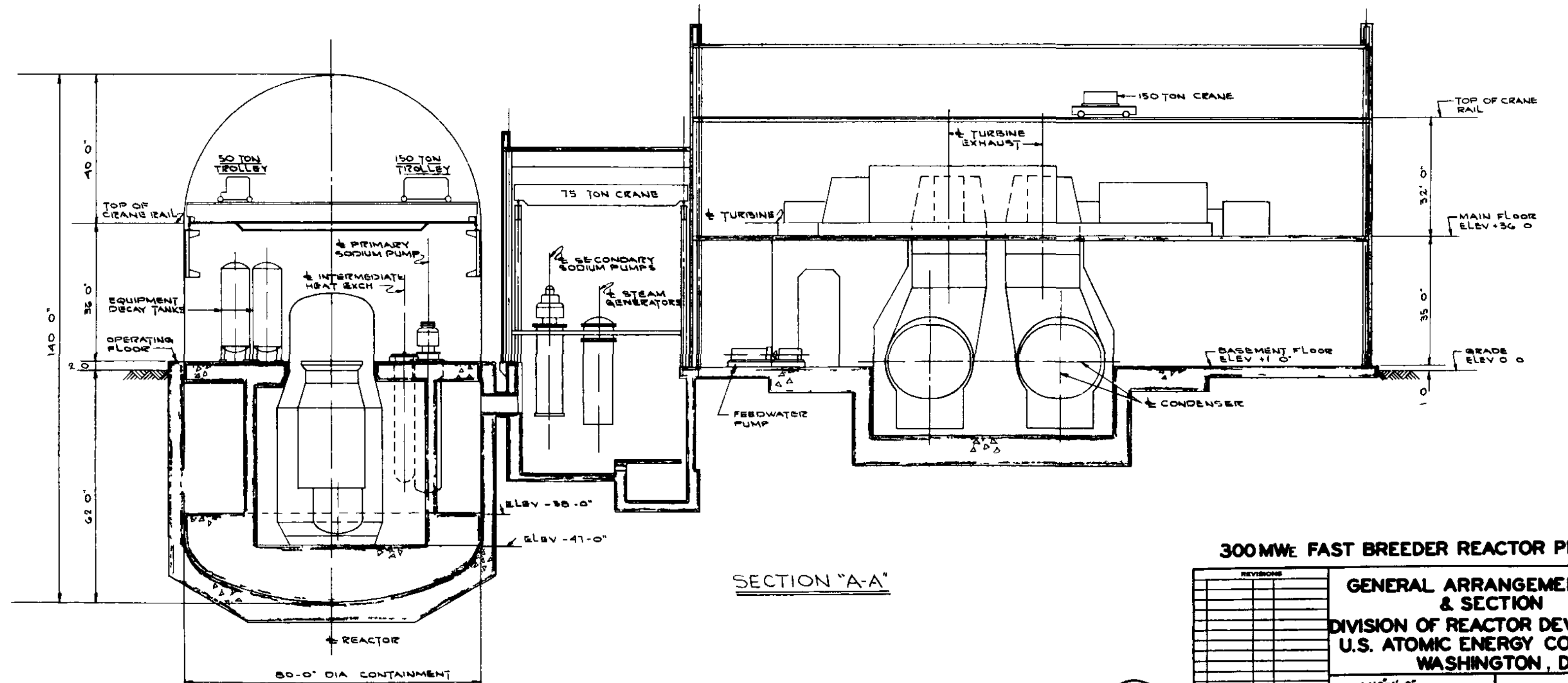
SECTION "A-A"

75 MWe FAST BREEDER REACTOR PLANT

REVISIONS	
	GENERAL ARRANGEMENT PLAN & SECTION **DIVISION OF REACTOR DEVELOPMENT** **U.S. ATOMIC ENERGY COMMISSION** **WASHINGTON, D.C.**
SCALE 1/16"=1-0" DRAWN R. JASKULA 8-23-57 CHECKED ENGINEER APPROVED	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
JOB NO 1957-15	DRAWING NO NS-707



PLAN



SECTION "A-A"

300 MWE FAST BREEDER REACTOR PLANT

REVISIONS			

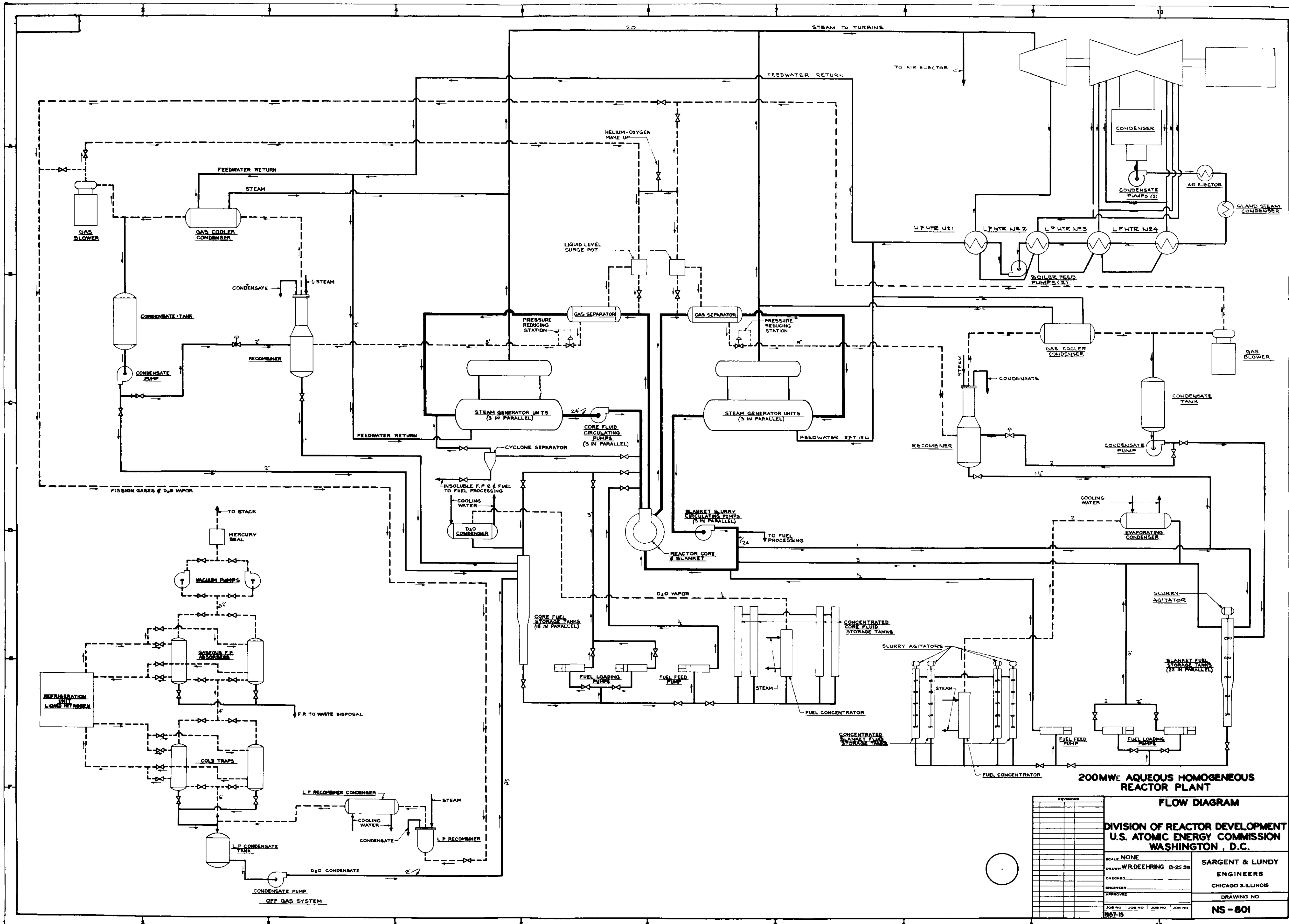
GENERAL ARRANGEMENT PLAN & SECTION
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/16"=1'-0"
DRAWN R. JASKULA 8-25-59
CHECKED
ENGINEER
APPROVED

