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PPPL-CFP--3085

Conf-940630--23

TECHNOLOGY ISSUES FOR DECOMMISSIONING THE TOKAMAK FUSION TEST REACTOR

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ABSTRACT

The approach for decommissioning the Tokamak Fusion Test Reactor has evolved from a conservative plan based on cutting up and burying all of the systems, to one that considers the impact tritium contamination will have on waste disposal, how large size components may be used as their own shipping containers, and even the possibility of recycling the materials of components such as the toroidal field coils and the tokamak structure. In addition, the project is more carefully assessing the requirements for using remotely operated equipment. Finally, a valuable cost database is being developed for future use by the fusion community.

I. INTRODUCTION

The Tokamak Fusion Test Reactor (TFTR) at Princeton Plasma Physics Laboratory (PPPL) will complete its experimental lifetime with a series of deuterium-tritium (D-T) pulses during FY 1994. As a result, the machine structures will become radioactive, and vacuum components will also be contaminated with tritium. Dose rate levels two years after machine shutdown will range from less than 1 millirem per hour (mr/h) for external structures, to hundreds of mr/h for the vacuum vessel. Therefore, dismantling operations will range from hands on activities to limited use of remotely operated equipment. Among the most challenging aspects will be dismantling and packaging the torus and the neutral beamlines, activities that will occur in the test cell. Figure 1 is a cutaway view of the torus and one beamline, and Figure 2 is a plan view of the test cell complex.

The primary decommissioning objective is to render the test cell complex re-usable for the next Department of Energy (DOE) fusion device, the Tokamak Physics Experiment. In October 1996, dismantling and removal (D&R) of the tokamak will commence and continue for approximately one and half years. The D&R technical objectives are: safely disassemble the activated and tritium-contaminated TFTR and various ancillary equipment in the test cell complex; package disassembled components in accordance with DOE and Department of Transportation (DOT) regulations; ship the packages to an approved DOE repository for disposal as low level radioactive waste (LLRW); and develop experience in remotely disassembling a large fusion reactor. In addition, the project will also consider recycling materials wherever practicable.

II. TECHNOLOGY ISSUES

In developing the details of the conceptual design, several challenging technology issues were identified that will be of interest to next generation fusion machines. These deal with tritium decontamination, remote/semi-remote dismantlement, and special packaging of components for disposal. In addition to assessing these activities, the TFTR decommissioning experience will also establish a cost database that will be useful for estimating costs for future fusion decommissioning projects.

A. Tritium Retention/Decontamination

The disposal of LLRW requires meeting DOT criteria for shipping, as well as the waste receiver's acceptance criteria for burial.[1,2] For a D-T burning tokamak, the primary constraint for shipping and burying LLRW is the quantity of tritium permitted in each package. Non-tritium contaminated radioactive waste may be shipped in "strong tight containers", which are the lowest classification for packaging integrity and require meeting handling criteria only. Tritium contaminated waste, however, must also meet packaging integrity to survive certain accident conditions. By limiting the total radioactivity content to 1000 curies (Ci) including tritium, "Type A" container rules apply. These require meeting a set of conditions for accident survival, and either the waste may be configured to be a Type A package, i.e. the neutral beam box can be its own container, or Type A containers that are readily available from manufacturers may be used for transport. By also limiting the radioactivity concentration in the container to less than 100 Ci/m^3 of tritium, no additional special packaging is required for shallow burial under present rules.

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In order to ensure that these limits are met, tritium retention after decontaminating the torus, the diagnostics, and beamlines must be determined. An estimate of the inventory expected at the end of D-T operations is being developed, along with a decontamination plan that will be implemented based on the experience of other laboratories that specialize in handling tritium. The preliminary results for room temperature surface retention are based on a linear relationship that was developed from empirical data. Figure 3 shows tritium surface retention as a function of pressure and time, after a moist air soak (for decontamination) at room temperature. Tritium retention is estimated to be 0.002 Ci/m^2 on clean stainless steel surfaces that were exposed to tritium at room temperature, and 0.02 Ci/m^2 for surfaces with an oil film such as the vacuum pumping forelines.[3]

1. Torus and diagnostics. Work is underway to determine tritium retention in the stainless steel and graphite tile-protected structures in the torus that were operated at elevated temperature. Those estimates are not available for reporting at this time. Tritium retention estimates are available for those components that will have operated at room temperature.

