SL-1974-4

APRIL 30, 1963

ENGINEERING EVALUATION STUDIES HEAVY WATER MODERATED POWER REACTOR PLANTS

QUARTERLY PROGRESS REPORT
JANUARY-MARCH, 1963

UNITED STATES ATOMIC ENERGY COMMISSION

SAVANNAH RIVER OPERATIONS OFFICE

CONTRACT AT (38-1) 213, MODIFICATIONS 7, 8 & 9

SARGENT & LUNDY, ENGINEERS
CHICAGO, ILLINOIS

FOREWORD

This report describes the progress made between January 1, 1962 and March 31, 1962, in a study concerned with heavy water moderated power reactor plants. The work is being performed by Sargent & Lundy for the Savannah River Operations Office of the United States Atomic Energy Commission under Contract No. AT(38-1) 213, Modifications 7, 8 and 9. The progress of the work being performed under this contract is being described in a series of quarterly reports.

The work is part of a continuing effort to advance the technology of heavy water moderated power reactors which was initiated at Sargent & Lundy in November, 1958 under Contract No. AT(38-1) 193. The initial work was directed toward the selection of that heavy water reactor concept offering the best power economics, and the preparation of a design and cost estimate for a natural uranium fueled prototype of the concept. The concept selected was one using a pressure tube reactor cooled with boiling D_2O and operating in a direct cycle.

Subsequently, under Contract AT(38-1) 213, a series of investigations was conducted to further refine the boiling D_2O direct-cycle plants as well as to examine alternate plant cycles and equipment component details. Current effort is focused on developing a high-speed computer program which will yield optimized plant designs of various concepts within a wide range of operating conditions and unit sizes.

The following reports, together with this one, present the results of studies completed to date:

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

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

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

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

SL-1661, Summary, Parts 1, 2 and 3, Design Study, Heavy Water Moderated Power Reactor Plants, dated June 30, 1959.

SL-1773, Evaluation and Design - Heavy Water Moderated Power Reactor Plants, dated April 28, 1960.

SL-1776, (NDA-2131-6), Design Evaluation and Comparison - 200 MWe, Boiling D_2O, Pressure Tube Indirect and Direct Cycle Power Reactor Plants, dated June 30, 1960.

SL-1815, Evaluation and Design, Heavy Water Moderated Power Reactor Plants, dated June 30, 1960.

SL-1829-1, Engineering Evaluation Studies, Heavy Water Moderated Power Reactor Plants, Quarterly Progress Report, July-September, 1960, dated October 25, 1960.

SL-1829-2, Engineering Evaluation Studies, Heavy Water Moderated Power Reactor Plants, Quarterly Progress Report, October-December, 1960, dated January 24, 1961.

SL-1829-3, Engineering Evaluation Studies, Heavy Water Moderated Power Reactor Plants, Quarterly Progress Report, January-March, 1961.

SL-1873, Engineering Evaluation Studies, Heavy Water Moderated Power Reactor Plants, dated June 30, 1961.

SL-1874, Heavy Water Reactor Plant Leakage, dated June 30, 1961.

SL-1915-1, Engineering Evaluation Studies, Heavy Water Moderated Power Reactor Plants, dated October 13, 1961.

SL-1915-2, Engineering Evaluation Studies, Heavy Water Moderated Power Reactor Plants, dated January 25, 1962.

SL-1915-3, Engineering Evaluation Studies, Heavy Water Moderated Power Reactor Plants, dated April 25, 1962.

SL-1949, Engineering Evaluation Studies, Heavy Water Moderated Power Reactor Plants, dated June 30, 1962.

SL-1974-1, Engineering Evaluation Studies, Heavy Water Moderated Power Reactor Plants, Quarterly Progress Report, April-June, 1962, dated July 15, 1962.

SL-1974-2, Engineering Evaluation Studies, Heavy Water Moderated Power Reactor Plants, Quarterly Progress Report, July-September, 1962, dated October 23, 1962.

SL-1974-3, Engineering Evaluation Studies, Heavy Water Moderated Power Reactor Plants, Quarterly Progress Report, October-December, 1962, dated January 10, 1963.

REPORT SL-1974-4

ENGINEERING EVALUATION STUDIES

HEAVY WATER MODERATED POWER

REACTOR PLANTS

TABLE OF CONTENTS

1.0 INTRODUCTION

The concept of a boiling D_2O reactor supplying steam directly to a turbine evolved from a series of studies conducted between November 1958 and June 1959. These studies indicated that a boiling D_2O direct-cycle plant would produce power at a lower cost than any other D_2O moderated reactor plant with its design based on then current technology and capable of operating on natural uranium. This concept was also chosen as that having the greatest development potential for further cost reductions.

Current activity is concerned with developing, in conjunction with E. I. du Pont de Nemours & Company, a computer program for economically optimizing the design of D_2O moderated power reactors. The concepts included in the program are all pressure tube reactors having "cold D_2O" moderator and cooled by: liquid D_2O, boiling D_2O, organic, and H_2O fog. For each concept, plant capacities of 300, 500 and 1000 MWe sizes are being examined. All the reactors operate in an indirect cycle, except for the boiling D_2O and H_2O fog cooled units which are used in a direct-cycle.

The program also includes an evaluation of the effects of adding fossil fired superheat to the D_2O moderated reactor plants. The superheaters are of conventional design and construction and will be fired by either coal or oil.

2.0 SUMMARY

Work on the computer program for the economic optimization of D_2O moderated power reactors, which is being done in conjunction with du Pont, is continuing. The performance and cost data for all the turbine plants and the boiling D_2O cooled, liquid D_2O and organic cooled reactor plants are complete. Three plant capacities are covered by the data: 300, 500 and 1000 MWe. Cost data for the fossil fired superheaters have been compiled and are presented herein.

2.1 Turbine Plants

Discrete turbine plant cost estimates have been completed for cycles operating in both D_2O and H_2O. The D_2O cycles use only saturated steam at throttle pressures of 1400, 1200, 1000, 800, 600, 400 and 165* psia, while the H_2O turbine plants include the use of superheated steam. The pressures considered for the H_2O turbine plants are 1500, 1400, 1200, 1000, 800, 600 and 165* psia and for each of these, five temperatures are used to span the range from saturation to about 1000 F.

Tables 2.1-I and 2.1-II summarize the operating and cost data developed for the 300 MWe turbine plants. These data are discussed in detail in Report SL-1949. Similar information for the 500 and 1000 MWe H_2O and D_2O turbine plants are summarized in Tables 2.1-III, 2.1-IV, 2.1-V and 2.1-VI. The latter are fully described in SL-1974-3. The efficiencies given in the summary tables are the gross turbine cycle efficiencies and the costs include the entire turbine plant beginning at the steam and feed-water piping connections at the reactor building wall. All costs are based on current; i.e., 1962, data and include only direct construction costs.

2.2 Reactor Plant Structures and Auxiliaries

Design and cost equations have been completely developed for three heavy water moderated reactor concepts: boiling D_2O cooled, liquid D_2O cooled and organic cooled. Table 2.2-I lists the cost components included in the program, and the items peculiar to each of the concepts is denoted together with an indication of whether it was considered as a variable or a constant. Each of the components is discussed in detail in Report SL-1974-3 for plant capacities of 300, 500 and 1000 MWe.

Design and cost equations have been developed for the 300, 500 and 1000 MWe H_2O fog cooled reactor plant structures and auxiliaries, with the exception of the saturated steam circulators. Components for these plants are discussed in detail in Section 3.2 of the report.

2.3 Fossil Fired Superheat

Cost data have been compiled to measure the effect of adding fossil fired superheat to the D_2O moderated power reactor plants. The superheaters are

*Applicable to 300 MWe, saturated steam plants only.

TABLE 2.1-I

SUMMARY OF 300 MWe H_2O TURBINE PLANT CHARACTERISTICS
Efficiency in %, Cost in millions of dollars