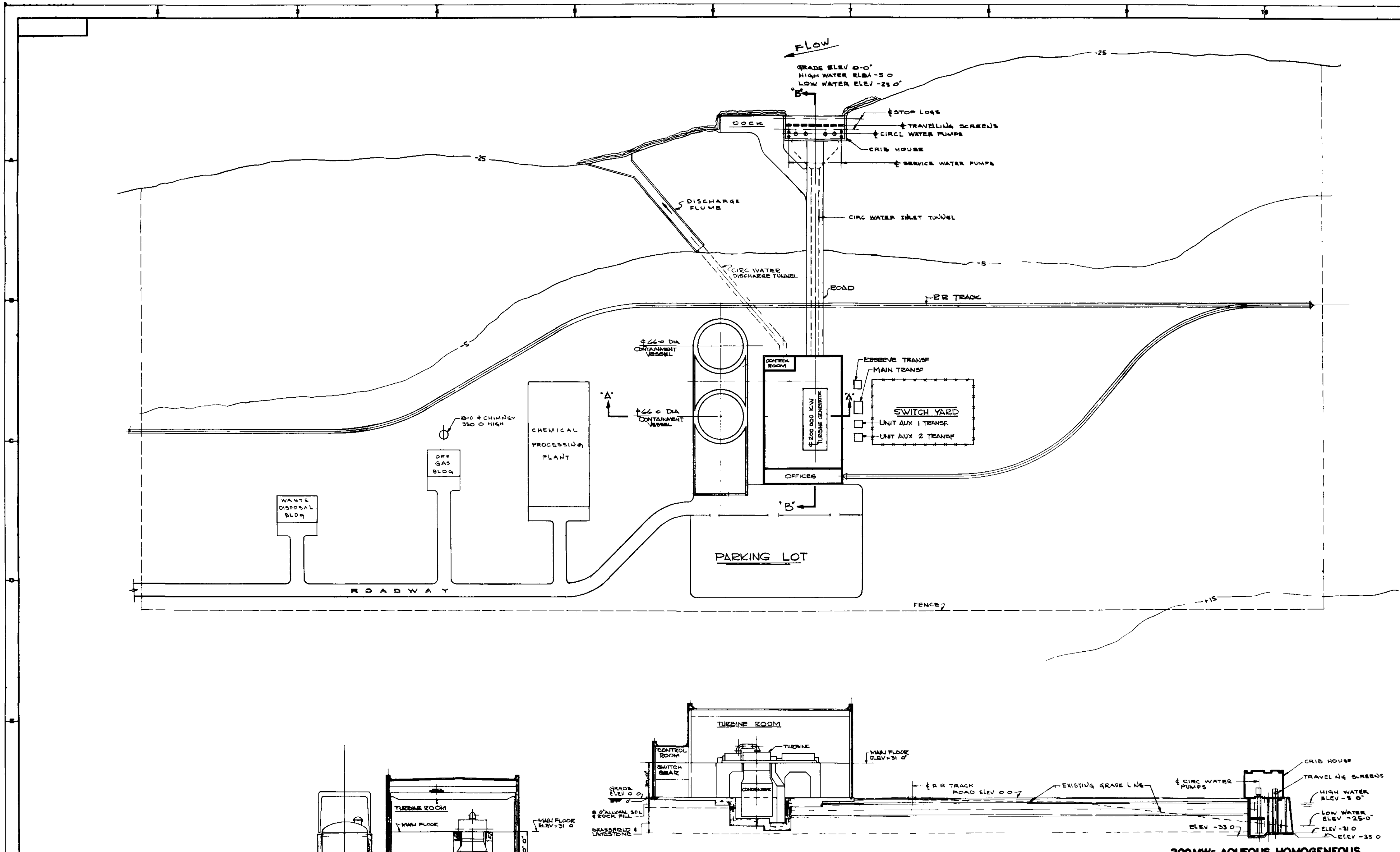
JOB NO.	JOB NO.	JOB NO.	JOB NO.
1957-15			

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-708



STEAM TO TURBINE
TO AIR EJECTOR
FEEDWATER RETURN
CONDENSER
CONDENSATE PUMPS (2)
AIR EJECTOR
GLAND STEAM CONDENSER
L P HTR № 1
L P HTR № 2
L P HTR № 3
L P HTR № 4
BOILER FEED PUMPS (2)
HELIUM-OXYGEN MAKE UP
STEAM
GAS BLOWER
GAS COOLER CONDENSER
LIQUID LEVEL SURGE POT
CONDENSATE
CONDENSATE TANK
RECOMBINER
CONDENSATE PUMP
GAS SEPARATOR
PRESSURE REDUCING STATION
STEAM GENERATOR UNITS (3 IN PARALLEL)
CORE FLUID CIRCULATING PUMPS (3 IN PARALLEL)
CYCLONE SEPARATOR
INSOLUBLE F.P. & FUEL TO FUEL PROCESSING
COOLING WATER
D2O CONDENSER
FISSION GASES & D2O VAPOR
BLANKET SLURRY CIRCULATING PUMPS (3 IN PARALLEL)
TO FUEL PROCESSING
REACTOR CORE & BLANKET
EVAPORATING CONDENSER
TO STACK
MERCURY SEAL
VACUUM PUMPS
GASEOUS F.P. ADSORBERS
REFRIGERATION UNIT LIQUID NITROGEN
F.P. TO WASTE DISPOSAL
COLD TRAPS
L P RECOMBINER CONDENSER
L P RECOMBINER
L P CONDENSATE TANK
D2O CONDENSATE
CONDENSATE PUMP
OFF GAS SYSTEM
D2O VAPOR
CORE FUEL STORAGE TANKS (15 IN PARALLEL)
FUEL LOADING PUMPS
FUEL FEED PUMP
CONCENTRATED CORE FLUID STORAGE TANKS
FUEL CONCENTRATOR
SLURRY AGITATORS
CONCENTRATED BLANKET FLUID STORAGE TANKS
SLURRY AGITATOR
BLANKET FUEL STORAGE TANKS (22 IN PARALLEL)
200MWe AQUEOUS HOMOGENEOUS REACTOR PLANT
FLOW DIAGRAM
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.
REVISIONS
SCALE NONE
DRAWN W.R. DEEHRING 8-25-59
CHECKED
ENGINEER
APPROVED
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO
NS-801
JOB NO
1957-15



