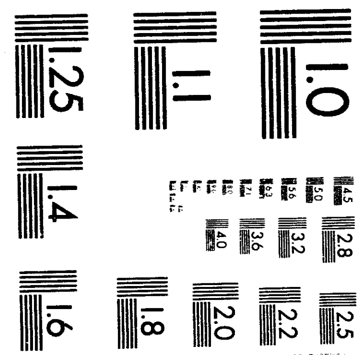
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DECONTAMINATION AND DECOMMISSIONING THE TOKAMAK FUSION TEST REACTOR

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Abstract

The Tokamak Fusion Test Reactor (TFTR) is scheduled to complete its end-of-life deuterium-tritium (D-T) experiments in September 1994. The D-T operation will result in the TFTR machine structure becoming activated, and plasma facing and vacuum components will be contaminated with tritium. The resulting machine activation levels after a two year cooldown period will allow hands on dismantling for external structures, but require remote dismantling for the vacuum vessel. The primary objective of the Decontamination and Decommissioning (D&D) Project is to provide a facility for construction of a new Department of Energy (DOE) experimental fusion reactor by March 1998. The project schedule calls for a two year shutdown period when tritium decontamination of the vacuum vessel, neutral beam injectors and other components will occur. Shutdown will be followed by an 18 month period of D&D operations. The technical objectives of the project are to: safely dismantle and remove components from the test cell complex; package disassembled components in accordance with applicable regulations; ship packages to a DOE approved disposal or material recycling site; and develop expertise using remote disassembly techniques on a large scale fusion facility. This paper discusses the D&D objectives, the facility to be decommissioned, and the technical plan that will be implemented.

Introduction

The TFTR is a magnetic confinement, toroidal shaped device for producing controlled nuclear fusion using hydrogen isotopes, i.e., deuterium and tritium. TFTR is the US DOE major experimental reactor in the Magnetic Fusion Energy Program. It is located at the James Forrestal Campus of Princeton University, and is operated by the Plasma Physics Laboratory (PPPL) of Princeton University for the US DOE.

The TFTR design, construction and plasma operation span from 1974 to final operations in 1994. Operations have progressed from hydrogen plasmas to deuterium plasmas through September, 1993. During this period, "hands on" accessibility was available to the machine even though the vacuum vessel and other components had become slightly activated and mildly tritium contaminated.[1] Experimental operations with tritium were initiated in September, 1993.[2] The experimental objectives are: to demonstrate fusion energy production (approximately 1-10 MJ per pulse); to study the plasma physics of large tokamaks; and to gain experience in the engineering problems associated with large fusion devices.

Completion of D-T operations is scheduled for September, 1994, and according to DOE Order 5820.2A[3], the facility is required to be decontaminated and decommissioned. A two year shutdown period will commence at that time. Dismantling of the tokamak systems, packaging, and shipping operations will follow shutdown, lasting approximately one and a half years. These activities will conclude the final phase of the TFTR Project.

+ Raytheon Engineers & Constructors * Grumman Corporation

Project Objectives

The primary objective of the TFTR D&D Project is to render the facility suitable for construction of the next DOE experimental fusion reactor, the Tokamak Physics Experiment (TPX), by March, 1998. To reach this objective it will be necessary to remove activated and tritium contaminated machine components. This will be achieved while keeping the dose equivalent to workers as low as reasonably achievable (ALARA).

1. Technical Objectives

The technical objectives for the D&D Project are similar to the objectives for dismantling of a nuclear power facility. Decommissioning technology from the nuclear fission industry will be utilized wherever possible to safely dismantle activated and contaminated systems. Due to the activation and contamination levels, it will be necessary to use remotely operable equipment to dismantle some components. Disassembled components will be packaged in compliance with DOE, Department of Transportation (DOT) and waste receiver requirements. The certified packages will then be transported to a DOE approved waste repository for low level radioactive waste (LLRW) disposal. The TFTR D&D Project differs from a typical D&D project in that the facility will not be returned to "greenfield" conditions, nor will it be released for unrestricted use. The DOE will retain ownership and reuse the facility for the next generation fusion reactor.

2. Schedule Objectives

The major milestones for the TFTR D&D Project are as follows:

o Conceptual Design Review	July, 1994
o End of Operations/Commence Shutdown	September, 1994
o Preliminary Design Review	February, 1995
o Final Design Review	February, 1996
o Begin Phase I D&D Operations	October, 1996
o Begin Phase II D&D Operations	April, 1997
o TPX Occupancy	March, 1998

Facility Description

The facilities involved in TFTR decommissioning are the test cell, test cell basement, hot cell, and mockup building. Only those systems or components which are located in the test cell or are connected to the vacuum pumping system are expected to require D&D. These systems and components include: vacuum vessel, machine structure, neutral beam injector systems, diagnostics, vacuum pumping system, machine area cooling water systems, fuel-pellet injectors, and the ion cyclotron resonant frequency (ICRF) system. Most of this equipment consists of large complex stainless steel and copper structures, some with tritium contamination.

