GCRA

GENERAL ATOMICS

FOREIGN/SUPPLIER DOCUMENT

DOCUMENT NUMBER	REV.
PC-000447	0

DISC	SYS	DOC. TYPE	PROJECT
—	—	CED	6302

NEXT INDENTURE DOC	ASSOCIATED P.O./CONTRACT NO.
—	DE-AC03-89SF17885

SIGNATURE LEVEL	QA LEVEL	EQUIP/ SAFETY CLASS	SEISMIC CATEGORY	ELEC CLASS
—	—	—	—	—

☐ R & D ☐ DV & S ☐ DESIGN	ISSUE DESCRIPTION/CWBS NO.
N/A	INITIAL ISSUE WBS 5900.1 W07659.00128

GCRA 94-003

PROJECTION OF O&M AND OWNER'S COSTS FOR GT-MHR PLANTS

COMMENTS: Cover page to C-14 = 130 pgs.

SIGNED

ISSUED/RELEASED: ISSUED 3 DATE: JUN 2 3 1995

GA 694 (REV 12/88)

LIST OF EFFECTIVE PAGES

PAGE	COUNT
Title Pages	3
i through vii	7
1-1 through 1-5	5
2-1 through 2-6	6
3-1 through 3-44	44
4-1 through 4-12	12
5-1 through 5-4	4
6-1 through 6-15	15
7-1 through 7-2	2
A-1 through A-12	12
B-1 through B-6	6
C-1 through C-14	14
Total	~~117~~ 130

Work Performed Pursuant to EPRI Project RP3630-01

by

GAS-COOLED REACTOR ASSOCIATES

DECEMBER 1994

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

THIS REPORT WAS PREPARED BY THE ORGANIZATION NAMED BELOW AS AN ACCOUNT OF WORK SPONSORED BY THE ELECTRIC POWER RESEARCH INSTITUTE, INC. (EPRI). NEITHER EPRI, ANY MEMBER OF EPRI, THE ORGANIZATION NAMED BELOW, NOR ANY PERSON ACTING ON BEHALF OF ANY OF THEM:

(A) MAKES ANY WARRANTY OR REPRESENTATION WHATSOEVER, EXPRESS OR IMPLIED, (I) WITH RESPECT TO THE USE OF ANY INFORMATION, APPARATUS, METHOD, PROCESS, OR SIMILAR ITEM DISCLOSED IN THIS REPORT, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, (II) THAT SUCH USE DOES NOT INFRINGE ON OR INTERFERE WITH PRIVATELY OWNED RIGHTS, INCLUDING ANY PARTY'S INTELLECTUAL PROPERTY, OR (III) THAT THIS REPORT IS SUITABLE TO ANY PARTICULAR USER'S CIRCUMSTANCE; OR

(B) ASSUMES RESPONSIBILITY FOR ANY DAMAGES OR OTHER LIABILITY WHATSOEVER (INCLUDING ANY CONSEQUENTIAL DAMAGES, EVEN IF EPRI OR ANY EPRI REPRESENTATIVE HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES) RESULTING FROM YOUR SELECTION OR USE OF THIS REPORT OR ANY INFORMATION, APPARATUS, METHOD, PROCESS, OR SIMILAR ITEM DISCLOSED IN THIS REPORT.

GAS-COOLED REACTOR ASSOCIATES

PC-000447/0

GCRA 94-003

PROJECTIONS OF O&M AND OWNER'S COSTS FOR GT-MHR PLANTS

Work Performed Pursuant to
EPRI Project RP3630-01

by

GAS-COOLED REACTOR ASSOCIATES

DECEMBER 1994

PC - 000447/0

TABLE OF CONTENTS

PC-010447/0

PC- 000447/0

PC-000447/0

APPENDICES

LIST OF TABLES

PC-000447/0

PC-000447/0

PC - 000447/0

LIST OF FIGURES

PC-000447/0

SECTION 1

INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

The purpose of this report is to provide projections of annual operation and maintenance (O&M) costs (exclusive of fuel costs), and owner's costs, for Gas Turbine-Modular Helium Reactor (GT-MHR) electric power plants. The projections herein are based on the current conceptual design definition of the GT-MHR, on the judgement of senior power plant management and engineering personnel, and on the assumption that technology and regulatory development programs will be successful. Estimates based on detailed design definition and plant staff task analyses will be conducted in future stages of plant development.

The GT-MHR Program reference plant design employs four reactors, each of which is coupled to a direct (i.e., Brayton) cycle power conversion system (PCS). Each reactor/PCS combination is referred to as a "reactor module" or simply, "module" and is rated at a thermal power level of 550 MW, with anticipated stretch capacity to 600 MW. The reference four-module GT-MHR plant produces 2200 MWt with a nominal electric output of 1050 MW. The plant design is described in Reference 1. Development and commercial deployment are assessed in the framework of the Energy Policy Act of 1992 as summarized in Reference 2. This approach permits development of a regulatory framework based on full-scale demonstration tests and deployment of standardized, NRC certified commercial nuclear power plants. Demonstration testing will be conducted on the first module of the Lead Plant. The first module with common facilities for it and three additional modules is referred to as the Prototype Plant. The deployment plan used herein (see Reference 3) projects receipt of a construction and operating license (COL) for the full four-module Lead Plant by 2010, about 30 months after completion of certification tests conducted on the single-module Prototype Plant. Lead Plant commercial operation would begin in about 2013. Long lead material for the Replica Plant (second four-module plant) is committed at completion of certification tests, with the third through the Target Plant (fifth plant, corresponding to at least 4500 MWe of installed capacity) committed at a rate compatible with manufacturing throughput. The Replica through the Target plants reach commercial operation between 2014 and 2017.

The estimates herein were developed by first assessing resources required for the four-module Lead Plant in a commercial environment, and then identifying the resources needed for the single-module Prototype Plant while anticipating plant expansion after the demonstration period. Since this estimate is for the first plant to be constructed and operated, current NRC and industry practices are assumed to generally apply. O&M costs for the Target Plant in a mature industry are assumed to further benefit from GT-MHR safety attributes with a substantial simplification of operational licensing requirements. Since the means to accomplish safety functions are embodied in the GT-MHR design, licensing requirements for the Target Plant will center on design verification and manufacture of the fuel and reactor modules, with a substantially reduced regulatory effort applied to operating plant activities. Once regulatory simplification has been confirmed in the successful operation of commercial plants, regulatory and operating provisions for the Lead, Replica and follow-on units are assumed to be revisited and standardized based on those for the Target Plant. That is, successful deployment will allow operating costs of early plants to be reduced to parity with the Target Plant. Projected costs for an "equilibrium" Target Plant are also included, based on achieving an expected stretch capacity of 600 MW reactor module thermal power.

1.2 BACKGROUND

This report is the product of a Tailored Collaboration (TC) Project funded by Pacific Gas & Electric, Ohio Edison and the Electric Power Research Institute to develop operational requirements for the GT-MHR plant. GT-MHR development is guided by the principle that advanced reactors must ensure the resolution of technical issues underlying the business risks of owning a nuclear power plant. The TC Project was undertaken with the objective of establishing the bases for:

- Design and operational requirements for GT-MHR development.

  The extent of reduction in demands on plant staff and on the business risks of GT-MHR plant ownership in a risk-based regulatory environment.

- Baseline estimates of O&M and owner's costs.

The first of these objectives is addressed in Reference 2, *Utility/User Incentives, Policies, and Requirements for the Gas Turbine-Modular Helium Reactor.* The technical bases for reduced demands on plant staff and reduced business risks are discussed in Reference 7, *O&M Cost/Risk Drivers at Current Nuclear Plants and MHTGR Development Priorities*, and Reference 10, *A Risk-Based Regulation Methodology for Deriving MHR Operational Licensing Requirements*. This report addresses the third objective and provides economic measures for considering the GT-MHR's potential to reduce the business risks of ownership. The estimates herein draw heavily on the Modular High Temperature Gas-Cooled Reactor (MHTGR) Project Feasibility Study (Reference 4) and related documents (References 3, 5 and 6), all of which incorporate the judgement and experience of senior utility personnel who worked at the Peach Bottom 1 and Fort St. Vrain gas-cooled reactor plants and of the GCRA Utility Advisory Committee whose members have many decades of operating experience with fossil and nuclear power plants. Insights from the TC Project are summarized in the following paragraphs.

Nuclear plant O&M costs have dramatically increased since the accident at Three Mile Island (TMI) in March 1979. In May 1992, a meeting of GCRA's Utility Advisory Committee was dedicated to a discussion of O&M cost drivers at current plants and priorities for gas-cooled reactor development. Five members of the Advisory Committee reviewed major factors contributing to O&M cost increases at plants within their respective utilities. While each plant history is unique, the individual experiences and perspectives had a common theme. Both industry and the NRC have been molded by the effort to minimize the potential for off-normal events, and thereby avoid another accident like the one at TMI. As discussed in Reference 7, at the root of O&M cost increases are (1) the mechanical and institutional complexity of the current nuclear enterprise, (2) the focus on avoiding another core melt accident like the one at TMI and (3) the NRC's practice of leveraging owner financial ratings to motivate improved performance.

O&M cost increases reflect important changes in work processes and the composition of plant staff from that expected when plants were committed. Current plant and corporate staffs include a much larger contingent of service professionals than anticipated. Staff with high-level cognitive skills are required to engage in an on-going dialogue with regulators and in closely scrutinized procurement transactions, equipment and personnel performance analysis, document maintenance and report preparation, and training programs. These work processes are far more interactive and sophisticated than foreseen for nuclear power, or required for other generation options. As a result, it is customary for current U.S. plants to be supported by large on-site engineering, training and administration staffs. According to an NEI (then NUMARC) study (Reference 8), there are on average twice as many operations and engineering personnel; three times the number of administrators; and four times as many training personnel at U.S. nuclear plants than at European nuclear plants. It is also usual practice to have a large number of off-site specialists and consultants involved with plant operations.

The GT-MHR safety concept forthrightly addresses the foremost technical issues underlying the business risks of owning a U.S. nuclear power plant in that it:

- Essentially eliminates the potential for a severe accident with core melt and disarray like occurred at TMI and precludes the need for offsite sheltering and evacuation plans by retaining fission products within ceramic-coated fuel particles for the full range of licensing basis events.
- Minimizes the safety significance of operator errors, equipment malfunctions, and common-mode failures and provides ample time to implement well-considered accident recovery measures by embodying the means to accomplish safety functions within the reactor design.

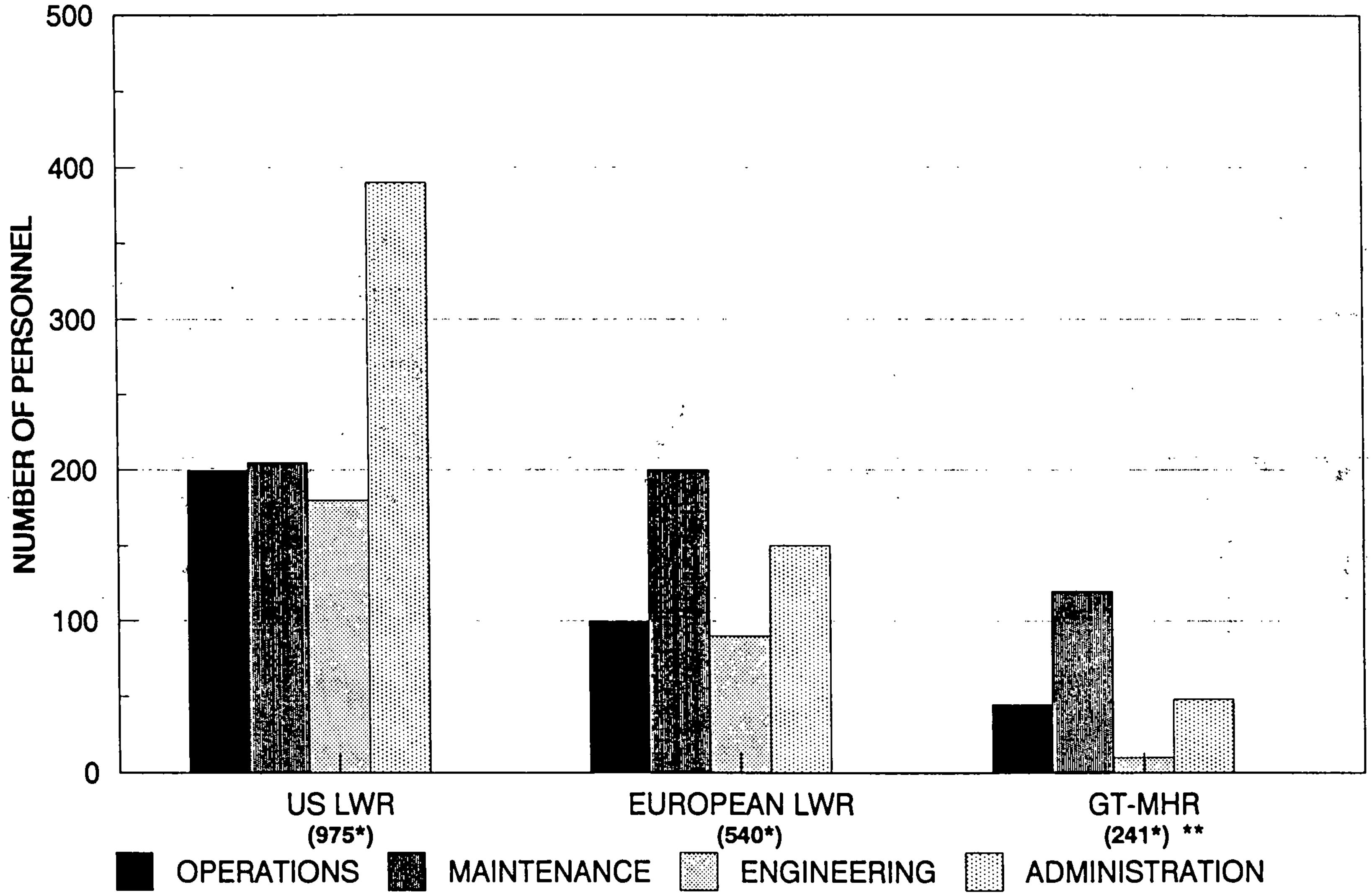
Eliminates the entire steam generation and condensation cycle.

Plant staffing and O&M cost estimates for Target GT-MHR plants assume that GT-MHR design and technology development programs will confirm these attributes and that an appropriate regulatory framework will be developed.

Figure 1-1 illustrates the changes in plant staff composition projected for the Target GT-MHR Plants compared to current U.S. and European LWR plants. Data for the current plants are from Reference 8. Whereas 58% (~560) and 45% (~240) of plant personnel at current U.S. and European plants, respectively, are engaged in engineering and administration; it is projected that only 25% of GT-MHR plant personnel (60) will be required for these functions, while about half of the GT-MHR plant staff will be engaged in maintenance work.

PC-000447/0 1

Figure 1-1
COMPARISON OF STAFF FOR CURRENT NUCLEAR AND TARGET GT-MHR PLANTS



* Total Number of Personnel

** Supplemented by COSO staff of 13 personnel

The bases for the GT-MHR estimates are explained in this report. These include the safety and technical attributes noted above with the attendant overall plant simplification, the use of a high-degree of automated control and information management, NRC certification of a standard plant based upon full-scale tests of a reactor module, and the formation of an owner/operator-based Central Operational Support Organization (COSO) to provide specialist resources to operating plants. As measures of the GT-MHR's potential to reduce business risks and demands on staff in comparison with current practice, it is estimated that:

The GT-MHR will require about 0.25 versus 1 person/MWe on the plant operating staff.

- Non-fuel O&M costs for Target GT-MHR plants will be in the range of 4.1 to 4.5 mills/kwhr versus 15.5 mills/kwhr for the average U.S. nuclear plant and 8.4 mills/kwhr for the average of the current top ten U.S. plants.

These comparisons provide measures of the incentives for GT-MHR development. The GT-MHR offers fundamental technological advancements in both power generation and nuclear safety. These advancements — elimination of the steam cycle and containment of fission products at the source of their generation — have the potential to dramatically simplify the business of generating electricity with nuclear energy.

SECTION 2

SUMMARY OF ESTIMATED O&M AND OWNER'S COSTS FOR GT-MHR PLANTS

2.1 SUMMARY OF ESTIMATED O&M AND OWNER'S COSTS

This section summarizes estimated non-fuel O&M and owner's costs for GT-MHR plants and the assumptions upon which the estimates are based. Summary plant data and O&M and owner's costs for the Prototype, Lead, Replica and Target GT-MHR Plants are provided in Table 2-1, along with projections for an "equilibrium" Target Plant.

2.2 OVERVIEW OF GT-MHR O&M COST

As shown in Table 2-1, four-module GT-MHR plants are estimated to require plant staffs ranging from 241 to 300 personnel, and the O&M component of power generation costs ranges from 4 to about 6 mills/kwhr. For comparison, the average U.S. nuclear plant has about 1,000 on-site personnel, and non-fuel O&M costs averaged 15.5 mills/kwhr in 1993. This estimate of O&M costs draws upon the Project Feasibility Study (Reference 4) in which Consumer's Power Company and Philadelphia Electric Company supported a detailed evaluation of the cost of deploying modular gas-cooled reactors at a utility site and on prior GCRA estimates (References 3, 5, and 6).

2.2.1 O&M Costs for Lead and Prototype GT-MHR Plants

Estimates of O&M costs were developed by first assessing resources required for the first four-module Lead Plant in a commercial environment, and then identifying the resources needed for the first reactor module and common facilities to accommodate addition of the second, third and fourth reactor modules after a demonstration testing period. Key assumptions are as follows:

- A stable regulatory environment will exist as a result of confirmatory results from design and technology development programs and regulatory interactions; e.g., fuel fission product retention capability is confirmed and operational licensing requirements are consistent with the risk-significance of plant equipment and personnel actions.

  Plant operation will be supported by an owner/operator-based Central Operational Support Organization (COSO).

- Plant operating programs will be developed by the vendor entity in conjunction with COSO and will be suitable for implementation with minimal development effort by plant staff.

  The plant design will incorporate highly automated plant control and information management systems.

PC-000447/0

Tabl 2-1
SUMMARY OF NON-FUEL O&M AND OWNER'S COSTS FOR GT-MHR PLANTS ('94$)

PLANT ATTRIBUTES & COST CATEGORIES	PROTOTYPE PLANT	LEAD PLANT	REPLICA PLANT	TARGET PLANT	EQUIL TARGET PLANT
PLANT ATTRIBUTES					
MODULES, #	1	4	4	4	4
POWER RATING, MWe	262	1050	1050	1050	1145
CAPACITY FACTOR, %	80	80	82	85	87
O&M COSTS					
POWER GENERATION COSTS					
PLANT STAFF, #	166	300	282	241	241
PLANT STAFF, M$/YR	8.52	15.58	14.64	12.7	12.7
MAINTENANCE MAT'L, M$/YR	0.99	2.21	1.96	1.96	1.96
SUPPLIES/EXPENS, M$/YR	1.95	6.67	6.63	6.53	6.62
TECHNICAL SUPPORT, M$/YR	1.19	2.09	1.98	1.79	1.79
SUBTOTAL, M$/YR	12.65	26.55	25.21	22.98	23.07
GENERAL/ADMIN COSTS					
PENSIONS/BENFTS, M$/YR	2.12	3.89	3.66	3.17	3.17
FEES (NRC, ET. AL.), M$/YR	4.15	4.15	4.15	2.75	2.75
PROP/LIAB INS, M$/YR	4.41	4.41	4.41	2.53	2.53
REPL PWR INS, M$/YR	0.00	0.53	0.53	0.53	0.53
OTHER G&A, M$/YR	1.90	3.98	3.78	3.45	3.46
SUBTOTAL, M$/YR	12.58	16.96	16.53	12.43	12.44
TOTAL O&M, M$/YR	25.23	43.51	41.74	35.41	35.51
TOTAL O&M, MILLS/KWHR	13.72	5.92	5.54	4.53	4.07
OWNER'S COSTS					
PROJECT STAFF, M-YR	164.2	276.4	135.1	112.2	112.2
PLANT STAFF, M-YR	363.8	579.8	559.5	371.4	371.4
PROJECT MGT, M$	12.77	21.58	10.77	8.89	8.89
FEES/TAXES/INS, M$	10.85	72.24	58.39	50.51	50.51
SPARE PARTS, M$	41.48	51.53	48.82	40.35	31.34
PLANT STAFF TRAINING, M$	29.22	49.49	46.58	33.10	33.10
GENERAL/ADMIN, M$	12.52	18.39	15.92	12.35	11.00
CONTINGENCY (15%), M$	16.02	31.99	27.07	21.78	20.23
TOTAL OWNER'S COST, M$	122.86	245.22	207.55	166.98	155.06

- Current nuclear industry practices with regard to operations will be required; e.g., a Control Room Supervisor with a Senior Reactor Operator License (SRO), the equivalent of one licensed reactor operator per reactor, and a security staff capable of mounting a five-man armed response team.

  The acceptability of essentially conventional power plant practices in the non-nuclear areas will be confirmed.

The following additional assumptions are used in estimating O&M costs for the Prototype Plant.

- The Prototype Plant will be constructed and operated for several years before the addition of the remaining three modules of the Lead Plant.

- Operating staff positions will be filled in a manner that facilitates future expansion to the full complement of Lead Plant staff.

  Pending the outcome of cost/risk sharing arrangements between the private sector and the government, nuclear fees and insurance premiums are the same for the single module Prototype Plant and the full four module Lead Plant.

It is also assumed that both the Prototype and Lead Plants achieve operating capacity factors of 80% (versus the design capacity factor of 87%).

2.2.2 O&M Costs for Target and Replica GT-MHR Plants

The GT-MHR Target Plant is defined in accordance with Reference 9 as the commercial facility that results in an installed capacity of 4500 MWe or greater. The GT-MHR Target Plant is the fifth four-module plant and would represent 5,250 MWe of installed capacity. Estimates of O&M costs assume significant institutional change as a result of successful prototype demonstration tests, licensing certification programs, and deployment of early commercial plants. Other key assumptions are as follows:

  The GT-MHR safety concept will be confirmed to essentially eliminate the potential for operator errors and equipment malfunctions to jeopardize public safety, and the need for provisions to manage severe accidents leading to core disarray like the accident at Three Mile Island.

- The offsite consequences of licensing basis events will be confirmed to be benign to the extent that planning for evacuation and sheltering of the public is not required. In addition, emergency planning activities; e.g., periodic drills, training and exercises, are assumed to be simplified to the extent that requirements can be fulfilled without substantial commitment of senior engineering, licensed operations, and emergency preparedness personnel to the preparation of elaborate accident progression scenarios and the development of detailed response plans.

  The Target Plant will be licensed such that only two SROs (the Shift and Plant Supervisors) are required on-site, the control room is adequately staffed with one licensed reactor operator for two reactors, and security requirements for mounting an armed response force are relaxed.

- Nuclear insurers will reflect the benign off-site nuclear consequences associated with credible GT-MHR accidents in reduced property damage insurance rates, and GT-MHR licensees will be exempt from current provisions of the Price-Anderson

PC-000447/0

Act wherein operating licensees can be assessed up to $10 million per reactor/per year/per loss associated with public liability.

A plant operating capacity factor of 85% is achieved, as compared to 80% for the Lead Plant.

A fully mature "equilibrium" Target Plant incorporates a reactor module power level increase to 600 MWt versus the reference 550 MWt design and achieves an operating capacity factor of 87%; i.e., equal to the design capacity factor.

The approach to estimating O&M costs for the Replica Plant involves judging the extent to which the institutional changes assumed to be in place for the Target Plant will have been brought about by the Prototype Plant Project at the time of commitment to the Replica Plant. Key assumptions are as follows:

With a few exceptions, staffing for the Operations, Technical and Administrative Divisions is estimated to be the same as for the Prototype Plant since demonstration of multi-module plant operations will not have been accomplished at the time of Replica Plant commitment.

- Maintenance Division staffing is assumed to be the same as for the Target Plant since its size is largely determined by then replicated plant equipment and O&M procedures.

A plant operating capacity factor of 82% is achieved, as compared to 80% for the Lead Plant, 85% for the Target Plant, and the design capacity of 87% for the "equilibrium" Target Plant.

2.2.3 Plant Configuration Sensitivity Studies

Brief studies were conducted to determine the sensitivity of O&M costs to the following changes in plant configuration: (1) individual control rooms for each reactor module versus a central control room (the reference) and (2) the number of reactor modules comprising the plant; i.e., 1, 2, 3, or 4 (the reference) modules. While it is clear that both of these options would incur higher operating costs than the reference four-module plant with a central control room, both would reduce risk and increase deployment flexibility. This study indicates that changing from a central to individual control rooms would increase the O&M component of the busbar cost of electricity from 4.5 to 5.0 mills/kwhr. While quite limited in scope, the evaluation of the number of reactor modules in the plant suggests that the GT-MHR can potentially compete in all four configurations and that a more thorough evaluation of design features that allow flexibility; e.g., individual control rooms, should be conducted (see Figure 5-1).

2.3 OVERVIEW OF OWNER'S COST

During the construction of a power plant, the owner incurs costs for its acquisition functions which include (1) project management; (2) fees, taxes and insurance; (3) spare parts and specific capital expenses; (4) staff training and startup and (5) administrative and general expenses. Like the estimates of O&M costs, these estimates of GT-MHR owner's costs also benefit from the Project Feasibility Study (Reference 4) in which Consumer's Power Company and Philadelphia Electric Company supported a detailed evaluation of the cost of deploying modular gas-cooled reactors at a utility site, as well as prior GCRA estimates. These estimates also assume successful development and deployment of the Prototype, Lead, Replica, Target and "equilibrium" Target Plants. Owner's costs for the "equilibrium" Target Plant are assumed to be the same as the Target Plant except that spare turbomachinery will be shared with another plant and the training simulator provided through COSO will be shared by five versus three plants. Schedule assumptions are described in more detail in Reference 3. The major cost drivers and assumptions for the owner's costs summarized in Table 2-1 are as follows:

Project Management: These costs are incurred by the owner for professional services to manage the owner's engineering, licensing, and quality assurance programs. The principal cost drivers are the duration of the effort (which extends from project inception to fuel loading) and the stage of plant/infrastructure development. The latter ranges from an embryonic vendor/utility/regulator infrastructure for the Prototype Plant to multiple, parallel commercial projects deploying a standard design with support from a mature COSO for the Target Plant. As shown in Table 2-1, the project management effort is estimated to require 276, 135, and 112 man-years, for the Lead, Replica and Target Plants, respectively.

- Fees, Taxes and Insurance: Dominant cost drivers are (1) property taxes which are from 70 to 85% of the total for these accounts and (2) the cost of NRC staff review which ranges from 20% of the Lead Plant account to 10% of the Target Plant account.

- Spare Parts: These accounts are dominated by provisions for spare turbomachinery and access to a training simulator. The Lead, Replica and Target Plants are assumed to each have a spare turbomachine (i.e., the turbine, compressor, bearings, and seals), while the "equilibrium" Target Plant is assumed to share this equipment with another plant. The Lead and Replica Plants are assumed to each have a simulator. As the industry matures, it is assumed that COSO operates and maintains the simulators at regional central facilities such that Target Plant costs are shared by two other plants and "equilibrium" Target Plant costs are shared by four other plants.

Plant Staff Training and Startup: This account is dominated by the cost of training the plant staff; i.e., their salaries and training expenses, and the cost of plant operation during the interval from fuel loading to commercial operation. It is assumed that staff training will start from 24 to 36 months before fuel loading, depending on the stage of plant development, for those personnel requiring licenses or specialized training and that the permanent operating staff is prepared to conduct startup operation one year before commercial operation. As shown in

PC-000447/0

Table 2-1, this effort is estimated to require 580, 560 and 371 man-years, for the Lead, Replica and Target Plants, respectively.

G&A and Contingency: General and administrative (G&A) costs are estimated at 15% of the above cost accounts except for the fees, taxes, and insurance account. A 15% allocation for contingencies is added for integration of owner's costs with other elements of the capital cost estimate.

SECTION 3

O&M COSTS FOR LEAD AND PROTOTYPE GT-MHR PLANTS

3.1 APPROACH TO ESTIMATING LEAD AND PROTOTYPE PLANT O&M COSTS

This section provides an estimate of O&M costs for the four-module GT-MHR Lead Plant and for the demonstration testing period of the first module the Lead Plant; i.e., the single-module Prototype Plant. These estimates draw heavily on the Project Feasibility Study (Reference 4) and the previous GCRA studies (References 3, 5, and 6). The approach to developing these estimates, plus the assumptions upon which they are based, are summarized in the following paragraphs.

It is assumed that the GT-MHR will be designed and deployed in accordance with the utility/user policies and requirements in Reference 2. From an operating perspective, the GT-MHR offers a fundamental simplification relative to other nuclear options by eliminating the steam generation and condensing cycle; e.g., the main circulator, steam generator, steam and feedwater systems, turbine-generators and their auxiliary systems employed in steam cycle MHTGRs. These systems and components are replaced by a direct cycle power conversion system (PCS) which is located within the reactor coolant boundary and employs advanced technologies to achieve thermal efficiency of about 47.7%. The components of the PCS include turbomachinery (the gas turbine and the generator), heat exchangers (recuperator, intercooler and precooler) and ducts and seals that channel reactor coolant flow.

While the direct cycle PCS is developmental, the utility/user requirement for an 87% capacity factor for the Target GT-MHR Plant is based on a number of well established technical factors. For example, the controlled helium environment should eliminate most of the sources of wear and corrosion encountered in conventional gas and steam turbines. The use of magnetic bearings will also reduce maintenance requirements by eliminating contact wear in rotating machinery and allow less frequent inspection and maintenance. High reliability and low maintenance is also expected for the recuperator, intercooler and precooler heat exchangers which operate at modest temperatures, pressures and flowrates. For the purposes of estimating O&M costs, it is assumed that maintenance needs for the PCS will be minimal.

In addition, the GT-MHR's unique safety characteristics have the potential to substantially ease operational licensing requirements compared to current nuclear plants. Operating nuclear plant O&M costs have risen steadily since the early 1980's. The major increases during this period since the accident at TMI have been in operating costs. New programs required by NRC and INPO initiatives have increased staff requirements in licensing, engineering and administration as well as operations, maintenance, training, and security, as well as off-site technical support. Such programs are labor intensive, and many require technical professionals.

RC-000447/0

As discussed in the Introduction, the GT-MHR deployment plan offers a path to develop an appropriate regulatory framework and deploy standardized, NRC certified commercial nuclear power plants based on prototype tests. Full-scale demonstration testing of the first reactor module is expected to support simplified licensing requirements by (1) validating the actual configuration and characteristics of passive safety features upon which the plant safety analysis is based, and (2) establishing a highly reliable and physically demonstrated baseline of acceptance criteria to be applied to the same features in commercial plants. Since the GT-MHR precludes core melt and disarray like occurred at the accident at TMI, the technology forthrightly addresses the foremost technical issue underlying the business risks of owning a nuclear power plant, and a stable regulatory environment is assumed.

Current nuclear industry practices are assumed to generally apply in estimates for on-site and off-site plant staff. However, it is also assumed that current trends within the industry toward focusing resources on risk-significant equipment and on employing a high degree of automated control and information management are successful. For example, stringent INPO training program requirements have been included, with appropriate consideration for the reduced amount of material to be addressed due to GT-MHR simplicity. On the other hand, in developing estimates of shift staffing, it was assumed that operating requirements would be less prescriptive than those currently mandated for light water reactors, in view of GT-MHR passive safety features, long time intervals for operator response to upset conditions, and the use of highly automated information management and plant control systems.

These attributes and design features will reduce requirements for the operator to analyze data and respond quickly during plant transients. Since the means to accomplish safety functions are embodied in the GT-MHR design, operational licensing requirements may center on design verification and manufacture of the fuel and reactor modules, with a substantially reduced regulatory effort applied to site activities. These factors are expected to add significantly to overall safety and ease licensing, and thereby reduce burdens on plant staff and the risks of delays in the licensing process. They are examined more thoroughly in Reference 10, and the resulting framework for simplified GT-MHR technical specifications is summarized in Appendix A. A critical assumption in this estimate of O&M costs is that simplified regulatory practices based on the principles of risk-based regulation will be accepted by the NRC and industry.

The estimates herein were developed by first assessing resources required for the first full four-module plant in a commercial environment, and then identifying the resources needed for a single module; i.e., it is assumed that the second, third and fourth modules will be added after demonstration testing on the first module is completed. For the purposes of estimating costs, a plant capacity factor of 80% is assumed for the single-module Prototype Plant and for the four-module Lead Plant as compared to 85% for the Target Plant and 87% for the "equilibrium" Target Plant. As discussed in Section 4, O&M costs for the GT-MHR in a mature industry should further benefit from GT-MHR safety attributes with a substantial simplification of operating requirements. Once regulatory simplification has been confirmed in the successful operation of early commercial plants, provisions for the Lead, Replica and follow-on units would be revisited and standardized based on those for the Target Plant; i.e., successful deployment will allow the higher initial operating costs of early plants to be reduced. (This consideration is not reflected in O&M costs estimated in this report but may be included in life-cycle cost calculations of return on investment.)

Estimates of non-fuel O&M costs for the Lead Plant were derived by first determining the needs of the operating plant and then assessing the resources to meet those needs in terms of plant staff, off-site assistance, and the cost of supplies, fees and insurance. The Nuclear Operating Plant Functional Needs shown in Table 3-1 were identified as requirements to operate the plant in a safe and economic manner under the purview of the NRC and industry oversight organizations; e.g., INPO and NEI. Some of these needs are clearly objective and immediately obvious, while others are more subjective. This list of functional needs represents a consensus of senior utility operations and engineering personnel based on several decades of experience with fossil, LWR and HTGR plants. All costs associated with meeting these needs are born by the operating plant regardless of how the need is met; i.e., whether by plant resources, by other corporate assets, or by contract.

It is also assumed that an owner/operator-based Central Operational Support Organization (COSO) is established in concert with design development and Prototype Plant deployment. This organization will be established by prospective commercial participants early in the GT-MHR development program as an integral part of the vendor/buyer/regulatory infrastructure. COSO will represent the technical interests of owner/operators of the first series of commercial plants starting early in the development of the Prototype Plant and continuing through construction and deployment of follow-on plants. COSO will interact with vendor entities to translate operating plant needs into design requirements and operating programs. The COSO role in GT-MHR commercial deployment is summarized in Appendix B (see also Reference 11).

