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MODULAR HIGH TEMPERATURE GAS-COOLED REACTOR PLANT CAPITAL AND BUSBAR GENERATION COST ESTIMATES

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LIST OF ACRONYMS

AC	Alternating Current
A-E	Architect-Engineer
AFUDC	Allowance for Funds Used During Construction
ASME	American Society of Mechanical Engineers
BE	Best Experience
BSDD	Building/Structure Design Description
CFR	Code of Federal Regulation
DOE	Department of Energy
DPC	Direct Payroll-related Costs
EAB	Exclusion Area Boundary
ECA	Energy Conversion Area
EEDB	Energy Economic Data Base
FDA	Final Design Approval
FGD	Flue Gas Desulfurization
FOAK	First-Of-A-Kind
GCRA	Gas-Cooled Reactor Associates
IEEE	Institute of Electrical and Electronic Engineers
LEU	Low Enriched Uranium
LPZ	Low Population Zone
ME	Median Experience
MHTGR	Modular High Temperature Gas-Cooled Reactor
NECDB	Nuclear Energy Cost Data Base
NI	Nuclear Island
NOAK	Nth-Of-A-Kind
NRC	Nuclear Regulatory Commission
O&M	Operation and Maintenance
OPDS	Overall Plant Design Specification
ORNL	Oak Ridge National Laboratory
P&ID	Piping and Instrument Diagram
PWR	Pressurized Water Reactor
QA	Quality Assurance
QC	Quality Control
RM	Reactor Manufacturer
SDD	System Design Description
SSDD	Subsystem Design Description

EXECUTIVE SUMMARY

SCOPE

Costs have been estimated to design, construct, operate and maintain Modular High Temperature Gas-Cooled Reactor (MHTGR) power plants. The cost estimates are based upon the conceptual design of the reference MHTGR plant for which a summary description is provided in the MHTGR Conceptual Design Summary Report (Reference 1). The reference MHTGR plant consists of four 350 MW(t) reactor modules and two turbine generators (4x2) which produce a net output of approximately 540 MWe. The reactor modules and all other equipment and facilities necessary for the control of radionuclides are contained on a Nuclear Island (NI). All other plant facilities are part of the Energy Conversion Area (ECA) which is physically separated from the NI.

Costs for reference MHTGR plants were developed for the following four cases:

1. A Lead plant consisting of the first commercial plant conforming to the reference 4x2 plant design including the licensing-related costs from Final Design Approval (FDA) through to completion of the design certification process. Approxmiate costs were also developed for the design, licensing and technology development necessary to obtain the FDA.

2. A Replica plant conforming to the certified design that follows the first commercial plant

3. A Target plant which is the Nth-Of-A-Kind (NOAK) equilibrium plant conforming to the certified design.

4. A large Target plant consisting of two power blocks with each power block conforming to the certified design.

The commercial operation dates assumed for cost estimating purposes were as follows:

1. Lead plant - January 1, 2000

2. Replica plant - January 1, 2005

3. Target plants - January 1, 2010

For the large Target plant, the above date reflects commercial operation of the first power block.

APPROACH

Costs were developed in general conformance with the Department of Energy (DOE) cost estimating guidelines (Reference 3) using the Energy Economic Data Base (EEDB) Program code of accounts. Using the DOE guidelines and the EEDB code of accounts allows a comparison between the MHTGR cost estimates and costs of other plants prepared in accordance with the guidelines based on a consistent set of financial parameters. All portions of the cost estimates are expressed in constant January 1987 dollars.

Costs were developed by GA Technologies and Combustion Engineering for the reactor plant equipment and by General Electric for the plant control systems. Costs for most of the other equipment, field labor, and field material necessary to construct the NI were developed by Bechtel. Costs for all the equipment, field labor, and field material necessary to construct the ECA were developed by Stone & Webster, as well as a few of the systems and buildings on the NI. GCRA developed the owner's cost and integrated the results of the overall cost estimates into this report.

In addition to the generation of base construction, overnight and total capital costs, levelized busbar costs were determined and compared with competing coal and pressurized water reactor (PWR) plants. The levelized busbar generation costs were developed using the methodology presented in the DOE Nuclear Energy Cost Data Base (NECDB) (Reference 2).

An assessment of operations and maintenance (O&M) costs was developed for the reference 4X2 MHTGR plant by a GCRA chaired Program task force familiar with

nuclear generating plant O&M requirements and the MHTGR design. The O&M costs include the expenses for onsite staff, maintenance materials and supplies, offsite technical support, nuclear regulatory fees, insurance premiums and administrative and general costs.

Fuel cycle costs were developed by GA Technologies based on their fuel fabrication cost estimates and reference parameters for uranium and separative work costs.

A decommissioning cost of $130/kWe for the MHTGR plants was assumed based upon the DOE guidelines for nuclear generating plant decommissioning costs.

SUMMARY COSTS

Table 1 presents cost summaries for the reference Lead, Replica and NOAK plants. The capital costs associated with the initial module and common facilities for the Lead plant were segregated as input for ongoing Lead plant deployment strategy development. However, the associated generation costs are given only for the completed four module Lead plant. The front-end engineering costs associated with the design, licensing and technology development are listed as separate line items but are also not included in the Lead plant generation costs. Table 2 presents cost summaries for variations of NOAK plants.

The evolution in the total costs for the Lead, Replica and NOAK plants is shown graphically in Figure 1. Excluding the front-end design/development costs, a 15% reduction in total base construction costs (Direct and Indirect Costs) is projected in going from the Lead to the NOAK plant. Lead plant First-Of-A-Kind (FOAK) capital costs account for about 2% of this reduction, reduced home office engineering due to design standardization and certification account for about 4% and the remaining 9% is attributable to learning. Cost reductions due to learning occur in construction of the reactor module equipment and in site construction labor. There is no significant learning associated with the balance of the plant equipment or the site construction materials since they are commercially available and presumed to be well down the production learning curve.

The owner's cost component of the indirect costs was estimated by GCRA for a 4 x 350 MWt MHTGR plant using a bottoms-up approach. The results indicate that owner's costs may vary from 10 to 20% of the other base construction costs depending on the location and utility approach. A representative, or expected value of approximately 15% was used in this report for the MHTGR. This compares to the current guidance provided in Reference 3 of 10% of the other base construction costs for owner's cost.

The contingency costs are a little over 20% of the base construction costs. For the nuclear grade portion of the plants the contingency is about 26% and for the industrial grade portion, the contingency is about 15%.

The interest during construction costs (i.e., AFUDC) are about 15% of the total capital costs for the Lead plant but drop down to about 12% for the Replica and NOAK plants. The Lead plant has a higher AFUDC cost since it is deployed in two phases resulting in an extended construction schedule.

COMPARISON WITH ALTERNATIVE PLANTS

Alternative Plant Costs

The MHTGR cost analyses have been evaluated in comparison with comparably sized coal plants and current generation pressurized water reactor (PWR) nuclear plants.

Capital costs for single unit 400 MWe and 600 MWe pulverized coal fired plants were obtained from the EEDB program. The EEDB cost models for these plants are based on the plants having precipitators, wet limestone scrubbers and natural draft cooling towers. The single unit 400 MWe and 600 MWe plant results were used to develop costs for two unit 800 MWe and 1200 MWe plants. Coal plant O&M costs were obtained along with the capital costs from the EEDB program. A representative U.S. coal cost of $1.75/MBTU (1987$ delivery price with a 1% real escalation up to and through the economic life of the plant) was used for determining the fuel cost component of the busbar cost based upon the projected coal cost data for the various regions of the U.S. The coal plant capital, O&M and fuel costs are summarized in Table 3.

The EEDB also maintains "best experience" (BE) and "median experience" (ME) PWR plant cost models. Using the BE model, plant capital, O&M and fuel costs were developed for 800 MWe and 1200 MWe PWR plants. These costs, along with the costs for a median experience 1200 MWe PWR plant, included for comparison purposes, are summarized in Table 4.

Comparison of Capital Costs

A graphical comparison of the capital costs, on a $/kWe basis, for the MHTGR NOAK plant, the single unit coal plants and the "best experience" 800 MWe PWR plant is provided in Figure 2. As illustrated in this figure, the direct costs are fairly comparable. The costs associated with the multiplicity of equipment in the MHTGR are offset by the engineered safety systems and poorer steam conditions in the PWR and the Flue Gas Desulfurization (FGD) equipment in the coal plants.

Excluding owner's costs, the PWR indirect costs are about 50% of the direct costs, the MHTGR indirects are about 25% of the directs and the coal plant indirects are about 19% of the directs. The MHTGR has substantially reduced the difference between nuclear (i.e., PWR) and coal plant indirect costs relative to the direct costs through design modularization/standardization, fewer required safety-related systems and the application of fossil plant construction practices for the physically separated ECA.

Higher contingency percentages for the nuclear plants, about 20% for both the MHTGR and PWR versus 15% for the coal plants, accentuate the difference between the nuclear and coal plants costs caused primarily by the indirect costs.

The interest costs for the coal and PWR plants were based by the EEDB on construction schedules of 4 and 6 years respectively. The shorter MHTGR construction schedule of about 3 years from start of site work, made possible by modularization, separated NI and ECA construction and fewer safety-related systems, maintains the MHTGR interest costs equivalent to those for the coal plants. The net result is an MHTGR capital cost on a $/kWe basis for a mid-size plant that is in the economically competitive range with an equivalent size coal plant.

Comparison of Busbar Generating Costs

A comparison of the NOAK MHTGR busbar costs with those for the 800 MWe PWR, and single unit coal plants is given in Figure 3. The capital cost components are in the same proportion as discussed in preceeding sections. The MHTGR and PWR fuel cost components are considerably less than those for the coal plants with the MHTGR being about 50% greater than the PWR fuel cost. The higher MHTGR fuel cost results from the high quality fuel that provides the fundamental basis for the MHTGR's passive safety concept. The MHTGR and PWR O&M costs are greater than the coal plants but, the MHTGR O&M costs approach those of the coal plants. The net result is that the estimated MHTGR busbar cost is less than those of the other plants indicating that the MHTGR has promise as a competitive alternative.

A comparison of the MHTGR equilibrium plant, coal plant and PWR busbar generating costs vs. plant size is shown on Figure 4. The single unit coal plant busbar cost data points have been overlaid with a band which indicates an estimate of the range of single unit plant busbar costs. Three data points based on EPRI derived coal plant capital costs are also included on Figure 4 which were used to help establish the estimate band range. The two-unit coal plant busbar cost data points plotted on Figure 4 indicate the trend in busbar costs for multi-unit plants. The single point estimates for the 800 and 1200 MWe best estimate PWRs are interconnected by the dashed line and, for illustration purposes, the MHTGR equilibrium plant data points have been connected by a single trend line.

The results as depicted on Figure 4 show that the MHTGR has an economic advantage versus coal over the range from 270 MWe for the basic 2X1 plant to 1080 MWe for the 8X4 plant. The reference 4X2 plant compares quite favorably with equivalent single unit coal plants. For coal plants sized beyond 500-600 MWe, the conventional practice is to utilize multi-units. Relative to the multi-unit coal plants, the MHTGR retains an economic advantage. Current PWR plants at sizes less than 800 MWe are, however, at a considerable economic disadvantage relative to coal or the MHTGR.

Using any reasonable mid-range for the coal cost estimates, the reference MHTGR achieves the utility/users goal established by GCRA of having an

evaluated economic advantage of at least 10% relative to comparably sized, state-of-the-art coal plants using a national average coal price projection. In addition, the MHTGR is competitive with a current generation, "best experience" 1200 MWe PWR on a 30-year levelized busbar cost basis.

SUMMARY CONCLUSIONS

Excluding the design, licensing and technology development costs necessary to obtain a FDA, the MHTGR base construction costs are estimated to decrease by 15% between construction of the first and the Nth plants. Nine percent is due to learning, 4% is due to design standardization and certification and 2% is FOAK capital costs. Since most of the equipment and materials are commercially available, learning occurs only in reactor equipment and site labor.

The MHTGR plant capital costs are more competitive with coal plants than PWR plants because of the steps taken to reduce indirect and AFUDC costs. The indirect costs have been minimized through design standardization and separation of nuclear and conventional construction. The AFUDC costs have been minimized by a shortened construction schedule made possible by separated construction, modularization, few required safety systems and incremental deployment.

In terms of busbar generation cost, MHTGR equilibrium plants meet the utility/user goal of having a 10% economic advantage over equivalent sized coal plants. The reference 540 MWe MHTGR equilibrium plant is computed to have about a 12% advantage over an equivalent size coal plant and an 800 MWe PWR plant. Constructing two of the equilibrium plant power blocks on the same site for a twice-size plant results in a large MHTGR which has about a 10% advantage over an equivalent size coal plant and is on par with a "best experience" 1200 MWe PWR. The lower economic advantage of the larger size is a consequence of the economy of multiplicity losing ground to the projected economy of scale in the large PWR plant size range. However, the MHTGR approach of 8 reactors and 4 turbines provides added flexibility to utilities in planning new capacity additions, matching increases in load growth and dispatching units on the system to meet load requirements and maintenance schedules. The value of these benefits have not been evaluated in this report

but are of critical importance to utilities in considering future capacity additions. An assessment of the economic risks associated with capacity size additions is provided in Reference 13.

Figure 1

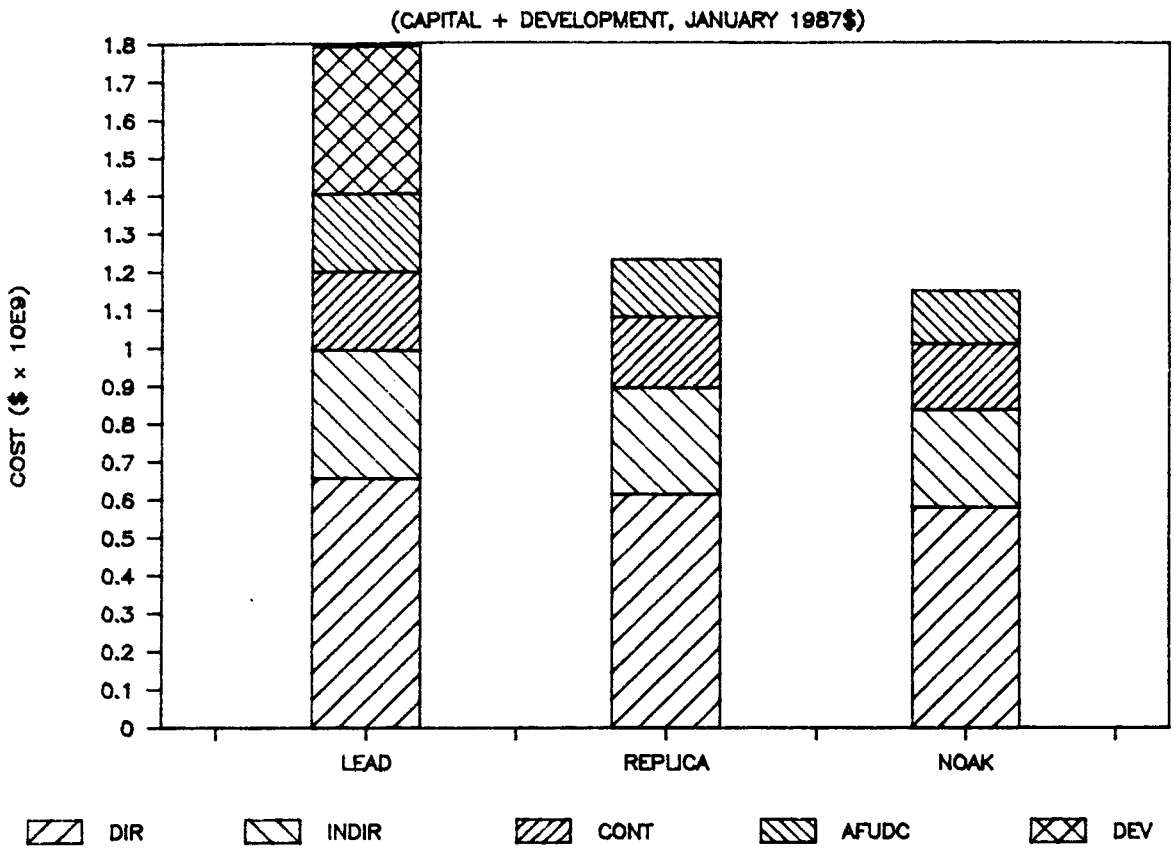


Figure 2

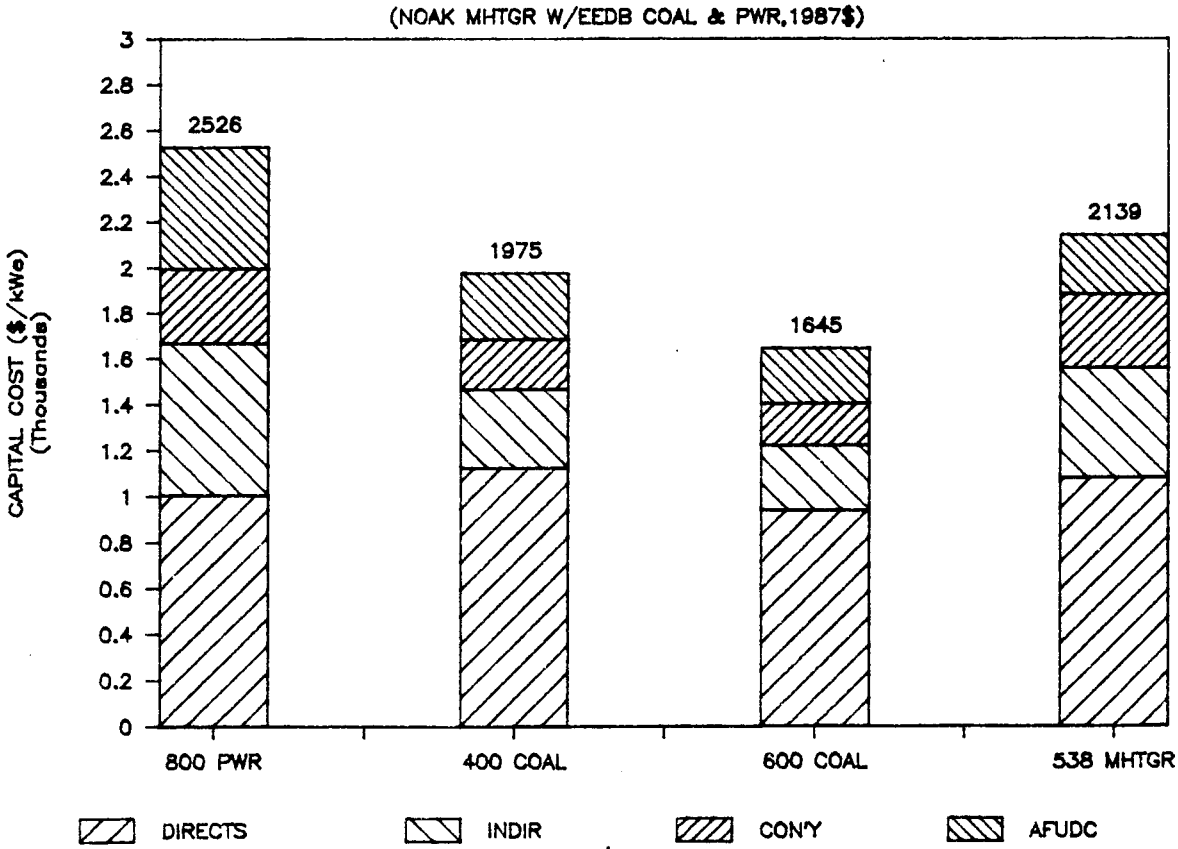


Figure 3

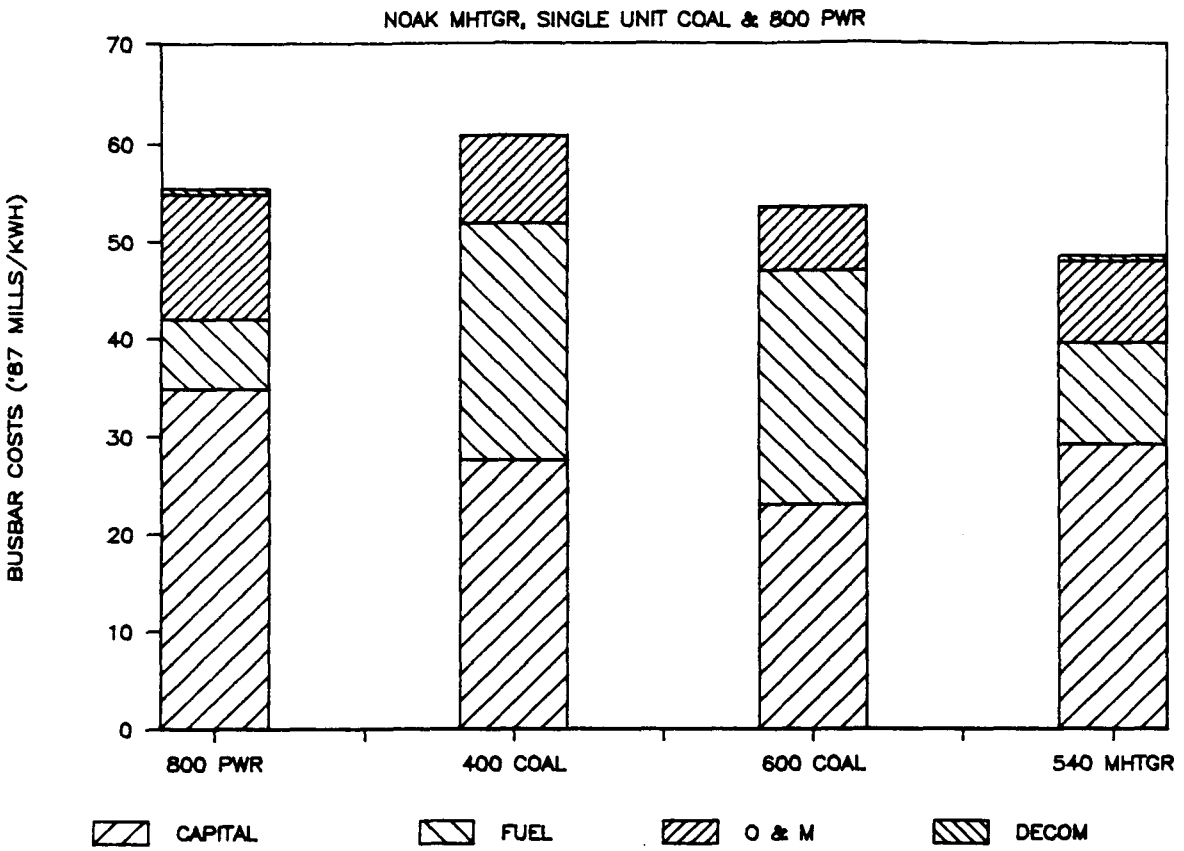
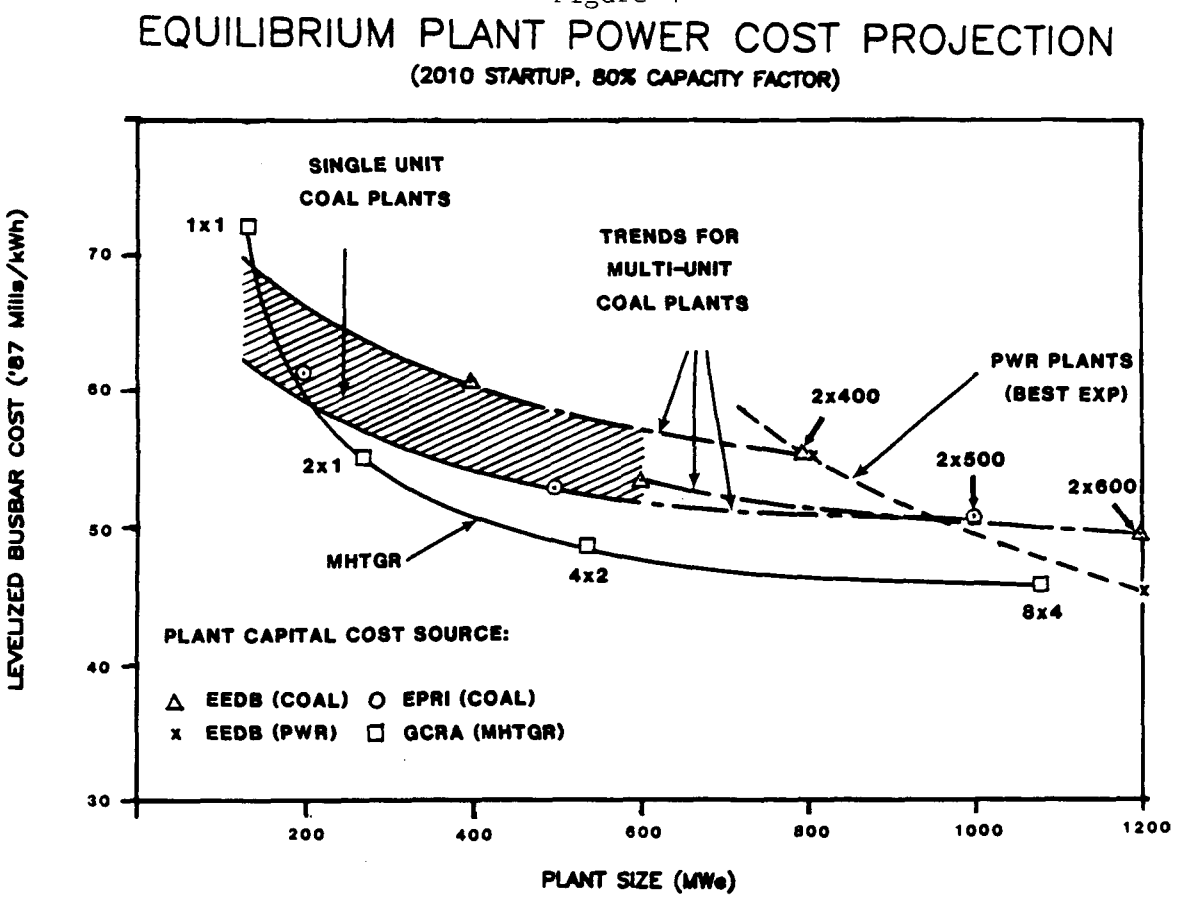


Figure 4



COAL COST: $1.75/MBTU IN '87$ WITH 1% REAL ESCALATION FOR 2010 STARTUP

TABLE 1
EVOLUTIONARY MHTGR PLANT GENERATING COSTS
(1987$)

	LEAD PLANT 1ST MODULE	LEAD PLANT 4 MODULE	REPLICA PLANT	NOAK PLANT
DESIGN DEVELOPMENT (M$)	272	N/A	N/A	N/A
TECHNOLOGY DEVELOPMENT (M$)	103	N/A	N/A	N/A
PERFORMANCE TESTING (M$)	13	N/A	N/A	N/A
TOTAL DESIGN/DEV (M$)	387	N/A	N/A	N/A
NET ELECTRIC RATING (MWe)	133	537.6	537.6	537.6
CAPACITY FACTOR	0.80	0.80	0.80	0.80
EEDB DIRECT COST ACC'TS (M$):				
LAND & LAND RIGHTS	2	2	2	2
STRUCTURES & IMPROVEMENTS	74	118	115	111
REACTOR PLANT EQUIPMENT	125	321	285	257
TURBINE PLANT EQUIPMENT	63	126	125	124
ELECTRIC PLANT EQUIPMENT	27	53	52	51
MISCELLANEOUS PLANT EQUIPMENT	11	13	13	13
MAIN COMDENSER HEAT REJECTION	18	24	23	23
TOTAL DIRECT COST	321	656	615	580
EEDB INDIRECT COST ACC'TS (M$):				
CONSTRUCTION SERVICES	47	79	73	70
HO ENGINEERING AND SERVICE	41	90	61	48
FO SUPERVISION & SERVICE	17	29	27	26
OWNER'S COST	75	141	119	113
TOTAL INDIRECT COST	181	339	280	257
BASE CONSTRUCTION COST (M$)	502	995	895	838
CONTINGENCY (M$)	100	206	186	173
TOTAL OVERNIGHT COST (M$)	602	1201	1081	1011
AFUDC (M$)	103	204	152	139
TOTAL CAPITAL COST (M$)	705	1405	1233	1150
FIXED CHARGE RATE	N/A	0.096	0.095	0.095
LEVELIZED CAPITAL COST (M$/YR)	N/A	138.5	117.8	109.8
ANNUAL O&M COST (M$/YR)	N/A	37.8	34.7	31.5
FUEL COST ($/MBTU)	N/A	1.51	1.34	1.08
CR & REFLECTOR COST (M$/YR)		3.0	3.0	3.0
LEVELIZED FUEL CYCLE COST (M$/YR)	N/A	53.6	47.9	39.2
DECOMMISSIONING COST (M$)	N/A	69.9	69.9	69.9
LEVELIZED DECOMMISSIONING (M$/YR)	N/A	2.1	2.1	2.1
TOTAL REVENUE REQUIREMENT (M$/YR)	N/A	231.9	202.4	182.6
BUSBAR COST (Mills/kWh)				
CAPITAL	N/A	36.8	31.3	29.2
O&M	N/A	10.0	9.2	8.4
FUEL	N/A	14.2	12.7	10.4
DECOMMISSIONING	N/A	0.5	0.5	0.5
TOTAL	N/A	61.6	53.7	48.5

TABLE 2
EQUILIBRIUM PLANT GENERATING COSTS
(1987$)

	ONE MODULE PLANT	TWO MODULE PLANT	FOUR MODULE PLANT	EIGHT MODULE PLANT
THERMAL RATING (MWt)	350	700	1400	2800
NET ELECTRIC RATING (MWe)	133.0	268.8	537.6	1075.2
CAPACITY FACTOR	0.80	0.80	0.80	0.80
EEDB DIRECT COST ACC'TS (M$):				
LAND & LAND RIGHTS	1	1	2	3
STRUCTURES & IMPROVEMENTS	46	68	111	216
REACTOR PLANT EQUIPMENT	82	142	257	477
TURBINE PLANT EQUIPMENT	41	64	124	248
ELECTRIC PLANT EQUIPMENT	19	26	51	102
MISCELLANEOUS PLANT EQUIPMENT	4	7	13	25
HEAT REJECTION EQUIPMENT	8	12	23	46
TOTAL DIRECT COST	200	319	580	1117
EEDB INDIRECT COST ACC'TS (M$):				
CONSTRUCTION SERVICES	24	39	70	138
HO OFFICE ENG'G & SERVICES	16	26	48	74
FIELD OFFICE AND SERVICES	9	14	26	52
OWNER'S COST	39	62	113	196
TOTAL INDIRECT COST	89	141	257	461
BASE CONSTRUCTION COST (M$)	289	460	838	1578
CONTINGENCY (M$)	60	95	173	323
TOTAL OVERNIGHT COST (M$)	348	555	1011	1901
AFUDC (M$)	48	76	139	255
TOTAL CAPITAL COST (M$)	396	631	1150	2157
FIXED CHARGE RATE	0.095	0.095	0.095	0.095
LEVELIZED CAPITAL COST (M$/YR)	38	60	110	206
ANNUAL O&M COST (M$/YR)	19.1	23.1	31.5	55.7
FUEL COST ($/MBTU)	1.08	1.08	1.08	1.08
CR & REFLECTOR COST (M$/YR)	0.75	1.5	3.0	6.0
LEVELIZED FUEL CYCLE COST (M$/YR)	9.8	19.6	39.2	78.3
DECOMMISSIONING COST,M$	17.3	34.9	69.9	139.8
LEVELIZED DECOMMISSIONING (M$/YR)	0.5	1.0	2.1	4.1
TOTAL REVENUE REQUIREMENT (M$/YR)	67.1	103.8	182.6	344.4
BUSBAR COST COMPONENTS (Mills/kWh)				
CAPITAL	40.5	31.9	29.2	27.4
O&M	20.5	12.2	8.4	7.4
FUEL	10.5	10.4	10.4	10.4
DECOMMISSIONING	0.5	0.5	0.5	0.5
TOTAL	72.0	55.1	48.5	45.7

TABLE 3
EEDB COAL PLANT GENERATING COSTS
$1.75/MBTU COAL; 1987$

	400 (MWe) PLANT	600 (MWe) PLANT	TWO UNIT 800 (MWe) PLANT	TWO UNIT 1200 (MWe) PLANT
NET ELECTRIC RATING (MWe)	400	600	800	1200
CAPACITY FACTOR	0.80	0.80	0.80	0.80
EEDB DIRECT COST ACC'TS (M$):				
LAND & LAND RIGHTS	5	5	9	9
STRUCTURES AND IMPROVEMENTS	69	82	122	145
BOILER PLANT EQUIPMENT	208	265	367	468
TURBINE PLANT EQUIPMENT	85	113	150	200
ELECTRIC PLANT EQUIPMENT	40	45	71	79
MISC. PLANT EQUIPMENT	24	26	42	46
HEAT REJECTION EQUIPMENT	19	27	34	48
TOTAL DIRECT COSTS	450	563	795	994
EEDB INDIRECT COST ACC'TS (M$):				
CONSTRUCTION SERVICES	39	48	69	85
HO ENGINEERING AND SERVICES	26	33	46	58
FO ENGINGINEERING AND SERVICES	19	23	34	41
OWNER'S COSTS	53	66	94	117
TOTAL INDIRECT COSTS	137	170	242	300
BASE CONSTRUCTION COST (M$)	587	733	1037	1294
CONTINGENCY (M$)	87	109	154	192
TOTAL OVERNIGHT COST (M$)	674	842	1190	1487
AFUDC (M$)	116	145	205	256
TOTAL CAPITAL COST (M$)	790	987	1395	1743
FIXED CHARGE RATE	0.098	0.098	0.098	0.098
LEVELIZED CAPITAL COST (M$/YR)	77.5	96.8	136.8	171.0
ANNUAL O&M COST (M$/YR)	24.8	27.5	37.9	43.0
FUEL COST				
COAL COST ($/MBTU)	1.75	1.75	1.75	1.75
PLANT HEAT RATE (BTU/kWh)	9684	9595	9684	9595
ANNUAL FUEL COST (M$/YR)	47.5	70.6	95.0	141.2
LEVELIZED FUEL COST (M$/YR)	67.8	100.8	135.6	201.5
REVENUE REQUIREMENT (M$/YR)	170.1	225.0	310.3	415.5
BUSBAR COST (Mills/kWh)				
CAPITAL	27.6	23.0	24.4	20.3
O & M	8.9	6.5	6.8	5.1
FUEL	24.2	24.0	24.2	24.0
TOTAL	60.7	53.5	55.3	49.4

TABLE 4
EEDB PWR GENERATING COSTS
(1987$)

	800 MW PLANT (WITH BEST EXPERIENCE CAPITAL COSTS)	1200 MW PLANT (WITH BEST EXPERIENCE CAPITAL COSTS)	1200 MW PLANT (WITH MEDIAN EXPERIENCE CAPITAL COSTS)
THERMAL RATING (MWt)	2400	3600	3600
NET ELECTRIC RATING (MWe)	800	1200	1200
CAPACITY FACTOR	0.80	0.80	0.80
EEDB DIRECT COST ACC'TS (M$):			
LAND & LAND RIGHTS	5	5	5
STRUCTURES & IMPROVEMENTS	187	229	353
REACTOR PLANT EQUIPMENT	265	324	404
TURBINE PLANT EQUIPMENT	193	236	286
ELECTRIC PLANT EQUIPMENT	72	88	132
MISCELLANEOUS PLANT EQUIPMENT	41	50	77
MAIN COMDENSER HEAT REJECTION	42	52	61
TOTAL DIRECT COST	805	984	1318
EEDB INDIRECT COST ACC'TS (M$):			
CONSTRUCTION SERVICES	144	176	322
HO ENGINEERING AND SERVICE	173	211	484
FO SUPERVISION & SERVICE	93	114	451
OWNER'S COST	120	147	256
TOTAL INDIRECT COST	530	648	1513
BASE CONSTRUCTION COST (M$)	1335	1632	2830
CONTINGENCY (M$)	261	319	553
TOTAL OVERNIGHT COST (M$)	1596	1951	3383
AFUDC (M$)	425	520	1302
TOTAL CAPITAL COST (M$)	2021	2471	4685
FIXED CHARGE RATE	0.097	0.097	0.098
LEVELIZED CAPITAL COST (M$/YR)	195.4	238.9	457.9
ANNUAL O&M COST (M$/YR)	72.6	79.1	79.1
FUEL CYCLE COST ($/MBTU)	0.69	0.69	0.69
LEVELIZED FUEL CYCLE COST (M$/YR)	39.6	59.4	59.4
DECOMMISSIONING COST (M$)	104.0	156.0	156.0
LEVELIZED DECOMMISSIONING (M$/YR)	3.1	4.6	4.6
TOTAL REVENUE REQUIREMENT (M$/YR)	310.6	382.0	601.0
BUSBAR COST (Mills/kWh)			
CAPITAL	34.9	28.4	54.5
O&M	12.9	9.4	9.4
FUEL	7.1	7.1	7.1
DECOMMISSIONING	0.5	0.5	0.5
TOTAL	55.4	45.4	71.5

SECTION 1
INTRODUCTION

1.1 BACKGROUND

The conceptual design of a reference Modular High Temperature Gas-Cooled Reactor (MHTGR) power plant is described in the MHTGR Conceptual Design Summary Report (Reference 1). Cost estimates to design, construct, operate and maintain MHTGR power plants conforming to the Reference 1 design are provided in this report. Evaluations of the MHTGR plant costs relative to alternative power plant costs are also provided.

So that comparisons of advanced nuclear power plant costs can be made on a consistent basis, the Department of Energy (DOE) has published guidelines (References 2 and 3) to provide a common set of groundrules and assumptions for the preparation of cost estimates. The groundrules and assumptions used for the MHTGR cost estimates, repeated here as required to provide a stand alone report, are based on the DOE guidelines of References 2 and 3 with the exceptions as itemized in Reference 14. The most significant exceptions are:

1) The MHTGR owner's indirect capital cost is based on a detail estimate in lieu of estimating owner's cost as a percentage of other base construction costs.

2) Contingency was estimated on an account-by-account basis

3) An 80% capacity factor was used for the MHTGR. An 80% capacity factor was also used for the alternative power plants in the generation cost comparisons.

Definition of some of the more pertinent terms used in this report are provided in Section 1.2 followed by a statement of the cost estimate scope in Section 1.3. The approach used for developing base construction capital costs is presented in Section 2. Conversion of the base construction costs to total capital cost is presented in Section 3 and busbar cost estimates are developed in Section 4. Costs for alternative power plants and comparative evaluations of the alternative power plants with the MHTGR are presented in Section 5.

1.2 DEFINITION OF TERMS

1.2.1 Lead Plant Costs

Lead plant costs include all costs from the initiation of preliminary design to the first commercial electricity-producing power plant of that type. Lead plant costs are subdivided into three categories: design and licensing, technology development, and first commercial power plant. Design and licensing includes the costs for the engineering and licensing activities necessary to obtain a Final Design Approval (FDA) from the Nuclear Regulatory Commission (NRC). Technology development costs include base technology for fuel and material qualification and component qualification testing required for the first commercial power plant plus any required test systems or facilities. The first commercial power plant is the first MHTGR plant that is sold to an entity for the purpose of commercial production of electric energy. The first commercial plant costs include all engineering, equipment, construction, site specific licensing, tests, tooling, project management, and other costs unique to the plant, which will not be incurred for subsequent plants of the identical design.

1.2.2 Replica Plant Costs

The Replica plant is the second commercial plant of identical design to the first commercial plant. The Replica plant costs include engineering, equipment, construction, testing, tooling, project management, and any other costs that are repetitive in nature and would be incurred in building subsequent plants of the identical design. The Replica plant also reflects the learning associated with building a second plant identical to the first commercial plant.

1.2.3 Target Plant Costs

The Target plant is the nth-of-a-kind (NOAK) or equilibrium commercial plant of identical design to the first commercial plant. The Target plant costs include all engineering, equipment, construction, testing, tooling, project management, and any other costs repetitive in nature that would be incurred if an identical plant were built. The Target plant also reflects the

learning experience associated with the construction of 4000 MWe of installed MHTGR capacity.

1.2.4 Base Construction Cost

The base construction cost is the plant capital cost consisting of the direct and indirect costs only. This cost is lower than the total capital cost because cost components such as contingency, interest, and escalation are not included. The specific cost items omitted from the base construction cost are listed in Table 2-2.

The direct costs are those costs directly associated on an item-by-item basis with the equipment and structures that comprise the complete power plant. The indirect costs are expenses for services applicable to the plant, such as architect-engineer (A-E) and reactor manufacturer (RM) home office engineering and design, A-E field office construction management, and owner's costs.

1.2.5 Total Overnight Cost

The total overnight cost is the base construction cost plus applicable contingency costs. It is referred to as an overnight cost in the sense that time value costs such as interest during construction are not included.

1.2.6 Total Capital Cost

The total capital cost is an all inclusive plant capital cost developed for the purpose of calculating the plant busbar electricity cost. This cost is the base construction cost plus contingency, escalation, and interest-related costs.

1.2.7 Nominal Cost of Money

The nominal cost of money is the percentage rate used in calculations involving the time value of money containing an inflation component. It explicitly provides for a real return on an investment over and above a return to keep up with inflation.

1.2.8 Real Cost of Money

The real cost of money is the percentage rate used in calculations involving the time value of money when no inflation component is included. Calculations using the real cost of money assume that the dollar maintains a constant value in terms of purchasing power and, thus, no return on an investment is needed for inflation.

1.2.9 Constant Dollars

Constant dollar cost is defined as the cost for an item measured in dollars that has general purchasing power as of some reference date. As inflation is generally associated with the erosion of the general purchasing power of the dollar, constant dollar analysis is said to exclude inflation.

1.2.10 Nominal Dollars

Costs including inflation are given in nominal dollars (sometimes referred to as current dollars).

1.2.11 Materials

Basically, materials include field-purchased (site material) and/or bulk items such as lumber, reinforcing, concrete, structural steel, and plumbing items. Prefabricated pipe is an equipment item. All other piping is a materials item with the exception of pipe for cryogenic fluids, which is an equipment item. Also, all wire and cable and raceways are material items, including those in building service power systems but excluding control system fibre optics cabling which is an equipment item.

1.2.12 Equipment

Generally, equipment includes all manufactured items. Such items may be procured on a design-and-build contract from qualified vendors, wherein design responsibility belongs to the seller (vendor) or the design responsibility is maintained by the reactor manufacturer or A-E on a so-called "build-to-print" basis.

1.2.13 Force Account

Force account involves the direct hiring and supervision of craftsmen to perform a construction activity by a prime contractor as opposed to the prime contractor hiring a subcontractor to perform these functions.

1.2.14 Reactor Module

A reactor module is a single reactor and steam generator which provides thermal heat as an integral part of a power production unit.

1.2.15 Construction Module

A construction module is a free-standing transportable preassembly of a section or portion of the plant. A construction module may be a preassembly of a single system or portion thereof or may contain elements of all the systems that exist in a given geographical location of the plant. The construction module may even contain parts of the building structure. A construction module would typically be assembled in a factory, shipped to the plant site and installed with a minimum of operations.

1.2.16 Common Plant Facilities

Common plant facilities are those systems, structures, and components that are required to support the operation of a first power unit at a new plant site and include such facilities as operations center, provisions for refueling, water supply, general fire systems, etc.

1.2.17 Nuclear Island (NI)

The NI is that portion of the plant that has within its boundary the standard reactor modules and safety-related buildings, structures, systems, portions of systems and components dedicated to assuring reactor shutdown, fission product retention, and security of vital areas including new (unirradiated) fuel. Non-safety-related buildings, structures, systems, portions of systems and components that support reactor operation or investment protection may also be included at the discretion of the designer.

1.2.18 Energy Conversion Area (ECA)

The ECA is that portion of the plant not included within the NI.