The test cell is a reinforced concrete structure with interior dimensions of 45m x 35m x 16.5m. This building houses the tokamak, neutral beam injector system, diagnostics devices and support systems. Concrete thicknesses are: roof, 1.7m; and walls, 1.5m. The test cell floor is designed to support the tokamak static weight of 1800 metric ton in a 12m diameter area. The test cell is equipped with a 110/25 ton capacity bridge crane. Figure 1 is a schematic plan view of the test cell, hot cell, and mock up building.

Basement space below the test cell houses diagnostic equipment, high voltage switchgear, vacuum pumping equipment, electrical bus runs and cooling water piping. The basement areas are constructed of reinforced concrete to provide shielding from test cell radiation. Minimal activation is expected in this area as a result of tritium operations. The tritium cleanup and waste handling systems are also located in the basement, and will be decontaminated at the end of the D&D Project.

The hot cell contains the decon facility, a clean room, and various diagnostic devices. It has interior dimensions of 18m x 35m x 16.5m. Construction is of reinforced concrete with the following thicknesses: roof, 1.7m; floor, 0.9m; north and south walls, 1.2m; and east and west walls, 0.9m. The hot cell floor is designed to support the 70 metric ton weight of a neutral beam injector. The overhead bridge crane in the hot cell has a capacity of 75/15 ton. Access from the test cell is by two large shielded openings. Unlimited personnel access to the hot cell will be available because it will not be activated or contaminated as a result of tritium operations. Present planning calls for radwaste packaging to be performed in the hot cell, along with routine decon operations.

The mockup building is of Butler-type construction. It will be used primarily as an equipment staging and storage area during D&D operations. This building is also the primary egress for all large packaged components leaving the test cell.

The TFTR complex is equipped with a liquid effluent collection (LEC) system which consists of three 15,000 gallon storage tanks located above grade in a concrete diked area outside of the main experimental building. All drains and pumps from the experimental area are discharged to the LEC tanks.

To support the D&D waste handling operations, construction of a radioactive waste storage building (RWSB) will occur during the shutdown phase of the project. The function of the RWSB will be for temporary storage of certified packages containing radioactive waste awaiting shipment off-site. This facility will also serve as a temporary storage area for TFTR components that are to be reused on TPX. Upon completion of the D&D, the RWSB will remain in service for the TPX Project to store low level, packaged radioactive material.

D&D Plan

The baseline plan is presented in detail in the TFTR Preliminary D&D Plan.[4] This plan was developed to provide cost and schedule estimates based on the conservative approach of dismantling, cutting, and packaging all components, and shipping them to the DOE's Hanford facility for disposal. The technical plan for meeting the D&D objectives addresses: site shutdown and preparation; D&D operations task descriptions; and radwaste handling and disposal. The plan is based on the assumptions that a total of 2×10^{21} neutrons will have been produced, and all plasma facing components, neutral beam injectors and machine vacuum components will be tritium contaminated. This results in test cell activation and contamination levels requiring precautionary measures for workers.

Site preparation includes shutdown of the TFTR at the conclusion of D-T operations, namely, removal from the site of all tritium storage inventories; decontamination of systems and components; de-energize, lockout and tagout of electrical and mechanical systems that are not required to support D&D or are to be dismantled; radiological characterization of the experimental areas; and visual inspections and surveillance. Dismantling and removal of non-radioactive and salvageable components will be completed during the shutdown phase. Tritium decontamination of internal systems will be difficult because of their complex configuration, materials of construction and large surface areas. The majority of the retained tritium will be adsorbed into the vacuum vessel graphite tiles and in the co-deposited layer of graphite on the vacuum vessel walls. The neutral beam injectors will also be highly contaminated because they operate with tritium and in addition, collect tritium from the plasma with their cryogenic pumping panels.

The effectiveness of various tritium removal techniques such as: plasma etching; moist air soaking; and gas purging is presently being investigated. A decontamination plan will be developed and implemented based on these results and the experience of other tritium facilities. The majority of the decontamination operations will occur during the early stages of the D&D shutdown phase. Localized decontamination will continue as required throughout the project to reduce subsequent personnel exposures, waste generated and to minimize overall D&D costs.

Radionuclide characterization will occur immediately after the conclusion of D-T operations and will provide the information required to finalize the planning of the D&D activities. It will affect the work schedule and manpower requirements, particularly those related to personnel exposure. Table 1 gives the maximum contact dose at various machine locations for different cooldown times. These personnel exposures have been calculated from a PPPL computer model.[5] The model is continually checked against actual dose rates attained during plasma operations. Based on the contact dose figures, all dismantling work from the TF coils to the center of the machine will be performed with remotely operable tooling and equipment.