No. of Feed-water Heaters			7		6		5		4		3		2		1	
Pressure Psia	Degrees F Superheat	Act. Steam Temp. °F	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost
1500	SAT.	596	36.4	-	36.0	-	35.5	-	34.8	-	33.9	-	32.8	-	31.8	-
	100	696	37.4	19.79	37.0	19.55	36.5	19.30	37.7	19.17	34.9	19.16	34.0	19.07	32.9	19.11
	200	796	38.5	18.45	38.1	18.17	37.6	18.66	36.8	18.54	35.9	18.44	35.0	18.39	33.8	18.41
	300	896	39.8	18.16	39.3	17.95	38.7	17.83	37.9	17.70	37.0	17.62	35.9	18.20	34.6	18.24
	400	996	40.8	18.20	40.4	17.99	39.8	17.88	38.8	17.76	37.8	17.70	36.7	17.62	35.4	18.28
1400	SAT.	587	36.0	20.44	35.7	20.02	35.2	19.81	34.5	19.70	33.6	19.65	32.6	19.66	31.4	19.76
	100	687	36.9	19.79	36.6	19.50	36.2	19.32	35.5	19.19	34.7	19.13	33.6	19.12	32.6	19.20
	200	787	38.1	18.39	37.8	18.20	37.3	18.65	36.6	18.54	35.7	18.47	34.6	18.42	33.4	18.46
	300	887	39.3	18.17	39.0	17.95	38.4	17.79	37.6	17.70	36.7	18.29	35.4	18.28	34.2	18.32
	400	987	40.4	18.21	40.1	18.03	39.4	17.91	38.6	17.79	37.6	17.75	36.4	18.36	35.1	18.40
1200	SAT.	567			35.2	20.15	34.9	19.92	34.4	19.73	33.6	19.64	32.6	19.63	31.4	19.71
	100	667			36.4	19.58	36.0	19.37	35.4	19.18	34.7	19.11	33.6	19.04	32.4	19.12
	200	767			37.4	18.88	37.1	18.70	36.6	18.55	35.8	18.45	34.6	18.37	33.3	18.40
	300	867			38.6	18.00	38.3	17.86	37.7	17.72	36.9	18.27	35.7	18.20	34.2	18.23
	400	967			39.7	18.06	39.4	17.93	38.8	17.80	37.9	17.68	36.6	17.62	35.1	18.28
1000	SAT.	545			34.3	20.07	34.0	19.93	33.5	19.76	32.8	19.70	31.9	19.65	30.7	19.76
	100	645			35.4	19.52	35.2	19.34	34.6	19.23	33.8	19.17	32.9	19.10	31.7	19.12
	200	745			36.6	18.81	36.4	18.65	35.7	18.51	34.9	18.46	33.9	18.41	32.6	18.40
	300	845			37.8	18.62	37.6	18.50	36.9	18.37	36.0	18.29	34.9	18.24	33.5	18.24
	400	945			38.9	17.87	38.7	17.76	37.9	17.63	37.1	17.59	35.9	18.15	34.4	18.13
800	SAT.	518			33.3	21.43	33.0	21.29	32.4	21.12	31.6	21.05	30.9	21.04	29.7	21.10
	100	618			34.3	19.43	34.2	19.29	33.6	19.12	32.8	19.09	32.0	20.43	30.7	20.52
	200	718			35.6	19.20	35.3	19.02	34.7	18.81	33.9	18.86	32.9	18.80	31.6	19.86
	300	818			36.8	18.60	36.5	18.46	35.9	18.31	34.9	18.26	33.9	18.19	32.4	18.21
	500	1018			38.9	17.92	38.7	17.82	38.0	17.67	36.9	18.27	35.7	18.17	34.1	18.20
600	SAT.	486					31.9	21.18	31.5	21.09	30.9	20.99	30.1	20.93	29.0	20.93
	100	586					32.9	18.87	32.6	18.75	32.0	18.68	31.2	20,45	30.0	20.43
	200	686					34.1	18.06	33.8	17.94	33.1	17.86	32.2	17.84	30.9	19.89
	400	886					36.3	17.82	36.0	17.74	35.4	17.66	34.4	17.61	32.7	17.57
	500	986					37.4	17.90	37.7	17.79	36.5	17.75	35.4	17.65	33.6	17.60
400	SAT.	445							29.3	21.88	29.0	21.77	28.3	21.67	27.2	21.66
	100	545							30.7	20.84	30.3	20.70	29.4	20.59	28.1	21.16
	200	645							31.9	18.31	31.6	20.45	30.6	20.34	29.1	20.32
	400	845							34.4	17.75	34.2	17.64	33.0	17.57	31.0	17.57
	500	945							35.4	17.87	35.3	17.77	34.0	17.67	32.0	17.66
165	SAT.	365									25.1	23.61	24.7	23.54	23.6	23.60

TABLE 2.1-II

SUMMARY OF 300 MWe D_2O TURBINE PLANT CHARACTERISTICS

EFFICIENCY IN %, COST IN MILLIONS OF DOLLARS

NO. OF FEED WATER HEATERS		7		6		5		4		3		2		1	
Pressure Psig	Sat. Steam Temp. F	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost
1400	586	35.0	21.24	34.7	20.76	34.2	20.40	33.5	20.03	32.7	19.86	31.6	19.86	30.5	19.90
1200	566			34.2	21.03	33.9	20.55	33.4	20.17	32.6	19.89	31.6	19.81	30.4	19.85
1000	545			33.3	20.88	33.0	20.54	32.5	20.16	31.8	19.90	30.9	19.82	29.8	19.84
800	520			32.3	22.15	31.9	21.80	31.4	21.45	30.7	21.27	29.9	21.24	28.8	21.10
600	488					30.7	21.76	30.4	21.46	29.9	21.22	29.1	20.98	28.1	20.92
400	448							28.3	22.19	28.0	21.89	27.3	21.71	26.3	21.70
165	374									24.1	23.58	23.7	23.44	22.6	23.45

TABLE 2.1-III

SUMMARY OF 500 MWe H_2O TURBINE PLANT CHARACTERISTICS
EFFICIENCY IN %, COST IN MILLIONS OF DOLLARS

No. of Feed-Water Heaters			7		6		5		4		3		2		1	
Pressure Psia	Degrees F Superheat	Act. Steam Temp. °F	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost
1500	SAT.	596	36.3	30.56	35.9	29.86	35.4	29.51	34.7	29.22	33.8	29.05	32.7	28.96	31.7	28.93
	100	696	37.1	29.64	36.8	29.02	36.4	28.64	35.7	28.43	34.8	28.19	33.8	28.03	32.8	28.06
	200	796	38.4	28.64	38.1	28.02	37.6	27.66	36.8	27.47	35.9	27.30	34.9	27.20	33.7	27.20
	300	896	39.7	27.98	39.2	27.68	38.6	27.45	37.8	27.26	36.8	27.10	35.6	26.98	34.4	27.00
	400	996	40.7	28.27	40.3	27.90	39.7	27.64	38.8	27.45	37.7	27.32	36.6	27.20	35.3	27.21
1400	SAT.	587	35.9	30.44	35.6	29.93	35.1	29.53	34.4	29.25	33.5	29.08	32.4	29.02	31.3	29.03
	100	687	36.8	29.53	36.5	28.94	36.0	28.65	35.4	28.44	34.6	28.20	33.5	28.09	32.4	28.20
	200	787	38.1	28.48	37.8	28.06	37.2	27.70	36.6	27.52	35.7	27.34	34.5	27.14	33.3	27.30
	300	887	39.2	28.07	38.9	27.72	38.3	27.45	37.5	27.27	36.6	27.13	35.4	27.03	34.1	27.11
	400	987	40.3	28.27	40.1	27.89	39.4	27.68	38.5	27.50	37.5	27.36	36.3	27.28	35.0	27.32
1200	SAT.	567			35.1	31.24	34.8	30.80	34.3	30.48	33.5	30.28	32.4	30.07	31.2	30.03
	100	667			36.2	29.09	35.9	28.30	35.3	28.51	34.5	28.33	33.4	28.07	32.2	28.08
	200	767			37.3	28.20	37.1	27.89	36.5	27.53	35.7	27.40	34.5	27.25	33.2	27.24
	300	867			38.5	27.80	38.2	27.58	37.7	27.37	36.8	27.21	35.6	27.07	34.1	27.06
	400	967			39.6	27.92	39.4	27.71	38.8	27.51	37.8	27.39	36.5	27.23	35.0	27.16
1000	SAT.	545			34.1	30.98	33.9	30.64	33.4	30.33	32.6	30.20	31.7	30.08	30.5	30.02
	100	645			35.3	28.78	35.1	28.66	34.4	28.47	33.7	28.34	32.8	28.12	31.6	28.06
	200	745			36.5	27.67	36.3	27.43	35.6	27.18	34.8	27.05	33.8	26.93	32.5	26.86
	300	845			37.6	27.48	37.4	27.22	36.8	27.06	35.9	26.93	34.8	26.80	33.4	26.69
	400	945			38.8	27.68	38.6	27.44	37.9	27.29	37.0	27.17	35.8	27.04	34.2	26.88
800	SAT.	518			33.1	30.79	32.8	30.54	32.3	30.28	31.6	30.12	30.8	30.10	29.5	30.02
	100	618			34.2	30.03	33.9	29.81	33.4	29.40	32.6	29.26	31.8	29.17	30.5	29.10
	200	718			35.4	27.64	35.2	27.31	34.6	27.01	33.7	26.88	32.8	26.78	31.3	26.79
	300	818			36.6	27.31	36.4	27.10	35.7	26.94	34.8	26.81	33.8	26.74	32.2	26.76
	500	1018			38.8	27.59	38.6	27.41	37.9	27.44	36.8	27.27	35.6	27.27	33.9	27.32
600	SAT.	486					31.6	30.48	31.3	30.25	30.7	30.06	29.9	29.92	28.8	29.85
	100	586					32.8	29.69	32.4	29.43	31.8	29.32	31.0	29.17	29.8	29.04
	200	686					33.9	28.88	33.6	28.69	32.9	28.34	32.0	28.19	30.7	28.13
	400	886					36.1	27.14	35.9	27.00	35.3	26.89	34.3	26.76	32.6	26.66
	500	986					37.3	27.40	37.1	27.29	36.4	27.16	35.3	27.05	33.5	26.99
400	SAT.	445							29.1	30.48	28.7	30.30	28.1	30.05	27.0	29.93
	100	545							30.5	29.54	30.2	29.37	29.2	29.15	27.9	29.01
	200	645							31.7	29.15	31.4	29.03	30.4	28.82	28.9	28.77
	400	845							34.2	28.75	34.0	28.52	32.8	28.40	30.8	28.46
	500	945							35.3	27.33	35.2	27.21	33.9	26.97	31.8	27.02