1.2.19 Power Block

The MHTGR power block consists of the NI and that portion of the ECA containing the power generation equipment. For the MHTGR reference plant, as described in Reference 1, the power block contains four reactor modules and two turbine generators. The reference MHTGR plant with a single power block corresponds to the single block plant in the Reference 3 DOE guidelines.

1.2.20 Power Unit

A power unit is that portion of the power block associated with a single turbine generator. For the reference plant, each power unit contains two reactor modules, and one turbine generator. The power unit corresponds to the building block in the Reference 3 DOE guidelines.

1.2.21 Nuclear Grade

For the purposes of the MHTGR cost estimates, nuclear grade implies practices which satisfy the requirements of 10CFR50, Appendix B.

1.2.22 Industrial Grade

For the purposes of the MHTGR cost estimates, industrial grade means practices which satisfy generally accepted commercial requirements.

1.3 MHTGR COST ESTIMATE SCOPE

The scope of the MHTGR cost estimate was the development of the estimated costs to design, construct, operate, and maintain reference MHTGR power plants. The reference MHTGR plant consists of a single power block which produces a net output of approximately 540 MWe. Costs were developed for the following four scenarios:

1. Lead reference plant (refer to Section 1.2 for definition of terms).

2. Replica reference plant.

3. Target reference plant.

4. Target large plant consisting of four power units (two reference plant power blocks) built with an economically optimum time between commercial operation of each power unit.

For the purpose of preparing the cost estimates, the commercial operation dates assumed for the first power unit in these scenarios were:

1. Lead - January 1, 2000

2. Replica - January 1, 2005

3. Target - January 1, 2010

Costs were developed using the DOE Energy Economic Data Base (EEDB) Program code of accounts. Using the EEDB code of accounts allows a comparison between the MHTGR cost estimates and costs of other plants reported in the EEDB format. All portions of the estimate are expressed in constant January 1987 dollars.

In addition to the generation of base construction, overnight and total capital costs, levelized total busbar costs were determined and compared with competing coal and pressurized water reactor (PWR) plants. The levelized busbar generation costs were developed using the methodology presented in the DOE Nuclear Energy Cost Data Base (NECDB), Ref. 2.

SECTION 2
COST ESTIMATE GROUNDRULES

This section describes the groundrules used to develop the base construction cost and provides the base construction cost estimate results and evaluations.

2.1 GENERAL GROUND RULES

1. The DOE EEDB program code of accounts was the structure used for cost estimating and cost accumulation. The EEDB code of accounts is an evolutionary expansion and modification of the NUS-531 code of accounts. A description of the EEDB code of accounts structure used for the MHTGR is provided in Section 2.3 and a listing of the accounts is given in Table A-1 (Appendix A).

2. The detail cost estimates were prepared by the MHTGR program participant(s) having technical responsibility for each plant item. Gas-Cooled Reactor Associates (GCRA) integrated the results and prepared the cost reports.

3. Detailed cost estimates were developed in constant January 1987 dollars.

4. The cost estimates reflect the MHTGR plant requirements and conceptual design as detailed in the Utility/User Requirements (Reference 4), the MHTGR Overall Plant Design Specification (OPDS), System Design Descriptions (SDDs), Subsystem Design Descriptions (SSDDs), Building and Structure Design Descriptions (BSDDs), and other formal design documentation.

5. The base construction cost estimates were developed as the most likely costs for a particular EEDB entry without interest, escalation, or contingency allowance defined in Section 3.0. The most likely cost is defined in Appendix C.

6. Assumed use of any government owned or operated facility was costed at full cost recovery, including all direct costs, allocable indirect costs, depreciation, and any other related general and administrative costs. The only government owned or operated facilities used are those required for the technology development program activities at the Oak Ridge National Laboratory (ORNL).

7. All construction and installation costs reflect a physically separated construction concept whereby nuclear grade and Seismic Category I construction are separated from industrial grade (non-nuclear) construction. All costs of equipment, materials, storage, quality assurance (QA), quality control (QC), and labor productivity for the non-nuclear areas reflect conventional commercial industrial grade practice. The portions of the plant constructed under each construction grade are given in Table 2-1.

8. The following general guidelines were used as aids in establishing system-to-system boundaries for costing purposes:

   a. The cost estimate for a system, equipment, facility, or structure include those costs associated with the developing, installing, and constructing the particular item described in the SDDs, SSDDs or BSDDs.

   b. For costing purposes, the boundaries of a system, facility, or structure are as defined in the SDDs, SSDDs or BSDDs and in the piping and instrumentation diagrams (P&IDs).

   c. The cost for all electrical power terminations, including connectors, are borne by the electrical power system. For building service power and lighting systems, the interface with the electrical power system is the individual power lighting panel.

d. The expense for terminating instrumentation and control cabling and wiring with the exception of control system fibre optics cabling were included in the electrical power system. This includes terminations with individual sensors as well as providing electrical interconnections between panels, cabinets, consoles, data processing units, controllers, etc. The control system fibre optics cabling was included with the control system.

e. Costs for routing and laying or pulling wire and cable in ducts, conduits, and trays was included in the electrical power system.

f. The costs for attachments to structures (e.g., anchor bolts and auxiliary steel) was borne by the equipment item requiring the support. Embedments were included in the costs of structures.

9. For large equipment items and modules, the site delivery transportation costs were identified as a line item.

10. The Target plant was assumed not to employ a dedicated factory for producing constructions modules.

11. The MHTGR cost estimates were based on the MHTGR construction schedules contained in Appendix G.

12. Costs of common plant facilities were identified at the three digit account level and listed separately in EEDB format.

13. In cases where equipment items or piping were combined with structural members to produce a factory-assembled construction module, a work sheet documenting each module was to be prepared. The work sheet was to identify by three-digit EEDB account the applicable items and costs that comprise the module. For each three digit account, the work sheet was to provide the equipment and material costs, shop and field labor hours and costs, factory overhead and profit, freight, and total module cost. In addition, the approach used to calculate each of the cost items was to be

documented. In the total plant cost estimate, costs for items that are part of a factory module were to remain in the EEDB account that represents that particular item (i.e., a construction module may have components from more than one account but the costs were to be assigned to the proper account).

14. For large factory equipment items such as the reactor vessel and internals, steam generators, heat exchangers, etc., supporting cost data by component were to be available for review. The supporting data was to include factory material cost, material weights, factory man-hours reoccurring cost, and total cost for each equipment item.

2.2 SPECIFIC COST ESTIMATING ASSUMPTIONS

The following specific assumptions were used in developing the MHTGR base construction cost estimates:

1. Assumptions on the organizational structure used in developing the cost estimates were as follows:

   a. Overall project management was assumed to be provided by a owner entity.

   b. A vendor entity was assumed to be responsible for the engineering and design, licensing support, manufacturing and construction management activities for the nuclear island. The same vendor entity was also assumed to be responsible for the entire plant.

2. The following assumptions apply to costing the Lead plant:

   a. Lead plant costs include all costs (as identified in Sec. 1.2.1) from the initiation of preliminary design up to and including the first commercial electricity-producing power plant of that type. The Lead plant costs include all technology and design development, engineering, equipment, construction, licensing, project management costs, and any other costs that are required in building a first-of-a-kind (FOAK) plant.

b. GCRA was responsible for preparing the cost estimate for the reference plant design, the technology development and the licensing activities required for the reference plant. These are the activities that fall under the heading entitled "Reference Plant Develop" on Figure 2-1 from initiation of preliminary design through FDA. The MHTGR program participants having technical responsibility for plant items were responsible for developing cost estimates for the Lead plant activities that fall under the heading entitled "Demo/Lead Plant Deploy" on Figure 2-1 plus the costs to obtain design certification after FDA. These are the first commercial plant costs.

c. The reference plant design, technology development and licensing cost estimates developed by GCRA were based on the cost estimates developed in support of the MHTGR Project Definition Study, Reference 5.

d. Lead plant costs were developed for deployment of the first commercial plant in two phases as shown on Figure 2-1. The first deployment phase consists of a single reactor module, one of the two turbine generators and the common facilities for the reference plant. After performance verification testing of the first reactor module (an approximate two year period) the balance of the first commercial reference plant is completed in a second deployment phase. The costs of the performance verification tests were estimated as a separate line item.

e. The Lead plant costs include the licensing activities necessary for first plant operation and a standard plant design certification.

f. Changes to the NRC regulations or major codes such as American Society of Mechanical Engineers (ASME) or Institute of Electrical and Electronic Engineers (IEEE) could be assumed during the design and construction period. To date, no regulation and/or code changes have been identified.

3. The following assumptions apply to the Replica and Target plant cost estimates:

   a. The design was assumed to be the certified design, identical to the first commercial plant (i.e., no product improvements were assumed).

   b. Equipment manufacture and plant construction were assumed to be performed by the same contractors as for the first commercial plant.

   c. No changes were assumed in NRC regulations or major codes and standards subsequent to obtaining design certification.

   d. The cost estimates include the cost for all site-specific licensing activities. A standardized plant design approval and certification was assumed such that there are only site-specific licensing activities.

   e. Replica and Target plant costs include all engineering, equipment, construction, testing, tooling, project management costs, and any other costs that are repetitive in nature and would be incurred in building an identical plant.

   f. For cost estimating purposes, the large Target plant plot plan was assumed to be as shown in Figure 2-2.

4. Labor rates for craftsmen employed to assemble equipment at an onsite fabrication shop were assumed to be the same as construction crew rates.

5. All plant construction was assumed to be accomplished by "force account". (Costs for all tasks are reported as equipment cost, material cost, and labor hours and cost.)

6. Reductions in costs of factory equipment not previously produced due to learning effects were assumed. A 94% unit learning curve was used for estimating individual factory equipment items being produced for the first time except where an alternate learning curve could be justified. The base or starting point for cost reduction due to learning was the first equipment item for the first commercial plant. For costing equipment items for the Target plant, it was assumed that the Target plant is that unit whose manufacturing first places the cumulative production at or in excess of 4000 MWe (i.e., the 8th reference plant containing the 29th, 30th, 31st, and 32nd reactor module and the 15th and 16th turbine generator). The cost for a given equipment item for the Target plant reflects the cumulative production history for that item as determined by the cumulative item requirements necessary to satisfy the above Target plant assumption. The same unit costs were used for the Target and large Target plants.

7. All engineering information, including specifications and drawings, was assumed to be released for construction in time for efficient planning and performance of the work. All equipment, material, and labor resources were assumed to be available as required.

8. The baseline construction was assumed to require no premium time (overtime) work to recover from schedule delays.

9. A rolling 4 x 10 hr. day, 70 hr. site construction workweek was used when dictated by the construction schedule. Premium payment costs were included for 1-1/2 time (2 hr.), weekend work, and general foreman overlap. In addition, "learning curve" improvements in the construction labor requirements for construction of subsequent units on the same site and in going from the Lead plant to the Replica plant and to the Target plants were incorporated.

10. Funding was assumed to be available as required to support uninterrupted design, testing, construction, installation, checkout, and plant start-up.

11. Site conditions for each plant were assumed to be within the envelope specified in the utility/user requirements (Reference 4). No significant cost differentials due to differences in site characteristics between the reference envelope and those at the "Middletown, U.S.A." site described in DOE's EEDB were identified. For each plant site:

    a. An adequate pool of qualified craft labor was assumed to be available.

    b. It was assumed that there were no unique nuclear or conventional licensing restrictions that would affect plant design, construction, or operation.

    c. Estimates cover work within the plant security fence and include the cooling water intake systems and structures.

    d. Soil and subsurface conditions are such that there are no unusual problems associated with soil-bearing capacity or rock removal, major cut and fill operations, and dewatering.

12. Site land was assumed to cost $10,000/acre. The total land cost was assumed to be incurred at the same time as the decision was made to build a plant. The site area was taken as 200 acres for the reference plant and 300 acres for the large Target plant.

13. Cost items excluded from the base construction cost estimate are listed in Table 2-2.

14. Site construction labor crew composite wage rates (base rate plus fringes) used for the estimates are given in Table 2-3.

15. No allowance was included in the cost estimate to cover major unforeseen costs that could result from such events as prolonged major strikes or prolonged severe climatic conditions.

2.3 COST ACCOUNT DEFINITIONS

2.3.1 Direct Capital Cost Accounts

Direct cost accounts include those construction and installation costs directly associated with the operating plant structures, systems, and components. The direct cost accounts are composed of equipment costs, site labor costs and material costs.

2.3.1.1 EQUIPMENT COSTS

Equipment costs include the costs for all design, analysis, fabrication, documentation preparation, predelivery testing, and follow-up engineering performed by equipment vendors; materials for all plant equipment; transportation and insurance expenses; provision of shipping fixtures and skids; warranties; preparation of maintenance and operations manuals and handling instructions; delivery of start-up and acceptance test equipment; on-site unloading and receiving inspection expenses; and overhead expenses.

All plant equipment, whether directly associated with the power generation systems or the facility systems, such as heating and ventilation, were included in this category.

2.3.1.2 SITE LABOR COST

The site labor portion of the construction and equipment installation costs includes all on-site activities related to permanent plant structures, systems, and equipment required for all aspects of power plant operation. The direct costs of all work crews and foremen to excavate, backfill, erect, and finish structures, and to place and install equipment, piping, wiring, etc., are included.

The costs associated with installing equipment items include the labor to transport the equipment from on-site storage to the final resting place as well as the labor to align the equipment and physically attach it to the supporting structure. In addition, the labor for providing mechanical hookups and electrical connections between interfacing systems is included.

2.3.1.3 SITE MATERIALS COST

Site materials include all materials purchased in the field and/or bulk items such as paint, concrete, rebar (excluding prefabricated rebar structures), welding rod, formwork, etc. All piping less than 2-1/2 in. nominal pipe size is a materials item with the exception of pipe for cryogenic fluids. Also all wire, cable, and raceways are material items, including those in building service power systems but excluding the control system fibre optics cabling.

2.3.2 Indirect Capital Cost Accounts

The EEDB indirect cost accounts include those construction support activities required to design and build the structures and systems described in the direct cost accounts. At the two-digit account level of detail, the EEDB indirect cost accounts describe the construction services, home office engineering and services, field office engineering and services and owner's costs.

The DOE guidelines of Reference 3 prefer that indirect costs be determined independently on a bottoms-up basis, but, when insufficient detailed information is available, they allow costs for certain indirect accounts to be estimated as a function of the direct costs. For the MHTGR cost estimates, A-E indirect costs for the NI were estimated on the basis of the Bechtel-developed algorithms presented in Appendix B. The indirect costs for the ECA portion of the plant were estimated independently by Stone and Webster. The reactor manufacturer's indirect cost and owner's cost was determined on the bottoms-up basis.

The following subsections provide a description of the indirect costs by three-digit account numbers.

2.3.2.1 CONSTRUCTION SERVICES COSTS (ACCOUNT 91)

Construction services include costs for A-E related activities associated with construction as indicated below:

- Temporary Construction Facilities (Account 911). This sub-account includes temporary structures and facilities, janitorial services, maintenance of temporary facilities, guards and security, roads, parking lots, laydown areas, and temporary electrical, heat, air, steam, and water systems, general cleanup, etc.

- Construction Tools and Equipment (Account 912). Construction tools and equipment include rental and/or purchase of construction equipment, small tools, and consumables (fuel, lubricants, etc.), as well as maintenance of construction equipment.

- Payroll Insurance and Taxes (Account 913). These expenses include insurance and taxes related to craft labor (direct and indirect including guards and janitors), such as social security taxes and state and federal unemployment taxes, workmen's compensation insurance, and general liability and property damage insurance.

- Permits, Insurance, and Local Taxes (Account 914). Consistent with other EEDB estimates, builders all-risk insurance will be the only cost included in Account 914. Payments to federal, state, and local governments for taxes, fees, and permits are to be included in Account 942, because they are plant specific.

2.3.2.2 ENGINEERING AND HOME OFFICE SERVICES COSTS (ACCOUNT 92)

Engineering and home office services costs include all management, engineering design, and associated support activities. This cost element includes the activities as given below:

- Reactor Module Engineering and Services (Account 920). These costs include reactor module engineering and design (both field and home office), procurement and expediting activities, estimating and cost control, engineering planning and scheduling, reproduction services and expenses associated with performance of the above functions (i.e., telephone, postage, computer use, travel, etc.). The costs for these services include salaries of personnel, direct payroll-related costs (DPC), overhead loading expenses, and fees for these services.

- Plant Engineering and Services (Account 921). These costs include A-E engineering and design (both field and home office), procurement and expediting activities, estimating and cost control, engineering planning and scheduling, reproduction services and expenses associated with performance of the above functions (i.e., telephone, postage, computer use, travel, etc.). The costs for these services include salaries of personnel, DPC, overhead loading expenses, and fees for these services.

- Home Office Quality Assurance (Account 922). This account includes the services of home office quality assurance engineers and staff personnel engaged in work on the project. Services include reviews, audits, vendor surveillance, etc., as required for design and construction of the nuclear-safety-related portion of the facility. Costs for these services include salaries, DPC, overhead loading, and expenses (i.e., travel) of these individuals.

- Home Office Project and Construction Management (Account 923). These services include those of the project manager, the construction manager and their assistants. Services of construction planning and scheduling, construction methods, labor relations, safety and security personnel are used as required. Costs for these services include salaries, DPC, overhead loading, and expenses.

2.3.2.3 FIELD SUPERVISION AND FIELD OFFICE SERVICES COSTS (ACCOUNT 93)

Field supervision and field office services include costs for A-E related activities associated with on-site management of construction, site QA, start-up and test, and the supporting costs for these functions as indicated below:

- Field Office Expenses (Account 931). These expenses include costs associated with purchase and/or rental of furniture and equipment (including reproduction), communication charges, postage, stationery, other office supplies, first aid, and medical expenses.

- Field Job Supervision (Account 932). This management function includes the resident construction superintendent and his assistants, craft labor supervisors, field accounting, payroll and administrative personnel, field construction schedulers, field purchasing personnel, warehousemen, survey parties, stenographers, and clerical personnel. Costs of these services include salaries, DPC, overhead loading, relocation costs of key personnel, and fees.

- Field Quality Assurance/Quality Control (Account 933). These services include those of personnel located at the job site engaged in equipment inspection, required documentation of safety-related equipment and inspection of construction activities. Costs included are salaries, DPC, and overhead loading.

- Plant Startup and Test (Account 934). These services are associated with the preparation of start-up and plant operation manuals and test procedures, direction and supervision of testing of equipment and systems as the plant nears completion and direction of start-up of the facility. Costs of these services include salaries, DPC, overhead loading, and miscellaneous related expenses. Costs of any craft labor required for start-up and testing activities are included in the appropriate direct cost line items.

2.3.2.4 OWNER'S COST (ACCOUNT 94)

Owner's costs include the costs of the owner for activities associated with the overall management and integration of the project and other costs not included in the direct capital costs incurred before the start of commercial operations as follows:

- Project Management Expenses (Account 941). This account includes the cost of the owner's staff for program management and integration, engineering, licensing, and quality assurance. It also includes supporting home office services such as estimating, planning and scheduling, and purchasing, as well as payment for outside supporting services directly associated with siting, building and startup of the plant.

- Fees, Taxes and Insurance (Account 942). These expenses cover all owner's nuclear and other insurance premiums and local taxes, sales taxes on purchased materials and equipment incurred during the course of the project, and permits, licenses, and fees. Builder's all-risk insurance is included in Account 914.

- Spare Parts, and Capital Equipment (Account 943). This account includes the initial stock of supplies, consumables and spare parts needed for testing and startup operations in addition to the plant inventories of gases (helium), fluids (water, lub oils), fuels (excluding nuclear fuel) and chemicals. Office furniture, communication equipment, transportation vehicles, laboratory equipment, house keeping gear, and other utility specific equipment are also part of this account.

- Staff Training and Startup (Account 944). The costs of the initial staffing and training of maintenance, operating, supervisory and administrative personnel are included in this account. This includes the preparation of all training materials and instruction costs, the salaries of the operating and the maintenance staff assigned to the plant prior to the plant acceptance, and their associated material and service expenses.

- G&A (Account 945). This includes administrative and general salaries plus related expenses, labor and certain regulatory expenses, outside services not applicable to other owner accounts, and public relation activities.

A detail estimate of the MHTGR owner's cost for the Lead, Replica and Target plants is reported in Reference 6. A summary of the owner's costs for each of above accounts from Reference 6 is provided in Table 2-4.

2.4 BASE CONSTRUCTION COST ESTIMATE RESULTS

2.4.1 Total Base Construction Costs

The base construction costs for each of the plant cases (Lead - Phase 1, Lead - Phase 2, Replica, NOAK and large NOAK) are summarized to the two-digit EEDB cost account level in Tables 2-5a through 2-5e with the costs separated between the NI and ECA. Summaries to the three-digit cost account level are given in a similar format for each of the plants in Appendix D. Lead plant cost data are provided as Phase 1 and Phase 2 corresponding to the requirement given in paragraph 2.2.2.d. The Design, Licensing, and Technology Development costs have not been included in the base construction costs. These costs are provided in Section 2.5.

The Owner's cost in the MHTGR base construction cost estimates deviate from the Reference 3 DOE guidelines. In the DOE guidelines, guidance is provided to estimate the owner's cost as 10% of the other indirect and direct base construction costs. The MHTGR Owner's cost estimates from Reference 6 included in Tables 2-5a through 2-5e show that the likely owner's cost for the MHTGR (and possibly other plants as well) could be about 15%. Since this is an area where the MHTGR costs are based on an approach that deviates from the DOE guidelines, a separate set of costs have been developed and included in Appendix E which contain MHTGR cost estimates conforming to DOE guidelines. The cost estimates contained in Appendix E should be used when making comparison of MHTGR costs with the costs of other technologies estimated in accordance with the Reference 3 DOE guidelines.

A comparison of the base construction costs for the Lead, Replica, and NOAK plants is given in Tables 2-6a, 2-6b, and 2-6c for the NI, ECA and total plant, respectively. The data in Tables 2-6a, 2-6b and 2-6c show that in evolving from the Lead to the NOAK plant, the NI base construction costs reduce by about 20%, the ECA costs reduce by about 11% and the total plant costs reduce by about 15%.

The data in Table 2-6a show that the major reductions in the NI costs occur in Account 22, Reactor Plant Equipment, and in the indirect costs with the

largest reduction being in Home Office Engineering, Account 92. The reduction in the Home Office Engineering account can be attributed primarily to design standardization while the reduction in the other indirect accounts and in the reactor plant equipment account are attributable to learning and the presence of FOAK costs in the Lead plant costs.

The data in Table 2-6b show that in the ECA, learning results in reductions on the order of 3% to the direct costs. More sizeable reductions occur in the indirect costs, essentially equivalent to those in the NI direct costs. As in the NI, the largest reduction occurs in the Home Office Engineering account attributable to design standardization. The balance of the reduction in the indirect costs reflect learning.

In total, design standardization as measured by the reductions which occur in the home office engineering base construction costs reduce the total plant costs by about 4%; the 11% balance of all reductions in base construction costs is attributable to learning plus Lead plant FOAK costs.

2.4.2 Factory Equipment and Site Material Costs

Summaries of the factory equipment and site material direct costs for the Lead, Replica and NOAK plants are given in Tables 2-7 and 2-8, respectively. The factory equipment direct costs account for nearly 50% of the total base construction costs. The site material costs account for less than 7% of the total base construction costs.

Table 2-7 shows that about 60% of the factory equipment costs are contained in Account 22, Reactor Plant Equipment. A breakdown of the main equipment items contained in Account 22 for the Lead, Replica, NOAK and Large NOAK plants is given in Table 2-9. The second most significant factory equipment account is the Turbine Plant Equipment, Account 23, which contains about 25% of the total factory equipment costs.

The only factory equipment accounts which contain any reductions in costs in evolving from the Lead to the NOAK plant are Structures & Improvements, Account 21, and Reactor Plant Equipment, Account 22. Sizeable percentage reductions occur in both of these accounts but since the structures account

contains only about 5% of the total equipment cost, the only significant reduction is in the Reactor Plant Equipment account. No reductions in cost occur in any of the ECA factory equipment cost accounts in evolving from the Lead to the NOAK plant since all of the ECA equipment is commercially available. The Reactor Plant Equipment account is accordingly the only account having any significant FOAK costs. Based on the data in Table 2-7, the FOAK cost and learning factor associated with the Reactor Plant Equipment account is approximately $21M and 0.95, respectively. These same results are obtained using the data in Table 2-9.

$21M FOAK represents about 2% of the total Lead plant base construction cost. Subtracting this from the 11% for learning plus FOAK identified in Section 2.4.1 results in a reduction due to learning of about 9% on a plant-wide basis. Since the NOAK plant is the 8th plant built (a total of three doublings) the overall learning factor is 0.97.

In the Site Materials Cost category, the data in Table 2-8 show that about 74% of the cost of these materials are in Structures and Improvements, Account 21. About 76% of the site materials cost occurs on the NI and, per Table 2-1, all of the NI site materials are nuclear grade. Even so, these nuclear grade site materials account for only about 5% of the total plant base construction costs. The other significant item of note is that there is no learning or other cost reduction effects associated with site materials between the Lead and NOAK plants since all of the materials are commercially available.

To permit comparison on a bulk basis of selected site materials (i.e., commodities) with alternative plants, bulk commodity data are given in Tables 2-10a and 2-10b for the NOAK and large NOAK plants, respectively (the Lead and Replica plants have the same quantities as the NOAK plant). The data in Tables 2-10a and 2-10b is provided by EEDB Account and area (NI and ECA). Some accounts contain data for only NI or ECA which means that there is none of the commodities in the area not listed. Also note that, per Table 2-1, the materials in the NI are nuclear grade.

2.4.3 Site Labor Costs

The data in Tables 2-5a through 2-5e indicate that direct site labor costs account for about 13% of the total base construction costs. A summary of the labor manhour requirements for the direct accounts is given in Table 2-11. All of the cost accounts show reductions in the labor manhours due to learning in going from the Lead to the NOAK plant. The NI accounts reduce by about 6% and the ECA accounts by about 10%. The overall reduction in labor hours due to learning is 8.5%. This compares to the total cost reduction described in the previous section due to learning of about 9%.

The labor manhours are summarized by craft at the two-digit account level for each of the plants in Table 2-12a through Table 2-12e for the following crafts: boilermakers, carpenters, electricians, ironworkers, laborers, millwrights, operating engineers, pipefitters, teamsters, and other craft labor. The data in these tables indicate the most highly utilized craft to be the electrician accounting for about 26% of the total direct labor hours. The next most utilized crafts are carpenter, iron worker, pipefitter and laborer with each accounting for between 13 and 16% of the total direct labor hours. All of the rest account for approximately another 15%.

2.4.4 Comparison of Commodities and Labor with Alternative Plants

Bulk commodity and craft labor data for an 1144 MWe PWR plant and a 488 MWe coal-fired plant are contained in Reference 11 in formats similar to those used for the MHTGR in Sections 2.4.2 and 2.4.3. Data are provided that represent both the industry's best PWR plant construction experience (PWR-BE) and the industry's median PWR plant construction experience (PWR-ME). The coal-fired plant is a high sulfur coal plant with a Flue Gas Desulfurization (FGD) system and electrostatic precipitator.

A comparison of the MHTGR NOAK plant bulk commodities and total craft labor with those for the best experience model 1144 MWe PWR plant and the 488 MWe coal plant data is given in Table 2-13 on a per unit power generation basis.

The results show some of the distinctive characteristics of the MHTGR plant relative to PWR and coal plants. The MHTGR plant utilizes more reinforcing steel and structural concrete than the PWR or coal plant due to the use of an embedded silo for housing each of the four reactor modules in the reference plant. On the other hand, the quantity of nuclear grade piping is an order of magnitude less than that required for a PWR due to the reduced number of safety-related systems in the MHTGR. Nuclear grade plus industrial grade piping in the MHTGR is about half of that required for a PWR.

The unit labor quantities for the MHTGR total less than either the PWR or coal plants. Many of the unit craft quantities are approximately equivalent between the MHTGR and PWR. The most significant craft which is not equivalent is the pipefitter where the MHTGR quantity is about half that of the PWR's. The pipefitter quantity difference reflects the piping quantity difference noted above.

The coal plant total unit labor quantity is more than either the MHTGR or PWR. The primary crafts causing the coal plant to have the highest unit labor quantity are boilermaker, pipefitter and bricklayer (bricklayer in the coal plant accounts for 204 MH/MWe and is included in the "Other" labor category). The boilermaker, pipefitter and bricklayer quantities reflect the intense on-site labor required for large boiler construction.

2.5 DESIGN, LICENSING AND TECHNOLOGY DEVELOPMENT COSTS

The design and licensing and technology development costs were developed by GCRA based on the data given in Reference 5. Adjustments were made to the data of Reference 5 to compensate for the following:

1. The cost estimate in Reference 5 is based on completion of licensing activities through Preliminary Design Approval whereas, the current estimate is based upon completion of licensing through Final Design Approval.

2. The design activities in Reference 5 were based on completion of the 4X2 reference plant design through preliminary design and completion of the final design of a one module demonstration plant. The current

estimate is for completion of the reference plant design through final design.

3. The cost estimate components in Reference 5 are escalated 5% to represent January 1987 dollars.

The resultant development cost estimate is $272 million for design and licensing, $103 million for technology and $13 million for performance testing. These cost components are broken down further in Table 2-14.

Assuming an unconstrained budget, the estimated years of expenditure and percentage of expenditure are as given in Table 2-15 based upon the Lead plant milestone schedule given in Figure 2-1. Figure 2-1 shows a Lead plant commercial operating date earlier than that identified to be assumed in Section 1.3 (i.e., January 1, 2000). This is because Figure 2-1 is the current reference MHTGR Lead plant target schedule and has been used in the cost estimate only for the yearly expenditure data for design, licensing and technology development given in Table 2-15.

TABLE 2-1

PLANT CONSTRUCTION GRADES

	NI		ECA
	Safety-Related	Non-Safety Related	
Structures	Nuclear Grade	Industrial Grade	Industrial Grade
Factory Equipment	Nuclear Grade	As Specified	Industrial Grade
Site Material	Nuclear Grade	Nuclear Grade	Industrial Grade
Site Labor	Nuclear Grade	Nuclear Grade	Industrial Grade

TABLE 2-2

PREFERENTIAL AND DISCRETIONARY ITEMS EXCLUDED FROM BASE CONSTRUCTION COSTS

- o Allowance for funds used during construction
- o Escalation
- o Contingency
- o Owner's discretionary items
  - Switchyard and transmission costs
  - Generator stepup transformer
  - Initial fuel supply

TABLE 2-3

1987 COMPOSITE LABOR CREWS AND RATES

EFFECTIVE DATE: JANUARY 1, 1987

COMPOSITE CREWS

Craft	Wage rate $/hr	Concrete Formwork rebar, embeds concrete		Structural Str. steel, misc. iron & archtectural		Earthwork Clearing excava., backfill		Mechanical equipment Installation		Piping Installation		Electrical & Instrumentation Installation	
		%	$/hr	%	$/hr	%	$/hr	%	$/hr	%	$/hr	%	$/hr
Boiler maker	$23.10							20	$4.62				
Carpenter	$21.19	40	$8.48	5	$1.06			5	$1.06	5	$1.06		
Electrician	$24.66							10	$2.47			95	$23.43
Iron Worker	$23.95	20	$4.79	75	$17.96			5	$1.20				
Laborer	$16.95	30	$5.09	5	$0.85	80	$13.56	5	$0.85	5	$0.85		
Millwright	$24.55							25	$6.14				
Operating Engr.	$21.94	5	$1.10	15	$3.29	15	$3.29	5	$1.10	5	$1.10		
Pipefitter	$25.33							25	$6.33	85	$21.53	5	$1.27
Teamster	$16.50					5	$0.83						
Others	$20.41	5	$1.02										
		100	$20.47	100	$23.16	100	$17.68	100	$23.76	100	$24.53	100	$24.69

TABLE 2-4
SUMMARY OF ESTIMATED OWNER'S COST
ACCOUNT 94
(1987$)

EEDB ACCOUNT NUMBER	DESCRIPTION	PH 1 LEAD PLANT COSTS,M$	% OF TOTAL	PH 2 LEAD PLANT COSTS,M$	% OF TOTAL	LEAD PLANT TOTAL COSTS,M$	% OF TOTAL	REPLICA PLANT COSTS,M$	% OF TOTAL	NOAK PLANT COSTS,M$	% OF TOTAL	LG NOAK PLANT COSTS,M$	% OF TOTAL
941.201	ENGINEERING/SITE MANAGEMENT	9.67		6.79		16.46		9.67		9.67		14.47	
941.202	QUALITY ASSURANCE	3.80		2.73		6.53		3.80		3.80		5.74	
941.203	PROJECT LICENSING	3.24		1.57		4.81		3.24		3.24		4.19	
941.204	PROJECT MANAGEMENT & CONTROL	5.26		2.88		8.14		5.26		5.26		7.24	
941	PROJECT MANAGEMENT	21.97	29%	13.96	21%	35.93	25%	21.97	19%	21.97	19%	31.64	16%
942.201	SALES AND PROPERTY TAXES	24.05		25.26		49.31		45.04		42.26		80.01	
942.202	LICENSING FEES AND PERMITS	5.00		0.00		5.00		5.00		5.00		5.00	
943.203	INSURANCE	1.00		2.50		3.50		3.50		3.50		5.00	
942	FEES, TAXES AND INSURANCE	30.05	40%	27.76	42%	57.81	41%	53.54	45%	50.76	45%	90.01	46%
943.201	INITIAL SPARE PARTS INVENTORY	4.00		6.00		10.00		10.00		10.00		18.00	
943.202	CONSUMABLES, SUPPLIES & COOLANTS	0.44		0.92		1.36		1.36		1.36		2.60	
943.203	PLANT EQUIPMENT AND FURNISHINGS	2.00		1.25		3.25		3.25		3.15		6.15	
943	SPARE PARTS AND CAPITAL EQUIPMENT	6.44	9%	8.17	12%	14.61	10%	14.61	12%	14.51	13%	26.75	14%
944.201	SITE STAFF	6.30		6.30		12.60		11.40		10.20		18.60	
944.202	MAINTENANCE MATERIALS	2.00		1.90		3.90		3.60		3.30		6.60	
944.203	STAFF TRAINING, SUPPLIES & EXPENSES	2.80		2.70		5.50		5.00		4.50		9.00	
944	STAFF TRAINING AND START-UP	11.10	15%	10.90	17%	22.00	16%	20.00	17%	18.00	16%	34.20	17%
945.201	GENERAL AND ADMINISTRATIVE	5.93	8%	4.95	8%	10.88	8%	8.49	7%	8.17	7%	13.89	7%
	TOTAL OWNER'S COST:	75.48	100%	65.75	100%	141.23	100%	118.61	100%	113.41	100%	196.49	100%
	% OF OTHER BASE CONSTRUCTION COSTS	17.69%		15.39%		16.54%		15.28%		15.66%		14.22%	

Table 2-5a

MHTGR LEAD PLANT - PHASE 1 BASE CONSTRUCTION COSTS

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL NI	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL ECA	TOTAL ESTIMATE
20	LAND & LAND RIGHTS	0.00	0	0.00	0.00	0.00	0.00	0	0.00	2.00	2.00	2.00
21	STRUCTURES & IMPROVEMENTS	8.22	1066	22.12	19.25	49.59	6.61	536	12.10	6.19	24.90	74.49
22	REACTOR PLANT EQUIPMENT	116.26	252	6.10	2.19	124.54	0.36	13	0.32	0.00	0.68	125.22
23	TURBINE PLANT EQUIPMENT	0.00	0	0.00	0.00	0.00	53.76	378	8.97	0.72	63.46	63.46
24	ELECTRIC PLANT EQUIPMENT	5.04	233	5.75	0.26	11.06	9.85	228	5.62	0.58	16.05	27.11
25	MISCELLANEOUS PLANT EQUIPMENT	0.25	37	0.90	2.57	3.72	4.41	93	2.26	0.16	6.83	10.55
26	MAIN CONDENSER HEAT REJECTION	0.00	0	0.00	0.00	0.00	9.60	294	6.49	2.04	18.12	18.12
	TOTAL DIRECT COST AND MANHOURS	129.77	1589	34.87	24.27	188.91	84.58	1542	35.75	11.70	132.03	320.95
91	CONSTRUCTION SERVICES	0.00	0	12.00	5.14	17.15	9.65	0	20.50	0.00	30.15	47.30
92	HOME OFFICE ENGINEERING AND SERVICE	15.20	0	10.87	0.00	26.07	3.05	0	12.13	0.00	15.18	41.25
93	FIELD OFFICE & SERVICE	0.00	0	5.91	1.12	7.03	3.51	0	6.66	0.00	10.17	17.20
94	OWNER'S COST	0.00	0	0.00	0.00	0.00	0.00	0	36.20	39.29	75.49	75.49
	TOTAL INDIRECT COST	15.20	0	28.78	6.27	50.24	16.21	0	75.49	39.29	130.99	181.24
	TOTAL BASE CONSTRUCTION COST AND MANHOURS	144.97	1589	63.65	30.54	239.16	100.80	1542	111.25	50.99	263.03	502.19

Table 2-5b

MHTGR LEAD PLANT - PHASE 2 BASE CONSTRUCTION COSTS

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	NI SITE LABOR HOURS	NI SITE LABOR COST	NI SITE MATERIAL	TOTAL NI	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	ECA SITE LABOR HOURS	ECA SITE LABOR COST	ECA SITE MATERIAL	TOTAL ECA	TOTAL ESTIMATE
20	LAND & LAND RIGHTS	0.00	0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
21	STRUCTURES & IMPROVEMENTS	7.33	749	15.57	15.45	38.34	2.47	88	2.04	0.23	4.73	43.08
22	REACTOR PLANT EQUIPMENT	183.29	365	8.85	2.23	194.36	0.83	31	0.75	0.00	1.58	195.94
23	TURBINE PLANT EQUIPMENT	0.00	0	0.00	0.00	0.00	53.58	357	8.56	0.29	62.43	62.43
24	ELECTRIC PLANT EQUIPMENT	4.75	262	6.47	0.26	11.48	8.57	217	5.36	0.55	14.49	25.97
25	MISCELLANEOUS PLANT EQUIPMENT	0.00	9	0.22	0.32	0.54	0.98	40	0.99	0.07	2.04	2.58
26	MAIN CONDENSER HEAT REJECTION	0.00	0	0.00	0.00	0.00	3.61	66	1.46	0.37	5.45	5.45
	TOTAL DIRECT COST AND MANHOURS	195.37	1386	31.11	18.25	244.73	70.04	799	19.16	1.51	90.72	335.45
91	CONSTRUCTION SERVICES	0.00	0	13.09	5.61	18.70	4.14	0	8.79	0.00	12.92	31.63
92	HOME OFFICE ENGINEERING AND SERVICE	28.10	0	10.76	0.00	38.86	2.12	0	7.80	0.00	9.92	48.78
93	FIELD OFFICE & SERVICE	0.00	0	5.94	1.13	7.08	1.50	0	2.86	0.00	4.36	11.43
94	OWNER'S COST	0.00	0	0.00	0.00	0.00	0.00	0	27.12	38.63	65.75	65.75
	TOTAL INDIRECT COST	28.10	0	29.80	6.74	64.64	7.76	0	46.56	38.63	92.95	157.60
TOTAL BASE CONSTRUCTION COST AND MANHOURS		223.47	1386	60.91	25.00	309.38	77.80	799	65.72	40.14	183.67	493.04

Table 2-5c

MHTGR REPLICA PLANT BASE CONSTRUCTION COSTS

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	NI SITE LABOR HOURS	NI SITE LABOR COST	NI SITE MATERIAL	TOTAL NI	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	ECA SITE LABOR HOURS	ECA SITE LABOR COST	ECA SITE MATERIAL	TOTAL ECA	TOTAL ESTIMATE
20	LAND & LAND RIGHTS	0.00	0	0.00	0.00	0.00	0.00	0	0.00	2.00	2.00	2.00
21	STRUCTURES & IMPROVEMENTS	14.50	1775	36.86	34.70	86.05	9.08	577	13.08	6.36	28.52	114.57
22	REACTOR PLANT EQUIPMENT	264.04	603	14.59	4.41	283.04	1.19	43	1.01	0.00	2.20	285.24
23	TURBINE PLANT EQUIPMENT	0.00	0	0.00	0.00	0.00	107.35	696	16.61	1.01	124.97	124.97
24	ELECTRIC PLANT EQUIPMENT	9.79	469	11.57	0.53	21.89	18.42	422	10.41	1.14	29.97	51.85
25	MISCELLANEOUS PLANT EQUIPMENT	0.25	46	1.10	2.89	4.24	5.38	126	3.09	0.23	8.70	12.94
26	MAIN CONDENSER HEAT REJECTION	0.00	0	0.00	0.00	0.00	13.24	341	7.53	2.38	23.15	23.15
	TOTAL DIRECT COST AND MANHOURS	288.58	2892	64.11	42.52	395.21	154.65	2205	51.73	13.12	219.50	614.71
91	CONSTRUCTION SERVICES	0.00	0	22.87	9.80	32.67	13.00	0	27.61	0.00	40.61	73.27
92	HOME OFFICE ENGINEERING AND SERVICE	24.40	0	21.20	0.00	45.60	3.10	0	12.60	0.00	15.70	61.30
93	FIELD OFFICE & SERVICE	0.00	0	11.31	2.15	13.47	4.73	0	8.97	0.00	13.70	27.17
94	OWNER'S COST	0.00	0	0.00	0.00	0.00	0.00	0	45.46	73.15	118.61	118.61
	TOTAL INDIRECT COST	24.40	0	55.38	11.95	91.74	20.83	0	94.64	73.15	188.61	280.35
TOTAL BASE CONSTRUCTION COST AND MANHOURS		312.98	2892	119.50	54.48	486.95	175.48	2205	146.36	86.27	408.11	895.07

Table 2-5d

MHTGR NOAK PLANT BASE CONSTRUCTION COSTS

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	NI SITE LABOR HOURS	NI SITE LABOR COST	NI SITE MATERIAL	NI TOTAL	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	ECA SITE LABOR HOURS	ECA SITE LABOR COST	ECA SITE MATERIAL	ECA TOTAL	TOTAL ESTIMATE
20	LAND & LAND RIGHTS	0.00	0	0.00	0.00	0.00	0.00	0	0.00	2.00	2.00	2.00
21	STRUCTURES & IMPROVEMENTS	12.74	1703	35.35	34.70	82.78	9.08	548	12.42	6.36	27.86	110.64
22	REACTOR PLANT EQUIPMENT	236.82	579	14.00	4.41	255.23	1.19	40	0.96	0.00	2.15	257.38
23	TURBINE PLANT EQUIPMENT	0.00	0	0.00	0.00	0.00	107.35	661	15.78	1.01	124.14	124.14
24	ELECTRIC PLANT EQUIPMENT	9.79	446	11.00	0.53	21.32	18.42	401	9.88	1.14	29.44	50.76
25	MISCELLANEOUS PLANT EQUIPMENT	0.25	44	1.05	2.89	4.19	5.38	120	2.93	0.23	8.55	12.74
26	MAIN CONDENSER HEAT REJECTION	0.00	0	0.00	0.00	0.00	13.24	324	7.15	2.38	22.77	22.77
	TOTAL DIRECT COST AND MANHOURS	259.60	2771	61.40	42.52	363.52	154.65	2094	49.13	13.12	216.90	580.42
91	CONSTRUCTION SERVICES	0.00	0	22.16	9.50	31.66	12.35	0	26.23	0.00	38.58	70.23
92	HOME OFFICE ENGINEERING AND SERVICE	13.00	0	20.54	0.00	33.54	2.98	0	11.23	0.00	14.21	47.75
93	FIELD OFFICE & SERVICE	0.00	0	10.91	2.08	12.98	4.49	0	8.52	0.00	13.01	26.00
94	OWNER'S COST	0.00	0	0.00	0.00	0.00	0.00	0	43.64	69.77	113.41	113.41
	TOTAL INDIRECT COST	13.00	0	53.60	11.57	78.18	19.82	0	89.62	69.77	179.21	257.38
TOTAL BASE CONSTRUCTION COST AND MANHOURS		272.60	2771	115.00	54.09	441.70	174.47	2094	138.75	82.89	396.11	837.81