A particularly important assumption with regard to the O&M cost estimates presented herein is that both plant operating programs and a trained plant staff will be in place at the time of plant start-up. The plant operating programs define the purpose and details of the work to be done by the plant staff. These programs must address all aspects of plant operation that significantly affect the means of complying with regulations, the productivity and effectiveness of the plant staff, and the overall economy of plant operation. It is further assumed that state-of-the-art information management systems utilizing user-friendly computer operations will be supplied as appropriate for all plant programs. (The vendor's costs to develop these programs in conjunction with COSO are included in plant capital costs. Estimate of owner's costs to recruit and train plant staff are included in Section 6.) Failure to have these programs in place at the time of plant startup would incur a significant risk of damage to the plant and would likely delay plant startup if public safety is at issue. Appendix C of this report provides an initial outline of plant operating programs for the GT-MHR.

Because this is an estimate of operating expenses, there are no provisions for engineering and construction work associated with plant modifications. Costs for government mandated or beneficial modifications to the plant are considered to be a

PC-000447/0

Table 3-1
OPERATING NUCLEAR PLANT FUNCTIONAL NEEDS

OPERATIONS Process Operation On/Off-site Operations Review Equipment Tagout, Logkeeping Technical Specifications	LICENSING NRC INPO State Regulatory Nuclear Insurance
MAINTENANCE Mechanical, Electrical Preventive/Corrective Instruments/Control Computers Inservice Inspection	TRAINING General Employee Operator Licensing Simulator INPO Accreditation Human Performance Evaluation Maintenance Craft
OUTAGE PLANNING Refueling, Scheduling Maintenance Modifications	ENGINEERING SUPPORT Minor/Major Modifications Independent Safety Engineering Systems Engineers
RADIATION PROTECTION-HEALTH PHYSICS Dosimetry, Bioassay ALARA, Off-site Environmental Testing	SPARE PARTS WAREHOUSE Requisitions Receiving/Disbursal
CHEMISTRY Conventional Radio-Chemistry	CONFIGURATION MANAGEMENT Document Control Change Process
LAUNDRY/ANTI-CONTAMINATION CLOTHING/RESPIRATORS	FIRE PROTECTION Fire Brigade, Equipment Testing
ADMINISTRATION Typing/Clerical Wage/Benefits Public Relations	EMERGENCY PLANNING Off-site/On-site Regulatory Interface Media Interaction
CONSTRUCTION Major/Minor Modifications	MEDICAL Fitness for Duty
REFUEL OPERATIONS Fuel Procurement Program	RADIOACTIVE WASTE Accumulation/Shipping
TIMEKEEPING/PAYROLL	PERSONNEL ADMINISTRATION
GROUNDS & HOUSEKEEPING	LEGAL
INDUSTRIAL SAFETY Hazardous Waste Program OSHA	SECURITY Guard Training, Key/Control Lock Repair/Changeout
QUALITY ASSURANCE/CONTROL Plan, Audits, Reports	NUCLEAR PLANT RELIABILITY DATA SYSTEM Failure Report, Data Base
SAFETY PERMITS, RADIATION WORK PERMITS, OTHERS Writing, Application/Removal	RECORDS MANAGEMENT Vendor Manuals Procedure Distribution

capital expense and are not included here. With a thorough development program and successful standardization, such costs should be small. Provisions for such costs are included in the plant capital cost estimate by incrementing the fixed charge rate 0.5%.

As described in Reference 12, the cost accounting breakdown shown in Table 3-2 encompasses approximately the same expenses as those prescribed for public utilities subject to the provisions of the Federal Power Act; i.e., the Federal Energy Regulatory Commission (FERC) uniform system of accounts. This structure was also used in O&M and owner's cost studies for gas-cooled reactors previously cited. The power generation cost accounts in Table 3-2 include the nuclear power generation accounts from FERC accounts 517 through 532 with the exception of accounts 518, Nuclear Fuel Expense; 521, Steam From Other Sources; 522, Steam Transferred; and 525, Rents. Nuclear Fuel Expense is considered separately in GT-MHR economic evaluations, and no costs are identified for accounts 521, 522, and 525 for estimating purposes. In addition to direct wages and salaries, the cost accounts for on-site staff and off-site corporate technical support include payroll tax and insurance (social security tax and employment insurance premiums).

The General and Administrative (G&A) cost accounts in Table 3-2 include G&A expense accounts from FERC accounts 920 through 935. The pensions and benefits estimate includes an allocation for account 926, Employee Benefits and Pensions, and also, as a cost estimating convenience, an allowance for Workers Compensation Insurance which is a part of account 925, Injuries and Damages. Nuclear regulatory fees are a part of account 928, Nuclear Regulatory Commission Expenses; plant property damage insurance premiums are a part of account 924, Property Insurance; and nuclear liability insurance premiums are a part of account 925, Injuries and Damages. Other G&A expenses are an allocation of all other FERC G&A accounts.

A LOTUS spreadsheet analysis was used to calculate costs in a manner essentially identical to that used in the BASIC program, HTGROM, described in Reference 12. This calculational method was also used in prior estimates reported in References 3, 4, 5, and 6.

3.2 LEAD PLANT STAFF ORGANIZATION

The Lead Plant consists of four reactor modules and produces 1050 MWe. As a framework for estimating costs, the plant staff is assumed to be organized in Operations, Maintenance, Technical, and Administrative Divisions as shown in Figure 3-1. Since costs are estimated on the basis of resources required to accomplish specific functions, they are essentially independent of the plant organization structure and other alignments are acceptable. Many plant personnel will have professional credentials in engineering or related fields, as well as GT-MHR-specific training and relevant plant work experience. The number and credentials of staff to meet the routine needs of the GT-MHR Lead Plant are estimated in the following sections.

The Prototype Plant (i.e., the first module and common facilities of the Lead Plant) will operate as a single module plant for about two years before the remaining three

PC-000447/0

Table 3-2
COST ACCOUNTING STRUCTURE

POWER GENERATION COSTS

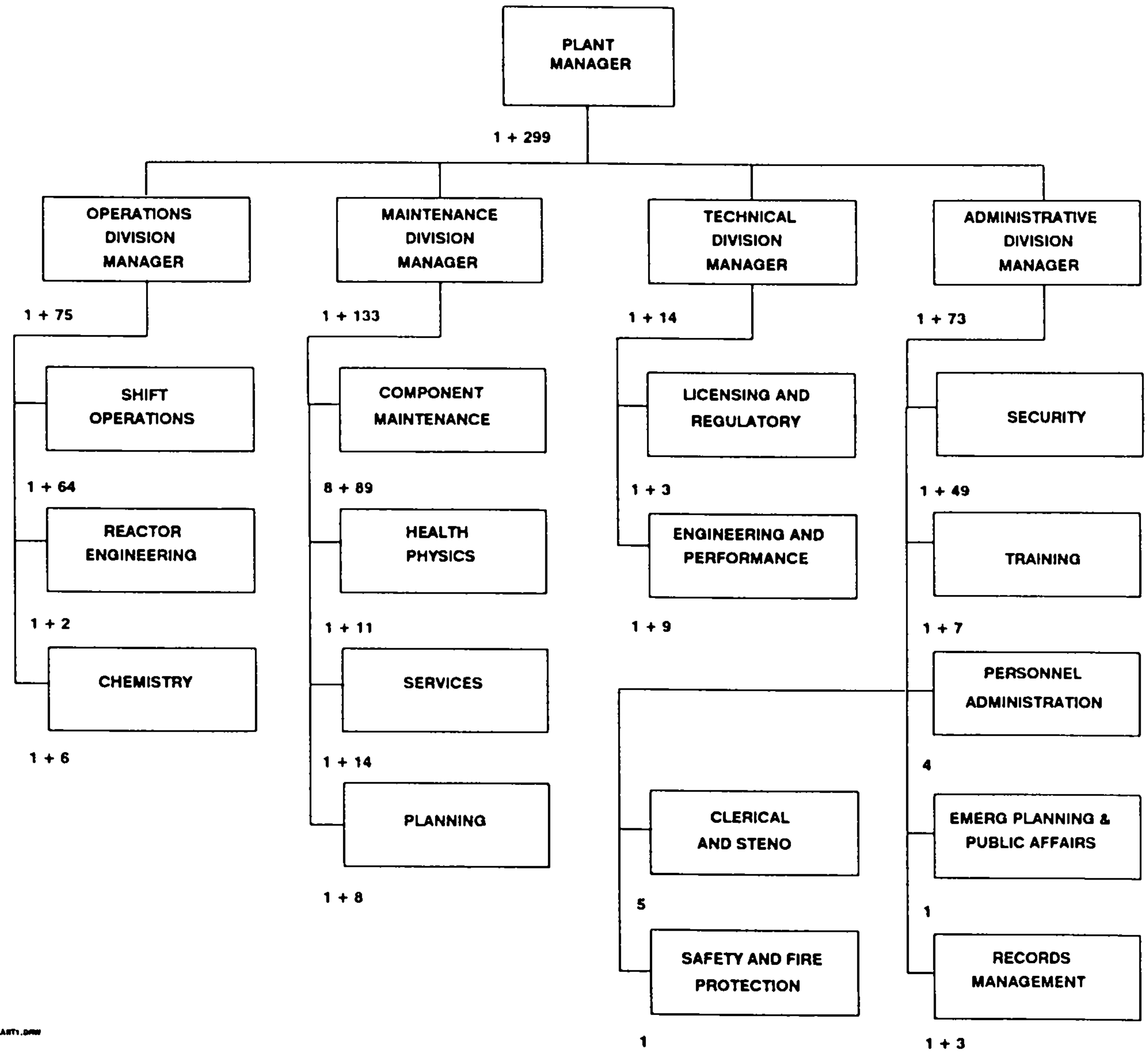
- ON-SITE STAFF
- MAINTENANCE MATERIALS
  - Fixed
  - Variable
- SUPPLIES AND EXPENSES
  - Fixed
  - Variable Reflector Block and Control Rod Replacement
  - Variable
- OFF-SITE TECHNICAL SUPPORT
  - Corporate
  - Central Operational Support Organization (COSO)

GENERAL AND ADMINISTRATIVE COSTS

- PENSIONS AND BENEFITS
- NUCLEAR REGULATORY FEES
- INSURANCE PREMIUMS
  - Public Liability
  - Property Damage
  - Replacement Power
- OTHER GENERAL AND ADMINISTRATIVE EXPENSES

PC-000447/0

Figure 3-1
GT-MHR LEAD PLANT ORGANIZATION



modules are added. As discussed in Section 6, it is assumed that the staff will be recruited and trained in a manner that makes efficient use of resources. That is, since the Prototype Plant uses one reactor module, its staff will be smaller than that for the Lead Plant. However, it will be organized to facilitate the addition of staff for the full four-module plant.

3.2.1 OPERATIONS DIVISION

The Operations Division is responsible for operating all plant systems and equipment, for overseeing and controlling all water and helium chemistry parameters, for monitoring and optimizing fuel performance, and for providing support to Maintenance Division personnel (i.e., removing equipment from service, conducting post-maintenance inspection and system functional tests, and returning equipment to service). As illustrated in Figure 3-2, the Operations Division consists of the Division Manager, 65 Operations, 7 Chemistry, and 3 Reactor Engineering personnel.

3.2.1.1 SHIFT OPERATIONS (1 Shift Manager; 6 Shift, 6 Plant, and 6 Control Room Supervisors; 42 Operators; 2 Helpers; and 2 Clerks)

Shift operations staffing is based on a six-team arrangement, a forty-hour work week, and an eight-hour work shift. The use of six teams allows continuous coverage for all posted positions with adequate coverage for operator retraining, maintenance support, and relief for leave, illness and vacation. (A five team arrangement was considered, but its use is not consistent with the policies of most utilities.) A shift cycle consists of five rotations over a six-week period; i.e., day, afternoon, night, training, and utility shifts, then back to day shift. The day, afternoon and night shifts fill posted positions that must be continuously staffed. The training shift provides four days for training in each six-week period to fulfill NRC, INPO and other training requirements. Although all four days will occasionally be needed for licensed operator training, it is expected that one or two days will frequently be available for non-posted work and short time relief. The utility shift is available to support special operations and maintenance activities, as well as to provide personnel relief. The utility shift is expected to be split between day and afternoon to support maintenance. The six-team staffing plan is illustrated in Table 3-3. It provides margin for occasional absences and avoids excessive overtime work.[1]

A Shift Supervisor is in charge of overall shift operations. This individual is trained in all disciplines associated with the safe operation of the plant and, as the manager of plant operations, ensures that the duties of the chemistry, health physics, instrumentation and other maintenance support services are performed as needed for efficient plant operation. The Shift Supervisor has the authority to direct all plant personnel in matters associated with plant safety. The Shift Supervisor is assisted by a Control Room

---

[1] Some nuclear plant have experimented with ten-hour shifts to improve productivity and employee morale. With modest adjustments, the strategy outlined above could be adapted for ten-hour shifts.

PC – 000447/0

Figure 3-2
GT-MHR LEAD PLANT
OPERATIONS DIVISION ORGANIZATION

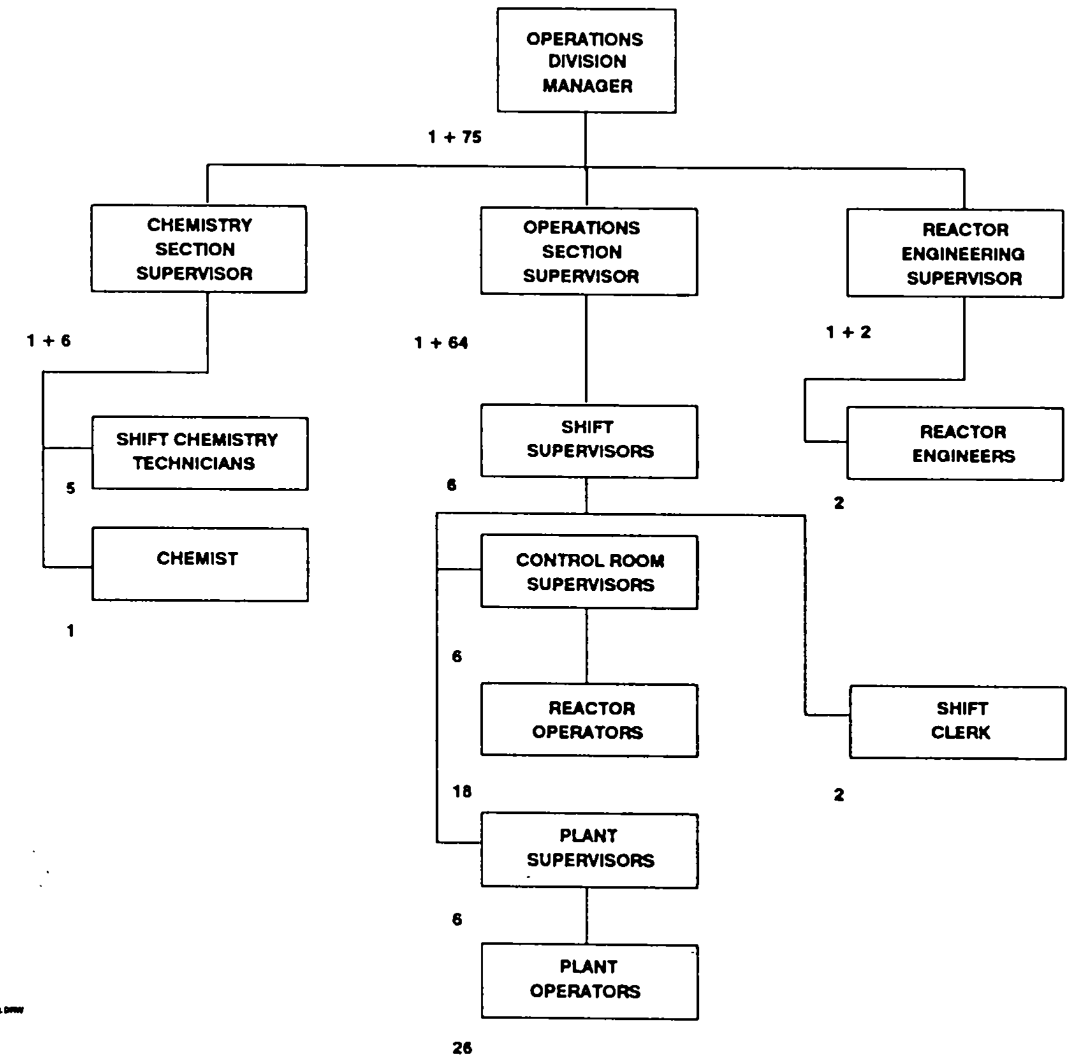


Table 3-3
GT-MHR SIX-TEAM STAFFING PLAN

TEAMS[1]	WEEK 1							WEEK 2							WEEK 3							WEEK 4							WEEK 5							WEEK 6						
	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
TEAM 1		D	D	D	D	D[2]				A	A	A	A	A	A	A[2]			N	N	N	N	N	N	N[2]			D	D	T	T	T	T[3]				U	U	U	U	U[4]	
TEAM 2	D	T	T	T	T				U	U	U	U	U			D	D	D	D	D				A	A	A	A	A	A	A			N	N	N	N	N	N	N			
TEAM 3	A	A			N	N	N	N	N	N	N			D	D	T	T	T	T				U	U	U	U	U			D	D	D	D	D				A	A	A	A	A
TEAM 4			A	A	A	A	A	A	A			N	N	N	N	N	N	N			D	D	T	T	T	T				U	U	U	U	U			D	D	D	D	D	
TEAM 5	N	N	N	N			D	D	T	T	T	T				U	U	U	U	U			D	D	D	D	D				A	A	A	A	A	A	A			N	N	N
TEAM 6		U	U	U	U	U			D	D	D	D	D				A	A	A	A	A	A	A			N	N	N	N	N	N	N			D	D	T	T	T	T	

NOTES:

(1) Including maintenance support staff, there are 14 personnel on each team: 1 Shift Supervisor, 2 Plant Supervisors, 1 Control Room Supervisor, 3 Control Room Operators, 3 NI/ECA Operators, 1 I&C Technician, 2 M&E Craftsmen, and 1 Health Physics Technician.

(2) Day (D), Afternoon (A), and Night (N) shifts are posted-positions; i.e., these positions must be continuously staffed.

(3) The Training (T) shift is conducted during the day and allows four days in each six-week cycle for training, including three days for the Licensed Operator Requalification Program.

(4) The Utility (U) shift is available for relief of posted-positions due to vacations, sick leave, etc., and for maintenance support (i.e., removing equipment from service, conducting post-maintenance inspection and system functional tests, and returning equipment to service). It may be split between days and afternoons.

Supervisor and a Plant Supervisor. The Shift Supervisor holds an NRC Senior Reactor Operator (SRO) license.

The Control Room Supervisor also holds an SRO license and fills the current regulatory requirement that a supervisor be posted in the control room. Three licensed Reactor Operators (RO) complete the staff for control room operations. Thus, current NRC requirements that a licensed reactor operator be posted in the control room for each reactor module are met. The work load and responsibilities for operating and monitoring the four reactor modules from the control room will be allocated to operators on the basis of task analyses and human factors, and a team approach will be developed.

The Plant Supervisor reports to the Shift Supervisor and also holds an SRO license. This person is trained in all operational processes and is responsible for the overall operation of the reactor modules and coordination of control room and roving operators. The latter are responsible for the local operation of ancillary plant equipment. In addition, the Plant Supervisor inspects plant operating components and oversees non-routine maintenance to ensure that operational support activities are performed correctly. The Plant Supervisor is designated as the Chief of the Fire Brigade which is comprised of one chemistry technician, one instrumentation technician, two maintenance mechanics and one operator. Security procedures will allow efficient movement of operators, the Fire Brigade, and the Security Response Team through secured areas.

Four roving operators (licensed ROs) will be dispatched from the control room and qualified to work throughout the entire plant. The work to be accomplished by roving operators is expected to be dramatically reduced compared to operator functions in current plants. The elimination of steam generation and condensing systems, active safety-related fluid systems, and the potential for systems interaction will reduce the complexity of the plant and the work-load on roving operators. In addition, much of the equipment monitoring and diagnostic functions assigned to operators in current plants will be automated. (The use of such systems is expected to provide a higher degree of accuracy and reliability than that attainable with current methods.)

The annual equivalent of two helpers is assumed to be engaged in on-the-job training for operator positions. The helper positions also ensure the availability of personnel to provide training relief and fill other vacancies. These two helpers (who will become operators after qualification) provide additional support on day shift operations.

Two clerks are provided to assist day and evening shifts with documentation, scheduling, and record keeping. The clerks will be trained in the use of the plant information management system for scheduling shift personnel, generating operations reports, and scheduling tests and preventive maintenance.

A Shift Technical Advisor is assumed to be unnecessary due to the simplicity of the plant and the long time intervals available to implement well-considered accident recovery plans.

PC-000447/0

3.2.1.2 REACTOR ENGINEERING (1 Supervisor and 2 Engineers)

The Reactor Engineering group is comprised of professionals and responsible for key nuclear plant systems (e.g., vessels, heat transport, shutdown cooling, neutron control, reactor protection, and reactor cavity cooling systems). Other duties include conducting surveillance and special tests, managing control rod and fuel burnup and the fuel procurement program, directing refueling operations, and routinely monitoring reactor systems. This group will also conduct the technical interface with reactor vendors and fuel suppliers.

The group consists of one supervisor and two professionals in nuclear engineering or physics with specialized training in GT-MHR core design and fuel management. They will be assisted by the Refueling Supervisors (see Section 3.2.2.1.3) when the latter are not directly engaged in refueling activities. In addition, personnel from COSO will support the Reactor Engineering Group in core management and fuel procurement functions.

Experience has shown that a dedicated reactor engineering group improves the reliability of operations. The reactor engineers will work closely with the refueling team and planning groups in the Maintenance Division to develop the reactor core alteration schedule for each refueling. They are also responsible for computer programming that pertains to refueling activities.

3.2.1.3 CHEMISTRY (1 Supervisor, 1 Chemist and 5 Technicians)

Because of the importance of the chemistry control function to successful plant operation, the Chemistry Group also reports to the Operations Supervisor. The Chemistry Group's responsibilities include the closed cooling water system, water make-up, and waste treatment; as well as helium chemistry and radioactive isotope quantification. Much of the work performed in current plants to maintain chemistry parameters within normal limits is routine and will likely be automated in future plants. It is assumed that the GT-MHR plant design will incorporate automated sampling and chemical analysis equipment and provide for computerized data analysis and report generation with the means to alert chemistry section supervision of variances from chemistry acceptance criteria.

It is estimated that a staff of seven personnel, including the Chemistry Supervisor, is required. The Chemistry Supervisor and a chemist assistant will hold professional credentials in chemistry and radiochemistry and have appropriate specialized training. Five technicians are required for shift coverage. The chemistry technician on shift is a member of the Fire Brigade. All technicians are qualified to do both conventional and radio-chemistry.

The degree to which the sampling, information management, and communication systems are integrated in the plant design will have a significant impact on the work load of Chemistry personnel. Full use of automated chemical sampling, analysis, and report generation will enhance reliability and help contain the costs of the chemistry activity.

An important aspect of this staffing estimate is the assumption that the plant design incorporates such systems.

3.2.2 MAINTENANCE DIVISION

The Maintenance Division is responsible for all planned and corrective maintenance of plant equipment. As shown in Figure 3-3, the Maintenance Division organization consists of sections for Component Maintenance, Health Physics, Plant Services, and Maintenance Planning. It is staffed in a manner that ensures safe, economic plant operation in accordance with government regulations and prudent business practices.

Maintenance work on nuclear systems in current plants entails many provisions for documented quality assurance that are not found in conventional power plant maintenance programs. Estimates for the GT-MHR Lead Plant provide for administrative controls on the maintenance of safety-significant equipment that will meet the expectations of the NRC, INPO, and American Nuclear Insurers (ANI). However, administrative controls for non-nuclear maintenance work are tailored to meet utility-controlled requirements as determined by plant management, and they need not meet current nuclear industry expectations in the areas of documentation, quality assurance, craftsman qualification and retraining, and requirements for formalized procedures.

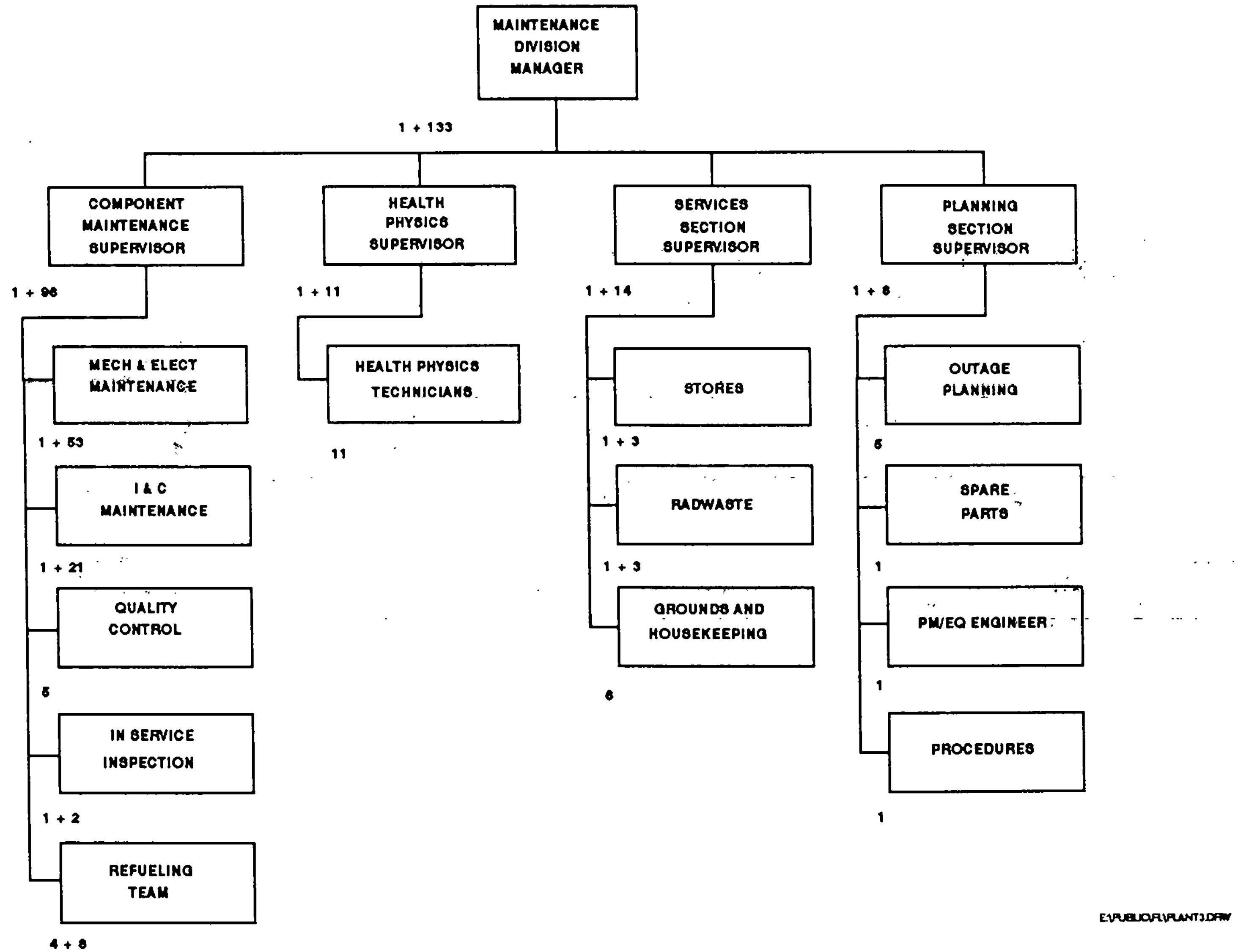
The conventional approach to managing work in non-nuclear areas is deemed appropriate since equipment failure in those areas will not pose a nuclear hazard. Significant savings in cost can be affected if this more traditional approach to maintenance management is adopted. For example, work planning can be oriented to enhancing efficiency by minimizing hold points for independent inspections and audits, and the time consumed by multiple oversight organizations (e.g., NRC, INPO and independent quality assurance personnel). The training of craftsmen can employ more on-the-job and less formal classroom instruction. Productivity is also increased by eliminating the need to have detailed, prescriptive procedures for non-complex or routine work. While it has been assumed that current nuclear plant maintenance practices will be implemented for all nuclear work on the Lead Plant, a more conventional plant maintenance program will be used elsewhere. Utility controls will ensure reliable plant operations.

3.2.2.1 COMPONENT MAINTENANCE SECTION (1 Section Supervisor, 8 Discipline Supervisors, 4 Discipline Foremen, 43 Craftsmen, 7 Craftsmen (annualized), 21 Technicians, 12 Technicians (annualized), and 2 Programmers)

The Component Maintenance Section has the responsibility for the repair, calibration, and preventive maintenance to be performed on all mechanical and electrical equipment including instrumentation and computers. In addition, this group will support refueling, in-service inspections, and quality control. It is composed of craftsmen of various disciplines, instrumentation and computer technicians, and computer programmers. The principal interfaces for this section are with the Planning, Health Physics and Operations groups. Except for shift coverage personnel, these staff are on a single-shift and will be assigned to day or evening shifts as necessary. An important

PC-000447/0

Figure 3-3
GT-MHR LEAD PLANT
MAINTENANCE DIVISION ORGANIZATION



assumption in this estimate is that the plant design incorporates a comprehensive computerized information management system (CIMS). This system will support a Reliability Centered Maintenance Program (e.g., as a repository for equipment reliability data and repair histories) and spare parts inventory management, as well as administrative functions.

3.2.2.1.1 INSTRUMENTS, CONTROLS AND COMPUTERS (I&C) (1 I&C Supervisor, 1 I&C Foreman, 16 I&C Technicians, 2 I&C Technicians (annualized), and 2 Programmers)

This group is responsible for planned and corrective maintenance of plant instrumentation, control systems, and computers with certain exceptions (e.g., air operated valves and associated solenoids) which are maintained by the mechanical or electrical maintenance group. The group conducts I&C surveillance tests, supports shift operations and repairs electrical breakers and relays.

It is expected that plant control and information management systems will provide highly reliable distributed digital process control and information processing with appropriate alarms for parameters exceeding prescribed limits and for control system malfunctions. Automated data collection, analysis and report generation techniques will be used to verify compliance with many surveillance test requirements. The design will provide for automatic electronic documentation and optional hard copy reports of instrument calibration and equipment diagnostics. Assuming this capability, the following work activities and staffing are anticipated:

SHIFT COVERAGE (1 I&C Technicians for each of 5 teams - total of 5)

These personnel will perform surveillance testing and preventive and corrective maintenance on instrumentation and computers. This staffing plan provides an extra technician to assist in routine maintenance on the day shift Monday through Friday (except Thursday).

INSTRUMENT ROUTINE MAINTENANCE (2 I&C Technicians)

Two technicians will perform plant instrumentation and routine or corrective maintenance. This effort can be supplemented as needed with shift technicians rotated into day work.

SECURITY AND TELEVISION (1 I&C Technician)

This person will service televisions and monitor card readers, X-ray machines, metal detectors, and central and secondary alarm station equipment. Shift technicians will also have sufficient training in this area to provide continuous response to problems.

PC000447/0

FIRE SYSTEM DETECTOR TESTING (0.5 I&C Technician)

This person will perform surveillance testing and maintenance on smoke and heat detectors as part of the Fire Protection program. Some of this work may be required by technical specifications. Design provisions to facilitate tests of smoke and heat detectors will avoid the need for scaffolding or temporary access devices.

RELAYS AND SUBSTATION EQUIPMENT (1 I&C Technician)

This person will perform all routine testing and calibration of protective relays in the plant and substations.

BREAKER PREVENTIVE MAINTENANCE (1 I&C Technician)

This person will rebuild and calibrate 480 volt circuit breakers and calibrate higher voltage circuit breakers as part of the preventive maintenance program.

PLANT COMPUTER (3 I&C Technicians and 2 Programmers)

These personnel will maintain plant computer hardware and update software.

METEOROLOGY & HEALTH PHYSICS INSTRUMENTATION (2 I&C Technicians)

These personnel will perform routine calibration and repair of portable test equipment, instruments, and monitors. Maintenance of some specialized equipment will be contracted.

PROCEDURE WRITER (0.5 Technical Writer)

This person will draft and revise routine I&C maintenance procedures.

One supervisor and a foreman are required to direct these 20 personnel. Assuming four 30-day planned outages every 18 months, 30% overtime for plant staff, and 5 temporary technicians; the annual equivalent of 2 technicians is required for outages.

3.2.2.1.2 MECHANICAL AND ELECTRICAL (M&E) MAINTENANCE (1 M&E Supervisor, 3 M&E Foremen, 43 M&E Craftsmen, 7 M&E Craftsmen (annualized))

This group is responsible for planned and corrective maintenance of mechanical and electrical equipment and for the installation of minor plant modifications. It is estimated that 25% of the M&E group will be electrical craftsmen. The estimate of M&E maintenance staff required for nuclear equipment is based on a reasonable extension of industry experience with HTGRs and LWRs, while labor productivity on non-nuclear mechanical and electrical equipment is expected to be about the same as in fossil-fueled plants. The estimate is based on the following assumptions:

- The four reactor modules are identical and allow the use of identical O&M procedures. The plant design incorporates features to facilitate maintenance; e.g., adequate access, cranes, rigging, and laydown area.

The administration of work orders and procedures and the filing of work reports will be automated.

The plant design will permit many on-line maintenance activities; e.g., servicing fire pumps, rotating screens, compressed air systems, heating boilers, cranes, elevators, ventilation systems, house generators, circuit breakers, and redundant components in process systems.

