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MAINTENANCE AND DISASSEMBLY CONSIDERATIONS FOR THE TECHNOLOGY DEMONSTRATION FACILITY*

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ABSTRACT

The Technology Demonstration Facility (TDF) is a tandem-mirror design concept carried out under the direction of Lawrence Livermore National Laboratory. It was conceived as a near-term device with a mission of developing engineering technology in a D-T fusion environment. Overall maintenance and component disassembly were among the responsibilities of the Fusion Engineering Design Center (FEDC). A configuration evolved that was based on the operational requirements of the components, as well as the requirements for their replacements. Component lifetime estimates were used to estimate the frequency and the number of replacements. In addition, it was determined that the need for remote handling equipment followed within 1.5 years after initial start-up, emphasizing the direct relationship betweem developing maintenance scenarios/equipment and the device configuration. Many of the scheduled maintenance operations were investigated to first order, and preliminary handling equipment concepts were developed.

INTRODUCTION

The Tandem Mirror TDF is a conceptual design of a near-term device with a mission of demonstrating engineering technology in a D-T fusion environment. The concept development was directed by Lawrence Livermore National Laboratory, and overall maintenance considerations and component disassembly were among the responsibilities of the FEDC. A configuration evolved that was based on the operational requirements of the components, as well as their replacements. Figure 1 is a rendering of TDF.

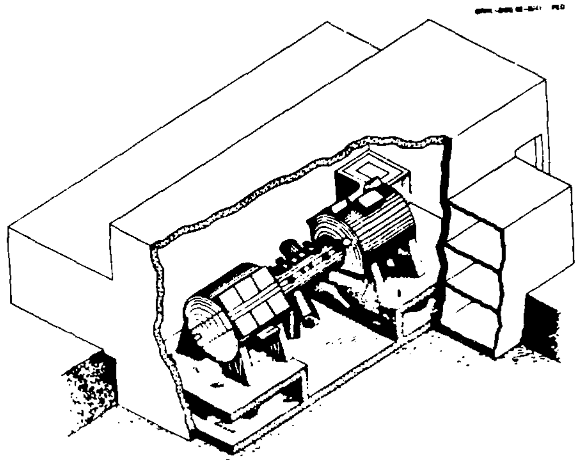

Fig. 1. An artist's rendering of the Tandem Mirror Technology Demonstration Facility

The overall length of the device is approximately 60 m; the central cell and anchor cell regions have a 7-m diameter; and the end cell diameter is approximately 16 m. These dimensions are measured to the outside of the shield boundary. The central cell shield is primarily 120 cm of stainless steel and water; the anchor cell shield is 60 cm of ordinary concrete. These shield thicknesses are based on a shutdown dose rate of 2.5 mrem/h after 24 h after shutdown at the shield boundary. Details of all of the TDF systems can be found in ref. 1.

This device embodies many high-technology systems and subsystems, each with operating characteristics that are life-limiting. Therefore, the integrated conceptual design was based on access to the components, modular independence of adjacent components, and frequency of component replacement. Among the system components considered are test

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modules, beam line sources, beam dumps, and choke coils.

MAINTENANCE PHILOSOPHY

Maintenance and disassembly of the major TDF systems were prime drivers of the configuration development, particularly with regard to access and handling. At the start of the TDF program, a maintenance philosophy was established to provide guidelines for the development of a configuration and its constituent components. The major aspects of this philosophy are listed below.

1. Contact maintenance operations are permitted 24 h after shutdown at the shield boundary, provided that major penetrations into the vessel are unopened. At the 2.5-mrem/h dose rate, workers may spend up to 400 h/year near the device without exceeding the ALARA limit of 1 rem/year for individuals.[2]

2. Major maintenance and disassembly operations must be possible under emergency conditions. This is practically a routine requirement since very little can be accomplished by contact means once the vessel is opened.

3. Component installations must be modularized. This will ease remote handling requirements for component replacement and is expected to enhance device availability.

4. Remote handling must use proven maintenance equipment technology. TDF was envisioned to be operational in about 10 years. Therefore, assuming equipment requirements are needed during Title II design, there is insufficient time to rely on major equipment advancements beyond the next 5 years.

MAINTENANCE OPERATIONS

Generally speaking, contact maintenance is defined to mean unsuited operations. Therefore, disassembly procedures in the reactor building include provisions for decontamination of tritium and activated particulate matter. It is a design goal for TDF that contact operations be unsuited; however, suited operations using portable life support systems are considered to be an acceptable mode of "hands-on" operations if contamination levels exceed maximum permissible concentrations.