Table 2-5e

MHTGR LARGE NOAK PLANT BASE CONSTRUCTION COSTS

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	NI SITE LABOR HOURS	NI SITE LABOR COST	NI SITE MATERIAL	NI TOTAL	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	ECA SITE LABOR HOURS	ECA SITE LABOR COST	ECA SITE MATERIAL	ECA TOTAL	TOTAL ESTIMATE
20	LAND & LAND RIGHTS	0.00	0	0.00	0.00	0.00	0.00	0	0.00	3.00	3.00	3.00
21	STRUCTURES & IMPROVEMENTS	25.48	3396	70.49	68.99	164.96	17.46	1013	22.96	11.02	51.44	216.40
22	REACTOR PLANT EQUIPMENT	436.22	1144	27.66	8.69	472.56	2.38	81	1.92	0.00	4.30	476.86
23	TURBINE PLANT EQUIPMENT	0.00	0	0.00	0.00	0.00	214.69	1322	31.56	2.02	248.27	248.27
24	ELECTRIC PLANT EQUIPMENT	19.58	891	22.00	1.05	42.63	36.84	801	19.77	2.28	58.88	101.51
25	MISCELLANEOUS PLANT EQUIPMENT	0.50	87	2.11	5.78	8.38	10.77	240	5.86	0.46	17.09	25.48
26	MAIN CONDENSER HEAT REJECTION	0.00	0	0.00	0.00	0.00	26.48	647	14.31	4.76	45.54	45.54
	TOTAL DIRECT COST AND MANHOURS	481.77	5518	122.26	84.51	688.54	308.62	4104	96.37	23.53	428.52	1117.07
91	CONSTRUCTION SERVICES	0.00	0	43.67	18.72	62.38	24.33	0	51.66	0.00	75.99	138.37
92	HOME OFFICE ENGINEERING AND SERVICE	15.50	0	36.97	0.00	52.47	4.47	0	17.46	0.00	21.93	74.40
93	FIELD OFFICE & SERVICE	0.00	0	22.06	4.20	26.26	8.84	0	16.80	0.00	25.64	51.90
94	OWNER'S COST	0.00	0	0.00	0.00	0.00	0.00	0	70.73	125.76	196.49	196.49
	TOTAL INDIRECT COST	15.50	0	102.70	22.92	141.11	37.64	0	156.65	125.76	320.05	461.17
TOTAL BASE CONSTRUCTION COST AND MANHOURS		497.27	5518	224.96	107.42	829.66	346.26	4104	253.02	149.29	748.58	1578.23

TABLE 2-6a
SUMMARY OF BASE CONSTRUCTION COSTS - NI
4 x 350 MW(t) MODULAR HTGR
(1987$)

EEDB ACCOUNT NO.	NUCLEAR ISLAND	LEAD PLANT COST (M$)	LEAD PLANT % OF TOTAL	REPLICA PLANT COST (M$)	REPLICA PLANT % OF TOTAL	NOAK PLANT COST (M$)	NOAK PLANT % OF TOTAL	% CHANGE LEAD TO NOAK
21	STRUCTURES & IMPROVEMENTS	87.9	8.85%	86.1	9.61%	82.8	9.88%	-5.86%
22	REACTOR PLANT EQUIPMENT	318.9	32.10%	283.0	31.62%	255.2	30.46%	-19.97%
23	TURBINE PLANT EQUIPMENT	0.0	0.00%	0.0	0.00%	0.0	0.00%	
24	ELECTRIC PLANT EQUIPMENT	22.5	2.27%	21.9	2.45%	21.3	2.54%	-5.43%
25	MISCELLANEOUS PLANT EQUIPMENT	4.3	0.43%	4.2	0.47%	4.2	0.50%	-1.60%
26	MAIN CONDENSER HEAT REJECTION	0.0	0.00%	0.0	0.00%	0.0	0.00%	
	TOTAL DIRECT COST	433.6	43.65%	395.2	44.15%	363.5	43.38%	-16.17%
91	CONSTRUCTION SERVICES	35.9	3.61%	32.7	3.65%	31.7	3.78%	-11.70%
92	HOME OFFICE ENGINEERING AND SERVICE	64.9	6.54%	45.6	5.09%	33.5	4.00%	-48.35%
93	FIELD OFFICE SUPERVISION & SERVICE	14.1	1.42%	13.5	1.50%	13.0	1.55%	-7.95%
94	OWNER'S COST (ALLOCATED TO ECA)	0.0	0.00%	0.0	0.00%	0.0	0.00%	
	TOTAL INDIRECT COST	114.9	11.56%	91.7	10.25%	78.2	9.33%	-31.96%
	BASE CONSTRUCTION COST - TOTAL $	548.5	55.21%	487.0	54.40%	441.7	52.71%	-19.48%

TABLE 2-6b
SUMMARY OF BASE CONSTRUCTION COSTS
4 x 350 MW(t) MODULAR HTGR
(1987$)

	ENERGY CONVERSION AREA	LEAD PLANT COST (M$)	LEAD PLANT % OF TOTAL	REPLICA PLANT COST (M$)	REPLICA PLANT % OF TOTAL	NOAK PLANT COST (M$)	NOAK PLANT % OF TOTAL	% CHANGE LEAD TO NOAK
20	LAND & LAND RIGHTS	2.0	0.20%	2.0	0.22%	2.0	0.24%	0.00%
21	STRUCTURES & IMPROVEMENTS	29.6	2.98%	28.5	3.19%	27.9	3.33%	-5.97%
22	REACTOR PLANT EQUIPMENT	2.3	0.23%	2.2	0.25%	2.1	0.26%	-4.75%
23	TURBINE PLANT EQUIPMENT	125.9	12.65%	125.0	13.96%	124.1	14.82%	-1.39%
24	ELECTRIC PLANT EQUIPMENT	30.5	3.07%	30.0	3.35%	29.4	3.51%	-3.60%
25	MISCELLANEOUS PLANT EQUIPMENT	8.9	0.89%	8.7	0.97%	8.5	1.02%	-3.66%
26	MAIN CONDENSER HEAT REJECTION	23.6	2.37%	23.1	2.59%	22.8	2.72%	-3.37%
	TOTAL DIRECT COST	222.8	22.38%	219.5	24.52%	216.9	25.89%	-2.63%
91	CONSTRUCTION SERVICES	43.1	4.33%	40.6	4.54%	38.6	4.60%	-10.45%
92	HOME OFFICE ENGINEERING AND SERVICE	25.1	2.52%	15.7	1.75%	14.2	1.70%	-43.39%
93	FIELD OFFICE SUPERVISION & SERVICE	14.5	1.46%	13.7	1.53%	13.0	1.55%	-10.44%
94	OWNER'S COST	141.2	14.19%	118.6	13.25%	113.4	13.54%	-19.70%
	TOTAL INDIRECT COST	223.9	22.50%	188.6	21.07%	179.2	21.39%	-19.97%
	BASE CONSTRUCTION COST - TOTAL $	446.7	44.88%	408.1	45.60%	396.1	47.28%	-11.32%

TABLE 2-6c
SUMMARY OF BASE CONSTRUCTION COSTS
4 x 350 MW(t) MODULAR HTGR
(1987$)

EEDB ACCOUNT NO.	TOTAL PLANT	LEAD PLANT COST (M$)	LEAD PLANT % OF TOTAL	REPLICA PLANT COST (M$)	REPLICA PLANT % OF TOTAL	NOAK PLANT COST (M$)	NOAK PLANT % OF TOTAL	% CHANGE LEAD TO NOAK
20	LAND & LAND RIGHTS	2.0	0.20%	2.0	0.22%	2.0	0.24%	0.00%
21	STRUCTURES & IMPROVEMENTS	117.6	11.81%	114.6	12.80%	110.6	13.21%	-5.89%
22	REACTOR PLANT EQUIPMENT	321.2	32.27%	285.2	31.87%	257.4	30.72%	-19.86%
23	TURBINE PLANT EQUIPMENT	125.9	12.65%	125.0	13.96%	124.1	14.82%	-1.39%
24	ELECTRIC PLANT EQUIPMENT	53.1	5.33%	51.9	5.79%	50.8	6.06%	-4.37%
25	MISCELLANEOUS PLANT EQUIPMENT	13.1	1.32%	12.9	1.45%	12.7	1.52%	-2.99%
26	MAIN CONDENSER HEAT REJECTION	23.6	2.37%	23.1	2.59%	22.8	2.72%	-3.37%
	TOTAL DIRECT COST	656.4	65.95%	614.7	68.68%	580.4	69.28%	-11.57%
91	CONSTRUCTION SERVICES	78.9	7.93%	73.3	8.19%	70.2	8.38%	-11.02%
92	HOME OFFICE ENGINEERING AND SERVICE	90.0	9.05%	61.3	6.85%	47.7	5.70%	-46.97%
93	FIELD OFFICE SUPERVISION & SERVICE	28.6	2.88%	27.2	3.04%	26.0	3.10%	-9.22%
94	OWNER'S COST	141.2	14.19%	118.6	13.25%	113.4	13.54%	-19.70%
	TOTAL INDIRECT COST	338.8	34.05%	280.4	31.32%	257.4	30.72%	-24.04%
	BASE CONSTRUCTION COST - TOTAL $	995.2	100.00%	895.1	100.00%	837.8	100.00%	-15.82%

TABLE 2-7
SUMMARY OF BASE CONSTRUCTION FACTORY EQUIPMENT COSTS
4 x 350 MW(t) MODULAR HTGR
(1987$)

EEDB ACCOUNT NO.	NUCLEAR ISLAND	LEAD PLANT COST (M$)	LEAD PLANT % OF TOTAL	REPLICA PLANT COST (M$)	REPLICA PLANT % OF TOTAL	NOAK PLANT COST (M$)	NOAK PLANT % OF TOTAL	% CHANGE LEAD TO NOAK
21	STRUCTURES & IMPROVEMENTS	15.6	3.2%	14.5	3.3%	12.7	3.1%	-18.1%
22	REACTOR PLANT EQUIPMENT	299.5	62.4%	264.0	59.6%	236.8	57.2%	-20.9%
23	TURBINE PLANT EQUIPMENT	0.0	0.0%	0.0	0.0%	0.0	0.0%	
24	ELECTRIC PLANT EQUIPMENT	9.8	2.0%	9.8	2.2%	9.8	2.4%	0.0%
25	MISCELLANEOUS PLANT EQUIPMENT	0.2	0.1%	0.2	0.1%	0.2	0.1%	0.0%
26	MAIN CONDENSER HEAT REJECTION	0.0	0.0%	0.0	0.0%	0.0	0.0%	
	TOTAL FACTORY EQUIPMENT COST	325.1	67.8%	288.6	65.1%	259.6	62.7%	-20.2%
	ENERGY CONVERSION AREA							
21	STRUCTURES & IMPROVEMENTS	9.1	1.9%	9.1	2.0%	9.1	2.2%	0.0%
22	REACTOR PLANT EQUIPMENT	1.2	0.2%	1.2	0.3%	1.2	0.3%	0.0%
23	TURBINE PLANT EQUIPMENT	107.3	22.4%	107.3	24.2%	107.3	25.9%	0.0%
24	ELECTRIC PLANT EQUIPMENT	18.4	3.8%	18.4	4.2%	18.4	4.4%	0.0%
25	MISCELLANEOUS PLANT EQUIPMENT	5.4	1.1%	5.4	1.2%	5.4	1.3%	0.0%
26	MAIN CONDENSER HEAT REJECTION	13.2	2.8%	13.2	3.0%	13.2	3.2%	0.2%
	TOTAL FACTORY EQUIPMENT COST	154.6	32.2%	154.7	34.9%	154.7	37.3%	0.0%
	TOTAL PLANT							
21	STRUCTURES & IMPROVEMENTS	24.6	5.1%	23.6	5.3%	21.8	5.3%	-11.4%
22	REACTOR PLANT EQUIPMENT	300.7	62.7%	265.2	59.8%	238.0	57.5%	-20.9%
23	TURBINE PLANT EQUIPMENT	107.3	22.4%	107.3	24.2%	107.3	25.9%	0.0%
24	ELECTRIC PLANT EQUIPMENT	28.2	5.9%	28.2	6.4%	28.2	6.8%	0.0%
25	MISCELLANEOUS PLANT EQUIPMENT	5.6	1.2%	5.6	1.3%	5.6	1.4%	0.0%
26	MAIN CONDENSER HEAT REJECTION	13.2	2.8%	13.2	3.0%	13.2	3.2%	0.2%
	TOTAL FACTORY EQUIPMENT COST	479.8	100.0%	443.2	100.0%	414.3	100.0%	-13.7%
	% OF TOTAL BASE CONSTRUCTION COST		48.3%		49.5%		49.4%	

TABLE 2-8
SUMMARY OF BASE CONSTRUCTION SITE MATERIAL COSTS
4 x 350 MW(t) MODULAR HTGR
(1987$)

EEDB ACCOUNT NO.		LEAD PLANT COST (M$)	LEAD PLANT % OF TOTAL	REPLICA PLANT COST (M$)	REPLICA PLANT % OF TOTAL	NOAK PLANT COST (M$)	NOAK PLANT % OF TOTAL	% CHANGE LEAD TO NOAK
21	STRUCTURES & IMPROVEMENTS	34.70	62.2%	34.70	62.3%	34.70	62.4%	0.0%
22	REACTOR PLANT EQUIPMENT	4.42	7.9%	4.41	7.9%	4.41	7.9%	-0.2%
23	TURBINE PLANT EQUIPMENT	0.00	0.0%	0.00	0.0%	0.00	0.0%	
24	ELECTRIC PLANT EQUIPMENT	0.53	0.9%	0.54	1.0%	0.53	0.9%	0.0%
25	MISCELLANEOUS PLANT EQUIPMENT	2.89	5.2%	2.89	5.2%	2.89	5.2%	0.0%
26	MAIN CONDENSER HEAT REJECTION	0.00	0.0%	0.00	0.0%	0.00	0.0%	
	TOTAL SITE MATERIAL COST	42.53	76.3%	42.53	76.4%	42.52	76.4%	0.0%
	ENERGY CONVERSION AREA							
20	LAND & LAND RIGHTS	2.00	3.6%	2.00	3.6%	2.00	3.6%	0.0%
21	STRUCTURES & IMPROVEMENTS	6.42	11.5%	6.36	11.4%	6.36	11.4%	-0.9%
22	REACTOR PLANT EQUIPMENT	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.0%
23	TURBINE PLANT EQUIPMENT	1.02	1.8%	1.01	1.8%	1.01	1.8%	-0.6%
24	ELECTRIC PLANT EQUIPMENT	1.14	2.0%	1.14	2.0%	1.14	2.0%	0.0%
25	MISCELLANEOUS PLANT EQUIPMENT	0.23	0.4%	0.23	0.4%	0.23	0.4%	0.0%
26	MAIN CONDENSER HEAT REJECTION	2.41	4.3%	2.38	4.3%	2.38	4.3%	-1.1%
	TOTAL SITE MATERIAL COST	13.21	23.7%	13.12	23.6%	13.12	23.6%	-0.7%
	TOTAL PLANT							
20	LAND & LAND RIGHTS	2.00	3.6%	2.00	3.6%	2.00	3.6%	0.0%
21	STRUCTURES & IMPROVEMENTS	41.11	73.8%	41.05	73.8%	41.05	73.8%	-0.1%
22	REACTOR PLANT EQUIPMENT	4.42	7.9%	4.41	7.9%	4.41	7.9%	-0.2%
23	TURBINE PLANT EQUIPMENT	1.02	1.8%	1.01	1.8%	1.01	1.8%	-0.6%
24	ELECTRIC PLANT EQUIPMENT	1.66	3.0%	1.67	3.0%	1.66	3.0%	0.0%
25	MISCELLANEOUS PLANT EQUIPMENT	3.12	5.6%	3.12	5.6%	3.12	5.6%	0.0%
26	MAIN CONDENSER HEAT REJECTION	2.41	4.3%	2.38	4.3%	2.38	4.3%	-1.1%
	TOTAL SITE MATERIAL COST	55.74	100.0%	55.65	100.0%	55.64	100.0%	-0.2%
	% OF TOTAL BASE CONSTRUCTION COST		5.6%		6.2%		6.6%	

Table 2-9

REACTOR PLANT EQUIPMENT PRICE ESTIMATES 4X350 MWt LEAD, REPLICA, NOAK AND LARGE NOAK PLANT
(JANUARY 1, 1987 $ MILLIONS)

ACCT.	DIRECT COSTS RM BASE SCOPE EQUIPMENT	LEAD PLANT	REPLICA PLANT	NOAK PLANT	LARGE NOAK PLANT
221.1	REACTOR SYSTEM				
221.11	NEUTRON CONTROL	14.300	13.300	11.300	22.600
221.12	REACTOR INTERNALS				
221.121	GRAPHITE REACTOR INTERNALS	28.600	22.900	20.900	41.900
221.122	METALLIC REACTOR INTERNALS	22.600	19.400	17.600	35.000
221.13	REACTOR CORE (W/O FUEL)	12.200	9.600	8.700	17.500
221.1	STEEL VESSEL SYSTEM				
222.111	REACTOR VESSEL & CROSS DUCT	47.500	42.000	37.900	75.800
222.112	STEAM GENERATOR PRESSURE VESSEL	20.400	18.000	16.200	32.400
222.12	REACTOR PRESSURE RELIEF	2.800	2.600	2.200	4.500
222.13	VESSEL SUPPORTS	4.300	3.800	3.400	6.900
223.1	HEAT TRANSPORT SYSTEM				
223.11	MAIN HELIUM CIRCULATOR	19.900	16.800	14.700	29.300
223.12	STEAM GENERATOR	29.300	26.900	23.000	46.000
225.1	SHUTDOWN COOLING SYSTEM				
225.11	SHUTDOWN CIRCULATOR	3.400	2.900	2.500	5.000
225.12	SHUTDOWN COOLING HEAT EXCHANGER	4.500	3.800	3.300	6.600
225.13	SHUTDOWN COOLING HEAT REMOVAL CONTROL	1.500	1.200	1.100	2.200
226.1	FUEL HANDLING, STORAGE & SHIPPING				
226.11	CORE REFUELING	23.000	21.000	19.100	19.100
226.12	SITE FUEL HANDLING	2.600	2.400	2.200	2.400
227.1	REACTOR SERVICE SYSTEM				
227.11	HELIUM PURIFICATION	2.700	2.600	2.300	4.600
227.162	REACTOR SERVICE EQUIPMENT	11.000	10.100	9.300	9.500
228.1	PLANT CONTROL DATA & INSTRUMENTATION SYS				
228.12	NSSS CONTROL	2.500	2.300	2.200	4.500
228.14	PLANT PROTECTION & INSTRUMENTATION SYS				
228.141	SAFETY PROTECTION	1.200	1.100	1.100	2.100
228.142	INVESTMENT PROTECTION & INSTRUMENTATION	1.500	1.500	1.400	2.900
228.143	SPECIAL NUCLEAR AREA INSTRUMENTATION	1.300	1.300	1.300	2.500
228.15	MISCELLANEOUS CONTROL & INSTRUMENTATION				
228.152	NI ANALYTICAL INSTRUMENTATION	.400	.400	.400	.700
229.1	REACTOR PLANT MISCELLANEOUS ITEMS				
229.11	CHECKOUT & STARTUP TEST EQUIPMENT	3.200	.700	.600	.600
229.12	MAINTENANCE MONITORING & ISI EQUIPMENT	1.500	1.300	1.100	1.100
229.13	TRANSPORTATION OF MAJOR EQUIPMENT	7.000	7.000	7.000	11.000
	TOTAL RM DIRECT EQUIPMENT COSTS	269.200	234.900	210.800	386.700

TABLE 2-10a
MHTGR NOAK PLANT BULK COMMODITY REPORT
(THOUSANDS)

BULK COMMODITY	UNITS	ACCT 21 NI	ACCT 21 ECA	ACCT 22 NI	ACCT 23 ECA	ACCT 24 NI	ACCT 24 ECA	ACCT 25 NI	ACCT 25 ECA	ACCT 26 ECA	TOTAL NI	TOTAL ECA	TOTAL PLANT
FORMWORK	SF	638.438	29.226	0.000	45.270	0.000	0.000	0.000	0.140	64.935	638.438	139.571	778.009
STRUCTURAL STEEL	TN	1.670	2.145	0.000	0.000	0.000	0.000	0.000	0.000	0.004	1.670	2.149	3.819
REINFORCING STEEL	TN	11.648	0.908	0.000	0.581	0.000	0.000	0.000	0.001	0.828	11.648	2.318	13.966
EMBEDDED STEEL	LB	464.890	40.390	0.000	56.370	0.000	0.000	0.000	0.075	5.700	464.890	102.535	567.425
STRUCTURAL CONCRETE	CY	94.809	12.834	0.000	7.741	0.000	0.000	0.000	0.003	11.125	94.809	31.703	126.512
CS < 2.5 IN PIPE	LF	0.000	0.000	0.000	5.690	3.617	2.855	3.500	8.050	0.000	7.117	16.595	23.712
SS < 2.5 IN PIPE	LF	0.000	0.000	2.000	1.000	0.000	0.000	0.000	9.000	5.597	2.000	15.597	17.597
CS > 2.5 IN PIPE	LF	0.000	0.000	0.000	24.269	0.000	0.000	4.500	4.700	15.800	4.500	44.769	49.269
SS > 2.5 IN PIPE	LF	0.000	0.000	0.150	1.250	0.000	0.000	0.000	0.000	0.000	0.150	1.250	1.400
CM > 2.5 IN PIPE	LF	0.000	0.000	0.000	5.910	0.000	0.000	0.000	0.000	0.000	0.000	5.910	5.910
WIRE AND CABLE	LF	0.000	0.000	177.000	0.000	1327.300	1338.700	0.000	0.000	0.000	1504.300	1338.700	2843.000
WIRE AND CABLE DUCT	LF	0.000	0.000	16.500	0.000	101.000	315.000	0.000	0.000	0.000	117.500	315.000	432.500

TABLE 2-10b
MHTGR LARGE NOAK PLANT BULK COMMODITY REPORT
(THOUSANDS)

BULK COMMODITY	UNITS	ACCT 21 NI	ACCT 21 ECA	ACCT 22 NI	ACCT 23 ECA	ACCT 24 NI	ACCT 24 ECA	ACCT 25 NI	ACCT 25 ECA	ACCT 26 ECA	TOTAL NI	TOTAL ECA	TOTAL PLANT
FORMWORK	SF	1274.126	51.987	0.000	90.540	0.000	0.000	0.000	0.280	129.870	1274.126	272.677	1546.803
STRUCTURAL STEEL	TN	3.224	4.290	0.000	0.000	0.000	0.000	0.000	0.000	0.008	3.224	4.298	7.522
REINFORCING STEEL	TN	23.246	1.674	0.000	1.162	0.000	0.000	0.000	0.002	1.656	23.246	4.494	27.740
EMBEDDED STEEL	LB	928.460	64.757	0.000	112.740	0.000	0.000	0.000	0.150	11.400	928.460	189.047	1117.507
STRUCTURAL CONCRETE	CY	188.958	23.574	0.000	15.482	0.000	0.000	0.000	0.006	22.250	188.958	61.312	250.270
CS < 2.5 IN PIPE	LF	0.000	0.000	0.000	11.380	3.617	2.855	7.000	16.100	0.000	10.617	30.335	40.952
SS < 2.5 IN PIPE	LF	0.000	0.000	4.000	2.000	0.000	0.000	0.000	18.000	5.597	4.000	25.597	29.597
CS > 2.5 IN PIPE	LF	0.000	0.000	0.000	46.145	0.000	0.000	9.000	9.400	31.600	9.000	87.145	96.145
SS > 2.5 IN PIPE	LF	0.000	0.000	0.300	2.500	0.000	0.000	0.000	0.000	0.000	0.300	2.500	2.800
CM > 2.5 IN PIPE	LF	0.000	0.000	0.000	11.820	0.000	0.000	0.000	0.000	0.000	0.000	11.820	11.820
WIRE AND CABLE	LF	0.000	0.000	354.000	0.000	2614.600	2677.400	0.000	0.000	0.001	2968.600	2677.401	5646.001
[illegible]	LF	0.000	0.000	33.000	0.000	202.000	630.000	0.000	0.000	0.000	235.000	630.000	865.000

TABLE 2-11
SUMMARY OF BASE CONSTRUCTION DIRECT LABOR HOURS
4 x 350 MW(t) MODULAR HTGR
(THOUSANDS OF HOURS)

EEDB ACCOUNT NO.		LEAD PLANT LABOR HOURS	LEAD PLANT % OF TOTAL	REPLICA PLANT LABOR HOURS	REPLICA PLANT % OF TOTAL	NOAK PLANT LABOR HOURS	NOAK PLANT % OF TOTAL	% CHANGE LEAD TO NOAK
	NUCLEAR ISLAND							
21	STRUCTURES & IMPROVEMENTS	1815.5	34.2%	1775.4	34.8%	1702.8	35.0%	-6.2%
22	REACTOR PLANT EQUIPMENT	617.8	11.6%	603.0	11.8%	578.5	11.9%	-6.4%
23	TURBINE PLANT EQUIPMENT	0.0	0.0%	0.0	0.0%	0.0	0.0%	
24	ELECTRIC PLANT EQUIPMENT	495.1	9.3%	468.6	9.2%	445.6	9.2%	-10.0%
25	MISCELLANEOUS PLANT EQUIPMENT	46.5	0.9%	45.5	0.9%	43.7	0.9%	-6.1%
26	MAIN CONDENSER HEAT REJECTION	0.0	0.0%	0.0	0.0%	0.0	0.0%	
	TOTAL SITE DIRECT LABOR HRS	2974.9	56.0%	2892.5	56.7%	2770.6	57.0%	-6.9%
	ENERGY CONVERSION AREA							
21	STRUCTURES & IMPROVEMENTS	623.6	11.7%	577.4	11.3%	548.5	11.3%	-12.0%
22	REACTOR PLANT EQUIPMENT	44.9	0.8%	42.5	0.8%	40.4	0.8%	-10.0%
23	TURBINE PLANT EQUIPMENT	734.3	13.8%	695.7	13.6%	660.9	13.6%	-10.0%
24	ELECTRIC PLANT EQUIPMENT	445.1	8.4%	421.9	8.3%	400.6	8.2%	-10.0%
25	MISCELLANEOUS PLANT EQUIPMENT	133.3	2.5%	126.3	2.5%	120.0	2.5%	-10.0%
26	MAIN CONDENSER HEAT REJECTION	359.6	6.8%	340.7	6.7%	323.7	6.7%	-10.0%
	TOTAL SITE DIRECT LABOR HRS	2340.7	44.0%	2204.5	43.3%	2094.0	43.0%	-10.5%
	TOTAL PLANT							
21	STRUCTURES & IMPROVEMENTS	2439.1	45.9%	2352.8	46.2%	2251.4	46.3%	-7.7%
22	REACTOR PLANT EQUIPMENT	662.7	12.5%	645.5	12.7%	618.9	12.7%	-6.6%
23	TURBINE PLANT EQUIPMENT	734.3	13.8%	695.7	13.6%	660.9	13.6%	-10.0%
24	ELECTRIC PLANT EQUIPMENT	940.2	17.7%	890.6	17.5%	846.1	17.4%	-10.0%
25	MISCELLANEOUS PLANT EQUIPMENT	179.8	3.4%	171.8	3.4%	163.6	3.4%	-9.0%
26	MAIN CONDENSER HEAT REJECTION	359.6	6.8%	340.7	6.7%	323.7	6.7%	-10.0%
	TOTAL SITE DIRECT LABOR HRS	5315.6	100.0%	5097.0	100.0%	4864.6	100.0%	-8.5%

TABLE 2-12a

MHTGR LEAD PLANT - PHASE 1 CRAFT LABOR

(MANHOURS IN THOUSANDS)

DIRECT COST ACCOUNTS

LABOR TYPE	ACCT 20 HRS	ACCT 21 HRS	ACCT 22 HRS	ACCT 23 HRS	ACCT 24 HRS	ACCT 25 HRS	ACCT 26 HRS	TOTAL HRS
BOILERMAKER	0.000	44.667	18.586	30.408	0.104	7.854	16.650	118.269
CARPENTER	0.000	341.827	9.309	32.418	0.102	4.782	43.775	432.213
ELECTRICIAN	0.000	79.742	84.960	43.176	434.848	36.642	16.294	695.663
IRON WORKER	0.000	422.029	28.163	16.663	0.439	2.798	27.648	497.740
LABORER	0.000	412.805	9.309	28.919	1.007	5.437	67.619	525.097
MILLWRIGHT	0.000	55.833	23.232	38.010	0.131	9.818	20.812	147.836
OPERATING ENGINEER	0.000	129.655	12.445	17.575	0.327	4.977	19.105	184.084
PIPEFITTER	0.000	67.264	79.834	168.356	23.841	57.791	75.330	472.417
TEAMSTER	0.000	9.330	0.000	0.050	0.057	0.042	2.054	11.532
OTHERS	0.000	39.152	0.000	2.151	0.000	0.005	4.508	45.816
TOTAL HRS	0.000	1602.305	265.838	377.726	460.855	130.147	293.795	3130.667

TABLE 2-12b
MHTGR LEAD PLANT - PHASE 2 CRAFT LABOR
(MANHOURS IN THOUSANDS)

DIRECT COST ACCOUNTS

LABOR TYPE	ACCT 20 HRS	ACCT 21 HRS	ACCT 22 HRS	ACCT 23 HRS	ACCT 24 HRS	ACCT 25 HRS	ACCT 26 HRS	TOTAL HRS
BOILERMAKER	0.000	10.250	29.763	28.161	0.044	0.390	5.424	74.032
CARPENTER	0.000	230.669	11.705	23.374	0.021	1.706	5.956	273.430
ELECTRICIAN	0.000	28.523	169.503	42.052	454.988	14.964	5.853	715.883
IRON WORKER	0.000	220.266	36.606	11.466	0.011	0.202	4.893	273.444
LABORER	0.000	227.843	11.705	21.377	0.021	1.706	15.290	277.942
MILLWRIGHT	0.000	12.812	37.203	35.201	0.056	0.488	6.780	92.539
OPERATING ENGINEER	0.000	61.455	15.594	16.413	0.021	1.719	4.622	99.824
PIPEFITTER	0.000	14.043	84.780	177.527	24.166	28.482	15.839	344.838
TEAMSTER	0.000	3.276	0.000	0.001	0.000	0.000	0.645	3.922
OTHERS	0.000	27.620	0.000	1.003	0.000	0.000	0.497	29.119
TOTAL HRS	0.000	836.756	396.858	356.573	479.328	49.656	65.799	2184.971

TABLE 2-12c

MHTGR REPLICA PLANT CRAFT LABOR

(MANHOURS IN THOUSANDS)

DIRECT COST ACCOUNTS

LABOR TYPE	ACCT 20 HRS	ACCT 21 HRS	ACCT 22 HRS	ACCT 23 HRS	ACCT 24 HRS	ACCT 25 HRS	ACCT 26 HRS	TOTAL HRS
BOILERMAKER	0.000	52.761	47.066	55.486	0.141	7.957	20.914	184.325
CARPENTER	0.000	556.673	20.483	52.864	0.117	6.218	47.122	683.476
ELECTRICIAN	0.000	104.188	247.599	80.743	842.863	48.978	20.982	1345.353
IRON WORKER	0.000	611.111	63.040	26.653	0.426	2.878	30.832	734.939
LABORER	0.000	623.511	20.483	47.658	0.974	6.841	78.568	778.035
MILLWRIGHT	0.000	65.951	58.833	69.358	0.176	9.946	26.142	230.406
OPERATING ENGINEER	0.000	183.186	27.319	32.201	0.330	6.417	22.483	271.936
PIPEFITTER	0.000	78.015	160.694	327.682	45.473	82.525	86.377	780.767
TEAMSTER	0.000	12.310	0.000	0.048	0.054	0.040	2.558	15.010
OTHERS	0.000	65.063	0.000	2.988	0.000	0.005	4.743	72.799
TOTAL HRS	0.000	2352.769	645.515	695.682	890.554	171.805	340.721	5097.045

TABLE 2-12d
MHTGR NOAK PLANT CRAFT LABOR

(MANHOURS IN THOUSANDS)

DIRECT COST ACCOUNTS

LABOR TYPE	ACCT 20 HRS	ACCT 21 HRS	ACCT 22 HRS	ACCT 23 HRS	ACCT 24 HRS	ACCT 25 HRS	ACCT 26 HRS	TOTAL HRS
BOILERMAKER	0.000	50.327	45.097	52.712	0.134	7.599	19.868	175.737
CARPENTER	0.000	533.438	19.640	50.212	0.111	5.929	44.762	654.091
ELECTRICIAN	0.000	99.467	237.372	76.706	800.808	46.550	19.933	1280.836
IRON WORKER	0.000	583.689	60.545	25.316	0.405	2.744	29.290	701.989
LABORER	0.000	597.705	19.640	45.267	0.926	6.520	74.637	744.695
MILLWRIGHT	0.000	62.908	56.372	65.890	0.168	9.499	24.835	219.672
OPERATING ENGINEER	0.000	175.162	26.210	30.590	0.313	6.117	21.358	259.751
PIPEFITTER	0.000	74.389	154.059	311.300	43.204	78.643	82.054	743.649
TEAMSTER	0.000	11.813	0.000	0.046	0.051	0.038	2.430	14.378
OTHERS	0.000	62.371	0.000	2.838	0.000	0.005	4.505	69.719
TOTAL HRS	0.000	2251.269	618.936	660.877	846.119	163.644	323.672	4864.516

TABLE 2-12e
MHTGR LARGE NOAK PLANT CRAFT LABOR

(MANHOURS IN THOUSANDS)

DIRECT COST ACCOUNTS

LABOR TYPE	ACCT 20 HRS	ACCT 21 HRS	ACCT 22 HRS	ACCT 23 HRS	ACCT 24 HRS	ACCT 25 HRS	ACCT 26 HRS	TOTAL HRS
BOILERMAKER	0.000	99.093	89.744	105.424	0.268	15.199	39.736	349.464
CARPENTER	0.000	1056.307	38.604	100.424	0.222	11.858	89.524	1296.938
ELECTRICIAN	0.000	198.278	474.519	153.412	1601.616	93.099	39.866	2560.789
IRON WORKER	0.000	1114.951	120.978	50.632	0.810	5.489	58.579	1351.439
LABORER	0.000	1184.106	38.604	90.535	1.851	13.040	149.273	1477.409
MILLWRIGHT	0.000	123.866	112.179	131.780	0.335	18.999	49.671	436.830
OPERATING ENGINEER	0.000	338.890	51.743	61.180	0.626	12.235	42.716	507.390
PIPEFITTER	0.000	146.835	297.969	622.599	86.409	157.286	164.108	1475.206
TEAMSTER	0.000	23.472	0.000	0.091	0.102	0.075	4.861	28.601
OTHERS	0.000	123.875	0.000	5.675	0.000	0.010	9.010	138.570
TOTAL HRS	0.000	4409.672	1224.340	1321.753	1692.237	327.288	647.344	9622.635

TABLE 2-13
COMPARISON OF COMMODITY & CRAFT LABOR QUANTITIES
ON A PER UNIT POWER GENERATION BASIS

COMMODITIES:	UNITS(1)	MHTGR NOAK PLANT	PWR-BE 1144MWe PLANT	COAL 488MWe PLANT
FORMWORK	SF/MWe	1447.2	1647.4	1297.4
STRUCTURAL STEEL	TN/MWe	7.1	6.2	30.6
REINFORCING STEEL	TN/MWe	26.0	17.8	7.3
EMBEDDED STEEL	TN/MWe	0.5	1.2	0.5
STRUCTURAL CONCRETE	CY/MWe	235.3	116.5	116.0
PIPING, NUCLEAR GR	LB/MWe	133.7	1915.6	0.0
PIPING, INDUSTRIAL GR	LB/MWe	3881.9	5913.9	7597.7
WIRE AND CABLE	FT/MWe	5288.3	4352.0	5450.8
WIRE AND CABLE DUCT	FT/MWe	804.5	587.5	906.6
DIRECT CRAFT LABOR:				
BOILERMAKER	MH/MWe	326.9	586.0	1303.4
CARPENTER	MH/MWe	1216.7	1185.5	649.9
ELECTRICIAN	MH/MWe	2382.5	1930.1	2091.7
IRON WORKER	MH/MWe	1305.8	1075.8	989.4
LABORER	MH/MWe	1385.2	1558.9	1396.9
MILLWRIGHT	MH/MWe	408.6	170.7	322.4
OPERATING ENGINEER	MH/MWe	483.2	792.5	798.6
PIPEFITTER	MH/MWe	1383.3	2580.9	3581.2
TEAMSTER	MH/MWe	26.7	132.1	149.9
OTHERS	MH/MWe	129.7	641.7	864.6
TOTAL CRAFT LABOR	MH/MWe	9048.6	10654.3	12148.0

(1) SF = SQUARE FEET, TN = TON, CY = CUBIC YARDS, LB = POUND
FT = FEET, MH = MANHOURS

TABLE 2-14
MHTGR FIRST-OF-A-KIND DEVELOPMENT COSTS
(1987$)

DESIGN DEVELOPMENT	M$
NI PLANT LEVEL DESIGN	43.7
PLANT CONTROL DATA SYSTEM DESIGN	8.0
REACTOR SYSTEM DESIGN	61.7
VESSEL SYSTEM DESIGN	7.1
REACTOR SERVICES GROUP DESIGN	10.0
HEAT TRANSPORT SYSTEM DESIGN	12.3
REACTOR CAVITY COOLING SYSTEM	3.4
SHUTDOWN COOLING SYSTEM DESIGN	8.3
PLANT PROTECTION & INSTRUMENTATION	8.0
FUEL HANDLING SYSTEM DESIGN	11.4
MISC. CONTROL & INSTRUMENTATION	2.0
OTHER NI SYSTEM LEVEL DESIGN	13.7
ECA PLANT LEVEL DESIGN	6.4
ECA SYSTEM LEVEL DESIGN	8.1
LICENSING	28.7
DESIGN QUALITY ASSURANCE	10.6
DESIGN PROJECT MANAGEMENT	28.6
	272.0
TECHNOLOGY DEVELOPMENT	
SAFETY AND RELIABILITY	1.3
FISSION PRODUCT	17.2
FUEL PROCESS	9.0
FUEL PERFORMANCE	10.5
REACTOR CAVITY COOLING SYSTEM	5.8
NEUTRON CONTROL	3.0
REACTOR INTERNALS	10.2
REACTOR CORE	17.3
REACTOR SERVICE EQUIPMENT	.4
CORE EXIT PLENUM & HOT DUCT FLOW	1.9
MAIN CIRCULATOR	5.5
STEAM GENERATOR	12.4
SAFETY PROTECTION	2.6
CORE REFUELING	2.6
NUCLEAR ISLAND CONTROL	1.2
SHUTDOWN COOLING SYSTEM	1.7
	102.6
PERFORMANCE TESTING	12.6
TOTAL FOAK DEVELOPMENT COSTS	387.2

TABLE 2-15

MHTGR FIRST-OF-A-KIND DEVELOPMENT

EXPENDITURES BY YEAR

YEAR	DESIGN & LICENSING	TECHNOLOGY DEVELOPMENT	PERFORMANCE TESTING
1988	6%	26%	0%
1989	11%	32%	0%
1990	25%	20%	0%
1991	25%	14%	0%
1992	20%	7%	0%
1993	8%	1%	33%
1994	3%		33%
1995	2%		34%
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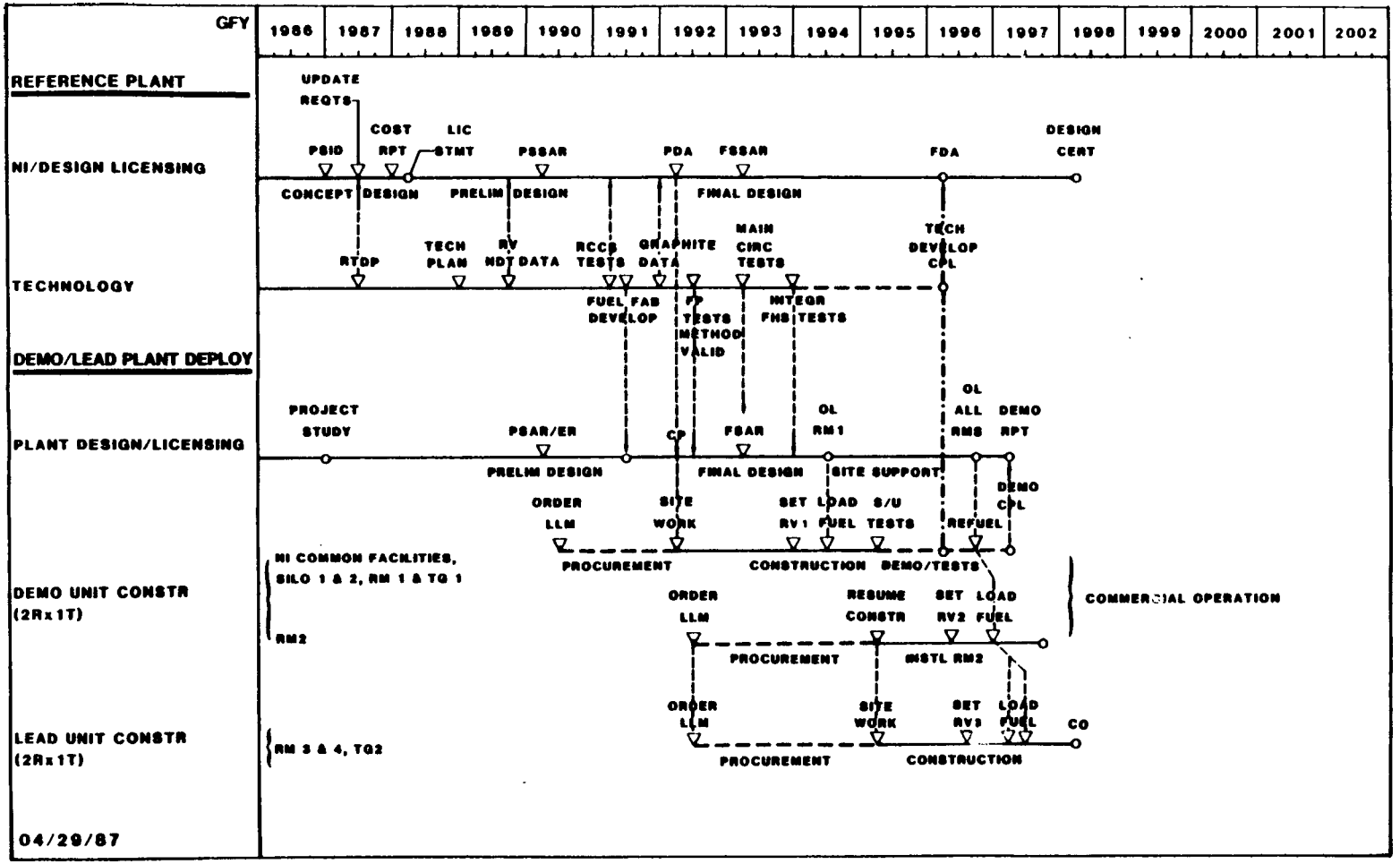
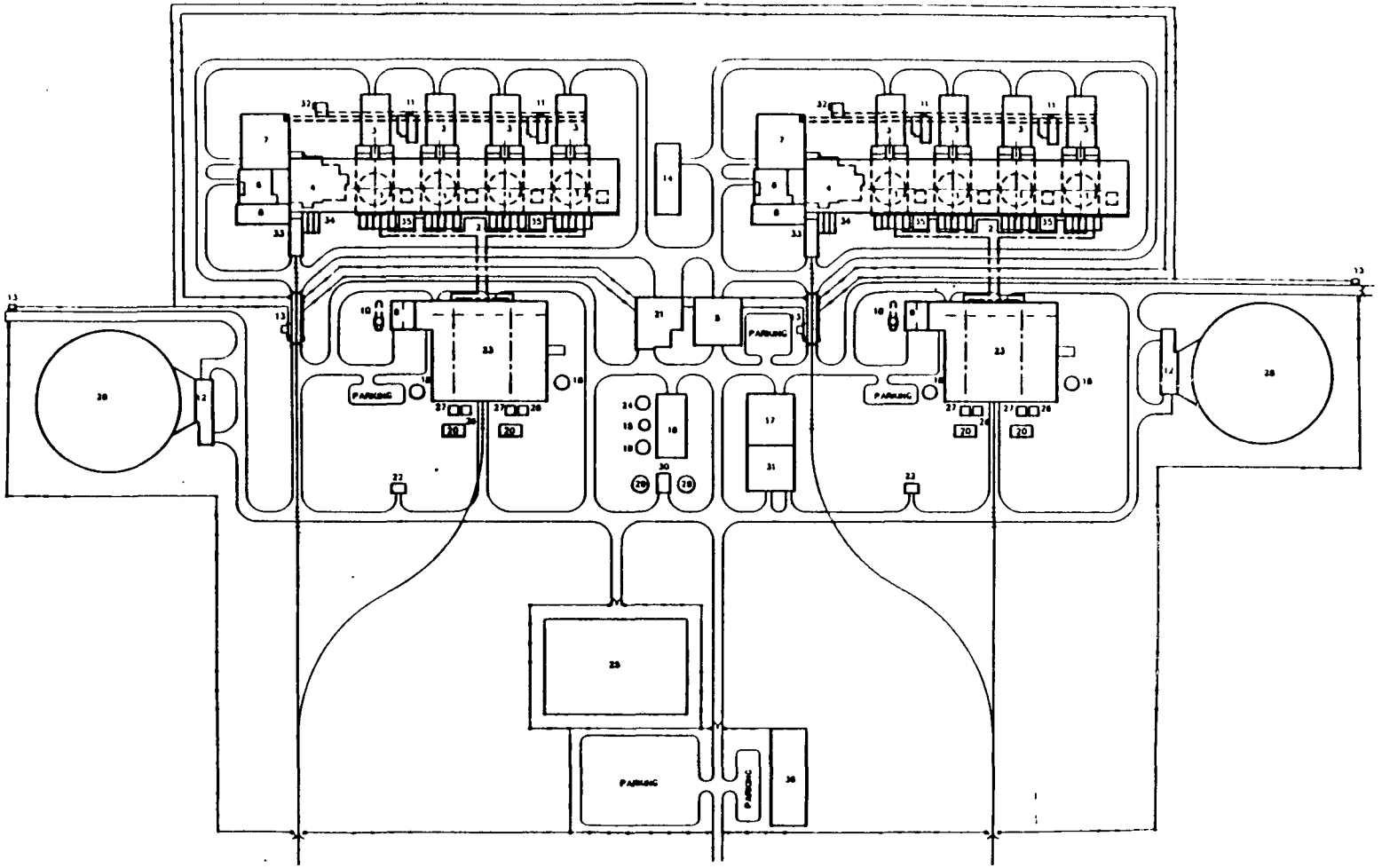
TOTAL	100%	100%	100%

Figure 2-1

MHTGR LEAD PLANT MILESTONE SCHEDULE



LARGE MHTGR PLANT



LEGEND

1. REACTOR BUILDING
2. MAIN STEAM & FEEDWATER PIPING
3. REACTOR AUXILIARY BUILDING
4. REACTOR SERVICE BUILDING
5. CONTROL BUILDING
6. PERSONNEL SERVICES BUILDING
7. RADIOACTIVE WASTE MANAGEMENT BUILDING
8. NUCLEAR ISLAND COOLING WATER BUILDING
9. STANDBY POWER BUILDING
10. FUEL OIL STORAGE TANK & PUMP HOUSE
11. HELIUM SERVICES BUILDING
12. CIRCULATING WATER PUMP HOUSE
13. GUARD HOUSE
14. HELIUM STORAGE STRUCTURE
15. CLARIFIER
16. MAKEUP WATER TREATMENT & AUXILIARY BOILER BUILDING
17. MAINTENANCE BUILDING
18. CONDENSATE SURGE TANK
19. DEMINERALIZED WATER STORAGE TANK
20. UNIT TRANSFORMER
21. NB WAREHOUSE
22. HYDROGEN STORAGE AREA
23. TURBINE BUILDING
24. FILTERED WATER STORAGE TANK
25. SWITCHYARD
26. STARTUP AUXILIARY TRANSFORMER
27. UNIT AUXILIARY TRANSFORMER
28. STATION COOLING TOWER
29. FIRE WATER STORAGE TANK
30. FIRE PUMP HOUSE
31. ECA WAREHOUSE
32. REMOTE SHUTDOWN BUILDING
33. WASHDOWN BAY
34. CHILLED WATER BUILDING
35. ELECTRICAL EQUIPMENT AREA
36. ADMINISTRATION BUILDING

NOTES:
1. SCALE: 1" = 150'-0"

GRAPHIC SCALE (FEET)

SECTION 3
TOTAL CAPITAL COST

This section presents the total overnight and total capital cost estimates and the methods used to develop them. The base construction cost as described in the previous section was the starting point for development of the total overnight and total capital costs.