M&E craft crews will be comprised of 50% fully qualified mechanics with the remainder being less-skilled mechanics and helpers. It is assumed that personnel will be in training approximately 8% of the time. M&E crews will include the usual distribution of machinists, welders, carpenters, riggers, pipe fitters, and electricians. In addition, the concept of "General Mechanic" will be utilized. The General Mechanic is fully qualified in a specific discipline and trained to perform non-complex work in allied disciplines; e.g., machinists may do some rigging, pipefitting, and electrical work. To minimize labor relation and personnel issues, these practices will be incorporated in labor agreements, and job descriptions will define qualifications. This concept has been shown to improve labor productivity and reduce cost at PECo's Peach Bottom 2 & 3 and Limerick 1 & 2 Plants.

Two M&E craftsmen will be placed on each of five teams (total of 10 personnel) to support operations. Administrative procedures will allow occasional overtime to efficiently complete assigned work.

Inspection and maintenance of the turbomachinery will be accomplished after removal from the PCS vessel. A spare turbomachinery unit (rotating equipment inside the reactor coolant boundary) will be available for exchange with operating units in any of the four reactor modules. This strategy will allow some decay of radioactive isotopes plated on the turbomachinery and permit maintenance to be performed while the plant is operating.

The M&E staffing estimate includes three annualized workers for turbomachinery maintenance; i.e., the equivalent of 12 man-months every refueling outage to remove and replace turbomachinery and to refurbish the unit when the plant is back on-line. Provisions are also included for an additional 18 man-months of temporary labor to supplement M&E maintenance staff. (In practice, to improve the productivity of contract labor, about 20% of the temporary labor requirement would be fulfilled by station forces working overtime.)

As discussed in the next section, the refueling strategy is based on the use of a dedicated team. However, these personnel are utilized in that capacity only about half time. When they are not engaged in refueling work, they are available to work as maintenance mechanics.

PC-00 0 5447/0

- This estimate is based on the judgement of senior utility personnel experienced with both fossil and nuclear plants. For example, non-nuclear maintenance cost estimates are extrapolated from turbine plant costs at the Philadelphia Electric Company's Cromby Station; a two-turbine, 400 MWe fossil plant. In some areas, estimates are based on data from the Fort St. Vrain HTGR Plant.

In summary, it is estimated that M&E maintenance work for the plant can be accomplished with one supervisor, three foremen (one of whom is electrical), and 43 craftsmen on permanent staff. An additional 7 annualized craftsmen for scheduled outages would be obtained from other sources.

3.2.2.1.3 REFUELING (4 Supervisors and 8 Technicians (annualized))

Plant availability is highly dependent on the success of refueling activities, and an especially trained and qualified group is assumed for GT-MHR refueling operations. A team-building concept will be employed to impart a high degree of individual commitment to the group and to achieving refueling goals. Refueling Supervisors will be dedicated to this effort, while non-supervisory personnel will be utilized as M&E craftsmen during plant operation. The team members selected for this group will be trained to perform health physics monitoring and to perform most aspects of mechanical, electrical and computer troubleshooting attendant with refueling operations. This estimate is based on conducting fuel handling activities with four shifts. One supervisor (with a special fuel handling license) and four maintenance craftsmen per shift for a total of 20 personnel are required.

Refueling a reactor module is estimated to require 16 days, plus another 4 days for fuel handling equipment setup, testing and removal. It is estimated that receipt and inspection of new fuel and reflector elements, and the preparation of spent fuel and used reflector elements for shipping, will require the equivalent of 17 days for the entire crew per refueling interval, based on about one and one-quarter man-hours per block. In addition, it is estimated that an equivalent of 6 days for the entire crew is needed for replacing and shipping spent control rods and that preventive maintenance of fuel handling equipment[2] will require 2 days per reactor. Thus, for each reactor module, an equivalent period of 46 days is required to receive and inspect new fuel, to refuel the reactor and maintain equipment, and to ship spent fuel. Administrative procedures will minimize discretionary absences during the refueling period, and some overtime work may be required to cover short duration absences.

For the four reactor module plant, 20 personnel will be needed for the equivalent of 184 days per 18-month refueling interval or 123 days per year. The four Refueling Supervisors will be engaged full time in work related to refueling. A portion of their time will be spent in refresher training to maintain their special fuel handling licenses. For the remainder of their time, they will be involved in other activities related to refueling, such as planning outages and assisting reactor engineers in developing the core alteration pattern for each refueling. When the other sixteen workers are not engaged in refueling

---

(2) Complex and corrective maintenance (e.g., break-down and overhaul) is assumed to be performed by the Mechanical and Electrical Group (previous section).

activities (~ 123 days per year), they will be used in routine maintenance activities. Thus, the annual equivalent of 8 maintenance technicians per year is estimated for refueling.

3.2.2.1.4 INSERVICE INSPECTION (ISI) (1 ISI Supervisor and 2 NDE Examiners (annualized))

The responsibilities of the ISI group include conducting nondestructive inspections and tests of the reactor primary system in accordance with plant technical specifications. The ISI Supervisor will be responsible for planning and administering ISI programs in accordance with ASME Section XI requirements and reporting results to appropriate regulatory authorities. This person will be trained in non-destructive examination (NDE) methods and certified ASNT Level III in the areas required by ASME Section XI. This person will also plan and administer erosion/corrosion control programs for other plant equipment. (Such programs would be conducted by other plant staff.) The COSO will also be a resource in conducting this work. The ISI Supervisor's principal interface will be with the Technical Group.

Assuming 8 personnel per day during a 21-day planned outage for each of the four reactors, it is estimated that the annual equivalent of two NDE certified examiners will be required. In the interest of economics and effectiveness, this effort would likely be subcontracted to NDE specialists.

In arriving at this estimate, it was assumed that ISI work will be conducted during one outage per refueling interval per reactor and that work during the outage will be continuous, vessel insulation will be minimal, and component insulation will be removable. It is also assumed that the plant design will incorporate the means to automate ultrasonic examination of the vessel welds; e.g., permanent tracks for vessel weld inspections. Also, it is expected that some M&E personnel are qualified to perform NDE in accordance with code requirements; e.g., ANSI B31.1, ASME XI. Health physics services required by the ISI program will be provided by plant staff.

Other ISI and surveillance activities will be conducted by plant staff. For example, neutron flux monitoring, feedwater and mainsteam isolation valve functional tests, pressure relief valve tests and reactor cavity cooling system screen and grating inspections will be performed by plant staff in the Engineering and Performance Group. Many of these activities will be performed during plant operation.

3.2.2.1.5 QUALITY CONTROL (5 Technicians (one is Lead))

The responsibility for quality control resides with cognizant group managers. While no dedicated quality control personnel are assumed in the Operating, Technical, and Administration Divisions; a dedicated Quality Control group is necessary for the Maintenance Division because of the volume and variety of their work. One lead and four other technicians with appropriate credentials in mechanical, electrical, instrumentation, and health physics areas are deemed necessary. In certain cases, this group will provide quality control services for operating evolutions.

PC-880447/0

3.2.2.2 HEALTH PHYSICS SECTION (HP) (1 HP Supervisor, 11 HP Technicians)

The function of the Health Physics Section is to protect personnel from radiological hazards, and their services are most frequently required by the Maintenance Division. An organizational consideration is whether administrative independence should be preserved between Health Physics workers and the personnel they serve. As described in Section 3.2.4.7, it is assumed that organization development programs will impart personnel safety as an integral part of the plant culture and minimize dissension between elements of the same organization. It is therefore assumed that the potential for high productivity will outweigh the benefits of organizational independence and the Health Physics Section is assigned to the Maintenance Division.

It is also assumed that a cross-training program will prepare all operations and maintenance personnel to do radiation monitoring for routine work and thereby reduce the number of dedicated Health Physics personnel. This cross-training concept is very important in containing operating costs and can be a significant contributor to the effectiveness of the radiation protection program.

It is estimated that a staff of 12 personnel, including the Health Physics Supervisor, is required. One person is assigned to each of six teams to support operations and perform routine surveys. Two persons are required to administer the external dosimetry program, which is assumed to be applied to only the nuclear areas of the plant. Four day shift positions are estimated for Health Physics' review of procedures and outage plans and to support the ALARA program.

3.2.2.3 SERVICES SECTION (1 Supervisor, 2 Foremen, 6 Craftsmen, and 6 Custodians)

The Services Section is comprised of Stores, Radwaste, and Grounds & Housekeeping groups. It is responsible for managing the warehouse, maintaining plant grounds and facilities, conducting certain aspects of the fire equipment surveillance effort, and performing radioactive waste handling activities.

3.2.2.3.1 STORES (1 Foreman, 3 Warehousemen (craftsmen))

The Stores group receives, stores and disburses both conventional and nuclear safety-significant equipment in accordance with approved requisitioning procedures. It also packages and ships articles as required. It is not responsible for procurement and expediting functions. The warehouse activity will be highly automated to reduce the number of personnel needed for record keeping and cost management. For example, procurement data (such as component specifications and vendor information) will be maintained in a computer database to facilitate re-orders, and an inventory control program to procure items in anticipation of planned outages and thereby avoid warehouse bottle-necks will be implemented.

It is estimated that one foreman and three warehousemen are required. These personnel will normally work days but will be available to support refueling and maintenance shift activities.

3.2.2.3.2 GROUNDS AND HOUSEKEEPING (G&H) (6 Custodians)

The Grounds and Housekeeping Program is important for the safe, efficient operation of the plant because of the effect it has on maintaining employee morale. An orderly plant also projects a statement of management attention to detail that can leave a positive impression on both the public and regulatory agencies. Responsibility for grounds and housekeeping will be shared by the G&H group and plant workers. The G&H group is responsible for custodial work such as cleaning floors, walls, windows, walkways, roads, lawns, and washrooms. While plant management must ensure that housekeeping assignments do not interfere with principal job responsibilities, non-supervisory plant workers will be assigned specific housekeeping work related to their discipline; e.g., operators will clean motors and control boards upon completion of the assigned tasks, and maintenance workers will clean-up the area after maintenance is completed. Housekeeping in the nuclear area will require radiation protection measures. (Control and clean-up of contaminated substances will be done by personnel from the Radioactive Waste group.) One person from the G&H group will be assigned to perform inspections and conduct minor maintenance on portable fire fighting equipment, first aid kits, ladders, and fire hoses as part of the safety and fire protection programs.

Based on this housekeeping concept - which involves plant workers as well as custodians - and considering the size and nature of the GT-MHR plant, it is estimated that 6 custodial personnel are required. It is assumed that much of their work will be routine and that the group is supervised by the Services Section Supervisor.

3.2.2.3.3 RADIOACTIVE WASTE (1 Foreman, 3 Craftsmen)

The Radioactive Waste group is responsible for handling, processing, storing, and shipping solid contaminated materials (e.g., laundering anti-contamination clothing and cleaning respirators) and for handling and solidifying contaminated liquid refuse. This group will also assist in liquid and gaseous waste transport under the direction of the chemistry group and perform housekeeping chores in the nuclear area related to contaminated substances. In addition, it assists the Refueling Team with handling, storing, and transporting fuel elements.

This group is responsible for implementing the requirements of the Hazard Communications Standard OSHA 1910.1200 and the plant hazardous materials program which will include such provisions as the means to avoid the generation of mixed waste requiring additional processing prior to disposal. The foreman will have special training in OSHA regulations as well as regulations pertaining to the transportation of hazardous and radioactive waste materials. The foreman will interface frequently with shift operations supervision and, with support from the chemistry section, act as a principal interface with OSHA and other regulatory personnel. The plant hazardous waste program

PC-000447/0

will be established prior to plant operation. It is estimated that one supervisor and three craftsmen are required.

3.2.2.4 MAINTENANCE PLANNING SECTION (MP)

This Section is comprised of Outage Planning, Spare Parts, Maintenance Procedures and Preventive Maintenance groups. An important assumption in estimating the resources required for the Maintenance Planning Section is that the plant has a comprehensive computerized information management system (CIMS). CIMS is expected to facilitate the work order process; the analysis (tracking and trending) of equipment failures; and documenting equipment history, repair times, and costs for use in planning future work.

3.2.2.4.1 OUTAGE PLANNING (1 MP Supervisor and 4 MP Technicians)

The Outage Planning group is responsible for planning reactor refueling, inservice inspection, preventive and corrective maintenance, and plant modification activities to be accomplished during planned outages. For the GT-MHR, the outage critical path will likely be determined by the duration of activities required for refueling. It is assumed that turbomachinery maintenance will be conducted off-line as described in Section 3.2.2.1.2. An effective, user friendly CIMS is expected to be in place such that the status of tasks can be maintained by individual task leaders.

Effective outage management is critical to achieve projected plant performance and economics. Accordingly, it is assumed that an MP Technician is dedicated to each reactor module to ensure the completeness of planning prior to outages and the effective execution of schedule critical path activities during the outage. Before the outage, the MP Technician will meet frequently with plant management and group supervisors to schedule activities, identify constraints, and establish the outage critical path schedule. During an outage, the MP Technician must maintain the status of in-progress work activities and provide management with the information needed to make timely decisions. Records of outage work, decisions made with regard to unanticipated work, and the cost of work will be maintained by this group for use in future planning activities and management prudence reviews; e.g., rate base hearings.

It is estimated that an MP Supervisor with one MP Technician for each module is required. During an outage, those MP personnel for unit(s) remaining on-line will be available to assist with work on the unit(s) being serviced.

3.2.2.4.2 SPARE PARTS (1 Foreman)

This person is responsible for identifying and procuring spare parts in accordance with the Spare Parts Program established prior to plant startup. This person must be knowledgeable of plant equipment and able to expedite procurement when necessary. An experienced maintenance person or storekeeper can serve in this position. When follow-on plants are deployed, this person will interface with COSO on matters pertaining to pooled inventory. It is expected that an effective CIMS will be used to automate procurement, inventory control and record keeping.

3.2.2.4.3 MAINTENANCE PROCEDURES (1 Foreman)

This person is responsible for updating maintenance procedures provided at plant startup. Duties entail resolving procedural issues with component specialists and acting as a facilitator in developing revisions. It is estimated that one person with a background in maintenance work and experienced in developing procedures will be required.

In making this estimate, it is assumed that a quality assurance program graded in accordance with the safety-significance of equipment has been implemented. COSO will play an important role in both assuring stability of detailed requirements and reducing the effort required of plant staff.

3.2.2.4.4 PREVENTIVE MAINTENANCE AND EQUIPMENT QUALIFICATION (PM/EQ) GROUP (1 Engineer and 1 Technician)

These personnel are responsible for managing the Reliability Centered Maintenance (RCM) program established prior to plant startup. They will work closely with plant professional staff and maintenance organizations to implement and document the program. The RCM program will utilize GT-MHR baseline reliability data supplemented by data from the INPO Nuclear Power Reliability Data System (NPRDS). Predictive maintenance based on equipment failure history via the NPRDS, computerized diagnostic instrumentation, and component tests (e.g., vibration testing of rotating equipment) will complement a traditional preventive maintenance program. It is expected that about one-third of maintenance activities will be corrective and two-thirds preventive. COSO will provide an additional technical resource for this effort. The engineer and technician will work closely with the Maintenance Planning technicians.

This group will also be responsible for assuring compliance with equipment qualification (EQ) requirements. It is assumed that the design will avoid locating important instrumentation and equipment in harsh environments and that it will incorporate sufficient redundancy to facilitate on-line testing and maintenance of such equipment.

Given a highly user friendly CIMS that allows craftsmen to access work orders and input data, and support from COSO; it is estimated that an engineer and a technician can adequately cover this effort.

3.2.3 TECHNICAL DIVISION

The Technical Division is responsible for apprising management of the operational and regulatory status of the plant. An appropriately qualified staff of technical professionals is necessary to fulfill this function. While system and component design information can be obtained from vendors, it is incumbent on the operating organization to master the safe, economic operation of the plant in accordance with the plant operating license. This group monitors overall plant performance, supports operation and maintenance, and maintains liaison with regulatory agencies, INPO and vendors. It is also responsible for interpreting data from off-site radioactive and environmental monitoring activities. COSO will provide a technical resource in this effort.

The Technical Division is organized in groups dedicated to Licensing and Regulatory activities and to Plant Engineering and Performance monitoring.

3.2.3.1 LICENSING AND REGULATORY (1 Supervisor and 3 Engineers)

This group reports to the Technical Division Manager and is responsible for the following functions:

Characterizing the issues/events leading to operating anomalies and coordinating their disposition with the appropriate agencies; i.e.:

- Filing Operating Experience Assessment (OEA) Reports (e.g., preparation and submittal of Significant Operator Experience Reports, Safety Evaluation Reports, Service Information Letters, Licensee Event Reports, and response to generic letters)
- Managing the fulfillment of commitments in response to OEA reports and other obligations.
- Developing and processing amendments to technical specifications.

Coordinating plant visits by organizations such as NRC, INPO, ANI, and state and local representatives.

- Attending all entrance and exit meetings with the above organizations, as well as supporting internal and external quality assurance audits.
- Coordinating, reviewing, and transmitting formal communications with the aforementioned groups. While this function may not include the development of original information, it does include delegating that function to the appropriate plant organization.
- Monitoring changes in the Code of Federal Regulations that pertain to nuclear and environmental matters and coordinating company responses as required.

With support from COSO, it is estimated that one Supervisor and 3 engineers can fulfill this role.

3.2.3.2 ENGINEERING AND PERFORMANCE (E&P) (1 E&P Supervisor, 5 E&P Engineers, and 4 E&P Technicians)

The principal responsibilities of the Engineering and Performance group are to monitor process parameters and system performance, analyze and report performance data and trends, coordinate and review the results of surveillance tests, provide systems engineering services, and conduct the off-site environmental monitoring program. In addition, this group is responsible for design, installation, post-installation acceptance testing, revisions to O&M procedures, and configuration management of minor modifications to the conventional aspects of the plant. This group will work closely with the preventive maintenance engineers in implementing the RCM Program. (Performance monitoring and systems engineering for reactor and fuel handling equipment will be done by the Reactor Engineering group.)

It is assumed that a highly effective CIMS will be in place to assist the plant engineering staff in monitoring plant performance and conducting technical work. The engineers in this group will complete the Licensed Operator Certification Program. It is estimated that this effort can be achieved with one supervisor, 5 engineers, and 4 technical assistants for a total of 10 personnel.

3.2.4 ADMINISTRATIVE DIVISION

The Administrative Division is responsible for security, training, personnel administration, emergency planning and public affairs, safety and fire protection, records management, and general clerical support.

3.2.4.1 SECURITY (1 Supervisor, 5 Foremen, 42 Guards and 2 Clerks)

The security force estimated for the Prototype plant meets the current requirements of Title 10 of the Code of Federal Regulations, Part 73, §73.55 (10CFR73.55). A total of 50 personnel, of which 10 are available to relieve other security personnel, are provided on a five shift basis.

Security supervision consists of one security supervisor and five shift security supervisors. The central and secondary alarm stations are manned with one alarm station operator per shift. Four fully qualified guards are provided on a five shift basis to provide access control, fulfill patrol requirements, and act as armed responders. The five shift arrangement allows for training on day shift and for relief.

One full time security instructor and a full time locksmith are included on day shift. The instructor is responsible for classroom training, proficiency demonstrations, qualification records, and procedure maintenance. The locksmith controls and issues keys, installs and maintains locks, and conducts required surveillance tests.

Two clerks are provided to screen visitors and issue clearances, to maintain procedures and records, and to perform other clerical duties.

PC-000447/0

This force provides the shift complement required by current regulations. The shift supervisor and four armed guards comprise the armed response force. No relief personnel are provided for the central and secondary alarm stations, and additional personnel may be required during long outages. While 10CFR73.55 currently requires a minimum force of five armed responders and the use of deadly force if necessary, some relaxation in mandated security response may be anticipated for the GT-MHR because of its safety characteristics, the small number of vital areas in the plant, and developments in electronic security measures.

3.2.4.2 TRAINING (1 Supervisor, 6 Instructors, and 1 Clerk/Typist)

The plant training organization is responsible for providing personnel training in support of operator licensing and requalification and general employee indoctrination in the following areas: maintenance, instrumentation, controls, health physics, chemistry, non-licensed operator progression and continuing education, right-to-know, fitness for duty, fire fighting, first aid, and industrial safety. In addition, the training organization will instruct selected plant staff in technical writing as it pertains to developing and revising procedures. State-of-the-art training aids will be utilized to improve quality and reduce cost. Training programs will meet NRC mandated operator licensing and requalification programs as well as industry (e.g., INPO) training and requalification program requirements.

The following assumptions were made in estimating the training force:

- INPO certification by the National Academy of Nuclear Training is required.
- Training services will be supplied for approximately 240 site personnel.
- Shift operators and certain licensed engineering staff may be in training 10% of their time. It is assumed that the Licensed Operator Requalification Program can be accomplished in three days during each shift cycle, for a total of 24 days per year. Operators are trained by COSO instructors on a simulator for one week a year.

  Craftsmen and technicians may be in training 5% of their time for nuclear requalification, emergency planning, first aid, fire-fighting, safety, and computer literacy.

  An interactive computerized training program will be utilized to facilitate individual education and training.

  The principal functions of the Training group are administration, lesson preparation, lesson delivery, and periodic review and upgrading of lesson plans. Some instructors will be required to hold NRC instructor certification.

The ratio of course "non-classroom" to classroom time for instructors is 3:1.[3]

This estimate is based on the experience of senior utility operations management personnel with both nuclear plant and maintenance training facilities, as well as the experience of nuclear plant training managers. In summary, it is estimated that this workload can be handled by one supervisor, one clerk/typist and six instructors.

3.2.4.3 PERSONNEL ADMINISTRATION (3 Clerks and 1 Nurse)

This group is responsible for personnel records and performance reviews, payroll, plus employee and medical services. It reports to the Administrative Division Manager. It is assumed that most record keeping and data handling functions are computerized. This group performs the following services:

- Maintenance of employee service records and the protection of confidential information.

  Review and approval of personnel performance reviews conducted by line organizations, coordination of wage and title changes and updating of personnel files.

  Administration of employee benefits and payroll functions, including review and approval of time charged by personnel in line organizations, enrollment in and changes to employee insurance and other benefits, withholding tax elections, etc.

  Maintaining a small site medical facility on day shift to conduct some physical examinations and provide documentation for re-licensing applications, as well as to handle routine illness reports, minor accidents, and drug testing. Medical needs during afternoon and night shifts will be met by the first aid team or off-site medical services. The nurse is expected to assist in the employee training related to medical topics; e.g., first aid, cardio-pulmonary resuscitation, drug and alcohol abuse, etc. The nurse position is considered to be cost effective and highly beneficial to employee morale.

All of these personnel are required to protect employee confidential information. It is estimated that the Administration Division Manager and the staff of three clerks and a nurse can provide these personnel administration functions.

3.2.4.4 EMERGENCY PLANNING & PUBLIC AFFAIRS (1 Engineer)

This person is responsible for coordinating on-site emergency plan requirements and communicating with off-site organizations in accordance with the Emergency

---

(3) "Non-classroom" instructor activities include preparing course material, assisting and evaluating students, and documenting compliance with mandatory training. While this ratio is consistent with current practices, it may be overly conservative since it does not account for instructors presenting the same subject matter to several classes and the potential for computer automated administration.

PC-000447/0

Preparedness Plan. All supporting positions required to implement the plan will be filled by plant staff. GT-MHR safety attributes (i.e, an extremely low risk to public health and safety and long time intervals to implement well-considered recovery actions) eliminate the need for an extensive corporate or community response organization to develop and periodically exercise emergency procedures and conduct training exercises. State and local plans that already exist for dealing with other industrial and natural hazards can be used to respond to potential GT-MHR accidents. The staff size and cost associated with the emergency planning function at the GT-MHR should be significantly smaller than that for current LWR operations.

This person will also act as public relations representative and spokesperson for the site. A person trained in plant operation and emergency planning requirements and skilled in liaison with political groups is required.

3.2.4.5 RECORDS MANAGEMENT (1 Foreman, 3 Clerks)

This group is responsible for maintaining a complete record of the plant design basis with appropriate supporting documents in accordance with prevailing NRC regulations; i.e, records maintenance aspects of the Configuration Management Program. This group will maintain and store as-built drawings, vendor manuals, correspondence, and other documentation necessary to control and maintain plant configuration. It is also responsible for distributing and controlling procedures and other documents pertaining to plant operation and for storing records in accordance with the requirements of 10CFR50, Appendix B, which will be subject to audit. This group will work closely with the Reactor Engineering and the Engineering and Performance groups. COSO will be a resource in this effort.

It is expected that the plant design will incorporate a highly automated information management system and provide for electronic records keeping. On this basis, it is estimated that a foreman and three clerks, who normally work on day shift, can fulfill these function.

3.2.4.6 CLERICAL & STENOGRAPHIC (5 Clerks)

This group is responsible for pooled secretarial and clerical services, and one is allocated to each of the following managers:

Plant Manager
Operations Division Manager
Maintenance Division Manager
Administrative Division Manager
Technical Division Manager

It is expected that the computerized plant information management system will greatly reduce the clerical work load found in current nuclear plants and that staff members will have routine access to the system. Computerized text management programs will permit most of the staff to produce correspondence which formerly required secretarial or clerical support.

3.2.4.7 INDUSTRIAL SAFETY AND FIRE PROTECTION (1 Engineer)

A full time safety professional will be responsible for the plant industrial safety and fire protection programs. Safety is considered a line responsibility that exists at every level in each department. Line managers are responsible for the safety of their operations and the employees involved. Safety is expected to be an integral part of every job, and it will be a priority factor in developing work procedures. Indoctrination in the principles of good safety practices; e.g., the notions that individual employees are responsible for their own safety and the effect of their actions on fellow employees, will be an integral part of the plant staff training and organization development programs.

It is estimated that one supervisor with professional credentials in this field can conduct the safety and fire protection programs provided the aforementioned management principles and individual commitment to safety and effective safety training programs are implemented. This person must be experienced in industrial safety, and cognizant of OSHA regulations, fire protection, and fire fighting programs.

3.3 SPECIFIC OPERATION AND MAINTENANCE EXPENSES

3.3.1 MAINTENANCE MATERIALS

Maintenance materials consist of noncapitalized hardware used in normal maintenance activities such as clothing; gasket materials; valve stems, bonnets, O-rings and packing; welding and pipe fitting materials, etc. The fixed portion (i.e., independent of power output) of this account is estimated as 37.5% of total salaries of craft and supervisory personnel. The variable component is assumed to be 12.5% of these salaries, multiplied by the ratio of actual to the design capacity factor. (This ratio is 1 for the purposes of this report.) These factors were used in prior studies (References 3, 4, 5, and 6) and are considered adequate for the GT-MHR at its current stage of development. In the future, some adjustment may be appropriate to more accurately reflect the simplification of the plant due to changing from steam cycle to Brayton cycle plants.

3.3.2 SUPPLIES AND EXPENSES

The supplies and expenses account includes the cost of consumable materials that are unrecoverable after use and of contract services for non-maintenance activities. The estimated annual cost of supplies and expenses shown in Table 3-4 was derived from discussions with Fort St. Vrain operations personnel, consultation with fossil plant management at the Philadelphia Electric Company's Cromby plant, and consideration of experience at LWR plants.

The annual cost of makeup materials is estimated at $1,026,000. This cost is dominated by a $967,000 per year allowance for helium makeup, based on an expected

PC-000447/0

Table 3-4
ANNUAL COST OF SUPPLIES AND EXPENSES (K$, 1994)

• MAKEUP MATERIALS	$1,026
▸ Helium - $967	
▸ Chlorine - $15	
▸ Lubricants - $10	
▸ Resin and Regeneration Chemicals - $34	
• MISCELLANEOUS	$546
▸ Payroll Computation, Budget, Corporate Accounting, etc. - $105	
▸ Facsimile/Telephones - $63	
▸ Office supplies, copying, postage, security background, psychological testing, drug testing, transportation, laboratory chemicals, uniforms, tools, janitorial supplies, etc. - $378	
• TRAINING AND ASSOCIATIONS	$370
▸ Professional Off-site Training/Supplies - $84	
▸ COSO Simulator Instruction - $210	
▸ Association Expenses (e.g. INPO) - $76	
• WASTE MANAGEMENT	$291
▸ Low Level Radioactive Waste - $236	
▸ Non-Radioactive Waste - $55	
• TOTAL ANNUAL FIXED COST OF SUPPLIES AND EXPENSES	$2,233
• ANNUAL VARIABLE COST OF CONTROL RODS AND REFLECTORS	$3,700
▸ Replacement Control Rods and Reflector Blocks - $2,950	
▸ Disposal of Used Control Rods and Reflector Blocks - $750	
• OTHER ANNUAL VARIABLE COST OF SUPPLIES AND EXPENSES	$735
▸ 0.1 Mills/KWH @ 80% Capacity Factor - $735	

loss of two helium inventories per year. (That is, the operating helium inventory of each reactor is 10,000 pounds, and a total of 80,000 pounds at a cost of $12.08 per pound is assumed lost each year). This assumption is thought to be conservative by former plant managers of the Fort St. Vrain and Peach Bottom 1 HTGRs, given appropriate attention to the design of helium piping and valves. Estimates for other materials are based on costs budgeted at plants with similar cooling water and makeup systems. Compared to steam cycle systems, the cost of lubricants, hydrogen and carbon dioxide are greatly reduced because the gas turbine is operated in a helium environment, and costs associated with makeup water requirements are also much reduced because of the absence of a steam and feedwater systems.

Estimates of miscellaneous, training and association, and waste management costs are judged to be representative. The training and association expenses include supplies for on-site training, fees for off-site professional training, and the cost of services for COSO simulator instruction. Also included are the cost of participating in industry professional associations, such as employee participation in the INPO and NEI activities (38 trips at $2,000 each). Waste management expenses include an allowance of $236,000 per year for compressible dry and other immobilized (e.g., with cement) low level radioactive waste and $55,000 per year for non-radioactive locally disposed waste.

The variable component of supplies and expenses; i.e., those that vary in relation to power output, is dominated by the cost of replacement control rods and reflectors estimated at $2.95 million per year and the cost of disposal of used control rods and reflectors estimated at $750,000 per year (Reference 13). The latter includes an average allowance of about $150 per cubic foot for disposal at a government site. Other variable costs are expected to be small for a base loaded plant. Examples are the variable cost of resin and regeneration materials and chemicals for feedwater demineralizers. An allowance of 0.1 mills per kilowatt hour, or $735,000 with an 80% capacity factor, has been included.

3.3.3 OFF-SITE TECHNICAL SUPPORT (5 Corporate, 15 COSO Consultants)

It is estimated that the annual equivalent of 15 COSO professional personnel to support plant operation and maintenance will be required. This estimate does not include an allowance for consultant support of plant modifications and capital improvements, which should be few with standardized plants. In addition, five quality assurance professionals assigned to corporate staff will fulfill the NRC requirement that the quality assurance function be independent of plant management.

These estimates of off-site technical support are based on the specialist assistance needed to fulfill NRC requirements and to operate the plant in a cost effective manner. Prudent management also requires access to experts on plant design and technology to assist plant staff in regulatory matters and in technical investigations, engineering, and problem resolution. For the GT-MHR, such services will be provided through COSO. The COSO role is envisioned as a means of extending design standardization to plant operations and as a cost effective means of providing specialist resources to plant owners. As described in Appendix B, COSO functions will include generic operating

PC-000447/0

practices, development and maintenance of plant operating programs, central fuel management support, and central vendor qualification. Generic regulatory interactions, wherein COSO acts as the point of inquiry and response to proposed regulatory changes, is considered a particularly critical function for avoiding the economic risks associated regulatory ratcheting and instability at current nuclear plants.

As a cautionary note, off-site technical support costs will rise significantly if the staff is not well trained in GT-MHR plant operation and the COSO is not functioning effectively. Further, the plant staff must be provided with detailed programs and procedures and be principally engaged in implementing those programs with very little effort required for program development or revision. As noted earlier, it is assumed that these programs and procedures will be developed with owner/operator involvement during Prototype Plant development and deployment (see Appendix C for more information on plant operating programs).

It is also noted that most current nuclear plants are supported by large off-site organizations and a cadre of consultants. Much of the work being done by these organizations results from post-TMI regulatory-imposed design changes and NRC and INPO program requirements to avoid a recurrence of an accident like the one at TMI. Additionally, other expectations of INPO and insurance carriers have created a heavy workload in this area. It is anticipated that such demands on current plants will be significantly reduced as the need for modifications and new programs is reduced. For these reasons, and the fundamentally different approach to nuclear safety afforded by the GT-MHR that precludes core melt and disarray like TMI, a stable regulatory environment is assumed. Key factors in bringing this about will be NRC certification of a standard commercial GT-MHR plant design via demonstration testing of the first module; i.e., the Prototype Plant. Another key factor in sustaining such an environment will be establishment of COSO as an owner/operator-based central technical support organization in concert with Prototype Plant deployment.

3.3.4 PAYROLL TAXES, PENSIONS AND BENEFITS

Payroll taxes, pensions and benefits are estimated to be 37% of the total salaries and wages for on-site and corporate off-site staff. Of this amount, 10% is legally required Social Security (7.5%) and Worker's Unemployment Compensation (2.5%) benefits. The latter varies widely depending on the company's claim history. Benefits not legally required but found in slightly varying amounts in most nuclear companies are about 25% of salaries and wages. These include pensions and premiums for group life, accident and disability insurance. Since staff costs are computed on the basis of full employee salary, absent time benefits (i.e, holidays (10 days), vacation (15 days) and sick leave (7 days)) of about 12.5% are not included. However, another 2% is included to recognize premium time paid to shift employees for holiday work, night shift, and certain weekend shifts. These assumptions are consistent with longstanding ORNL guidelines provided in Reference 9.

PC-000447/0

3.3.5 NUCLEAR REGULATORY COMMISSION AND OTHER NUCLEAR FEES

NRC regulations provide for recovery of expenses by collection of fees from reactor licensees. Fee information can be found in 10CFR170/171. All operating reactor licensees must pay a Power Reactors fee which is essentially the same for each type. Also an additional surcharge is levied on operating reactors to recover certain NRC costs not directly or solely associated with operating reactors. Fees are assessed for reviewing applications and responding to requests for licenses, approvals, amendments, and inspections and vary from year to year. These fees are calculated using a published NRC hourly rate with maximums in some categories. Under certain cases, exemptions from the annual fee may be granted by the Commission. Also, the size of each reactor compared to total electric output may be a basis for determining the fee. In addition, INPO and NEI are sponsored by nuclear utilities and serve primarily as advisors to nuclear operating plant management on regulatory matters. They recover costs by fees levied on participants. Fees associated with these entities are summarized in Table 3-5. The NRC fees are consistent with ORNL guidelines provided in Reference 9, while fees for INPO and NEI are based on utility experience.

