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MFTF-α+T End Cell Vacuum Vessel and Nuclear Shield Trade Studies*

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INTRODUCTION

The MFTF-α+T configuration[1] is a proposed upgrade of the Mirror Fusion Test Facility (MFTF) presently under construction at the Lawrence Livermore National Laboratory, Livermore, California. The purposes of the MFTF-α+T device are first to advance physics knowledge of plasma confinement, using a DT-burning plasma, and second, to demonstrate the system integration of reactor components in a nuclear environment.

The integral vacuum vessel/shield of the α+T device,[2] which provides the plasma with the required vacuum integrity, is the primary load-carrying structure. It consists of a three-piece cylinder, separated into two end cells and one center cell, with domed ends and maintenance access hatches. In addition, the vessel is the common cryogenic dewar for the magnet system.

Nuclear (bulk) shielding is provided to protect personnel, limit damage to sensitive components, and to allow hands-on maintenance at the outside surface of the vacuum vessel. The shield thickness is sufficient to limit the shutdown (biological) dose rate in the vault to 0.5 mrem/hour, 24 hours after shutdown. The shielding is varied in thickness, composition, and radial geometry, as required to provide local protection. The superconducting (SC) coils are protected with sufficient shielding to prevent excessive nuclear heating.

Three separate and distinct vacuum vessel and nuclear shield trade studies were performed in series. The studies are: vacuum topology, nuclear shield location and composition, and water bulk shield location and material selection.

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DISCLAIMER

VACUUM TOPOLOGY STUDY

The vacuum topology study was started in November 1982, and the objective of the study was to identify, evaluate, and select a viable vacuum boundary for the proposed MFTF-B upgrade. The MFTF-B configuration was the baseline concept at that time. The initial upgrade concept used all of the existing end cell coils, two existing sets of four-center cell solenoid coils, a new 4-m DT axicell section in the center of the device, and added a 1-m-long test module at the center. The following four vacuum topology configurations were considered: (1) existing MFTF-B configuration with all of the superconducting coils located inside the vacuum boundary, (2) same as Configuration I, except the addition of vacuum vessel to existing and new superconducting coils, (3) same as Configuration I, except the addition of isolating vacuum valve and a separate vacuum vessel for the SC axicell coils, and (4) same as Configuration III, except for the use of a combined first wall/vacuum vessel concept for the axicell. Vacuum topology Configuration I was selected on the basis of low cost.

NUCLEAR SHIELD LOCATION AND COMPOSITION

After completion of the vacuum topology study, six concepts were considered for the location and composition of the nuclear shield. Concept IV was selected upon completion of the trade study, on the basis of cost and simplicity. Concept IV consists of a new 8.3-m-dia. vacuum vessel with the concrete bulk shield inside the vessel.

The six concepts are as follows:

Concept I - existing vacuum vessel with external concrete shield with support structure; Concept II - existing vacuum vessel with self-supporting external concrete shield; Concept III - existing vacuum vessel with internally located clad concrete shield; Concept IV - new 8.3-m-dia. vacuum vessel with internally located clad concrete shield; Concept V - new 5.8-m-dia. vacuum vessel with external ~~shield~~ STEEL and concrete shield; Concept VI - new 5.8-m-dia. vacuum vessel with external concrete shield. Concepts I, II, III, and IV have an equivalent of 50 cm of steel/water shield internal to the vacuum vessel, and Concepts V and VI have 15 cm of the internal shield.

WATER BULK SHIELD LOCATION AND MATERIAL SELECTION

After completion of the "Nuclear Shield Location and Composition" trade study, an alternate shielding concept was identified. The alternate is 160 cm of water, followed by 5 cm of boron carbide (B_4C) and 5 cm of lead (Pb). Five concepts for the water bulk shield were studied, using an 8.3-m-dia. end cell vacuum vessel. The integrated vacuum vessel/bulk water container concept, Concept XI, was selected on the basis of cost and ease of device maintenance. The five concepts are discussed below.

Concepts VII and VIII are similar, the only difference being the container material. The material for Concept VII is stainless steel and 5083-0 aluminum for Concept VIII. In both cases, the containers are located outside and supported by the vacuum vessel. The materials for the water containers for Concepts IX and X are stainless steel and 5083-0 aluminum, respectively. The water containers for Concepts IX and X are located inside and supported from the vacuum vessel. The combination of the bulk water container and vacuum containment functions resulted in Concept XI. In all five bulk water containment concepts, the water requires circulation.

SUMMARY

A final comparison of the 11 concepts considered for location and shielding composition resulted in the selection of Concept XI as the reference vacuum vessel/shield design. The selection is mainly based on the following criteria:

- cost
- bulk shield and vacuum vessel weight
- ease and/or access for maintenance

REFERENCES

1. W. D. Nelson, ed., "MFTF-α+T Progress Report," Fusion Engineering Design Center, Oak Ridge National Laboratory, ORNL/FEDC-83/9 (to be published).
2. J. Kirchner, "Vacuum Vessel and Nuclear Shield Design for the MFTF-α+T," IEEE Proceedings of the 10th Symposium on Fusion Engineering, Philadelphia, Pennsylvania, December 1983.