3.1 CONTINGENCY

The expected total overnight cost is computed as the most likely base construction cost plus a contingency cost estimated as a percentage of the base construction cost. An explanation of the expected, most likely and contingency costs is provided in Appendix C.

The MHTGR participant having responsibility for each system, component or structure in the direct cost accounts provided a contingency for each of their cost accounts. To maintain consistency, contingency percentages and requirements for their use were defined as follows. For those systems that are innovative, that represent a substantial departure from previously built designs, or that require a high assurance of quality in construction and operation (e.g., nuclear grade systems), a nominal contingency cost of 25% of the applicable base cost was a groundrule. For systems or components that are standard, current, off-the-shelf technology items that are being applied in a normal, industrial grade application, a nominal contingency cost of 15% of the applicable base cost was the groundrule.

Account contingencies could be adjusted upwards or downwards from the above nominal values based upon the estimator's judgement of the uncertainties. For example, if a nuclear grade structure was well-defined and of a type previously constructed with known costs, then the estimator could make a judgement that the contingency should be less than the nominal value of 25%. Similarly, if there was a system or structure which had, in the estimator's judgement, above average uncertainties associated with it, then a contingency somewhat greater than the nominal value could be used. All such judgements were made relative to the nominal values.

3.2 TOTAL OVERNIGHT COST

The total overnight cost (base construction cost plus contingency) for each of the plant cases is summarized in Table 3-1a through Table 3-1e. The costs are separated between nuclear grade and industrial grade for identification of the respective contingencies included in each category. The total contingency cost for the nuclear grade portion of the plants, when estimated on a cost account level using the guidance provided in Section 3.1, is approximately 26%. This compares to the nominal guidance of 25% for nuclear grade items. The difference can be attributed almost wholly to home office engineering for the nuclear island (Account 92) where a contingency estimate of 40% was used. The contingency for the industrial grade portion is approximately 15% for each of the plants, consistent with the nominal guidance. The net overall contingency for the MHTGR plant cases estimated is between 20 and 22 percent.

Contingency cost is an area where the MHTGR cost estimates deviate slightly from the Reference 2 DOE groundrules. In Appendix E, cost tables are provided which contain MHTGR cost estimates conforming to DOE groundrules. In the Appendix E tables, contingency cost has been computed as 25% and 15% for the nuclear and industrial grade portions respectively.

3.3 CASHFLOW

As in the case of the contingency estimate, the MHTGR participant having responsibility for each system, component or structure in the direct cost account provided a cashflow estimate. The cashflow estimate identified the month from the beginning of the project that the cashflow starts and the percentage expended each month beginning with the identified starting month through succeeding, but not necessarily successive, months to 100% expenditure (e.g., 10% on 5th month, 20% on 7th, 8th, 9th, 10th and 10% on 12th month could be indicated).

3.4 ESCALATION

Escalation during the design and construction period was assumed to be occurring at the same rate as inflation; that is, there is no real escalation

during this period. Since the total cost is expressed in constant 1987 dollars as defined in Section 2.1, escalation is zero when expressed in constant dollars.

3.5 INTEREST DURING CONSTRUCTION AND TOTAL CAPITAL COST

Interest during construction costs (also called allowance for funds used during construction, or AFUDC) was calculated based on the real, average cost of money. The financial parameters given in Table 3-2 were used in determining interest costs. The Tax Reform Act of 1986 no longer allows bond interest as a tax deduction during construction. Thus, the average and not tax-adjusted cost of money was used in determining the real cost of money for calculating interest during construction.

The methodology used to develop cashflows and interest during construction costs for each plant using the data described in Section 3.3 is presented in Appendix F. Cumulative cashflow curves with and without interest during construction are contained in Appendix F. The interest costs from Appendix F and resultant total capital costs for each of the plants estimated are included in Tables 3-1a through 3-1e.

The Lead plant interest costs account for about 14.5% of the total capital cost whereas, for the Replica, NOAK, and large NOAK plants, the interest costs account for only about 12.5% of the total capital cost. The difference in these two interest percentages is attributable to the extended Lead plant construction schedule resulting from deploying the plant in two phases.

TABLE 3-1a
MHTGR LEAD PLANT - PHASE 1 TOTAL CAPITAL COST ESTIMATE
(MILLIONS OF 1987$)

EEDB Account No.	Account Description	Nuclear grade cost	Industrial grade cost	Total cost
20	Land and land rights	0.0	2.0	2.0
21	Structures and improvements	33.0	41.5	74.5
22	Reactor plant equipment	122.1	3.1	125.2
23	Turbine plant equipment	0.0	63.5	63.5
24	Electric plant equipment	0.0	27.1	27.1
25	Miscellaneous plant equipment	3.4	7.1	10.6
26	Main condenser heat rejection	0.0	18.1	18.1
	Total direct costs	158.5	162.4	320.9
91	Construction services	17.1	30.2	47.3
92	AE home office engineering	26.1	15.2	41.2
93	Field office supervision	7.0	10.2	17.2
94	Owner's expenses	0.0	75.5	75.5
	Total indirect costs	50.2	131.0	181.2
	BASE CONSTRUCTION COST - Total $	208.8	293.4	502.2
	- $/kW(e)	1553.5	2183.0	3736.4
	CONTINGENCY	55.2	44.5	99.7
	TOTAL OVERNIGHT COST - Total $	264.0	337.9	601.9
	- $/kW(e)	1964.5	2513.8	4478.3
	ESCALATION	0.0	0.0	0.0
	INTEREST DURING CONSTRUCTION			102.9
	TOTAL CAPITAL COST - Total $			704.8
	- $/kW(e)			5243.9

TABLE 3-1b
MHTGR LEAD PLANT - PHASE 2 TOTAL CAPITAL COST ESTIMATE
(MILLIONS OF 1987$)

EEDB Account No.	Account Description	Nuclear grade cost	Industrial grade cost	Total cost
20	Land and land rights	0.0	0.0	0.0
21	Structures and improvements	29.7	13.4	43.1
22	Reactor plant equipment	193.7	2.3	195.9
23	Turbine plant equipment	0.0	62.4	62.4
24	Electric plant equipment	0.0	26.0	26.0
25	Miscellaneous plant equipment	0.5	2.0	2.6
26	Main condenser heat rejection	0.0	5.4	5.4
	Total direct costs	223.9	111.5	335.4
91	Construction services	18.7	12.9	31.6
92	AE home office engineering	38.9	9.9	48.8
93	Field office supervision	7.1	4.4	11.4
94	Owner's expenses	0.0	65.8	65.8
	Total indirect costs	64.6	93.0	157.6
	BASE CONSTRUCTION COST - Total $	288.6	204.5	493.0
	- $/kW(e)	715.7	507.1	1222.8
	CONTINGENCY	76.8	29.7	106.5
	TOTAL OVERNIGHT COST - Total $	365.3	234.2	599.5
	- $/kW(e)	906.1	580.9	1487.0
	ESCALATION	0.0	0.0	0.0
	INTEREST DURING CONSTRUCTION			101.0
	TOTAL CAPITAL COST - Total $			700.5
	- $/kW(e)			1737.5

TABLE 3-1c
MHTGR REPLICA PLANT TOTAL CAPITAL COST ESTIMATE
(MILLIONS OF 1987$)

EEDB Account No.	Account Description	Nuclear grade cost	Industrial grade cost	Total cost
20	Land and land rights	0.0	2.0	2.0
21	Structures and improvements	62.4	52.2	114.6
22	Reactor plant equipment	280.0	5.2	285.2
23	Turbine plant equipment	0.0	125.0	125.0
24	Electric plant equipment	0.0	51.9	51.9
25	Miscellaneous plant equipment	4.0	9.0	12.9
26	Main condenser heat rejection	0.0	23.1	23.1
	Total direct costs	346.3	268.4	614.7
91	Construction services	32.7	40.6	73.3
92	AE home office engineering	45.6	15.7	61.3
93	Field office supervision	13.5	13.7	27.2
94	Owner's expenses	0.0	118.6	118.6
	Total indirect costs	91.7	188.6	280.4
	BASE CONSTRUCTION COST - Total $	438.1	457.0	895.1
	- $/kW(e)	814.9	850.1	1664.9
	CONTINGENCY	117.4	68.8	186.2
	TOTAL OVERNIGHT COST - Total $	555.5	525.8	1081.3
	- $/kW(e)	1033.3	978.0	2011.3
	ESCALATION	0.0	0.0	0.0
	INTEREST DURING CONSTRUCTION			151.5
	TOTAL CAPITAL COST - Total $			1232.8
	- $/kW(e)			2293.1

TABLE 3-1d
MHTGR NOAK PLANT TOTAL CAPITAL COST ESTIMATE
(MILLIONS OF 1987$)

EEDB Account No.	Account Description	Nuclear grade cost	Industrial grade cost	Total cost
20	Land and land rights	0.0	2.0	2.0
21	Structures and improvements	60.8	49.8	110.6
22	Reactor plant equipment	252.3	5.1	257.4
23	Turbine plant equipment	0.0	124.1	124.1
24	Electric plant equipment	0.0	50.8	50.8
25	Miscellaneous plant equipment	3.9	8.8	12.7
26	Main condenser heat rejection	0.0	22.8	22.8
	Total direct costs	317.0	263.4	580.4
91	Construction services	31.7	38.6	70.2
92	AE home office engineering	33.5	14.2	47.7
93	Field office supervision	13.0	13.0	26.0
94	Owner's expenses	0.0	113.4	113.4
	Total indirect costs	78.2	179.2	257.4
	BASE CONSTRUCTION COST - Total $	395.2	442.6	837.8
	- $/kW(e)	735.1	823.4	1558.4
	CONTINGENCY	106.4	66.6	173.0
	TOTAL OVERNIGHT COST - Total $	501.6	509.2	1010.8
	- $/kW(e)	932.9	947.2	1880.2
	ESCALATION	0.0	0.0	0.0
	INTEREST DURING CONSTRUCTION			139.2
	TOTAL CAPITAL COST - Total $			1150.0
	- $/kW(e)			2139.1

TABLE 3-1e
MHTGR LARGE NOAK PLANT TOTAL CAPITAL COST ESTIMATE
(MILLIONS OF 1987$)

EEDB Account No.	Account Description	Nuclear grade cost	Industrial grade cost	Total cost
20	Land and land rights	0.0	3.0	3.0
21	Structures and improvements	120.9	95.5	216.4
22	Reactor plant equipment	466.7	10.2	476.9
23	Turbine plant equipment	0.0	248.3	248.3
24	Electric plant equipment	0.0	101.5	101.5
25	Miscellaneous plant equipment	7.8	17.6	25.5
26	Main condenser heat rejection	0.0	45.5	45.5
	Total direct costs	595.4	521.6	1117.1
91	Construction services	62.4	76.0	138.4
92	AE home office engineering	52.5	21.9	74.4
93	Field office supervision	26.3	25.6	51.9
94	Owner's expenses	0.0	196.5	196.5
	Total indirect costs	141.1	320.1	461.2
	BASE CONSTRUCTION COST - Total $	736.5	841.7	1578.2
	- $/kW(e)	685.0	782.8	1467.9
	CONTINGENCY	199.0	124.2	323.2
	TOTAL OVERNIGHT COST - Total $	935.6	965.9	1901.4
	- $/kW(e)	870.1	898.3	1768.4
	ESCALATION	0.0	0.0	0.0
	INTEREST DURING CONSTRUCTION			255.2
	TOTAL CAPITAL COST - Total $			2156.6
	- $/kW(e)			2005.8

TABLE 3-2

PLANT CAPITAL COST

FINANCIAL PARAMETERS

(For Calculating AFUDC)

Capitalization (%)	
Debt	50
Preferred stock	10
Common equity	40
Return on capitalization (%/year)	
Debt interest	9.7
Preferred dividend	9
Common equity return	14
Average nominal cost of money (%/year)	11.35
Inflation rate (%/year)	5.0
Real (inflation-free) cost of money (%/year)	6.05

SECTION 4
BUSBAR GENERATION COST

4.1 GENERAL ASSUMPTIONS AND METHODOLOGY

A total plant energy generation cost or busbar cost includes the capital, nonfuel operation and maintenance, fuel, and decommissioning costs and is expressed as a cost/unit energy. For the MHTGR estimates, constant dollar levelized busbar costs were determined. In the constant dollar levelized approach, the year-by-year unit price of electricity is assumed to rise in current dollar terms at the rate of inflation. The method used to determine this unit price is to calculate the present value (using the effective cost of money as a discount rate) of all the plant costs and divide that amount by the present value of the energy generated over the life of the plant. A complete description of the levelized cost approach can be found in the "Nuclear Energy Cost Data Base" (Reference 2).

Following the general assumptions listed below, the treatment of each cost component is discussed, and a summary of the various cost elements are presented.

- The levelized busbar cost is expressed in 1987 dollars as defined in Section 2.1.

- The capacity factor for each power block is 80%, equal to the plant equivalent availability requirement given in Reference 4.

- The assumed operating life of each power unit is 30 years for cost estimating purposes.

- The present worth discount rate is 9.57%/year, nominal, and 4.355%/year, real. The general inflation rate is 5%/year.

- Cost is calculated in a manner consistent with the Tax Reform Act of 1986.

4.2 CAPITAL COST

Under the assumption of equal annual energy generation, the equation for calculating the constant dollar levelized capital cost can be expressed as:

$$LCC = \frac{FCR \sum_i CAP_i/(1 + d)^{t_i - t_1}}{E \times \sum_i 1/(1 + d)^{t_i - t_1}},$$

where

- LCC = levelized capital cost
- FCR = fixed charge rate
- CAP_i = total capital cost for unit i
- d = real cost of money
- t_i = commercial operation data for unit i
- E = annual energy generation for single unit

The fixed charge rate is given by the following expression from Reference 3:

$$FCR = 0.015775\ (IDC/TCC) + 0.093357$$

where

- IDC = interest during construction in constant 1987 $
- TCC = total capital cost in constant 1987 $

Parameters that were used in determining the above fixed charge rate expression are given in Table 4-1.

For a single-unit plant, the above equation for levelized capital cost reduces to:

$$LCC = (FCR \times CAP)/E$$

4.3 OPERATING AND MAINTENANCE COSTS

The nonfuel operating and maintenance costs (O&M) costs are incurred from commercial operation and throughout the operating life of the plant. For this estimate, only the first 30 years of operation were considered. Certain

O&M costs such as those for materials and supplies are partially dependent on the amount of energy generated by the plant. These variable costs are added to the fixed costs independent of generation to arrive at a total annual O&M cost. A description of each O&M expense is defined in Table 4-2.

Estimates of the MHTGR O&M costs are given in Reference 7. The site staff requirements, shown in Table 4-3 are based on the reduced maintenance staffing estimate described in Reference 7. The total O&M costs are presented in Table 4-4 for the Target and large Target plants and are subdivided into fixed and variable costs per Reference 3. Table 4-4 includes the cost for disposal of spent control rods and reflector blocks; this cost is not included in the corresponding table in Reference 7.

The one-block Target plant O&M cost estimates have been increased a nominal 20% for the one-block Lead plant and 10% for the Replica plant to account for anticipated higher costs for these first two plants. For the Lead plant the first reactor module and one turbine generator are scheduled to operate for approximately two years prior to deployment of the balance of the one-block plant. A full one-block staffing complement is assumed to be available for initial operation of the first module, which should provide adequate staffing for initial startup and operation.

Since the O&M costs were not available on a per power unit basis and with the assumption of there being no real escalation, the levelized O&M costs for each of the plants was determined by simply dividing the annual O&M costs by the annual energy generation.

4.4 FUEL COSTS

Complete fuel cycle costs for 30 years of operation were estimated. The fuel cycle was subdivided into its components (e.g., uranium ore purchase, conversion, enrichment, fabrication, reprocessing, and waste disposal). Costs and quantities were developed for each component over the assumed operating period. The fuel cycle cost analysis is presented in Reference 8 and the cost of replacement control rods and reflectors is presented in Reference 9. These References document all assumptions such as unit costs, processing losses, mass balance data, and lead and lag time for costs.

Fuel cycle costs were determined using the following bases:

1. The reference fuel per DOE direction for all cases was LEU/Th once through.

2. Fuel management plans, including mass flows and their timing into and out of the reactor were developed.

3. The cost for an equilibrium cycle fuel element was determined in terms of $/element. The costs were subdivided into components related to capital facility amortization, fuel facility O&M costs, hardware costs, and fresh heavy metal (as applicable).

4. It was assumed that spent fuel leaving the reactor has no economic value.

5. The cost of each batch of fuel was capitalized and depreciated by a 200% declining balance method over five years. To properly reflect the tax depreciation, the fuel cycle analysis was performed in nominal rather than constant dollar terms.

The reference unit costs used in developing fuel cycle costs were as follows:

U_3O_8, $/lb	34.75	1.0
Conversion, $/kg U	8.20	0
Enrichment, $/kg SWU	110	-3.4 to 2005, 0 thereafter
Waste disposal, mills/kWh	1	0

All fuel cycle costs for the power plant were present-worthed to the year 1987 for use in developing the total busbar cost.

The MHTGR fresh fuel fabrication costs are given in Table 4-5 and the levelized fuel costs are presented in Table 4-6. Note that the cost of the first core is in the fuel cycle cost; there is no plant capital cost associated with the first core (per Table 2-2).

4.5 DECOMMISSIONING

In the absence of a specific decommissioning estimate, the Reference 3 guidelines provide a default option. The default value is $143 million (1987 dollars) for an 1100-MWe unit. This value was linearly scaled (i.e., $130/kWe) for the MHTGR plants. It was assumed that an external sinking fund of tax-free state bonds earning 6.5%/year, nominally, will be established over the operating life of the plant to accumulate the necessary funds for decommissioning. The present worth of this decommissioning fund can be calculated using the expression:

$$PWDC = \frac{DC_o \times SFF(6.5,30) \times \sum_i 1/1(1 + d)^{t_i - t_1}}{(1 + d)^{30} \times SFF(X,30)}$$

where

- PWDC = present worth of total decommissioning costs
- DC_o = decommissioning cost in reference year's dollars for one unit
- SFF(r,t) = sinking fund factor at rate r for t years, that is $r/[(1+r)^t-1]$
- d = real cost of money
- X = tax-adjusted nominal cost of money
- t_i = commercial operation date for unit i.

The constant dollar levelized cost of decommissioning can be expressed as

$$LCDC = \frac{CRF \times PWDC}{E \times \sum_i 1/(1 + d)^{t_i - t_1}},$$

where

- LCDC = levelized decommissioning cost
- PWDC = present worth of total decommissioning costs
- E = annual energy generation for single unit
- CRF = capital recovery factor for 30 years at the real cost of money
- d = real cost of money
- t_i = commercial operation date for unit i.

4.6 TOTAL BUSBAR COST

The levelized total busbar cost is simply the sum of the levelized costs for capital, O&M, fuel, and decommissioning. The results are given in Table 4-7 for the Lead, Replica, NOAK, and large NOAK plants. The cost of replacement control rods and reflector blocks is included in Table 4-7 as a separate line item in the levelized fuel cycle cost. The addition of the replacement control rods and reflector blocks cost is the reason why the fuel component of the busbar cost in Table 4-7 is greater than that given in Table 4-6.

TABLE 4-1

PLANT CAPITAL COST

FIXED CHARGE RATE PARAMETERS

Investment tax credit	0%
Effective (tax adjusted) cost of money	9.573%/year
Inflation rate	5%/year
Real cost of money	4.355%/year
Combined state and federal tax rate	36.64%
Property tax rate (% of capital investment)	2%/year
Interim replacement rate (% of investment)	0.5%/year
Book life	30 years
Tax depreciation duration (Nuclear)	15 years
Tax depreciation component (% declining balance)	150%
Accounting method	Normalized

TABLE 4-2

NONFUEL O&M EXPENSE ACCOUNT DESCRIPTIONS

Account	Description
On-site staff	Includes all personnel assigned to the plant site. See Table 4-3 for typical categories.
Maintenance materials	Can be either variable or fixed costs. Consists of noncapitalized hardware used in normal maintenance activities.
Supplies and expenses	Can be either variable or fixed costs. Consists of consumable materials and other unrecoverable items such as makeup fluids, chemicals, gases, lubricants, office and personnel supplies, and monitoring and record supplies; costs for on-site radioactive and nonradioactive waste management activities; costs for disposal of absorber and other replaceable reflector/shield elements.
Off-site support	Activities by personnel not assigned full time to the plant site; examples are safety reviews, off-site training, environmental monitoring, meteorological surveys, power planning, fuel studies, and other owner home office activities directly supporting the plant.
Pensions and benefits	Costs of pensions and benefits, including worker's compensation insurance, provided for the on-site and off-site staff.

TABLE 4-2 (Cont.)

NONFUEL O&M EXPENSE ACCOUNT DESCRIPTIONS

Account	Description
Regulatory fees	NRC annual fees and review costs as well as other routine safety, environmental, and health physics inspections.
Insurance premiums	Costs for commercial and government liability insurance, property damage insurance, and replacement power insurance.
Other A&G	Administrative and general salaries and related expenses.

TABLE 4-3

ESTIMATED ANNUAL SALARIES, STAFFING, AND COSTS FOR ONSITE O&M STAFFING (JANUARY 1987 DOLLARS)

Job Title	Salary ($/Year)	One-Block Target Plant Number	One-Block Target Plant Total ($/Year)	Two-Block Target Plant Number	Two-Block Target Plant Total ($/Year)
Plant Manager's Office					
Plant manager	100,000	1	100,000	1	100,000
Assistant manager	70,000	1	70,000	2	140,000
Training	49,000	5	245,000	8	392,000
Safety and fire protection	41,000	1	41,000	1	41,000
Administrative services	27,000	25	675,000	32	864,000
Health services	27,000	1	27,000	2	54,000
Security	24,000	34	816,000	40	960,000
Subtotal		68		86	
Operations					
Supervision	51,000	6	306,000	12	612,000
Shift operation	43,000	32	1,376,000	64	2,752,000
Shift Maint. Support	43,000	12	516,000	24	1,032,000
Subtotal		50	2,198,000	100	4,396,000
Maintenance					
Supervisor	48,000	7	336,000	14	672,000
Crafts	34,000	83	2,822,000	166	5,644,000
Annualized peak maintenance	34,000	3	102,000	6	204,000
Quality control	37,000	5	185,000	10	370,000
Warehouse	31,000	6	186,000	9	279,000
Subtotal		104		205	
Technical and Engineering					
Reactor engineering	51,000	3	153,000	5	255,000
Radiochemistry and water chemistry	48,000	8	384,000	14	672,000
Engineering	44,000	6	264,000	12	528,000
Technician	36,000	6	216,000	12	432,000
Health physics	36,000	13	468,000	24	864,000
Subtotal		36	1,485,000	67	2,751,000
Total without payroll tax and insurance		258	9,288,000	458	16,867,000
Payroll tax and insurance (at 10%)			929,000		1,687,000
Total with payroll tax and insurance			10,217,000		18,554,000

TABLE 4-4

ANNUAL O&M COST ESTIMATES FOR NOAK MHTGR PLANTS
(JANUARY 1987 DOLLARS)

	One-block Target Plant	Two-block Target Plant
Net rating MW(e)	538	1076
Capacity factor, %	80	80
Annual generation, kWh/year	3.77×10^9	7.54×10^9
Onsite staff	258	458
Power Generation Costs (10^6 $/year)		
Onsite staff	10.2	18.6
Maintenance materials		
Fixed	2.4	4.8
Variable	0.9	1.8
Subtotal	3.3	6.6
Supplies and expenses		
Fixed	4.1	8.2
Variable		
Plant	0.4	0.8
CR and Reflector Disposal	1.2	2.4
Subtotal	5.7	11.4
Offsite technical support	2.2	2.2
Subtotal, power generation costs		
Fixed	18.9	33.8
Variable	2.5	5.0
Subtotal	21.4	38.8
A&G Costs (10^6 $/year)		
Pensions and benefits	2.6	4.5
Nuclear regulatory fees	1.0	2.0
Insurance premiums	3.5	5.0
Other A&G	3.0	5.4
Subtotal	10.1	16.9
Total O&M Costs (10^6 $/year)		
Fixed	29.0	50.7
Variable	2.5	5.0
Total	31.5	55.7
Mills/kWh	8.4	7.4

TABLE 4-5

MHTGR FRESH FUEL FABRICATION COSTS

(1987$/Element)

Item	FOAK	Replica	NOAK
Initial Core and Reloads 1-3	38,200	33,300	19,300
Reloads 4-6	33,300	19,300	11,500
Reloads 7-10	19,300	11,500	11,500
Reloads 11-end	11,500	11,500	11,500

TABLE 4-6

30-YEAR LEVELIZED FUEL COSTS*, 1987$

Year	Fuel (Mills/kWh)	Fab (Mills/kWh)	Waste Disposal (Mills/kWh)	Total (Mills/kWh)	Total ($/MBtu)
2000 (FOAK)	5.50	6.90	1.0	13.4	1.51
2005 (Replica)	5.60	5.30	1.0	11.9	1.34
2010 (NOAK)	5.80	3.70	1.0	10.5	1.17
NOAK (Equilibrium Fab)	5.80	2.90	1.0	9.7	1.08

*Excluding replacement control rods and reflector blocks.

TABLE 4-7
LEVELIZED BUSBAR GENERATION COSTS
JANUARY 1987$

	LEAD PLANT	REPLICA PLANT	NOAK PLANT	LARGE NOAK PLANT
THERMAL RATING (MWt)	1400	1400	1400	2800
NET ELECTRIC RATING (MWe)	537.6	537.6	537.6	1075.2
CAPACITY FACTOR	0.80	0.80	0.80	0.80
FIXED CHARGE RATE	0.096	0.095	0.095	0.095
LEVELIZED CAPITAL COST (M$)	138.5	117.8	109.8	206.3
ANNUAL O&M COST (M$)	37.8	34.7	31.5	55.7
FUEL COST ($/MBTU)	1.51	1.34	1.08	1.08
CONTR ROD & REFLECTOR COST (M$/YR)	3.0	3.0	3.0	6.0
LEVELIZED FUEL CYCLE COST (M$/YR)	53.6	47.9	39.2	78.3
DECOMMISSIONING COST,M$	69.89	69.89	69.89	139.78
LEVELIZED DECOMMISSIONING COST (M$)	2.06	2.06	2.06	4.13
TOTAL REVENUE REQUIREMENT (M$)	231.9	202.4	182.6	344.4
BUSBAR COST (Mills/kWh)				
CAPITAL	36.8	31.3	29.2	27.4
O&M	10.0	9.2	8.4	7.4
FUEL	14.2	12.7	10.4	10.4
DECOMMISSIONING	0.5	0.5	0.5	0.5
TOTAL	61.6	53.7	48.5	45.7

SECTION 5
COMPARISON OF COSTS WITH ALTERNATIVE POWER PLANTS

This section provides alternative power plant cost data and an evaluation of the economic competitiveness of the MHTGR relative to alternative power plants. Cost data on alternate power plants are contained in Reference 3. The alternative power plants in Reference 3 which are applicable for comparison with the MHTGR plants are:

1. 400 and 600 MWe single unit coal plants.

2. 800 and 1200 MWe multi-unit coal plants.

3. 800 and 1200 MWe PWR plants.

The following general assumptions were applied in the development of the levelized busbar generation costs for the alternative power plants:

- The levelized busbar cost was expressed in 1987 dollars as defined in Section 2.1.

- The capacity factor for all alternative plants was assumed to be 80%, equivalent to that established for the MHTGR even though actual capacity factors for PWR and coal plants are closer to 70%.

- The operating life of each plant was assumed to be 30 years for cost estimating purposes.

- The present worth discount rate was assumed to be 9.57%/year, nominal, and 4.355%/year, real. The general inflation rate was assumed to be 5%/year.

- Owner's cost of 10% was applied (versus the approximate 15% applied to the MHTGR plants based on the Reference 6 study).

5.1 ALTERNATIVE POWER PLANT COSTS

5.1.1 Capital Cost

Since it is assumed that there is no real escalation in capital costs, the capital cost of a plant in real terms is independent of the commercial operation date. Because of the multi-unit coal plants, assumed to be two unit plants, eight capital cost estimates (see Table 5-1) were needed to satisfy the alternative power plant configurations for comparison with the MHTGR. The alternative plant capital cost estimates from Reference 3, developed using the CONCEPT code and cost data developed in the DOE EEDB program (Refs. 10 and 11), are summarized in Table 5-1.

The construction period for the coal and nuclear plants was assumed to be 4 and 6 years, respectively. Three commercial operation dates were assumed, the years 2000, 2005 and 2010 for single units and for the first unit of the two-unit plants. The second unit in the two-unit plants was assumed to follow the first by 1 year. The coal-fired plants have precipitators and wet-lime scrubbers. The PWR plants conform to current licensing standards. All plants use natural draft wet cooling towers.

The PWR plants conform to 1986 licensing standards. The PWR costs reflect assumptions in the quantities of commodities, equipment, installation man-hours, and indirect costs that are similar to the best cost experience for stations recently constructed. These costs are provided as representative values of typical future plants under an improved managerial and regulatory climate. To allow for comparisons to the industry's current median experience, the capital costs by the two-digit EEDB account for a 1200-MWe median experience and best experience PWR are provided in Table 5-2, also from Reference 3.

5.1.2 Operating and Maintenance Costs

Similar to the capital cost, the assumption of no real escalation of O&M costs allows the constant dollar cost estimate to be independent of the year that the cost is actually incurred. Six O&M cost estimates were needed for

estimating the alternative power plant configurations. The six O&M cost estimates are given in Table 5-3 from Reference 3 and were calculated using the OMCOST code (Ref. 12).

5.1.3 Fuel Costs

The delivered price of coal was assumed to be $1.75/MBtu (1987$). The real escalation of coal was assumed to be 1.0%/year. For the PWR cases, an extended burnup fuel (54,000 MWD/MT) was assumed. The fuel cycle unit costs assumed are given in Table 5-4 from Reference 3.

5.1.4 Decommissioning

The cost of decommissioning an 1100-MWe PWR plant is estimated to be $143 million in 1987 dollars. Decommissioning costs are assumed to vary linearly with size and escalate at the rate of inflation. A sinking fund similar to that described in Section 4.5 is used to accumulate the necessary funds during the operation of the plant.

5.1.5 Total Busbar Cost

The capital, O&M, fuel, and for the PWRs, decommissioning costs make up the total busbar cost. Each component as well as the total busbar cost expressed as a constant dollar levelized unit cost for the alternative power plants for comparison with the MHTGR are summarized in Table 5-5.

5.2 MHTGR COMPARISON WITH ALTERNATIVES

5.2.1 Comparison of Capital Costs

Capital cost comparisons, on a $/kWe basis, of the MHTGR and the alternative power plants, are presented in Tables 5-6 and 5-7. In Table 5-6 the NOAK MHTGR plant capital costs are compared to the 800 MWe PWR and the 400 and 600 MWe single unit coal plants. In Table 5-7 the large NOAK MHTGR plant is compared to the 1200 MWe PWR and the 800 and 1200 MWe two-unit coal plants.

Examining the data in Table 5-6 on an account-by-account basis discloses the following:

Land & Land Rights - The costs included for the coal plants are probably artificially high due to the use of a land cost equivalent to that for the PWR plant. The MHTGR land costs should be and are less than that for a PWR due to the Low Population Zone (LPZ) being equal to the Exclusion Area Boundary (EAB).

Structures & Improvements - The MHTGR costs, without a containment structure required for the PWR, fall expectedly less than the PWR but are more than the coal plant costs due to the hardened and embedded NI structures.

Reactor (Boiler) Equipment - The costs of the four plants follow an economy of scale trend. The multiplicity of equipment costs in the MHTGR and the FGD equipment in the coal plants apparently balance off with the complexity of safety equipment in the PWR.

Turbine Plant Equipment - The MHTGR costs are higher as a result of using two turbines rather than one as used in the other plants. The PWR costs are the highest even in the presence of the economy of scale due to its poorer steam conditions.

Electric Plant Equipment - The MHTGR costs, although enveloped by the coal plant costs, are on the order of 15% higher than an equivalent sized coal plant due to multiplicity of equipment. The PWR costs, relative to its scale, are considerably higher than the 600 MWe coal plant costs. This is a consequence of the safety-related aspects of the PWR electrical systems (e.g., the safety-related emergency generators, Class 1E AC distribution systems, etc.).

Miscellaneous Plant Equipment - The MHTGR costs are considerably less than those for either the PWR or coal plants. This is primarily the consequence of there being minimal need for waste water treatment facilities for the MHTGR. There are extensive needs for waste water

treatment facilities for regeneration streams from water reactors and to clean up the water used in the FGD systems on coal plants.

Main Condenser Heat Rejection - The MHTGR costs are somewhat lower than equivalent coal plant costs due to the use of forced draft vs. natural draft cooling towers. The PWR costs are highest due to the use of natural draft cooling towers plus the higher waste heat load due to poorer steam conditions.

Total Direct Cost - The MHTGR cost falls between the 400 and 600 MWe coal plants but is on the order of 8-10% higher than an equivalent size coal plant primarily due to the more costly structures and turbine plant. The MHTGR cost is also higher than the 800 MWe PWR cost but, scale-wise, the PWR is not as close as the MHTGR to the cost of an equivalent sized single unit coal. The PWR costs are high relative to coal and the MHTGR due to the safety-related requirements in the structures and electrical plant accounts and the effects of poorer steam conditions on the costs in the turbine plant and heat rejection accounts.

Construction Services - Both the MHTGR and PWR costs are considerably higher than the coal plant costs due to nuclear grade construction requirements. The MHTGR costs are, however, significantly less than those for the PWR; this is attributable to separation of construction between the NI and ECA and fewer safety-related systems.

Home Office Engineering - The MHTGR home office engineering is higher than that required for coal plants, but is significantly less than that required for the PWR. However, even with a standardized and certified design, the MHTGR home office engineering costs appear to be about 50% higher than the coal plants. Note that if the difference between the PWR and the MHTGR costs are taken as the effect of design standardization, then relative to the total plant cost, design standardization has reduced the plant cost by about 5% which is comparable to the 4% computed in Section 2.4

Field Office Supervision - The MHTGR costs are in the expected range relative to the coal plant costs and are significantly less than the PWR

costs. The lower costs relative to the PWR are attributable to the separation of NI and ECA construction and fewer safety-related systems.

Owner's Cost - The MHTGR owner's cost is higher than the coal plant and PWR cost as a result of having been developed on a different basis. The PWR and coal plant owners cost is simply 10% of the direct and other indirect costs. The MHTGR cost is based on a detail cost estimate.

Total Indirect Costs - The total indirect costs show a marked difference between the nuclear and convention (i.e., coal) plants. This is attributable to nuclear grade construction services and nuclear licensing. The MHTGR has cut the difference between the PWR and coal plant indirect costs by more than half through design standardization and separation of NI and ECA construction and the fewer number of safety systems. The PWR indirects are 66% of the direct costs, the coal indirects are 30% and the MHTGR indirects are 44% (the MHTGR indirects would be only 37% if the owner's cost was estimated on the same basis as the coal and PWR plants).

Base Construction Costs - The direct costs of the plants can be regarded as somewhat comparable. However, the addition of the indirect costs cause the base construction costs of the MHTGR and PWR plants to be in a range of about 20% higher than the coal plants.

Contingency - The MHTGR and PWR plants have contingencies of about 20% whereas the coal plant contingencies are about 15%.

Total Overnight Costs - The difference in contingency costs between the nuclear and coal plants accentuates the difference between the nuclear and coal plant costs caused by the indirect cost differences.

AFUDC - The AFUDC costs are very dependent on the construction schedules. The coal and PWR schedules are 4 and 6 years respectively, whereas, the MHTGR schedule from start of site work is 3 years for the NOAK plant. (See Appendix G) The shorter MHTGR construction schedule is a consequence of separated construction, modularization, fewer safety-related systems and

incremental deployment. As a result, even though the MHTGR overnight cost is greater than the coal plant costs, the required AFUDC is about equivalent to that required by the coal plants. The PWR AFUDC is, however, double that of the MHTGR and coal plants due to its longer construction schedule and highest total overnight cost.

Total Capital Cost - The MHTGR cost is somewhat higher than the coal plant costs primarily due to higher indirect and contingency costs. The PWR costs are considerably higher due to higher indirect, contingency and AFUDC costs.

In summary, the MHTGR capital costs are more competitive with coal plants than PWR plants because of the steps taken to reduce indirect and AFUDC costs. The indirect costs have been controlled through design standardization and separation of nuclear and conventional construction. The AFUDC costs have been minimized by a shortened construction schedule made possible by separated construction, modularization, fewer safety systems and incremental deployment.

The capital cost data in Table 5-7 show that the costs in terms $/kWe for all of the large plants are less than the costs for the mid-size plants due to economy of scale effects. The PWR costs are reduced the most by the economy of scale, the MHTGR costs are reduced the least and the reduction in the coal plant costs is approximately mid-way between the PWR and MHTGR cost reductions. This is because the PWR equipment size is scaled up for the higher plant output whereas there is simply a doubling of the equipment and most of the structures for the large MHTGR. For the coal plants, there is a doubling of the boiler equipment but not the turbine equipment. As a consequence, the MHTGR capital costs for a large plant are not as close to an equivalent size coal plant as the mid-size plant but are still within the competitive range. Relative to the large PWR, the MHTGR would have a better load-growth matching capability due to sequential deployment.

5.2.2 Comparison of Busbar Generating Costs

A direct comparison can be made of the MHTGR busbar generating costs in Table 4-7 with the busbar generating costs of the alternative plants summarized in

Table 5-5. The NOAK MHTGR busbar costs are compared with the single unit coal plants and the 800 MWe PWR in Table 5-8. The large NOAK MHTGR plant is compared with the two-unit coal plants and the 1200 MWe PWR in Table 5-9. All of the data in Tables 5-8 and 5-9 are for plants with a 2010 commercial operation date (the assumed commercial operation date for the MHTGR NOAK plants).

Examination of the busbar generating cost components in Table 5-8 indicates the following:

Capital - The capital cost busbar components compare to one another in the same way as the capital costs on a $/kWe basis discussed in the previous section.

O&M - The NOAK MHTGR O&M costs, although greater than an equivalent size coal plant, are, nevertheless, significantly less than those for the PWR plant. The MHTGR inherent safety characteristics result in much less complex safety systems to operate and maintain.

Fuel - Both the MHTGR and the PWR have a considerable advantage over the coal plants in fuel costs. The MHTGR fuel costs are, however, greater than the PWR fuel costs. The more expensive MHTGR fuel is a primary tradeoff that has been made in the MHTGR plant for eliminating the need for emergency planning for evacuation and sheltering of the public.