Table 3-5
NRC AND OTHER NUCLEAR FEES (K$, 1994)

	COST
• NRC FEES	
► Annual Facility	$2,800
► Operating Reactor Surcharge	$ 270
► Inspection (maximum)	$ 300
► Amendment Requests	$ 130
► 10CFR55 - Operator License Review Test	$ 40
TOTAL NRC FEES	$3,540
• INPO FEES	$ 390
NEI FEES	$ 220
TOTAL NRC, INPO, AND NEI FEES	$4,150

PC- 000447/04

3.3.6 NUCLEAR LIABILITY AND PROPERTY DAMAGE INSURANCE

Nuclear liability insurance protection of $200 million is required for any plant with greater than 100 MWe output. This coverage insures against losses due to bodily injury and property damage to others arising from a nuclear incident. The 1988 extension of the Price-Anderson Act set the limit of liability of a nuclear incident at $7 billion per loss. Commercial nuclear insurance pools provide the first $200 million, and each operating licensee can be assessed up to $10 million per reactor/per year/per loss for the balance.

The insurance premium for the primary $200 million insurance coverage is dependent on population density surrounding the site. Multiple units qualify for a discount. Treating the four-reactor GT-MHR plant as a unit, this insurance is estimated to cost $630,000 per year. This assumption is consistent with the ORNL guidelines in Reference 9. The secondary financial protection requirement through participation in the pool of nuclear plant licensees costs $11,000 per year.

Liability coverage is also extended to suppliers and transporters. An allowance of $7,000 is provided for this expense. An indemnity fee of $3,000 is assessed by the NRC to cover administrative costs of certifying that insurance is in compliance with regulations. The total premium for liability insurance is estimated at $651,000 per year. Approximately 75% of paid premiums are placed in a reserve fund and become available for return after ten years based on the loss experience of the pool.

Nuclear property insurance coverage insures against direct loss, resulting from radioactive contamination and all other risks of direct physical damage on a replacement cost basis. Deductibles of $500,000 to $1.0 million are common practice. The minimum coverage of about $1.1 billion is assumed to be applicable based on the guidelines in Reference 9.

The first $500 million of property insurance coverage is provided by either the commercial nuclear insurance pool or Nuclear Mutual Limited. The excess over $500 million is provided by a combination of Nuclear Electric Insurance Limited (NEIL) and commercial nuclear insurance pools. The insurance premium is estimated to cost $2.5 million per year for primary coverage and $1.261 million per year for excess coverage. These premiums are also consistent with the ORNL guidelines in Reference 9. Nuclear insurance costs are summarized in Table 3-6. Premiums for replacement power insurance at an annual rate of $530,000 are also included in the estimate.

3.3.7 OTHER GENERAL AND ADMINISTRATIVE (G&A) EXPENSES

For the purposes of this estimate, other G&A expenses are estimated as 15% of the sum of direct power generation costs (the sum of costs for on-site staff, maintenance materials, supplies and expenses and off-site support). This rate for G&A expenses is consistent with utility ownership and in accordance with Reference 9. Somewhat different rates may be appropriate for non-utility ownership (e.g., Independent Power Producers). Property taxes and the cost of interim replacements are not included in this report but are considered in establishing the plant capital cost fixed charge rate.

PC-000447/0

Table 3-6
NUCLEAR INSURANCE PREMIUMS (K$, 1994)

COVERAGE	COST
• PUBLIC LIABILITY - $200M	
▸ Primary	$ 630
▸ Secondary	$ 11
▸ Suppliers and Transporters and Indemnity Fee	$ 10
Total Liability Premium	$651
PROPERTY DAMAGE - $1100M	
▸ Primary Coverage	$2,500
▸ Excess Coverage	$1,261
Total Property Damage Premium	$3,761
Total Insurance Premium	$4,412

3.4 SUMMARY OF LEAD PLANT OPERATION AND MAINTENANCE COSTS

The results of this study show an annual operating expense for the GT-MHR Lead Plant of $43.5 million or 5.9 mills per kilowatt hour at an 80% capacity factor. As summarized in Table 3-7, plant staff size is estimated at 300 persons. This estimate includes the annual equivalent of a number of technicians and craftsmen used to temporarily supplement permanent staff during planned outages.[4]

[4] A reviewer commented that the plant organization shown in Figure 3-1 and tabulated in Table 3-7 poses a disproportionate number of management personnel; i.e., about 20% have the title and salary of manager, supervisor or foreman. While alternate organization structures are certainly possible, the focus of this effort is on estimating the resources required to accomplish the plant functional needs identified in Table 3-1; i.e., the plant organization shown in Figure 3-1 merely provides a convenient structure for the estimating process. Since most of the personnel positions in question are assumed to perform plant functional as well as personnel management duties, the effect on estimated O&M costs is thought to be small. Another reviewer noted that significant variances (i.e., on the order of 20%) in the salaries of individual positions, such as between the technical and administrative managers, occur in practice as a result of differences in the skill-level required of parallel positions. This estimate has adopted the salary structure posed in ORNL guidelines (Reference 9). Refinements such as those noted may be appropriate in future estimates.

PC-000447/0

Table 3–7
GT–MHR LEAD PLANT STAFF (94$)

	Position	Salary (94$)	Number Staff	Total Salaries
Plant Manager		128,176	1	128,176
Operations Division	Manager	89,303	1	89,303
Chemistry	Supervisor	65,769	1	65,769
	Chemist	61,041	1	61,041
	Technician	45,807	5	229,036
Reactor Engr.	Supervisor	65,769	1	65,769
	Engineer	56,314	2	112,627
Shift Operations	Supervisor	65,769	1	65,769
	Shift supv.	65,769	18	1,183,844
	Operator	55,158	44	2,426,944
	Shift clerk	34,040	2	68,081
Subtotal Operations			76	4,368,184
Maintenance Division	Manager	89,303	1	89,303
Component Maint.	Supervisor	61,041	8	488,331
	Foreman	55,158	4	220,631
	Craftsman	43,391	43	1,865,805
	Annualized	43,391	19	824,425
	Technician	43,391	21	911,207
	Programmer	55,158	2	110,316
Health Physics	Supervisor	61,041	1	61,041
	Technician	47,068	11	517,748
Services	Supervisor	61,041	1	61,041
	Foreman	55,158	2	110,316
	Craftsman	43,391	6	260,345
	Custodian	30,993	6	185,961
Planning	Supervisor	61,041	1	61,041
	Engineer	55,158	1	55,158
	Foreman	55,158	2	110,316
	Technician	46,963	5	234,815
Subtotal Maintenance			134	6,167,799
Technical Division	Manager	89,303	1	89,303
Licensing	Supervisor	65,769	1	65,769
	Engineer	56,314	3	168,941
Engr & Perf	Supervisor	65,769	1	65,769
	Engineer	56,314	5	281,568
	Technician	45,807	4	183,229
Subtotal Technical			15	854,578
Administrative Division	Manager	89,303	1	89,303
Security	Supervisor	45,807	1	45,807
	Foreman	34,040	5	170,201
	Guard+2 clk	30,573	44	1,345,220
Training	Supervisor	61,987	1	61,987
	Instructor	55,158	6	330,947
	Clerical	34,040	1	34,040
Personnel Admin.	Clks&Nurse	34,040	4	136,161
Emergency & P.R.	Engineer	56,734	1	56,734
Records Mgt.	Foremen	45,807	1	45,807
	Clerical	34,040	3	102,121
Clerical	Clerical	34,040	5	170,201
Safety & Fire	Engineer	52,531	1	52,531
Subtotal Administrative			74	2,641,061
Total Site			300	14,159,798
Offsite Staff, Corporate		45,800	5	229,000
Offsite Consultants, COSO		110,700	15	1,660,500
Total O&M Staff			320	16,049,298

A detailed breakdown of cost results is shown on Table 3-8. Power generation costs, including staff salary and payroll taxes, maintenance materials, supplies and expenses and offsite technical support, amounts to $26.5 million or 61% of total O&M costs. The estimated G&A costs, which includes employee benefits, nuclear liability and property damage insurance, fees and dues, is $17.0 million or 39% of total O&M costs.

It is important to note that this estimate is based on known requirements, supplemented by the judgement of senior utility operating personnel. On this basis, these projections are considered to be a mean estimate; i.e, actual costs are expected to have an equal likelihood of being higher or lower.

3.5 O&M COSTS FOR THE GT-MHR PROTOTYPE PLANT

The deployment strategy for the GT-MHR uses the first reactor module of the four unit Lead Plant to conduct demonstration testing in support of NRC design certification. The Prototype Plant will be constructed and operated for several years before the addition of the second, third and fourth modules.

O&M costs for the Prototype Plant were derived by assessing the portion of Lead Plant resources described in the previous section that are required for operation of a single module. Staff size, materials and services are reduced, but not proportionally. In effect, this strategy delays hiring the full complement of plant staff. (Staff buildup is described in Section 6.) Supplies and expenses, materials, services, fees,insurance and other costs are adjusted for the reduced staff size and power output.

The deployment plan summarized above entails conducting formal testing programs in support of design certification. This effort will require that operating procedures unique to test conditions be supplied to the operating entity and appropriate training be completed prior to startup. It is also expected that vendor and regulatory personnel will participate in demonstration testing as test consultants and observers. COSO will represent operating interests in the definition, development and conduct of the demonstration program.

3.5.1 PROTOTYPE PLANT STAFFING

Table 3-9 presents a breakdown of staff positions corresponding to the detailed descriptions in Section 3.2 and identifies the reductions for the single module Prototype Plant.

3.5.1.1 PROTOTYPE PLANT OPERATIONS DIVISION STAFFING

Compared to that for the four module Lead Plant, the Operations Division is reduced from 76 to 40 personnel due to a reductions of 1 shift operations manager, 5 plant supervisors, 12 control room and 12 roving operators, and one clerk, 1.5 reactor engineers, and 1.5 chemists and 2 chemistry technicians. Thus for each shift, the Prototype Plan has two supervisors with SRO licenses: one overall plant supervisor and a supervisor in the control room. The control room supervisor is required by current

PC-000447/0

Table 3-8
GT-MHR LEAD PLANT O&M COST SUMMARY (94$)

Plant Performance		
Net Plant Rating, MWe		1,050
Base Capacity Factor, %		80
Annual Net Generation, million kwh		7,356
Power Generation Costs ($million/year)		
On-site staff salary and payroll taxes	300 persons	15.58
Maintenance materials		
Fixed		1.66
Variable		0.55
Subtotal		2.21
Supplies and expenses		
Fixed		2.23
Variable Reflector Blocks and Control Rods		3.70
Variable		0.74
Subtotal		6.67
Offsite technical support		
Corporate	5 persons	0.43
COSO	15 persons	1.66
Subtotal		2.09
Subtotal, power generation costs		
Fixed		21.56
Variable		4.99
Subtotal		26.55
General and Administrative Costs ($million/year)		
Pensions and benefits		3.89
Nuclear regulatory fees		4.15
Liability insurance		0.65
Property insurance		3.76
Replacement power insurance		0.53
Other general & administrative expenses		3.98
Subtotal		16.96
Total O&M Costs ($million/year)		
Fixed		38.52
Variable		4.99
Total Nonfuel O&M Costs, $million/yr		43.51
Total Nonfuel O&M Costs, mills/kwh		5.92

PC-000447/0

Table 3–9
OPERATING STAFF COMPARISON
GT–MHR LEAD VS. PROTOTYPE PLANTS

PLANT STAFF POSITION	LEAD PLANT (4 MODULES)			PROTOTYPE PLANT (1 MODULE)			SUMMARY					SEE SECTION 3.5.1 FOR EXPLANATIONS OF DIFFERENCES
	STAFF	TEAMS	TOTAL	STAFF	TEAMS	TOTAL	LEAD	PROTO	DELTA	L	P	
PLANT MANAGER	1	1	1	1	1	1	1	1	0			
OPERATIONS DIV MGR	1	1	1	1	1	1	1	1	0			
SHIFT OPERATIONS MGR	1	1	1	0	1	0	1	0	−1			
SHIFT SUPERVISORS, SRO	1	6	6	1	6	6	6	6	0			
PLANT SUPERVISORS, SRO	1	6	6	1	1	1	6	1	−5			
PLANT SUPER, QUALIFIED	0	6	0	0	1	0	0	0	0			
CONT RM SUPERVISORS, SRO	1	6	6	1	6	6	6	6	0			
CONT RM OPERATORS, RO	3	6	18	1	6	6	18	6	−12			
ROVING OPERATORS	4	6	24	2	6	12	24	12	−12			
HELPERS (ANNUAL)	2	1	2	2	1	2	2	2	0			
CLERKS	1	2	2	1	1	1	2	1	−1	65	34	SHIFT OPERATIONS
REACTOR ENGR SUPERVISOR	1	1	1	1	1	1	1	1	0			
REACTOR ENGINEERS	2	1	2	0.5	1	0.5	2	0.5	−1.5	3	1.5	REACTOR ENGINEERING
CHEMISTRY SUPERVISOR	1	1	1	0.5	1	0.5	1	0.5	−0.5			
CHEMIST	1	1	1	0	1	0	1	0	−1			
RAD/CLEAN CHEM TECH	1	5	5	1	2	2	5	2	−3			
RELIEF RAD/CLEAN TECH.	0	1	0	1	1	1	0	1	1	7	3.5	CHEMISTRY
SUBTOTAL OPERATIONS DIV.							76	40	−36			
MAINTENANCE DIV MGR	1	1	1	1	1	1	1	1	0			
COMPONENT MAINTENANCE SUPER.	1	1	1	1	1	1	1	1	0			
I&C AND CMPUTR SUPER	1	1	1	0	1	0	1	0	−1			
I&C AND CMPUTR FOREMEN	1	1	1	1	1	1	1	1	0			
I&C SHFT COVERAGE TECH	1	5	5	1	5	5	5	5	0			
I&C SECURITY & TV TECH	1	1	1	0.3	1	0.3	1	0.3	−0.7			
I&C FIRE DETECT TECH	0.5	1	0.5	0.2	1	0.2	0.5	0.2	−0.3			
I&C RLAYS/SBSTN EQUP TECH	1	1	1	0.3	1	0.3	1	0.3	−0.7			
I&C BRKR PREV MAINT TECH	1	1	1	0.3	1	0.3	1	0.3	−0.7			
I&C PLT CMPUTR TECH	3	1	3	0.8	1	0.8	3	0.8	−2.2			
I&C PLT CMPUTR PROGRAMMER	2	1	2	0.5	1	0.5	2	0.5	−1.5			
I&C HLTH PHYSCS TECH	2	1	2	0.5	1	0.5	2	0.5	−1.5			
I&C PROCEDURE WRITER	0.5	1	0.5	0.2	1	0.2	0.5	0.2	−0.3			
I&C ROUTINE/GENERAL	2	1	2	0.3	1	0.3	2	0.3	−1.7			
I&C TECH (ANNUAL)	2	1	2	0.3	1	0.3	2	0.3	−1.7	22	9.7	I&C STAFF
M&E MAINTEN SUPER	1	1	1	0	1	0	1	0	−1			
M&E MAINTEN FOREMEN	3	1	3	1	1	1	3	1	−2			
M&E SHFT COVERAGE	2	5	10	2	5	10	10	10	0			
M&E CRAFTSMEN	33	1	33	10	1	10	33	10	−23			
M&E T−G (ANNUAL)	3	1	3	1	1	1	3	1	−2			
M&E OUTAGE (ANNUAL)	4	1	4	1	1	1	4	1	−3	54	23	M&E STAFF
REFUELING SUPER.	4	1	4	4	1	4	4	4	0			
REFUELING TECH (ANNUAL)	8	1	8	2	1	2	8	2	−6	12	6	REFUELING
ISI SUPERVISOR	1	1	1	1	1	1	1	1	0			
ISI NDE TECH (ANNUAL)	2	1	2	0.8	1	0.8	2	0.8	−1.2	3	1.8	ISI
QC TECHNICIANS	5	1	5	1	1	1	5	1	−4	5	1	QUALITY CONTROL
HEALTH PHYSICS SUPERVISOR	1	1	1	0.5	1	0.5	1	0.5	−0.5			
HLTH PHYS SHIFT	1	5	5	1	3	3	5	3	−2			
HLTH PHSC NI DOSIM	2	1	2	1	1	1	2	1	−1			
HLTH PHYS PROCED/REV	4	1	4	1	1	1	4	1	−3	12	5.5	HEALTH PHYSICS
SERVICES SUPERVISOR	1	1	1	1	1	1	1	1	0			
STORES FOREMAN	1	1	1	1	1	1	1	1	0			
WAREHOUSEMEN	3	1	3	1	1	1	3	1	−2			
GRNDS & HSKPNG	6	1	6	4	1	4	6	4	−2			
RADWASTE FOREMAN	1	1	1	0	1	0	1	0	−1			
RADWASTE CRAFTSMEN	3	1	3	1	1	1	3	1	−2	15	8	SERVICES
PLANNING SUPERVISOR	1	1	1	1	1	1	1	1	0			
OUTAGE PLANNERS	5	1	5	1	1	1	5	1	−4			
SPARE PARTS FOREMAN	1	1	1	0.5	1	0.5	1	0.5	−0.5			
MAINTEN. PROCED FOREMAN	1	1	1	0.5	1	0.5	1	0.5	−0.5			
PM/EQ ENGR	1	1	1	1	1	1	1	1	0	9	4	PLANNING
SUBTOTAL MAINTENANCE DIV.							134	61	−73			
TECHNICAL DIV MGR	1	1	1	1	1	1	1	1	0			
LICENSING & REG SUPER	1	1	1	0	1	0	1	0	−1			
LICENSING & REG ENGR	3	1	3	2	1	2	3	2	−1	4	2	LICENSING ENGR
ENGR & PERF SUPERVISOR	1	1	1	0	1	0	1	0	−1			
ENGR & PERF ENGR	5	1	5	2.2	1	2.2	5	2.2	−2.8			
ENGR & PERF TECH	4	1	4	1	1	1	4	1	−3	10	3.2	PERFORMANCE ENGR
SUBTOTAL TECHNICAL DIV.							15	6.2	−8.8			
ADMINISTRATIVE DIV MGR	1	1	1	1	1	1	1	1	0			
SECURITY SUPERVISOR	1	1	1	1	1	1	1	1	0			
SHIFT SECURITY FOREMEN	1	5	5	1	5	5	5	5	0			
SECURITY GUARDS	4	5	20	4	5	20	20	20	0			
CAS & SAS GUARD	2	5	10	2	5	10	10	10	0			
RELIEF GUARDS	10	1	10	5	1	5	10	5	−5			
SECRTY INSTR.& LOCKSMITH	2	1	2	2	1	2	2	2	0			
SECURITY CLERKS	2	1	2	1	1	1	2	1	−1	50	44	SECURITY
TRAINING SUPERVISOR	1	1	1	1	1	1	1	1	0			
TRAINING INSTRUCTORS	6	1	6	3	1	3	6	3	−3			
TRAINING CLERKS	1	1	1	1	1	1	1	1	0	8	5	TRAINING
PERSONNEL ADMIN	4	1	4	2	1	2	4	2	−2			
EMERG PLNG/PUB AFFAIRS	1	1	1	1	1	1	1	1	0			
RECORDS MGT FOREMAN	1	1	1	1	1	1	1	1	0			
RECORDS MGT CLERKS	3	1	3	1	1	1	3	1	−2			
CLERICAL & STENO	5	1	5	2	1	2	5	2	−3			
SAFETY/FIRE ENGR	1	1	1	0.3	1	0.3	1	0.3	−0.7	15	7.3	ADMIN STAFF
SUBTOTAL ADMIN. DIV.							74	57.3	−16.7			
TOTAL STAFF			300			166			134			

PC-000447/0

regulations. In addition, there will be one licensed control room RO and two roving operators. The equivalent of 1.5 reactor engineers, three chemistry personnel, and the division manager complete the staffing for the Operations Division.

The Plant Supervisor position for the Prototype Plant is designated a day shift (i.e., not a posted position on a rotating shift) such that work hours overlap day and evening operator shifts and the Plant Supervisor can interact with both. The Plant Supervisor is also expected to visit plant equipment on a frequent basis, review process data, and assist in the preparation of work orders for plant maintenance. The Plant Supervisor interfaces with plant operators, shift supervision and the maintenance planning group. This person will hold an SRO license.

The Prototype Plant has two operators in the control room. Both are NRC licensed, one an SRO, in accordance with current NRC requirements. It is expected that this requirement will be revised after demonstration testing for the operation of follow-on plants because of GT-MHR characteristics.

It is estimated that one professional, with support from COSO, can manage the Chemistry and Health Physics groups. The water chemistry requirements for the GT-MHR are not complex. Personnel involved with helium chemistry and radiochemistry will require specialist training, but many of the sampling and data analysis functions will be automated. The Health Physics requirements for the Prototype Plant will be routine. The combined number of Chemistry and Health Physics personnel is reduced from 19 for the Lead Plant to 8 for the Prototype Plant.

3.5.1.2 PROTOTYPE PLANT MAINTENANCE DIVISION STAFFING

The number of Maintenance Division personnel is reduced from 134 to 61 since only one reactor module will be in operation. This change is dominated by personnel reductions in Mechanical and Electrical (M&E) (54 to 23), Instrumentation and Controls (I&C) (22 to 9.7), and Services (15 to 8). While the number of M&E foremen is decreased from 3 to 1; M&E shift coverage of 10 (2 craftsmen on each of 5 teams) is maintained because of regulatory requirements. Likewise, one I&C technician for shift coverage has been retained. The rationale for other reductions is as follows:

<u>Refueling</u> All four refueling supervisors have been retained because of the first-of-a-kind nature of the plant and anticipated follow-on units. However, because of the delayed startup of the second unit, the formation of the dedicated refueling group is delayed, and the number of annualized refueling technicians has been reduced from 8 to 2. The Prototype Plant will utilize personnel from the maintenance division supervised by refueling supervisors and vendor personnel as needed.

<u>Inservice Inspection</u>. The staff ISI supervisor is retained in anticipation of plant expansion, and the number of annualized ISI technicians is reduced from 2 to an equivalent of 0.8; i.e., about 14 man-months every refueling outage.

Quality Control The number of QC technicians is reduced from 5 to 1, because of the reduced volume and frequency of nuclear related work with only one operating unit.

- Health Physics As described above, the Health Physics and Chemistry functions are combined for the Prototype Plant and staffing reflects the reduced amount of work for a single module plant. Health physics technicians will be posted for periods when maintenance work is usually conducted; i.e., the day and evening shifts and on weekends. Two technicians, in addition to supervisory personnel, are assigned to revising dosimetry procedures and reviewing ALARA provisions in maintenance plans. This estimate is based on the assumption that all operating and maintenance personnel will be qualified to perform non-complex health physics functions.

Maintenance work for the Prototype Plant has been estimated in a manner similar to that used for the Lead Plant estimate. In many cases, fractions of a man year are indicated. Estimated costs are independent of whether these resources are hired as permanent staff or acquired as contract labor.

3.5.1.3 PROTOTYPE PLANT TECHNICAL DIVISION STAFFING

The Technical Division is reduced from 15 to 6. This group must have the capability to advise plant management of the plant's operational status on a daily basis and to interact with the regulator. However, during Prototype Plant startup and demonstration testing, it is assumed that vendor and COSO personnel provide a strong element of support for regulatory interactions and systems engineering work.

3.5.1.4 PROTOTYPE PLANT ADMINISTRATIVE DIVISION STAFFING

This division is reduced from 74 to 57 personnel. The training staff is reduced from 7 instructors to 4 because of fewer staff. Clerical and stenographic work is reduced as a result of fewer people on staff and reduced documentation requirements. The security staff is reduced by 5 of the 10 relief guards on the assumption that guard support will be available from the construction guard force assigned to forthcoming units.

3.5.2 PROTOTYPE PLANT SPECIFIC OPERATION AND MAINTENANCE EXPENSES

3.5.2.1 PROTOTYPE PLANT MAINTENANCE MATERIALS

The cost of Maintenance Materials is estimated as described in Section 3.3.1; i.e., the fixed portion is estimated as 37.5% of total salaries of craft and supervisory personnel and the variable component is assumed to be 12.5% of these salaries.

3.5.2.2 PROTOTYPE PLANT SUPPLIES AND EXPENSES

The cost of replaceable reactor parts, waste management, and makeup materials shown in Table 3-4 is reduced in proportion to the number of modules. The costs for the

PC-000447/0

Miscellaneous and for the Training and Associations categories are reduced in proportion to staff.

3.5.2.3 PROTOTYPE PLANT OFF-SITE TECHNICAL SUPPORT

A somewhat arbitrary allowance of 2 corporate quality assurance specialists and 9 COSO consultants has been included, as compared to 5 corporate and 15 COSO consultants for the Lead Plant. Estimates of off-site support are particularly subjective in the context of demonstration testing of the first reactor module. While substantial designer/vendor participation during this phase is anticipated, this allowance is considered a reasonable allocation to facilitate transition to Lead Plant operation.

3.5.2.4 PROTOTYPE PLANT PAYROLL TAXES, PENSIONS AND BENEFITS

Payroll taxes, pensions and benefits are reduced in proportion to staff size.

3.5.2.5 PROTOTYPE PLANT NRC AND OTHER NUCLEAR FEES

Fees for NRC, INPO and NEI are assumed to be the same as those for the four module Lead Plant. However, depending on the ownership of the Prototype Plant, NRC fees may be reduced. For example, if it is owned by the government during this period, NRC fees may be omitted.

3.5.2.6 PROTOTYPE PLANT NUCLEAR INSURANCE

Insurance premiums are assumed to be the same as for the full four unit Prototype Plant. However, no replacement power insurance is included during the demonstration phase.

3.5.2.7 PROTOTYPE PLANT OTHER GENERAL AND ADMINISTRATIVE EXPENSES

As described in Section 3.3.7, other G&A expenses are estimated as 15% of the sum of direct power generation costs (the sum of on-site staff, maintenance materials, supplies and expenses and off-site support) in accordance with ORNL guidelines in Reference 9.

3.5.3 SUMMARY OF PROTOTYPE PLANT OPERATION AND MAINTENANCE COSTS

It is estimated that 166 personnel are required for the Prototype Plant, including the annual equivalent of temporary personnel used during refueling and outages. The remainder of the 300 personnel estimated for the Prototype Plant would be hired during expansion to the four-module Lead Plant.

A detailed breakdown of cost results in the format used for the Prototype Plant is shown in Table 3-10. Total non-fuel O&M cost is $25.2 million with a 13.7 mills/kwhr at a capacity factor of 80%. Power generation costs, including staff salary and payroll taxes, maintenance materials, supplies and expenses, and offsite technical support

PC-000447/0

amounts to $12.6 million or 50% of total cost. G&A costs, which includes employee benefits, nuclear liability and property damage insurance, fees and dues, are also $12.6 million. Compared to the Lead Plant, a relatively greater share of Prototype Plant O&M costs are allocated to fees and insurance. As for the Lead Plant, these estimates are considered mean values based on known requirements and successful development programs. Uncertainties in reactor performance and regulatory interactions are beyond the scope of this study.

PC-000447/0

Table 3–10
GT–MHR PROTOTYPE PLANT O&M COST SUMMARY (94$)

Plant Performance		
Net Plant Rating, MWe		262.4
Base Capacity Factor, %		80
Annual Net Generation, million kwh		1839
Power Generation Costs ($million/year)		
On–site staff salary and payroll taxes	166 persons	8.52
Maintenance materials		
Fixed		0.74
Variable		0.25
Subtotal		0.99
Supplies and expenses		
Fixed		0.84
Variable Reflector Blocks and Control Rods		0.93
Variable		0.18
Subtotal		1.95
Offsite technical support		
Corporate	2 persons	0.19
COSO	9 persons	1.00
Subtotal		1.19
Subtotal, power generation costs		
Fixed		11.29
Variable		1.36
Subtotal		12.65
General and Administrative Costs ($million/year)		
Pensions and benefits		2.12
Nuclear regulatory fees		4.15
Liability insurance		0.65
Property insurance		3.76
Replacement power insurance		0.00
Other general & administrative expenses		1.90
Subtotal		12.58
Total O&M Costs ($million/year)		
Fixed		23.87
Variable		1.36
Total Nonfuel O&M Costs, $million/yr		25.23
Total Nonfuel O&M Costs, mills/kwh		13.72

SECTION 4

O&M COSTS FOR REPLICA, TARGET AND "EQUILIBRIUM" TARGET GT-MHR PLANTS

4.1 APPROACH TO ESTIMATING TARGET PLANT O&M COSTS

The GT-MHR Target Plant is defined in accordance with Reference 9 as the commercial facility that results in an installed capacity of 4500 MWe or greater. The GT-MHR Target Plant is the fifth four-module plant and would represent 5,250 MWe of installed capacity. As discussed in Section 3.1, GT-MHR commercial deployment provides for demonstration testing of the first module of the Lead Plant (i.e., the Prototype Plant) and NRC certification of a standard commercial design. The GT-MHR deployment plan projects receipt of a construction and operating license (COL) for the full four-module Lead Plant by 2010, about 30 months after completion of certification tests conducted on the single-module Prototype Plant. Lead Plant commercial operation would begin in about 2013. Long lead material for the Replica Plant (second four-module plant) is committed at completion of certification tests, with the third through the Target Plant committed at a rate compatible with manufacturing throughput. The Replica through the Target plants reach commercial operation between 2014 and 2017. Projected costs for an "equilibrium" Target Plant are also included, based on achieving an expected stretch capacity of 600 MW reactor module thermal power.

This deployment plan provides for regulatory development in concert with reactor design and technology development and prototype tests of a reactor module. It is intended to reduce uncertainty in the regulatory environment and enhance institutional acceptance of the GT-MHR from the outset of commercial deployment. For the purposes of the Target Plant estimate, it is assumed that GT-MHR design and technology development programs are successful; i.e., they confirm the following aspects of GT-MHR technology that allow reliance on passive features and inherent characteristics:

- **High Heat Capacity** - The high heat capacity of the graphite-moderated core in concert with the relatively low power density of the core results in a very slow response to imbalances in heat generation and removal during accident conditions. *The large thermal capacitance of the MHR core is a primary factor in the unique ability of the MHR to withstand an indefinite loss of coolant during power operation.*

- **High Temperature Capability** - The graphite structural elements of the core maintain strength (strength actually increases at elevated temperature) to temperatures far in excess of conceivable accident conditions. This property provides assurance that the core remains in a well characterized geometry. *Low probability accident analysis is greatly simplified and uncertainties reduced by eliminating the potential for reconfiguration of core materials; i.e., severe core melt.*

- **Inert, Single Phase Coolant** - Because the helium coolant is chemically inert, does not serve as a neutron moderator, and is not required for decay heat rejection; *whole classes of accidents are reduced or eliminated.* In addition, the use of helium eliminates the possibility of a change of phase of the coolant (i.e., liquid to vapor) under accident conditions. Thus, complex semi-empirical relationships for flow and heat transfer characteristics as a function of geometry, boiling regime, etc., are avoided. *Accident analysis is greatly simplified and uncertainties reduced by the elimination of consideration of two-phase flow and heat transfer.*

- **Negative Reactivity Coefficient** - The core coefficient and fuel characteristics are specifically designed to provide a strong negative temperature coefficient of reactivity over the full range of operating conditions. As a result, increases in temperature resulting from imbalances in energy generation and removal automatically act to decrease reactor power. *This characteristic places an inherent limit on temperatures that can be achieved while the core is critical.*

- **Reactor Size and Configuration** (maximum power level, annular core configuration, uninsulated steel reactor vessel) - These design features are specified to limit the amount of decay heat and allow removal of decay heat by thermal radiation from the reactor vessel, while maintaining coated particle fuel temperatures within allowable limits. The power level limit results in a low power density, a key factor in the heat capacity characteristic discussed earlier. *These characteristics, in concert with the high heat capacity, place an inherent limit on the temperatures reached by the fuel, reactor internal structures, and reactor vessel due to post-shutdown decay heat under accident conditions.*

  Reactor Cavity Cooling System (RCCS) - The RCCS removes heat from the reactor cavity by natural circulation of outside air through ductwork and cooling panels located within the reactor cavity. *The RCCS maintains acceptable reactor cavity concrete temperatures under normal operating conditions and, in conjunction with the features discussed above, limits the reactor internals and reactor vessel to acceptable temperatures under accident conditions.*

In developing O&M cost estimates for the GT-MHR Target Plant, it was noted that reliance on passive features and inherent characteristics makes the GT-MHR fundamentally different than LWRs in the following respects:

- The reactor coolant does not serve a safety function.

- The most important safety functions are accomplished without moving parts, external power sources, initiating signals, or human actions.

  The GT-MHR has no counterpart to core damage as a threshold of safety degradation, but allows the characterization of accidents in terms of absolute risk.

- The GT-MHR eliminates the potential for a large, energetic source term and reduces the domain of public risk considerations.

Long time intervals are available to implement accident recovery measures.

Thus, it can be anticipated that the GT-MHR safety concept will substantially relieve the areas of greatest uncertainty in the operation of current LWRs:

- Human error probability
- Configuration management
- The potential for adverse systems interactions
- The consequences of low probability events

The GT-MHR safety concept enables features relevant to safety to be embodied in the design, verified by full-scale tests, and monitored during operation. Safety significant site activities may then emphasize (1) the installation, inspection, and maintenance of a relatively small scope of passive equipment, and (2) the continuous monitoring of the principal means by which safety functions are accomplished. When successfully developed, the MHR safety concept will:

- Essentially eliminate the potential for operator errors and equipment malfunctions to jeopardize public safety, and the need for provisions to manage severe accidents leading to core disarray. This will (1) ease regulatory demands on owner/operator management, and (2) lessen investor concern about the potential for interruption of operations.

- Preclude the need for sheltering and evacuation plans for the off-site public, which will ease the public's concern for reactor safety and investor concerns regarding the potential for interruption of operations. Existing local plans to respond to environmental and industrial hazards will be sufficient.

- Allow the bulk of the plant to be designed, constructed, operated, and maintained to utility/user-controlled standards, which will reduce costs and increase investor confidence.