Cooling Time	Inside VV Port Cover	Outboard side of TF Coil Case	Outboard of Support Column
	μSv/hr (mrem/hr)	μSv/hr (mrem/hr)	μSv/hr (mrem/hr)
6 mos.	2E4 (2000)	1.6E3 (160)	60 (6)
1 yr.	8E3 (800)	700 (70)	20 (2)
2 yr.	2.6E3 (260)	240 (24)	6 (0.6)
5 yr.	800 (80)	40 (4)	1 (0.1)

Table 1. TFTR Activation Levels (Calculated) After Generation of 2×10^{21} D-T Neutrons

Plasma arc cutters, hydraulic shears and other mechanical cutters will be used to perform the dismantling tasks. Figure 2 is an elevation showing a remote dismantling operation. Due to geometric constraints, D&D of the vacuum vessel will involve cutting operations inside the torus. The present plan calls for remote dismantling of the vacuum vessel utilizing the TFTR Maintenance Manipulator Arm (MMA) equipped with a plasma arc cutter. Containment structures will be used to limit the spread of contamination during dismantling operations.

Preliminary calculations of radioactive material inventories for TFTR components indicate that the D&D waste will be Class A LLRW. They will consist of: stainless steel and aluminum structures; piping and components; copper coils and bus bars; stabilized radioactive liquids; and personnel protective equipment. All radwaste will be packaged and transported to a DOE approved waste repository. The total neutron induced radioactivity inventory to be disposed of has been estimated at 50 TBq (1400 Ci). The amount of radwaste generated