Personnel and maintenance equipment are not permitted in the reactor building during the operation of the device. The biological hazard for personnel is obvious. For the equipment, neutron-induced activation must be avoided because it necessitates remotely maintaining the maintenance equipment. It is for this reason that the overhead crane systems, which must remain in the reactor building, are stored behind a shielded enclosure at one end of the facility. Other equipment, such as the manipulator systems, transporters, and miscellaneous tools, is stored outside the reactor building.

The magnetic coils must be deenergized during both contact and remote maintenance operations. This is primarily a safety consideration for the personnel, maintenance equipment, and magnets. The concern relates to two factors:

1. The energy stored in the larger coils is significant, being measured in megajoules.

2. The magnetic fields of the coils are significant and can affect the operation of electric motors in the manipulator systems or create projectiles from small, nonmagnetic tools.

The coils can, however, be kept at their operating temperature if the maintenance operations do not involve disturbing the magnet systems. For example, in replacing a test module the coils would be deenergized but could be kept at liquid helium temperature.

SCHEDULED COMPONENT REPLACEMENTS

Most major components will require scheduled maintenance or replacement during the device lifetime, and all components may require unscheduled replacement. Provisions for these unscheduled replacements have been considered in developing the baseline configuration, although the emphasis has been placed on scheduled maintenance operations. A number of components have been identified as requiring periodic replacement. The designs of these components and their positions on the device were very much influenced by the maintainability considerations of access and modularity which were previously mentioned.

Figure 2 shows the "first-time" replacement of major components as a function of calendar time. Note that the 15-year device lifetime is equivalent to 5.4 full-power years (FPY), given the assumed availability goal also shown in the figure. Most of the components require replacement during the first 3 years, although some components, such as the superconducting solenoid coils, are lifetime systems. The data compiled for this chart are based on estimates provided by the various TDF component designers.

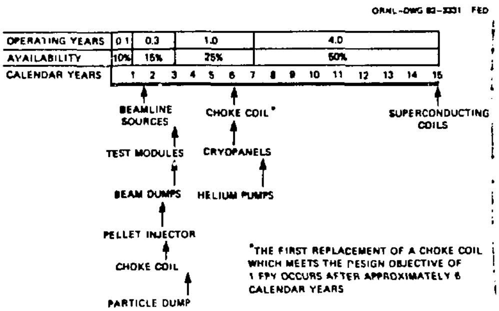

Fig. 2. First-time replacement of major components as a function of calendar time

Two important points can be derived from Fig. 2. First, maintenance procedures and equipment must be in place early in the operating phase of the program. Slightly more than 1.5 years after start-up, the first use of remote handling equipment occurs, implying that maintenance considerations must be factored into the designs early. Second, it behooves the component designer to seek extended lifetimes where they can be realistically achieved. This figure shows that the first changeout of a choke coil occurs after 6 calendar years instead of 2.5 if the operating lifetime can be extended from 0.25 FPY to 1 FPY.

Figure 3 examines one component, the choke coils, over the device lifetime. The coil has an estimated lifetime of 0.25 FPY, and there are 21 scheduled replacements for the choke coil. During the last phase of device operation, which has 50% availability, the changeouts occur approximately twice each year. A chart for a lifetime of 1 FPY for the choke coil would show 5 changeouts over 15 calendar years. Similar charts can be developed for any component.

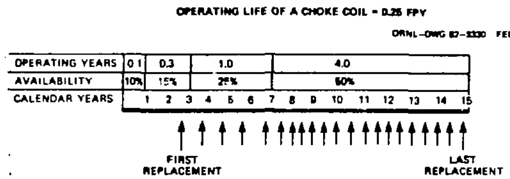

Fig. 3. Choke coil replacements as a function of calendar time

COMPONENT REPLACEMENT CONCEPTS

This section presents abbreviated scenarios for some of the component replacements considered during the configuration development. For each case, it is always assumed that maintenance operations will be done in a hands-on mode whenever possible. Therefore, maintenance personnel are involved as long as the device is unopened. They are responsible for setting up equipment, such as scaffolding, manipulators, and fixtures; and they perform on-site inspection prior to starting operations.

The necessary remote maintenance equipment basically consists of manipulators, viewing systems, transporters, and handling machines. Because of the near-term time scale of TDF, only currently available equipment is considered. Manipulator systems are used to accomplish the functions of a human and, in general, include closed-circuit television, available in 2-D or 3-D imagery, and in color or black and white. Transport systems include overhead cranes, handling devices. and transport devices in the reactor building. This equipment is used to remove and install components on the device and to move components to the hot cell.

