6.0 RELIABILITY, AVAILABILITY, AND MAINTAINABILITY ASSESSMENT

6.1 INTRODUCTION

A preliminary reliability, availability, and maintainability (RAM) assessment was performed on the SOMBRERO and Osiris reactor plants. The primary objectives were to assess the RAM aspects of the two designs and to establish availability goals for the major plant systems to aid in planning future development efforts.

6.2 AVAILABILITY ASSESSMENT

The SOMBRERO and Osiris power plant designs are not detailed enough to estimate plant availability with any confidence. The approach, therefore, was to first make a rough estimate of the availability of the plant subsystems and then to use these estimates to establish availability goals for the major plant systems that combine to the give the desired availability goal for the entire plant. The initial estimates are in essence weighting factors for allocating system availability goals.

To assess the availability, each reactor plant was partitioned into four major systems: driver, reactor, target (fabrication, injection, and tracking), and energy conversion/balance-of-plant. Each of these major systems was divided further into several functional subsystems, and an achievable availability was estimated for each subsystem. The estimated availability was determined based on existing similar systems or comparable systems taking into account expected component lifetime, equipment random failure rate, power output fractions, manufacturing process capacity factor, and in-process storage capacity.

The estimated availability values for the major SOMBRERO and Osiris systems are summarized in Table 6.1. The availability due to unplanned down-time is slightly less than 70% for both plants.

Table 6.1. Estimated Availability for Osiris and SOMBRERO Plant Systems (Due to Unplanned Events)

	Osiris	SOMBRERO
Driver Systems	0.87	0.89
Reactor Systems	0.90	0.89
Target Systems	0.92	0.90
Energy Conversion & BOP	0.96	0.96
Total	0.69	0.68

Based on the estimated subsystem availability, the overall plant availability goal was apportioned to individual subsystems according to a model described in Ref. 16. An overall plant availability goal of 75% is assumed for the IFE reactor plants so as to be comparable to other fusion reactor studies and current large electric power generating systems . To achieve this goal, the required effective operation availability is 81% after allowing for an assumed downtime of four weeks each year to account for preventive maintenance activities.

Availability allocation is apportioned for plant systems from the top down according to the reliability and maintainability characteristics of the systems in such a way as to achieve the plant availability goal. The availability apportionment indicates the optimum balance of availabilities for all systems in the plant. The allocation process serves as a means of assessing the design and defines availability improvement targets in system design refinement. These improvements include better system design, application of redundancy, changes in maintenance concepts, or combination of these options.

Using an effective operation availability goal of 81% for the IFE reactor system and the estimated system availability values in the above section, the availability goals for various SOMBRERO and Osiris plant systems are established as indicated in Table 6.2. Comparing these goals to the rough estimates given in Table 6.1 indicates that for both plants, 4-5% improvements are need for the drivers, reactors, and target systems, and a 2% improvement is required for the BOP availability in order to meet the overall plant availability goal. However, since RAM data for these systems are mostly nonexistent, or at best available from limited experimental results, these results should not be considered conclusive. More definitive assessments will require detailed designs and evaluations of the plant systems, additional data obtained from extended test periods, and eventually the integration of driver, target, reactor, and BOP systems in an experimental test facility.

Table 6.2. Allocated Availability Goals for SOMBRERO and Osiris

	Osiris	**SOMBRERO**
Driver Systems	0.94	0.93
Reactor Systems	0.94	0.95
Target Systems	0.94	0.94
Energy Conversion & BOP	0.98	0.98
Total Unplanned	0.81	0.81
Planned	0.92	0.92
Overall	0.75	0.75

6.3 MAINTAINABILITY OF THE OSIRIS PLANT

An analysis was performed on the sequence and type of activities required in order to remove and replace the Osiris vacuum cover, fabric blanket assemblies, and the maintenance of other reactor support equipment. The activities that define the classes of operation for the Osiris reactor design are as follows:

- High and Low Pressure Flibe Inlet Pipe Disconnect
- Driver Seal Flange Unbolting and Retraction
- Vacuum Chamber Cover Unfastening and Interference Removal
- Vacuum Chamber Cover and Attached Internals Removal
- Reinstallation

The Osiris reactor building size is dictated by the maintenance handling requirements for the vacuum vessel cover and reactor internals. These requirements were due to the complexity of refurbishment operations associated with these components, constraints which dictated that the cover and internals be removed as one piece. The physical size of these components and the complexity of refurbishment operations suggested that it is prudent to "replace in kind" rather than "refurbish in place." With this in mind, it became apparent that the remote handling equipment needs to have common access to both the reactor building and the hot cell/maintenance areas. To accommodate this requirement, a large movable shield wall is provided. As illustrated in Fig. 6.1, this shield wall is located between the reactor building and hot cell, and the crane bay containing all of the overhead operated remote handling equipment is open to both. The remote handling equipment is protected from neutron activation during reactor operation by extending the shield wall in place and locating the equipment at the far end of the hot-cell facility. The hot cell contains both a clean room in which to store the new replacement cover and reactor internals (thus isolating them from the old contaminated internals being removed) and a hot storage area, which is a large temporary containment that houses the old components being removed.