Decommissioning - Relative to the other busbar cost components, nuclear plant decommissioning costs based on the Reference 3 guidance are minor additions, on the order of only about 1% of the total busbar cost.

Total busbar cost - The net results show that the NOAK MHTGR busbar generating cost has about a 12% economic advantage over an equivalent size coal plant and the 800 MWe PWR plant.

The fuel and decommissioning costs for the large plants in Table 5-9 are essentially the same as the corresponding costs for the smaller plants in Table 5-8. The economy of scale effects on the large plant capital costs

have been described in Section 5.2.1. The O&M costs follow an economy of scale trend with a pattern similar to that for the capital costs. The net result is that the PWR benefits the most from the economy of scale, the MHTGR benefits the least and the coal plants are in between. Nevertheless, the large MHTGR having considerable multiplicity of equipment still maintains about a 10% advantage over an equivalent size coal plant and is about on par with a 1200 MWe single unit PWR.

In summary, the terms of busbar generation cost, MHTGR equilibrium plants meet the goal in Reference 4 of having a 10% economic advantage over equivalent sized coal plants. The reference 540 MWe MHTGR equilibrium plant is computed to have about a 12% advantage over an equivalent size coal plant and a 800 MWe PWR plant. Constructing two of the equilibrium plant power blocks on the same site for a twice-size plant results in a large MHTGR which has about a 10% advantage over an equivalent size coal plant and is on par with a 1200 MWe PWR. The lower economic advantage of the larger size is a consequence of the economy of multiplicity losing ground to the economy of scale in the large plant size range.

TABLE 5-1

ALTERNATIVE POWER PLANT CAPITAL COST DATA

Plant Type	Total Capital Cost (1987$ 10^6)
400-MW(e) single-unit coal	790
400-MW(e) first of two units coal	793
400-MW(e) second of two units coal	602
600-MW(e) single-unit coal	987
600-MW(e) first of two units coal	991
600-MW(e) second of two units coal	752
800-MW(e) PWR	2021
1200-MW(e) PWR	2471

TABLE 5-2

1200 MWe PWR CAPITAL COSTS

from Reference 3

(Millions 1987$)

Account		Median experience	Best experience
20.	Land and Land Rights	5	5
21.	Structures and Improvements	353	229
22.	Reactor Plant Equipment	404	324
23.	Turbine Plant Equipment	286	236
24.	Electric Plant Equipment	132	88
25.	Miscellaneous Plant Equipment	77	50
26.	Main Cond. Heat Reject. System	61	52
	TOTAL DIRECT COSTS	1318	984
91.	Construction Services	322	176
92.	Home Office Engr. and Service	484	211
93.	Field Office Engr. and Serv.	451	114
94	Owner's Costs	256	147
TOTAL INDIRECT COSTS		1512	648
	BASE CONSTRUCTION COST	2830	1632
	- [$/kW(e)]	2358	1360
	CONTINGENCY[a]	553	319
	TOTAL OVERNIGHT COST	3383	1951
	- [$/kW(e)]	2819	1626
	ESCALATION	0	0
	INTEREST DURING CONSTRUCTION[b]	1302	520
	TOTAL CAPITAL COST	4685	2471
	- [$/kW(e)]	3904	2059

a Nuclear grade construction assumptions: 65% Account 21, 100% Account 22, 50% Account 24, 50% Account 92-94.

b Based on eight year construction time for median case and six year construction time for best case.

TABLE 5-3

ALTERNATIVE POWER PLANT O&M COST DATA

from Reference 3

Plant Type	Annual O&M Cost (1987$ 10^6)
400-MW(e) single-unit coal	24.0
600-MW(e) single-unit coal	26.3
800-MW(e) two-unit coal	36.3
1200-MW(e) two-unit coal	40.8
800-MW(e) PWR	72.2
1200-MW(e) PWR	78.7

TABLE 5-4

FUEL CYCLE UNIT COST PARAMETERS

from Reference 3

	1987 Price	Real Escalation Rate (%/year)
Uranium ore ($/lb)	23	2.0
Conversion ($/kg U)	8.20	0
Enrichment ($/kg SWU)	110	-1.5 to 2005, 0 thereafter
Fabrication ($/kg HM)	245	0
Waste disposal (mills/kWh)	1	0

TABLE 5-5

ALTERNATIVE POWER PLANT GENERATION COST ESTIMATE SUMMARY

(80% CAPACITY FACTOR)

Plant	Year of Commercial Operation	Levelized Cost (1987 mills/kWh) Capital	O&M	Fuel	Decom	Total
400 MWe Single-Unit Coal	2000	27.6	8.9	21.9	---	58.4
	2005	27.6	8.9	23.0	---	59.5
	2010	27.6	8.9	24.2	---	60.7
600 MWe Single-Unit Coal	2000	23.0	6.5	21.7	---	51.3
	2005	23.0	6.5	22.8	---	52.4
	2010	23.0	6.5	24.0	---	53.5
800 MWe Two-Unit Coal	2000	24.5	6.9	22.0	---	53.4
	2005	24.5	6.9	23.1	---	54.5
	2010	24.5	6.9	24.3	---	55.6
1200 MWe Two-Unit Coal	2000	20.4	5.2	21.8	---	47.4
	2005	20.4	5.2	22.9	---	48.5
	2010	20.4	5.2	24.1	---	49.7
800 MWe PWR	2000	34.9	12.9	6.7	.6	55.0
	2005	34.9	12.9	6.8	.6	55.1
	2010	34.9	12.9	7.1	.6	55.4
1200 MWe PWR	2000	28.4	9.4	6.7	.6	45.0
	2005	28.4	9.4	6.8	.6	45.1
	2010	28.4	9.4	7.1	.6	45.4

TABLE 5-6
COMPARISON OF MID-SIZE PLANT CAPITAL COSTS ON $/kWe BASIS
NOAK MHTGR VS EEDB SINGLE UNIT COAL PLANTS
AND 800MWe PWR
(1987$)

	PWR-BE 800 MWe	COAL w/FGD 400 MWe	COAL w/FGD 600 MWe	4x2 MHTGR 540 MWe
EEDB DIRECT COST ACC'TS:				
LAND & LAND RIGHTS	6	13	8	4
STRUCTURES & IMPROVEMENTS	234	173	137	206
REACTOR (BOILER) PLANT EQUIPMENT	331	520	442	479
TURBINE PLANT EQUIPMENT	241	213	188	231
ELECTRIC PLANT EQUIPMENT	90	100	75	94
MISCELLANEOUS PLANT EQUIPMENT	51	60	43	24
MAIN CONDENSER HEAT REJECTION	53	48	45	42
TOTAL DIRECT COST	1006	1125	938	1080
EEDB INDIRECT COST ACC'TS:				
CONSTRUCTION SERVICES	180	98	80	131
HO ENGINEERING AND SERVICE	216	65	55	89
FO SUPERVISION & SERVICE	117	48	38	48
OWNER'S COST	150	133	110	211
TOTAL INDIRECT COST	662	343	283	479
BASE CONSTRUCTION COST	1668	1468	1222	1558
CONTINGENCY	326	218	182	322
TOTAL OVERNIGHT COST	1995	1685	1403	1880
AFUDC	532	290	242	259
TOTAL CAPITAL COST	2526	1975	1645	2139

TABLE 5-7
COMPARISON OF LARGE PLANT CAPITAL COSTS ON $/kWe BASIS
LARGE NOAK MHTGR VS EEDB TWO UNIT COAL PLANTS
AND 1200MWe PWR
(1987$)

	PWR-BE 1200 MWe	COAL w/FGD 800 MWe	COAL w/FGD 1200 MWe	8x4 MHTGR 1075 MWe
EEDB DIRECT COST ACC'TS:				
LAND & LAND RIGHTS	4	11	7	3
STRUCTURES & IMPROVEMENTS	191	152	121	201
REACTOR (BOILER) PLANT EQUIPMENT	270	459	390	444
TURBINE PLANT EQUIPMENT	197	188	166	231
ELECTRIC PLANT EQUIPMENT	73	88	66	94
MISCELLANEOUS PLANT EQUIPMENT	42	53	38	24
MAIN CONDENSER HEAT REJECTION	43	42	40	42
TOTAL DIRECT COST	820	993	828	1039
EEDB INDIRECT COST ACC'TS:				
CONSTRUCTION SERVICES	147	86	71	129
HO ENGINEERING AND SERVICE	176	57	49	69
FO SUPERVISION & SERVICE	95	42	34	48
OWNER'S COST	123	117	97	183
TOTAL INDIRECT COST	540	302	250	429
BASE CONSTRUCTION COST	1360	1296	1079	1468
CONTINGENCY	266	192	160	301
TOTAL OVERNIGHT COST	1626	1488	1239	1768
AFUDC	433	256	213	237
TOTAL CAPITAL COST	2059	1744	1452	2006

TABLE 5-8
COMPARISON OF MID-SIZE PLANT BUSBAR GENERATING COSTS
NOAK MHTGR VS EEDB SINGLE UNIT COAL PLANTS
AND 800MWe PWR
(1987 Mills/kWh)

	PWR-BE 800 MWe	COAL w/FGD 400 MWe	COAL w/FGD 600 MWe	4x2 MHTGR 540 MWe
CAPITAL	34.9	27.6	23.0	29.2
O&M	12.9	8.9	6.5	8.4
FUEL	7.1	24.2	24.0	10.4
DECOMMISSIONING	0.6	0.0	0.0	0.5
TOTAL	55.5	60.7	53.5	48.5

TABLE 5-9
COMPARISON OF LARGE PLANT BUSBAR GENERATING COSTS
LARGE MHTGR VS EEDB TWO UNIT COAL PLANTS
AND 1200MWe PWR
(1987 Mills/kWh)

	PWR-BE 1200 MWe	COAL w/FGD 800 MWe	COAL w/FGD 1200 MWe	8x4 MHTGR 1075 MWe
CAPITAL	28.4	24.5	20.4	27.4
O&M	9.4	6.9	5.2	7.4
FUEL	7.1	24.3	24.1	10.4
DECOMMISSIONING	0.6	0.0	0.0	0.5
TOTAL	45.5	55.7	49.7	45.7

SECTION 6
REFERENCES

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4. "Utility/User Requirements for the Modular High Temperature Gas-Cooled Reactor Plant," GCRA 86-002, Rev. 2, (September 1986).

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14. Letter to Gordon W. Dean, "MHTGR Cost Estimating Groundrules and Procedures," GCRA/DOE-SAN (1018) dated April 3, 1987.

APPENDIX A

TABLES OF ACCOUNTS AND COMMODITIES

TABLE A-1

EEDB CODE OF ACCOUNTS
FOR THE MHTGR PLANT
CAPITAL COSTS

20 LAND AND LAND RIGHTS

200 - LAND AND LAND RIGHTS

21 STRUCTURES AND IMPROVEMENTS
- 211 - YARD WORK
- 212 - REACTOR BUILDING
- 213 - TURBINE BUILDING
- 214 - OPERATION CENTER
- 215 - REACTOR SERVICE BUILDING
- 216 - RADIOACTIVE WASTE MANAGEMENT BUILDING
- 217 - NOT USED
- 218A - PERSONNEL SERVICES BUILDING
- 218B - NOT USED
- 218C - MAKEUP WATER TREATMENT & AUXILIARY BOILER BUILDING
- 218D - FIRE PUMP HOUSE
- 218E - HELIUM STORAGE BUILDING
- 218G - HYDROGEN STORAGE AREA
- 218H - GUARD HOUSE
- 218I - NUCLEAR ISLAND WAREHOUSE
- 218J - ECA WAREHOUSE
- 218K - MAINTENANCE BUILDING
- 218U - STANDBY POWER BUILDING
- 218X - NUCLEAR ISLAND COOLING WATER BUILDING
- 218Z - REACTOR AUXILIARY BUILDINGS

22 REACTOR PLANT EQUIPMENT

- 221 - REACTOR SYSTEM
- 222 - VESSEL SYSTEM
- 223 - HEAT TRANSPORT SYSTEM
- 224 - REACTOR CAVITY COOLING SYSTEM
- 225 - SHUTDOWN COOLING SYSTEM
- 226 - FUEL HANDLING, STORAGE & SHIPPING SYSTEM
- 227 - REACTOR SERVICE SYSTEMS
- 228 - PLANT CONTROL, DATA AND INSTRUMENTATION SYSTEM
- 229 - REACTOR PLANT MISCELLANEOUS ITEMS

23 TURBINE PLANT EQUIPMENT

- 231 - TURBINE GENERATOR
- 233 - CONDENSING SYSTEM
- 234 - FEED HEATING SYSTEM
- 235 - OTHER TURBINE PLANT EQUIPMENT
- 236 - INSTRUMENTATION AND CONTROL
- 237 - TURBINE PLANT MISCELLANEOUS ITEMS

24 ELECTRIC PLANT EQUIPMENT

241 - SWITCHGEAR
242 - STATION SERVICE EQUIPMENT
243 - SWITCHBOARDS
244 - PROTECTIVE EQUIPMENT
245 - ELECTRICAL STRUCTURES AND WIRING CONTAINERS
246 - POWER AND CONTROL WIRING

25 MISCELLANEOUS PLANT EQUIPMENT

251 - TRANSPORTATION AND LIFT EQUIPMENT
252 - AIR, WATER, AND STEAM SERVICE SYSTEMS
253 - COMMUNICATIONS EQUIPMENT
254 - FURNISHINGS AND FIXTURES

26 MAIN CONDENSER HEAT REJECTION SYSTEM

261 - STRUCTURES
262 - MECHANICAL EQUIPMENT

91 CONSTRUCTION SERVICES

911 - TEMPORARY CONSTRUCTION FACILITIES
912 - CONSTRUCTION TOOLS AND EQUIPMENT
913 - PAYROLL INSURANCE AND TAXES
914 - PERMITS, INSURANCE AND LOCAL TAXES

92 HOME OFFICE ENGINEERING AND SERVICES

920 - REACTOR MODULE ENGINEERING & SERVICES
921 - PLANT ENGINEERING & SERVICES
922 - HOME OFFICE QUALITY ASSURANCE
923 - HOME OFFICE PROJECT & CONSTRUCTION MANAGEMENT

93 FIELD OFFICE AND SERVICES

931 - FIELD OFFICE EXPENSES
932 - FIELD JOB SUPERVISION
933 - FIELD OFFICE QUALITY ASSURANCE/QUALITY CONTROL
934 - TEST AND START-UP ENGINEERING

94 OWNER'S COST

941 - PROJECT MANAGEMENT EXPENSES
942 - FEES, TAXES, AND INSURANCE
943 - SPARE PARTS, AND CAPITAL EQUIPMENT
944 - STAFF TRAINING AND START-UP
945 - G & A

TABLE A-2

COMMODITY CODES FOR THE MHTGR PLANT

COMMODITY NO.	DESCRIPTION
	STRUCTURAL GROUP
1100	LAND AND LAND RIGHTS
1105	CLEARING
1110	SURFACING
1115	LANDSCAPING
1120	EXCAVATION
1130	BACKFILL
1201	SHEETING
1202	DEWATERING
1203	PILING
1204	ICE WALL
1205	SCOUR PROTECTION
1210	ROCKBOLTS & ANCHORS
1220	ROADS, WALKS, AND PARKING LOTS
1221	FENCE
1222	RAILROAD TRACKWORK
1230	BRIDGES
1240	WATERFRONT WORK
1250	DIKES
1260	DAMS
1280	STACKS
1290	BUILDING COMPLETE
1300	MISCELLANEOUS STRUCTURAL WORK
1400	REINFORCING
1420	FORMWORK
1421	METAL DECKING
1422	SLIPFORMS
1430	CONCRETE INSTALLATION
1440	OTHER MISCELLANEOUS CONCRETE WORK
1480	GUNITE
1500	EMBEDDED IRON
1530	LINER WORK
1600	STRUCTURAL STEEL
1610	MISC. STRUCTURAL STEEL
1624	MISC. STRUCTURAL STEEL
1640	IRONWORK
1645	HANDRAILS AND LADDERS
1650	CHECKERED PLATE, GRATING, AND TREADS
1670	EXPANSION JOINTS
1700	SIDING
1710	EXTERIOR DOORS, SASH, AND LOUVERS
1720	VENTILATORS
1730	ROOFING, FLASHING, AND ROOF INSULATION
1800	ARCHITECTURAL AND INTERIOR FINISH
1805	INTERIOR MASONRY
1810	INTERIOR DOORS, SASH, AND LOUVERS

1830 INTERIOR PARTITIONS
1840 CEILINGS
1850 TILEWORK
1870 FLOORING
1910 PAINTING - STRUCTURES
1920 PAINTING - EQUIPMENT
1930 PAINTING - PIPE & ACCESSORIES

MECHANICAL GROUP

2000 NSSS EQUIPMENT SUPPLIED BY GA TECHNOLOGIES
2100 NSSS EQUIPMENT SUPPLIED BY OTHERS
2200 PUMPS
2300 SHOP FABRICATED TANKS
2350 FIELD FABRICATED TANKS
2380 PUMP MOTORS AND DRIVES FURNISHED SEPARATELY
2410 HEAT EXCHANGERS
2450 MISCELLANEOUS MECHANICAL EQUIPMENT
2451 CHLORINATION EQUIPMENT
2452 MAKE-UP DEMINERALIZER EQUIPMENT
2453 CONDENSATE POLISHING EQUIPMENT
2454 SEWAGE TREATMENT EQUIPMENT
2460 FEEDWATER HEATERS AND DEAERATORS
2475 CRANES
2485 NUCLEAR FUEL HANDLING EQUIPMENT
2490 OTHER MATERIAL HANDLING EQUIPMENT
2500 TURBINE GENERATOR AND ACCESSORIES
2510 TURBINE GENERATOR AUXILIARY EQUIPMENT
2520 CONDENSER
2530 CONDENSER ASSOCIATED EQUIPMENT
2540 SCREENWELL EQUIPMENT
2550 COOLING TOWERS
2555 COOLING TOWER EQUIPMENT
2560 AUXILIARY BOILER
2570 AUXILIARY BOILER EQUIPMENT
2580 WATER SPRAY FIRE PROTECTION SYSTEMS
2581 WATER SPRAY FIRE PROTECTION EQUIPMENT
2582 CO2 FIRE PROTECTION SYSTEM
2583 CO2 FIRE PROTECTION EQUIPMENT
2584 HALON FIRE PROTECTION SYSTEMS
2585 HALON FIRE PROTECTION EQUIPMENT
2587 PORTABLE FIRE EXTINGUISHERS
2588 OTHER FIRE PROTECTION EQUIPMENT
2600 SERVICE AND INSTRUMENT AIR SYSTEM
2601 INSTRUMENT AIR SYSTEM
2603 STORM SEWER SYSTEM
2605 PLUMBING SYSTEMS
2607 HEATING, VENTILATING, AND AC SYSTEMS
2609 DOMESTIC WATER SYSTEM
2611 DOMESTIC WATER SYSTEM EQUIPMENT
2613 SANITARY SEWER SYSTEM
2615 WATER WELLS
2617 PLUMBING FIXTURES AND EQUIPMENT
2620 VANEAXIAL FANS

2630 CENTRIFUGAL FANS
2650 HEATING AND AIR CONDITIONING EQUIPMENT
2750 DUCTWORK
2756 LOUVERS & DAMPERS
2780 AIR FILTRATION EQUIPMENT
2840 MECH SPECIALTY ITEMS
2850 BUILDING SERVICE SPECIALTY ITEMS
2900 PRELIMINARY OPERATIONS AND TESTS
2910 PRE-SERVICE INSPECTION
2920 IN-SERVICE INSPECTION
2950 OTHER MECHANICAL SPECIALTY ITEMS

INSTRUMENTATION GROUP

3020 PLANT CONTROL SYSTEM
3040 PLANT PROTECTION SYSTEM
3100 OTHER INSTRUMENTS AND CONTROLS
3300 CONTROL BOARDS AND PANELS
3370 COMPUTERS
3380 INSTRUMENT RACKS
3390 INSTRUMENT TUBING, PIPING, VALVES, & FITTINGS
3400 INSTRUMENT CABLE AND TERMINATIONS
3410 CONTROL CABLE AND TERMINATIONS

ELECTRICAL GROUP

4000 YARD LIGHTING
4010 ELECTRICAL PENETRATIONS
4040 GROUNDING SYSTEM
4050 CATHODIC PROTECTION SYSTEM
4070 HEAT TRACING CABLE AND TERMINATIONS
4075 HEAT TRACING EQUIPMENT AND CONTROLS
4100 BUILDING LIGHTING AND ELECTRIC POWER
4200 CONDUIT INCL. SUPPORTS (EXCL. LIGHTING CONDUIT)
4280 CABLE TRAY INCLUDING SUPPORTS
4300 POWER CABLE INCLUDING TERMINATIONS - 600 VOLT
4400 POWER CABLE INCLUDING TERMINATIONS - 5KV
4500 POWER CABLE INCLUDING TERMINATIONS - 15KV
4600 ISOLATED PHASE BUS
4610 NONSEGREGATED PHASE BUS
4620 TRANSFORMERS
4680 SURGE AND PROTECTIVE EQUIPMENT
4700 POWER DISTRIBUTION EQUIPMENT
4710 UNIT SUBSTATIONS
4720 MOTOR CONTROL CENTERS
4730 POWER DISTRIBUTION PANELS
4735 MISCELLANEOUS POWER DISTRIBUTION EQUIPMENT
4750 AUXILIARY POWER TRANSFORMER
4760 EMERGENCY GAS TURBINE GENERATOR
4770 BATTERIES
4771 BATTERY CHARGERS

4773 STATIC INVERTERS
4774 UNINTERRUPTIBLE POWER SUPPLIES
4780 LOAD SEQUENCER
4790 MISCELLANEOUS AUXILIARY POWER SUPPLY EQUIPMENT
4800 COMMUNICATIONS SYSTEM AND EQUIPMENT
4810 SECURITY SYSTEM AND EQUIPMENT
4870 UNDERGROUND DUCTLINE INCLUDING MANHOLES

VALVE GROUP

5010 VALVES 2 IN. & BELOW-CARBON STEEL
5020 VALVES 2 IN. & BELOW-ALLOY STEEL
5030 VALVES 2 IN. & BELOW-STAINLESS STEEL
5050 VALVES 2 IN. & BELOW-MONEL/INCONEL/INCOLOY
5070 VALVES 2 IN. & BELOW-NONFERROUS
5090 VALVES 2 IN. & BELOW-OTHER
5100 VALVES 2.5 IN. & ABOVE-CARBON STEEL
5200 VALVES 2.5 IN. & ABOVE-ALLOY STEEL
5300 VALVES 2.5 IN. & ABOVE-STAINLESS STEEL
5500 VALVES 2.5 IN. & ABOVE-MONEL/INCONEL/INCOLOY
5700 VALVES 2.5 IN. & ABOVE-NONFERROUS
5800 VALVES 2.5 IN. & ABOVE-COPPER
5900 VALVES 2.5 IN. & ABOVE-OTHER

PIPE GROUP

6010 PIPE & FTGS. 2 IN. & BELOW INCL. WELDING-C.S.
6020 PIPE FTGS. 2 IN. & BELOW INCL. WELDING-ALLOY STEEL
6030 PIPE & FTGS. 2 IN. & BELOW INCL. WELDING-STAINLESS STEEL
6050 PIPE & FTGS. 2 IN. & BELOW INCL. WELDING-MONEL/INCONEL/INCOLOY
6070 PIPE & FTGS. 2 IN. & BELOW INCL. JOINING-NONFERROUS
6090 PIPE & FTGS. 2 IN. & BELOW INCL. JOINING-OTHER
6100 PIPE & FTGS. 2.5 IN. & ABOVE INCL. BLTD. JNTS.-C.S.
6200 PIPE & FTGS. 2.5 IN. & ABOVE INCL. BLTD. JNTS.-ALLOY STEEL
6300 PIPE & FTGS. 2.5 IN. & ABOVE INCL. BLTD. JNTS.-STAINLESS STEEL
6500 PIPE & FTGS. 2.5 IN. & ABOVE INCL. BLTD. JNTS.-MONEL/INCONEL/
INCOLOY
6700 PIPE & FTGS. 2.5 IN. & ABOVE INCL. BLTD. JNTS.-NONFERROUS
6800 PIPE & FTGS. 2.5 IN. & ABOVE - COPPER
6900 PIPE & FTGS. 2.5 IN. & ABOVE INCL. BLTD. JNTS.-OTHER

PIPING ACCESSORIES & WELDING GROUP

7010 MISCELLANEOUS ERECTION MATERIAL
7020 PIPING INSULATION
7021 EQUIPMENT INSULATION
7022 DUCTWORK INSULATION
7030 PIPE SUPPORTS & RESTRAINTS EXCL. WHIP RESTRAINTS
7031 PIPE WHIP RESTRAINTS

7040 SPECIALTIES
7100 PIPE WELDING-2.5 IN. & ABOVE-CARBON STEEL
7200 PIPE WELDING-2.5 IN. & ABOVE-ALLOY STEEL
7300 PIPE WELDING-2.5 IN. & ABOVE-STAINLESS STEEL
7500 PIPE WELDING-2.5 IN. & ABOVE-MONEL/INCONEL/INCOLOY
7700 PIPE JOINING-2.5 IN. & ABOVE-NONFERROUS
7800 PIPE WELDING-2.5 IN. & ABOVE-COPPER
7900 PIPE WELDING-2.5 IN. & ABOVE-OTHER

INDIRECT GROUP

8100 A-E HOME OFFICE AND FIELD OFFICE ORGANIZATION
8200 QUALITY ASSURANCE
8300 TEST AND START-UP ENGINEERING
8400 CONSTRUCTION EQUIPMENT
8500 SCAFFOLDING
8600 TEMPORARY CONSTRUCTION FACILITIES
8910 INSURANCE
8920 PAYROLL TAXES
8930 STATE AND LOCAL TAXES
8940 PERMITS AND LICENSES
9000 RM HOME OFFICE ENGINEERING

APPENDIX B

ALGORITHMS FOR ESTIMATING INDIRECT COSTS

APPENDIX B

RECOMMENDED ALGORITHMS FOR ESTIMATING INDIRECT COSTS

GENERAL

Indirect costs are directly related to the labor and material value of the direct cost estimate, and to the overall project schedule. Bechtel has studied the relationships between direct and indirect costs on a series of pre-TMI nuclear plants and coal plants. Indirect costs were categorized into fixed, scope-related, and time-related components, and correlated with "nuclear" and "conventional" direct costs. Based on judgement and experience, the algorithms described below are recommended for equilibrium (Nth of a kind) advanced reactor projects.

In the formulas which follow, the following terms are used:

NI = Nuclear Island

ECA = Energy Conversion Area

NC = Nuclear Construction - applies to nuclear portions of NI requiring QA/QC

CC = Conventional Construction - applies to portions of NI and all of ECA including any offsite prefabricated subassemblies.

P = Power level, 540 MW(e) for Reference MHTGR Plant

PL = 1200 MW(e), (constant) reference LWR power level

LN = Field Labor Cost for ECA

M = Schedule duration (start of construction to commercial operation)

N = Total direct costs for NC, less value of equipment supplied by Reactor Manufacturer.

F = Total Direct Costs for CC portion of plant, excluding equipment supplied by Reactor Manufacturer and Turbine generator. (Includes value of any prefabricated modules unless nuclear grade).

T = N + F

A = NC equipment and site material costs, excluding portion supplied by Reactor Manufacturer.

B = NC site direct labor costs plus NC portions of 91 and 93 accounts.

C = CC equipment and site material costs, excluding portions supplied by Reactor Manufacturer and T/G Manufacturer.

D = CC Site direct labor costs plus CC portions of 91 and 93 accounts.

Account 91 -- Construction Services Costs

An algorithm has been developed for this account in which the costs were divided, using Bechtel experience, into three components each for the NI and ECA: a fixed component, a variable component related to scope, and a variable component related to schedule. The individual factors provide a means to account, in consistent manner, for unique plant design and construction features, such as:

- Nuclear vs. non-nuclear scope splits
- Levels of site labor (reduced with modularization)
- Construction schedules (varies with plant size and construction methods)

This approach permits the differences between plants to be factored into this indirect cost.

The algorithms derived for estimating construction services cost for any plant size are as follows:

For Nuclear Construction

$$\text{Account 91} = 3.5 \times 10^6 \, (P/PL)^{1/3} + 0.48 \, LN + 2.2 \times 10^5 \, (P/PL)^{1/2} \, M$$

For Conventional Construction (including NI CC related off-site fabricated equipment)

$$\text{Account 91} = 3.5 \times 10^6 \, (P/PL)^{2/3} + 0.34 \, LF + 2.2 \times 10^5 \, (P/PL)^{1} \, M$$

Total = NC + CC portions

Account 92 -- Home Office Engineering and Services Costs

These indirect costs are comprised of three elements:

- Site specific home office engineering costs
- Procurement related home office engineering costs
- Field construction related home office engineering costs

Site specific indirect costs result principally from the engineering activities required to adapt the standard plant design to the factors associated with particular sites. These include cooling water source, location, and quality; utility grid interfaces; soil and ground water characteristics; environmental conditions; and associated site specific licensing and permitting.

Procurement related indirect costs are associated with the activities to competitively procure equipment and site construction materials. They

include preparation of procurement packages; bid evaluation and contract award; supplier expediting; and source inspection.

Field construction related home office engineering costs are associated with the support of site labor, construction services and field office engineering and services. Included are construction management, with planning and control of project cost and schedule; quality assurance activities; engineering support of construction; and administrative support activities.

The following algorithms were derived for estimating these home office service costs for any plant size:

Nuclear Construction Portion

$$\text{Account } 92 = 32 \times 10^6 \left(^N/_T\right) + 0.16\ A + 0.11\ B$$

Conventional Construction

$$\text{Account } 92 = 6 \times 10^6 \left(^F/_T\right) + 0.07\ C + 0.02\ D$$

Total = NC + CC portions

These algorithms are consistent with relevant Bechtel experience modified to account for the repetitive engineering and other home office services needed for replication of a certified standard design under the prescribed DOE guidelines. The individual factors provide a means to account in a consistent manner for:

- Different nuclear vs. non-nuclear scope splits
- Different degrees of field construction vs. off-site shop assembly
- Different direct field labor requirements.

Account 93 -- Field Office Engineering and Services Costs

These costs were divided, using Bechtel experience, into NC and CC components. These factors provide a means to account, in a consistent manner, for unique plant design and construction features, such as:

- Nuclear vs. non-nuclear scope splits
- Levels of site labor
- Construction schedules

This approach permits the differences between plants to be factored into this indirect cost.

The algorithms derived for estimating field services costs for any plant size follow:

For Nuclear Construction

$$\text{Account 93} = 0.23\ LN + 7 \times 10^4\ (P/PL)^{1/2}\ M$$

For Conventional Construction

$$\text{Account 93} = 0.15\ LF + 7 \times 10^4\ (P/PL)^{1}\ M$$

Total = NC + CC portions

Selection of Cost Basis

It is clear that the ECA direct and indirect cost estimate should be based on conventional construction. For the nuclear island, however, there are also items which would normally be costed as conventional construction but because they must be constructed as part of the nuclear island, site-related costs are assumed to be based on nuclear QA/QC construction. Offsite work,

however, will not be subject to nuclear QA/QC even though it will be installed in the nuclear island and should be estimated based on conventional construction. Conventional construction would therefore apply to the direct cost of non safety-related shop fabricated systems/modules, etc., and associated home office engineering (Account 92), even though they are installed in the nuclear island. Table B-1 summarizes the cost estimating basis.

Table B-1

BASIS FOR SELECTION OF COST ESTIMATING FACTORS AND ALGORITHMS

	Nuclear Island		ECA
	NC Portion (Safety Related)	CC portion (Not Safety Related)	CC portion (All)
Direct Costs			
Equipment	As specified	As specified	As specified
Shop Fab. Preassemblies	Nuclear	Conventional	Conventional
Site Materials	Nuclear	Nuclear	Conventional
Site Labor	Nuclear	Nuclear	Conventional
Site Indirect Costs			
91 Account	Nuclear	Nuclear	Conventional
93 Account	Nuclear	Nuclear	Conventional
Home Office Indirect Costs			
92 Account	Nuclear	Conventional	Conventional

APPENDIX C

MOST LIKELY, EXPECTED AND CONTINGENCY COSTS

APPENDIX C

MOST LIKELY, EXPECTED AND CONTINGENCY COSTS

The expected overnight cost is the base construction cost plus contingency cost. Groundrules are provided in Section 3 for calculation of contingency cost as a percentage of base construction cost. The base construction cost is, in turn, defined in Section 2 to be the most likely cost. The relevance of these terms and their interrelationship is described in this Appendix.

Most Likely Cost

If there were several cost estimates for a given item, where the item has uncertainties and complexities associated with it, experience indicates that the distribution of the estimated costs would be typically like that shown in Figure C-1(a) with a characteristically skewed to-the-right shape. The highest point on the distribution corresponds to the estimate value for which there are the largest number of estimates. This value, known in statistics as the mode, is the most likely value (i.e., the highest probability value). The base construction cost estimates were to represent the most likely cost value.

Expected Cost and Contingency

Referring again to Figure C-1, note that the median estimate value (value for which there are an equal number of lower and higher estimates) is typically somewhat larger than the most likely estimate value. Similarly, the mean estimate value (weighted average value = $\sum$ estimate value x number/total number) is greater than the most likely value and the median value. For the skewed distribution such as that shown in Figure C-1(a), the mean is considered in statistics to be the indicator of "expected" value. The basis for the mean being the indicator of expected cost is shown in Figure C-1(b). The mean can be seen to be more centrally located in the 10 to 90% cumulative probability range than either the mode or median.

For the MHTGR cost estimates, the mean value representing the expected cost was computed as the most likely cost plus a contingency cost where, the contingency cost was a given percentage of the most likely cost.

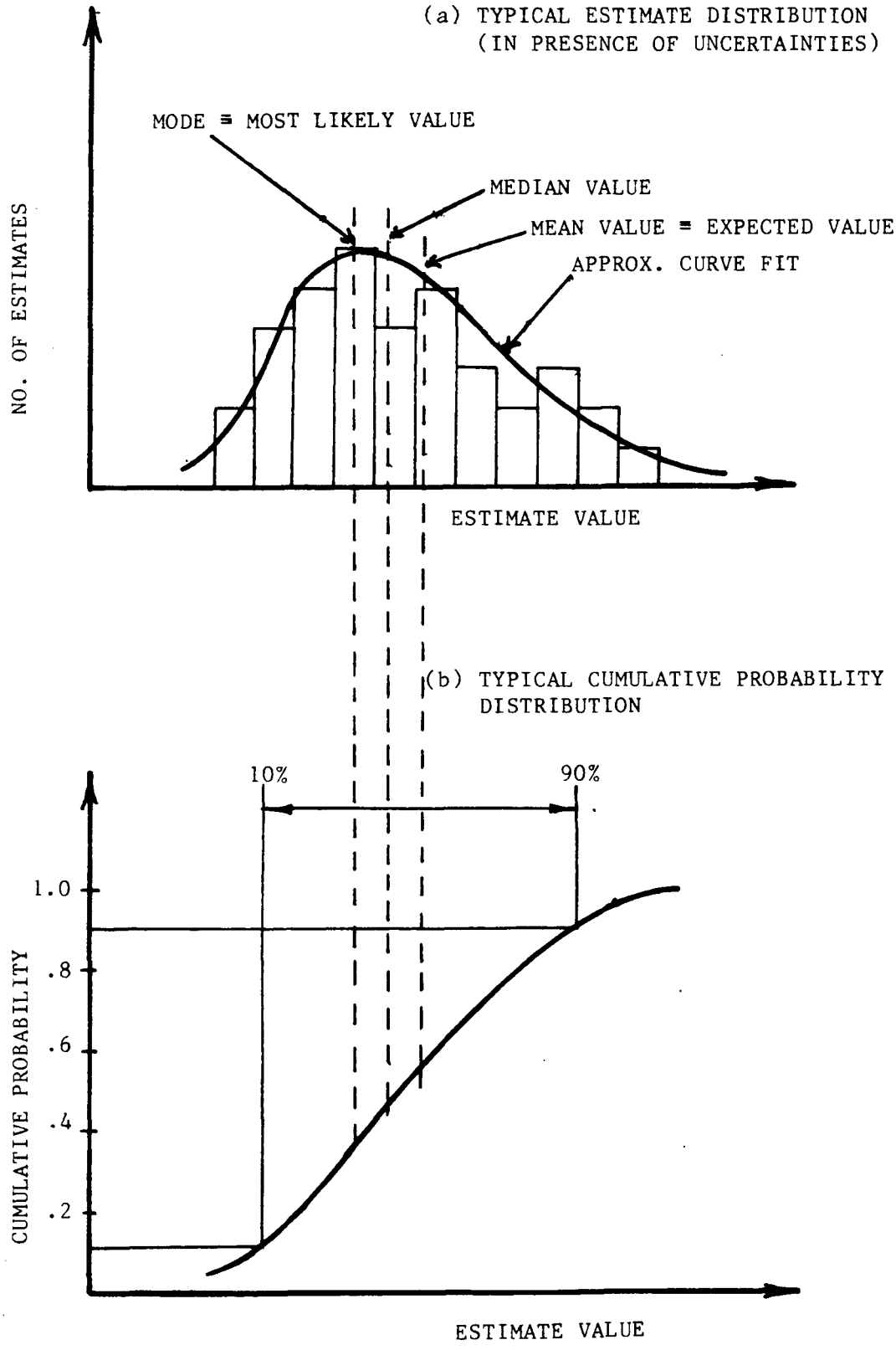


FIGURE C-1 ESTIMATE VALUE DISTRIBUTIONS

APPENDIX D

THREE-DIGIT LEVEL COST SUMMARIES

Table D-1

MHTGR LEAD PLANT - PHASE 1 BASE CONSTRUCTION COSTS

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	NI SITE LABOR HOURS	NI SITE LABOR COST	NI SITE MATERIAL	NI TOTAL NI	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	ECA SITE LABOR HOURS	ECA SITE LABOR COST	ECA SITE MATERIAL	ECA TOTAL ECA	TOTAL ESTIMATE
20	LAND & LAND RIGHTS											
200.	LAND & LAND RIGHTS	0.000	0	0.000	0.000	0.000	0.000	0	0.000	2.000	2.000	2.000
	TOTAL ACCOUNT 20	0.000	0	0.000	0.000	0.000	0.000	0	0.000	2.000	2.000	2.000
21	STRUCTURES & IMPROVEMENTS											
211.	YARDWORK	0.000	54	1.215	1.643	2.858	2.846	201	4.557	1.331	8.735	11.593
212.	REACTOR BUILDING	7.899	514	10.674	10.312	28.885	0.000	0	0.000	0.000	0.000	28.885
213.	TURBINE BUILDING	0.000	0	0.000	0.000	0.000	2.380	131	2.899	1.015	6.294	6.294
214.	OPERATIONS CENTER	0.000	0	0.000	0.000	0.000	0.409	149	3.409	3.448	7.266	7.266
214A	OPERATIONS CENTER A	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
214B	OPERATIONS CENTER B	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
215.	REACTOR SERVICE BUILDING	0.000	264	5.311	4.221	9.531	0.000	0	0.000	0.000	0.000	9.531
216.	RADIOACTIVE WASTE BUILDING	0.323	67	1.451	0.719	2.493	0.000	0	0.000	0.000	0.000	2.493
218A	PERSONNEL SERVICES BUILDING	0.000	61	1.267	0.700	1.967	0.000	0	0.000	0.000	0.000	1.967
218C	MAKEUP WATER TREATMENT & AUX. BLDG.	0.000	0	0.000	0.000	0.000	0.285	14	0.320	0.107	0.712	0.712
218D	FIRE PUMP HOUSE	0.000	0	0.000	0.000	0.000	0.045	3	0.059	0.009	0.113	0.113
218E	HELIUM STORAGE STRUCTURE	0.000	10	0.220	0.397	0.617	0.000	0	0.000	0.000	0.000	0.617
218G	HYDROGEN STORAGE AREA	0.000	0	0.000	0.000	0.000	0.004	1	0.014	0.009	0.027	0.027
218H	GUARD HOUSE	0.000	2	0.036	0.019	0.055	0.000	0	0.000	0.000	0.000	0.055
218I	NUCLEAR ISLAND WAREHOUSE	0.000	6	0.141	0.201	0.341	0.000	0	0.000	0.000	0.000	0.341
218J	ECA WAREHOUSE	0.000	0	0.000	0.000	0.000	0.123	8	0.176	0.055	0.355	0.355
218K	MAINTENANCE BUILDING	0.000	0	0.000	0.000	0.000	0.361	21	0.462	0.140	0.962	0.962
218U	STANDBY POWER BUILDING	0.000	0	0.000	0.000	0.000	0.162	9	0.200	0.075	0.436	0.436
218V	BUILDING V	0.000	22	0.449	0.205	0.653	0.000	0	0.000	0.000	0.000	0.653
218W	BUILDING W	0.000	22	0.443	0.189	0.632	0.000	0	0.000	0.000	0.000	0.632
218X	NUCLEAR ISLAND COOLING WATER BLDG.	0.000	8	0.173	0.232	0.405	0.000	0	0.000	0.000	0.000	0.405
218Z	REACTOR AUXILLARY BUILDING	0.000	36	0.743	0.412	1.154	0.000	0	0.000	0.000	0.000	1.154
	TOTAL ACCOUNT 21	8.222	1066	22.122	19.250	49.594	6.614	536	12.096	6.190	24.900	74.494

Table D-1 Cont.

(1987$ MILLIONS)
(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL NI	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL ECA	TOTAL ESTIMATE
22	REACTOR PLANT EQUIPMENT											
221.	REACTOR SYSTEM	19.425	17	0.413	0.079	19.917	0.000	0	0.000	0.000	0.000	19.917
222.	VESSEL SYSTEM	18.750	16	0.368	0.140	19.258	0.000	0	0.000	0.000	0.000	19.258
223.	HEAT TRANSPORT SYSTEM	12.300	2	0.048	0.005	12.353	0.000	0	0.000	0.000	0.000	12.353
224.	REACTOR CAVITY COOLING SYSTEM	1.818	30	0.691	0.163	2.672	0.000	0	0.000	0.000	0.000	2.672
225.	SHUTDOWN COOLING SYSTEM	3.348	17	0.411	0.265	4.024	0.000	0	0.000	0.000	0.000	4.024
226.	FUEL HANDLING, STOR. & SHIP. SYS.	28.927	34	0.821	0.544	30.291	0.000	0	0.000	0.000	0.000	30.291
227.	REACTOR SERVICE SYSTEMS	12.124	56	1.354	0.602	14.080	0.000	0	0.000	0.000	0.000	14.080
228.	PLANT CONTROL, DATA & INSTRU. SYS.	12.814	80	1.970	0.386	15.169	0.000	0	0.000	0.000	0.000	15.169
229.	REACTOR PLANT MISCELLANEOUS ITEMS	6.750	1	0.025	0.005	6.780	0.357	13	0.320	0.000	0.677	7.456
	TOTAL ACCOUNT 22	116.256	252	6.100	2.189	124.544	0.357	13	0.320	0.000	0.677	125.220
23	TURBINE PLANT EQUIPMENT											
231.	TURBINE GENERATOR	0.000	0	0.000	0.000	0.000	30.716	114	2.585	0.662	33.963	33.963
233.	CONDENSING SYSTEM	0.000	0	0.000	0.000	0.000	4.771	75	1.796	0.014	6.580	6.580
234.	FEED HEATING SYSTEM	0.000	0	0.000	0.000	0.000	4.019	57	1.383	0.009	5.411	5.411
235.	OTHER TURBINE PLANT EQUIPMENT	0.000	0	0.000	0.000	0.000	7.154	102	2.481	0.037	9.672	9.672
236.	INSTRUMENTATION & CONTROL	0.000	0	0.000	0.000	0.000	7.103	29	0.727	0.000	7.830	7.830
237.	TURBINE PLANT MISCELLANEOUS ITEMS	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
	TOTAL ACCOUNT 23	0.000	0	0.000	0.000	0.000	53.763	378	8.971	0.722	63.456	63.456
24	ELECTRIC PLANT EQUIPMENT											
241.	SWITCHGEAR	0.000	0	0.000	0.000	0.000	5.203	15	0.381	0.000	5.584	5.584
242.	STATION SERVICE EQUIPMENT	3.104	7	0.179	0.010	3.292	2.230	17	0.418	0.031	2.678	5.971
243.	SWITCHBOARDS	0.115	1	0.015	0.000	0.131	0.543	2	0.060	0.000	0.603	0.733
244.	PROTECTIVE EQUIPMENT	0.239	8	0.197	0.000	0.436	0.255	24	0.601	0.000	0.856	1.292
245.	ELECT. STRUCT & WIRING CONTAINERS	0.545	161	3.981	0.253	4.779	0.143	127	3.137	0.554	3.834	8.613
246.	POWER & CONTROL WIRING	1.037	56	1.380	0.000	2.418	1.474	41	1.021	0.000	2.495	4.913

Table D-1 Cont.