200 MWe AQUEOUS HOMOGENEOUS REACTOR PLANT

PROPERTY PLAT

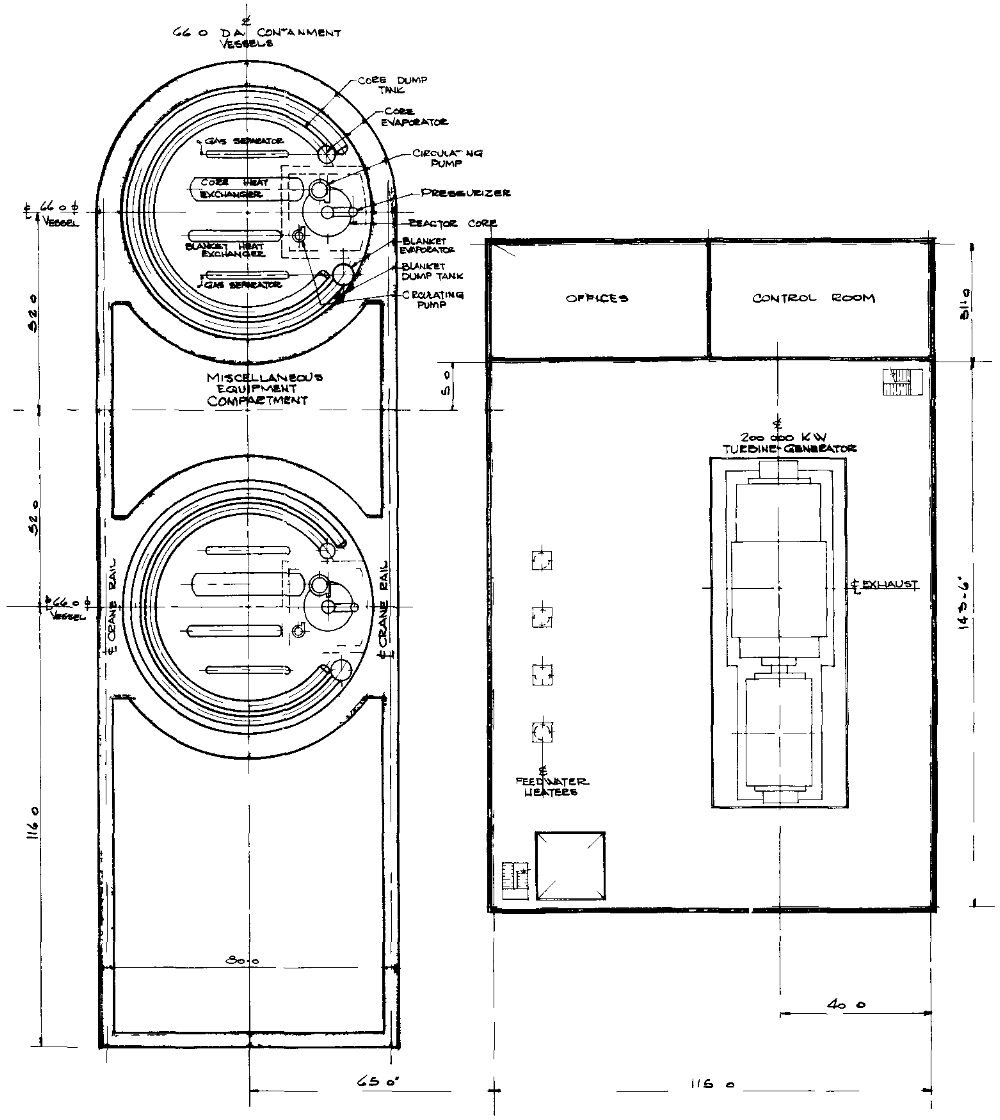
REVISIONS

DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D. C.

SCALE 1"= 50 0" & AS NOTED
DRAWN E J VICTORINE 8 25-[illegible]
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15

SARGENT & LUNDY ENGINEERS
CHICAGO 3 ILLINOIS

DRAWING NO NS-802



200 MWE AQUEOUS HOMOGENEOUS REACTOR PLANT

REVISIONS

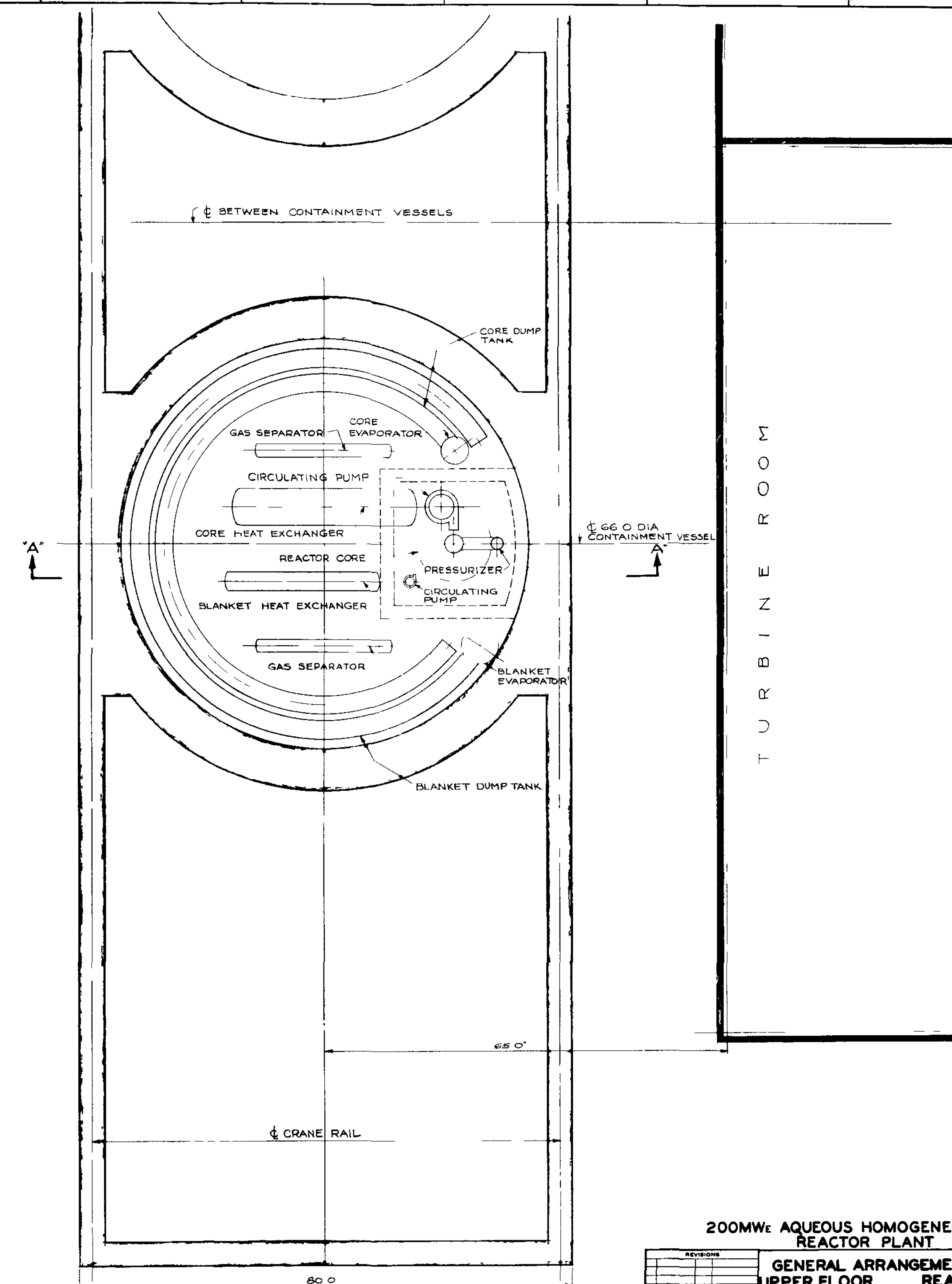
GENERAL ARRANGEMENT PLAN
TURBINE BLDG & REACTOR BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/16"=1'-0"
DRAWN A J SCHALL 8-25 59
CHECKED
ENGINEER
APPROVED