TABLE 2.1-IV

SUMMARY OF 500 MWe D_2O TURBINE PLANT CHARACTERISTICS

EFFICIENCY IN %, COST IN MILLIONS OF DOLLARS

NO. OF FEED WATER HEATERS		7		6		5		4		3		2		1	
Pressure Psig	Sat. Steam Temp. F	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost
1500	595	35.0	31.49	34.7	30.37	34.2	29.97	33.4	29.28	32.6	28.93	31.6	28.76	30.6	28.68
1400	586	34.6	31.34	34.3	30.54	33.8	29.93	33.1	29.29	32.3	28.95	31.2	28.83	30.1	28.75
1200	566			33.8	32.11	33.5	31.34	33.0	30.64	32.2	30.11	31.2	29.87	30.0	29.87
1000	545			32.9	31.98	32.6	31.27	32.1	30.60	31.4	30.16	30.5	29.97	29.3	29.99
800	520			31.8	31.29	31.5	30.66	31.1	30.12	30.3	29.83	29.6	29.74	28.3	29.75
600	488					30.3	31.09	30.0	30.47	29.4	30.09	28.7	29.84	27.6	29.84
400	448							27.9	30.72	27.5	30.26	26.8	29.88	25.8	29.83

TABLE 2.1-V

SUMMARY OF 1,000 MWe H_2O TURBINE PLANT CHARACTERISTICS
EFFICIENCY IN %, COST IN MILLIONS OF DOLLARS

No. of Feed-water Heaters			7		6		5		4		3		2		1	
Pressure Psia	Degrees F Superheat	Act. Steam Temp. °F	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost
1500	SAT.	596	35.8	54.21	35.4	53.02	34.8	52.18	34.2	51.79	33.3	51.49	32.1	51.51	30.8	51.65
	100	696	36.6	52.00	36.3	51.16	35.9	50.61	35.2	50.25	34.4	49.95	33.3	49.92	32.1	50.12
	200	796	38.0	50.82	37.7	49.87	37.2	49.31	36.4	48.97	35.5	48.60	34.4	48.57	33.1	48.76
	300	896	39.4	49.81	38.9	49.25	38.3	48.74	37.4	48.43	36.4	48.18	35.2	48.13	33.9	48.32
	400	996	40.6	49.59	40.1	48.92	39.4	48.58	38.5	48.30	37.5	48.06	36.2	47.95	34.8	48.09
1400	SAT.	587	35.3	54.13	35.0	53.05	34.5	52.37	33.8	51.93	33.0	51.54	31.8	51.64	30.5	51.90
	100	687	36.3	52.35	36.0	51.17	35.5	50.59	34.9	50.25	34.0	49.93	33.0	49.78	31.7	50.21
	200	787	37.7	50.70	37.3	49.97	36.8	49.37	36.1	49.00	35.2	48.75	34.0	48.72	32.7	49.07
	300	887	38.9	49.90	38.6	49.35	37.9	48.80	37.1	48.52	36.2	48.30	35.0	48.36	33.5	48.51
	400	987	40.0	49.60	39.8	49.06	39.1	48.66	38.2	48.34	37.2	48.13	35.9	48.04	35.4	48.27
1200	SAT.	567			34.5	52.95	34.2	52.18	33.7	51.40	32.9	51.02	31.8	50.78	30.4	50.88
	100	667			35.7	51.52	35.3	51.04	34.8	50.49	34.0	50.12	32.9	49.79	31.5	50.05
	200	767			36.9	50.22	36.5	49.72	36.0	49.03	35.1	48.75	34.0	48.57	32.5	48.79
	300	867			38.1	49.46	37.8	49.06	37.2	48.67	36.3	48.37	35.1	48.21	33.5	48.44
	400	967			39.3	49.10	39.0	48.75	38.4	48.35	37.5	48.07	36.1	47.93	34.4	48.02
1000	SAT.	545			33.5	53.08	33.2	52.42	32.7	51.85	31.9	51.60	31.0	51.44	29.7	51.54
	100	645			34.7	51.23	34.4	50.75	33.8	50.38	33.1	50.13	32.2	50.03	30.8	50.00
	200	745			36.0	49.73	35.7	49.25	35.1	48.89	34.3	48.63	33.3	48.51	31.8	48.52
	300	845			37.2	49.42	36.9	48.90	36.3	48.64	35.4	48.43	34.3	48.29	32.7	48.12
	400	945			38.4	49.07	38.2	48.61	37.4	48.37	36.6	48.19	35.4	48.00	33.7	47.90
800	SAT.	518			32.4	52.01	32.0	51.58	31.5	51.14	30.7	50.91	29.9	50.96	28.6	51.02
	100	618			33.5	50.82	33.2	50.39	32.7	49.61	31.9	49.42	31.1	49.47	29.6	49.56
	200	718			34.8	49.22	34.5	48.65	33.9	48.09	33.1	47.95	32.2	47.86	30.6	48.08
	300	818			36.1	48.46	35.8	47.99	35.2	47.70	34.2	47.48	33.2	47.50	31.5	47.62
	500	1018			38.4	47.87	38.2	47.61	37.5	47.34	36.3	47.16	35.2	47.07	33.3	47.20
600	SAT.	486					30.7	49.54	30.4	49.21	29.8	49.00	29.0	48.89	27.9	48.87
	100	586					32.0	48.25	31.6	47.78	31.0	47.63	30.2	47.45	28.9	47.50
	200	686					33.2	46.89	32.9	46.44	32.2	46.20	31.3	45.93	29.9	46.05
	400	886					35.6	45.87	35.3	45.63	34.8	45.46	33.7	45.27	31.8	45.28
	500	986					36.8	46.15	36.6	45.88	35.9	45.67	34.8	45.51	32.8	45.61
400	SAT.	445							29.1	58.61	28.7	58.26	28.1	57.64	27.0	57.53
	100	545							30.5	56.73	30.2	56.40	29.2	55.83	27.9	55.68
	200	645							31.7	55.90	31.4	55.65	30.4	55.24	28.9	55.14
	400	845							34.2	55.08	34.0	54.62	32.8	54.19	30.8	54.50
	500	945							35.3	52.30	35.2	52.06	33.9	51.58	31.8	51.68

TABLE 2.1-VI

SUMMARY OF 1000 MWe D_2O TURBINE PLANT CHARACTERISTICS

EFFICIENCY IN %, COST IN MILLIONS OF DOLLARS

NO. OF FEED WATER HEATERS		7		6		5		4		3		2		1	
Pressure Psig	Sat. Steam Temp. F	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost	η	Cost
1500	597	34.4	55.99	34.1	54.28	33.6	52.78	33.0	51.64	32.2	51.10	31.4	50.87	29.9	50.77
1400	586	34.2	55.61	33.8	53.85	33.3	52.70	32.6	51.59	31.8	51.02	31.2	50.89	29.4	50.82
1200	566			33.3	54.87	33.0	53.46	32.5	52.05	31.7	51.17	30.7	51.13	29.4	50.83
1000	545			32.3	54.63	32.0	53.40	31.5	52.17	30.8	51.30	30.0	50.99	28.7	51.10
800	520			31.2	53.23	30.8	52.12	30.3	51.12	29.6	50.57	29.2	50.44	27.7	50.55
600	488					29.6	50.52	29.3	49.45	28.7	48.74	27.9	48.32	26.8	48.37
400	448							27.9	58.89	27.5	57.97	26.8	57.22	25.8	57.19

TABLE 2.2-I

PROGRAM COST COMPONENTS

Item	Concept*	Variable or Constant
Land and Land Rights	BLOF	Constant
Access Roads and Ground Improvements	BLOF	Constant
Containment Building	BLOF	Variable
D_2O Distillation System	BLOF	Constant
Miscellaneous Structures	BLOF	Constant
Fuel Handling System	BLOF	Constant
Reactor Building Heating, Ventilating and Air Conditioning	BLOF	Variable
Reactor Building Crane	BLOF	Variable
Turbine Plant	BLOF	Variable
Steam and F.W. Piping in Reactor Building	BLOF	Variable
Operating and Maintenance Cost	BLOF	Variable
Moderator Cooling System	BLOF	Variable
Moderator Purification System	BLOF	Constant
Moderator Make-Up System	BLOF	Constant
Moderator Storage Tanks	BLOF	Variable
Aqueous Waste Disposal System	BLOF	Constant
Poison Injection System	BLOF	Constant
Reactor Plant D_2O Inventory	BLOF	Variable
Turbine Plant D_2O Inventory	B	Variable
Miscellaneous Systems Piping	BLOF	Constant
Coolant Filtering System	O	Variable
New Coolant Make-Up System	BLO	Constant
Coolant Storage Tanks, Vents and Drains	BLO	Variable
Emergency and Shutdown Cooling System	BLOF	Variable
Coolant Degasification and Pressurizing System	O	Variable
Coolant Purification System	BLOF	Variable
Waste Gas Handling System	BLOF	Variable
Organic Waste Disposal System	O	Variable
Non-Organic Off-Gas System	BLOF	Constant
Auxiliary Power	BLOF	Variable
Steam Tracing System	O	Constant
Steam Recirculating System	F	Variable
Water Recirculating System	F	Variable

*Symbol	Concept
B	Boiling D_2O Cooled
L	Liquid D_2O Cooled
O	Organic Cooled
F	H_2O Fog Cooled

of conventional design and construction and are fired by either coal or oil. The outlet steam temperature for all superheaters is constant at 1000 F and the inlet steam temperatures and pressures cover the entire range of values considered for the turbine plants discussed above. The range of steam flow rates included in the superheater analysis have been established so that they can be applied to plants having 300, 500 and 1000 MWe capacity.