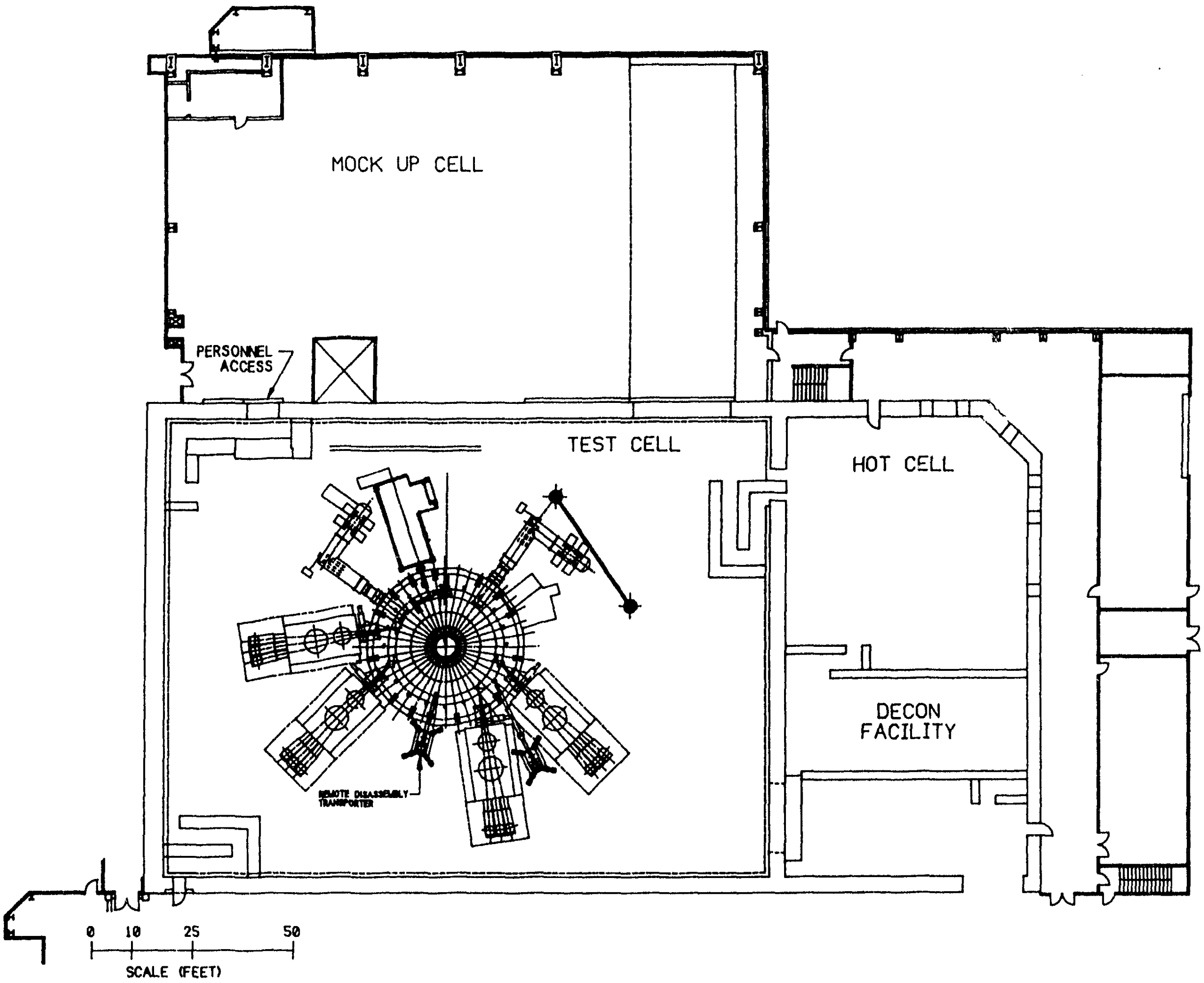

Figure 1. Plan view of the TFTR test cell, hot cell, mock up building.

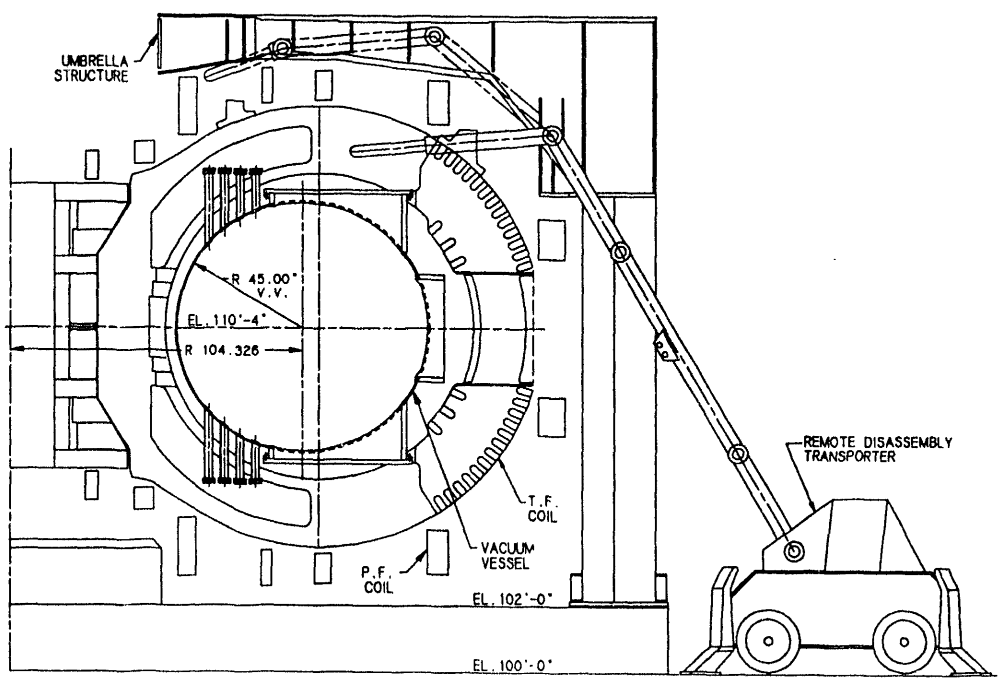

Figure 2. Elevation of the TFTR showing a remote dismantling operation.

during D&D, including stabilizer and void space filler, is estimated to be 2300 tons. At present, the repository is assumed to be the Westinghouse Hanford Company (WHC) site. Packaging of the waste will be in compliance with DOE and DOT regulations, PPPL procedures, and WHC waste acceptance requirements.[6]

Progress Towards D&D

In compliance with DOE's "National Environmental Policy Act Implementation Procedures" (10 CFR 1021), an Environmental Assessment (EA)[7] has been prepared for the project. This document is in the review cycle, and approval is anticipated in September, 1994. At that time, a Finding Of No Significant Impact (FONSI) will be issued. Engineering studies in support of an upcoming conceptual design review are the focus of this year's activities. These include: cutting approaches for the vacuum vessel; assessing remotely operated equipment for disassembly; estimating tritium retention and decontamination methods; and packaging and shipping options. In addition, detailed work procedures will be developed to assure worker and facility safety for shutdown operations. These will include: decontamination; lockout/tagout; dismantling; and radionuclide characterization starting in October, 1994.

Conclusion

TFTR will be the first fusion facility to undergo D&D. The experience gained from tritium decontamination, implementation of remote handling techniques, and lessons learned from D&D will provide valuable information for the design of future large scale fusion devices such as the International Thermonuclear Experimental Reactor (ITER). Since D&D costs have become a major expenditure for nuclear facilities, it is important to develop detailed estimates at the inception of a new project. Decommissioning cost and schedule estimates for future fusion projects can be based on actual data taken from the TFTR Project.

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