JOB NO	OB NO	OB NO	OB NO
1957-15			

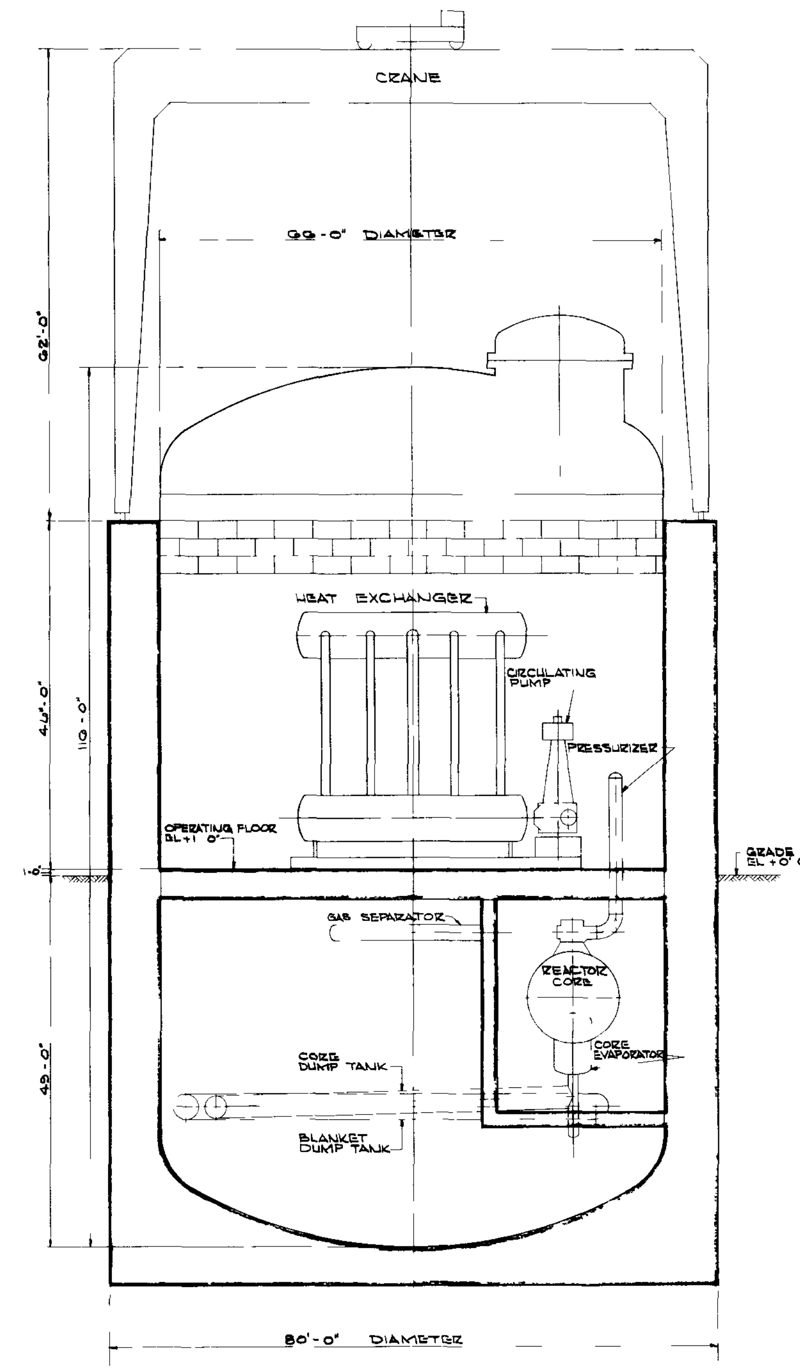
SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

DRAWING NO
NS-803



200MWe AQUEOUS HOMOGENEOUS REACTOR PLANT

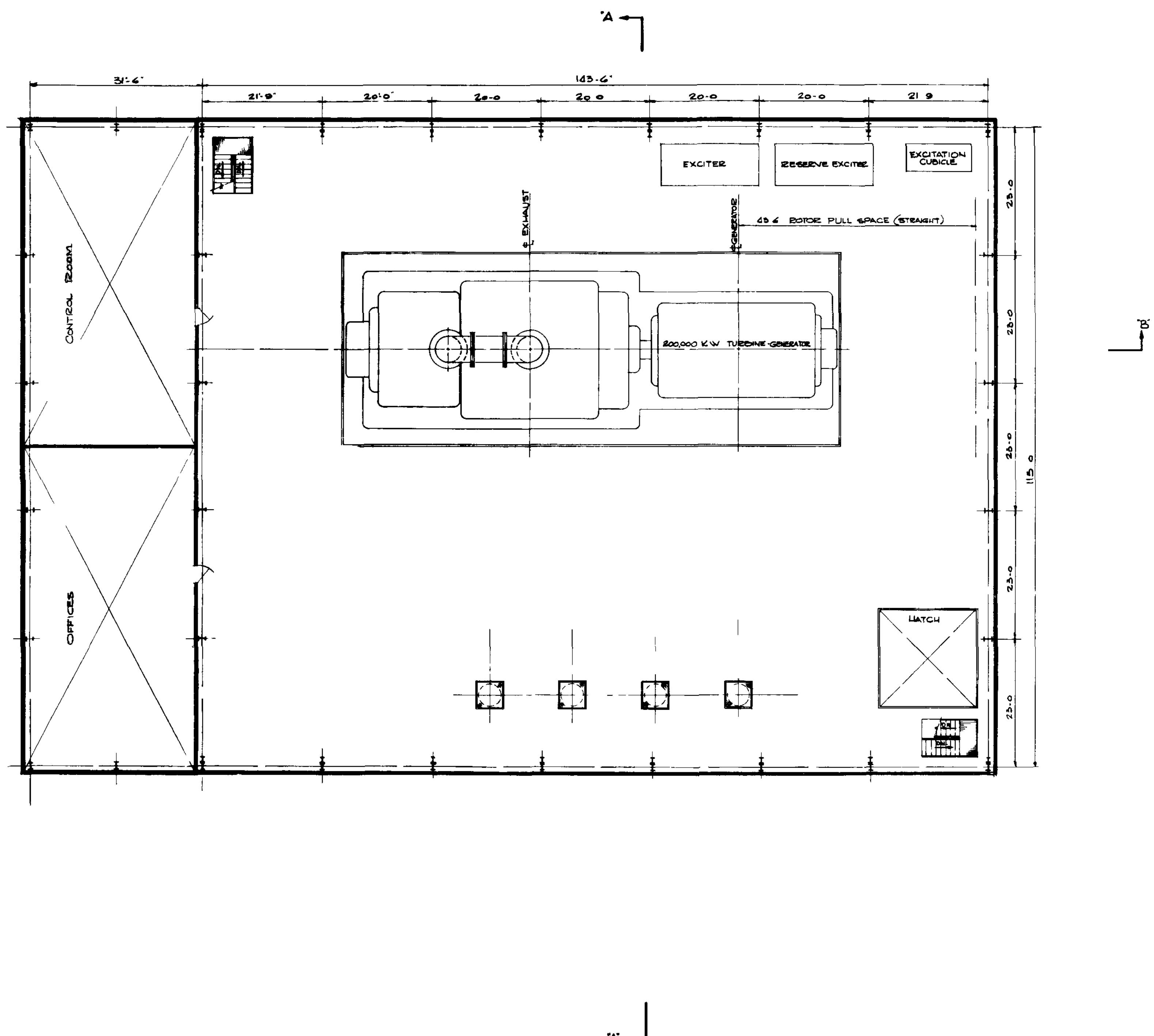
REVISIONS	GENERAL ARRANGEMENT PLAN UPPER FLOOR REACTOR BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.
SCALE 1/8"=1'-0"	SARGENT & LUNDY ENGINEERS CHICAGO 3 ILLINOIS
DRAWN C LINNEMANN 8 25 59	
CHECKED	
ENGINEER	
APPROVED	DRAWING NO
JOB NO 1957-15	NS-804