- Provide an approach to defense-in-depth against the release of fission products that reduces demands on the plant operating staff and the perceived need for regulatory oversight of plant operations management. This will reduce the business risks of nuclear plant ownership.

For the purposes of projecting Target Plant O&M costs, the following specific assumptions with regard to institutional acceptance are made relative to those cited in Section 3 for the Lead Plant:

- The Target Plant can be licensed with only two Senior Reactor Operators on site and none is required in the control room. Further, public health and safety can be assured without reliance on the control room, its contents, the automated control

PC-000447/0

system, or operator actions to mitigate accidents. These factors are expected to justify reductions in the amount of formal instruction mandated by NRC and INPO and the size of the training staff.

The productivity of maintenance personnel working on non-safety-significant equipment will be on par with those in multiple unit conventional plants. For this to happen, the current expectations of NRC and INPO in the areas of documentation, quality assurance, craftsman qualification and retraining, and prescriptive procedures must have evolved to accept the appropriateness of essentially conventional practices for much of the GT-MHR plant.

- Regulatory provisions for security will recognize that the radiological consequences of credible acts of sabotage are less than EPA guidelines for off-site protection of the public and that GT-MHR vital areas housing fuel-storage facilities and plant safety equipment are geographically small and easily secured.

  A plant operating capacity factor of 85% is achieved, as compared to 80% for the Lead Plant and 82% for the Replica Plant.

Assuming that owner/operator interests (e.g., COSO) lead an ongoing program sustained throughout design development and early deployment to establish management and operating practices appropriate to the GT-MHR within the industry, the resulting demands on the owner/operator plant organization should be on par with those for other modern commercial enterprises involving hazardous materials.

O&M cost estimates for the GT-MHR Target Plant in Section 4.2 are based on the foregoing assumptions and expressed in terms of incremental change from the Lead Plant estimate given in Sections 3.2 through 3.4. Also in Section 4.2, an estimate for the fully mature "equilibrium" Target Plant is presented. That is, it is further assumed that the reactor module power level is increased to 600 MWt versus the reference 550 MWt design and an operating capacity factor equal to the design capacity factor of 87% is achieved, while costs not related to power output remain the same as for the Target Plant. In Section 4.3, estimates for the Replica Plant are expressed in terms of incremental changes from both the Lead and Target Plants.

4.2 GT-MHR TARGET AND "EQUILIBRIUM" TARGET PLANT O&M COST ESTIMATE

The discussions of costs for the GT-MHR Target Plant in Section 4.2.1 and 4.2.2 apply as well to the "equilibrium" Target Plants. Costs are summarized for both in Section 4.2.3.

4.2.1 GT-MHR TARGET PLANT STAFFING REQUIREMENTS

The following sections discuss the rationale for projected reductions in staff relative to that estimated for the Lead Plant. Table 4-1 presents a breakdown of staff positions corresponding to the detailed descriptions provided in Section 3 and the assumptions stated in the preceding section. A plant organization comprised of Operations,

Table 4−1
OPERATING STAFF COMPARISON:
GT−MHR LEAD VS TARGET PLANT STAFF

PLANT STAFF POSITION	LEAD PLANT STAFF	LEAD PLANT TEAMS	LEAD PLANT TOTAL	TARGET PLANT STAFF	TARGET PLANT TEAMS	TARGET PLANT TOTAL	SUMMARY PROTO	SUMMARY TARGET	SUMMARY DELTA	L	T	SEE SECTION 4.2.1 FOR EXPLANATIONS OF DIFFERENCES
PLANT MANAGER	1	1	1	1	1	1	1	1	0			
OPERATIONS DIV MGR	1	1	1	1	1	1	1	1	0			
SHIFT OPERATIONS MGR	1	1	1	1	1	1	1	1	0			
SHIFT SUPERVISORS, SRO	1	6	6	1	6	6	6	6	0			
PLANT SUPERVISORS, SRO	1	6	6	1	6	6	6	6	0			
PLANT SUPER, QUALIFIED	0	6	0	0	6	0	0	0	0			
CONT RM SUPERVISORS, SRO	1	6	6	0	6	0	6	0	−6			
CONT RM OPERATORS, RO	3	6	18	3	6	18	18	18	0			
ROVING OPERATORS	4	6	24	3	6	18	24	18	−6			
HELPERS (ANNUAL)	2	1	2	2	1	2	2	2	0			
CLERKS	1	2	2	1	1	1	2	1	−1	65	52	SHIFT OPERATIONS
REACTOR ENGR SUPERVISOR	1	1	1	1	1	1	1	1	0			
REACTOR ENGINEERS	2	1	2	2	1	2	2	2	0	3	3	REACTOR ENGINEERING
CHEMISTRY SUPERVISOR	1	1	1	1	1	1	1	1	0			
CHEMIST	1	1	1	0	1	0	1	0	−1			
RAD/CLEAN CHEM TECH	1	5	5	1	5	5	5	5	0			
RELIEF RAD/CLEAN TECH.	0	1	0	0	1	0	0	0	0	7	6	CHEMISTRY
SUBTOTAL OPERATIONS DIV.							76	62	−14			
MAINTENANCE DIV MGR	1	1	1	1	1	1	1	1	0			
COMPONENT MAINTENANCE SUPER.	1	1	1	1	1	1	1	1	0			
I&C AND CMPUTR SUPER	1	1	1	1	1	1	1	1	0			
I&C AND CMPUTR FOREMEN	1	1	1	1	1	1	1	1	0			
I&C SHFT COVERAGE TECH	1	5	5	1	5	5	5	5	0			
I&C SECURITY & TV TECH	1	1	1	1	1	1	1	1	0			
I&C FIRE DETECT TECH	0.5	1	0.5	0.5	1	0.5	0.5	0.5	0			
I&C RLAYS/SBSTN EQUP TECH	1	1	1	1	1	1	1	1	0			
I&C BRKR PREV MAINT TECH	1	1	1	1	1	1	1	1	0			
I&C PLT CMPUTR TECH	3	1	3	3	1	3	3	3	0			
I&C PLT CMPUTR PROGRAMMER	2	1	2	2	1	2	2	2	0			
I&C HLTH PHYSCS TECH	2	1	2	2	1	2	2	2	0			
I&C PROCEDURE WRITER	0.5	1	0.5	0.5	1	0.5	0.5	0.5	0			
I&C ROUTINE/GENERAL	2	1	2	1	1	1	2	1	−1			
I&C TECH (ANNUAL)	2	1	2	1	1	1	2	1	−1	22	20	I&C STAFF
M&E MAINTEN SUPER	1	1	1	1	1	1	1	1	0			
M&E MAINTEN FOREMEN	3	1	3	2	1	2	3	2	−1			
M&E SHFT COVERAGE	2	5	10	2	5	10	10	10	0			
M&E CRAFTSMEN	33	1	33	28	1	28	33	28	−5			
M&E T−G (ANNUAL)	3	1	3	2	1	2	3	2	−1			
M&E OUTAGE (ANNUAL)	4	1	4	3	1	3	4	3	−1	54	46	M&E STAFF
REFUELING SUPER.	4	1	4	4	1	4	4	4	0			
REFUELING TECH (ANNUAL)	8	1	8	8	1	8	8	8	0	12	12	REFUELING
ISI SUPERVISOR	1	1	1	1	1	1	1	1	0			
ISI NDE TECH (ANNUAL)	2	1	2	2	1	2	2	2	0	3	3	ISI
QC TECHNICIANS	5	1	5	4	1	4	5	4	−1	5	4	QUALITY CONTROL
HEALTH PHYSICS SUPERVISOR	1	1	1	1	1	1	1	1	0			
HLTH PHYS SHIFT	1	5	5	1	5	5	5	5	0			
HLTH PHSC NI DOSIM	2	1	2	2	1	2	2	2	0			
HLTH PHYS PROCED/REV	4	1	4	2	1	2	4	2	−2	12	10	HEALTH PHYSICS
SERVICES SUPERVISOR	1	1	1	1	1	1	1	1	0			
STORES FOREMAN	1	1	1	1	1	1	1	1	0			
WAREHOUSEMEN	3	1	3	3	1	3	3	3	0			
GRNDS & HSKPNG	6	1	6	6	1	6	6	6	0			
RADWASTE FOREMAN	1	1	1	1	1	1	1	1	0			
RADWASTE CRAFTSMEN	3	1	3	3	1	3	3	3	0	15	15	SERVICES
PLANNING SUPERVISOR	1	1	1	1	1	1	1	1	0			
OUTAGE PLANNERS	5	1	5	3	1	3	5	3	−2			
SPARE PARTS FOREMAN	1	1	1	0.5	1	0.5	1	0.5	−0.5			
MAINTEN. PROCED FOREMAN	1	1	1	0.5	1	0.5	1	0.5	−0.5			
PM/EQ ENGR	1	1	1	1	1	1	1	1	0	9	6	PLANNING
SUBTOTAL MAINTENANCE DIV.							134	118	−16			
TECHNICAL DIV MGR	1	1	1	1	1	1	1	1	0			
LICENSING & REG SUPER	1	1	1	1	1	1	1	1	0			
LICENSING & REG ENGR	3	1	3	2	1	2	3	2	−1	4	3	LICENSING ENGR
ENGR & PERF SUPERVISOR	1	1	1	1	1	1	1	1	0			
ENGR & PERF ENGR	5	1	5	3	1	3	5	3	−2			
ENGR & PERF TECH	4	1	4	3	1	3	4	3	−1	10	7	PERFORMANCE ENGR
SUBTOTAL TECHNICAL DIV.							15	11	−4			
ADMINISTRATIVE DIV MGR	1	1	1	1	1	1	1	1	0			
SECURITY SUPERVISOR	1	1	1	1	1	1	1	1	0			
SHIFT SECURITY FOREMEN	1	5	5	1	5	5	5	5	0			
SECURITY GUARDS	4	5	20	2	5	10	20	10	−10			
CAS & SAS GUARD	2	5	10	1	5	5	10	5	−5			
RELIEF GUARDS	10	1	10	5	1	5	10	5	−5			
SECRTY INSTR.& LOCKSMITH	2	1	2	2	1	2	2	2	0			
SECURITY CLERKS	2	1	2	2	1	2	2	2	0	50	30	SECURITY
TRAINING SUPERVISOR	1	1	1	1	1	1	1	1	0			
TRAINING INSTRUCTORS	6	1	6	4	1	4	6	4	−2			
TRAINING CLERKS	1	1	1	1	1	1	1	1	0	8	6	TRAINING
PERSONNEL ADMIN	4	1	4	3	1	3	4	3	−1			
EMERG PLNG/PUB AFFAIRS	1	1	1	0	1	0	1	0	−1			
RECORDS MGT FOREMAN	1	1	1	1	1	1	1	1	0			
RECORDS MGT CLERKS	3	1	3	2	1	2	3	2	−1			
CLERICAL & STENO	5	1	5	5	1	5	5	5	0			
SAFETY/FIRE ENGR	1	1	1	1	1	1	1	1	0	15	12	ADMIN STAFF
SUBTOTAL ADMIN. DIV.							74	49	−25			
TOTAL STAFF			300			241			59			

PC-000447/0

Maintenance, Technical and Administrative Divisions as shown in Figure 3-1 is assumed. As for the Lead Plant, these estimates incorporate the judgement and experience of senior utility personnel with HTGR and LWR plants.

4.2.1.1 GT-MHR TARGET PLANT OPERATIONS DIVISION

The Operations Division is reduced from 76 to 62 personnel. The major factor in this change is a reduction in the number of operations staff from 65 to 52. It is assumed that the Shift and Plant Supervisors are the only Senior Reactor Operators assigned to shift work, that none is required in the control room, and that the control room is adequately staffed with three licensed reactor operators responsible for the four power units. Power unit operations are under the direction of the Plant Supervisor and require three roving operators to cover the plant. The number of Helpers (operators in training) can be reduced from four to two because of the reduced number of licensed positions to fill. Overall plant activities (e.g., shift maintenance, radiation protection, chemistry, security, as well as operation of plant systems) are supervised by the Shift Supervisor. The functions of the Chemist are assumed to be accomplished by the Chemistry Supervisor.

4.2.1.2 GT-MHR TARGET PLANT MAINTENANCE DIVISION

The Maintenance Division is reduced from 134 to 118 personnel. The main factor is a reduction in mechanical and electrical maintenance personnel from 54 to 46. This area benefits from implementation of conventional practices and reduction in nuclear-related training. The period between preventive maintenance on both components and instruments will have lengthened as a result of mature reliability centered maintenance programs on standard plants.

4.2.1.3 GT-MHR TARGET PLANT TECHNICAL DIVISION

A stable regulatory environment; mature, standardized procedures; and an experienced COSO justify a reduction in Licensing and Performance Engineers. COSO personnel will be engaged in monitoring and consulting at all GT-MHR plants, and therefore able to respond efficiently to individual plant needs. The Technical Division staff is reduced from 15 to 11.

4.2.1.4 GT-MHR TARGET PLANT ADMINISTRATIVE DIVISION

The Administrative Division is reduced from 74 to 49 personnel. Decreases include reductions in training staff from 8 to 6 personnel, which are consistent with staff reductions and the use of mature, standardized procedures, and reductions in the security staff from 50 to 30. With regard to the latter, it is expected that evolving security regulations will allow the number of armed responders to be reduced from five to three and that the requirement for a continuously staffed secondary alarm station will have been eliminated. It is also assumed that evolving regulations will recognize technological improvements which reduce dependence on human reliability.

4.2.2 GT-MHR TARGET PLANT SPECIFIC OPERATION AND MAINTENANCE EXPENSES

The treatment of Maintenance Materials, Supplies and Expenses; Payroll Taxes, Pensions and Benefits; and other Administrative and General Expenses for the Target plant remain as described in Section 3 of this report. Offsite Technical Support, Nuclear Regulatory Commission and Other Nuclear Fees, and Nuclear Insurance are treated slightly different. The number of quality assurance personnel is reduced from 5 to 4 and the number of COSO consultants is reduced from 15 to 13 for the Target Plant. This adjustment reflects maturity of practices and personnel experience with the standard plant. As shown in Table 4-2, the only change in NRC and Other Nuclear Fees is for the Annual Facility Fee which is reduced by 50% for the Target Plant in accordance with Reference 9. This adjustment reflects the expectation that the NRC staff effort will be substantially reduced for the standard plant in comparison to the first-of-a-kind effort required for the Lead Plant.

Table 4-2
NRC AND OTHER NUCLEAR FEES (K$, 1994)

	LEAD PLANT	TARGET PLANT
NRC FEES		
▸ Annual Facility	$2,800	$1,400
▸ Operating Reactor Surcharge	$ 270	$ 270
▸ Inspection	$ 300	$ 300
▸ Amendment Requests	$ 130	$ 130
▸ 10CFR55 - Operator License Review Test	$ 40	$ 40
TOTAL NRC FEES	$3,540	$2,140
INPO FEES	$ 390	$ 390
NEI FEES	$ 220	$ 220
TOTAL NRC, INPO, AND NEI FEES	$4,150	$2,750

With regard to Nuclear Insurance, if the attributes ascribed to the GT-MHR are established; namely, that both the likelihood and consequence of severe nuclear accidents are substantially reduced relative to current plants, it is reasonable to expect that these factors will eventually be reflected in reduced property damage insurance rates, and a 50% reduction relative to insurance for the Lead Plant is assumed. In addition, it is reasonable to expect that GT-MHR licensees would be exempt from current provisions of

PC-000447/011

the Price-Anderson Act wherein operating licensees can be assessed up to $10M per reactor/per year/per loss associated with public liability. Like for the Lead Plant, it is assumed that commercial plant owners will carry replacement power insurance and an allowance for a $530,000 annual premium is included.

4.2.3 SUMMARY OF TARGET PLANT OPERATION AND MAINTENANCE COSTS

The results of this study show an annual operating expense for the GT-MHR Target Plant of $35.4 million or 4.5 mills per kilowatt hour at an 85% capacity factor. As shown Table 4-1, staff size is estimated at 241 persons. Salaries are the same as those for the Lead Plant shown in Table 3-7. This estimate includes the annual equivalent of a number of technicians and craftsmen used to temporarily supplement permanent staff during planned outages.

A detailed breakdown of cost results is shown on Table 4-3. Power generation costs, including staff salary and payroll taxes, maintenance materials, supplies and expenses and offsite technical support amount to $23.0 million or 65% of total O&M costs. G&A costs, which include employee benefits, nuclear liability and property damage insurance, fees and dues, are $12.4 million or 35% of total O&M costs.

As for the Lead Plant, this estimate is based on known requirements, supplemented by the judgement of senior utility operating personnel. On this basis, these projections are considered to be a mean estimate; i.e., actual costs are expected to have an equal likelihood of being higher or lower.

Table 4-4 presents a summary of O&M costs for the "equilibrium" Target GT-MHR Plant. These costs assume the same staff size and other costs estimated for the Target Plant with the further assumption that the expected stretch in reactor module power output from 550 to 600 MWt is achieved along with an increase from 85 to 87% in plant capacity factor. The reference GT-MHR plant design includes provisions in the reactor and PCS design that will allow the power increase if currently assumed margins are confirmed. The more optimistic plant capacity factor is consistent with values being assumed on other advanced reactor programs. These assumptions result in an 11% reduction in the O&M component of the busbar cost of electricity to 4.1 mills per kilowatt hour.

4.3 GT-MHR REPLICA PLANT O&M COST ESTIMATE

It is assumed that the second GT-MHR plant is a reproduction of the Lead Plant except for site specific items; i.e., the Replica Plant. The approach to estimating O&M costs for the Replica Plant involves judging the extent to which the institutional changes assumed to be in place for the Target Plant will have been brought about during the course of the Lead Plant Project. The GT-MHR deployment plan projects commitment to the Replica Plant coincident with completion of certification tests on the Prototype Plant, several years before commercial operation of the full four-module Lead Plant. O&M cost estimates for the Replica Plant are based on the following assumptions:

Table 4–3
GT–MHR TARGET PLANT O&M COST SUMMARY (94$)

Plant Performance		
Net Plant Rating, MWe		1,050
Base Capacity Factor, %		85
Annual Net Generation, million kwh		7,815
Power Generation Costs ($million/year)		
On–site staff salary and payroll taxes	241 persons	12.70
Maintenance materials		
Fixed		1.47
Variable		0.49
Subtotal		1.96
Supplies and expenses		
Fixed		2.05
Variable Reflector Block and Control Rod Replacement		3.70
Variable		0.78
Subtotal		6.53
Offsite technical support		
Corporate	4 persons	0.35
COSO	13 persons	1.44
Subtotal		1.79
Subtotal, power generation costs		
Fixed		18.01
Variable		4.97
Subtotal		22.98
General and Administrative Costs ($million/year)		
Pensions and benefits		3.17
Nuclear regulatory fees		2.75
Liability insurance		0.65
Property insurance		1.88
Replacement power insurance		0.53
Other general & administrative expenses		3.45
Subtotal		12.43
Total O&M Costs ($million/year)		
Fixed		30.44
Variable		4.97
Total Nonfuel O&M Costs, $million/yr		35.41
Total Nonfuel O&M Costs, mills/kwh		4.53

pc-000447/0

Table 4-4
GT-MHR EQUILIBRIUM TARGET PLANT O&M COST SUMMARY (94$)

Plant Performance		
Net Plant Rating, MWe		1,145
Base Capacity Factor, %		87
Annual Net Generation, million kwh		8,726
Power Generation Costs ($million/year)		
On-site staff salary and payroll taxes	241 persons	12.70
Maintenance materials		
Fixed		1.47
Variable		0.49
Subtotal		1.96
Supplies and expenses		
Fixed		2.05
Variable Reflector Block and Control Rod Replacement		3.70
Variable		0.87
Subtotal		6.62
Offsite technical support		
Corporate	4 persons	0.35
COSO	13 persons	1.44
Subtotal		1.79
Subtotal, power generation costs		
Fixed		18.01
Variable		5.06
Subtotal		23.07
General and Administrative Costs ($million/year)		
Pensions and benefits		3.17
Nuclear regulatory fees		2.75
Liability insurance		0.65
Property insurance		1.88
Replacement power insurance		0.53
Other general & administrative expenses		3.46
Subtotal		12.44
Total O&M Costs ($million/year)		
Fixed		30.45
Variable		5.06
Total Nonfuel O&M Costs, $million/yr		35.51
Total Nonfuel O&M Costs, mills/kwh		4.07

PC-000447/0

- A plant operating capacity factor of 82% is achieved, as compared to 80% for the Lead Plant and 85% for the Target Plant.

  With the exceptions of the Chemist and one Instructor positions, staffing for the Operations, Technical and Administrative Divisions is estimated to be the same as for the Lead Plant since demonstration of multi-modules operations will not have been accomplished at the time of Replica Plant commitment.

  Maintenance Division staffing is assumed to be the same as for the Target Plant since its size is largely determined by then replicated conventional plant equipment and O&M procedures. This allows a reduction of 16 personnel relative to the Lead Plant.

Thus, it is estimated that a staff of 282 personnel is required for the Replica Plant. Other costs (maintenance materials, supplies and expenses, fees and insurance, and off-site support) remain as estimated for the Lead Plant. O&M costs for the Replica Plant are summarized in Table 4-5. Power generation costs, including staff salary and payroll taxes, maintenance materials, supplies and expenses and offsite technical support amounts to $25.2 million or 64% of total cost. G&A costs, which include employee benefits, nuclear liability and property damage insurance, fees and dues, are $16.5 million or 36% of the total cost.

PC-000447/0 1

Table 4-5
GT-MHR REPLICA PLANT O&M COST SUMMARY (94$)

Plant Performance		
Net Plant Rating, MWe		1,050
Base Capacity Factor, %		82
Annual Net Generation, million kwh		7,539
Power Generation Costs ($million/year)		
On-site staff salary and payroll taxes	282 persons	14.64
Maintenance materials		
Fixed		1.47
Variable		0.49
Subtotal		1.96
Supplies and expenses		
Fixed		2.18
Variable Reflector Blocks and Control Rods		3.70
Variable		0.75
Subtotal		6.63
Offsite technical support		
Corporate	5 persons	0.43
COSO	14 persons	1.55
Subtotal		1.98
Subtotal, power generation costs		
Fixed		20.27
Variable		4.94
Subtotal		25.21
General and Administrative Costs ($million/year)		
Pensions and benefits		3.66
Nuclear regulatory fees		4.15
Liability insurance		0.65
Property insurance		3.76
Replacement power insurance		0.53
Other general & administrative expenses		3.78
Subtotal		16.53
Total O&M Costs ($million/year)		
Fixed		36.80
Variable		4.94
Total Nonfuel O&M Costs, $million/yr		41.74
Total Nonfuel O&m Costs, mills/kwh		5.54

SECTION 5

PLANT CONFIGURATION SENSITIVITY STUDIES

5.1 INTRODUCTION

Studies were conducted to determine the sensitivity of O&M costs to (1) individual control rooms for each module versus a central control room (the reference) and (2) the number of reactor modules in the plant; i.e., 1, 2, 3, or 4 (the reference) modules. While it is clear that both of these options would incur higher operating costs than the reference four-module plant with a central control room, both would reduce risk and increase deployment flexibility. In the case of individual versus central control rooms, the avoided risk is the reduced likelihood of delays in certification due to issues emerging during regulatory review of control room design and staffng plans. (See Reference 14 for a more complete discussion of NRC's position on operator staffing and function for advanced reactors.) With regard to the number of modules per plant, the concern is one of being able to accommodate a broad range of owner/operators in a global market.

5.2 INDIVIDUAL VERSUS A CENTRAL CONTROL ROOM

For the reference plant design, Shift operations is staffed by a Shift Supervisor and Plant Supervisor (both SROs and not posted in the control room), three reactor operators (ROs and posted in the control room), and three roving operators (ROs). If individual control rooms for each reactor module were adopted, the reference functions for the Shift and Plant SROs would be retained, but 8 reactor operators (2 ROs for each control room) and 5 roving operators are required. The additional roving operators are deemed necessary to ensure adequate in-plant response to control room operator directions. Increments in shift operations and support staff for individual control rooms are shown in Table 5-1 for GT-MHR Target Plants. This change would increase the O&M component of the busbar cost of electricity from 4.5 to 5.0 mills/kwhr.

5.3 NUMBER OF REACTOR MODULES PER PLANT

O&M costs for 1, 2, 3, and 4 module GT-MHR plants are summarized in Table 5-2. These costs are based on incremental changes relative to the reference 4 module plant design with a central control room. In Figure 5-1, the O&M component of the busbar cost of electricity for each stage of plant development (i.e., Prototype, Lead, Replica and Target plants) is plotted for 1, 2, 3, and 4 module plants. Also shown in Figure 5-1 is the average O&M cost for the top ten U.S. LWR plants in 1993 of 8.4 mills/kwhr (adapted from Reference 15). (Per Reference 16, the U.S. LWR industry average in 1993 was about 15.5 mills/kwhr.) While this comparison is limited in scope to O&M costs, it suggests that the GT-MHR can potentially compete in all four configurations and that a more thorough evaluation of design features that support flexibility; e.g., individual control rooms, should be conducted.

PC-000447/0

Table 5–1
INDIVIDUAL VS CENTRAL CONTROL ROOMS
GT-MHR TARGET PLANTS ('94$)

		Salary (94$)	Central Cntrl Rm	Individual Cntrl Rm	Delta
Plant Manager	Position	128,176	1	1	0
Operations Division	Manager	89,303	1	1	0
Chemistry	Supervisor	65,769	1	1	0
	Chemist	61,041	0	0	0
	Technician	45,807	5	5	0
Reactor Engr.	Supervisor	65,769	1	1	0
	Engineer	56,314	2	2	0
Shift Operations	Supervisor	65,769	1	1	0
	Shift supv.	65,769	12	12	0
	Operator	55,158	38	80	42
	Shift clerk	34,040	1	2	1
Subtotal Operations			62	105	43
Maintenance Division	Manager	89,303	1	1	0
Component Maint.	Supervisor	61,041	8	8	0
	Foreman	55,158	3	3	0
	Craftsman	43,391	38	38	0
	Annualized	43,391	16	16	0
	Technician	43,391	19	21	2
	Programmer	55,158	2	2	0
Health Physics	Supervisor	61,041	1	1	0
	Technician	47,068	9	9	0
Services	Supervisor	61,041	1	1	0
	Foreman	55,158	2	2	0
	Craftsman	43,391	6	6	0
	Custodian	30,993	6	7	1
Planning	Supervisor	61,041	1	1	0
	Engineer	55,158	1	1	0
	Foreman	55,158	1	1	0
	Technician	46,963	3	3	0
Subtotal Maintenance			118	121	3
Technical Division	Manager	89,303	1	1	0
Licensing	Supervisor	65,769	1	1	0
	Engineer	56,314	2	2	0
Engr & Perf	Supervisor	65,769	1	1	0
	Engineer	56,314	3	3	0
	Technician	45,807	3	3	0
Subtotal Technical			11	11	0
Administrative Division	Manager	89,303	1	1	0
Security	Supervisor	45,807	1	1	0
	Foreman	34,040	5	5	0
	Guard+2 clk	30,573	24	24	0
Training	Supervisor	61,987	1	1	0
	Instructor	55,158	4	4	0
	Clerical	34,040	1	1	0
Personnel Admin.	Clks&Nurse	34,040	3	3	0
Emergency & P.R.	Engineer	56,734	0	0	0
Records Mgt.	Foremen	45,807	1	1	0
	Clerical	84,040	2	2	0
Clerical	Clerical	34,040	5	5	0
Safety & Fire	Engineer	52,531	1	1	0
Subtotal Administrative			49	49	0
Total Site			241	287	46
Offsite Staff, Corporate		45,800	4	4	0
Offsite Consultants, COSO		110,700	13	13	0
Total O&M Staff			258	304	46

PC-000447/0

Table 5–2

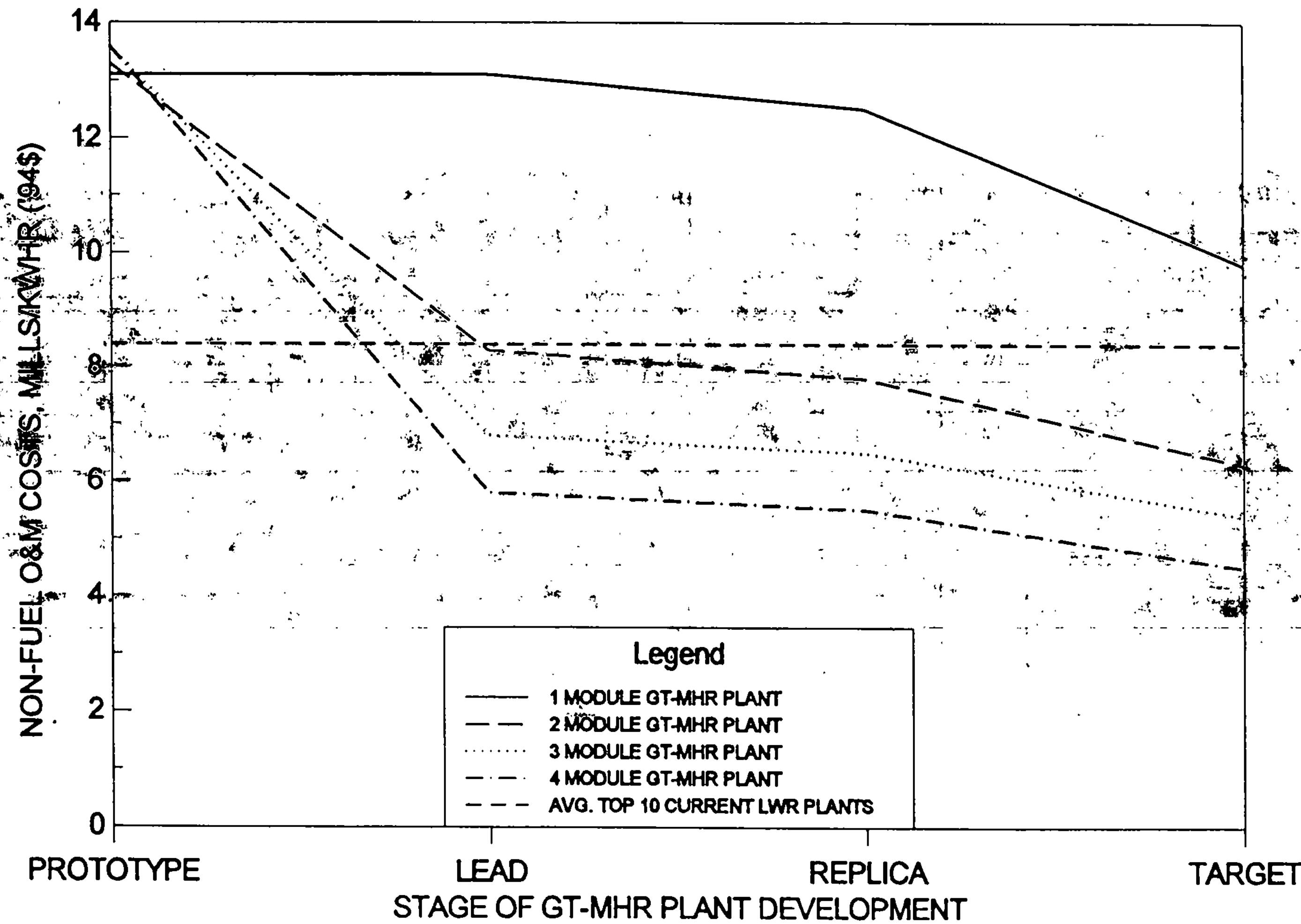
NON–FUEL O&M COSTS FOR 1, 2, 3, & 4 MODULE GT–MHR PLANTS ('94$)

	ONE MODULE PLANT				TWO MODULE PLANT				THREE MODULE PLANT				FOUR MODULE PLANT			
	PRO	LEAD	REPL	TRGT	PRO	LEAD	REPL	TRGT	PRO	LEAD	REPL	TRGT	PRO	LEAD	REPL	TRGT
POWER, MWe	262	262	262	262	262	525	525	525	262	787	787	787	262	1050	1050	1050
CAP FACT, %	80	80	82	85	80	80	82	85	80	80	82	85	80	80	82	85
PLANT STAFF	157	157	151	132	161	204	190	172	166	261	248	228	166	300	282	241
POWER GEN, M$	11.9	11.9	11.5	10.6	12.2	16.8	15.8	14.9	12.6	22.3	21.3	20.3	12.6	26.3	25.0	22.8
A&G, M$	12.2	12.2	12.2	8.6	12.3	13.6	13.5	9.9	12.4	15.2	15.2	11.6	12.4	16.3	16.4	12.3
TOTAL, M$	24.1	24.1	23.6	19.1	24.5	30.4	29.2	24.8	25.0	37.4	36.5	31.9	25.0	42.6	41.3	35.0
MILLS/KWHR	13.1	13.1	12.5	9.8	13.3	8.3	7.8	6.3	13.6	6.8	6.5	5.4	13.6	5.8	5.5	4.5

PC-000447/0

Figure 5-1

O&M COSTS VS MODULES PER GT-MHR PLANT



SECTION 6

OWNER'S COSTS FOR GT-MHR PLANTS

6.1 APPROACH TO ESTIMATING OWNER'S COSTS FOR GT-MHR PLANTS

During the construction of a power plant, the owner incurs costs for its functions which include (1) project management; (2) fees, taxes and insurance; (3) spare parts and specific capital expenses; (4) staff training and startup and (5) administrative and general expenses. The estimate of owner's costs in this section builds on the estimates of plant staff and operating costs developed in Sections 3 and 4 of this report for the Prototype, Lead, Replica, Target, and "equilibrium" Target Plants. Owner's costs for the "equilibrium" Target Plant are assumed to be the same as the Target Plant except that spare turbomachinery will be shared with another plant.

6.1.1 Owner's Cost Accounts

Federal Energy Regulatory Commission (FERC) organizes owner's costs into the following five subaccounts.

- Project Management Expenses (Account 941). This account includes the cost of the owner's project staff to manage and integrate its engineering, licensing, and quality assurance efforts. It also includes supporting home office services such as estimating, planning and scheduling, and purchasing, as well as payment for outside support services directly associated with siting, construction and startup of the plant.