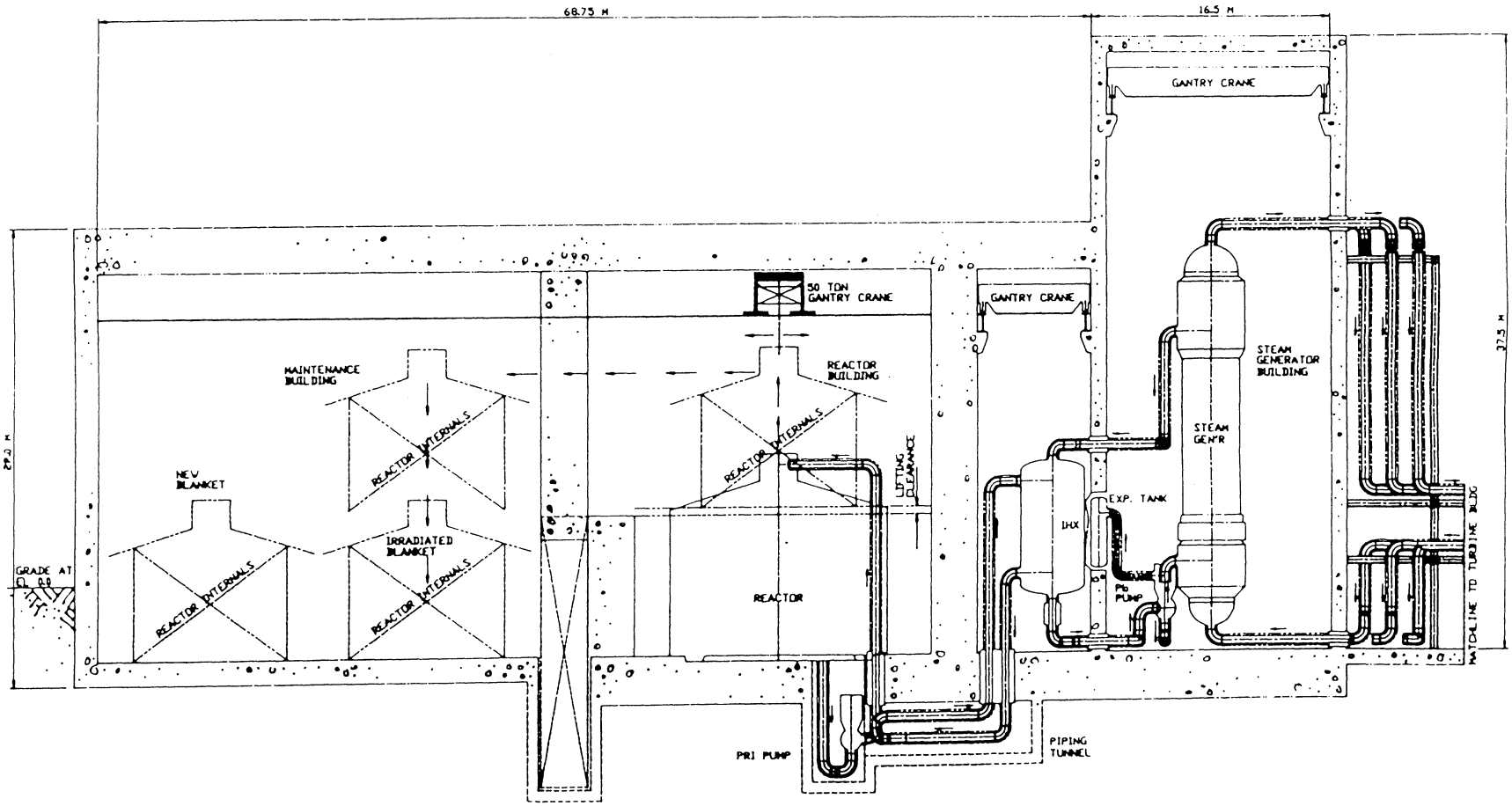

Fig. 6.1. Cross section view of Osiris maintenance procedure.

6.4 MAINTAINABILITY OF THE SOMBRERO PLANT

A methodology similar to the Osiris was used to develop an approach for remote maintenance of the SOMBRERO reactor. An analysis was performed on the sequence and type of activities required in order to remove and replace the reactor module assemblies and the optics within the reactor building. An evaluation of the activities was performed to define the classes of operations that would be conducted. In an effort to determine a baseline case for overall remote handling equipment operational envelopes and equipment and component handling sequences (for maintenance activities), the activities that would define the classes of operation for the SOMBRERO reactor design are as follows:

- Upper Plenum/Inlet Pipe Removal
- Module Removal/Replacement
- Mirror and Optics Maintenance
- IHX Maintenance
- Reactor Support Equipment Maintenance
- Beam Handling Equipment Maintenance
- Hot Cell Operations.