SECTION AA

200MWe AQUEOUS HOMOGENEOUS REACTOR PLANT

REVISIONS	GENERAL CROSS SECTION "A-A" REACTOR BLD'G DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.	
	SCALE 1/8"=1-0" DRAWN C LINNEMANN 8 25 59 CHECKED ENGINEER APPROVED	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
	JOB NO 1957-15 | JOB NO | JOB NO | JOB NO	DRAWING NO NS-805



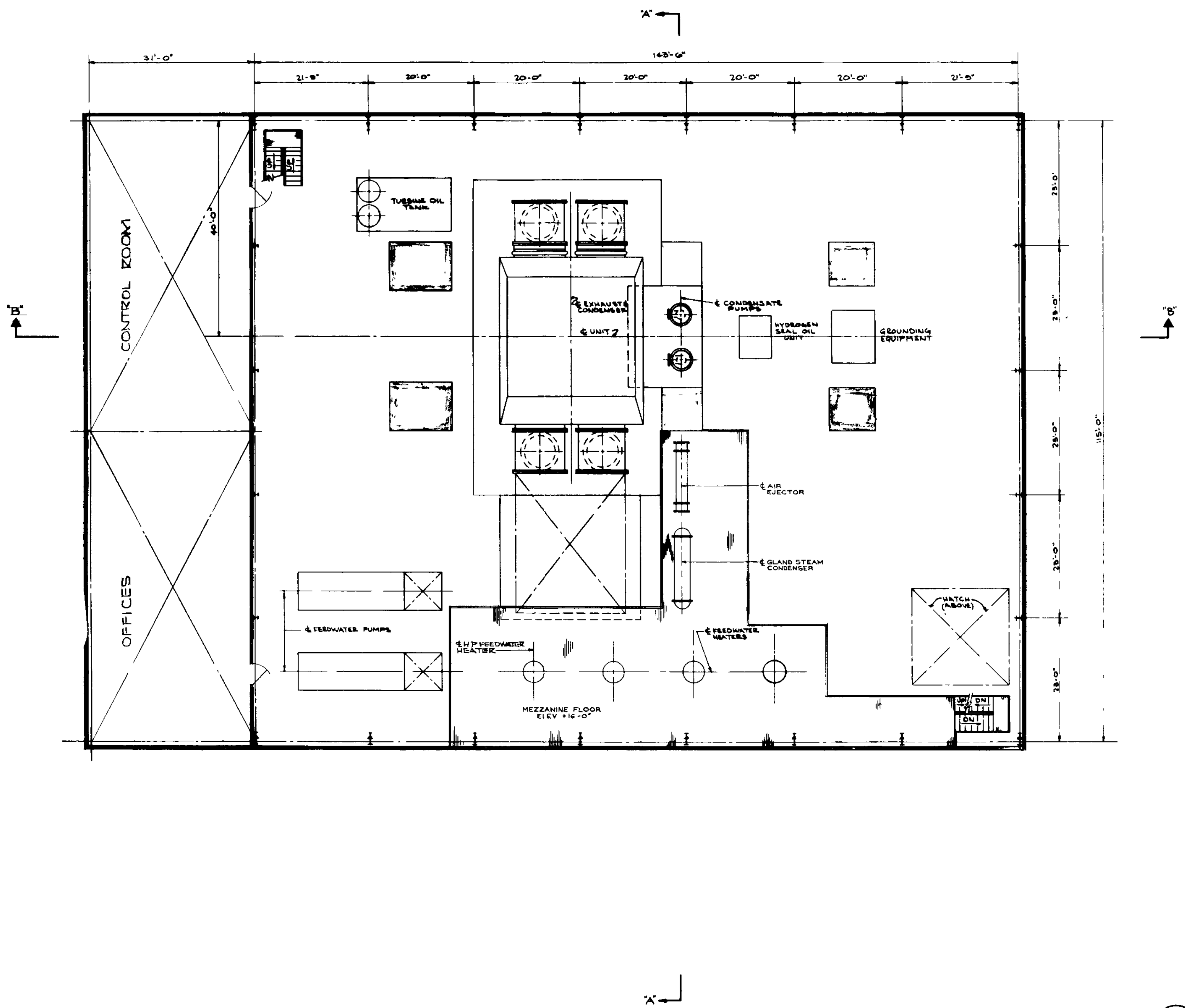
200 MWe AQUEOUS HOMOGENEOUS REACTOR PLANT

GENERAL ARRANGEMENT PLAN
MAIN FLOOR TURBINE BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8"=1'-0"
DRAWN A. SCHALL 8-25-59
CHECKED
ENGINEER
APPROVED
JOB NO 1957-15