3.0 COMPUTER PROGRAM FOR ECONOMIC OPTIMIZATION STUDIES

During fiscal year 1961, a series of studies was undertaken in conjunction with du Pont to reappraise certain heavy water moderated power reactor concepts which had indicated economic promise. These concepts included liquid and boiling heavy water cooled pressure tube reactors fueled with UO_2 rods, UO_2 tubes or U-metal tubes. Both direct and indirect cycles were considered for the boiling D_2O cooled reactor. The initial work on these plants was done using a nominal plant capacity of 300 MWe.

In March and April, 1962, the program was extended to include pressure tube reactors cooled by organic, H_2O fog and gas. (The study concerned with gas cooled D_2O moderated reactor plants has been deleted.) Also plants having nominal capacities of 500 and 1000 MWe were added to the scope of work.

The intent of the program is to:

1) Systematically update all the concepts and ensure that the designs are on a comparable basis.

2) Attain a measure of the effects on cost of certain parametric variations in the designs.

3) Obtain a degree of optimization relative to the reactor design that had not been attained in earlier studies.

A computer program is being developed for performing the design and cost calculations for the plants of all sizes.

The results of the studies are expected to indicate the energy cost for each design on a common basis, focus attention on the parameters most strongly influencing energy costs, indicate directions for research and development programs leading to cost reductions and provide a rapid means for computing the changes in energy cost resulting from plant design variations. The effects of significant changes in the basic technological limits, on the cost of equipment and fuel, and the effect of cost accounting factors can also be readily evaluated.

In the study, du Pont is developing the design and cost factors associated with the reactor, primary coolant piping, primary coolant pumps, steam generators, reactor control systems, shield cooling systems, fuel handling system, shield materials and cost accounting factors. The design and cost factors associated with the turbine-generator plant structures and equipment, miscellaneous structures, reactor plant structures and certain reactor plant auxiliary systems are being developed by Sargent & Lundy. The computer program is being prepared by du Pont for use with the IBM-704 computer located at the Savannah River Laboratory.

In accordance with the above plant cost items, a division has been made in the discussion below such that the turbine plant operating and cost parameters include the complete turbine plant, starting at the steam and feed-water piping connections at the steam generators or the steam drums. Thus the turbine plant costs include the turbine-generator, condenser, condensate and feed-water system, the turbine building, circulating water system equipment and structures, turbine plant electrical auxiliaries, and all general plant service equipment; e.g., service water pumps, fire pumps, etc. The information being supplied by Sargent & Lundy for the reactor buildings and reactor auxiliary equipment is discussed separately for each concept.

3.1 Turbine Plants

In order that the opportunity for true optimization exist within the program, a wide range of turbine plant steam and feed-water conditions were considered. Seven steam pressures: 400, 600, 800, 1000, 1200, 1400 and 1500 psia, have been used and for each of these, five temperature conditions have been selected in order to span the range from the saturation temperature to approximately 1000 F. The number of feed-water heating stages varies from one to seven to provide a range of final feed-water temperatures of 150 to 515 F. Three plant capacities are considered (300, 500 and 1000 MWe) in order to measure the effect of unit size on cost.

All of the reactor concepts being evaluated employ H_2O steam as the turbine working fluid, except the boiling D_2O cooled direct-cycle plant. Since the latter concept provides saturated D_2O steam to the turbine, a special set of operating and cost parameters have been prepared for these plants based on the use of D_2O.

A summary of the performance and cost data for the 300, 500 and 1000 MWe turbine plants is presented in Section 2.1 above. Detailed estimated cost breakdowns for these plants are presented in Reports SL-1949 and SL-1974-3.

3.2 Reactor Plant Structures and Auxiliaries

Four D_2O moderated power reactor concepts are being evaluated in the program: boiling D_2O cooled, liquid D_2O cooled, organic cooled and H_2O fog cooled. The gas cooled D_2O moderated reactor was deleted from the scope of work. Du Pont is furnishing the design and cost equations for the reactors, primary coolant system, fuel and fuel handling, shielding, reactor instrumentation and control and the cost parameters. The remaining structures and equipment associated with the reactor plant are being furnished by Sargent & Lundy.

The design and cost equations for the boiling D_2O, liquid D_2O and organic cooled reactor structures and auxiliaries have been completed for the 300, 500 and 1000 MWe plants and are discussed in detail in Report SL-1974-3. Similar equations for the H_2O fog cooled reactor plant have been completed, with the exception of the steam recirculation system, and are discussed below. Table 3.2-I lists the cost components that have been included and indicates whether or not each item was considered as a variable or a constant. Each cost component, with the exception of the turbine plant, is discussed in the succeeding paragraphs wherein the design and cost bases are given together with the governing variables.

TABLE 3.2-I

PROGRAM COST COMPONENTS

Item	Concept*	Variable or Constant
Land and Land Rights	BLOF	Constant
Access Roads and Ground Improvements	BLOF	Constant
Containment Building	BLOF	Variable
D_2O Distillation System	BLOF	Constant
Miscellaneous Structures	BLOF	Constant
Fuel Handling System	BLOF	Constant
Reactor Building Heating, Ventilating and Air Conditioning	BLOF	Variable
Reactor Building Crane	BLOF	Variable
Turbine Plant	BLOF	Variable
Steam and F.W. Piping in Reactor Building	BLOF	Variable
Operating and Maintenance Cost	BLOF	Variable
Moderator Cooling System	BLOF	Variable
Moderator Purification System	BLOF	Constant
Moderator Make-Up System	BLOF	Constant
Moderator Storage Tanks	BLOF	Variable
Aqueous Waste Disposal System	BLOF	Constant
Poison Injection System	BLOF	Constant
Reactor Plant D_2O Inventory	BLOF	Variable
Turbine Plant D_2O Inventory	B	Variable
Miscellaneous Systems Piping	BLOF	Constant
Coolant Filtering System	O	Variable
New Coolant Make-Up System	BLO	Constant
Coolant Storage Tanks, Vents and Drains	BLO	Variable
Emergency and Shutdown Cooling System	BLOF	Variable
Coolant Degasification and Pressurizing System	O	Variable
Coolant Purification System	BLOF	Variable
Waste Gas Handling System	BLOF	Variable
Organic Waste Disposal System	O	Variable
Non-Organic Off-Gas System	BLOF	Constant
Auxiliary Power	BLOF	Variable
Steam Tracing System	O	Constant
Steam Recirculating System	F	Variable
Water Recirculating System	F	Variable

*Symbol	Concept
B	Boiling D_2O Cooled
L	Liquid D_2O Cooled
O	Organic Cooled
F	H_2O Fog Cooled

3.2.1 H_2O Fog Cooled Reactor

The H_2O fog cooled reactor consists of a cylindrical calandria tank which is vertically pierced by Zr-2 pressure tubes containing the coolant and fuel elements. Liquid H_2O and saturated H_2O steam are mixed at the bottom of each pressure tube to form a relatively low quality fog. The fog passes upward through the core where a portion of the fluid droplets are vaporized. The fog mixture leaves the coolant tubes at the top of the reactor and is passed to steam drums wherein saturated steam and water are separated.

A portion of the steam leaving the drums is compressed by a group of centrifugal steam compressors and is recirculated to the reactor inlet. The rest of the primary steam is used in the turbine to produce electric power.

Saturated water in the steam drum is mixed with feed-water returning from the turbine plant and is then force-recirculated to the reactor inlet.

Fig. 3.2-1 shows the arrangement of the primary recirculation system. Du Pont is furnishing the fog cooled reactor design and Sargent & Lundy is supplying the design and cost equations for the primary steam and water recirculation systems.

Land and Land Rights

The site used for the plant corresponds to that given in Reference 2, as the standard Atomic Energy Commission site. Accordingly the cost of the land and land rights is established as $360,000 for the 300, 500 and 1000 MWe plants.

Access Roads and Ground Improvements

Based upon the assumed conditions of the standard Atomic Energy Commission site and the site layout given in SL-1815, the access roads and ground improvements have been estimated to be a constant for each plant size. The cost includes all permanent access roads, general site improvements and rail interconnections. Because of slight variation in the parking lot size with plant capacity there is a difference in the cost assigned to each unit: $480,000, $510,000, $550,000 for the 300, 500 and 1000 MWe plants respectively.