Test Modules

Figure 4 shows the removal of a test module located at the upper centerline of the central cell. Note that this module includes the test specimen as an integral part of the shield plug. After the service connections are removed and the vacuum flange interface between the module and the vacuum boundary of the central cell is unfastened, a lifting fixture is assembled to the module flange for overhead handling. All of these operations are manually assisted before the test module is lifted out. The weight of the module is estimated to be 50 to 70 tonnes, and its overall dimensions are 1.2 × 1.6 × 4.3 m.

Reinstalling the replacement module requires an alignment fixture indexed and mounted to the central cell. Reinstallation is totally remote until the module is again seated on the vacuum flange.

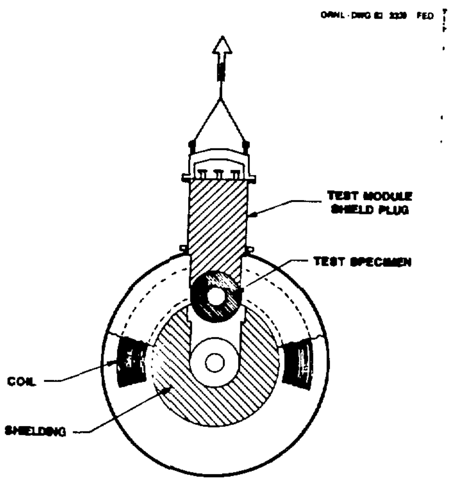

Fig. 4. Test module removal

Choke Coil

Figure 5 shows the removal of the choke coil. This operation is essentially the same as that for the test module because of the coil's upper centerline location. The choke coil is expected to be one of the most frequently replaced components; hence, it was located for easy, overhead access. Before this module (shield plug and magnet) is lifted out, all operations are contact. The choke coil module weighs approximately 20 tonnes and also requires an alignment fixture for reinstallation.

Central-Cell Beam Dump

Figure 5 also shows the orientation and radial movement of a beam dump. Removal of these components requires handling equipment that accommodates the off-vertical motion, which precludes the use of the overhead crane. Maintenance equipment of this type is shown in subsequent figures.

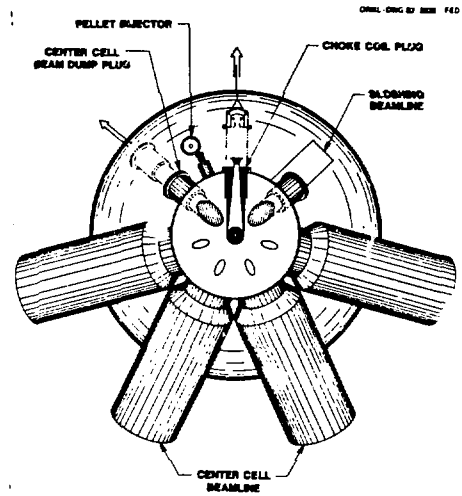

Fig. 5. Choke coil removal

Anchor Sloshing Beamline

Figure 6 shows the removal of the beam line components as a rail-mounted pallet assembly, enabling the entire system to be handled as one large module. This approach is required because of the limited access available for the beam lines. The ion source is the one component that can be independently changed after removing its service connections and the shield cover. A rail-mounted extraction device is required to pull the pallet after the vacuum flange interface is disconnected. Figure 6 is also typical for the anchor and transition pumping beam lines. The weight of the largest pallet for these beam lines is estimated to be less than 50 tonnes.

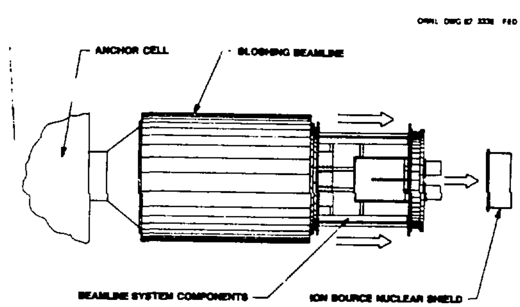

Fig. 6. Modular assembly of a beamline

<u>Central-cell beam line</u>. The disassembly procedure for the central cell beam lines is more complex than that of the other beam lines and results from minimizing the clearance required to the reactor building walls. Figure 7 shows the disassembly arrangement. The first component to be removed is a module consisting of the nuclear shield and the rear superconducting magnetic shield. This module interfaces with the beam line at the rear vacuum bulkhead where the sources are mounted. (This module is also removed to gain access to the sources for their replacement.) The second module to be removed is the rear half of the nuclear shield, which provides ample access to the pallet-mounted beam line components. The remaining nuclear shield and magnetic shield are essentially fixed to the device.