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

DRAWING NO
NS-806



200 MWe AQUEOUS HOMOGENEOUS REACTOR PLANT

REVISIONS

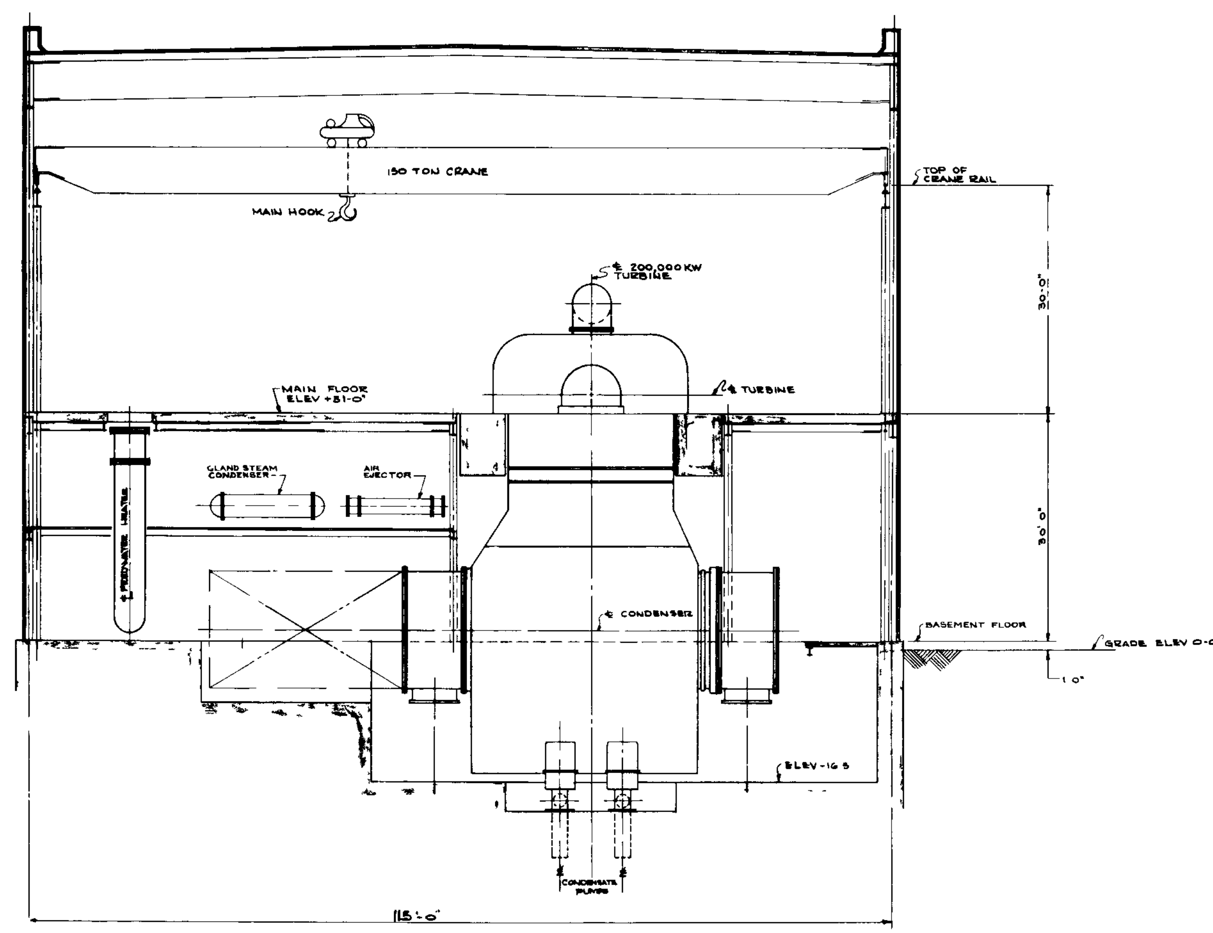
GENERAL ARRANGEMENT PLAN
MEZZ. & BSMT. FLRS. TURBINE BLDG.
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SCALE 1/8" = 1'-0"
DRAWN R JASKULA 8-25-59
CHECKED
ENGINEER
APPROVED

JOB NO	JOB NO	JOB NO	JOB NO
1957-15			

SARGENT & LUNDY
ENGINEERS
CHICAGO 3, ILLINOIS

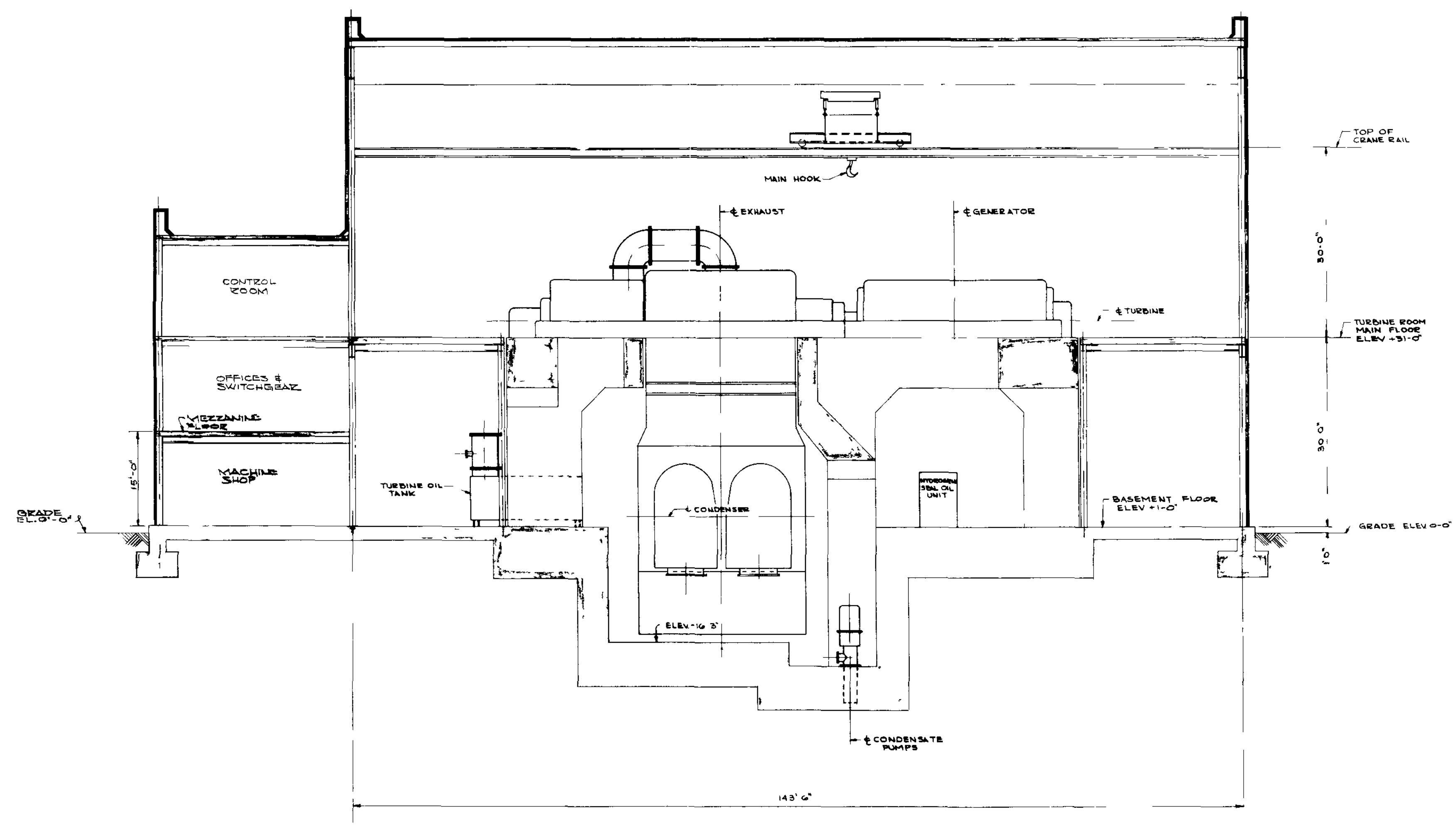
DRAWING NO
NS-807



SECTION "A-A"

