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An All-Remote Configuration for the ETR-INTOR Tokamak Design*

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The objective of this study is to develop a comparison of the costs and engineering implications of improving tritium containment and shielding as required for personnel access (FED-INTOR)[1] versus adopting a totally remotely operated and maintained design (ETR-INTOR).[2] The work presently underway has focused on developing a device configuration which is amenable to all-remote operations, reducing the biological shielding on the plasma chamber, assessing tritium containment requirements for both designs, and developing facility layouts for both designs.

A starting point for developing the design, which does not require personnel access, was to establish the minimum shield requirements necessary to protect peripheral components. Protection of the superconducting toroidal field (TF) coils was chosen. It was anticipated that this would reduce device cost and improve access. For the all-remote design, the shield thickness was established at 50 cm[3] compared to 105 cm[1] for the personnel access design. In addition, the TF coil bore was reduced by 0.5 m to reduce cost by taking advantage of the thinner shield. The design, which resulted from these changes, appears to adversely impact cost, operations, and maintenance. The impurity control system requires split divertor modules (24 instead of 12) which require translational as well as radial motion for replacement. Clearly, the remote handling equipment for these modules will be more complex. The reactor

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cell wall, consisting of a steel liner and concrete, increased in thickness from 188 cm to 316 cm[3] in order to meet the biological requirement to the outside environment. This results in a 50% increase in concrete volume, which is expected to increase the building cost. Activation in the reactor cell increased by 4 orders-of-magnitude, suggesting that the longevity of maintenance equipment will be reduced and that subsequent decommissioning and waste disposal requires handling material which is more highly activated. The nuclear heating to the TF coils increased by 2-1/2 times, requiring as much as a doubling of refrigeration equipment. The preliminary conclusion, thus far, regarding shielding and configuration development is that a minimum shield thickness for an all-remote design may increase overall cost.

Improving the FED-INTOR design to ensure personnel access has focused on meeting the ALARA requirement for worker dose rate by increasing the shield thickness. An increase of 11 cm[3] (from 105 to 116) has been calculated in order to reduce activation at the shield boundary from 2.5 mrem/h to 0.5 mrem/h.

The evaluation of tritium containment for both designs is based in part on the earlier FED-INTOR[1] work. Major conclusions reached were 1) maintenance generates a major fraction of tritium releases; 2) tritium leakage from water coolant systems is a major factor of tritium releases; 3) environmental releases are the same for both designs; 4) an atmospheric tritium recovery (ATR) system for maintaining levels <50 $\mu Ci/m^3$ is not economically justified; 5) higher availability may be achieved with an all-remote design if a significant number of maintenance tasks can be done in <24 h (this is because the personnel access design

requires a 24 h cooldown period before workers are permitted in the reactor cell).

Three facility designs are in a preliminary stage of development. They all embody the requirements for removal of large components such as torus sectors, and they provide laydown area for the cryostat dome and the poloidal field coils. The personnel access design facility has a reactor cell which is separated from the hot cells and incorporates a minimum wall thickness (188 cm). The all-remote design facility has a common hall for the reactor cell and the hot cells which allows the use of a single main crane system. It incorporates the 318-cm wall thickness. A hybrid facility was developed and is based on features of the above designs. It has a common hall but incorporates 188-cm walls because of additional shielding on the device. A summary of the various volumetric parameters for the three facilities is shown in Table 1.

The preliminary results, thus far, indicate that an all-remote reactor design based upon protecting peripheral device components from neutron induced activation will result in a reactor system which appears more costly and will not necessarily enhance remote maintenance operations.

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Table 1. Summary of volumetric parameters for the three facility options

	Personnel Access	All-Remote	Hybrid
Total bldg. Vol (M^3) × 10^3	222	221	178
Concrete Vol (M^3) × 10^3	65	95	56
Enclosed Vol (M^3) × 10^3	156	132	132
ATR Vol (M^3) × 10^3	106	121	121

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