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL NI	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL ECA	TOTAL ESTIMATE
	TOTAL ACCOUNT 24	5.041	233	5.753	0.263	11.056	9.847	228	5.618	0.584	16.049	27.106
25	MISCELLANEOUS PLANT EQUIPMENT											
251.	TRANSPORTATION & LIFT EQUIPMENT	0.249	19	0.445	1.925	2.619	0.573	3	0.067	0.000	0.640	3.259
252.	AIR WATER & STEAM SERVICE SYSTEMS	0.000	15	0.358	0.243	0.600	1.681	48	1.177	0.164	3.022	3.623
253.	COMMUNICATIONS EQUIPMENT	0.000	0	0.000	0.000	0.000	1.086	34	0.850	0.000	1.936	1.936
254.	FURNISHINGS & FIXTURES	0.000	4	0.095	0.406	0.501	1.067	7	0.168	0.000	1.235	1.736
	TOTAL ACCOUNT 25	0.249	37	0.898	2.574	3.720	4.406	93	2.262	0.164	6.833	10.553
26	MAIN CONDENSER HEAT REJECTION											
261.	STRUCTURES	0.000	0	0.000	0.000	0.000	0.093	105	2.142	1.594	3.828	3.828
262.	MECHANICAL EQUIPMENT	0.000	0	0.000	0.000	0.000	9.505	188	4.345	0.442	14.291	14.291
	TOTAL ACCOUNT 26	0.000	0	0.000	0.000	0.000	9.597	294	6.486	2.035	18.119	18.119
	TOTAL DIRECT COST AND MANHOURS	129.767	1589	34.873	24.275	188.914	84.585	1542	35.754	11.695	132.034	320.949
91	CONSTRUCTION SERVICES											
911.	TEMPORARY CONSTRUCTION FACILITIES	0.000	0	6.517	1.543	8.060	3.492	0	2.495	0.000	5.987	14.047
912.	CONSTRUCTION TOOLS & EQUIPMENT	0.000	0	0.686	3.430	4.116	6.161	0	4.678	0.000	10.839	14.955
913.	PAYROLL, INSURANCE & TAXES	0.000	0	4.802	0.000	4.802	0.000	0	4.780	0.000	4.780	9.582
914.	PERMITS, INSURANCE AND LOCAL TAXES	0.000	0	0.000	0.171	0.171	0.000	0	8.546	0.000	8.546	8.717
	TOTAL ACCOUNT 91	0.000	0	12.004	5.145	17.149	9.653	0	20.499	0.000	30.152	47.301
92	HOME OFFICE ENGINEERING AND SERVICE											

Table D-1 Cont.

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	NI SITE LABOR HOURS	NI SITE LABOR COST	NI SITE MATERIAL	NI TOTAL	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	ECA SITE LABOR HOURS	ECA SITE LABOR COST	ECA SITE MATERIAL	ECA TOTAL	TOTAL ESTIMATE
920.	HOME OFFICE 920.	15.200	0	0.000	0.000	15.200	0.000	0	0.000	0.000	0.000	15.200
921.	HOME OFFICE SERVICES	0.000	0	8.149	0.000	8.149	2.150	0	8.580	0.000	10.730	18.879
922.	HOME OFFICE QA	0.000	0	1.630	0.000	1.630	0.000	0	0.000	0.000	0.000	1.630
923.	HOME OFFICE CONSTRUCTION MANAGEMENT	0.000	0	1.087	0.000	1.087	0.900	0	3.550	0.000	4.450	5.537
	TOTAL ACCOUNT 92	15.200	0	10.866	0.000	26.066	3.050	0	12.130	0.000	15.180	41.246
93	FIELD OFFICE & SERVICE											
931.	FIELD OFFICE EXPENSES	0.000	0	0.422	0.562	0.984	0.981	0	0.000	0.000	0.981	1.965
932.	FIELD JOB SUPERVISION	0.000	0	3.867	0.000	3.867	2.519	0	6.487	0.000	9.006	12.873
933.	FIELD OFFICE QA/QC	0.000	0	0.352	0.000	0.352	0.000	0	0.000	0.000	0.000	0.352
934.	TEST AND START-UP ENGINEERING	0.000	0	1.265	0.562	1.828	0.009	0	0.176	0.000	0.185	2.013
	TOTAL ACCOUNT 93	0.000	0	5.905	1.125	7.030	3.509	0	6.663	0.000	10.172	17.202
94	OWNER'S COST											
941.	PROJECT MANAGEMENT SERVICES	0.000	0	0.000	0.000	0.000	0.000	0	21.970	0.000	21.970	21.970
942.	FEES, TAXES, AND INSURANCE	0.000	0	0.000	0.000	0.000	0.000	0	0.000	30.050	30.050	30.050
943.	SPARE PARTS AND CAPITAL EQUIPMENT	0.000	0	0.000	0.000	0.000	0.000	0	0.000	6.440	6.440	6.440
944.	STAFF TRAINING AND STARTUP	0.000	0	0.000	0.000	0.000	0.000	0	8.300	2.800	11.100	11.100
945.	G & A	0.000	0	0.000	0.000	0.000	0.000	0	5.930	0.000	5.930	5.930
	TOTAL ACCOUNT 94	0.000	0	0.000	0.000	0.000	0.000	0	36.200	39.290	75.490	75.490
	TOTAL INDIRECT COST	15.200	0	28.775	6.270	50.245	16.212	0	75.492	39.290	130.994	181.239
TOTAL BASE CONSTRUCTION COST AND MANHOURS		144.967	1589	63.648	30.544	239.159	100.797	1542	111.246	50.985	263.028	502.188

Table D-2

MHTGR LEAD PLANT - PHASE 2 BASE CONSTRUCTION COSTS

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	NI SITE LABOR HOURS	NI SITE LABOR COST	NI SITE MATERIAL	NI TOTAL	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	ECA SITE LABOR HOURS	ECA SITE LABOR COST	ECA SITE MATERIAL	ECA TOTAL	TOTAL ESTIMATE
20	LAND & LAND RIGHTS											
200.	LAND & LAND RIGHTS	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
	TOTAL ACCOUNT 20	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
21	STRUCTURES & IMPROVEMENTS											
211.	YARDWORK	0.000	0	0.000	0.000	0.000	0.093	0	0.010	0.021	0.124	0.124
212.	REACTOR BUILDING	7.333	640	13.338	14.210	34.880	0.000	0	0.000	0.000	0.000	34.880
213.	TURBINE BUILDING	0.000	0	0.000	0.000	0.000	2.376	87	2.026	0.207	4.608	4.608
214.	OPERATIONS CENTER	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
214A	OPERATIONS CENTER A	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
214B	OPERATIONS CENTER B	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
215.	REACTOR SERVICE BUILDING	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
216.	RADIOACTIVE WASTE BUILDING	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
218A	PERSONNEL SERVICES BUILDING	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
218C	MAKEUP WATER TREATMENT & AUX. BLDG.	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
218D	FIRE PUMP HOUSE	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
218E	HELIUM STORAGE STRUCTURE	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
218G	HYDROGEN STORAGE AREA	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
218H	GUARD HOUSE	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
218I	NUCLEAR ISLAND WAREHOUSE	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
218J	ECA WAREHOUSE	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
218K	MAINTENANCE BUILDING	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
218U	STANDBY POWER BUILDING	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
218V	BUILDING V	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
218W	BUILDING W	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
218X	NUCLEAR ISLAND COOLING WATER BLDG.	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
218Z	REACTOR AUXILLARY BUILDING	0.000	109	2.228	1.235	3.463	0.000	0	0.000	0.000	0.000	3.463
	TOTAL ACCOUNT 21	7.333	749	15.566	15.445	38.344	2.469	88	2.036	0.228	4.733	43.076

Table D-2 Cont.

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL NI	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL ECA	TOTAL ESTIMATE
22	REACTOR PLANT EQUIPMENT											
221.	REACTOR SYSTEM	58.275	50	1.186	0.237	59.698	0.000	0	0.000	0.000	0.000	59.698
222.	VESSEL SYSTEM	56.250	44	1.057	0.420	57.727	0.000	0	0.000	0.000	0.000	57.727
223.	HEAT TRANSPORT SYSTEM	36.900	6	0.136	0.015	37.051	0.000	0	0.000	0.000	0.000	37.051
224.	REACTOR CAVITY COOLING SYSTEM	1.958	37	0.867	0.238	3.063	0.000	0	0.000	0.000	0.000	3.063
225.	SHUTDOWN COOLING SYSTEM	7.050	20	0.477	0.240	7.767	0.000	0	0.000	0.000	0.000	7.767
226.	FUEL HANDLING, STOR. & SHIP. SYS.	5.500	9	0.219	0.491	6.210	0.000	0	0.000	0.000	0.000	6.210
227.	REACTOR SERVICE SYSTEMS	8.868	36	0.885	0.410	10.163	0.000	0	0.000	0.000	0.000	10.163
228.	PLANT CONTROL, DATA & INSTRU. SYS.	3.535	163	4.019	0.180	7.734	0.000	0	0.000	0.000	0.000	7.734
229.	REACTOR PLANT MISCELLANEOUS ITEMS	4.950	0	0.000	0.000	4.950	0.832	31	0.746	0.000	1.578	6.528
	TOTAL ACCOUNT 22	183.286	365	8.847	2.230	194.364	0.832	31	0.746	0.000	1.578	195.942
23	TURBINE PLANT EQUIPMENT											
231.	TURBINE GENERATOR	0.000	0	0.000	0.000	0.000	30.513	88	2.034	0.250	32.797	32.797
233.	CONDENSING SYSTEM	0.000	0	0.000	0.000	0.000	4.771	75	1.795	0.014	6.580	6.580
234.	FEED HEATING SYSTEM	0.000	0	0.000	0.000	0.000	5.592	79	1.935	0.023	7.549	7.549
235.	OTHER TURBINE PLANT EQUIPMENT	0.000	0	0.000	0.000	0.000	5.598	84	2.070	0.008	7.676	7.676
236.	INSTRUMENTATION & CONTROL	0.000	0	0.000	0.000	0.000	7.103	29	0.727	0.000	7.830	7.830
237.	TURBINE PLANT MISCELLANEOUS ITEMS	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
	TOTAL ACCOUNT 23	0.000	0	0.000	0.000	0.000	53.577	357	8.561	0.294	62.433	62.433
24	ELECTRIC PLANT EQUIPMENT											
241.	SWITCHGEAR	0.000	0	0.000	0.000	0.000	4.741	18	0.450	0.000	5.191	5.191
242.	STATION SERVICE EQUIPMENT	2.788	6	0.146	0.010	2.944	1.330	9	0.234	0.000	1.564	4.508
243.	SWITCHBOARDS	0.029	0	0.004	0.000	0.033	0.456	2	0.048	0.000	0.504	0.537
244.	PROTECTIVE EQUIPMENT	0.060	2	0.050	0.000	0.110	0.076	7	0.181	0.000	0.257	0.367
245.	ELECT. STRUCT & WIRING CONTAINERS	0.234	159	3.928	0.253	4.415	0.061	122	3.015	0.554	3.630	8.045
246.	POWER & CONTROL WIRING	1.639	95	2.344	0.000	3.983	1.908	58	1.435	0.000	3.343	7.326

Table D-2 Cont

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	NI SITE LABOR HOURS	NI SITE LABOR COST	NI SITE MATERIAL	NI TOTAL	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	ECA SITE LABOR HOURS	ECA SITE LABOR COST	ECA SITE MATERIAL	ECA TOTAL	TOTAL ESTIMATE
	TOTAL ACCOUNT 24	4.749	262	6.472	0.263	11.484	8.571	217	5.364	0.554	14.489	25.973
25	MISCELLANEOUS PLANT EQUIPMENT											
251.	TRANSPORTATION & LIFT EQUIPMENT	0.000	1	0.014	0.075	0.089	0.007	0	0.003	0.000	0.010	0.099
252.	AIR WATER & STEAM SERVICE SYSTEMS	0.000	9	0.211	0.240	0.451	0.633	24	0.594	0.067	1.294	1.745
253.	COMMUNICATIONS EQUIPMENT	0.000	0	0.000	0.000	0.000	0.325	16	0.384	0.000	0.709	0.709
254.	FURNISHINGS & FIXTURES	0.000	0	0.000	0.000	0.000	0.012	1	0.013	0.000	0.026	0.026
	TOTAL ACCOUNT 25	0.000	9	0.225	0.315	0.540	0.978	40	0.994	0.067	2.039	2.579
26	MAIN CONDENSER HEAT REJECTION											
261.	STRUCTURES	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
262.	MECHANICAL EQUIPMENT	0.000	0	0.000	0.000	0.000	3.611	66	1.462	0.372	5.446	5.446
	TOTAL ACCOUNT 26	0.000	0	0.000	0.000	0.000	3.611	66	1.462	0.372	5.446	5.446
	TOTAL DIRECT COST AND MANHOURS	195.368	1386	31.110	18.253	244.731	70.039	799	19.164	1.515	90.717	335.448
91	CONSTRUCTION SERVICES											
911.	TEMPORARY CONSTRUCTION FACILITIES	0.000	0	7.108	1.683	8.791	1.497	0	1.069	0.000	2.566	11.357
912.	CONSTRUCTION TOOLS & EQUIPMENT	0.000	0	0.748	3.741	4.489	2.641	0	2.005	0.000	4.646	9.135
913.	PAYROLL, INSURANCE & TAXES	0.000	0	5.237	0.000	5.237	0.000	0	2.048	0.000	2.048	7.285
914.	PERMITS, INSURANCE AND LOCAL TAXES	0.000	0	0.000	0.187	0.187	0.000	0	3.663	0.000	3.663	3.850
	TOTAL ACCOUNT 91	0.000	0	13.093	5.611	18.704	4.138	0	8.785	0.000	12.923	31.627
92	HOME OFFICE ENGINEERING AND SERVICE											

Table D-2 Cont.

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL NI	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL ECA	TOTAL ESTIMATE
920.	HOME OFFICE 920.	28.100	0	0.000	0.000	28.100	0.000	0	0.000	0.000	0.000	28.100
921.	HOME OFFICE SERVICES	0.000	0	8.074	0.000	8.074	1.250	0	4.370	0.000	5.620	13.694
922.	HOME OFFICE QA	0.000	0	1.615	0.000	1.615	0.000	0	0.000	0.000	0.000	1.615
923.	HOME OFFICE CONSTRUCTION MANAGEMENT	0.000	0	1.076	0.000	1.076	0.870	0	3.430	0.000	4.300	5.376
	TOTAL ACCOUNT 92	28.100	0	10.765	0.000	38.865	2.120	0	7.800	0.000	9.920	48.785
93	FIELD OFFICE & SERVICE											
931.	FIELD OFFICE EXPENSES	0.000	0	0.425	0.566	0.991	0.420	0	0.000	0.000	0.420	1.411
932.	FIELD JOB SUPERVISION	0.000	0	3.892	0.000	3.892	1.079	0	2.780	0.000	3.859	7.751
933.	FIELD OFFICE QA/QC	0.000	0	0.354	0.000	0.354	0.000	0	0.000	0.000	0.000	0.354
934.	TEST AND START-UP ENGINEERING	0.000	0	1.274	0.566	1.840	0.004	0	0.075	0.000	0.079	1.919
	TOTAL ACCOUNT 93	0.000	0	5.944	1.132	7.076	1.503	0	2.855	0.000	4.358	11.434
94	OWNER'S COST											
941.	PROJECT MANAGEMENT SERVICES	0.000	0	0.000	0.000	0.000	0.000	0	13.970	0.000	13.970	13.970
942.	FEES, TAXES, AND INSURANCE	0.000	0	0.000	0.000	0.000	0.000	0	0.000	27.760	27.760	27.760
943.	SPARE PARTS AND CAPITAL EQUIPMENT	0.000	0	0.000	0.000	0.000	0.000	0	0.000	8.170	8.170	8.170
944.	STAFF TRAINING AND STARTUP	0.000	0	0.000	0.000	0.000	0.000	0	8.200	2.700	10.900	10.900
945.	G & A	0.000	0	0.000	0.000	0.000	0.000	0	4.950	0.000	4.950	4.950
	TOTAL ACCOUNT 94	0.000	0	0.000	0.000	0.000	0.000	0	27.120	38.630	65.750	65.750
	TOTAL INDIRECT COST	28.100	0	29.801	6.743	64.645	7.761	0	46.560	38.630	92.951	157.596
TOTAL BASE CONSTRUCTION COST AND MANHOURS		223.468	1386	60.911	24.997	309.376	77.800	799	65.724	40.145	183.668	493.044

Table D-3

MHTGR REPLICA PLANT BASE CONSTRUCTION COSTS

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	NI SITE LABOR HOURS	NI SITE LABOR COST	NI SITE MATERIAL	NI TOTAL	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	ECA SITE LABOR HOURS	ECA SITE LABOR COST	ECA SITE MATERIAL	ECA TOTAL	TOTAL ESTIMATE
20	LAND & LAND RIGHTS											
200.	LAND & LAND RIGHTS	0.000	0	0.000	0.000	0.000	0.000	0	0.000	2.000	2.000	2.000
	TOTAL ACCOUNT 20	0.000	0	0.000	0.000	0.000	0.000	0	0.000	2.000	2.000	2.000
21	STRUCTURES & IMPROVEMENTS											
211.	YARDWORK	0.000	53	1.194	1.643	2.837	2.939	191	4.328	1.352	8.620	11.457
212.	REACTOR BUILDING	14.177	1132	23.566	24.522	62.265	0.000	0	0.000	0.000	0.000	62.265
213.	TURBINE BUILDING	0.000	0	0.000	0.000	0.000	4.756	193	4.354	1.161	10.271	10.271
214.	OPERATIONS CENTER	0.000	0	0.000	0.000	0.000	0.409	141	3.229	3.448	7.087	7.087
214A	OPERATIONS CENTER A	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
214B	OPERATIONS CENTER B	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
215.	REACTOR SERVICE BUILDING	0.000	260	5.220	4.221	9.441	0.000	0	0.000	0.000	0.000	9.441
216.	RADIOACTIVE WASTE BUILDING	0.323	64	1.375	0.719	2.417	0.000	0	0.000	0.000	0.000	2.417
218A	PERSONNEL SERVICES BUILDING	0.000	60	1.246	0.700	1.947	0.000	0	0.000	0.000	0.000	1.947
218C	MAKEUP WATER TREATMENT & AUX. BLDG.	0.000	0	0.000	0.000	0.000	0.285	14	0.304	0.107	0.696	0.696
218D	FIRE PUMP HOUSE	0.000	0	0.000	0.000	0.000	0.045	2	0.055	0.009	0.110	0.110
218E	HELIUM STORAGE STRUCTURE	0.000	10	0.217	0.397	0.614	0.000	0	0.000	0.000	0.000	0.614
218G	HYDROGEN STORAGE AREA	0.000	0	0.000	0.000	0.000	0.002	1	0.014	0.011	0.027	0.027
218H	GUARD HOUSE	0.000	2	0.035	0.019	0.054	0.000	0	0.000	0.000	0.000	0.054
218I	NUCLEAR ISLAND WAREHOUSE	0.000	6	0.138	0.201	0.338	0.000	0	0.000	0.000	0.000	0.338
218J	ECA WAREHOUSE	0.000	0	0.000	0.000	0.000	0.123	7	0.167	0.055	0.345	0.345
218K	MAINTENANCE BUILDING	0.000	0	0.000	0.000	0.000	0.361	19	0.437	0.140	0.938	0.938
218U	STANDBY POWER BUILDING	0.000	0	0.000	0.000	0.000	0.162	9	0.190	0.075	0.426	0.426
218V	BUILDING V	0.000	22	0.441	0.205	0.646	0.000	0	0.000	0.000	0.000	0.646
218W	BUILDING W	0.000	21	0.435	0.189	0.624	0.000	0	0.000	0.000	0.000	0.624
218X	NUCLEAR ISLAND COOLING WATER BLDG.	0.000	7	0.170	0.232	0.402	0.000	0	0.000	0.000	0.000	0.402
218Z	REACTOR AUXILLARY BUILDING	0.000	138	2.818	1.647	4.465	0.000	0	0.000	0.000	0.000	4.465
	TOTAL ACCOUNT 21	14.500	1775	36.855	34.695	86.050	9.081	577	13.079	6.359	28.519	114.569

Table D-3 Cont.

(1987$ MILLIONS)
(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL NI	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL ECA	TOTAL ESTIMATE
22	REACTOR PLANT EQUIPMENT											
221.	REACTOR SYSTEM	65.200	66	1.567	0.316	67.083	0.000	0	0.000	0.000	0.000	67.083
222.	VESSEL SYSTEM	66.400	59	1.396	0.560	68.356	0.000	0	0.000	0.000	0.000	68.356
223.	HEAT TRANSPORT SYSTEM	43.700	8	0.180	0.020	43.900	0.000	0	0.000	0.000	0.000	43.900
224.	REACTOR CAVITY COOLING SYSTEM	3.513	65	1.516	0.396	5.425	0.000	0	0.000	0.000	0.000	5.425
225.	SHUTDOWN COOLING SYSTEM	8.838	36	0.870	0.505	10.213	0.000	0	0.000	0.000	0.000	10.213
226.	FUEL HANDLING, STOR. & SHIP. SYS.	31.814	43	1.023	1.034	33.871	0.000	0	0.000	0.000	0.000	33.871
227.	REACTOR SERVICE SYSTEMS	19.525	90	2.187	1.013	22.724	0.000	0	0.000	0.000	0.000	22.724
228.	PLANT CONTROL, DATA & INSTRU. SYS.	16.049	236	5.826	0.566	22.441	0.000	0	0.000	0.000	0.000	22.441
229.	REACTOR PLANT MISCELLANEOUS ITEMS	9.000	1	0.024	0.005	9.029	1.189	43	1.010	0.000	2.199	11.228
	TOTAL ACCOUNT 22	264.039	603	14.588	4.414	283.041	1.189	43	1.010	0.000	2.199	285.24
23	TURBINE PLANT EQUIPMENT											
231.	TURBINE GENERATOR	0.000	0	0.000	0.000	0.000	61.229	192	4.376	0.912	66.518	66.518
233.	CONDENSING SYSTEM	0.000	0	0.000	0.000	0.000	9.543	143	3.402	0.027	12.972	12.972
234.	FEED HEATING SYSTEM	0.000	0	0.000	0.000	0.000	9.617	129	3.143	0.026	12.785	12.785
235.	OTHER TURBINE PLANT EQUIPMENT	0.000	0	0.000	0.000	0.000	12.753	177	4.311	0.045	17.109	17.109
236.	INSTRUMENTATION & CONTROL	0.000	0	0.000	0.000	0.000	14.206	56	1.378	0.000	15.583	15.583
237.	TURBINE PLANT MISCELLANEOUS ITEMS	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
	TOTAL ACCOUNT 23	0.000	0	0.000	0.000	0.000	107.346	696	16.610	1.010	124.967	124.967
24	ELECTRIC PLANT EQUIPMENT											
241.	SWITCHGEAR	0.000	0	0.000	0.000	0.000	9.943	32	0.787	0.000	10.731	10.731
242.	STATION SERVICE EQUIPMENT	5.892	12	0.308	0.020	6.219	3.560	25	0.618	0.031	4.208	10.427
243.	SWITCHBOARDS	0.144	1	0.018	0.000	0.162	0.999	4	0.102	0.000	1.101	1.264
244.	PROTECTIVE EQUIPMENT	0.299	9	0.234	0.000	0.533	0.331	30	0.741	0.000	1.072	1.604
245.	ELECT. STRUCT & WIRING CONTAINERS	0.779	303	7.494	0.506	8.779	0.204	236	5.829	1.107	7.141	15.920
246.	POWER & CONTROL WIRING	2.677	142	3.517	0.000	6.194	3.381	94	2.333	0.000	5.714	11.908

Table D-3 Cont.

(1987$ MILLIONS)
(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL NI	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL ECA	TOTAL ESTIMATE
	TOTAL ACCOUNT 24	9.790	469	11.571	0.526	21.887	18.418	422	10.411	1.138	29.967	51.853
	MISCELLANEOUS PLANT EQUIPMENT											
21.	TRANSPORTATION & LIFT EQUIPMENT	0.249	19	0.449	2.000	2.698	0.580	3	0.066	0.000	0.646	3.344
22.	AIR WATER & STEAM SERVICE SYSTEMS	0.000	23	0.557	0.483	1.040	2.314	69	1.678	0.231	4.223	5.262
23.	COMMUNICATIONS EQUIPMENT	0.000	0	0.000	0.000	0.000	1.411	47	1.170	0.000	2.581	2.581
24.	FURNISHINGS & FIXTURES	0.000	4	0.093	0.406	0.499	1.080	7	0.171	0.000	1.251	1.750
	TOTAL ACCOUNT 25	0.249	46	1.099	2.889	4.236	5.385	126	3.085	0.231	8.701	12.937
26	MAIN CONDENSER HEAT REJECTION											
261.	STRUCTURES	0.000	0	0.000	0.000	0.000	0.089	100	2.029	1.597	3.715	3.715
262.	MECHANICAL EQUIPMENT	0.000	0	0.000	0.000	0.000	13.146	241	5.502	0.784	19.433	19.433
	TOTAL ACCOUNT 26	0.000	0	0.000	0.000	0.000	13.236	341	7.531	2.381	23.148	23.148
	TOTAL DIRECT COST AND MANHOURS	288.578	2892	64.114	42.524	395.215	154.654	2205	51.726	13.120	219.500	614.715
91	CONSTRUCTION SERVICES											
911.	TEMPORARY CONSTRUCTION FACILITIES	0.000	0	12.413	2.940	15.353	4.703	0	3.360	0.000	8.063	23.416
912.	CONSTRUCTION TOOLS & EQUIPMENT	0.000	0	1.307	6.533	7.840	8.297	0	6.300	0.000	14.597	22.437
913.	PAYROLL, INSURANCE & TAXES	0.000	0	9.147	0.000	9.147	0.000	0	6.437	0.000	6.437	15.584
914.	PERMITS, INSURANCE AND LOCAL TAXES	0.000	0	0.000	0.327	0.327	0.000	0	11.508	0.000	11.508	11.835
	TOTAL ACCOUNT 91	0.000	0	22.867	9.800	32.667	13.000	0	27.605	0.000	40.605	73.272
92	HOME OFFICE ENGINEERING AND SERVICE											

Table D-3 Cont.

(1987$ MILLIONS)
(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	NI SITE LABOR HOURS	NI SITE LABOR COST	NI SITE MATERIAL	NI TOTAL	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	ECA SITE LABOR HOURS	ECA SITE LABOR COST	ECA SITE MATERIAL	ECA TOTAL	TOTAL ESTIMATE
920.	HOME OFFICE 920.	24.400	0	0.000	0.000	24.400	0.000	0	0.000	0.000	0.000	24.400
921.	HOME OFFICE SERVICES	0.000	0	15.902	0.000	15.902	1.990	0	8.230	0.000	10.220	26.122
922.	HOME OFFICE QA	0.000	0	3.180	0.000	3.180	0.000	0	0.000	0.000	0.000	3.180
923.	HOME OFFICE CONSTRUCTION MANAGEMENT	0.000	0	2.120	0.000	2.120	1.110	0	4.370	0.000	5.480	7.600
	TOTAL ACCOUNT 92	24.400	0	21.203	0.000	45.603	3.100	0	12.600	0.000	15.700	61.303
93	FIELD OFFICE & SERVICE											
931.	FIELD OFFICE EXPENSES	0.000	0	0.808	1.077	1.885	1.321	0	0.000	0.000	1.321	3.206
932.	FIELD JOB SUPERVISION	0.000	0	7.407	0.000	7.407	3.392	0	8.736	0.000	12.128	19.535
933.	FIELD OFFICE QA/QC	0.000	0	0.673	0.000	0.673	0.000	0	0.000	0.000	0.000	0.673
934.	TEST AND START-UP ENGINEERING	0.000	0	2.424	1.077	3.502	0.013	0	0.237	0.000	0.250	3.752
	TOTAL ACCOUNT 93	0.000	0	11.313	2.155	13.468	4.726	0	8.973	0.000	13.699	27.167
94	OWNER'S COST											
941.	PROJECT MANAGEMENT SERVICES	0.000	0	0.000	0.000	0.000	0.000	0	21.970	0.000	21.970	21.970
942.	FEES, TAXES, AND INSURANCE	0.000	0	0.000	0.000	0.000	0.000	0	0.000	53.540	53.540	53.540
943.	SPARE PARTS AND CAPITAL EQUIPMENT	0.000	0	0.000	0.000	0.000	0.000	0	0.000	14.610	14.610	14.610
944.	STAFF TRAINING AND STARTUP	0.000	0	0.000	0.000	0.000	0.000	0	15.000	5.000	20.000	20.000
945.	G & A	0.000	0	0.000	0.000	0.000	0.000	0	8.490	0.000	8.490	8.490
	TOTAL ACCOUNT 94	0.000	0	0.000	0.000	0.000	0.000	0	45.460	73.150	118.610	118.610
	TOTAL INDIRECT COST	24.400	0	55.382	11.955	91.737	20.826	0	94.638	73.150	188.614	280.351
TOTAL BASE CONSTRUCTION COST AND MANHOURS		312.978	2892	119.496	54.479	486.952	175.480	2205	146.364	86.270	408.114	895.066

Table D-4
MHTGR NOAK PLANT BASE CONSTRUCTION COSTS

(1987$ MILLIONS)
(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	NI SITE LABOR HOURS	NI SITE LABOR COST	NI SITE MATERIAL	NI TOTAL	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	ECA SITE LABOR HOURS	ECA SITE LABOR COST	ECA SITE MATERIAL	ECA TOTAL	TOTAL ESTIMATE
20	LAND & LAND RIGHTS											
200.	LAND & LAND RIGHTS	0.000	0	0.000	0.000	0.000	0.000	0	0.000	2.000	2.000	2.000
	TOTAL ACCOUNT 20	0.000	0	0.000	0.000	0.000	0.000	0	0.000	2.000	2.000	2.000
21	STRUCTURES & IMPROVEMENTS											
211.	YARDWORK	0.000	51	1.150	1.643	2.793	2.939	182	4.111	1.352	8.403	11.196
212.	REACTOR BUILDING	12.418	1086	22.614	24.522	59.554	0.000	0	0.000	0.000	0.000	59.554
213.	TURBINE BUILDING	0.000	0	0.000	0.000	0.000	4.756	184	4.135	1.161	10.051	10.051
214.	OPERATIONS CENTER	0.000	0	0.000	0.000	0.000	0.409	134	3.068	3.448	6.925	6.925
214A	OPERATIONS CENTER A	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
214B	OPERATIONS CENTER B	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
215.	REACTOR SERVICE BUILDING	0.000	249	5.002	4.221	9.222	0.000	0	0.000	0.000	0.000	9.222
216.	RADIOACTIVE WASTE BUILDING	0.323	61	1.306	0.719	2.348	0.000	0	0.000	0.000	0.000	2.348
218A	PERSONNEL SERVICES BUILDING	0.000	58	1.195	0.700	1.896	0.000	0	0.000	0.000	0.000	1.896
218C	MAKEUP WATER TREATMENT & AUX. BLDG.	0.000	0	0.000	0.000	0.000	0.285	13	0.288	0.107	0.680	0.680
218D	FIRE PUMP HOUSE	0.000	0	0.000	0.000	0.000	0.045	2	0.053	0.009	0.107	0.107
218E	HELIUM STORAGE STRUCTURE	0.000	9	0.205	0.397	0.602	0.000	0	0.000	0.000	0.000	0.602
218G	HYDROGEN STORAGE AREA	0.000	0	0.000	0.000	0.000	0.002	1	0.013	0.011	0.026	0.026
218H	GUARD HOUSE	0.000	2	0.034	0.019	0.053	0.000	0	0.000	0.000	0.000	0.053
218I	NUCLEAR ISLAND WAREHOUSE	0.000	6	0.133	0.201	0.334	0.000	0	0.000	0.000	0.000	0.334
218J	ECA WAREHOUSE	0.000	0	0.000	0.000	0.000	0.123	7	0.159	0.055	0.337	0.337
218K	MAINTENANCE BUILDING	0.000	0	0.000	0.000	0.000	0.361	18	0.416	0.140	0.916	0.916
218U	STANDBY POWER BUILDING	0.000	0	0.000	0.000	0.000	0.162	8	0.180	0.075	0.416	0.416
218V	BUILDING V	0.000	21	0.423	0.205	0.628	0.000	0	0.000	0.000	0.000	0.628
218W	BUILDING W	0.000	21	0.417	0.189	0.606	0.000	0	0.000	0.000	0.000	0.606
218X	NUCLEAR ISLAND COOLING WATER BLDG.	0.000	7	0.162	0.232	0.394	0.000	0	0.000	0.000	0.000	0.394
218Z	REACTOR AUXILLARY BUILDING	0.000	133	2.705	1.647	4.352	0.000	0	0.000	0.000	0.000	4.352
	TOTAL ACCOUNT 21	12.741	1703	35.346	34.695	82.782	9.081	548	12.423	6.359	27.863	110.645

Table D-4 Cont

(1987$ MILLIONS)
(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL NI	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL ECA	TOTAL ESTIMATE
22	REACTOR PLANT EQUIPMENT											
221.	REACTOR SYSTEM	58.500	63	1.505	0.316	60.321	0.000	0	0.000	0.000	0.000	60.321
222.	VESSEL SYSTEM	59.700	56	1.340	0.560	61.600	0.000	0	0.000	0.000	0.000	61.600
223.	HEAT TRANSPORT SYSTEM	37.700	7	0.173	0.020	37.893	0.000	0	0.000	0.000	0.000	37.893
224.	REACTOR CAVITY COOLING SYSTEM	2.988	63	1.457	0.390	4.835	0.000	0	0.000	0.000	0.000	4.835
225.	SHUTDOWN COOLING SYSTEM	7.728	34	0.835	0.505	9.068	0.000	0	0.000	0.000	0.000	9.068
226.	FUEL HANDLING, STOR. & SHIP. SYS.	28.335	41	0.981	1.034	30.350	0.000	0	0.000	0.000	0.000	30.350
227.	REACTOR SERVICE SYSTEMS	17.323	86	2.097	1.013	20.432	0.000	0	0.000	0.000	0.000	20.432
228.	PLANT CONTROL, DATA & INSTRU. SYS.	15.849	226	5.585	0.566	22.000	0.000	0	0.000	0.000	0.000	22.000
229.	REACTOR PLANT MISCELLANEOUS ITEMS	8.700	1	0.023	0.005	8.728	1.189	40	0.960	0.000	2.148	10.877
	TOTAL ACCOUNT 22	236.823	579	13.996	4.409	255.229	1.189	40	0.960	0.000	2.148	257.377
23	TURBINE PLANT EQUIPMENT											
231.	TURBINE GENERATOR	0.000	0	0.000	0.000	0.000	61.229	182	4.157	0.912	66.298	66.298
233.	CONDENSING SYSTEM	0.000	0	0.000	0.000	0.000	9.543	135	3.232	0.027	12.802	12.802
234.	FEED HEATING SYSTEM	0.000	0	0.000	0.000	0.000	9.617	122	2.986	0.026	12.628	12.628
235.	OTHER TURBINE PLANT EQUIPMENT	0.000	0	0.000	0.000	0.000	12.753	168	4.096	0.045	16.893	16.893
236.	INSTRUMENTATION & CONTROL	0.000	0	0.000	0.000	0.000	14.206	53	1.309	0.000	15.515	15.515
237.	TURBINE PLANT MISCELLANEOUS ITEMS	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
	TOTAL ACCOUNT 23	0.000	0	0.000	0.000	0.000	107.346	661	15.779	1.010	124.136	124.136
24	ELECTRIC PLANT EQUIPMENT											
241.	SWITCHGEAR	0.000	0	0.000	0.000	0.000	9.943	30	0.748	0.000	10.691	10.691
242.	STATION SERVICE EQUIPMENT	5.892	12	0.292	0.020	6.203	3.560	24	0.587	0.031	4.177	10.380
243.	SWITCHBOARDS	0.144	1	0.017	0.000	0.161	0.999	4	0.097	0.000	1.096	1.258
244.	PROTECTIVE EQUIPMENT	0.299	9	0.222	0.000	0.521	0.331	29	0.704	0.000	1.035	1.556
245.	ELECT. STRUCT & WIRING CONTAINERS	0.779	288	7.119	0.506	8.404	0.204	224	5.535	1.107	6.847	15.251
246.	POWER & CONTROL WIRING	2.677	136	3.351	0.000	6.028	3.381	90	2.212	0.000	5.593	11.621

Table D-4 Cont.

(1987$ MILLIONS)
(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL NI	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL ECA	TOTAL ESTIMATE
	TOTAL ACCOUNT 24	9.790	446	11.002	0.526	21.317	18.418	401	9.883	1.138	29.439	50.757
25	MISCELLANEOUS PLANT EQUIPMENT											
251.	TRANSPORTATION & LIFT EQUIPMENT	0.249	18	0.431	2.000	2.679	0.580	3	0.062	0.000	0.643	3.322
252.	AIR WATER & STEAM SERVICE SYSTEMS	0.000	22	0.535	0.483	1.017	2.314	65	1.594	0.231	4.139	5.156
253.	COMMUNICATIONS EQUIPMENT	0.000	0	0.000	0.000	0.000	1.411	45	1.111	0.000	2.522	2.522
254.	FURNISHINGS & FIXTURES	0.000	4	0.089	0.406	0.495	1.080	7	0.163	0.000	1.243	1.738
	TOTAL ACCOUNT 25	0.249	44	1.055	2.889	4.192	5.385	120	2.931	0.231	8.547	12.738
26	MAIN CONDENSER HEAT REJECTION											
261.	STRUCTURES	0.000	0	0.000	0.000	0.000	0.089	95	1.928	1.597	3.614	3.614
262.	MECHANICAL EQUIPMENT	0.000	0	0.000	0.000	0.000	13.146	229	5.227	0.784	19.157	19.157
	TOTAL ACCOUNT 26	0.000	0	0.000	0.000	0.000	13.236	324	7.154	2.381	22.771	22.771
	TOTAL DIRECT COST AND MANHOURS	259.603	2771	61.399	42.518	363.520	154.654	2094	49.130	13.120	216.904	580.424
91	CONSTRUCTION SERVICES											
911.	TEMPORARY CONSTRUCTION FACILITIES	0.000	0	12.030	2.849	14.879	4.468	0	3.192	0.000	7.660	22.539
912.	CONSTRUCTION TOOLS & EQUIPMENT	0.000	0	1.266	6.331	7.598	7.882	0	5.985	0.000	13.867	21.465
913.	PAYROLL, INSURANCE & TAXES	0.000	0	8.864	0.000	8.864	0.000	0	6.115	0.000	6.115	14.979
914.	PERMITS, INSURANCE AND LOCAL TAXES	0.000	0	0.000	0.317	0.317	0.000	0	10.933	0.000	10.933	11.250
	TOTAL ACCOUNT 91	0.000	0	22.160	9.497	31.657	12.350	0	26.225	0.000	38.575	70.232
92	HOME OFFICE ENGINEERING AND SERVICE											

Table D-4 Cont.

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	NI SITE LABOR HOURS	NI SITE LABOR COST	NI SITE MATERIAL	NI TOTAL	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	ECA SITE LABOR HOURS	ECA SITE LABOR COST	ECA SITE MATERIAL	ECA TOTAL	TOTAL ESTIMATE
920.	HOME OFFICE 920.	13.000	0	0.000	0.000	13.000	0.000	0	0.000	0.000	0.000	13.000
921.	HOME OFFICE SERVICES	0.000	0	15.402	0.000	15.402	1.900	0	7.330	0.000	9.230	24.632
922.	HOME OFFICE QA	0.000	0	3.080	0.000	3.080	0.000	0	0.000	0.000	0.000	3.080
923.	HOME OFFICE CONSTRUCTION MANAGEMENT	0.000	0	2.054	0.000	2.054	1.080	0	3.900	0.000	4.980	7.034
	TOTAL ACCOUNT 92	13.000	0	20.535	0.000	33.535	2.980	0	11.230	0.000	14.210	47.745
93	FIELD OFFICE & SERVICE											
931.	FIELD OFFICE EXPENSES	0.000	0	0.779	1.039	1.818	1.255	0	0.000	0.000	1.255	3.073
932.	FIELD JOB SUPERVISION	0.000	0	7.141	0.000	7.141	3.222	0	8.299	0.000	11.521	18.662
933.	FIELD OFFICE QA/QC	0.000	0	0.649	0.000	0.649	0.000	0	0.000	0.000	0.000	0.649
934.	TEST AND START-UP ENGINEERING	0.000	0	2.337	1.039	3.376	0.012	0	0.225	0.000	0.237	3.613
	TOTAL ACCOUNT 93	0.000	0	10.906	2.077	12.984	4.489	0	8.524	0.000	13.013	25.997
94	OWNER'S COST											
941.	PROJECT MANAGEMENT SERVICES	0.000	0	0.000	0.000	0.000	0.000	0	21.970	0.000	21.970	21.970
942.	FEES, TAXES, AND INSURANCE	0.000	0	0.000	0.000	0.000	0.000	0	0.000	50.760	50.760	50.760
943.	SPARE PARTS AND CAPITAL EQUIPMENT	0.000	0	0.000	0.000	0.000	0.000	0	0.000	14.510	14.510	14.510
944.	STAFF TRAINING AND STARTUP	0.000	0	0.000	0.000	0.000	0.000	0	13.500	4.500	18.000	18.000
945.	G & A	0.000	0	0.000	0.000	0.000	0.000	0	8.170	0.000	8.170	8.170
	TOTAL ACCOUNT 94	0.000	0	0.000	0.000	0.000	0.000	0	43.640	69.770	113.410	113.410
	TOTAL INDIRECT COST	13.000	0	53.601	11.574	78.176	19.819	0	89.619	69.770	179.208	257.384
TOTAL BASE CONSTRUCTION COST AND MANHOURS		272.603	2771	115.000	54.093	441.696	174.473	2094	138.749	82.890	396.112	837.808

Table D-5

MHTGR LARGE NOAK PLANT BASE CONSTRUCTION COSTS

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	NI SITE LABOR HOURS	NI SITE LABOR COST	NI SITE MATERIAL	NI TOTAL	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	ECA SITE LABOR HOURS	ECA SITE LABOR COST	ECA SITE MATERIAL	ECA TOTAL	TOTAL ESTIMATE
20	LAND & LAND RIGHTS											
200.	LAND & LAND RIGHTS	0.000	0	0.000	0.000	0.000	0.000	0	0.000	3.000	3.000	3.000
	TOTAL ACCOUNT 20	0.000	0	0.000	0.000	0.000	0.000	0	0.000	3.000	3.000	3.000
21	STRUCTURES & IMPROVEMENTS											
211.	YARDWORK	0.000	103	2.300	3.286	5.586	5.879	360	8.153	2.692	16.723	22.310
212.	REACTOR BUILDING	24.836	2173	45.228	49.044	119.108	0.000	0	0.000	0.000	0.000	119.10
213.	TURBINE BUILDING	0.000	0	0.000	0.000	0.000	9.511	367	8.270	2.322	20.103	20.10
214.	OPERATIONS CENTER	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
214A	OPERATIONS CENTER A	0.000	0	0.000	0.000	0.000	0.362	116	2.671	3.001	6.034	6.034
214B	OPERATIONS CENTER B	0.000	0	0.000	0.000	0.000	0.298	98	2.262	2.418	4.978	4.978
215.	REACTOR SERVICE BUILDING	0.000	498	10.003	8.441	18.444	0.000	0	0.000	0.000	0.000	18.444
216.	RADIOACTIVE WASTE BUILDING	0.646	121	2.612	1.439	4.697	0.000	0	0.000	0.000	0.000	4.697
218A	PERSONNEL SERVICES BUILDING	0.000	115	2.390	1.401	3.791	0.000	0	0.000	0.000	0.000	3.791
218C	MAKEUP WATER TREATMENT & AUX. BLDG.	0.000	0	0.000	0.000	0.000	0.429	19	0.433	0.161	1.023	1.023
218D	FIRE PUMP HOUSE	0.000	0	0.000	0.000	0.000	0.045	2	0.053	0.009	0.107	0.107
218E	HELIUM STORAGE STRUCTURE	0.000	9	0.205	0.397	0.602	0.000	0	0.000	0.000	0.000	0.602
218G	HYDROGEN STORAGE AREA	0.000	0	0.000	0.000	0.000	0.008	1	0.026	0.018	0.052	0.052
218H	GUARD HOUSE	0.000	3	0.068	0.038	0.106	0.000	0	0.000	0.000	0.000	0.106
218I	NUCLEAR ISLAND WAREHOUSE	0.000	12	0.266	0.401	0.667	0.000	0	0.000	0.000	0.000	0.667
218J	ECA WAREHOUSE	0.000	0	0.000	0.000	0.000	0.247	14	0.317	0.110	0.674	0.674
218K	MAINTENANCE BUILDING	0.000	0	0.000	0.000	0.000	0.361	18	0.416	0.140	0.916	0.916
218U	STANDBY POWER BUILDING	0.000	0	0.000	0.000	0.000	0.323	17	0.360	0.149	0.832	0.832
218V	BUILDING V	0.000	42	0.846	0.409	1.255	0.000	0	0.000	0.000	0.000	1.255
218W	BUILDING W	0.000	41	0.835	0.378	1.213	0.000	0	0.000	0.000	0.000	1.213
218X	NUCLEAR ISLAND COOLING WATER BLDG.	0.000	14	0.323	0.465	0.788	0.000	0	0.000	0.000	0.000	0.788
218Z	REACTOR AUXILLARY BUILDING	0.000	266	5.410	3.294	8.704	0.000	0	0.000	0.000	0.000	8.704
	TOTAL ACCOUNT 21	25.482	3396	70.487	68.993	164.962	17.463	1013	22.959	11.020	51.442	216.405

Table D-5 Cont.