200 MWe AQUEOUS HOMOGENEOUS
REACTOR PLANT

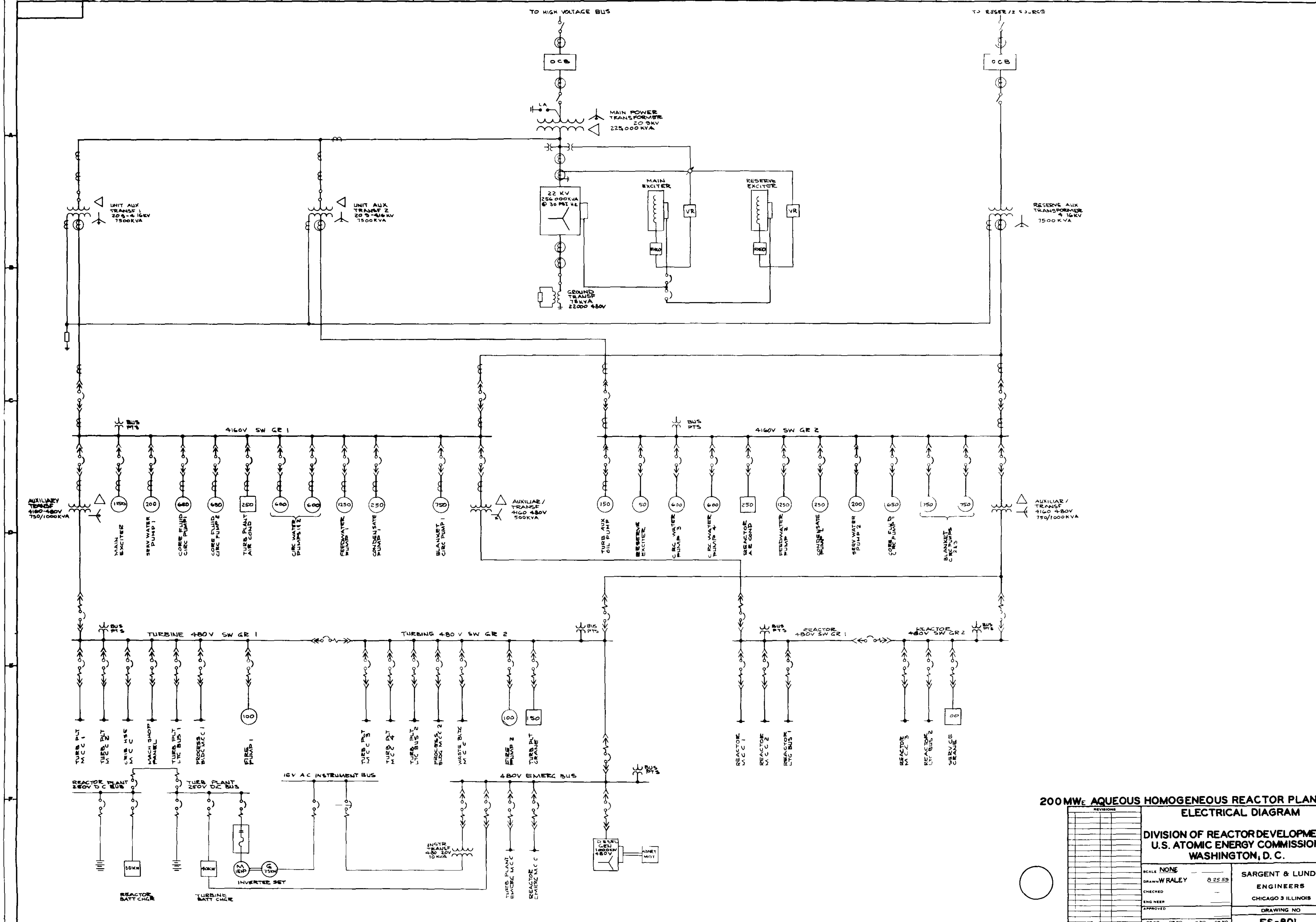
REVISIONS	GENERAL CROSS SECTION "A-A" TURBINE BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.
SCALE 1/8" = 1'-0" DRAWN F RUSSO 8 25 59 CHECKED ENGINEER APPROVED	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
JOB NO 1957-15 / JOB NO / JOB NO / JOB NO	DRAWING NO NS-808



SECTION "B-B"

200 MWe AQUEOUS HOMOGENEOUS REACTOR PLANT

REVISIONS	LONGITUDINAL SECTION "B-B" TURBINE BLDG. DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.	
	SCALE 1/8"=1'-0"	SARGENT & LUNDY ENGINEERS CHICAGO 3, ILLINOIS
	DRAWN T DENNEN 8-25-59	
	CHECKED	
	ENGINEER	
	APPROVED	DRAWING NO
	JOB NO 1957-15 / JOB NO / JOB NO / JOB NO	NS-809