Containment Building

The reactor building consists of a carbon steel cylinder with a hemispherical dome and hemiellipsoidal bottom and is designed to completely contain the entire primary coolant inventory located within the building, should it be released. Building design equations are written so that a minimum size is set based upon equipment sizes. The containment vessel wall thickness is then calculated in accordance with Section VIII of the ASME Unfired Pressure Vessel Code. A minimum dome thickness of 0.5 in. is stipulated for structural stability and, to avoid field weld stress

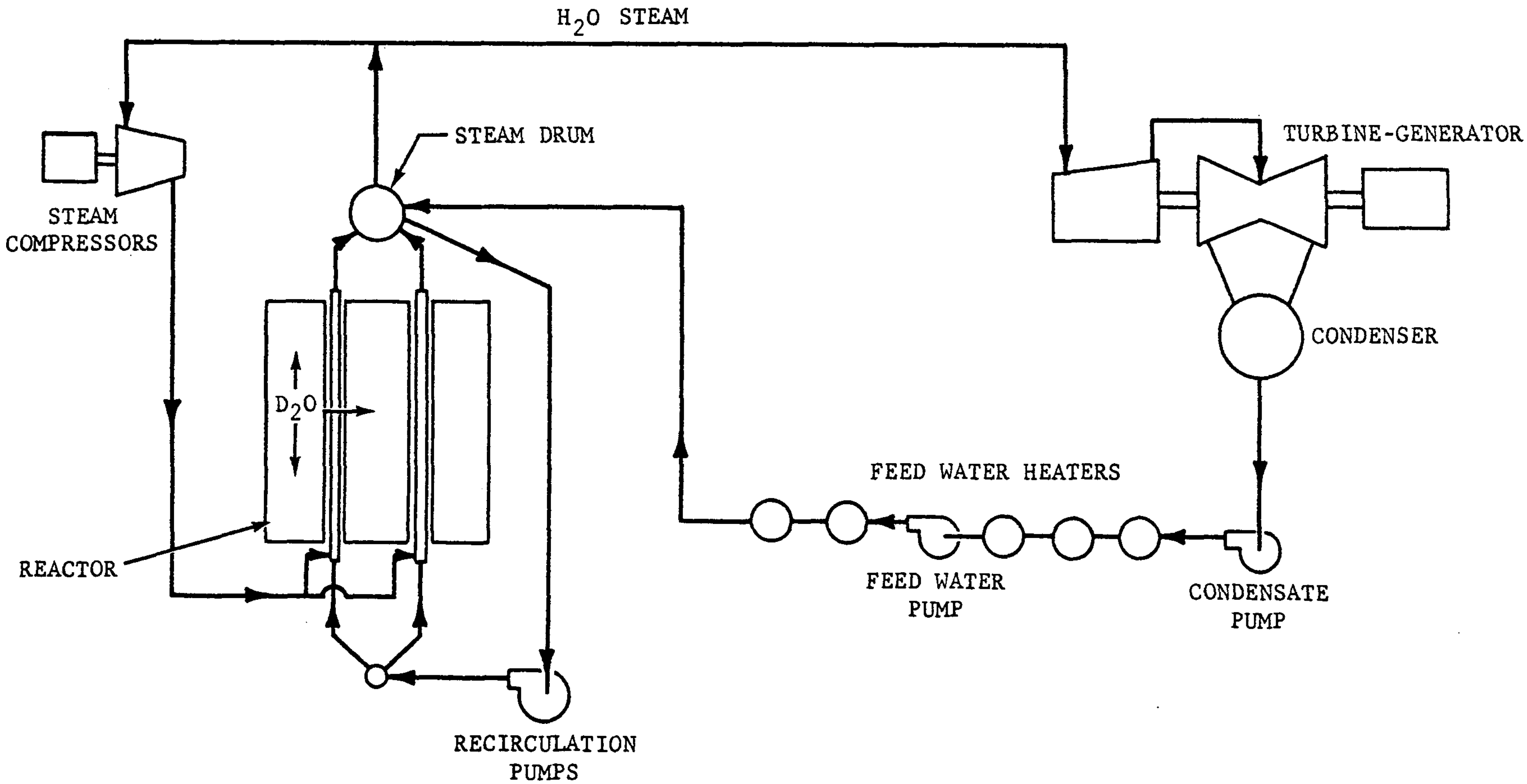


FIG. 3.2-1 PRIMARY COOLANT SYSTEM

H_2O Fog Cooled Reactor

SARGENT & LUNDY
ENGINEERS
CHICAGO

relieving, a maximum wall thickness is set at 1.5 in. If the wall thickness calculation leads to a value in excess of 1.5 in. using the minimum building dimensions, the building size is increased until the vessel wall attains a value of 1.5 in.

When the building dimensions are established in accordance with the above criteria, they are coupled with appropriate unit costs to yield the total building cost, including the steel vessel, substructure, external treatment, shadow shielding and all internal structures.

D_2O Distillation System

A D_2O distillation column is provided to remove small quantities of H_2O inleakage on a continuous basis. The cost of this system is estimated at a constant $155,000 for the 300 and 500 MWe plants, and includes all necessary equipment structures and electrical work. It was felt that, in view of the larger system inventory associated with the 1000 MWe plant, two such columns would be required at a cost of $310,000.

Miscellaneous Structures

Miscellaneous structures including the gate house, warehouses, oil pump house, temporary construction facilities, etc., are included in the program as a constant $190,000, $265,000 and $470,000 for the 300, 500 and 1000 MWe plants respectively.

Fuel Handling Systems

The cost of the fuel handling facilities, including a building, transfer canal, machinery, storage racks, shipping coffins, etc., all located external to the reactor building (i.e., the cost does not include the reactor refueling machinery), is estimated at a constant $1,430,000, $1,600,000 and $2,200,000 for the 300, 500 and 1000 MWe plants respectively.

Reactor Building Heating, Ventilating and Air Conditioning

A complete system of heating, ventilating and air conditioning is provided to maintain environmental conditions within the reactor building. The cost of the system varies depending primarily upon the cooling load needed to remove motor and equipment heat.

Reactor Building Crane

A crane is provided within the reactor building at a cost which varies directly with its span. The crane total cost is thus determined by the reactor building diameter.

Operating and Maintenance Cost

The cost of operating and maintaining the plant is included in accordance with the Atomic Energy Commission Cost Evaluation Handbook plus the annual cost of D_2O losses. Since the only D_2O system in this plant is the low temperature, unpressurized moderator system, the unrecoverable D_2O losses were estimated to be 0.5% per year of the total inventory (as contrasted to 2% annually for the D_2O cooled units).

Moderator Cooling System

Since the reactor operates with a "cold" unpressurized D_2O moderator, a system is provided to remove the moderator heat picked up in the core-region. The power to the moderator is 4% of the total thermal power for gamma absorption and neutron moderation together with a calculated heat loss transferred across the pressure tube-calandria tube gas gap. A maximum moderator temperature of 190 F is limiting to avoid the need for pressurizing the calandria.

Two one-half capacity moderator cooling circuits are provided, each having a heat exchanger and circulating pump. All materials in contact with the moderator outside the reactor are stainless steel and, correspondingly, a fluid velocity of 40 fps is used in the piping to minimize D_2O hold-up.

The primary variables dictating the cost of the moderator cooling system are the total reactor thermal power and the average moderator temperature selected for normal reactor operation.

Moderator Purification System

In order to insure maintenance of moderator purity, a bypass purification loop is provided. The loop consists of a heat exchanger, a cation and a mixed bed ion exchanger, a circulating pump and a stainless steel piping system. The purification system is nominally sized to be able to purify the entire contents of the moderator system in 100 hours. The cost of the moderator purification system is estimated to be a constant $60,000, $90,000 and $165,000 for the 300, 500 and 1000 MWe plants respectively.

Moderator Make-Up System

A system for maintaining constant moderator level and for transferring D_2O into and out of the moderator system is provided in the form of level control pumps, piping and instrumentation. The system is estimated to cost a constant $20,000, $30,000 and $55,000 for the 300, 500 and 1000 MWe plants respectively.

Moderator Storage Tanks

A stainless steel storage tank is provided with a capacity equal to the entire moderator system inventory plus a nominal working allowance. The cost of the storage tank varies with the system D_2O inventory.

Aqueous Waste Disposal System

A complete on-site aqueous waste disposal system is provided in a building devoted solely to the processing of reactor plant wastes. The system consists basically of ion exchangers, storage tanks and activity monitors capable of handling radioactive liquid wastes continuously or batchwise. Normally, the liquid wastes are monitored and discharged into the circulating water system effluent. If, however, the waste activity rises above tolerance, provision is made for routing the fluid through ion exchangers and/or storage until it can be discharged to the river.

The cost of the aqueous waste disposal system, including all equipment, storage tanks, structures, piping and instrumentation and control is a constant $390,000*, $470,000 and $730,000 for the 300, 500 and 1000 MWe plants respectively.

Poison Injection System

A complete system for automatically injecting a liquid neutron poison (probably boric acid) into the moderator D_2O is provided at a constant cost of $170,000, $190,000 and $210,000 for the 300, 500 and 1000 MWe plants respectively.

Miscellaneous Systems and Piping

Included in this miscellaneous account are: D_2O collection tanks, leakage collection system, radiation monitoring equipment, the constant portions of the reactor building electrical auxiliaries and other miscellaneous piping. The total estimated cost of these items is $1,150,000, $1,550,000 and $2,360,000 for the 300, 500 and 1000 MWe plants respectively.

Emergency and Shutdown Cooling System

A heat removal system rated at 10% of the full reactor thermal power is provided to cool the primary system during both normal and emergency shutdown conditions. When high activity is measured in the primary steam lines to the turbine, an emergency shutdown is initiated which causes isolation valves to close in both the main steam and feed-water pipes. Concurrently the reactor is shut down, but to prevent overpressurizing the reactor piping and to remove decay heat this substantially sized system is provided. The system also removes decay heat during normal shutdown for refueling, etc.