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

- 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 coolants (helium), gases (carbon dioxide, hydrogen, nitrogen, etc.) fluids (demineralized water, lubricants, etc.), auxiliary fuels (fuel oil) and chemicals. Office furniture, communication equipment, vehicles, laboratory equipment, housekeeping supplies, and other spare parts and equipment are also part of this account.

Staff Training and Startup (Account 944). This account includes the costs of training the initial supervisory, operating, maintenance, and administrative staff and their salaries, as well as the cost of maintenance materials and supplies, for the period prior to commercial operation.

PC-000447/0

General and Administrative (Account 945). This account includes the salaries of certain administrative and public relations personnel plus general expenses, certain regulatory expenses, and contract services not applicable to other owner accounts.

6.1.2 Background and Assumptions

The ORNL guidelines (Reference 9) indicate that the preferred approach to developing an estimate of the owner's cost is to consider the scope of the account. However, if that is not possible, it is recommended that owner's cost be estimated as 15% of the other direct and indirect base construction costs. This estimate of GT-MHR owner's costs benefits from the MHTGR Project Feasibility Study (Reference 4) in which Consumer's Power Company and Philadelphia Electric Company supported a detailed evaluation of the cost of deploying modular gas-cooled reactors at a utility site.

For the purposes of this estimate, the owner's costs are based on a hypothetical East/West Central site in accordance with ORNL guidelines. In general, the East/West Central site owner's costs are considered to be representative of the costs for a wide variety of sites but are not specific to any one site. Factors which could cause the owner's cost to vary from site-to-site include the application and rate of sales taxes, the method of valuing property and the tax rate applied, and owner-specific choices (e.g., staff salaries, G&A rate, spare parts philosophy, etc.).

This estimate of owner's costs takes credit for sharing resources between the commercial plants included in the initial deployment scenario. Standardization is one of the keys to successful deployment of the GT-MHR or any other advanced nuclear reactor. Without standardization, each reactor is unique and must deal separately with regulatory issues, design modifications and O&M procedures. Experience in the U.S. has shown that dealing with unique designs can be very expensive in terms of capital cost, operating cost, and risk of regulatory shutdown. It is assumed that the NRC will certify a standard design based on the successful completion of Prototype Plant testing and reference plant design and licensing activities. In addition, it is assumed that prospective owners will organize COSO to deal with the vendor and regulator on generic issues as outlined in Appendix B.

6.2 PROJECT MANAGEMENT EXPENSES (Account 941).

The owner's project management costs are the expenses the owner incurs for project management services to license and build the plant on the owner's site. Estimates of staff composition, size and costs are organized in the following subaccounts:

Account 941.1 - Engineering/Site Management
Account 941.2 - Quality Assurance
Account 941.3 - Project Licensing
Account 941.4 - Project Management & Control

The estimated costs for these accounts are summarized in Table 6-1. Salaries are consistent with those used in estimating operating staff costs in Sections 3 and 4.

Similarly, payroll taxes are assumed to be 10% of salary and employee benefits are assumed to be 25% of salary; however, no allowance for overtime has been included since this period is prior to commercial operation. The components of these accounts are discussed for the Prototype, Lead, Replica and Target Plants in the following sections. The distributions of costs by accounts and with time are as shown in Tables 6-1 and 6-2.

6.2.1 Prototype Plant

The GT-MHR Prototype Plant consists of one reactor module and all plant common facilities for the complete four module Lead Plant. For the purposes of estimating owner's project management costs, it is assumed that the plant is located at a government site and that the government will own and operate it through the demonstration program and NRC certification of the standard GT-MHR design.

As shown in Table 6-2, the owner's project management effort is required for a 10-year period extending from 7 years before to 3 years after start of site work. A small team is brought together early in the project to investigate alternative sites and perform environmental impact studies. Project approval is assumed to occur about three years prior to start of site work. Fuel loading occurs in the third year after start of site work, and related project management activities are completed by the end of that year. Most technical activities performed in the interval between the start of fuel loading and commercial operation will be under the direction of the plant operations manager and these costs are included in Account 944.1.

Project management expenses for the Lead Plant Expansion are estimated to cost $12.8 million for a 164.2 man-year effort.

6.2.2 Lead Plant

The GT-MHR Lead Plant consists of the Prototype Plant and the Lead Plant Expansion; i.e., the private sector's addition of second, third and fourth reactor modules. It is assumed that the NRC will grant a combined operating license for the full four-module Lead Plant based on successful operation of the Prototype Plant and their review of the Lead Plant design. The Lead Plant is assumed to be constructed under a fixed price, turnkey commercial contract; i.e., a fully operational facility will be supplied to the owner.

For such an arrangement, a small project management team is assumed sufficient to oversee execution of the contract and to fulfill the owner's regulatory responsibilities. The owner's Lead Plant project management effort is required for a period of 6 years extending from 3 years before to 3 years after start of site work.

The Lead Plant Expansion project management team is mobilized three years before start of site work for the second reactor module of the Lead Plant. This staff will have gained experience on either the Prototype Plant project management team or plant operating staff. Relative to Prototype Plant project, the Lead Plant construction schedule is shorter as a result of prior construction of the first module and common facilities, and the scope of engineering, quality assurance, and administrative efforts are reduced due to a shorter schedule. The licensing effort is reduced due to use of the Prototype Plant

PC-000447/011

Table 6–1
PROJECT MANAGEMENT EXPENSES ('94$)

ACCOUNT 941	SALARY $/YEAR	PROTOTYPE PLANT		LEAD PLANT EXPANSN		REPLICA PLANT		TARGET PLANT	
		MAN-YR	COST, $	MAN-YR	COST, $	MAN-YR	COST, $	MAN-YR	COST, $
941.1 ENGINEERING/SITE MGT									
CIVIL ENGINEER	56,314	9.5	534,978	4.5	253,411	7.7	433,614	6	337,881
ELECTRICAL ENGINEER	56,314	5.5	309,724	5.8	326,618	5.3	298,462	4.8	270,305
MECHANICAL ENGINEER	56,314	5.5	309,724	5.8	326,618	5.3	298,462	3.8	213,991
I&C ENGINEER	56,314	4.5	253,411	5.8	326,618	4.3	242,148	3.8	213,991
NUCLEAR ENGINEER	56,314	3.5	197,097	5.8	326,618	3.3	185,835	2.8	157,678
SUBTOTAL 941.1		28.5	1,604,935	27.7	1,559,884	25.9	1,458,520	21.2	1,193,846
941.2 QUALITY ASSURANCE									
QA/QC MANAGER	65,769	9.75	641,249	5.8	381,461	8.3	545,884	6.8	447,280
QA/QC ENGINEERS	56,314	10.5	591,292	9.8	551,872	8.3	467,402	7.8	439,245
QA/QC AUDIT/INSPECTORS	46,963	5.8	272,385	5	234,815	4	187,852	4.8	225,422
SUBTOTAL 941.2		26.1	1,504,926	20.6	1,168,148	20.6	1,201,138	19.4	1,111,897
941.3 PROJECT LICENSING									
LICENSING MANAGER	65,769	9.7	637,961	5.8	381,461	8.3	545,884	6.8	447,230
LICENSING ENGINEER	56,314	33	1,858,346	15.1	850,334	24.6	1,385,312	17.8	1,002,380
ADMIN/CLERICAL	30,573	16.7	510,572	5	152,866	7.2	220,127	6	183,439
SUBTOTAL 941.3		59.4	3,006,878	25.9	1,384,661	40.1	2,151,323	30.6	1,633,049
941.4 PROJECT MGT & CNTRL									
PROJECT MANAGER	128,176	10.2	1,307,398	5.8	743,422	8.3	1,063,863	6.8	871,599
PROJECT ENGINEER	89,303	7	625,122	5.8	517,958	7.8	696,564	6.3	562,610
PLANNING & CONTROL	47,068	12	564,816	10.3	484,800	12.8	602,470	11.3	531,868
COST ACCOUNTING	47,068	11	517,748	10.3	484,800	11.3	531,868	9.8	461,266
ADMINISTRATIVE ASSISTANT	32,400	10	324,000	5.8	187,920	8.3	268,920	6.8	220,320
SUBTOTAL 941.4		50.2	3,339,084	38	2,418,901	48.5	3,163,686	41	2,647,663
PAYROLL TAXES	10%		945,582		653,159		797,467		658,646
BENEFITS	25%		2,363,956		1,632,898		1,993,667		1,646,614
TOTAL ACCOUNT 941		164.2	12,765,360	112.2	8,817,652	135.1	10,765,799	112.2	8,891,716

PC-000447/0

Table 6–2
PROJECT MANAGEMENT STAFF (MAN–YEARS)

	ACCTS	YRS FRM STRT OF SITE WRK	−8	−7	−6	−5	−4	−3	−2	−1	1	2	3	4	TOTAL
PROTOTYPE PLANT	941.1	CIVIL ENGINEER		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5		9.5
	ENGR/	ELECTRICAL ENGINEER						1.0	1.0	1.0	1.0	1.0	0.5		5.5
	SITE	MECHANICAL ENGINEER						1.0	1.0	1.0	1.0	1.0	0.5		5.5
	MGT	I&C ENGINEER							1.0	1.0	1.0	1.0	0.5		4.5
		NUCLEAR ENGINEER								1.0	1.0	1.0	0.5		3.5
		SUBTOTAL 941.1		1.0	1.0	1.0	1.0	3.0	4.0	5.0	5.0	5.0	2.5		28.5
	941.2	QA/QC MANAGER		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8		9.8
	QUAL	QA/QC ENGINEERS						1.0	2.0	2.0	2.0	2.0	1.5		10.5
	ASSUR	QA/QC AUDIT/INSPECTORS						1.0	1.0	1.0	1.0	1.0	0.8		5.8
		SUBTOTAL 941.2		1.0	1.0	1.0	1.0	3.0	4.0	4.0	4.0	4.0	3.1		26.1
	941.3	LICENSING MANAGER	0.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5		9.7
	PRJCT	LICENSING ENGINEER		1.0	2.0	2.0	3.0	5.0	6.0	6.0	5.0	2.0	1.0		33.0
	LICNSG	ADMIN/CLERICAL	0.2	1.0	1.0	1.0	2.0	2.0	3.0	3.0	2.0	1.0	0.5		16.7
		SUBTOTAL 941.3	0.4	3.0	4.0	4.0	6.0	8.0	10.0	10.0	8.0	4.0	2.0		59.4
	941.4	PROJECT MANAGER	0.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		10.2
	PRJCT	PROJECT ENGINEER					1.0	1.0	1.0	1.0	1.0	1.0	1.0		7.0
	MGT/	PLANNING & CONTROL					1.0	1.0	2.0	2.0	2.0	2.0	2.0		12.0
	CNTRL	COST ACCOUNTING						1.0	2.0	2.0	2.0	2.0	2.0		11.0
		ADMINISTRATIVE ASSISTANT		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		10.0
		SUBTOTAL 941.4	0.2	2.0	2.0	2.0	4.0	5.0	7.0	7.0	7.0	7.0	7.0		50.2
		TOTAL STAFF	0.6	7.0	8.0	8.0	12.0	19.0	25.0	26.0	24.0	20.0	14.6		164.2
LEAD PLANT EXPANSN	941.1	CIVIL ENGINEER						1.0	1.0	1.0	1.0	0.5	0.0		4.5
	ENGR/	ELECTRICAL ENGINEER						1.0	1.0	1.0	1.0	1.0	0.8		5.8
	SITE	MECHANICAL ENGINEER						1.0	1.0	1.0	1.0	1.0	0.8		5.8
	MGT	I&C ENGINEER						1.0	1.0	1.0	1.0	1.0	0.8		5.8
		NUCLEAR ENGINEER						1.0	1.0	1.0	1.0	1.0	0.8		5.8
		SUBTOTAL 941.1						5.0	5.0	5.0	5.0	4.5	3.2		27.7
	941.2	QA/QC MANAGER						1.0	1.0	1.0	1.0	1.0	0.8		5.8
	QUAL	QA/QC ENGINEERS						1.0	2.0	2.0	2.0	2.0	0.8		9.8
	ASSUR	QA/QC AUDIT/INSPECTORS						1.0	1.0	1.0	1.0	1.0	0.0		5.0
		SUBTOTAL 941.2						3.0	4.0	4.0	4.0	4.0	1.6		20.6
	941.3	LICENSING MANAGER						1.0	1.0	1.0	1.0	1.0	0.8		5.8
	PRJCT	LICENSING ENGINEER						3.0	3.0	3.0	3.0	1.5	1.6		15.1
	LICNSG	ADMIN/CLERICAL						1.0	1.0	1.0	1.0	1.0	0.0		5.0
		SUBTOTAL 941.3						5.0	5.0	5.0	5.0	3.5	2.4		25.9
	941.4	PROJECT MANAGER						1.0	1.0	1.0	1.0	1.0	0.8		5.8
	PRJCT	PROJECT ENGINEER						1.0	1.0	1.0	1.0	1.0	0.8		5.8
	MGT/	PLANNING & CONTROL						2.0	2.0	2.0	2.0	1.5	0.8		10.3
	CNTRL	COST ACCOUNTING						2.0	2.0	2.0	2.0	1.5	0.8		10.3
		ADMINISTRATIVE ASSISTANT						1.0	1.0	1.0	1.0	1.0	0.8		5.8
		SUBTOTAL 941.4						7.0	7.0	7.0	7.0	6.0	4.0		38.0
		TOTAL STAFF						20.0	21.0	21.0	21.0	18.0	11.2		112.2
REPLICA PLANT	941.1	CIVIL ENGINEER				1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7		7.7
	ENGR/	ELECTRICAL ENGINEER							1.0	1.0	1.0	1.0	1.0	0.3	5.3
	SITE	MECHANICAL ENGINEER							1.0	1.0	1.0	1.0	1.0	0.3	5.3
	MGT	I&C ENGINEER								1.0	1.0	1.0	1.0	0.3	4.3
		NUCLEAR ENGINEER								0.0	1.0	1.0	1.0	0.3	3.3
		SUBTOTAL 941.1				1.0	1.0	1.0	3.0	4.0	5.0	5.0	4.7	1.2	25.9
	941.2	QA/QC MANAGER				1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3	8.3
	QUAL	QA/QC ENGINEERS							1.0	2.0	2.0	2.0	1.0	0.3	8.3
	ASSUR	QA/QC AUDIT/INSPECTORS							1.0	1.0	1.0	1.0	0.0		4.0
		SUBTOTAL 941.2				1.0	1.0	1.0	3.0	4.0	4.0	4.0	2.0	0.6	20.6
	941.3	LICENSING MANAGER				1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3	8.3
	PRJCT	LICENSING ENGINEER				1.0	3.0	4.0	4.0	4.0	3.0	3.0	2.0	0.6	24.6
	LICNSG	ADMIN/CLERICAL				1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2		7.2
		SUBTOTAL 941.3				3.0	5.0	6.0	6.0	6.0	5.0	5.0	3.2	0.9	40.1
	941.4	PROJECT MANAGER				1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3	8.3
	PRJCT	PROJECT ENGINEER				0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3	7.8
	MGT/	PLANNING & CONTROL				0.5	1.0	2.0	2.0	2.0	2.0	2.0	1.0	0.3	12.8
	CNTRL	COST ACCOUNTING					1.0	1.0	2.0	2.0	2.0	2.0	1.0	0.3	11.3
		ADMINISTRATIVE ASSISTANT				1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3	8.3
		SUBTOTAL 941.4				3.0	5.0	6.0	7.0	7.0	7.0	7.0	5.0	1.5	48.5
		TOTAL STAFF				8.0	12.0	14.0	19.0	21.0	21.0	21.0	14.9	4.2	135.1
TARGET PLANT	941.1	CIVIL ENGINEER					1.0	1.0	1.0	1.0	1.0	1.0	0.0		6.0
	ENGR/	ELECTRICAL ENGINEER							1.0	1.0	1.0	1.0	0.8		4.8
	SITE	MECHANICAL ENGINEER							0.0	1.0	1.0	1.0	0.8		3.8
	MGT	I&C ENGINEER							0.0	1.0	1.0	1.0	0.8		3.8
		NUCLEAR ENGINEER							0.0	0.0	1.0	1.0	0.8		2.8
		SUBTOTAL 941.1					1.0	1.0	2.0	4.0	5.0	5.0	3.2		21.2
	941.2	QA/QC MANAGER					1.0	1.0	1.0	1.0	1.0	1.0	0.8		6.8
	QUAL	QA/QC ENGINEERS							1.0	2.0	2.0	2.0	0.8		7.8
	ASSUR	QA/QC AUDIT/INSPECTORS							1.0	1.0	1.0	1.0	0.8		4.8
		SUBTOTAL 941.2					1.0	1.0	3.0	4.0	4.0	4.0	2.4		19.4
	941.3	LICENSING MANAGER					1.0	1.0	1.0	1.0	1.0	1.0	0.8		6.8
	PRJCT	LICENSING ENGINEER					1.0	3.0	4.0	4.0	3.0	2.0	0.8		17.8
	LICNSG	ADMIN/CLERICAL					1.0	1.0	1.0	1.0	1.0	1.0	0.0		6.0
		SUBTOTAL 941.3					3.0	5.0	6.0	6.0	5.0	4.0	1.6		30.6
	941.4	PROJECT MANAGER					1.0	1.0	1.0	1.0	1.0	1.0	0.8		6.8
	PRJCT	PROJECT ENGINEER					0.5	1.0	1.0	1.0	1.0	1.0	0.8		6.3
	MGT/	PLANNING & CONTROL					0.5	2.0	2.0	2.0	2.0	2.0	0.8		11.3
	CNTRL	COST ACCOUNTING						1.0	2.0	2.0	2.0	2.0	0.8		9.8
		ADMINISTRATIVE ASSISTANT					1.0	1.0	1.0	1.0	1.0	1.0	0.8		6.8
		SUBTOTAL 941.4					3.0	6.0	7.0	7.0	7.0	7.0	4.0		41.0
		TOTAL STAFF					8.0	13.0	18.0	21.0	21.0	20.0	11.2		112.2

PC-000447/0

site and NRC certified, standard reactor modules. Project management activities are completed with plant startup in the third year after start of site work.

The total owner's costs for the Lead Plant is the sum of costs for the Prototype Plant and for the Lead Plant Expansion, i.e., the addition of the second, third and fourth reactor modules. Project management expenses for the Lead Plant Expansion are estimated to cost $8.8 million for a 112.2 man-year effort. When added to the costs for the Prototype Plant the total project management resources required for the Lead Plant are 276.4 man-years and $21.6 million.

6.2.3 Replica Plant

The Replica Plant is the second four-module GT-MHR plant and the first of a series of identical commercial plants ordered concurrent with the decision to add the second, third and fourth reactor modules to the Prototype Plant. The Replica Plant is also constructed under a fixed price, turnkey contract. The owner's project management effort is required for 9 years, extending from 5 years before to 4 years after start of site work. Relative to the Lead Plant, additional time is needed to obtain licenses and permits for construction at a new site assumed to have characteristics within the envelope of standard plant siting parameters.

The project schedule provides for site specific licensing but also takes credit for learning on the Lead Plant project and the use of a one-step licensing process. The project management staffing effort is similar to that for the Lead Plant Expansion in that the project management staff peaks at 21 personnel. However, the project management staff is required for a longer period of time to accommodate site specific licensing activities.

Project management expenses for the Replica Plant are estimated to cost $10.8 million for a 135.1 man-year effort.

6.2.4 Target Plant

The GT-MHR Target Plant is also assumed to be constructed under fixed price, turnkey contracts and is the fifth identical GT-MHR plant. The owner's project management effort is required for two years less time than for the Replica Plant and extends from 4 years before to 3 years after the start of site work. The project management effort for the Target Plant is 17% less than for the Replica Plant due to the shorter project schedule. Plant startup takes place in the 3rd year after start of site work and related project management activities end that year. Project management expenses for the Target Plant are estimated to cost $8.9 million for a 112.2 man-year effort.

6.3 FEES, TAXES AND INSURANCE COSTS (Account 942)

Estimates of owner's fees, taxes and insurance costs for GT-MHR plants are organized in the following subaccounts:

PC-000447 0

Account 942.1 - Sales[1] and Property Taxes
Account 942.2 - Licensing Fees and Permits
Account 942.3 - Insurance

The estimated costs for these accounts are summarized in Table 6-3. The components of these accounts are discussed for the Prototype, Lead, Replica and Target Plants in the following sections.

6.3.1 Owner's Property Taxes (Account 942.1)

Property taxes are based on an annual assessment of property value. Actual property tax payments are due during the year after the property is assessed. One year of property taxation is assumed prior to the start of site construction work to cover the land value and improvements prior to construction. The year-by-year property value assessments for tax purposes are assumed to be one-half of the average year-by-year accrued capital cost as determined from the plant capital cost cash flow. (The assessed value is less than the average accrued cost since the full value of the accrued cost is not realized until the plant becomes operational.) This convention for estimating the assessed value is based on the approach used in Reference 17.

The property tax rate is assumed to be 2% in accordance with the financial parameters specified in Reference 18. However, actual property tax rates vary from site to site. The resultant estimates of property taxes to be paid by the owner prior to start of commercial operation are summarized in Table 6-3 based on estimates of the total plant capital costs to the nearest \$50 million. (The Lead Plant cost assumes one-half the cost of the Prototype Plant plus the full cost of adding the second, third and fourth reactor modules.) No property taxes are applied to the Prototype Plant because it is assumed to be deployed at a government site and owned by the federal government.

6.3.2 Owner's Licensing Fees and Permits (Account 942.2)

These costs are comprised of NRC application fees, the full cost of NRC staff review of licensing submittals (the dominant contributor), and state and local fees. They are summarized in Table 6-3. Estimates for the first and last of these cost categories are relatively straightforward. NRC fees are delineated in 10CFR170. According to the July 1994 fee schedule, the application fee for a construction permit for a nuclear power reactors is \$125,000. Based on experience, the cost of state and local fees is estimated to be about \$600,000 for any GT-MHR project except the Prototype Plant, which is assumed to be owned by the federal government and located at a government site. However, the costs of NRC staff review functions (e.g., reviews of submittals for Combined Operating Licenses) are to be billed for the full amount and empirical cost data are based on the two-step licensing process.

---

(1) It is noted that sales taxes are not applied to power generation facilities in the majority of the states and that such taxes are applicable to only a small percentage of total plant equipment and site material costs. Sales taxes have not been included in these estimates of the GT-MHR owner's costs.

PC-000447/0

Table 6-3
FEES, TAXES AND INSURANCE COSTS ('94$)

ACCOUNT 942	PROTOTYPE PLANT	LEAD PLANT	REPLICA PLANT	TARGET PLANT
942.1 OWNER'S PROPERTY TAXES				
ASSUMED CAPITAL COST	900	1,800	1,800	1,600
PROPERTY TAX RATE	0%	2%	2%	2%
EFFECTIVE TAX BASIS	1,350	2,520	2,394	2,080
SUBTOTAL 942.1	0	50,000,000	48,000,000	42,000,000
942.2 LICENSING FEES/PERMITS				
NRC APPLICATION FEE	125,000	250,000	125,000	125,000
NRC STAFF REVIEW AT FULL COST	10,725,000	16,975,000	5,250,000	5,250,000
(EQUIV NRC STAFF MAN-YEARS)	43	68	21	21
STATE AND LOCAL FEES/PERMITS	0	600,000	600,000	600,000
SUBTOTAL 942.2	10,850,000	17,825,000	5,975,000	5,975,000
942.3 OWNER'S INSURANCE				
PUBLIC LIABILITY	0	650,000	650,000	650,000
PROPERTY DAMAGE	0	3,760,000	3,760,000	1,880,000
SUBTOTAL 942.3	0	4,410,000	4,410,000	2,530,000
TOTAL ACCOUNT 942	10,850,000	72,235,000	58,385,000	50,505,000

The estimate of owner's cost for NRC staff review of GT-MHR applications using a two-step licensing process is based on the assumption that staff costs for the one- and two-step processes are equal. An equivalent cost based on fee data from earlier versions of 10CFR170 and current NRC staff billing rates is calculated as follows. The 1984 fee schedule list the cost for reviewing Construction Permit applications as $3 million. Assuming this fee is representative of NRC staff costs and an inflation rate of 5% per year, a conservative estimate of current costs (1994$) for the GT-MHR would be $4.8 million. Similarly, the 1988 fee schedule lists the costs for reviewing applications for Operating Licenses as $3,077,400, or $4,125,000 in 1994 dollars. Thus, the cost of the two-step process in current dollars would be $8,925,000. Assuming the two-step process will cost the same and using the 1994 billing rate for NRC professional staff of $133 per hour and 1880 man-hours per year (2080 hours less 200 hours vacation, sick, and holiday hours), this cost represents a 36 man-year effort by NRC staff.

Based on the GT-MHR deployment plan and schedule, the NRC staff effort to review the GT-MHR Prototype Plant is estimated to require about 43 man-years and $10.7 million. Commitment to the Lead Plant Expansion (i.e., the addition of the second, third and fourth reactor module) follows successful licensing, startup, and initiation of the certification test program on the Prototype Plant. The NRC staff review of the application for Lead Plant Expansion will be concurrent with the certification for the standard GT-MHR design which will be completed prior to issuance of the combined operating license for the full four module Lead Plant. An additional 25 man-years of staff effort is anticipated for the Prototype Plant Expansion resulting in a total cost for NRC staff review for the Lead plant of about $17 million.

The NRC licensing fees for all plants following the Lead Plant are assumed to be based on a NRC certified design and directed to the resolution of site/owner-specific issues. For sites within the envelope of parameters for the certified design, this effort should be relatively modest. This review process is assumed to require 21 man-years and about $5.3 million of NRC professional staff time.

6.3.3 Owner's Insurance (Account 942.3)

Nuclear power plant public liability and property damage insurance coverage during construction is assumed to begin one year before commercial operation of the first reactor, or about the time nuclear fuel is received on site. Accordingly, insurance costs during construction are assumed to be equivalent to the total of the annual premiums developed in Sections 3 and 4 of this report. The owner/operator is assumed to be self-insured for standard hazard insurance and no costs are included for hazard insurance in this estimate.

The government is assumed to be the applicant, constructor, and operator of the Prototype Module and to self-insure. Therefore, no insurance costs were applied during construction of the plant. The property damage insurance premiums for the Target Plant are assumed to be 50% of that for the Prototype and Replica Plants based on assumed confirmation of GT-MHR inherent safety characteristics. The insurance premiums for the Prototype, Lead, Replica and Target Plants shown in Table 6-3 are consistent with those in Tables 3-8 and 4-4 of this report.

6.4 SPARE PARTS AND CAPITAL EQUIPMENT (Account 943)

The estimate for spare parts and capital equipment is organized in the following subaccounts:

Account 943.1 - Initial Spare Parts Inventory
Account 943.2 - Consumables, Supplies & Coolants
Account 943.3 - Plant Equipment and Furnishings

Each of these accounts is discussed in the following sections. The associated costs are summarized in Table 6-4.

6.4.1 Initial Spare Parts Inventory (Account 943.1)

The initial spare parts inventory includes those needed for testing and plant start-up operations. Cost estimates for the initial spare parts to be supplied by the owners of the GT-MHR Prototype, Lead, Replica and Target Plants are given in 6-4. An allowance equal to the average cost of the units in the plant is included for a spare turbomachine (i.e., the turbine, compressor, bearings, and seals). The provision of a spare turbomachine for every four-module plant is considered a conservative assumption. As future work shows that the reliability of turobmachinery is such that spares can be shared by several plants, this cost may be reduced. For the "equilibrium" Target Plant, it is assumed that spare turbomachinery will be shared with another plant.

PC-000447/0

Table 6-4
SPARE PARTS & CAPITAL EQUIPMENT ('94$)

ACCOUNT 943	PROTOTYPE PLANT	LEAD PLANT	REPLICA PLANT	TARGET PLANT
943.1 OWNER'S SPARE PARTS				
SPECIFIC SPARE EQUIPMENT	21,960,000	20,340,000	18,504,000	16,056,000
FACTORY EQUPM'T AND MATER'LS	287,000,000	796,000,000	748,000,000	696,000,000
SPARE PARTS ALLOCATION, %	3%	2%	2%	2%
SUBTOTAL 943.1	30,560,000	36,240,000	33,504,000	29,956,000
943.2 CONSUMABLES/SUPPLIES/COOLANT				
HELIUM INVENTORY, LBS/REACTOR	10,000	10,000	10,000	10,000
MAKEUP HE (2 INVENTORIES), LBS	20,000	80,000	80,000	80,000
HELIUM COST AT $12.08/LB, $	241,644	966,575	966,575	966,575
FUEL OIL, K GAL/PLANT	30	30	30	30
FUEL OIL AT $1.05/GAL (2% ESC.), $	40,749	44,990	65,557	48,698
DEMIN WATER, K GAL/PLANT	600	700	700	700
DEMIN. WATER (FLUSH), K GAL/PLANT	320	1,280	1,280	1,280
DEMIN. WATER AT $0.15/GAL, $	138,000	297,000	297,000	297,000
MISC SUPPLIES (10% OF ABOVE), $	42,039	130,856	132,913	131,227
SUBTOTAL 943.2	462,432	1,439,421	1,462,045	1,443,501
943.3 EQUIPMENT AND FURNISHINGS				
PLANT SIMULATOR	7,350,000	7,350,000	7,350,000	2,450,000
FACTORY EQUPM'T AND MATER'LS	31,000,000	65,000,000	65,000,000	65,000,000
EQUPM'T/FRNSHGS ALLOCATION, %	10%	10%	10%	10%
SUBTOTAL 943.3	10,450,000	13,850,000	13,850,000	8,950,000
TOTAL ACCOUNT 943	41,472,432	51,529,421	48,816,045	40,349,501

Although designers have not yet developed a recommended initial inventory of spare parts, an allowance of 2% of the factory equipment and material costs for spares has been identified in discussions with GT-MHR Program participants as adequate to support plant testing and start-up of the Lead, Replica, and Target Plants. The Prototype Plant is assumed to require a higher spare parts allotment because no sharing between modules is possible, and an allowance of 3% has been used.

6.4.2 Consumables, Supplies & Coolants (Account 943.2)

This account covers the cost of the initial plant inventories of reactor coolant, fossil fuels, demineralized water and chemicals. It does not include the initial nuclear fuel inventory which is included in the fuel cycle cost.

Quantity estimates and associated costs for the consumables, supplies and coolants based on currently available design information are given in Table 6-4, including an allowance for miscellaneous supplies. These estimates apply equally to the Lead, Replica and Target Plants. Prototype Plant costs have been adjusted to reflect the requirements of one reactor with common facilities. Additional costs for materials and supplies associated with operation and maintenance activities by the owner during construction are included in Account 944.

6.4.3 Plant Equipment and Furnishings (Account 943.3)

This account contains the cost of the owner's specific equipment such as office furniture, tools, vehicles, laboratory equipment, housekeeping gear, etc. In addition, an allowance of $7.35 million is included for a plant simulator, $4.75 million for the simulator equipment and $2.6 million for building space to house the simulator and classrooms. It is assumed that COSO operates and maintains the simulators at regional central facilities such that Target Plant costs are shared by two other plants and "equilibrium" Target Plant costs are shared by four other plants. This would be a departure from current practice and but should be acceptable with truly standardized GT-MHR designs.

In the Project Feasibility Study (Reference 4), owner's specific equipment was estimated to be approximately 10% of factory equipment and materials cost, and this allocation is used in this estimate. Costs are summarized in Table 6-4.

6.5 STAFF TRAINING AND START-UP (Account 944)

Estimates for staff training and start-up costs are organized in the following accounts:

Account 944.1 - Plant Operating Staff
Account 944.2 - Maintenance Materials
Account 944.3 - Supplies and Expenses

These accounts are discussed in the following sections.

6.5.1 Plant Operating Staff (Account 944.1)

The costs incurred by the owner to develop the plant operating staff are summarized in Table 6-5. As described in Sections 3 and 4 of this report, the sizes of the Prototype, Lead, Replica and Target Plant staffs are estimated to be 166, 300, 282 and 241 personnel, respectively. Table 6-6 shows the rate at which these staffs are recruited and trained in advance of commercial operation. Staff salaries are as shown in Table 3-7. Plant-specific assumptions for these estimates are summarized in the following paragraphs.