200 MWe AQUEOUS HOMOGENEOUS REACTOR PLANT

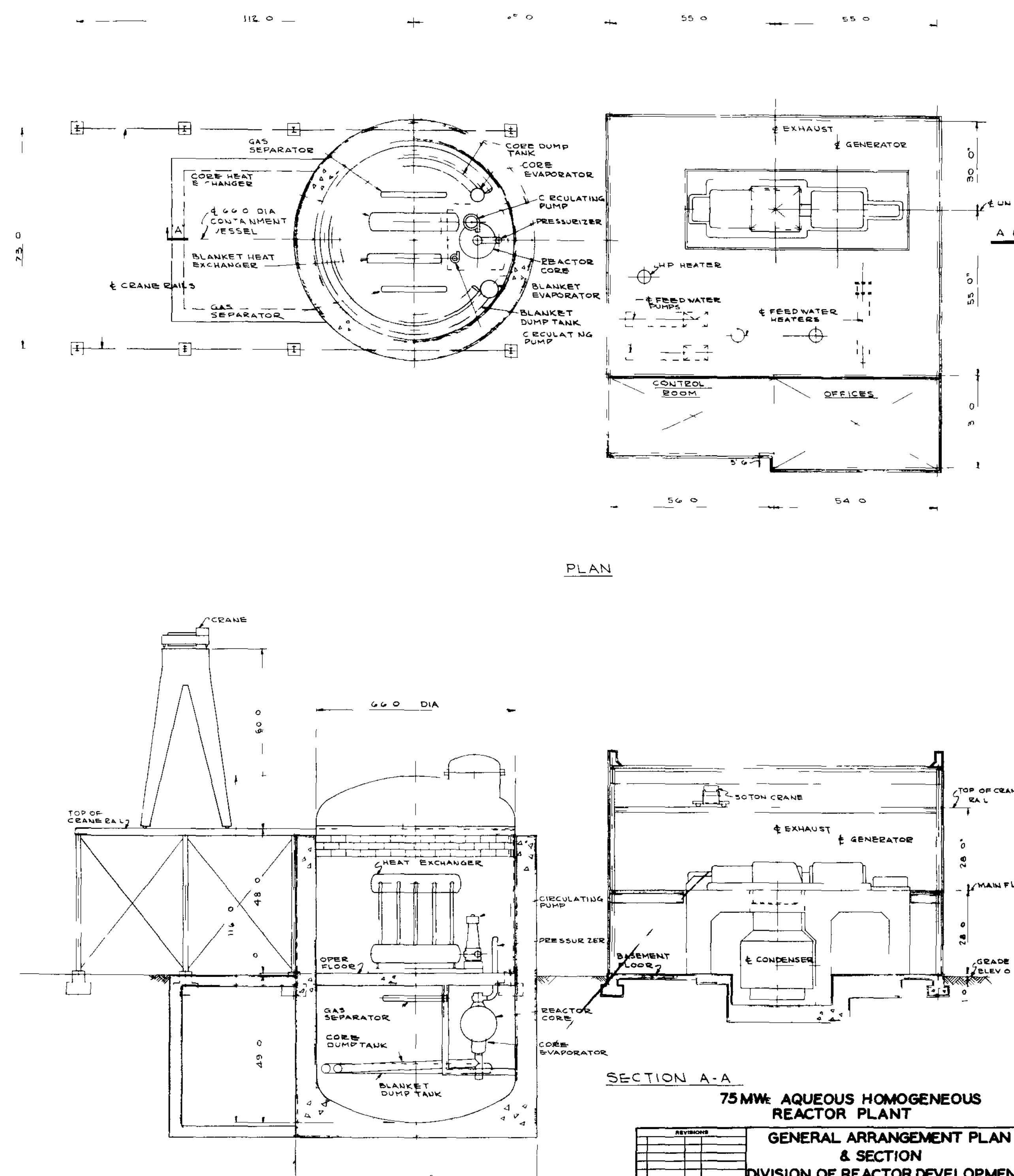
ELECTRICAL DIAGRAM

DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D. C.

SCALE NONE
DRAWN W RALEY 8-25-59

SARGENT & LUNDY
ENGINEERS
CHICAGO 3 ILLINOIS

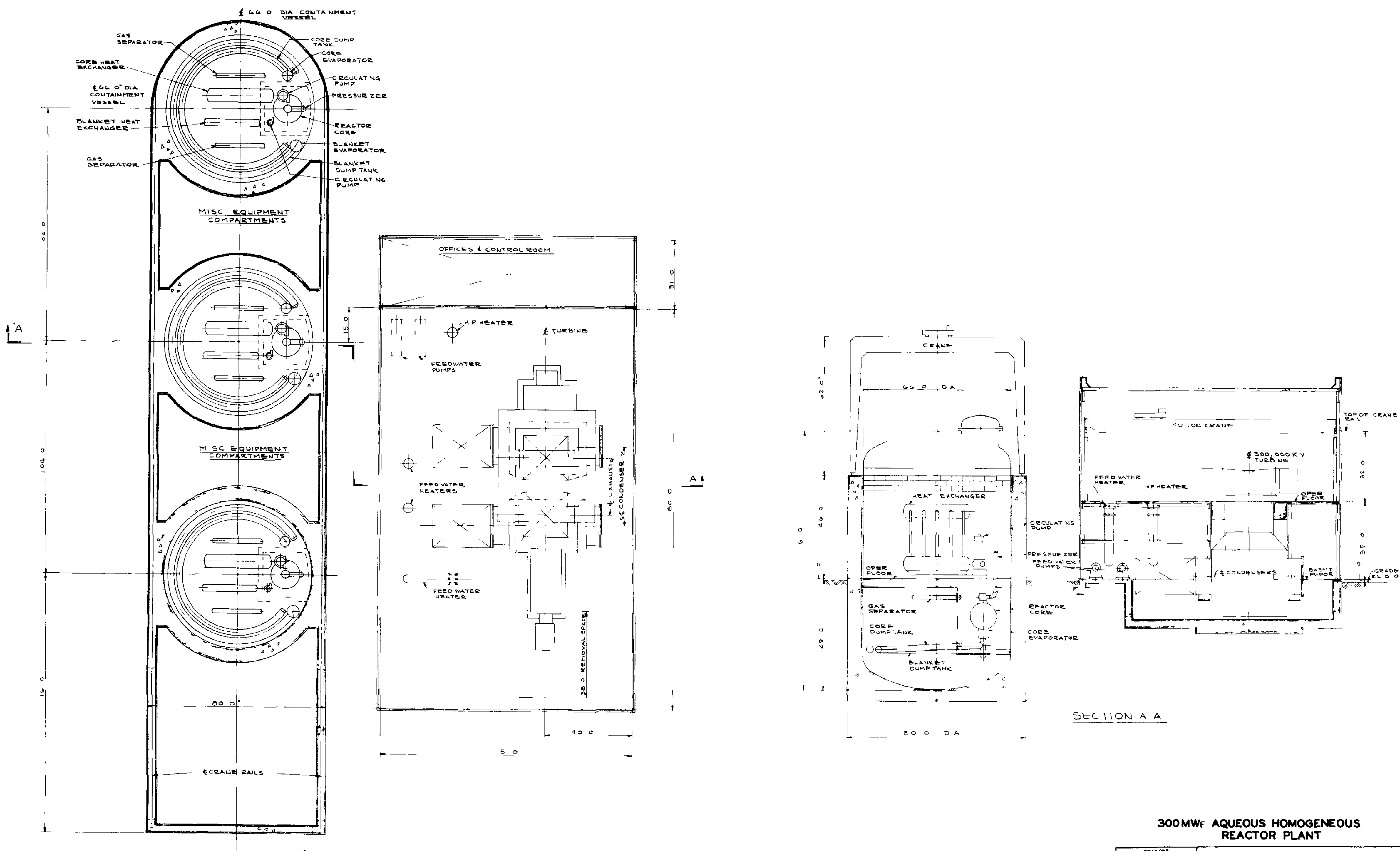
DRAWING NO
ES-801



75 MWe AQUEOUS HOMOGENEOUS REACTOR PLANT

REVISIONS	GENERAL ARRANGEMENT PLAN & SECTION
	DIVISION OF REACTOR DEVELOPMENT U.S. ATOMIC ENERGY COMMISSION WASHINGTON, D.C.

SCALE 1/16" = 1' 0"	SARGENT & LUNDY ENGINEERS CHICAGO 3 ILLINOIS
DRAWN C. KUSZYNSKI 8-25-59	
CHECKED	
ENGINEER	
APPROVED	DRAWING NO
JOB NO 1957-15	NS-810



300 MWe AQUEOUS HOMOGENEOUS REACTOR PLANT

GENERAL ARRANGEMENT PLAN & SECTION
DIVISION OF REACTOR DEVELOPMENT
U.S. ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

SARGENT & LUNDY ENGINEERS CHICAGO 3 ILLINOIS

DRAWING NO NS-811