The system consists of a stainless steel condenser-cooler, two full-size circulating pumps (one powered by normal a-c and one powered by emergency d-c), and a system of flow control valves and piping. The system cost varies with the total reactor thermal power and the primary system operating pressure.

Coolant Purification System

A bypass purification loop to maintain primary coolant purity and chemistry is connected to the reactor recirculation piping. The system contains a

*These costs also include the waste gas handling apparatus, see below.

prefilter, a cation and a mixed bed ion exchanger, an after filter, a regenerative heat exchanger followed by a cooler and a circulating pump. Normally flow through the loop is maintained by the driving head across one of the primary recirculation pumps; however, the system is designed to handle four times the normal flow for emergency clean up. At such times a separate circulating pump is used to overcome increased system pressure drop.

Waste Gas Handling System

A system of filters, piping, monitoring instruments and high-pressure storage tanks is provided for the processing of gaseous plant wastes. Ultimately these wastes are discharged at tolerable levels through a stack wherein they are diluted by building ventilation air. The cost associated with this system is included in the costs cited above for the aqueous waste disposal building and equipment.

Off-Gas System

A recirculated helium blanket is maintained over the D_2O moderator in the reactor calandria. This blanket serves to collect dissociated D_2O and other gases which may be evolved. The gas mixture is circulated through a catalytic recombiner which is followed by condensing and desiccant drying apparatus to recover virtually all D_2O vapor. The noncondensible gases are vented to the waste disposal system.

The estimated cost of the D_2O off-gas system is \$182,000, \$270,000 and \$500,000 for the 300, 500 and 1000 MWe plants respectively, and includes all D_2O recovery equipment, blowers, piping, instrumentation and control apparatus.

Auxiliary Power

In order to determine the plant electrical auxiliary power requirements, a set of data giving the pumping power for each of the discrete turbine plants was prepared. To these amounts, the reactor plant auxiliary power is added in the code to yield the total for the plant.

Steam Recirculation System

The steam recirculation system consists of the saturated steam compressors and associated piping to conduct steam from the drums to the reactor inlet headers. Design and cost equations have been prepared for this system with the exception of including data on the steam compressors. Completion of this item for coding is pending receipt of manufacturer's data on the steam compressor costs.

Water Recirculation System

The water recirculation system includes the main coolant recirculating pumps and all associated piping and valves. The design and cost equations for this system have been completed and are consistent with the similar system used in the boiling D_2O cooled reactor plant. The system cost varies with plant size, steam temperature and reactor inlet and outlet steam quality.

3.3 Fossil Fired Superheat

To evaluate the effect on energy cost of incorporating a fossil fired superheater in the heavy water moderated power reactor plants, design and cost data have been compiled as input to the computer program. The superheaters are based on conventional designs and construction practices and are either coal or oil fired. The outlet steam temperature for all the superheaters is constant at 1000 F and the inlet steam temperatures and pressures cover the entire range of values considered for the turbine plants; i.e., 400 to 1500 psia and from saturation temperature to slightly less than 1000 F. The range of steam flow rates included was established so that the data are applicable to the 300, 500 and 1000 MWe plants.

3.3.1 Superheaters

The fossil fired superheater designs and costs were developed by the major manufacturers of this equipment. Fig. 3.3-1 shows the arrangement of a typical superheater complex. The example shown has two furnaces; however, for the cases where low steam flow and heat input are encountered a one-furnace design would be used.

The principal components of each superheater are: the steam cooled furnace walls, steam cooled division walls, steam cooled connection walls and heat transfer surface, headers, interconnecting piping, and all structural supports. All auxiliary equipment such as soot blowers, steam temperature controls, flues and ducts, air heaters, dust collectors, platforms, etc., have also been included.

The coal fired units are fueled with pulverized coal. Coal pulverizing equipment would be located in front of the unit. Forced draft fans are located near the base of the stack and feed directly to a Ljungstrom air preheater.

The oil fired superheaters are similar in all respects to the coal fired units except for the fuel supply and ash removal equipment.

The thermal efficiency associated with the coal fired superheaters is assumed to be 89% while that of the oil fired superheaters is 88%.

3.3.2 Fuel Supply Systems

A complete coal storage and supply system has been provided at the plant site. Dwg. NS-820-A shows the location of the major components of the system on the standard Atomic Energy Commission site. Coal is brought to the site by rail and unloaded at a car dumping station. A 90 day inventory of coal is assumed to be stored at the site. Auxiliary facilities for coal handling (coal unloading conveyor, reclaim hoppers and stocking out conveyor),

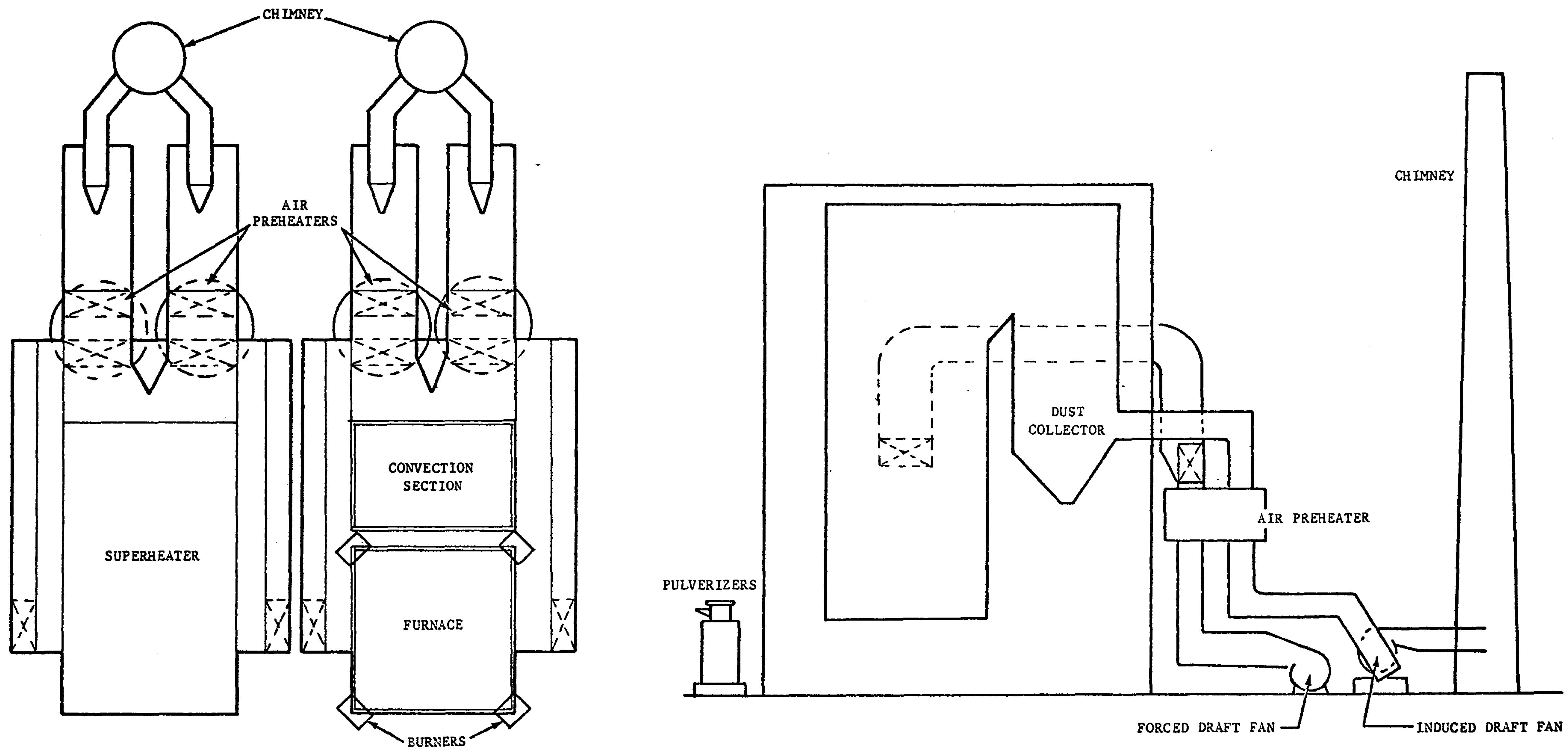


FIG. 3.3-1 TYPICAL SUPERHEATER

SARGENT & LUNDY
ENGINEERS
CHICAGO

therefore, have been included. Coal is transported from the yard storage pile, via a standard enclosed conveyor and transfer tower, to bunkers adjacent to the superheaters.

The conveyor system is sized so that the bunkers (which have a 24 hour capacity) can be filled in 8 hours.

For the oil fired superheaters, an oil storage tank, with a capacity for storing 60 days' supply of Bunker "C" oil, has been furnished. All oil pumping and heating equipment necessary for transporting the oil from the tank to the burners via a "day" tank are included. It is assumed the fuel oil will also be brought to the site by rail and all unloading appurtenances are included.

3.3.3 Ash Handling

The coal fired superheaters include a complete system for removing ash from the dry bottom furnace and transporting the ash by sluicing to the storage area indicated on Dwg. NS-820-A. Dust collectors are included with each superheater and dust handling and disposal facilities are incorporated in the ash handling system. All ash piping sluice water pumps, etc., are included.