(1987$ MILLIONS)
(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	NI SITE LABOR HOURS	NI SITE LABOR COST	NI SITE MATERIAL	NI TOTAL	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	ECA SITE LABOR HOURS	ECA SITE LABOR COST	ECA SITE MATERIAL	ECA TOTAL	TOTAL ESTIMATE
22	REACTOR PLANT EQUIPMENT											
221.	REACTOR SYSTEM	117.000	127	3.009	0.632	120.641	0.000	0	0.000	0.000	0.000	120.641
222.	VESSEL SYSTEM	119.400	113	2.681	1.120	123.201	0.000	0	0.000	0.000	0.000	123.201
223.	HEAT TRANSPORT SYSTEM	75.400	15	0.346	0.040	75.786	0.000	0	0.000	0.000	0.000	75.786
224.	REACTOR CAVITY COOLING SYSTEM	5.977	126	2.913	0.781	9.671	0.000	0	0.000	0.000	0.000	9.671
225.	SHUTDOWN COOLING SYSTEM	15.457	69	1.670	1.010	18.137	0.000	0	0.000	0.000	0.000	18.137
226.	FUEL HANDLING, STOR. & SHIP. SYS.	35.371	82	1.961	2.068	39.400	0.000	0	0.000	0.000	0.000	39.400
227.	REACTOR SERVICE SYSTEMS	23.214	158	3.864	1.893	28.970	0.000	0	0.000	0.000	0.000	28.970
228.	PLANT CONTROL, DATA & INSTRU. SYS.	31.697	452	11.171	1.132	44.000	0.000	0	0.000	0.000	0.000	44.000
229.	REACTOR PLANT MISCELLANEOUS ITEMS	12.700	2	0.046	0.010	12.756	2.377	81	1.919	0.000	4.297	17.053
	TOTAL ACCOUNT 22	436.216	1144	27.662	8.685	472.563	2.377	81	1.919	0.000	4.297	476.860
23	TURBINE PLANT EQUIPMENT											
231.	TURBINE GENERATOR	0.000	0	0.000	0.000	0.000	122.458	365	8.314	1.825	132.597	132.597
233.	CONDENSING SYSTEM	0.000	0	0.000	0.000	0.000	19.085	271	6.464	0.054	25.603	25.603
234.	FEED HEATING SYSTEM	0.000	0	0.000	0.000	0.000	19.233	244	5.972	0.052	25.257	25.257
235.	OTHER TURBINE PLANT EQUIPMENT	0.000	0	0.000	0.000	0.000	25.505	336	8.192	0.089	33.786	33.786
236.	INSTRUMENTATION & CONTROL	0.000	0	0.000	0.000	0.000	28.412	106	2.618	0.000	31.029	31.029
237.	TURBINE PLANT MISCELLANEOUS ITEMS	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0.000	0.000	0.000
	TOTAL ACCOUNT 23	0.000	0	0.000	0.000	0.000	214.693	1322	31.559	2.020	248.272	248.272
24	ELECTRIC PLANT EQUIPMENT											
241.	SWITCHGEAR	0.000	0	0.000	0.000	0.000	19.887	61	1.496	0.000	21.383	21.383
242.	STATION SERVICE EQUIPMENT	11.783	24	0.584	0.039	12.407	7.119	48	1.174	0.061	8.354	20.761
243.	SWITCHBOARDS	0.288	1	0.035	0.000	0.323	1.998	8	0.194	0.000	2.192	2.515
244.	PROTECTIVE EQUIPMENT	0.597	18	0.444	0.000	1.042	0.661	57	1.408	0.000	2.069	3.111
245.	ELECT. STRUCT & WIRING CONTAINERS	1.557	577	14.238	1.013	16.808	0.408	448	11.071	2.215	13.693	30.501
246.	POWER & CONTROL WIRING	5.353	271	6.702	0.000	12.055	6.762	179	4.424	0.000	11.186	23.241

Table D-5 Cont

(1987$ MILLIONS)
(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL NI	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL ECA	TOTAL ESTIMATE
	TOTAL ACCOUNT 24	19.579	891	22.004	1.052	42.635	36.836	801	19.766	2.276	58.878	101.513
25	MISCELLANEOUS PLANT EQUIPMENT											
251.	TRANSPORTATION & LIFT EQUIPMENT	0.497	36	0.861	4.000	5.358	1.160	5	0.125	0.000	1.286	6.644
252.	AIR WATER & STEAM SERVICE SYSTEMS	0.000	44	1.069	0.965	2.034	4.628	131	3.188	0.462	8.278	10.312
253.	COMMUNICATIONS EQUIPMENT	0.000	0	0.000	0.000	0.000	2.822	90	2.222	0.000	5.045	5.045
254.	FURNISHINGS & FIXTURES	0.000	8	0.179	0.812	0.991	2.159	14	0.326	0.000	2.485	3.476
	TOTAL ACCOUNT 25	0.497	87	2.109	5.777	8.383	10.769	240	5.862	0.462	17.093	25.477
26	MAIN CONDENSER HEAT REJECTION											
261.	STRUCTURES	0.000	0	0.000	0.000	0.000	0.185	190	3.855	3.187	7.228	7.228
262.	MECHANICAL EQUIPMENT	0.000	0	0.000	0.000	0.000	26.293	458	10.453	1.569	38.315	38.315
	TOTAL ACCOUNT 26	0.000	0	0.000	0.000	0.000	26.478	647	14.309	4.756	45.543	45.543
	TOTAL DIRECT COST AND MANHOURS	481.774	5518	122.262	84.508	688.544	308.617	4104	96.374	23.534	428.525	1117.069
91	CONSTRUCTION SERVICES											
911.	TEMPORARY CONSTRUCTION FACILITIES	0.000	0	23.706	5.615	29.320	8.800	0	6.288	0.000	15.088	44.408
912.	CONSTRUCTION TOOLS & EQUIPMENT	0.000	0	2.495	12.477	14.972	15.528	0	11.790	0.000	27.318	42.290
913.	PAYROLL, INSURANCE & TAXES	0.000	0	17.467	0.000	17.467	0.000	0	12.046	0.000	12.046	29.513
914.	PERMITS, INSURANCE AND LOCAL TAXES	0.000	0	0.000	0.624	0.624	0.000	0	21.538	0.000	21.538	22.162
	TOTAL ACCOUNT 91	0.000	0	43.669	18.715	62.384	24.328	0	51.662	0.000	75.990	138.374
92	HOME OFFICE ENGINEERING AND SERVICE											

Table D-5 Cont.

(1987$ MILLIONS)

(MANHOURS IN THOUSANDS)

ACCOUNT NO.	ACCOUNT DESCRIPTION	NUCLEAR ISLAND (NI) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL NI	ENERGY CONVERSION AREA (ECA) FACTORY EQUIPMENT	SITE LABOR HOURS	SITE LABOR COST	SITE MATERIAL	TOTAL ECA	TOTAL ESTIMATE
920.	HOME OFFICE 920.	15.500	0	0.000	0.000	15.500	0.000	0	0.000	0.000	0.000	15.500
921.	HOME OFFICE SERVICES	0.000	0	27.725	0.000	27.725	2.720	0	10.500	0.000	13.220	40.945
922.	HOME OFFICE QA	0.000	0	5.545	0.000	5.545	0.000	0	0.000	0.000	0.000	5.545
923.	HOME OFFICE CONSTRUCTION MANAGEMENT	0.000	0	3.697	0.000	3.697	1.750	0	6.960	0.000	8.710	12.407
	TOTAL ACCOUNT 92	15.500	0	36.967	0.000	52.467	4.470	0	17.460	0.000	21.930	74.397
93	FIELD OFFICE & SERVICE											
931.	FIELD OFFICE EXPENSES	0.000	0	1.576	2.101	3.677	2.472	0	0.000	0.000	2.472	6.149
932.	FIELD JOB SUPERVISION	0.000	0	14.444	0.000	14.444	6.347	0	16.349	0.000	22.696	37.140
933.	FIELD OFFICE QA/QC	0.000	0	1.313	0.000	1.313	0.000	0	0.000	0.000	0.000	1.313
934.	TEST AND START-UP ENGINEERING	0.000	0	4.727	2.101	6.828	0.024	0	0.450	0.000	0.474	7.302
	TOTAL ACCOUNT 93	0.000	0	22.061	4.202	26.263	8.843	0	16.799	0.000	25.642	51.905
94	OWNER'S COST											
941.	PROJECT MANAGEMENT SERVICES	0.000	0	0.000	0.000	0.000	0.000	0	31.640	0.000	31.640	31.640
942.	FEES, TAXES, AND INSURANCE	0.000	0	0.000	0.000	0.000	0.000	0	0.000	90.010	90.010	90.010
943.	SPARE PARTS AND CAPITAL EQUIPMENT	0.000	0	0.000	0.000	0.000	0.000	0	0.000	26.750	26.750	26.750
944.	STAFF TRAINING AND STARTUP	0.000	0	0.000	0.000	0.000	0.000	0	25.200	9.000	34.200	34.200
945.	G & A	0.000	0	0.000	0.000	0.000	0.000	0	13.890	0.000	13.890	13.890
	TOTAL ACCOUNT 94	0.000	0	0.000	0.000	0.000	0.000	0	70.730	125.760	196.490	196.490
	TOTAL INDIRECT COST	15.500	0	102.696	22.917	141.113	37.641	0	156.651	125.760	320.052	461.165
TOTAL BASE CONSTRUCTION COST AND MANHOURS		497.274	5518	224.958	107.425	829.657	346.258	4104	253.025	149.294	748.577	1578.234

APPENDIX E

MHTGR CAPITAL COSTS PER DOE GROUNDRULES

APPENDIX E

MHTGR COSTS PER DOE GROUNDRULES

There are two primary areas where the MHTGR cost estimates deviate from DOE groundrules to cause a significant effect on the capital costs. These are Owner's Costs and Contingency. The MHTGR estimates for both these two items cause the MHTGR capital costs to be higher than that which would be estimated if the DOE groundrules were used. In Tables E-1 through E-6, MHTGR plant capital cost data are provided in which both the owner's cost and contingency have been estimated in accordance with the DOE groundrules. These data are included to permit evaluations with alternative technologies on a comparable basis.

TABLE E-1
MHTGR LEAD PLANT - PHASE 1 TOTAL CAPITAL COST ESTIMATE
PER DOE GROUNDRULES
(MILLIONS OF 1987$)

EEDB Account No.	Account Description	Nuclear grade cost	Industrial grade cost	Total cost
20	Land and land rights	0.0	2.0	2.0
21	Structures and improvements	33.0	41.5	74.5
22	Reactor plant equipment	122.1	3.1	125.2
23	Turbine plant equipment	0.0	63.5	63.5
24	Electric plant equipment	0.0	27.1	27.1
25	Miscellaneous plant equipment	3.4	7.1	10.6
26	Main condenser heat rejection	0.0	18.1	18.1
	Total direct costs	158.5	162.4	320.9
91	Construction services	17.1	30.2	47.3
92	AE home office engineering	26.1	15.2	41.2
93	Field office supervision	7.0	10.2	17.2
94	Owner's expenses	0.0	42.7	42.7
	Total indirect costs	50.2	98.2	148.4
	BASE CONSTRUCTION COST - Total $	208.8	260.6	469.4
	- $/kW(e)	1553.5	1938.9	3492.3
	CONTINGENCY	52.2	39.1	91.3
	TOTAL OVERNIGHT COST - Total $	261.0	299.7	560.7
	- $/kW(e)	1941.8	2229.7	4171.5
	ESCALATION	0.0	0.0	0.0
	INTEREST DURING CONSTRUCTION			95.9
	TOTAL CAPITAL COST - Total $			656.6
	- $/kW(e)			4885.4

TABLE E-2
MHTGR LEAD PLANT - PHASE 2 TOTAL CAPITAL COST ESTIMATE
PER DOE GROUNDRULES
(MILLIONS OF 1987$)

EEDB Account No.	Account Description	Nuclear grade cost	Industrial grade cost	Total cost
20	Land and land rights	0.0	0.0	0.0
21	Structures and improvements	29.7	13.4	43.1
22	Reactor plant equipment	193.7	2.3	195.9
23	Turbine plant equipment	0.0	62.4	62.4
24	Electric plant equipment	0.0	26.0	26.0
25	Miscellaneous plant equipment	0.5	2.0	2.6
26	Main condenser heat rejection	0.0	5.4	5.4
	Total direct costs	223.9	111.5	335.4
91	Construction services	18.7	12.9	31.6
92	AE home office engineering	38.9	9.9	48.8
93	Field office supervision	7.1	4.4	11.4
94	Owner's expenses	0.0	42.7	42.7
	Total indirect costs	64.6	69.9	134.6
	BASE CONSTRUCTION COST - Total $	288.6	181.5	470.0
	- $/kW(e)	715.7	450.0	1165.7
	CONTINGENCY	72.1	27.2	99.4
	TOTAL OVERNIGHT COST - Total $	360.7	208.7	569.4
	- $/kW(e)	894.6	517.5	1412.2
	ESCALATION	0.0	0.0	0.0
	INTEREST DURING CONSTRUCTION			96.0
	TOTAL CAPITAL COST - Total $			665.4
	- $/kW(e)			1650.3

TABLE E-3
MHTGR LEAD PLANT TOTAL CAPITAL COST ESTIMATE
PER DOE GROUNDRULES
(MILLIONS OF 1987$)

EEDB Account No.	Account Description	Nuclear grade cost	Industrial grade cost	Total cost
20	Land and land rights	0.0	2.0	2.0
21	Structures and improvements	62.7	54.9	117.6
22	Reactor plant equipment	315.8	5.4	321.2
23	Turbine plant equipment	0.0	125.9	125.9
24	Electric plant equipment	0.0	53.1	53.1
25	Miscellaneous plant equipment	4.0	9.2	13.1
26	Main condenser heat rejection	0.0	23.6	23.6
	Total direct costs	382.5	273.9	656.4
91	Construction services	35.9	43.1	78.9
92	AE home office engineering	64.9	25.1	90.0
93	Field office supervision	14.1	14.5	28.6
94	Owner's expenses	0.0	85.4	85.4
	Total indirect costs	114.9	168.1	283.0
	BASE CONSTRUCTION COST - Total $	497.4	442.0	939.4
	- $/kW(e)	925.1	822.2	1747.4
	CONTINGENCY	124.3	66.3	190.6
	TOTAL OVERNIGHT COST - Total $	621.7	508.3	1130.0
	- $/kW(e)	1156.4	945.6	2102.0
	ESCALATION	0.0	0.0	0.0
	INTEREST DURING CONSTRUCTION			192.0
	TOTAL CAPITAL COST - Total $			1322.0
	- $/kW(e)			2459.1

TABLE E-4
MHTGR REPLICA PLANT TOTAL CAPITAL COST ESTIMATE
PER DOE GROUNDRULES
(MILLIONS OF 1987$)

EEDB Account No.	Account Description	Nuclear grade cost	Industrial grade cost	Total cost
20	Land and land rights	0.0	2.0	2.0
21	Structures and improvements	62.4	52.2	114.6
22	Reactor plant equipment	280.0	5.2	285.2
23	Turbine plant equipment	0.0	125.0	125.0
24	Electric plant equipment	0.0	51.9	51.9
25	Miscellaneous plant equipment	4.0	9.0	12.9
26	Main condenser heat rejection	0.0	23.1	23.1
	Total direct costs	346.3	268.4	614.7
91	Construction services	32.7	40.6	73.3
92	AE home office engineering	45.6	15.7	61.3
93	Field office supervision	13.5	13.7	27.2
94	Owner's expenses	0.0	77.6	77.6
	Total indirect costs	91.7	147.6	239.4
	BASE CONSTRUCTION COST - Total $	438.1	416.0	854.1
	- $/kW(e)	814.9	773.9	1588.7
	CONTINGENCY	109.5	62.4	171.9
	TOTAL OVERNIGHT COST - Total $	547.6	478.4	1026.0
	- $/kW(e)	1018.6	889.9	1908.5
	ESCALATION	0.0	0.0	0.0
	INTEREST DURING CONSTRUCTION			143.8
	TOTAL CAPITAL COST - Total $			1169.8
	- $/kW(e)			2175.9

TABLE E-5
MHTGR NOAK PLANT TOTAL CAPITAL COST ESTIMATE
PER DOE GROUNDRULES
(MILLIONS OF 1987$)

EEDB Account No.	Account Description	Nuclear grade cost	Industrial grade cost	Total cost
20	Land and land rights	0.0	2.0	2.0
21	Structures and improvements	60.8	49.8	110.6
22	Reactor plant equipment	252.3	5.1	257.4
23	Turbine plant equipment	0.0	124.1	124.1
24	Electric plant equipment	0.0	50.8	50.8
25	Miscellaneous plant equipment	3.9	8.8	12.7
26	Main condenser heat rejection	0.0	22.8	22.8
	Total direct costs	317.0	263.4	580.4
91	Construction services	31.7	38.6	70.2
92	AE home office engineering	33.5	14.2	47.7
93	Field office supervision	13.0	13.0	26.0
94	Owner's expenses	0.0	72.4	72.4
	Total indirect costs	78.2	138.2	216.4
	BASE CONSTRUCTION COST - Total $	395.2	401.7	796.8
	- $/kW(e)	735.1	747.2	1482.2
	CONTINGENCY	98.8	60.3	159.0
	TOTAL OVERNIGHT COST - Total $	494.0	461.9	955.9
	- $/kW(e)	918.8	859.2	1778.1
	ESCALATION	0.0	0.0	0.0
	INTEREST DURING CONSTRUCTION			131.6
	TOTAL CAPITAL COST - Total $			1087.5
	- $/kW(e)			2022.9

TABLE E-6
MHTGR LARGE NOAK PLANT TOTAL CAPITAL COST ESTIMATE
PER DOE GROUNDRULES
(MILLIONS OF 1987$)

EEDB Account No.	Account Description	Nuclear grade cost	Industrial grade cost	Total cost
20	Land and land rights	0.0	3.0	3.0
21	Structures and improvements	120.9	95.5	216.4
22	Reactor plant equipment	466.7	10.2	476.9
23	Turbine plant equipment	0.0	248.3	248.3
24	Electric plant equipment	0.0	101.5	101.5
25	Miscellaneous plant equipment	7.8	17.6	25.5
26	Main condenser heat rejection	0.0	45.5	45.5
	Total direct costs	595.4	521.6	1117.1
91	Construction services	62.4	76.0	138.4
92	AE home office engineering	52.5	21.9	74.4
93	Field office supervision	26.3	25.6	51.9
94	Owner's expenses	0.0	138.2	138.2
	Total indirect costs	141.1	261.7	402.9
	BASE CONSTRUCTION COST - Total $	736.5	783.4	1519.9
	- $/kW(e)	685.0	728.6	1413.6
	CONTINGENCY	184.1	117.5	301.6
	TOTAL OVERNIGHT COST - Total $	920.7	900.9	1821.6
	- $/kW(e)	856.3	837.9	1694.2
	ESCALATION	0.0	0.0	0.0
	INTEREST DURING CONSTRUCTION			244.5
	TOTAL CAPITAL COST - Total $			2066.0
	- $/kW(e)			1921.5

APPENDIX F

CALCULATION OF INTEREST COST DURING CONSTRUCTION

APPENDIX F

CALCULATION OF INTEREST COST DURING CONSTRUCTION

Cashflow estimates were provided by the program participants having responsibility for estimating the cost accounts. The cashflow estimates were provided in terms of either monthly percentage expenditures or monthly dollar expenditures. All of the cashflow data were converted to monthly percentages, multiplied through by the computed account cost and the results summed to develop a total cashflow for each plant estimate.

F.1 LEAD PLANT - PHASE I

Most participants provided the cashflow data on a quarterly basis and most data fell on the same month in the quarter. As a result, the summed monthly cashflow data, when plotted on a scale of months from start of site work has a jagged shape as illustrated in Figure F-1 for Phase 1 of the Lead plant. Although the jagged monthly cashflow is quite usable for calculation of interest during construction, such a cashflow produces a fairly rough cumulative cashflow curve. The data was smoothed out by determining a series of average monthly costs to produce the same total expenditures for selected periods of time. This approach produced the stepped monthly cashflow also shown in Figure F-1. The stepped cashflow can be envisioned as a uniform series of monthly expenditures which is periodically adjusted to meet project requirements.

The stepped monthly cashflow shown in Figure F-1 results in the cumulative cashflow curves for the Lead Phase 1 plant shown in Figure F-2 with and without interest during construction (i.e., AFUDC) for the construction period on the Lead plant construction schedule given in Appendix G.

The cumulative cashflow without AFUDC is simply the expression:

$$C_i = C_{i-1} + c_i$$

where,

C_i = cumulative cashflow at month i
c_i = cashflow for month i

The cumulative cashflow with AFUDC was determined using the expression:

$$A_i = A_{i-1}(1 + I/12) + c_i$$

where,

A_i = cumulative cashflow with interest included at month i
I = interest rate (real cost of money)
= 6.05% from Table 3.2
c_i = cashflow for month i

The numerical results for the Lead plant-Phase 1 AFUDC and total capital cost based on the above procedures are summarized in Table F-1.

F.2 LEAD PLANT - PHASE 2

Figure F-3 shows the smoothed monthly cashflow data for Phase 2 of the Lead plant. The monthly cashflow based on the smoothed data was appropriated between the second reactor module (RM 2) and the third and fourth reactor module (RM 3+4). The first reactor module (RM 1) and associated power conversion equipment was deployed in Phase 1 of the Lead plant. The addition of RM 2 to the Phase 1 plant completes one power unit and RM 3+4 plus the associated power conversion equipment and facilities comprises a second power unit.

The cumulative cashflow curves, with and without interest during construction, determined in the same manner as described previously for Phase 1 are shown in Figure F-4 for RM 2, RM 3+4 and the total for Phase 2. As can be seen in Figure F-4, the cashflow for RM 2 ends at its commercial operating date as identified on the Lead plant construction schedule given in Appendix G. All cashflow beyond the commercial operating date for RM 2 has been

assigned to RM 3+4. However, as can be seen from Figure F-3, the cashflow requirements between the commercial operating date for RM 2 and that for the second power unit (RM 3+4) is rather minimal. The AFUDC and total capital cost data are summarized in Table F-1.

F.3 REPLICA PLANT

The smoothed monthly cashflows for the total Replica plant and each of the Replica plant power units are shown in Figure F-5. For the Replica plant the cashflow was appropriated between power unit 1 and power unit 2. Power unit 1 contains the cost for the necessary plant common facilities, the first and second reactor modules and the power conversion facilities and equipment associated with the first and second reactor modules. Power unit 2 contains the costs for the third and fourth reactor modules and the associated power conversion equipment and facilities. No attempt was made to subdivide the costs to a per reactor module basis.

The resultant cumulative cashflow curves, with and without interest during construction for each of the two power units and for the total plant are shown in Figure F-6. The AFUDC and total capital cost data are summarized in Table F-1.

NOAK Plant

The NOAK plant smoothed monthly cashflow data are shown in Figure F-7. The resultant cumulative cashflow curves with and without interest during construction for power units 1, 2 and total plant are shown in Figure F-8. The resultant AFUDC and total capital cost data are summarized in Table F-1.

Large NOAK Plant

The smoothed monthly cashflow data for the large NOAK plant are shown in Figure F-9 for the first power block (Units 1 & 2), the second power block (Units 3 & 4) and the total plant. The cashflow data in Figure F-9 for the first power block is the same as that for the NOAK plant given in Figure F-7. The cashflow data for the second power block, split between power unit

3 and 4, is shown in Figure F-10. The resultant cumulative cashflow curves with and without interest during construction are shown in Figure F-11 for power block 1 (units 1 and 2), power block 2 (units 3 and 4) and for the total plant. The cumulative cashflow curves, including interest during construction, for each power unit in the large NOAK plant are shown in Figure F-12. The resultant AFUDC and total capital cost data are summarized in Table F-1.

TABLE F-1
SUMMARY OF AFUDC & TOTAL CAPITAL COSTS

	TOTAL OVERNIGHT COST(M$)	AFUDC (M$)	TOTAL CAPITAL COST(M$)
LEAD PLANT - PHASE 1	601.9	102.9	704.8
LEAD PLANT - PHASE 2			
RM 2	109.0	19.7	128.7
RM 3+4	490.5	81.3	571.8
TOTAL	599.5	101.0	700.5
LEAD PLANT (SUMMED)			
UNIT 1	710.9	122.7	833.5
UNIT 2	490.5	81.3	571.8
TOTAL	1201.4	203.9	1405.3
REPLICA PLANT			
UNIT 1	635.9	98.5	734.4
UNIT 2	445.4	53.1	498.4
TOTAL	1081.3	151.5	1232.8
NOAK PLANT			
UNIT 1	585.9	88.7	674.6
UNIT 2	424.9	50.6	475.5
TOTAL	1010.8	139.2	1150.0
LARGE NOAK PLANT			
UNIT 1	585.9	88.7	674.6
UNIT 2	424.9	50.6	475.5
UNIT 3	520.0	73.6	593.6
UNIT 4	370.6	42.4	413.0
TOTAL	1901.4	255.2	2156.6