Due to the large physical size of reactor building (dictated by the optics requirements), an innovative approach to crane operations and rigging and handling of components was necessary. For this case, both the polar crane and annular crane make use of the National Institute for Standards and Technology (NIST) high payload automated crane concept. This concept employs a modified Stewart platform where the hook and block-and-tackle are normally located. This platform allows for very stable control of heavy offset payloads at long distances from the cable drum and trolley assembly. The most unique design feature of SOMBRERO is the remote handling equipment designed to handle the chamber modules. Each of these modules is approximately 24-m tall and 8-m deep. Due to space restrictions in the center reactor building volume, each of these modules is designed to be removed and replaced one at a time. As illustrated in Fig. 6.2, the removal sequence dictates that the module be lowered to the bottom of the inner cylindrical chamber, installed on a polar carriage assembly (which accommodates radial positioning), and tilted out of the lower access door via a transport carriage, through the annular space and into the hot cell facility. This whole evolution is analogous to current practices in fuel bundle handling systems currently in use.

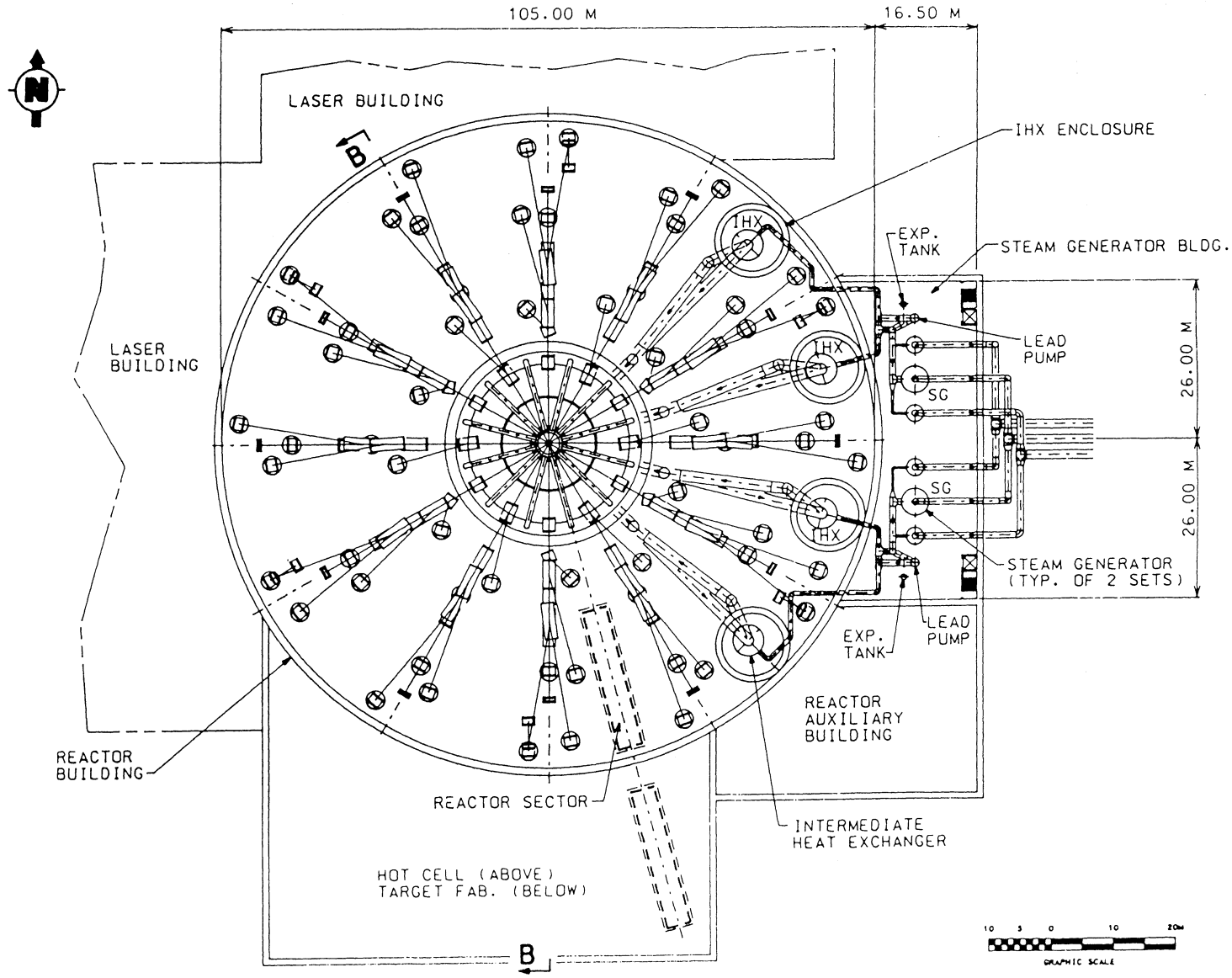

Fig. 6.2. Cross section view of SOMBRERO maintenance procedure.