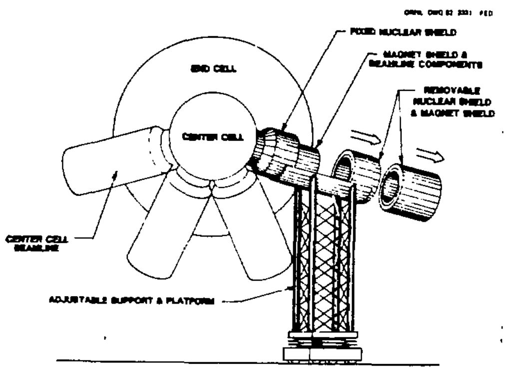

Fig. 7. Central cell beam line disassembly

The adjustable support platform is used to assist an extraction device (not shown) that handles the pallet assembly before it is lifted by the overhead crane. The extraction device for the operation shown would be mounted to the building wall in a manner like that shown for the cryopanel removal in Fig. 8.

<u>Cryopanels</u>. Each end cell contains 36 2- by 4-m cryopanel pumps. The panels are arranged in modular assemblies of three panels each, as shown in Fig. 8. This module is a manageable size that does not impact the building wall dimensions established by the central-cell beam line removal.

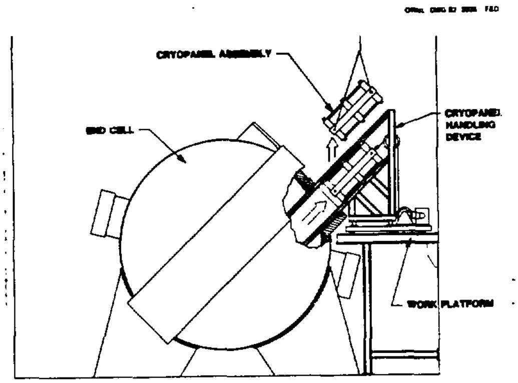

Fig. 8. Cryopanel modular removal

Fig. 8 shows the removal of one of the six lower panel assemblies. The cryopanel handling device removes the shielded access cover to gain entrance into the end cell and then pulls the track-mounted assembly out using the principle of the inclined plane. This handling device can be vertically and horizontally adjusted with the jackpads and the wheels of the trolley bed, respectively. The overhead crane is ultimately used to deliver the component to the hot cell entrance.

<u>Particle dump</u>. The particle dump consists of a number of panel modules connected to common inlet and outlet coolant manifolds. Figure 9 shows the removal of one panel using a mobile handling device. Access to the panels is gained by removing a lower shielded cover.

<u>Helium pumps</u>. Figure 10 shows the removal of a helium pump module using a handling device similar to that used for the particle dump.

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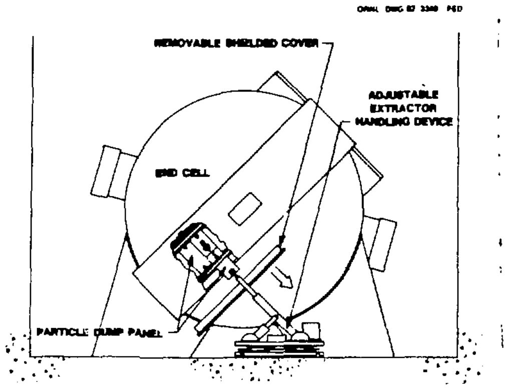

Fig. 9. Particle dump removal

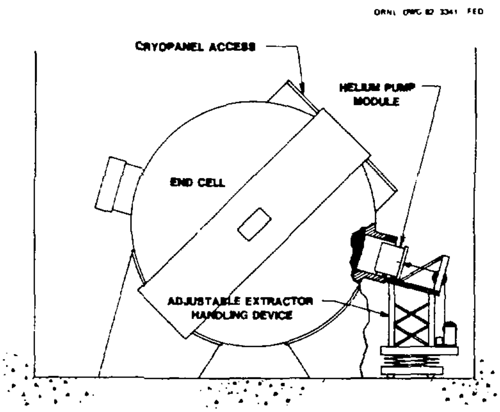

Fig. 10. Helium pump modular removal

REFERENCES

1. "Tandem Mirror Technology Demonstration Facility," *UCID-19328*, Lawrence Livermore National Laboratory (1983).

2. "Requirements for Radiation Protection," U.S. Department of Energy Order 5480.1, Chapter XI.

DISCLAIMER