Prototype Plant: The on-site staff required to operate and maintain the Prototype Plant is 166 personnel, including 163 full time plus annualized outage support personnel equivalent to about 48 man-months during a fuel cycle (i.e., about 3 man-years). The build-up of this staff during the construction period is assumed to occur in a manner similar to that described in the Project Feasibility Study (Reference 4) and is estimated to require a 364 man-year effort over a period of 6.5 years. This projection is based on the following assumptions:

- Training of the permanent operations staff begins 48 months prior to start of commercial operation of the reactor. This will allow about three years of

PC-000447/01

Table 6–5
STAFF TRAINING AND STARTUP COSTS ('94$)

ACCOUNT 944	PROTOTYPE PLANT	LEAD PLANT	REPLICA PLANT	TARGET PLANT
944.1 PLANT OPERATING STAFF				
STAFF MAN–YEARS BEFORE COL	364	580	560	371
STAFF SALARIES	19,019,780	30,191,672	29,187,907	20,213,962
TAXES & BENEFITS	6,656,923	10,567,085	10,215,767	7,074,887
OFFSITE CONSULTANTS, COSO	996,300	2,656,800	1,549,800	1,439,100
SUBTOTAL 944.1	26,673,002	43,415,557	40,953,474	28,727,949
944.2 MAINTENANCE MATERIALS				
EQUIVALENT OPERATING YEARS	0.92	0.83	0.75	0.58
MATR'LS COST, $/YEAR OPERATION	740,000	1,660,000	1,470,000	1,470,000
SUBTOTAL 944.2	678,333	1,445,000	1,102,500	857,500
944.3 SUPPLIES AND EXPENSES				
EQUIVALENT OPERATING YEARS	2.20	1.93	1.98	1.54
S/E COST YEAR OF OPERATION	850,000	2,280,000	2,280,000	2,280,000
SUBTOTAL 944.3	1,868,202	4,632,059	4,523,617	3,513,660
TOTAL ACCOUNT 944	29,219,538	49,492,616	46,579,591	33,099,108

Table 6–6
PLANT OPERATING STAFF BUILD–UP (MAN–YEARS, 94$)

	YRS FRM STRT OF SITE WRK	–3	–2	–1	1	2	3	4	MAN–YR	COST, $
P	PLANT MANAGER	0.5	1.0	1.0	1.0	1.0	1.0	1.0	6.5	833,146
R	OPERATIONS DIVISION		0.5	1.5	21.5	28.0	37.5	38.0	127.0	7,722,829
O	MAINTENANCE DIVISION				3.5	10.0	37.1	59.0	109.5	5,347,471
T	TECHNICAL DIVISION			1.0	1.0	3.1	5.7	6.2	17.0	1,106,518
O	ADMINSTRATIVE DIVISION		0.5	1.0	6.0	7.7	32.3	56.3	103.8	4,009,815
	TOTAL	0.5	2	4.5	33	49.7	114	161	363.8	19,019,780
L	PLANT MANAGER									
D	OPERATIONS DIVISION			10.0	18.5	33.0	28.8		90.3	5,198,177
	MAINTENANCE DIVISION			1.0	6.0	22.5	58.4		87.9	4,109,545
E	TECHNICAL DIVISION			1.0	2.0	5.8	7.0		15.8	929,198
X	ADMINSTRATIVE DIVISION			1.0	4.0	3.7	13.4		22.1	934,972
P	TOTAL			13.0	30.5	65.0	107.6		216.1	11,171,892
R	PLANT MANAGER	0.5	1.0	1.0	1.0	1.0	1.0		5.5	704,969
E	OPERATIONS DIVISION		2.0	13.2	51.0	69.1	75.0		210.3	12,413,134
P	MAINTENANCE DIVISION			1.0	23.5	56.5	102.0		183.0	8,895,169
L	TECHNICAL DIVISION		1.0	3.0	8.5	12.2	15.0		39.7	2,421,607
C	ADMINSTRATIVE DIVISION		1.0	6.0	9.5	31.5	73.0		121.0	4,753,028
A	TOTAL	0.5	5.0	24.2	93.5	170.3	266.0		559.5	29,187,907
T	PLANT MANAGER	0.2	1.0	1.0	1.0	1.0	0.5		4.7	602,428
A	OPERATIONS DIVISION		2.0	20.0	45.0	56.4	31.0		154.4	9,117,240
R	MAINTENANCE DIVISION		1.0	5.0	12.0	42.1	59.0		119.1	6,013,441
G	TECHNICAL DIVISION			3.0	5.5	9.5	5.5		23.5	1,473,502
E	ADMINSTRATIVE DIVISION	0.2	2.0	6.0	9.5	27.5	24.5		69.7	3,007,351
T	TOTAL	0.4	6.0	35.0	73.0	136.5	120.5		371.4	20,213,962

PC-000447/0

training prior to loading fuel.

- The trained staff is in place 12 months before commercial operation and prepared to conduct pre-operational testing and startup operations.

The estimated cost of salaries, payroll taxes, fringe benefits, and COSO consultants is $26.7 million as shown in Table 6-5. COSO support is estimated at 9 man-years.

- Lead Plant: The buildup of permanent plant operating staff for the four module Lead Plant is assumed to follow the pattern used for the Prototype Plant as also shown in Table 6-6. Somewhat less time is required since most management and senior operations personnel will have been recruited and trained for the Prototype Plant. During the addition of the second, third and fourth reactor modules; an additional 134 equivalent full time personnel are added to the operating staff. The initial Lead Plant operating staff is estimated to include 288 full time and 12 annualized personnel. A 216 man-year effort is needed to develop staff for the Lead Plant Expansion, resulting in a total Lead Plant effort of about 580 man-years. Other major assumptions are:

  - Training of the Lead Plant Expansion staff begins 36 months prior to start of commercial operation of the second reactor module on the plant site. This will allow about 2.5 years training prior to loading fuel.

  - The trained staff is in place 9 months before commercial operation and prepared to conduct pre-operational testing and startup operations.

  The estimated cost of salaries, payroll taxes, fringe benefits, and COSO consultants for the four module Lead Plant is $43.4 million as shown in Table 6-5. COSO support is estimated at 15 man-years.

- Replica Plant: Training, startup, and operating experience is assumed to benefit the Replica Plant owner/operator through COSO activities. The on-site staff required to operate and maintain the Replica Plant is 282 personnel, including 274 full time and 8 annualized outage support personnel. The buildup of this staff during the construction period is shown in Table 6-6. A effort to develop the operating staff is estimated to 559.5 man-years. Key assumptions associated with this estimate are as follow:

  - Training of the permanent O&M staff will begin about 39 months prior to commercial operation of the first reactor module versus 48 months for the Prototype Plant.

  - The trained staff is in place 8 months before commercial operation and prepared to conduct pre-operational testing and startup operations.

PC-000447/0

The estimated cost of salaries, payroll taxes, fringe benefits, and COSO consultants for the four module Replica Plant is about $41 million as shown in Table 6-5. COSO support is estimated at 14 man-years.

Target Plant: Similar to the Replica Plant; the training, startup, and operating experience accrued through previous plants is assumed to benefit Target Plant owner/operators via COSO activities. The on-site staff required to operate and maintain the Target Plant is 241 personnel, including 233 full time and 8 annualized outage support personnel. As for the other plants, the buildup of this staff during the construction period is shown in Table 6-6. A total operating staff commitment of 371.4 man-years is estimated over a period just over 4 years. The assumptions associated with this staffing buildup include the following:

- Training of the permanent staff will begin 30 months in advance of commercial operation of the first reactor module versus 48 and 39 months for the Prototype and Replica Plants, respectively.
- The trained staff is in place 6 months before commercial operation and prepared to conduct pre-operational testing and startup operations.

The estimated cost of salaries, payroll taxes, fringe benefits, and COSO consultants for the four module Target Plant is $28.7 million as shown in Table 6-5. COSO support is estimated at 13 man-years.

6.5.2 Maintenance Materials (Account 944.2)

The maintenance materials included in this account are those used by the plant operating staff during the plant construction and start-up period. For cost estimating purposes, the use of maintenance materials is assumed to occur at the same rate per full staff year estimated for the fixed component of maintenance materials in Sections 3 and 4 of this report. It is assumed that the owner takes responsibility for plant startup prior to fuel load. Fuel load to full power operation is assumed to be 11 months for the Prototype Plant, 10 months for the Lead Plant Expansion reactors, 9 months for the Replica Plant and 7 months for the Target Plant. The resultant cost estimates for the plants are summarized in Table 6-5.

6.5.3 Supplies and Expenses (Account 944.3)

This account is similar to Account 944.2 for maintenance materials and covers the costs of supplies and expenses used by the O&M staff during the construction and start-up period. Similar to the estimate for maintenance materials, the cost of supplies and expenses is assumed to be the same per full staff year as the fixed component of the O&M supplies and expenses estimated in Sections 3 and 4 of this report. The costs for control rod and reflector block replacement and disposal are excluded. Data for "Equivalent Operating Years" in Table 6-5 are calculated by dividing the number of "Staff Man-Years Before COL" also identified in Table 6-5 by the size of plant operating staff.

The resultant cost estimates for the Prototype, Lead, Replica and Target Plant supplies and expenses are summarized in Table 6-5.

6.6 GENERAL AND ADMINISTRATIVE (Account 945)

An allowance of 15% of Accounts 941, 943 and 944 is assumed to cover general and administrative (G&A) expenses. This allocation was used in prior estimates and in the calculation of other operating G&A expenses in Sections 3 and 4 of this report.

6.7 SUMMARY OF GT-MHR OWNER'S COSTS (Account 94)

The GT-MHR owner's costs are summarized in Table 6-7. The estimates in accounts 941 through 945 are considered "most likely" values. A 15% contingency is applied to their sum as a judgmental increment to effect a "mean" estimate; i.e., an estimate for which actual costs are expected to have an equal likelihood of being higher or lower. A comparison reveals the expected trend of decreasing owner's costs as the stage of plant development advances. Owner's costs for the "equilibrium" Target Plant are assumed to be the same as the Target Plant except that spare turbomachinery will be shared with another plant and simulators will be shared through COSO as described in Section 6.4.3.

Table 6-7
GT-MHR OWNER'S COST ESTIMATE ('94$)

ACCOUNTS 941, 942, 943, 944, 945	PROTOTYPE PLANT	LEAD PLANT	REPLICA PLANT	TARGET PLANT
941 PROJECT MANAGEMENT EXPENSES				
941.1 ENGINEERING/SITE MGT	2,166,662	4,272,505	1,969,002	1,611,692
941.2 QUALITY ASSURANCE	2,031,650	3,608,649	1,621,536	1,501,062
941.3 PROJECT LICENSING	4,059,286	5,928,578	2,904,286	2,204,617
941.4 PROJECT MGT & CNTRL	4,507,763	7,773,279	4,270,976	3,574,345
TOTAL ACCOUNT 941	12,765,360	21,583,012	10,765,799	8,891,716
942 FEES, TAXES AND INSURANCE				
942.1 OWNER'S PROPERTY TAXES	0	50,000,000	48,000,000	42,000,000
942.2 LICENSING FEES/PERMITS	10,850,000	17,825,000	5,975,000	5,975,000
942.3 OWNER'S INSURANCE	0	4,410,000	4,410,000	2,530,000
TOTAL ACCOUNT 942	10,850,000	72,235,000	58,385,000	50,505,000
943 SPARE PARTS & CAPITAL EQUIPMENT				
943.1 OWNER'S SPARE PARTS	30,560,000	36,240,000	33,504,000	29,956,000
943.2 CNSMBLES/SUPPLS/COOLNT	462,432	1,439,421	1,462,045	1,443,501
943.3 EQUIPMENT AND FURNISHINGS	10,450,000	13,850,000	13,850,000	8,950,000
TOTAL ACCOUNT 943	41,472,432	51,529,421	48,816,045	40,349,501
944 STAFF TRAINING AND STARTUP				
944.1 PLANT OPERATING STAFF	26,673,002	43,415,557	40,953,474	28,727,949
944.2 MAINTENANCE MATERIALS	678,333	1,445,000	1,102,500	857,500
944.3 SUPPLIES AND EXPENSES	1,868,202	4,632,059	4,523,617	3,513,660
TOTAL ACCOUNT 944	29,219,538	49,492,616	46,579,591	33,099,108
945 GENERAL AND ADMINISTRATIVE	12,518,599	18,390,757	15,924,215	12,351,049
CONTINGENCY (15%)	16,023,889	31,984,621	27,070,598	21,779,456
TOTAL OWNER'S COST	**122,849,819**	**245,215,427**	**207,541,248**	**166,975,830**

SECTION 7

REFERENCES

1. *GT-MHR Conceptual Design Description Report,* General Atomics, GA 910720, November 1994.

2. *Utility/User Incentives, Policies, and Requirements for the Gas Turbine-Modular Helium Reactor,* Gas-Cooled Reactor Associates, GCRA 94-004 (EPRI Project RP3630-01), October 1994.

3. *Estimate of Owner's Cost for Modular HTGR Plants,* Gas-Cooled Reactor Associates, GCRA 90-003, Revision 1, July 1993.

4. *Feasibility Study for a Modular High Temperature Gas-Cooled Reactor Lead Plant Project,* prepared by Bechtel, Consumers Power Company, Gas-Cooled Reactor Associates General Atomics, HTR Gmbh, and Siemens, May 1990.

5. *Utility Projections of Operation and Maintenance Costs for Modular HTGR Plants,* Gas-Cooled Reactor Associates, GCRA 90-005, March 1990.

6. *Utility Projections of Operation and Maintenance Costs for Modular HTGR Plants,* Gas-Cooled Reactor Associates, GCRA 90-005, Revision 1, July 1993.

7. *O&M Cost/Risk Drivers at Current Nuclear Plants and MHTGR Development Priorities,* Gas-Cooled Reactor Associates, GCRA 94-001 (EPRI Project RP3630-01), January 1994.

8. *NUMARC Says U.S. Plants Average 1.8 Times More Workers Than Europe,* Nucleonics Week, April 1, 1993.

9. *Cost Estimate Guidelines for Advanced Nuclear Power Technologies,* Oak Ridge National Laboratory, ORNL/TM-10071/R3, March 1993.

10. *A Risk-Based Regulation Methodology for Deriving MHR Operational Licensing Requirements,* Gas-Cooled Reactor Associates, GCRA 94-002 (EPRI Project RP3630-01), June 1994.

11. *Development of a Central Operation Support Organization for the MHTGR,* Gas-Cooled Reactor Associates, GCRA 90-004, April 1990.

12. *Cost Estimates for Modular HTGR Operation and Maintenance,* Oak Ridge National Laboratory and Gas-Cooled Reactor Associates, DOE-HTGR-87-087, August 1987.

PC-000447/0 1

13. Letter from C. B. Scott (General Atomics) to L. D. Mears (Gas-Cooled Reactor Associates), *Annual Operating & Maintenance Costs - Replaceable Reflectors and Control Rods - GT-MHR*, October 24, 1994.

14. NRC SECY-93-092, *Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and PIUS) and CANDU Designs and Their Relationship to Current Regulatory Requirements,* April 8, 1993.

15. *Controlling Nuclear O&M Costs*, Power Engineering Magazine, pp. 25-30, August 1994.

16. *Industry Updates Strategic Plan to Reduce O&M Costs*, Nuclear Energy Overview, NEI, November 7, 1994.

17. Letter to Lewis, J.G. et al, from Kessler, W.E., *MHTGR FOAK Owner's Costs,* Consumers Power Company, October 10, 1989.

18. *MHTGR Cost Estimating Groundrules & Procedures,* HP 10701, Revision 4, May 1993.

PC-000447/0

Appendix A

CONCEPTUAL FRAMEWORK FOR DEVELOPING GT-MHR TECHNICAL SPECIFICATIONS

1. INTRODUCTION

A critical assumption in the estimate of O&M costs in this report is that simplified regulatory practices based on the principles of risk-based regulation will be accepted by the NRC and industry. Since the inception of work on the modular gas-cooled reactor safety concept in the early 1980s, its potential to simplify the means to accomplish safety functions and regulatory requirements has been recognized (Reference A1). This Appendix presents a conceptual framework for developing technical specifications for the GT-MHR based on the principles of risk-based regulation; i.e., the allocation of licensee and regulatory resources in accordance with the risk-significance of equipment reliability and personnel actions. The background of current U.S. regulations, technological differences between GT-MHR and LWR, and the GT-MHR approach to nuclear safety are considered in developing this framework and are summarized herein. Finally, this Appendix presents "strawman" criteria for GT-MHR technical specifications adapted from the NRC *Final Policy Statement on Technical Specifications Improvements for Nuclear Power Reactors* and provides recommendations for future work.

2. BACKGROUND

2.2 EMERGENCE OF RISK-BASED REGULATION

The study reported in Reference A2 was undertaken to advance a methodology for deriving operational licensing requirements for the Gas Turbine-Modular Helium Reactor (GT-MHR) in a manner that appropriately addresses the reactor's passive features and inherent characteristics. While the bulk of U.S. regulatory practice is rooted in deterministically derived provisions for LWRs, there are strong indications of increased acceptance of a risk-based regulation (RBR) philosophy. The NRC staff has defined risk-based regulation as the use of probabilistic risk assessment (PRA) insights to focus licensee and regulatory attention on design and operational issues commensurate with their impact on risk to the public (Reference A3).

The application of RBR in the regulatory process is expected to allow the operators of current nuclear plants greater flexibility to efficiently manage their plants while maintaining or increasing the current level of safety. This shift in regulatory philosophy is fortuitous for GT-MHR regulatory development since its economic potential is predicated on establishing safety characteristics such that the extensive use of commercial practices is acceptable. Since RBR is based on the systematic yet unprejudiced nature of PRA procedures, it also offers a framework for developing regulatory provisions for the GT-MHR independent of deterministic licensing practices that has evolved over the course of LWR deployment.

PC-000447/0

2.2 TECHNOLOGICAL DIFFERENCES BETWEEN LWR AND GT-MHR

The extensive and complex body of regulatory practice that has evolved in the United States over the past three decades has been dominated and defined by current LWR technology. The implications of fundamental differences between LWR and MHR technology must be understood at the outset of deriving appropriate regulations for the GT-MHR. A brief review of LWR technological characteristics that have guided the evolution of current safety regulations, and comparison with MHR attributes, is provided in the following paragraphs. It is acknowledged that these insights pertain to the potential for an advanced reactor. Realizing such potential is contingent upon the success of design development and licensing programs.

The hazard associated with current LWRs that has been identified as posing the greatest risk to the public is the consequences associated with core damage. Core damage frequency is a "surrogate" risk measure in that core damage is an LWR event that defines a threshold to rapid progression of core redistribution with the potential for a large energetic source term, as opposed to a quantified health risk. The use of core damage frequency as a risk measure is an important simplifying assumption for LWR technology. Its use in the context of operating regulations is necessary because severe LWR accidents leading to the release of fission products can include highly complex phenomena. For example, a severe accident sequence might include core melt ejection through the reactor vessel to the containment, the formation of combustible gases such as hydrogen and carbon monoxide when molten metallic core material (corium) reacts with containment concrete, high energy pressure loads on the containment due to steam line rupture or gas explosion, structural failure or degradation of the containment, and the energetic release of fission products propelled by steam and combustible gases.

All of these phenomena have been the subject of extensive safety research, and plant designs incorporate provisions to mitigate the progression of such accident sequences. However, the characterization of severe accidents is described as entailing "inherent uncertainties."[(1)(2)] (See also Reference A4). As a result of significant uncertainties in characterizing risk to the public, current LWR operating and regulatory practice is oriented to avoiding the severe accident domain. Thus, challenges to safety-related equipment are considered unacceptable and incur regulatory sanctions when they do occur.

While the GT-MHR core can be damaged in the literal sense, the movement of significant amounts of fuel from its design location requires the decomposition of ceramic

---

(1) The NRC staff notes, "... the use of probabilistic information in developing performance based criteria may be more appropriate and robust, when applied to the potential for severe core damage or to system availability (Level 1) under given conditions rather than to public risk (Level 3). The inherent uncertainties in assessments of individual or societal risk make analyses of such parameters more amenable to comparisons with goals rather than determination of compliance with criteria."

(2) Such severe accident sequences can be treated analytically within the context of RBR methodology via another surrogate risk measure, "conditional containment failure probability;" however, the engineering algorithms necessarily entail such inherent uncertainties.

fuel particle coatings, a process that occurs slowly under conditions of sustained high temperature, fluence and chemical attack, concomitant with the release of sufficient energy to cause dispersal. No credible accident sequences have been identified that lead to core disarray or to the energetic release of a large inventory of fission products to the environs. The GT-MHR safety concept arrests the progression of events prior to the relocation of fuel from its design location within ceramic coated particles. Even the consequences of severe events (event frequencies in the range 1×10^{-4} to 5×10^{-7} per plant year) are limited to the dispersion of a very small amount of fission products present in initially defective fuel particles or contaminants.

In this context, the GT-MHR has no counterpart to core damage frequency as a threshold of safety degradation. Similarly, the concept of conditional containment failure probability does not apply. Therefore, the GT-MHR safety concept eliminates many of the uncertainties associated with calculating health risk to the public. With consideration of uncertainties, it limits immediate public health risk during highly improbable events to a level below the regulatory threshold for EPA requirements for plans to shelter and evacuate the offsite public. In addition, the GT-MHR permits successive challenges to reactor components (e.g., multiple loss-of-coolant or loss-of-flow events) without exposing the public to significant risk.[3]

In contrast with current technology, GT-MHR technology permits characterization of absolute risk and its use in regulatory processes. Moreover, absolute risks associated with improbable events are in a completely different domain than those of current plants; i.e., a domain for which planning for public intervention is the policy consideration versus a domain for which immediate health effects and latent fatalities are the considerations.

3. THE GT-MHR SAFETY CONCEPT AND ANALYSES

MHR safety analyses center on applying the laws of physics to verify the conditions imposed on the ceramic-coated fuel particle during postulated accidents. Proof of adequate safety need not rely on the reliability of pumps, valves, and their associated services or on the probability of correct operator actions. Focusing on issues of fuel particle integrity simplifies MHR safety analyses. Passive features and inherent characteristics incorporated in the design to accomplish the following four functions ensure that radionuclide retention within the fuel particle remains acceptable:

1. Control of core geometry
2. Control of core heat generation

...

(3) The MHR safety concept allows the plant to be operated with an "acceptable number of challenges" to equipment as opposed to pursuing an operating goal of "eliminating challenges" to safety-related equipment per NRC Technical Specification criteria for current LWR (See discussion in Section 4). Because inherent characteristics limit the conditions imposed on the MHR's two principal fission product barriers (the ceramic fuel particle coatings and the steel reactor coolant boundary), their failure mode is progressive degradation; i.e., cumulative damage. In both cases, time-at-temperature/stress, the number of strain cycles, and fluence are key parameters in determining service life. For example, the duty cycle for MHR vessels includes three conduction cooldown events in the life of the plant. The robustness of the MHR containment system resides in its ability to sustain several challenges to fission product barriers without significant risk to the public.

PC-000447/0

3. Control of core heat dissipation
4. Control of chemical attack

The MHR safety concept has been applied in the designs of 350 MWt and 450 MWt reactor modules for steam cycle MHR plants and as well as in the design of reactor modules for the GT-MHR (see References A5 and A6). The fundamental safety principles are common to these designs. Figure A-1 shows the design features and equipment selected by designers to ensure that the above functions are reliably accomplished over the full range of licensing basis events for the steam cycle MHR concept.

The equivalent of a Level 3 PRA was developed for the MHR steam cycle plant conceptual design; i.e., the analysis includes an assessment of consequences (absolute risk to the public). It is the most comprehensive probabilistic assessment of the MHR safety concept conducted to date; albeit at the conceptual design stage and without the aid of computer integration. Among the insights from PRA and deterministic analyses are that the MHR is fundamentally different than the LWR in the following respects:

- The reactor coolant does not serve a safety function with regard to controlling nuclear heat generation (i.e., water reactor coolant serves as a neutron moderator) or to controlling decay heat dissipation (i.e., water reactor coolant transfers heat to the environment).

  Local core melt, core disarray, a breach of the reactor coolant boundary, core melt ejection, and the release of a large inventory of fission products cannot occur as result of a result of a loss of coolant or anticipated transient without scram (ATWS) accident[4].

- The potential for a large, energetic source term is eliminated. (See Reference A7[5]).

- Long time intervals are available for operator actions and the restoration of equipment to arrest the progression of events.

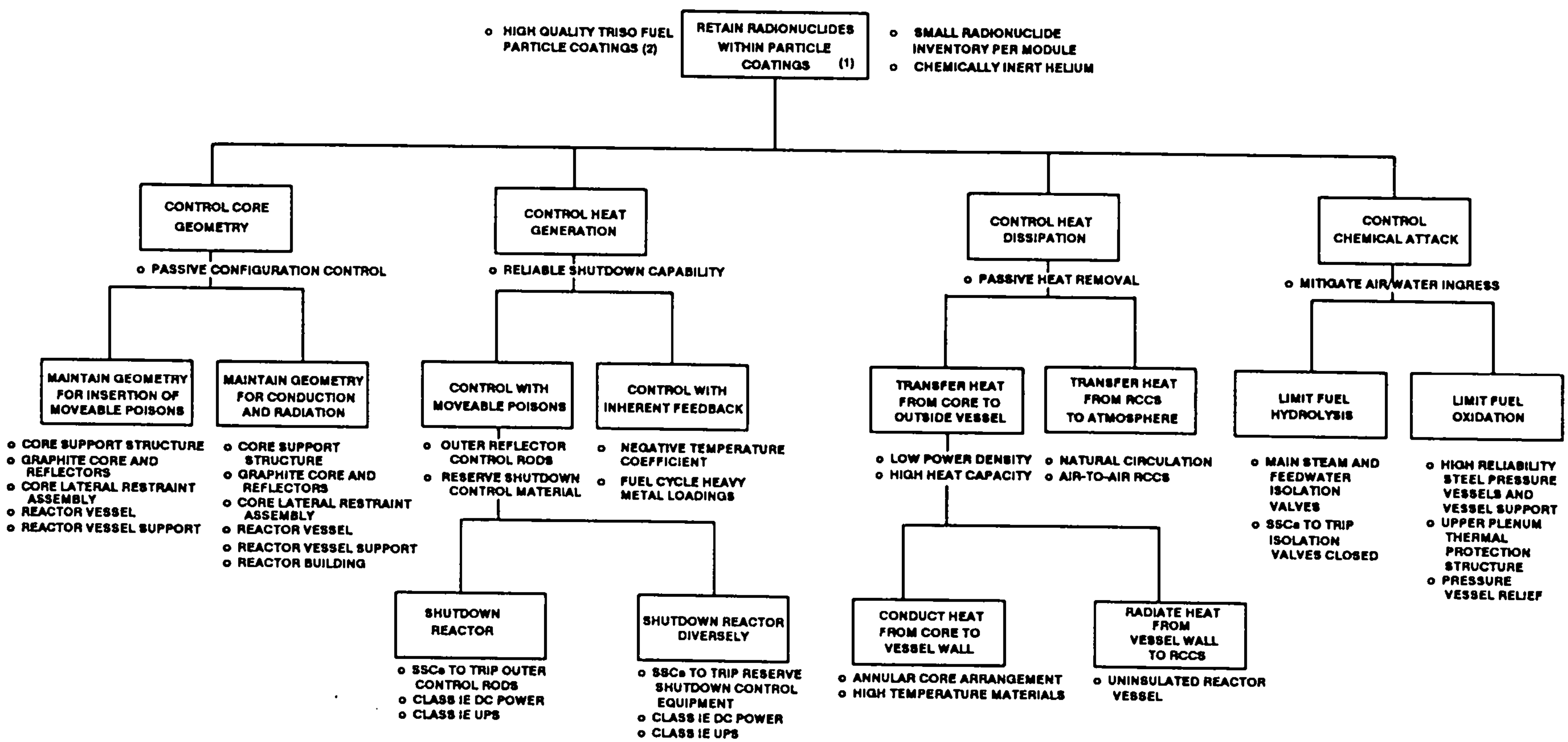
In addition, the ultimate means to accomplish MHR decay heat removal (conduction, convection and radiation to the ultimate heat sink) and to control nuclear heat generation (reactor negative temperature coefficient) are always present and continuously functioning, and therefore do not require initiating signals, moving parts, or human actions.

---

(4) No credible accident sequences have been identified that lead to core disarray or to the energetic release of a large inventory of fission products to the environs. In this context, the MHR has no counterpart to core damage frequency (CDF) as a threshold of safety degradation. See the discussion Section 5.

(5) With regard to whether a conventional containment structure or some other mitigation system or process should be required for the MHR, the ACRS stated, "Neither the designers, the NRC staff, nor members of the ACRS have been able to postulate accident scenarios of reasonable credibility, for which an additional physical barrier to release of fission products is required in order to provide adequate protection to the public."

Figure A-1
MHR RADIONUCLIDE CONTROL FUNCTIONS AND DESIGN SELECTIONS



(1) ATTRIBUTES ARE PRECEDED BY o
DESIGN SELECTIONS ARE PRECEDED BY o
(2) ALLOWABLE COATING DEFECTS DESIGNED TO MEET EPA PROTECTION ACTION GUIDELINES

MHRRADIO.DRW

PC-000447/0

PC-000447/0

4. "STRAWMAN" GT-MHR TECHNICAL SPECIFICATION CRITERIA

The NRC and industry have worked to improve technical specifications for current LWRs over the past decade. This effort culminated in issuance of the *Final Policy Statement on Technical Specifications Improvements for Nuclear Power Reactors* in July 1993 (Reference A8). It provides insight to the Commission's views on the use of PRA to derive technical specifications and a point of departure for developing a framework for GT-MHR technical specifications. The following paragraphs contain excerpts from the Policy Statement with annotations explaining "strawman" adaptations to the GT-MHR.

> . . . the Commission has added a fourth criterion[6] to capture requirements which operating experience or probabilistic safety assessment (PSA) show to be significant to public health and safety. . . the Commission concluded the criteria should be codified through rulemaking.
>
> . . . Some commenters stated that if PSA is used to impose Technical Specifications for some high-risk items, it should also be used to remove some low-risk items. . . Since the first three criteria in the Policy Statements are derived from the plant safety analysis report which is deterministic in nature,[7] (but which itself incorporates qualitative risk insights) the Commission believes that a broad application of PSA to remove individual requirements from Technical Specifications is generally counter to the philosophy of the first three criteria.
>
> The extension of the sole use of PSA to remove individual requirements from Technical Specifications would need to be founded in a broader policy of risk-based regulation which the Commission is currently pursuing at a level more inclusive than Technical Specification improvements. . .
>
> The Commission policy in this regard is consistent with its Policy Statement on "Safety Goals for the Operation of Nuclear Power Plants," 51 FR 30028, August 21, 1986. The Policy Statement on Safety Goals states in part, ". . . probabilistic results should be reasonably balanced and supported through use of deterministic arguments. In this way, judgments can be made. . . about the degree of confidence to be given to these [probabilistic] estimates and assumptions.

---

(6) The "fourth criterion" is with regard to the three presented in the Proposed Policy Statement of February 6, 1987. The four LWR criteria and "strawman criteria" for the MHR are discussed later.

(7) This statement makes the point that the criteria put forth in this Policy Statement are derived from deterministic safety analyses for LWR; therefore, specific to current LWR technology and design philosophy; i.e., based on the use of diverse and redundant active systems to avoid a loss-of-coolant accident and a large, energetic source term. Alternate criteria, specific to the passive design philosophy and founded on the principles of risk-based regulation, must be developed for the MHR.

The Policy Statement identifies four criteria for defining the scope of Technical Specifications. These criteria are intended to be consistent with . . . 10CFR50.36.

. . . emphasis is placed on two general classes of technical matters: (1) those related to the prevention of accidents,[8] and (2) those related to mitigation of the consequences of accidents. The first is captured by criteria (1), (4) and to some extent criterion (2) in that they alert the operator to a situation when accident initiation is more likely. The second is explicitly addressed and captured by criteria (2), (3) and (4).[9]

The purpose of Technical Specifications is to impose those conditions or limitations upon reactor operation necessary to obviate the possibility of an abnormal situation or event giving rise to an immediate threat[10] to the public health and safety by identifying those features that are of controlling importance[11] to safety and establishing on them certain conditions of operation which cannot be changed without prior Commission approval.

The following criteria[12][13] delineate those constraints on design and operation of nuclear power plants that are derived from the plant safety

---

(8) For the purposes of interpreting guidance from this Policy Statement for use in developing MHR Technical Specifications, the term "accident" is taken to mean the potential to move sufficient amounts of fuel from its design location (i.e., core damage or disarray) to constitute an immediate threat to public health and safety (i.e., potential for a prompt dose exceeding 10CFR100 limits).

(9) Within the above interpretation of the term "accident," the MHR passive design philosophy places much greater emphasis on accident prevention than is the case for LWR in that passive features and inherent characteristics arrest the progression of events prior to the movement of significant amounts of fuel from its design location within the core over a credible range of events (i.e., the range of events satisfactory to the NRC and ACRS).

(10) For the purpose of developing MHR Technical Specifications, the phrase "obviate the possibility" is interpreted as pertaining to Design Basis Events; i.e., events of frequency $>10^{-4}$, and the phrase "immediate threat" is defined as the potential for a prompt fission product release exceeding 10CFR100 limits.

(11) For the purposes of developing MHR Technical Specifications, the phrase "those features that are of controlling importance" is interpreted to mean the attributes, or combination of attributes, of SSCs that, if diminished or destroyed, would potentially result in an immediate threat to public health and safety; i.e., doses exceeding 10CFR100 limits. These attributes, or combination of attributes, arrest the progression of Design Basis Events prior to an "accident" as defined in Footnote (9). They are identified by application of the principles of risk-based regulation methodology.

(12) These criteria are essentially the same as those used for the AP600 - Chapter 16, AP600 Standard Safety Analysis Report, June 26, 1992.

(13) "Strawman" adaptations specific to the MHR are noted by ~~strikeout~~ and <u>underline</u>. While these MHR criteria are in a very early stage of development, they are based on a balance of probabilistic and deterministic evaluations and application of the principles of risk-based regulation. They are posed here as a starting point for development within the MHR Program, to be refined as design and technology development allow more comprehensive treatment and as dialogue with the NRC progresses.

PC-000447/0

analysis report and that belong in Technical Specifications in accordance with 10CFR50.36 and the purpose of Technical Specifications stated above.

GT-MHR Criterion 1: Installed instrumentation that is used to detect, and indicate in the control room, a significant abnormal degradation of the ~~reactor coolant pressure boundary~~ fuel particle coatings.

Discussion of GT-MHR Criterion 1: A basic concept in the adequate protection of the public health and safety is the prevention of accidents by retaining fission products within ceramic coated fuel particles for the full range of licensing basis events. . . ~~thus reducing the likelihood of a loss of coolant accident.~~ This criterion is intended to ensure that Technical Specifications control those instruments specifically installed to detect excessive ~~reactor coolant system leakage~~ fission products within the reactor coolant pressure boundary.

GT-MHR Criterion 2: ~~A process variable, design feature,~~ A design feature, process variable, or operating restriction that is an initial condition of a Design Basis ~~Accident (DBA)~~ Event (DBE) or Transient analysis that either assumes the failure of or presents ~~a challenge~~ an unacceptable challenge[14] to the integrity of a fission product barrier.

Discussion of GT-MHR Criterion 2: Another basic concept in the adequate protection of the public health and safety is that the plant should be operated within the bounds of the initial conditions assumed in the existing Design Basis ~~Accident~~ Event and Transient analyses and that the plant will be operated to preclude ~~unanalyzed accidents and transients~~ unacceptable challenges. . . The purpose of this criterion is to capture those process variables that have initial values assumed in the Design Basis ~~Accident~~ Event and Transient analyses, and which are monitored and controlled during power operation. . . This criterion also includes. . . design features and operating restrictions (pressures/temperatures/fluence limits) and cumulative damage to primary fission product barriers needed to preclude ~~unanalyzed, accidents and transients~~ unacceptable challenges.

(14) An "unacceptable challenge" would cause a primary fission product barriers to exceed cumulative damage criteria (see Footnote (23) for discussion). This approach differs from regulation based on the probability of an accident (e.g., core damage) and poses regulation based on a finite number of events, the cumulative effects of which degrade the margin with which passive features accomplish safety functions.