3.3.4 Auxiliary Facilities and Systems

A concrete chimney complete with foundation has been included for each superheater together with all requisite insulated ductwork and breeching. Personnel facilities are furnished for the superheater operators; however, it was assumed that these would be integrated with the overall plant facilities and therefore constitute a minor addition.

Electrical auxiliary equipment together with all necessary cables and wiring have been included for the superheater complex.

3.3.5 Main Steam Piping

Costs for the main steam piping to and from the fossil fired superheaters were derived in terms of data already developed for the plants without superheaters. Detailed cost breakdowns for the entire range of turbine plants have been published in Reports SL-1949 and SL-1974-3. To obtain the superheater piping costs, the estimated cost of the main steam piping listed in the above breakdowns are multiplied by a set of constant factors as follows:

$$\left[\begin{array}{l}\text{Cost of piping from}\\ \text{superheater to}\\ \text{turbine building}\end{array}\right] = (4.75)\left[\begin{array}{l}\text{Cost of main steam piping}\\ \text{@ 1000 F for appropriate}\\ \text{pressure flow}\end{array}\right]^{*}$$

$$\left[\begin{array}{l}\text{Cost of piping from}\\ \text{reactor building to}\\ \text{superheater}\end{array}\right] = (3.75)\left[\begin{array}{l}\text{Cost of main steam piping}\\ \text{@ the appropriate steam}\\ \text{generator outlet conditions}\end{array}\right]^{*}$$

*Obtained from tabular values given in SL-1949 and SL-1974-3.

3.3.6 Cost Data

The cost associated with adding a coal or oil fired superheater complex to the D_2O moderated power reactor plants is given in Figs. 3.3-2 and 3.3-3 respectively. The estimates include direct costs only for the items mentioned above. Note that costs are given in terms of dollars per 1000 Btu/hr input to the steam as a function of steam flow rate and pressure. Because all input steam conditions are not saturated, it was necessary to use these arbitrary units to accommodate all conditions of pressure temperature and flow.