FIGURE F-1

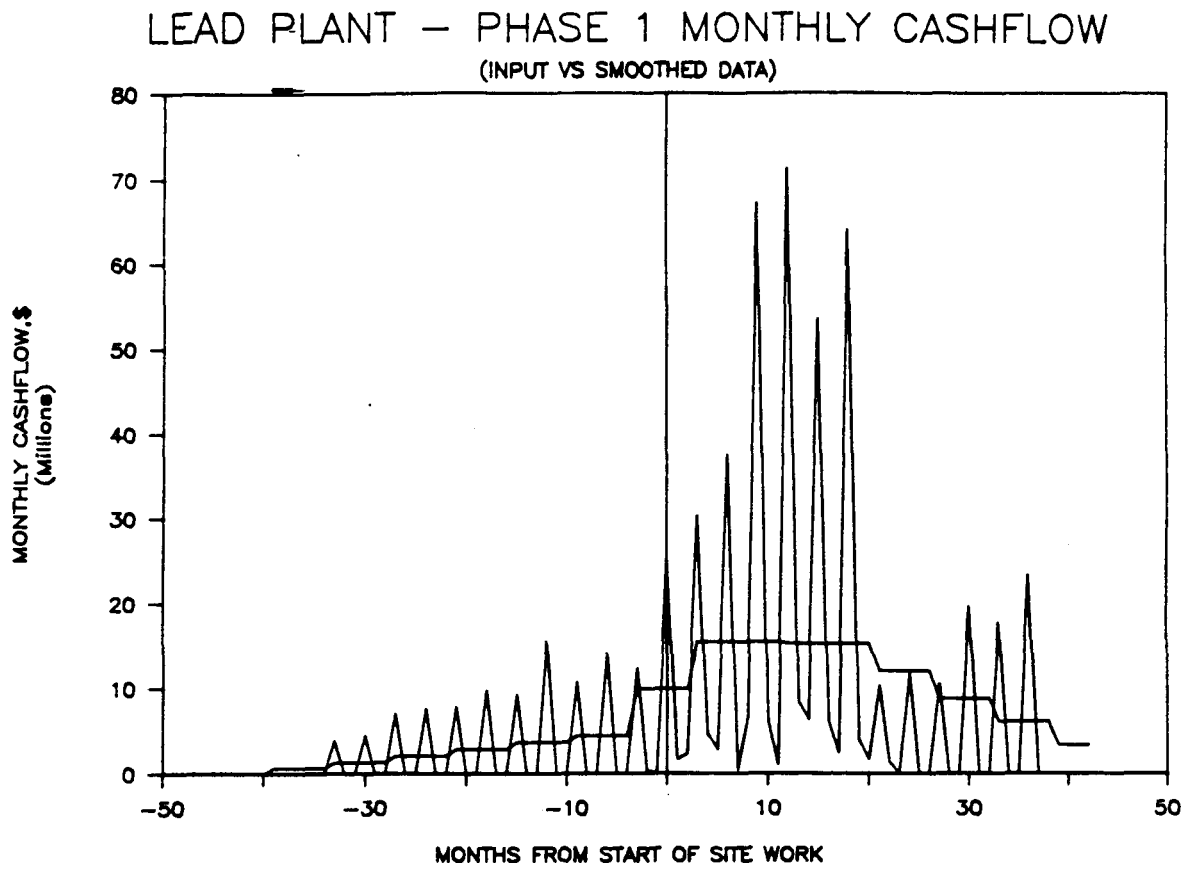


FIGURE F-2

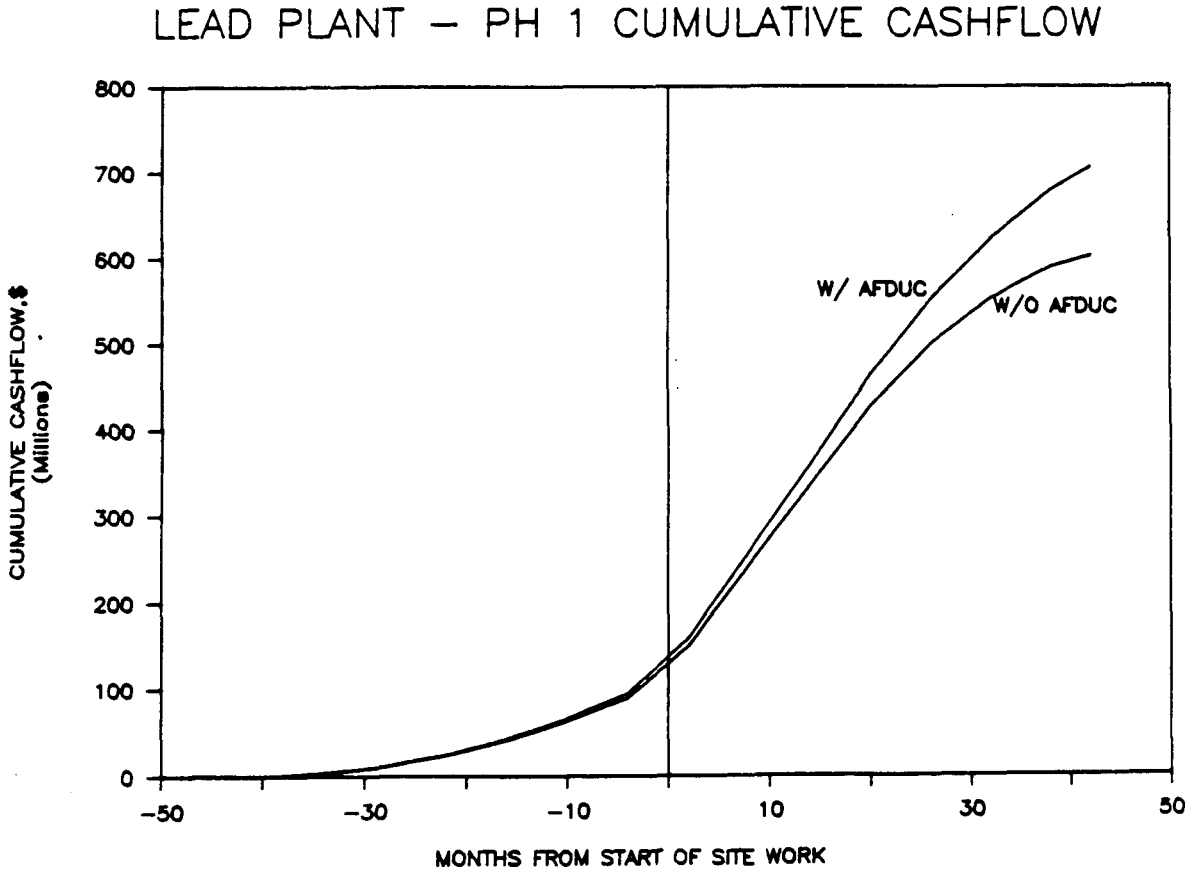


Figure F-3

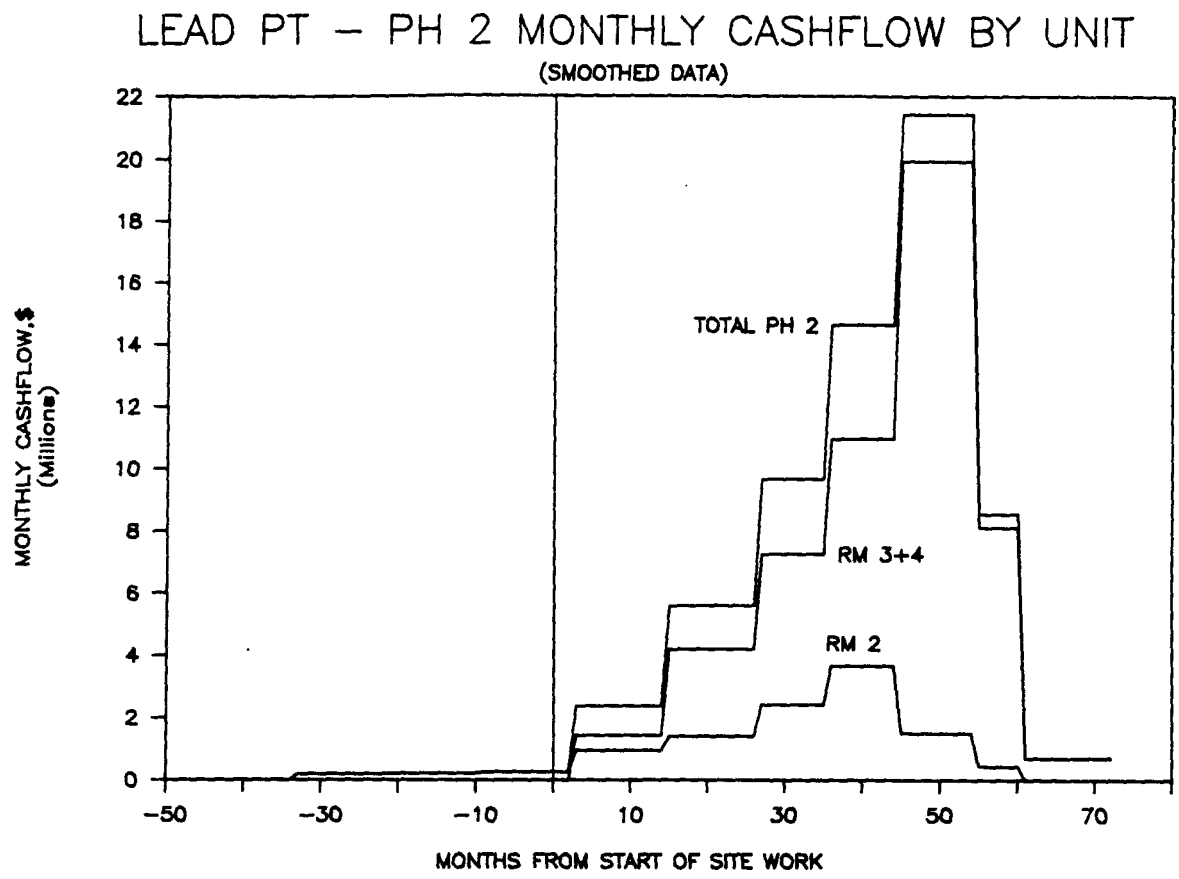


Figure F-4

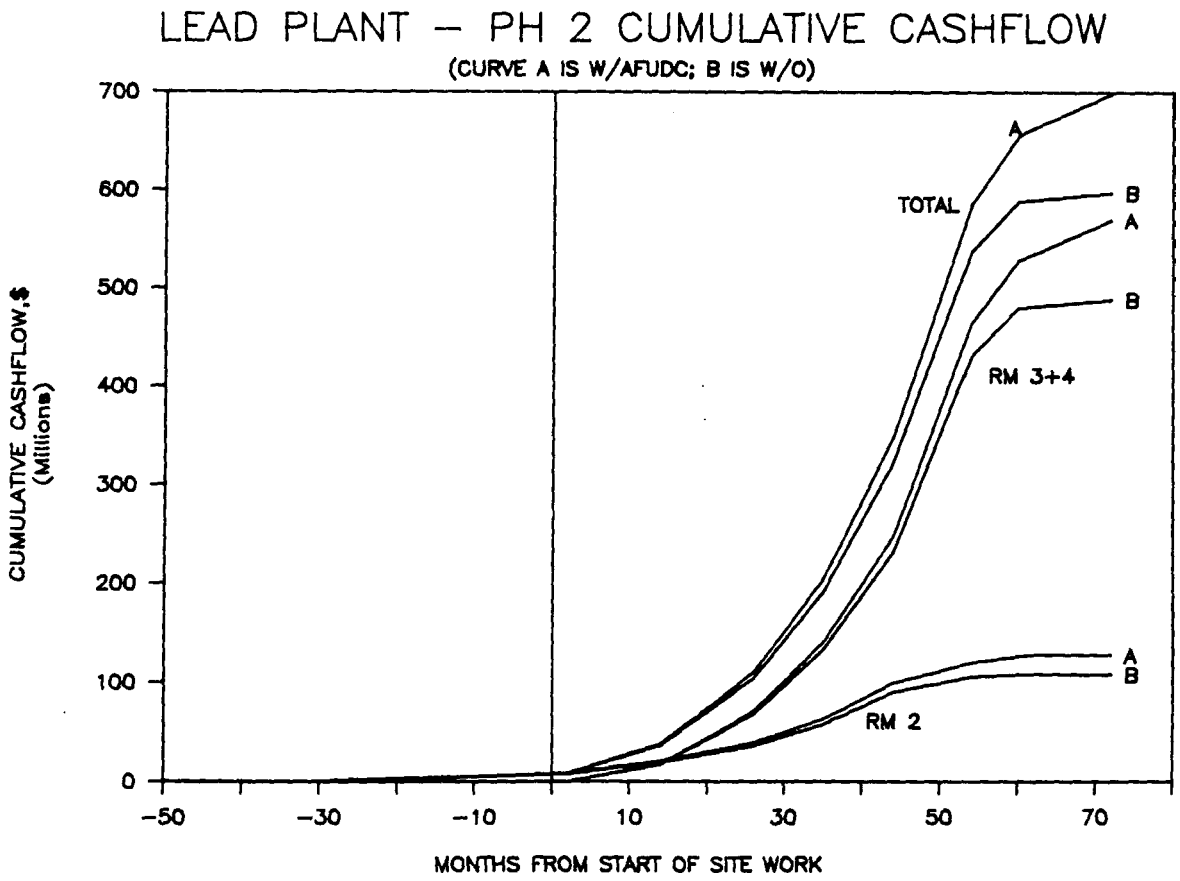


Figure F-5

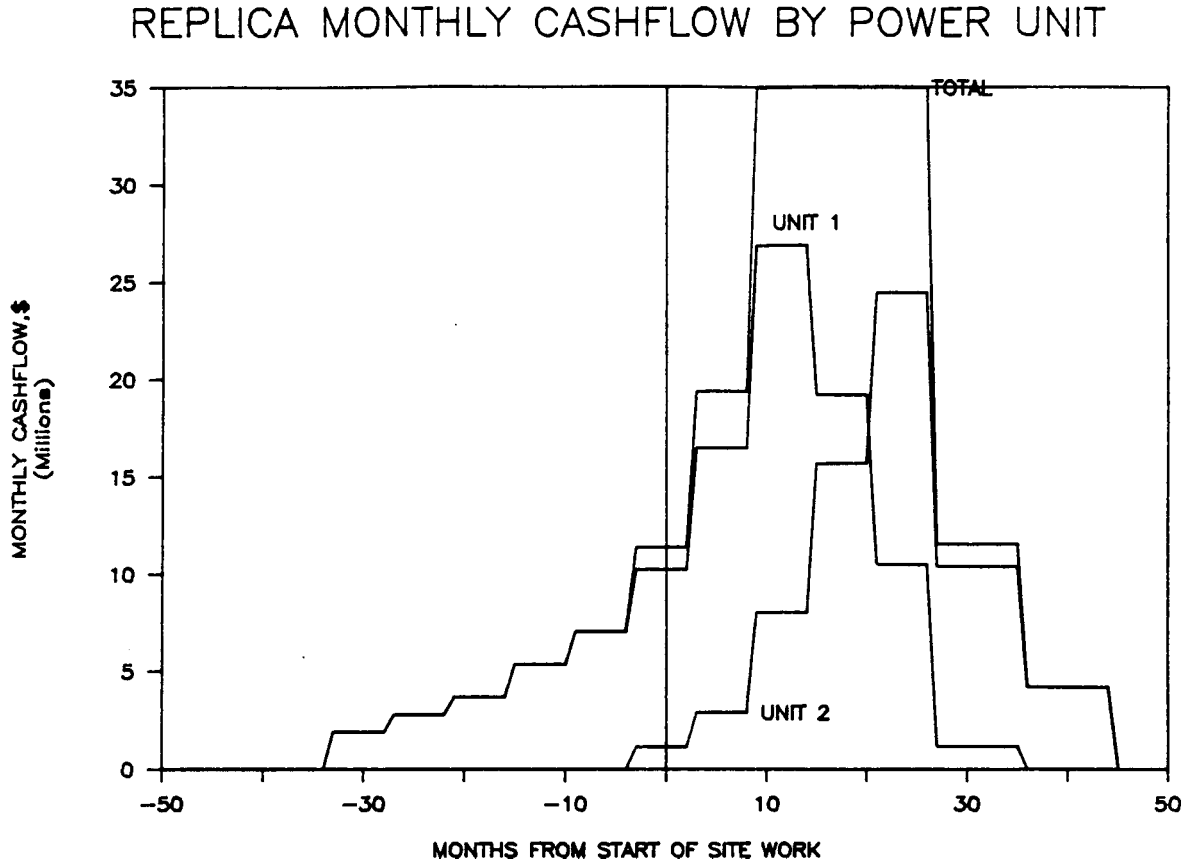


Figure F-6

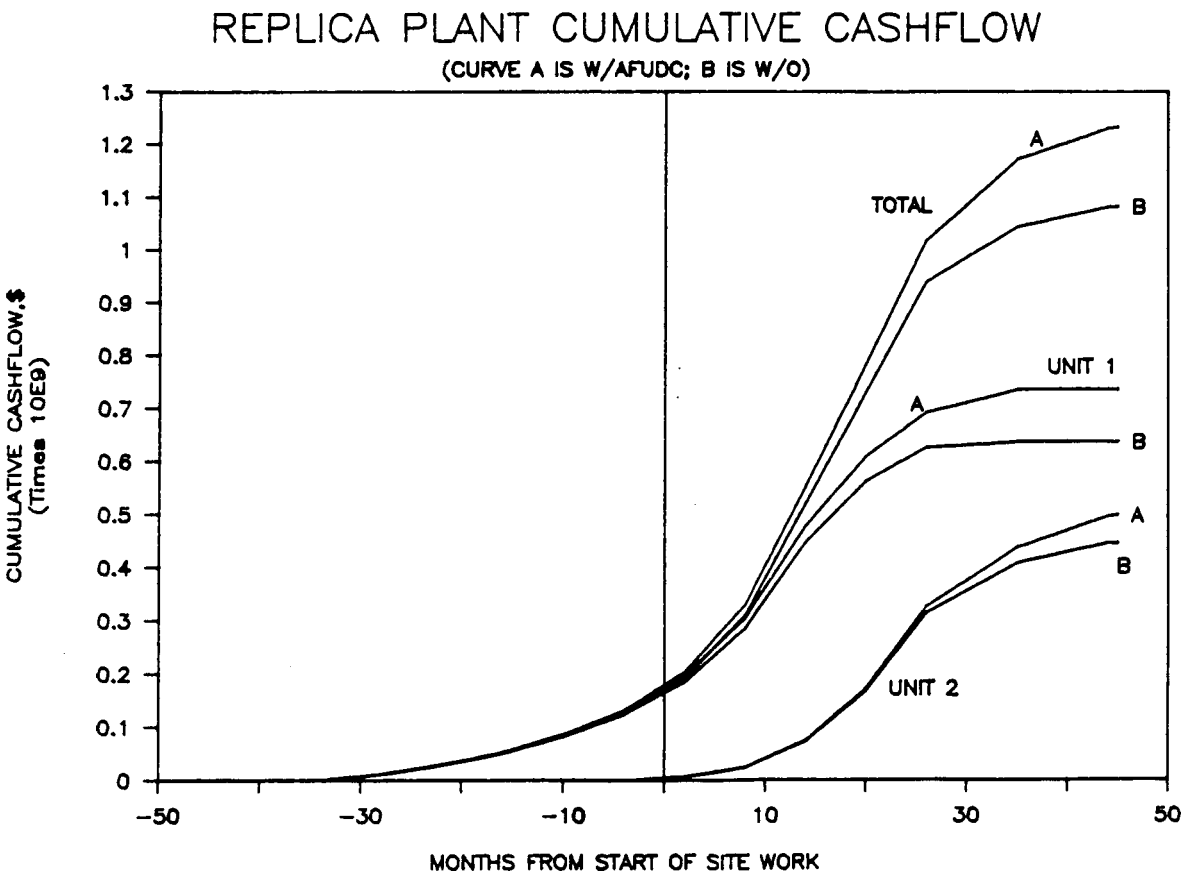


Figure F-7

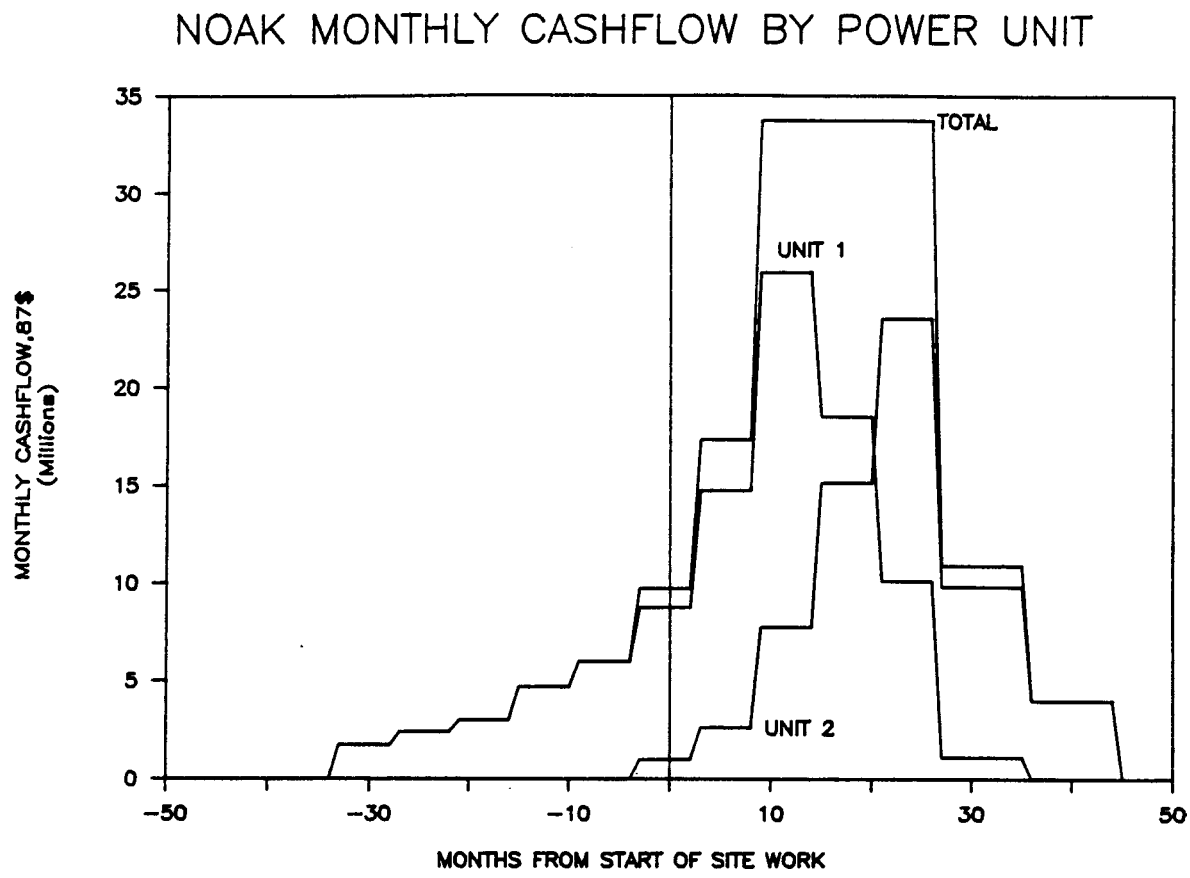


Figure F-8

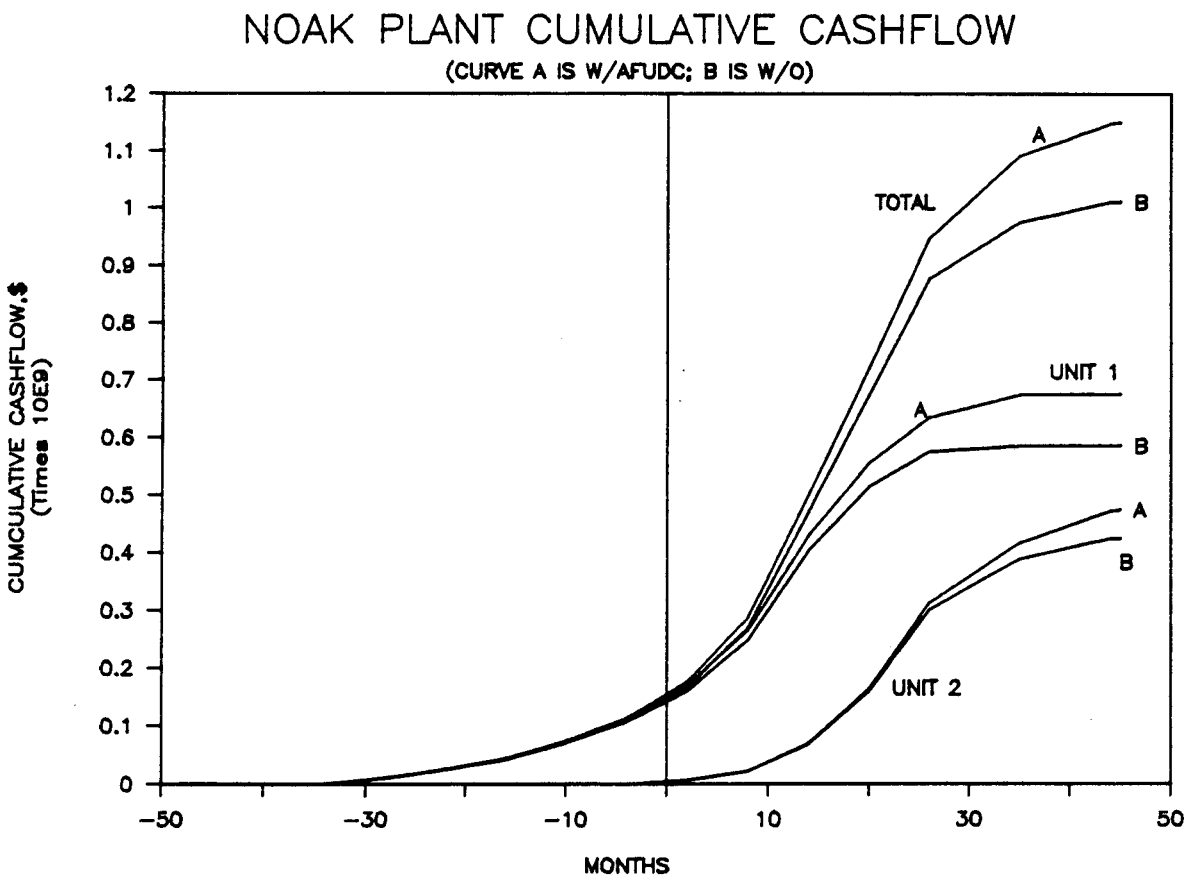


Figure F-9

LARGE NOAK PLANT MONTHLY CASHFLOW

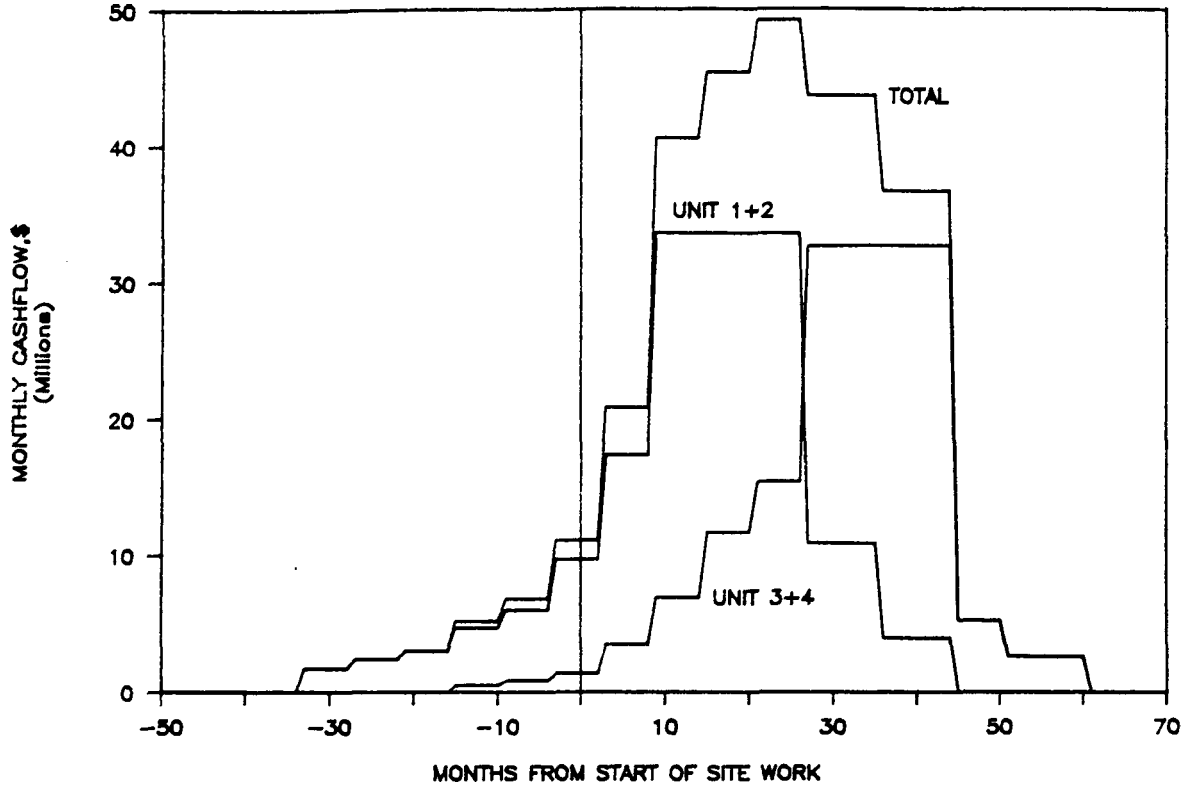


Figure F-10

LG NOAK POWER UNIT 3&4 MONTHLY CASHFLOW

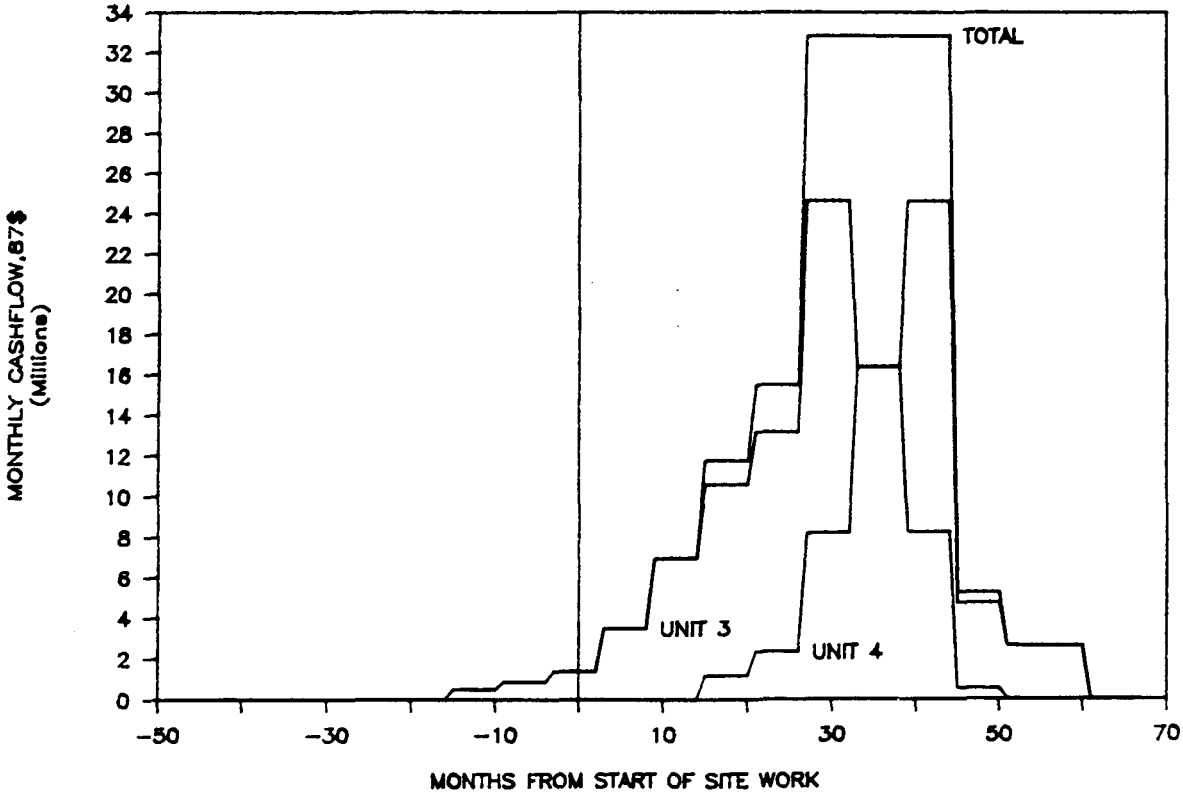


Figure F-11

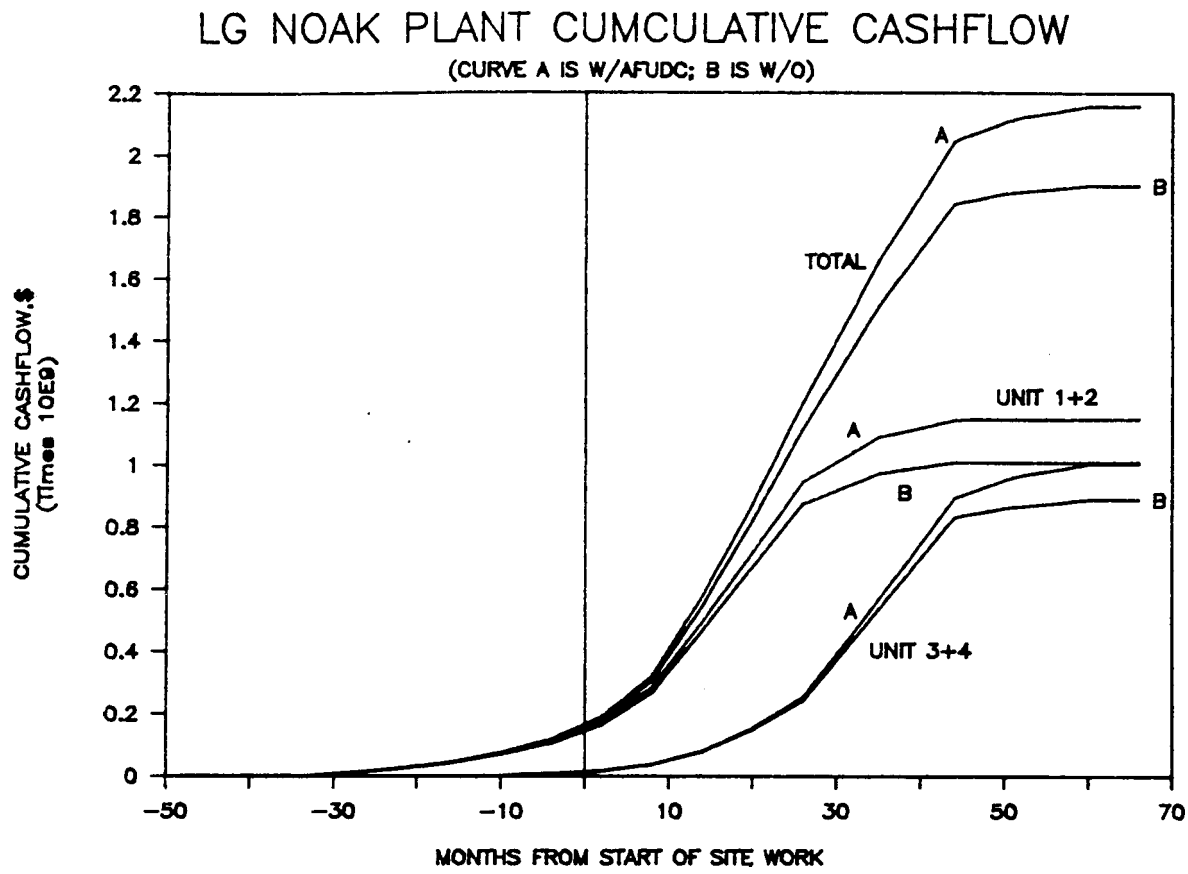
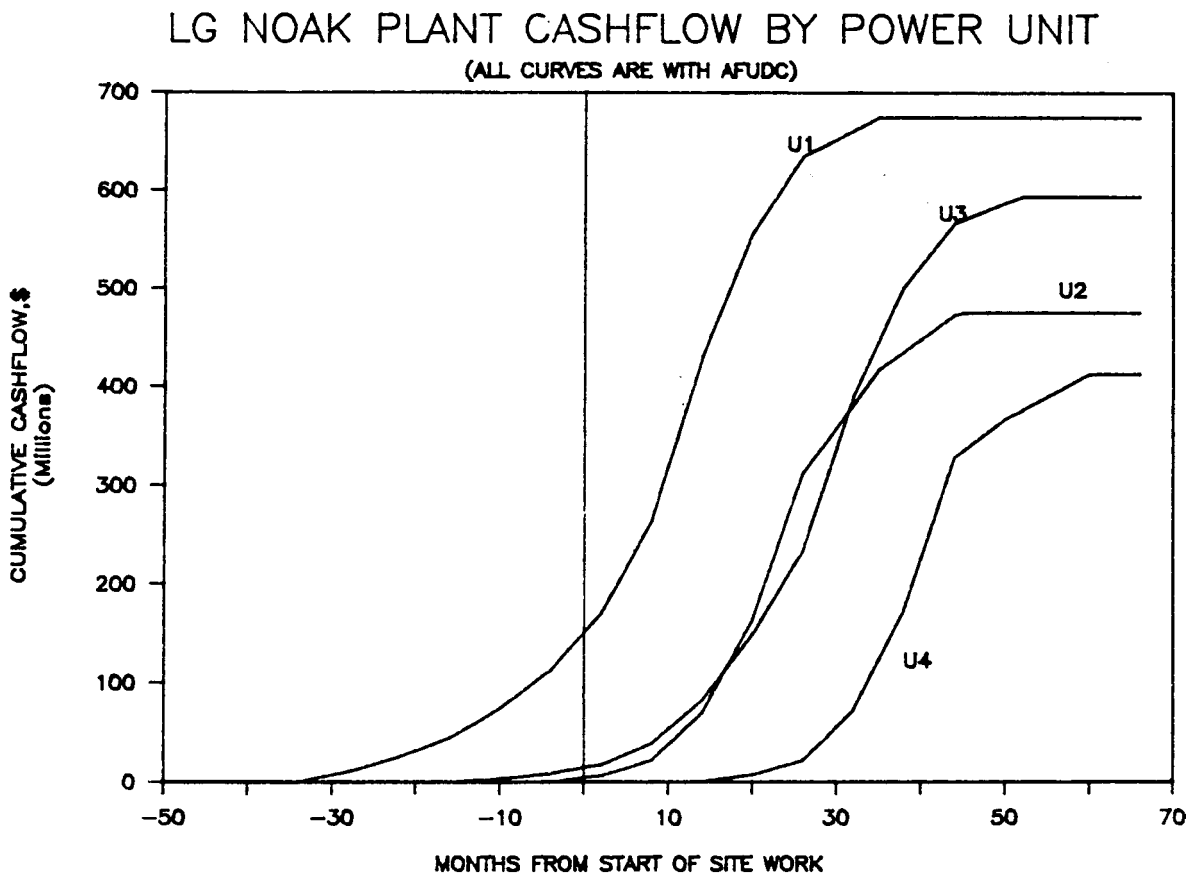


Figure F-12



APPENDIX G

MHTGR PLANT CONSTRUCTION SCHEDULES

- o LEAD PLANT
- o REPLICA/NOAK PLANT
- o LARGE NOAK PLANT

V

MILESTONES

NOTICE TO PROCEED

START SITE WORK (CP)

START STRL CONCRETE

START RM INSTALLATION UNIT 1

FUEL LOAD UNIT 1

CO UNIT 1

START RM INSTALLATION UNIT 2

REFUEL UNIT 1 / FUEL LOAD UNIT 2

CO UNIT 2

CO UNITS 3&4

MONTHS

PROCUREMENT

REACTOR MODULE (RM)

ORDER FABRICATE & DELIVER RM #1

ORDER RM #2

ORDER RM #3

ORDER RM #4

AT SITE RM #1

ORDER FABRICATE & DELIVER RM #'S 2,3 & 4

AT SITE RM #2

AT SITE RM #3

AT SITE RM #4

TURBINE GENERATOR (TG)

ORDER FABRICATE & DELIVER TG #1

AT SITE TG1

ORDER FABRICATE & DELIVER TG2

AT SITE TG2

CONSTRUCTION - NUCLEAR ISLAND

REACTOR MODULE #1

- EXCAVATION & SUBSTRUCTURE
- SUPERSTRUCTURE- REACTOR BLDG(RB), REACTOR AUX BLDG(RAB) HELIUM SERVICES BLDG(HSB)
- PPG/MECH/ELECT- REACTOR BLDG(RB), REACTOR AUX BLDG(RAB) HELIUM SERVICES BLDG(HSB)
- TESTING- REACTOR MODULE #1 COMPLEX

CLEAR GRADE

SET RISER PANELS 1

SILO 1 TO GRADE

SUPERSTRUCTURE #1

SET RM #1

PPG/MECH/ELECT #1

FUEL IN SITE

INST. FUEL

STARTUP TESTING

REACTOR CRITICAL

LOW POWER TESTS

STEAM AVAILABLE

POWER ASCENSION TESTING

CO #1

DOW COMPLETE

REFUEL

REFUEL COMPLETE

COMMON FACILITIES

- REACTOR SERVICE/NUCLEAR ISL. COOLING WATER/ CHILLED WATER BUILDING/WASHDOWN BAY
- PERSONNEL SRVCS BLDG
- RADWASTE MGMT BLDG
- MISC - REMOTE SHUTDOWN BLDG/ HELIUM STORAGE STRUCTURE/ NUCLEAR ISLAND WAREHOUSE

SUBSTR #2B

PPG/MECH/ELECT

RCA

FDC & STRUCTURE

PPG/MECH/ELECT

EV FDC & STRUCTURE

EV PPG/MECH/ELECT

NSSS SAFETY RELATED STRUCT/PPG/MECH/ELECT

EV SUB 2

SILO 2 TO GRADE

REACTOR MODULE #2

- EXCAVATION & SUBSTRUCTURE
- SUPERSTRUCTURE-RB, RAB
- PPG, MECH, ELECT - RB, RAB
- TESTING - REACTOR MODULE #2 COMPLEX

SUPERSTRUCTURE #2

SET RISER PANELS 2

PPG/MECH/ELECT #2

CONSTR COMPL TESTS

FUEL IN SITE

INST. FUEL

STARTUP TESTING

LOW POWER TESTS

POWER ASCEN TESTING

CO #2

SET RISER PANELS 3

SILO 3 TO GRADE

REACTOR MODULE #3

- EXCAVATION & SUBSTRUCTURE
- SUPERSTRUCTURE - RB, RAB, HSB
- PPG, MECH, ELECT - RB, RAB, HSB
- TESTING - REACTOR MODULE #3 COMPLEX

SUPERSTRUCTURE #3

SET RISER PANELS 3

PPG/MECH/ELECT #3

CONSTR COMPL TESTS

FUEL IN SITE

INST. FUEL

STARTUP TESTING

LOW POWER TESTS

POWER ASCEN TESTING

SET RISER PANELS 4

SILO 4 TO GRADE

REACTOR MODULE #4

- EXCAVATION & SUBSTRUCTURE
- SUPERSTRUCTURE - RB, RAB
- PPG, MECH, ELECT - RB, RAB
- TESTING - REACTOR MODULE #4 COMPLEX

SUPERSTRUCTURE #4

SET RISER #4

PPG/MECH/ELECT #4

CONSTR COMPL TESTS

FUEL IN SITE

INST. FUEL

STARTUP TESTING

LOW POWER TESTS

POWER ASCEN TESTING

CO #3&4

CONSTRUCTION - ENERGY CONVERSION AREA

OPERATIONS CENTER

FDN & STRUCTURE COMPLETE

PPG/MECH/ELECT - START

PPG/MECH/ELECT - COMPLETE

TURBINE/STANDBY POWER BLDG

FOUNDATION COMPLETE

STRUCTURAL & SUPERSTR TG1

TURB GEN & AUXILIARIES 1

SET TG1

CONDENSER 1

PPG/MECH/ELECT 1

PEDESTAL & SUPERSTR TG2

TURB GEN & AUXILIARIES 2

CONDENSER 2

PPG/MECH/ELECT 2

ECA POWER UNIT TESTING

POWER UNIT AR TESTING

MAKEUP WTR/AUX BLR/MAINT BLDG

CLEAR & GRADE

FDN & STRUCTURE COMPLETE

PPG/MECH/ELECT - START

PPG/MECH/ELECT - COMPLETE

CW PUMPHOUSE/COOLING TOWER

FDN & STRUCTURE COMPLETE

PPG/MECH/ELECT - START

PPG/MECH/ELECT - COMPLETE

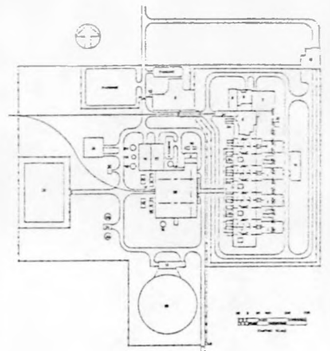
MISC YARD STRUCTURES/FACILITIES

INCLUDES:
- ECA WAREHOUSE
- YARD TANKS
- PUMPHOUSES
- GAS STORAGE AREAS
- YARD ELECTRICAL FACILITIES
- GUARD HOUSES

PROJECT SCHEDULE ASSUMPTIONS AND BASES

- LOAD FUEL ON UNIT 2 FOLLOWS REFUEL OF UNIT 1
- UNITS 3 & 4 BASED ON DELIVERY SCHEDULE OF NSSS.
- NO REGULATORY OR POLITICAL CONSTRAINTS.
- NO MANPOWER OR CASH FLOW CONSTRAINTS.
- SEISMIC SITE.
- NOTICE TO PROCEED TO CONSTRUCTION PERMIT (CP) IS 33 MONTHS.
- BULK CONSTRUCTION SCHEDULE BASED ON SEGREGATED CONSTRUCTION AND ALTERNATING 4-DAY, 10-HOUR WORK-SHIFT CONCEPT.
- QUANTITIES USED IN SCHEDULE DEVELOPMENT BASED ON CURRENT CONCEPTUAL DRAWINGS.

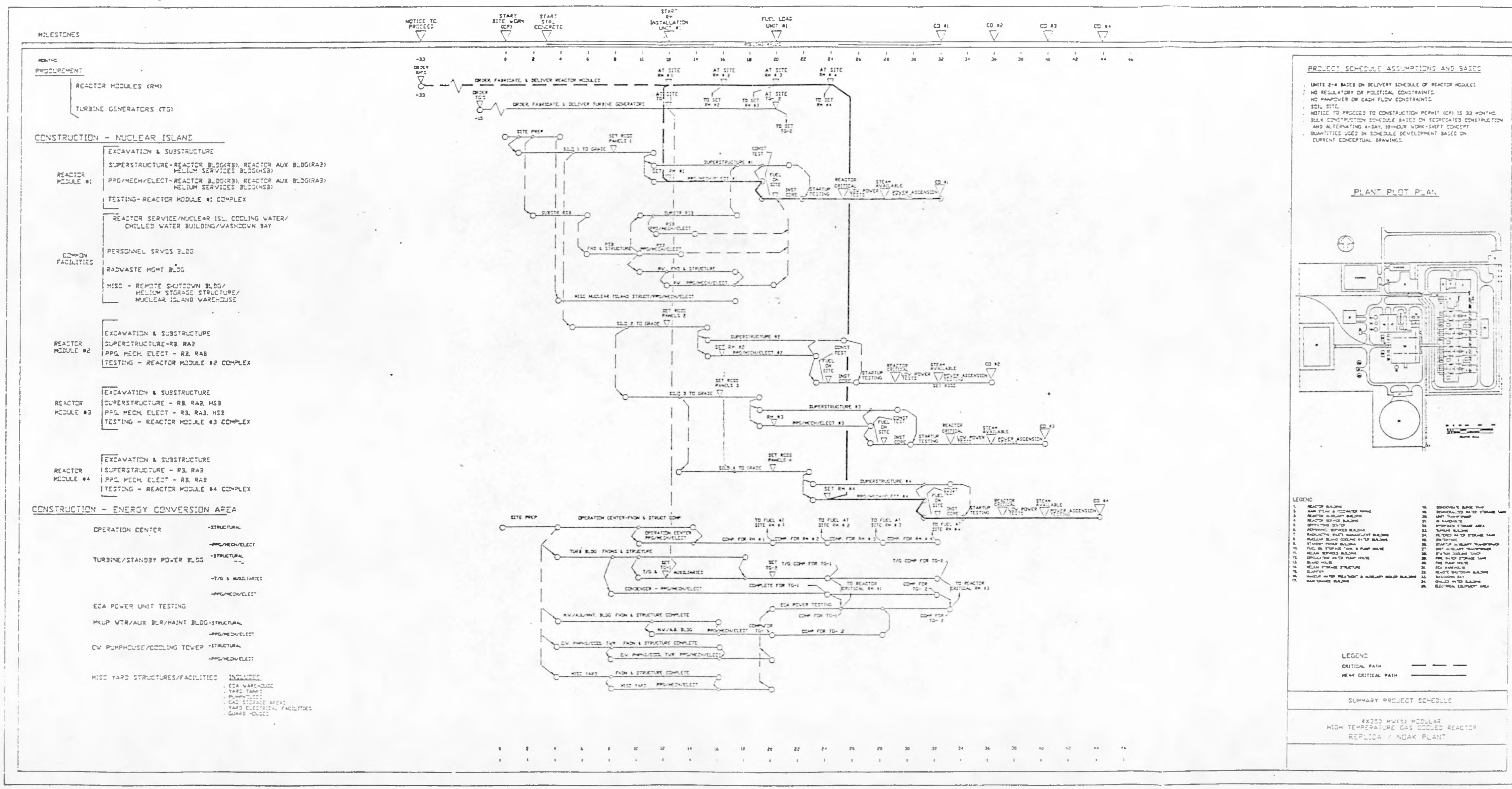
PLANT PLOT PLAN



LEGEND

CRITICAL PATH

NEAR CRITICAL PATH


MILESTONES
NOTICE TO PROCEED
START SITE WORK (CP)
START STR. CONCRETE
START RM INSTALLATION UNIT #1
FUEL LOAD UNIT #1
CO #1
CO #2
CO #3
CO #4
MONTHS
PROCUREMENT
REACTOR MODULES (RM)
TURBINE GENERATORS (TG)
ORDER, FABRICATE, & DELIVER REACTOR MODULES
ORDER, FABRICATE, & DELIVER TURBINE GENERATORS
CONSTRUCTION - NUCLEAR ISLAND
REACTOR MODULE #1
EXCAVATION & SUBSTRUCTURE
SUPERSTRUCTURE-REACTOR BLDG(RB), REACTOR AUX BLDG(RAB) HELIUM SERVICES BLDG(HSB)
PPG/MECH/ELECT-REACTOR BLDG(RB), REACTOR AUX BLDG(RAB) HELIUM SERVICES BLDG(HSB)
TESTING-REACTOR MODULE #1 COMPLEX
COMMON FACILITIES
REACTOR SERVICE/NUCLEAR ISL. COOLING WATER/ CHILLED WATER BUILDING/WASHDOWN BAY
PERSONNEL SRVCS BLDG
RADWASTE MGMT BLDG
MISC - REMOTE SHUTDOWN BLDG/ HELIUM STORAGE STRUCTURE/ NUCLEAR ISLAND WAREHOUSE
REACTOR MODULE #2
EXCAVATION & SUBSTRUCTURE
SUPERSTRUCTURE-RB, RAB
PPG, MECH, ELECT - RB, RAB
TESTING - REACTOR MODULE #2 COMPLEX
REACTOR MODULE #3
EXCAVATION & SUBSTRUCTURE
SUPERSTRUCTURE - RB, RAB, HSB
PPG, MECH, ELECT - RB, RAB, HSB
TESTING - REACTOR MODULE #3 COMPLEX
REACTOR MODULE #4
EXCAVATION & SUBSTRUCTURE
SUPERSTRUCTURE - RB, RAB
PPG, MECH, ELECT - RB, RAB
TESTING - REACTOR MODULE #4 COMPLEX
CONSTRUCTION - ENERGY CONVERSION AREA
OPERATION CENTER
TURBINE/STANDBY POWER BLDG
ECA POWER UNIT TESTING
MKUP WTR/AUX BLR/MAINT BLDG
CW PUMPHOUSE/COOLING TOWER
MISC YARD STRUCTURES/FACILITIES
SITE PREP
SUPERSTRUCTURE
FUEL ON SITE
INST CORE
STARTUP TESTING
REACTOR CRITICAL
STEAM AVAILABLE
POWER ASCENSION
OPERATION CENTER-FNDN & STRUCT COMP
PROJECT SCHEDULE ASSUMPTIONS AND BASES
PLANT PLOT PLAN
LEGEND
CRITICAL PATH
NEAR CRITICAL PATH
SUMMARY PROJECT SCHEDULE
4X350 MW(t) MODULAR
HIGH TEMPERATURE GAS COOLED REACTOR
REPLICA / NOAK PLANT

MILESTONES

NOTICE TO PROCEED

START SITE WORK (CP)

START STR. CONCRETE

START RM INSTALLATION UNIT #1

FUEL LOAD UNIT #1

CD #1 · CD #2 · CD #3 · CD #4 · CD #5 · CD #6 · CD #7 · CD #8

PLOTTING RATE 1

MONTHS

PROCUREMENT

- REACTOR MODULES (RM) — ORDER, FABRICATE, & DELIVER REACTOR MODULES
- TURBINE GENERATORS (TG) — ORDER, FABRICATE, & DELIVER TURBINE GENERATORS

CONSTRUCTION - NUCLEAR ISLAND

REACTOR MODULES #1 & #5
- EXCAVATION & SUBSTRUCTURE
- SUPERSTRUCTURE- REACTOR BLDG(RB), REACTOR AUX BLDG(RAB) HELIUM SERVICES BLDG(HSB)
- PPG/MECH/ELECT- REACTOR BLDG(RB), REACTOR AUX BLDG(RAB) HELIUM SERVICES BLDG(HSB)
- TESTING- REACTOR MODULE #1 & #5 COMPLEXES

COMMON FACILITIES A & B
- REACTOR SERVICE/NUCLEAR ISL. COOLING WATER/ CHILLED WATER BUILDING/WASHDOWN BAY
- PERSONNEL SRVCS BLDG
- RADWASTE MGMT BLDG
- MISC - REMOTE SHUTDOWN BLDG/ HELIUM STORAGE STRUCTURE/ NUCLEAR ISLAND WAREHOUSE

REACTOR MODULES #2 & #6
- EXCAVATION & SUBSTRUCTURE
- SUPERSTRUCTURE-RB, RAB
- PPG, MECH, ELECT - RB, RAB
- TESTING - REACTOR MODULE #2 & #6 COMPLEXES

REACTOR MODULES #3 & #7
- EXCAVATION & SUBSTRUCTURE
- SUPERSTRUCTURE - RB, RAB, HSB
- PPG, MECH, ELECT - RB, RAB, HSB
- TESTING - REACTOR MODULE #3 & #7 COMPLEXES

REACTOR MODULES #4 & #8
- EXCAVATION & SUBSTRUCTURE
- SUPERSTRUCTURE - RB, RAB
- PPG, MECH, ELECT - RB, RAB
- TESTING - REACTOR MODULE #4 & #8 COMPLEXES

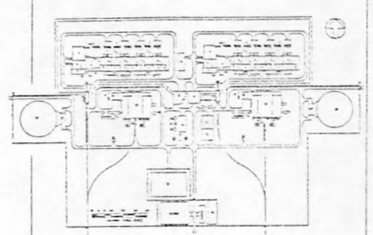
CONSTRUCTION - ENERGY CONVERSION AREA

- CONTROL BUILDING — -STRUCTURAL; -PPG/MECH/ELECT
- TURBINE/STANDBY POWER BLDG — -STRUCTURAL; -T/G & AUXILIARIES; -PPG/MECH/ELECT
- ECA POWER UNIT TESTING
- MAKEUP WTR/AUX BLR BLDG — -STRUCTURAL; -PPG/MECH/ELECT
- MAINTENANCE BLD/ECA WAREHS — -STRUCTURAL; -PPG/MECH/ELECT
- CW PUMPHOUSE/COOLING TOWER — -STRUCTURAL; -PPG/MECH/ELECT
- MISC YARD STRUCTURES/FACILITIES — SUBSTATION; ELECTRIFICATION BLDG; FUEL TANKS; WATER TANKS; LAYDOWN STORAGE AREAS; YARD ELECTRICAL FACILITIES; GUARD HOUSES

PROJECT SCHEDULE ASSUMPTIONS AND BASES

1. UNITS 2-8 BASED ON DELIVERY SCHEDULE OF REACTOR MODULES
2. NO REGULATORY OR POLITICAL CONSTRAINTS.
3. NO MANPOWER OR CASH FLOW CONSTRAINTS.
4. [illegible] SITE.
5. NOTICE TO PROCEED TO CONSTRUCTION PERMIT (CP) IS 33 MONTHS.
6. BULK CONSTRUCTION SCHEDULE BASED ON SEQUENCED CONSTRUCTION AND ALTERNATING 4-DAY, 10-HOUR WORK-SHIFT CONCEPT.
7. QUANTITIES USED IN SCHEDULE DEVELOPMENT BASED ON CURRENT CONCEPTUAL DRAWINGS.

PLANT PLOT PLAN



LEGEND

1. REACTOR BUILDING
2. MAIN STEAM & FEEDWATER PIPING
3. REACTOR AUXILIARY BUILDING
4. REACTOR SERVICE BUILDING
5. CONTROL BUILDING
6. HOUSING, SERVICES BUILDING
7. RADIOACTIVE WASTE MANAGEMENT BUILDING
8. NUCLEAR ISLAND COOLING WATER BUILDING
9. STANDBY POWER BUILDING
10. FUEL OIL STORAGE TANK & PUMP HOUSE
11. HEAVEN SERVICES BUILDING
12. CIRCULATING WATER PUMP HOUSE
13. GUARD HOUSE
14. RAILROAD STORAGE STRUCTURE
15. CLARIFIER
16. MAKEUP WATER TREATMENT & AUXILIARY BOILER BUILDING
17. MAINTENANCE BUILDING
18. DEMINERALIZED WATER STORAGE TANK
19. UNIT TRANSFORMER
20. #1 WAREHOUSE
21. HYDRAZINE STORAGE AREA
22. TURBINE BUILDING
23. FILTERED WATER STORAGE TANK
24. SWITCHYARD
25. EMERGENCY AUXILIARY TRANSFORMER
26. CIRCULATING WATER PUMPHOUSE
27. STATION COOLING TOWER
28. FIRE WATER STORAGE TANK
29. FIRE PUMP HOUSE
30. ESF WAREHOUSE
31. REACTOR SERVICES BUILDING
32. ADMINISTRATION BUILDING
33. ENGINEERED SAFEGUARDS BUILDING
34. ENGINEERED SAFEGUARDS BUILDING
35. ELECTRICAL EQUIPMENT AREA
36. ADMINISTRATION BUILDING

LEGEND

CRITICAL PATH

NEAR CRITICAL PATH

COMPANY PROJECT IDENTIFIER

NUCLEAR POWER STATION
HIGH TEMPERATURE GAS COOLED REACTOR
LARGE WORK PLAN