PC-000447/0

GT-MHR Criterion 3: A structure, system or component that is part of the primary ~~success path~~[15] means to accomplish safety functions and which functions or actuates to ~~mitigate~~ arrest the progression of a Design Basis ~~Accident~~ Event or Transient that either assumes the failure of or presents ~~a challenge~~ an unacceptable challenge to the integrity of a fission product barrier.

> Discussion of GT-MHR Criterion 3: A third concept in the adequate protection of the public health and safety is that in the event that a postulated Design Basis ~~Accident~~ Event or Transient should occur, structures, systems, and components are available to function or to actuate in order to ~~mitigate the consequence~~ arrest the progression of the Design Basis ~~Accident~~ Event or Transient. . . It is the intent of this criterion to capture into Technical Specifications only those structures, systems, and components that are part of the primary ~~success path~~ means to accomplish safety functions of a safety sequence analysis. . . The primary ~~success path~~ means to accomplish safety functions for a particular mode of operation does not include backup and diverse equipment.

GT-MHR Criterion 4: A structure, system, or component which operating experience or probabilistic safety assessment has shown to be significant to public health and safety.

> Discussion of GT-MHR Criterion 4: It is Commission policy that licensees retain in their Technical Specifications LCOs, action statements, and Surveillance Requirements for the following systems which operating experience and PSA have generally shown to be significant to public health and safety and any other SSCs that meet this criterion:
>
> - ~~Reactor Core Isolation Cooling/Isolation Condenser~~
> - ~~Residual Heat Removal~~
> - ~~Standby Liquid Control~~
> - ~~Recirculation Pump Trip~~

(15) The phrase "success path" is synonymous with the phrase "means to accomplish safety functions." The latter is used in the NRC's Advanced Reactor Policy Statement which encourages innovation and simplicity in this regard. With a few exceptions, the "means to accomplish safety functions" is embodied in the design of the reactor module; e.g., decay heat rejection via conduction, convection and radiation. The functional analysis approach to the development of MHR Technical Specifications (versus a systems approach) should be used to facilitate the understanding of changes in design philosophy from current LWR to the MHR. For example, while the reactor vessel provides safety-related functions with regard to reactor configuration, decay heat rejection, and prevention of chemical attack; its function of retaining reactor coolant is not safety-related. Experience has shown that these distinctions are initially difficult to communicate to those unfamiliar with the MHR.

PC- 000447/0

- Diverse and redundant reactor shutdown systems[16]

  It is the intent of this criterion that those requirements that PSA or operating experience exposes as significant to public health and safety, consistent with the Commission's Safety Goal and Severe Accident Policies, be retained or included in Technical Specifications. . . Further, as a part of the Commission's ongoing program of Improving Technical Specifications, it will continue to consider methods to make better use of risk and reliability information for defining future generic Technical Specification requirements.

. . . with regard to the fourth criterion, each Limiting Condition of Operation, Action, and Surveillance Requirement should have supporting Bases. The Bases should at a minimum address the following questions and cite references to appropriate licensing documentation (e.g., FSAR, Topical Report) to support the Bases.

1. What is the justification for the Technical Specification, i.e., which criterion requires it to be in the Technical Specifications?

2. What are the bases for each LCO, i.e., why was it determined to be the lowest functional capability or performance level for the system or component in question necessary for safe operation of the facility and what are the reasons for the Applicability of the LCO?

3. What are the Bases for each Action, i.e., why should this remedial action be taken if the associated LCO cannot be met, how does this Action relate to other Action associated with the LCO, and what justifies continued operation of the system or component at the reduced state from the state specified in the LCO for the allowed time period?

4. What are the Bases for each Limiting Safety System Setting?

5. What are the Bases for each Surveillance Requirement and Surveillance Frequency, i.e., what specific functional requirement is the surveillance designed to verify?. Why is this surveillance necessary at the specified frequency to assure that the system or component function is maintained, that facility operation will be within the safety limits, and that the LCO will be met?

. . . In answering these questions the Bases for each number (e.g., Allowable Value, Response Time, Completion Time, Surveillance Frequency), state, condition,

---

[16] The control rods and RSCE are identified as safety-related (despite low risk significance) on the basis that they provide redundant means to achieve a subcritical reactor state and <u>ultimately arrest challenges to fission product barriers.</u>

and definition (e.g., operability) should be clearly specified. As an example, a number might be based on engineering judgment, past experience or PSA insights but this should be clearly stated.

5. RECOMMENDED APPROACH TO GT-MHR TECHNICAL SPECIFICATIONS

It is recommended that an effort to develop conceptual technical specifications for the GT-MHR be implemented at an early stage. Pursuing such an effort ensures that:

- The technical issues underlying the business risks of owning nuclear power plants will be addressed early in the design, technology and regulatory development program.

- The economic benefits of GT-MHR passive features and inherent characteristics are appropriately reflected in O&M cost estimates.

An effort to develop technical specifications would also provide designers with an opportunity for productive interaction with utility/user personnel and feedback to the design process.

The following insights from the work reported herein are offered for further consideration:

- Risk analysis technology should be used to ensure that operating programs and regulations are consistent with the risk-significance of plant equipment, personnel actions, and the provisions of emergency plans.

- GT-MHR technology appears to offer the potential for establishing a clear interface between the regulator and the owner/operator; i.e., only a small scope of equipment is risk-significant and most of that is passive. This delineation should be clarified and implemented through the technical specifications development process.

- The technical specifications should be organized by function (e.g., by the radionuclide control functions shown in Figure A-1) rather than by system. This approach should facilitate the initial use of results from safety analyses in the development of technical specifications and plant operating programs, as well as the use of risk analysis methods in the operating plant.

6. REFERENCES

A1. Reutler, R., and G. H. Lohnert, *The Modular High Temperature Reactor*, Nuclear Technology: Vol. 62, pp. 22-30, July 1983.

A2. *A Risk-Based Regulation Methodology for Deriving MHR Operational Licensing Requirements*, Gas-Cooled Reactor Associates, GCRA 94-002 (EPRI Project RP3630-01), June 1994.

PC-000447/0

A3. USNRC, *Memorandum to the Commission on Risk-Based Regulation*, February 22, 1993.

A4. D. Ward (Chairman ACRS) to K. Carr (Chairman NRC), *Proposed Criteria to Accommodate Severe Accidents in Containment Design*, May 17, 1991.

A5. Gotschall, H. L., *The Modular High Temperature Gas-Cooled Reactor: A Cost/Risk Competitive Nuclear Option*, Journal of Engineering for Gas Turbines and Power, Transactions of the American Society of Mechanical Engineers, January, 1994.

A6. *Evaluation of the Gas Turbine Modular Helium Reactor*, DOE-HTGR-90308, issued by Gas-Cooled Reactor Associates, December 1993.

A7. W. Kerr (Chairman ACRS) to L. Zech (Chairman NRC), *Preapplication Safety Evaluation Report for the Modular High Temperature Gas-Cooled Reactor*, October 13, 1988.

A8. USNRC, *Final Policy Statement on Technical Specifications Improvements for Nuclear Power Reactors*, Federal Register/Vol. 58, No. 139, July 22, 1993.

RE-000447/0

Appendix B

FUNCTIONS OF THE GT-MHR CENTRAL OPERATION SUPPORT ORGANIZATION

1. INTRODUCTION

The mission of a Central Operation Support Organization (COSO), and options for its formation, were initially outlined by the GCRA Utility Working Group in 1990 (see Reference B1). The COSO role was envisioned as a means of extending design standardization to plant operations and as a cost effective means of providing specialist resources to plant owners. In the interim, the scope of off-site support services to be provided by COSO has been further developed in staffing plans and O&M cost estimates for modular gas-cooled reactors. This Appendix describes the mission and functions envisioned for a Central Operation Support Organization (COSO) during GT-MHR commercial deployment. It also presents recommendations for further defining the role and costs of such an entity.

As described in Reference B2, the deployment of current nuclear plants severely taxed the technical management resources of virtually every U.S. nuclear utility. The complexity and variety of plant designs led to individual regulatory treatment which placed individual utilities in vulnerable positions to contend with the litigious U.S. regulatory process. In addition to contending with plant operations and interacting with the NRC, individual utilities must conduct a technical interface with a proliferation of oversight agencies; e.g., INPO, the Environmental Protection Agency (EPA), the Federal Emergency Management Agency, and the NEI. These factors, the concern that a weak-performing utility might precipitate an accident, and the potential for nuclear regulatory action to place company-wide financial ratings at risk all contributed to the need for a much larger contingent of skilled service professionals and consultants than initially envisioned. These factors are among the most important O&M cost drivers at current plants.

As described in Reference B3, the GT-MHR deployment strategy poses that such issues should be addressed via an owner/operator-based COSO offering specialized skills and services (see Table B-1) as part of the emerging utility/user infrastructure. The functions assumed for COSO in the body of this report are summarized in the following sections.

2. COSO ROLE AND FUNCTIONS

2.1 THE COSO MISSION

The COSO mission is to represent operator interests in GT-MHR plant design, licensing, construction, startup and operation in a manner consistent with the MHR deployment strategy; i.e., to guide the development of plant operating characteristics and regulations so that the GT-MHR is compatible with resources of a broad range of owner/operators. Assuming that owner/operator interests (e.g., COSO) lead an ongoing program sustained throughout design development and early deployment to establish management and operating practices appropriate to the GT-MHR within the industry, the

PC-000447/0

Table B-1
FUNCTIONS OF THE GT-MHR CENTRAL OPERATIONAL SUPPORT ORGANIZATION

- Generic operating practices and regulatory interactions
  - Review/condensation/dissemination of operating experience
  - Resolution of generic licensing-related issues with the NRC
- Development, maintenance, and upgrading of plant operational support programs
  - Design baseline control, design basis documentation support
  - Operating and refueling procedures
  - Simulation facilities, INPO accredited training program support, plant reliability database
  - Surveillance and in-service inspection (ISI) programs
  - Preventive maintenance, spare parts, plant modification programs
  - Security plans and procedures
- Central fuel management support
  - Fuel burnup history/future reload support
  - Software development/maintenance
  - Fuel procurement support
- Management and administration of pooled spare parts inventory.
- Central vendor/contractor qualification program

resulting demands on the owner/operator plant organization should be on par with those for other modern commercial enterprises involving hazardous materials. Generic regulatory interactions, wherein COSO acts as the point of inquiry and response to proposed regulatory changes, is considered a particularly critical function for avoiding the economic risks associated regulatory ratcheting and instability at current nuclear plants.

2.2 THE COSO ROLE DURING THE GT-MHR DEVELOPMENT PHASE

It is assumed that COSO will be established by prospective commercial participants early in the GT-MHR development program as an integral part of the vendor/buyer /regulatory infrastructure. Prior to Prototype Plant deployment, COSO's function will be to translate operating plant needs into design requirements and operating programs for development by vendor entities. COSO personnel will also conduct periodic reviews to confirm that design requirements are interpreted appropriately and that the design includes adequate provisions for O&M functions such as those outlined in the examples in Table B-2.

The most important role envisioned for COSO during the development phase is in the area of plant operating programs. As discussed in the body of this report, a critical assumption with regard to projected O&M costs is that those programs are in place well in advance of plant startup. Long before such programs are needed at the plant site, the major elements of operating programs should be established so that operational considerations can be addressed in design reviews without substantial risk to design program costs and schedules. The programs should be in nearly final at the start of plant staff training occurs about three before fuel loading of the Prototype Plant. Initial outlines of operating programs currently envisioned for the GT-MHR are presented in Appendix C of this report.

2.3 THE COSO ROLE DURING PROTOTYPE PLANT DEPLOYMENT

The COSO role during Prototype Plant deployment will be shaped by cost/risk sharing arrangements yet to be negotiated; however, the focus of COSO activities will remain on advancing its capability to support commercial plants. For example, it is anticipated that COSO will play a lead role in regulatory interactions pertaining to operational licensing requirements, demonstrations of the operator role, and the adequacy of operating programs during both Prototype Plant deployment and the review of the Lead Plant design. COSO will also play a lead role in training the Prototype Plant operating staff and in conducting owner/operator interface between the government interests, vendors and prospective Lead Plant owners during this period. This experience will position COSO to support commercial deployment of NRC certified standard design.

2.4 THE COSO ROLE DURING COMMERCIAL DEPLOYMENT

It is assumed that COSO will be sufficiently established to play a lead role in staff development and regulatory interactions aimed at maintaining standard O&M programs for the Lead Plant and follow-on commercial plants. The functions outlined for COSO in the body of this report are summarized by the divisions of the assumed GT-MHR plant

PC-000447/0 1

Table B-2
COSO DESIGN REVIEW FUNCTIONS - EXAMPLES

- PLANT PERSONNEL MOVEMENT
  - The plant arrangement, equipment location, security measures, and provisions for personnel access should consider efficient personnel movement, particularly during refueling outages.
- EQUIPMENT QUALIFICATION REQUIREMENTS
  - The design should avoid locating instrumentation in a harsh environment and thereby ease maintenance work and equipment qualification requirements.
- EQUIPMENT REDUNDANCY
  - The design should incorporate sufficient redundancy to meet the availability goals and limit the likelihood of shutdowns due to failure of a single piece of equipment. Appropriate attention should be given to ancillary equipment such as control room chillers, computer room chillers, instrument air compressors, etc.
- FIRE PROTECTION PROGRAM (10CFR50 APPENDIX R REQUIREMENTS)
  - Whenever practicable, the design should avoid penetrations in fire walls for cables, ducts and piping that require inspection and testing in accordance with 10CFR50, Appendix R.
- INSTRUMENTATION ACCESS AND TESTING
  - The capability to expeditiously test instrumentation must be factored into the design of such systems. Factors to be considered include physical access to instruments to perform maintenance, testing, and calibration of instruments. (For example, smoke detectors at current plants require access every six months and usually require temporary scaffolding for access.) Functional or calibration tests of instrumentation systems should not require jumpers or removing leads.
- EQUIPMENT SELECTION
  - The means to perform preventive and corrective maintenance should be considered in establishing the design, selection, and location of equipment.

PC-000447/

organization (see Figure 3-1) as follows:

OPERATIONS DIVISION

On-call support to plant Shift Operations and support for updating and implementing operating procedures.

Specialist support to Reactor Engineering for day-to-day monitoring of reactor systems, conducting surveillance tests, managing control rod and fuel burnup and the fuel procurement program, and directing refueling operation.

MAINTENANCE DIVISION

Specialist support for updating and implementing maintenance procedures.

Technical resource for managing the Reliability Centered Maintenance (RCM) program established prior to plant startup and updating GT-MHR and NPRDS baseline reliability data with data from operating GT-MHR plants.

Specialist support for the inspection and maintenance of instrumentation and control systems, refueling equipment, reactor internal structures, the direct cycle power conversion system, and information management systems; as well as support for conducting such programs as the helium chemistry and radiation protection, in-service inspection, and outage planning.

Management and administration of the central pooled spare parts inventory, with emphasis on expensive, reliable equipment whose failure would incur a serious operating penalty during procurement; e.g., generators, recuperator sections, etc.

TECHNICAL DIVISION

Specialist engineering resource to support liaison with regulatory agencies, INPO and vendors.

Specialist support for Licensing and Performance Engineers to:

- Prepare for and coordinate plant visits by organizations such as NRC, INPO, ANI, and state and local representatives.
- Monitor changes in the Code of Federal Regulations that pertain to nuclear and environmental matters and coordinate company responses as required.
- Characterize the issues/events leading to operating anomalies and coordinate their disposition with the appropriate agencies.
- Develop and process amendments to technical specifications.

RC-000447/0

- Interpret data from off-site radioactive and environmental monitoring.

ADMINISTRATIVE DIVISION

Instruction of and support for the plant training staff and owner/operator of central plant simulators shared by three to five plants.

Support for implementing the records management aspects of the Configuration Management Program; e.g.: maintaining and storing as-built drawings, vendor manuals, correspondence, and other documentation necessary to control and maintain the plant configuration in accordance with the requirements of 10CFR50, Appendix B.

Specialist resource for implementation of the biological, thermal and radioactive elements of the environmental program.

3. RECOMMENDED AREAS FOR FURTHER DEVELOPMENT

At this time, neither the COSO role nor the effort to develop plant operating programs have not been explicitly identified in GT-MHR cost estimates. Both the change from current practices and the highly interactive role envisioned for COSO are such that a more complete conceptual development of COSO's role and functions should be undertaken if that concept is to remain a significant element of the GT-MHR deployment strategy.

It is recommended that COSO functions and costs be estimated in a manner similar to that used to estimate GT-MHR plant O&M costs. The bases for such an estimate are the COSO functions summarized in this Appendix, the outline of GT-MHR operating programs in Appendix C, and the COSO resources required for GT-MHR plants identified in the body of this report. Elements of the estimate should include the definition of organizational needs and a framework (such as the approach used to develop Lead Plant staffing estimates in Section 3.2 of this report) for staffing COSO. This information would provide the basis for future work to develop COSO capitalization requirements and a business plan.

4. REFERENCES

B1. *Development of a Central Operation Support Organization for the MHTGR*, Gas-Cooled Reactor Associates, GCRA 90-004, April 1990.

B2. *O&M Cost/Risk Drivers at Current Nuclear Plants and MHTGR Development Priorities,* Gas-Cooled Reactor Associates, GCRA 94-001, January 1994.

B3. *Utility/User Incentives, Policies, and Requirements for the Modular High Temperature Gas-Cooled Reactor,* Gas-Cooled Reactor Associates, GCRA 94-004, October 1994.

PC-000447/0

Appendix C

GT-MHR PLANT OPERATING PROGRAM OUTLINES

INTRODUCTION

Plant operating programs define the purpose and details of the work to be done by the plant staff. As noted in the body of this report, cost estimates herein are based on the assumption that plant operating programs have been developed and implemented sufficiently in advance of fuel loading to permit their use in operational reviews and staff training. That is, it is assumed that the plant vendor has progressively developed these programs in conjunction with the Central Operation Support Organization (COSO, see Appendix B) through the conceptual, preliminary and final design phases. The cost of these programs is assumed to be included in plant capital costs. It is further assumed that the plant design incorporates state-of-the-art information management systems as needed to implement electronic documentation for all programs. Failure to have these programs in place at the time of plant startup (fuel loading) will reduce plant productivity, increase cost, and may delay commercial operations. The following twenty programs are representative and outlined in this Appendix:

1. Management Information/Electronic Documentation
2. Training Programs (INPO accredited)
3. Operating Procedures
4. Refueling Procedures
5. Configuration Management
6. Preventive/Reliability-Centered Maintenance Program
7. Surveillance Testing
8. Inservice Inspection Program
9. Chemistry Program
10. Plant Modification Program
11. Quality Assurance for Operation
12. Fire Protection Program (10CFR50, Appendix R)
13. Security Plan/Procedures
14. OSHA Hazardous Materials
15. Environmental Monitoring (Offsite)
16. Emergency Preparedness Plan
17. Vendor Manuals
18. Equipment History
19. Spare Parts
20. Nuclear Power Reliability Data System (NPRDS)

1. MANAGEMENT INFORMATION/ELECTRONIC DOCUMENTATION

General Comments/Assumptions:

The GT-MHR has the potential to employ highly automated plant control and information management systems. Models for such programs are in place at some operating fossil and nuclear plants and experience with those systems should be used in developing such systems for the GT-MHR. The architecture of such systems should reflect the perspective of nuclear plant management with regard to type, form and frequency of information handling.

Such features must be fully functional at plant fuel loading and startup, and facilities (e.g., simulators) for staff training must be available 2 to 3 years in advance of plant startup.

All plant staff will be trained in the use of computer-based information management systems so that they can receive work assignments, enter the status of work, and describe work processes electronically; i.e., the goal is a "paperless" plant.

Automated data collection, analysis, and report generation and on-line O&M procedures will be employed wherever practicable.

User friendly (graphical or menu-driven computer interfaces) terminals and data entry devices (e.g., bar code scanners) will be used to enhance clerical productivity.

2. TRAINING PROGRAMS

End Item:

INPO accredited training programs to develop and maintain a technically proficient plant staff.

Content:

- Training programs sufficient for plant personnel to develop and/or maintain proficiency in both the manual and intellectual job skills. Training programs oriented to topics ranging from safety practices to licensing requalification are required for about 80% of the plant staff; e.g.:
  - Senior Reactor Operators
  - Licensed Reactor Operators
  - Reactor Engineers

PC-000447/0

- Instrumentation Technicians
- Chemistry Technicians
- Radiation Protection Technicians
- Mechanical & Electrical Maintenance Technicians
- Instrumentation & Control Technicians
- Craftsmen

Training programs that will fulfill INPO accreditation requirements including:

- Formal job analyses
- Instructor qualification
- Teaching methods and methods for determining instructional content and the training effectiveness.

Comments:

Training programs have the potential to significantly impact plant economics. Inadequate programs increase the risk of personnel error and regulatory sanctions, while overly ambitious programs reduce personnel productivity. It is assumed that NRC and INPO will accept a scope of instruction based on the risk-significance of personnel functions and not impose rigorous training programs on the whole staff.

3. OPERATING PROCEDURES

End Item:

Detailed, computer automated operating procedures for all plant process systems and components as the bases for both staff training and plant operation.

Content:

Categories for plant systems and components specifying those which require specific procedures versus those using generic procedures.

Detailed procedures specifying:

- System parameter limits, interface requirements and starting, stopping , and monitoring requirements for all plant states.

- The steps to start, stop, and monitor each process component through plant evolutions.

- A program for maintaining procedures that ensures consistent format, consideration of human factors, and built-in checks on procedure applicability and documentation control.

Comments:

A special subset of the operating procedures is the procedures for isolation (e.g, Safety/Blocking procedures) which specify actions to be taken to place a component and its environs in a safe condition for personnel maintenance work. Such procedures identify the steps for tagging-out equipment and the means to avoid operation which could compromise safety. Because of their implications on personnel safety and plant economics, these procedures are subject to especially thorough review.

4. REFUELING PROCEDURES

End Item:

Detailed procedures for conducting safe, efficient fuel handling operations from receipt of new fuel to disposal of spent fuel, with emphasis on plant operations and fuel handling during refueling outages.

Content:

Detailed procedures including provisions for:

- Receiving, inspecting and handling new and spent fuel and for shipping spent fuel.
- Testing refueling equipment prior to, during, and after refueling operations.
- Communications between the refueling floor and the control room and between machine operators.
- Entry and restoration (including closure testing) of the reactor vessel.
- Control and documentation of fuel movements.
- Recovery, handling and shipment of vessel material coupons for non-destructive tests.
- Inspection of the reactor vessel and reactor internals.

Comments:

The GT-MHR plant staffing plan assumes that fuel handling equipment operators will be dedicated to this activity and will assist in routine plant maintenance when they are not required for fuel handling. Refueling Supervisors will have special fuel handling licenses.

5. CONFIGURATION MANAGEMENT

End Item:

A program to ensure that the operating configuration of all safety- and economically-significant plant systems and components is immediately accessible to plant management and operating staff and to ensure that design basis documentation is continuously maintained in accordance with regulatory requirements.

Content:

The means (e.g., automated information collection) to monitor the status of plant systems and equipment; e.g., set points, valve positions, maintenance tagout, etc.

Design basis documentation and the means to implement on-going document maintenance.

Comments:

Although requirements for the GT-MHR should be less complex than for current plants, the requirement for formal configuration management systems emerged in the LWR industry early in the 1980s. Developing and implementing such programs in operating plants has been quite expensive, as has the requirement to identify and maintain design basis documentation. The GT-MHR Program has the opportunity to develop a formal configuration management program during design that could be transferred to the owner/operator. Most elements of the configuration management program should be included in the plant staff training and startup programs.

6. PREVENTIVE/RELIABILITY-CENTERED MAINTENANCE PROGRAM

End Item:

A program for conducting Reliability Centered Maintenance (RCM) based on state-of-the-art diagnostics and industry-wide, vendor-specific, and actual component data.

PC-000447/0

Content:

- Electronic technical manuals capable of automatically relating equipment fault detection and diagnostics to applicable repair procedures, including an inventory of spare parts.
- Technician skill requirements and estimated mean-time-to-repair.
- Automated work orders and reports for use in tracking equipment reliability. Such electronic forms should identify the component, frequency of preventive maintenance, spare parts required for inspection (gaskets, O-rings, sealants, coatings, etc), specific items to be inspected and limits of acceptability, special instructions and tools, and descriptions of the equipment conditions observed and the maintenance implemented.

Comments:

The initial elements of this program should be available from the design program. That is, the databases and reliability analyses used by the designer should include historical industry data for much of the plant. This information should be supplemented with vendor-specific component data as the design is finalized and with on-line reliability records when the plant is operating.

7. SURVEILLANCE TESTING

End Item:

Detailed procedures for conducting equipment surveillance required by the plant technical specifications.

Content:

- For equipment subject to surveillance, develop the means to:
  - Identify the requirement, objective, test interval, test procedure, instrumentation, acceptance criteria, technician credentials and reporting requirements.
  - Implement an automated process for scheduling surveillance tests and signaling the omission of scheduled tests.
  - Generate a management summary report which indicates tests completed, test failed, and follow up action.
  - Input failures or exceptions to the Equipment History and NPRDS when appropriate.

8. INSERVICE INSPECTION PROGRAM

End Item:

A program for inservice inspection (ISI) that meets the NRC requirements.

Content:

ISI program for the reactor vessel, reactor internal structures and other components subject to ASME Section XI.

- For equipment subject to ISI, develop the means to:
  - Identify the requirement, objective, ISI interval, inspection procedure, instrumentation, acceptance criteria, technician credentials and reporting requirements.
  - Implement an automated process for scheduling ISI and signaling omitted inspections.
  - Generate a management summary report which indicates inspections completed, detected faults, and follow up action.
  - Input failures or exceptions to the Equipment History and NPRDS when appropriate.

9. CHEMISTRY PROGRAM

End Item:

A program to control the chemistry of process fluids throughout the plant and thereby avoid unplanned and extended outages to remediate excessive corrosion and degradation.

Content:

- Procedures for sampling and analyzing helium coolant, cooling water, and other process fluids.

  For all fluid systems subject to chemistry control, develop the means to:
  - Identify the requirement, objective, sampling interval, sampling procedure, instrumentation, acceptance criteria, technician credentials and reporting requirements.
  - Implement an automated process for scheduling chemical sampling and annunciating omitted tests.

PC-000447/0

- Generate a management summary report which indicates chemical analyses completed, detected faults, and follow up action.

- Input exceptions to the Equipment History and NPRDS when appropriate.

Comments:

Chemistry control is important to reliable plant operation. Process systems subject to chemistry control include the reactor, closed cooling water, make-up water, and waste treatment systems. Much of the work to maintain chemistry parameters within normal limits is routine and will be automated. It is assumed that the GT-MHR plant design will incorporate automated sampling and chemical analysis equipment and provide for computerized data analysis and report generation with the means to alert chemistry section supervision of variances from chemistry acceptance criteria.

10. PLANT MODIFICATION PROGRAM

End Item:

A program and implementing procedures for modifying plant systems, structures and components in accordance with regulatory requirements.

Content:

Categorization of SSCs according to whether they are (1) subject to NRC review or (2) not subject to NRC review.

- Detailed procedures for the design, review, and approval of modifications to SSCs that (1) are subject to NRC review and (2) are not subject to NRC review and for their quality assurance programs; i.e., the processes to:

  - Initiate and log modifications.

  - Track the progress of the modification and conduct on- and off-site independent reviews.

  - Identify and track commitment dates (especially NRC commitments)

  - Verify approval by on- and off-site authorities

  - Update the plant configuration design basis and equipment histories.

11. QUALITY ASSURANCE FOR OPERATIONS

End Item:

A detailed definition of Quality Assurance activities necessary for plant operation to comply with the provisions of 10CFR50, Appendix B, and owner/operator-controlled standards.

Content:

- Categorization of equipment subject to "graded" quality assurance.
- Detailed procedures for implementing a quality assurance program for the functions of purchasing, receiving, and storing plant equipment and materials; for operating and maintaining the plant; and for auditing plant management.
- Special quality assurance procedures for nuclear fuel.
- Automated support of the quality assurance function wherever practicable.

Comments:

O&M cost estimates for the GT-MHR assume successful implementation of graded quality assurance in accordance with the risk-significance of equipment and personnel functions and that conventional (utility-controlled) quality assurance programs will be adequate for much of the plant.

12. FIRE PROTECTION PROGRAM

End Item:

A fire protection program suitable for implementation that meets the requirements of 10CRF50, Appendix R and the expectations of insurance underwriters.

Content:

The fire protection program will identify the:

- Location of fire fighting equipment
- Type, criteria and frequency of equipment tests
- Composition of the plant fire brigade
- Content of fire fighter training programs

PC/000447/0

- Procedures for conducting/reporting fire drills and for obtaining off-site assistance
- Process for familiarizing off-site firemen with the plant design and safety program

- The fire protection program will address the:
  - Potential for explosive mixtures in rooms, building spaces, tanks, etc.
  - Appropriate use of alarms, signs, ventilating fans, and other protective measures.
  - Unimpaired movement of fire fighting personnel through spaces that are potentially secured.
- The schedule and procedures for fire protection tests and drills will be automated whenever practicable to ensure appropriate staff response and management reports.

Comments:

See Appendix R for space/room combustible limits, posting requirements, fire fighting methods, and tests required of fire wall penetrations, smoke/fire detectors and alarms, and fire doors and dampers.

13. SECURITY PLAN

End Item:

A plan and detailed procedures for securing the plant that is acceptable to the NRC.

Content:

10CFR73 stipulates that nuclear plants must have a security plan and specifies topics to be addressed; e.g, the plan must:

- Provide a layout of the plant and its surrounding environment.
- Show the location of security posts, the gatehouse, and primary and secondary alarm stations and describe methods of communication.
- Describe and justify the size and qualification of the security force and the scope of periodic drills and the training and drug programs.

- Provide for an armed response team and for off-site assistance from local law enforcement.

- Describe security patrols and the control of personnel and vehicle ingress/egress.

- Procedures required to implement the plan, e.g.: Primary and Secondary Alarm Station operating/communication procedures; and search, access, communications and reporting procedures.

14. OSHA HAZARDOUS MATERIALS

End Item:

A program meeting OSHA requirements for notifying employees about the presence of hazardous materials in the workplace.

Content:

A list of on-site hazardous materials with their locations, amounts, and antidotes and recommended methods for handling and disposal.

Programs defining personnel responsibilities and procedures to audit to the use, movement and security of hazardous materials.

Comments:

The Plant Hazardous Materials Program is assumed to be under the direction of the Chemistry Supervisor and much of the Program can be automated.

15. ENVIRONMENTAL MONITORING

End Item:

An environmental monitoring program that meets NRC and EPA requirements.

Content:

- Detailed procedures identifying the test parameters and frequency, acceptance criteria, technician credentials, and documentation requirements.

Comments:

GT-MHR plants will be required to have offsite environmental monitoring programs for radiation effects; e.g., milk, grass, and air sampling.

PC-000447/0

16. EMERGENCY PREPAREDNESS PLAN

End Item:

A plan to protect site personnel and the public from the effects of a nuclear accident that meets NRC requirements.

Content:

- Current regulations require that emergency preparedness plans include the following:
  - The method of notifying offsite governing agencies that an accident has occurred.
  - A description and location of on-site and off-site emergency organizations and facilities.
  - Vehicle routes for evacuating the public within ten miles of the plant.
  - Training programs for offsite assistance personnel; e.g., school bus drivers, local police, hospital receiving personnel, etc.
  - The responsibilities of key personnel, a description of the accident assessment and decision-making processes, and the options for obtaining expert technical support.

Comments:

The GT-MHR Program position is that radioactive releases to the off-site public will be less than those for which the EPA requires emergency notification and sheltering plans. Provisions to assure civil preparedness for other environmental and industrial hazards are expected to be adequate to address all hazards posed by GT-MHR. It is likely that some elements of the above planning requirements will be imposed on early GT-MHR plants.

17. ELECTRONIC VENDOR MANUAL PROGRAM

End Item:

Current vendor installation, operating and maintenance manuals for all plant components in electronic format; e.g., CD-ROM.

Content:

- A plan for acquiring all vendor technical manuals in an electronic format suitable for accessing via the plant information management system.

- Procedures for interfacing vendor electronic technical manuals (VETM) with the plant configuration control program such that vendor data reflects the current design configuration.
- Provisions to interface VETM with equipment integral diagnostics and guide technician troubleshooting and repair procedure.

Comments:

The GT-MHR Program should develop a systems engineering approach to specifying equipment that employs integral diagnostics and VETMs in conjunction with the plant information management system.

18. EQUIPMENT HISTORY

End Item:

An automated program for collecting and analyzing equipment repair and maintenance data for use by the Reliability Centered Maintenance Program and by Licensing Engineers.

Content:

Automated equipment identification (e.g., bar coding) that accesses complete technical description and repair and maintenance history.

Automated reliability trend analyses and comparison with industry average experience.

Data interfaces with the Reliability Centered Maintenance Program and the Plant Configuration Management Programs.

Comments:

Equipment history is another aspect that must be considered in the architecture of the plant information management system.

19. SPARE PARTS

End Item:

A program for managing the spare parts inventory in a cost effective manner.

Content:

- Vendor recommended spare parts inventory for plant systems and components.

PC-000447/0 1

- Automated inventory control including database links to applications throughout the plant, part specifications and primary/secondary vendor data for procurement, and pricing data.
- Shelf life or other special storage instructions, e.g.: temperature, humidity.

Comments:

The approach to managing the spare parts inventory is another aspect that must be considered in the architecture of the plant information management system.

20. NUCLEAR POWER RELIABILITY DATA SYSTEM (NPRDS)

End Item:

An automated program for collecting and reporting reliability data in a manner acceptable to INPO.

Content:

- Automated equipment identification (e.g., bar coding) that accesses complete technical description and repair and maintenance history.
- Automated reliability trend analyses and comparison with industry average experience.
- Data interfaces with the Equipment History, Reliability Centered Maintenance, and the Configuration Management Programs and with INPO.

Comments:

The approach to supporting the INPO NPRDS is another aspect that must be considered in the architecture of the plant information management system.