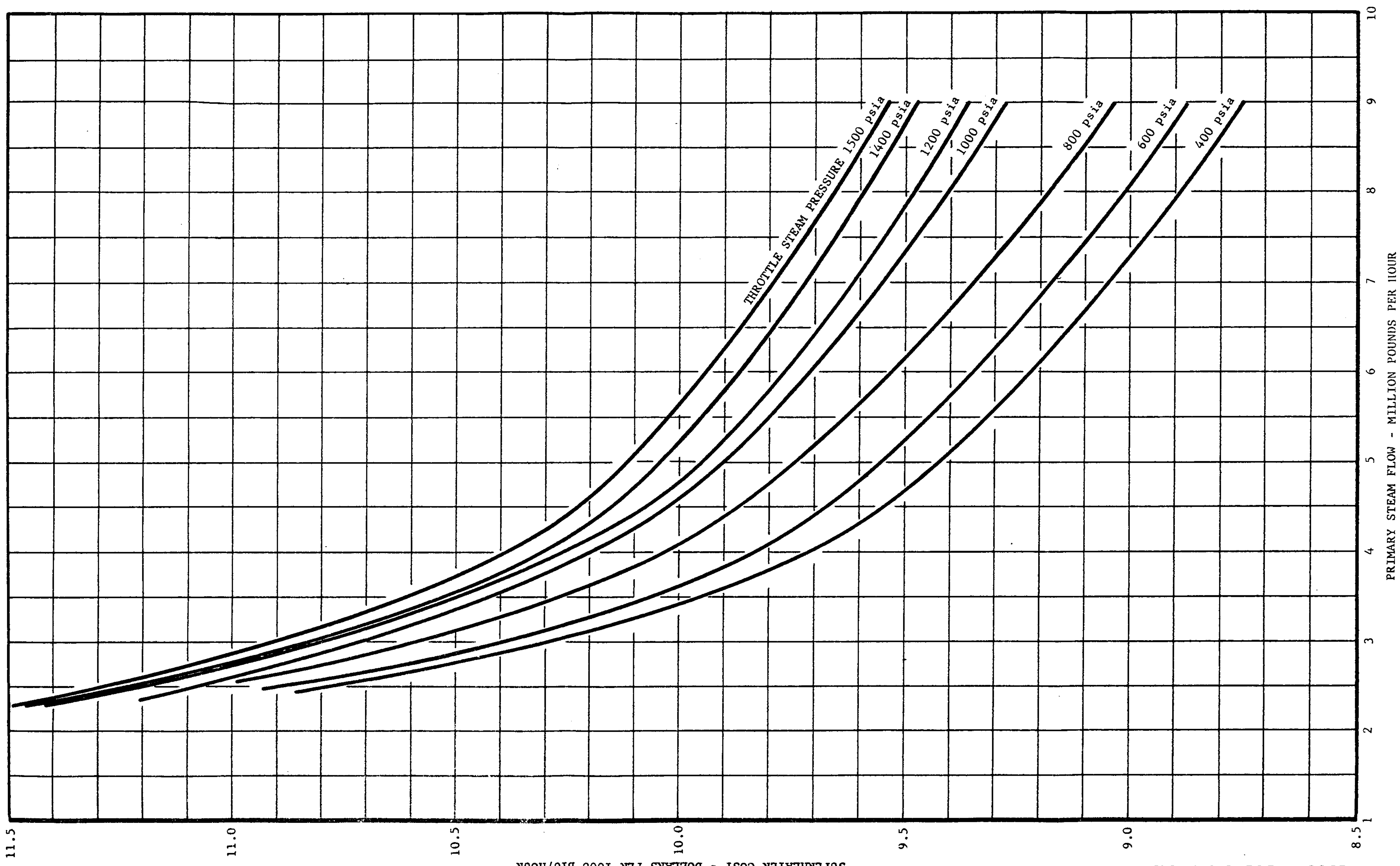


FIG. 3.3-2 TOTAL COST
Coal Fired Superheater

SARGENT & LUNDY
ENGINEERS
CHICAGO

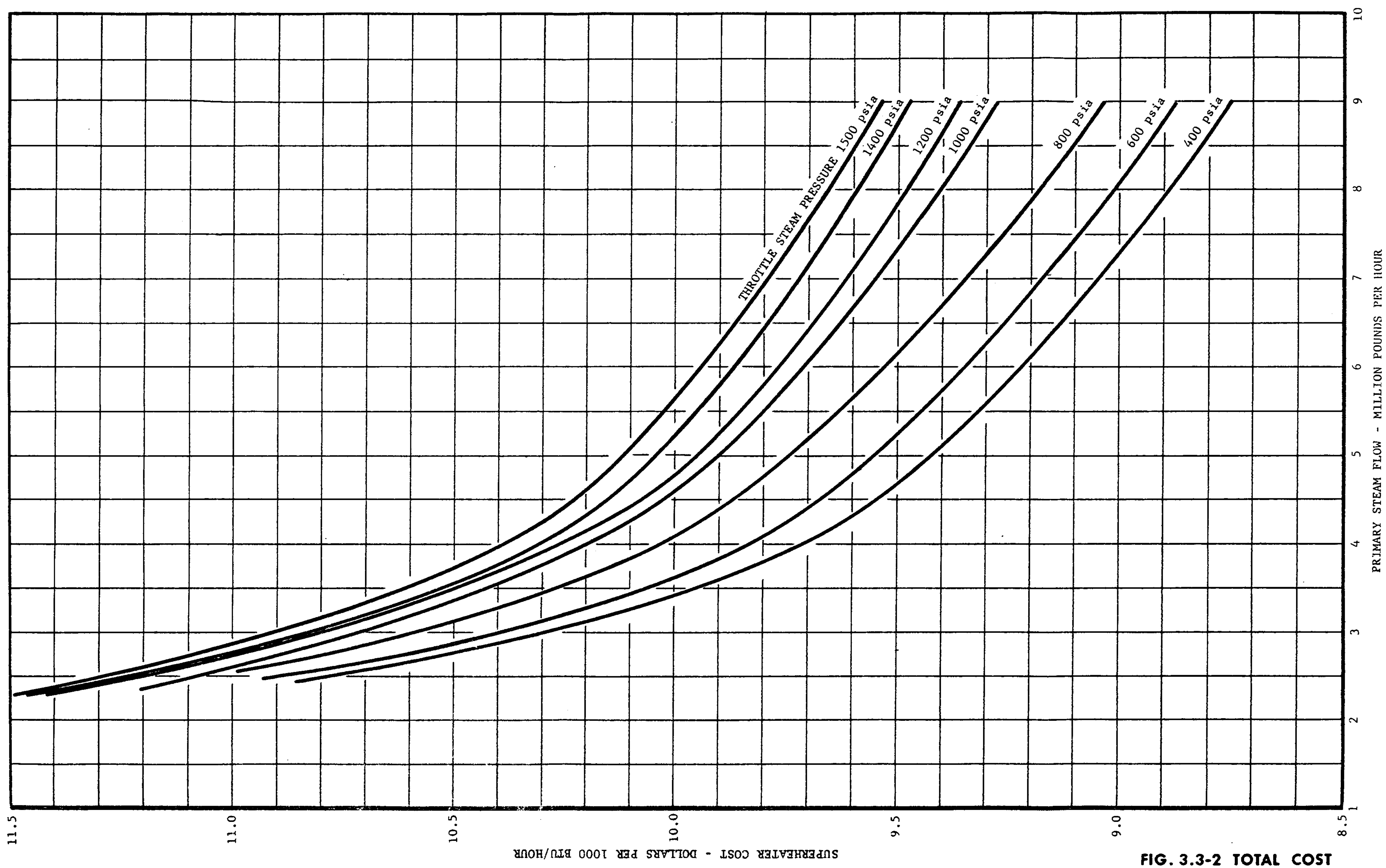


FIG. 3.3-2 TOTAL COST
Coal Fired Superheater

SARGENT & LUNDY
ENGINEERS
CHICAGO

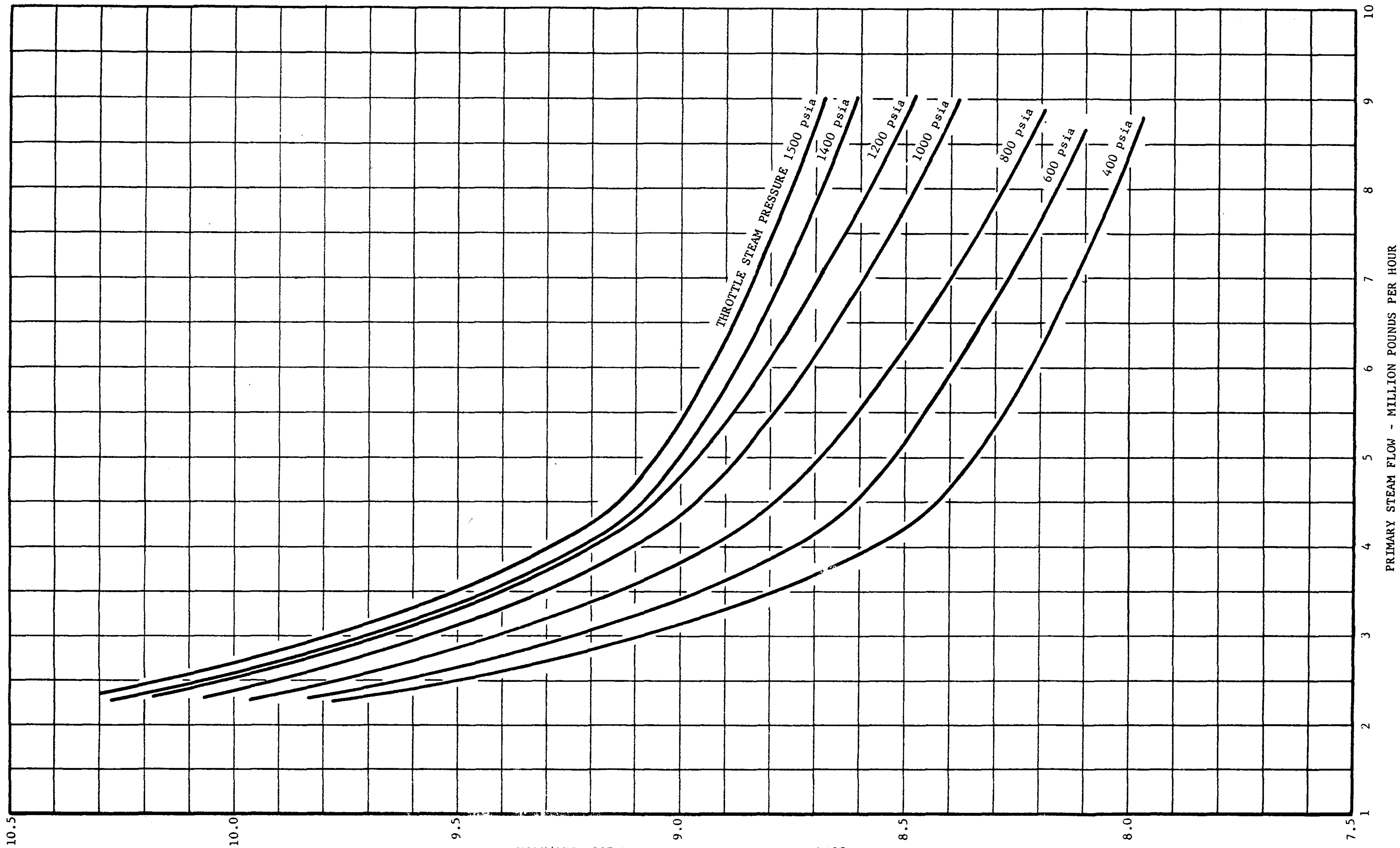


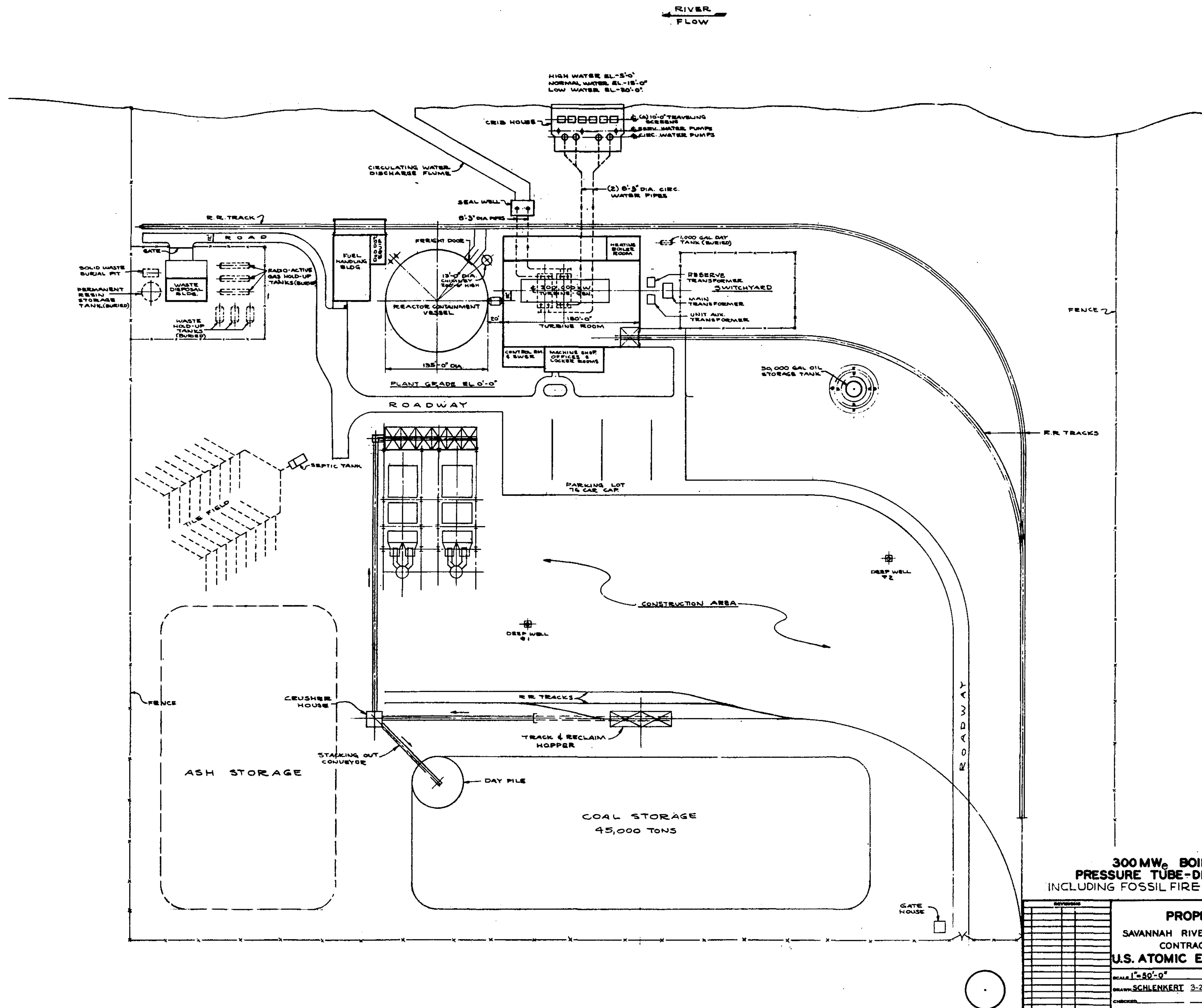
FIG. 3.3-3 TOTAL COST
Oil Fired Superheater

4.0 REFERENCES

1. SL-1949, Engineering Evaluation Studies, Heavy Water Moderated Power Reactor Plants, dated June 30, 1962.

2. Nuclear Power Plants Cost Evaluation Handbook, USAEC, December 31, 1961.

3. DP-707, A Computer Program for Economic Studies of Heavy Water Power Reactors, J. W. Wade, March, 1962.



300 MW$_e$ BOILING D_2O
PRESSURE TUBE-DIRECT CYCLE
INCLUDING FOSSIL FIRED SUPERHEATER

REVISIONS	**PROPERTY PLAT** SAVANNAH RIVER OPERATIONS OFFICE CONTRACT AT(38-1)213 **U.S. ATOMIC ENERGY COMMISSION**
SCALE 1"=50'-0" DRAWN SCHLENKERT 3-24-63 CHECKED ENGINEER APPROVED	**SARGENT & LUNDY** ENGINEERS CHICAGO 3, ILLINOIS
JOB NO. 2897-10	DRAWING NO. **NS-820A**