The estimated internal surface area of all (room temperature) diagnostics is 76 m^2. Based on the information above, it is estimated that the retained tritium in these eighty diagnostics that are appended to the torus is 0.2 Ci. It is clear that these components will easily meet the shipping and burial criteria outlined above. The only constraint for packaging and shipping will be the weight limits of the various standard containers.

2. Neutral beamlines. Estimating the retained tritium in the beamlines is more complicated because of the variety of operating conditions and materials. For the clean, metallic surfaces with an estimated tritium exposure of 300 Pascal-hours (Pa-h), 0.02 Ci/m^2 was used; for painted surfaces, i.e. the cryopanels, 0.2 Ci/m^2 was used. For most other internal components, 0.05 Ci/m^2 was used for an adsorption factor. Implanted tritium levels are uncertain at this time and are awaiting experimental results. The estimated tritium retained on the exposed internal surface areas in one neutral beam box is 102 Ci. This does not include tritium that will be buried by ion implantation, or adsorbed at elevated temperature in some of the beamline components.[4]

3. Decontamination. A preliminary schedule for removing tritium from TFTR following the end of D-T experiments has been proposed.[5] It presently consists of one month of high-power pulsing with deuterium, several weeks of discharge cleaning and pump down, several weeks for sampling using remote handling techniques, He-O^2 glow discharge (or some variant), and one to three moist air backfills followed by pump down. Obviously, these will be varied where downstream measurements indicate added benefits. Currently, the approach assumes that the torus and everything connected to it, namely the beamlines and diagnostics, will be decontaminated simultaneously. One of the modifications under consideration is cleaning the beamlines separately from the torus. Approximately eight months are required from the start of pulsed cleaning operations to making the final determination of retained tritium inventory.

B. Special Packaging

Careful consideration of LLRW packaging requirements has the potential to reduce personnel exposure, cost, the number of shipments to the disposal site, and the volume of material to be disposed of. Among the studies done were using vacuum vessel segments as shipping/burial containers, and using a beamline box as its own container. These have the potential to eliminate extensive remote cutting operations for volume-reduction, eliminate the need for up to one hundred containers, and reduce associated handling for transport and burial. When it was determined that qualifying these components to meet Type A container criteria could take more than a year, it was decided to use pre-approved, vendor-supplied containers. It now remains to design an interface between the pre-approved container and the heavy component so that structural integrity is preserved.

Similar considerations were investigated for disposing of the toroidal field coils. In this case however, the activation level will be as much as an order of magnitude less, and there is no tritium contamination. Hence, meeting Type A container criteria are not required, only the criteria for strong tight containers. It seems that the coils meet these even as monolithic structures, and may be left intact for shipping and burial. It is estimated that 140 standard containers will not be required, along with substantial cutting and handling savings. These structures are in fact, candidates for metal recycling as an alternative to burial.

C. Dismantling

Remote/semi-remote handling equipment and procedures will be required to dismantle components at, or near the torus, as well as for segmenting the vacuum vessel. Minimal use of personnel for these activities is the goal in order to minimize person-rem exposure, ensure meeting the requirements of DOE's Radiological Control Manual, and meet "as low as reasonably achievable" (ALARA) guidelines.[6] Several existing systems are being studied regarding physical and operational characteristics, their availability, and cost for use in vessel dismantling and cutting operations. To varying degrees, these appear to meet requirements for reaching structure, piping, and diagnostics around and on top of the machine, for carrying various tools including a manipulator and hydraulic shear, and for remote operation.

D. Cost Database

Finally, the TFTR D&D Project will develop a cost database that covers all aspects of decontamination and dismantlement. It is envisaged that this information will be valuable for developing cost algorithms for estimating decommissioning costs for other fusion machines. Presently, the cost estimating database for D&D is limited to fission experimental and commercial power plants; much of that information is simply not relevant to a fusion reactor. The importance of accurate D&D cost estimates is underscored by the fact that D&D requires significant funding and budgetary planning, and the cost of D&D is required, under certain conditions, to be included in a project's "Total Estimated Cost" by DOE Order 4700.1.[7]

ACKNOWLEDGMENTS

The authors acknowledge Robert (Bob) Fleming for his efforts in developing the tritium issues studies, and wish him well in his retirement from PPPL. This work was supported by U.S. DOE Contract DE-AC02-76-CH03073.

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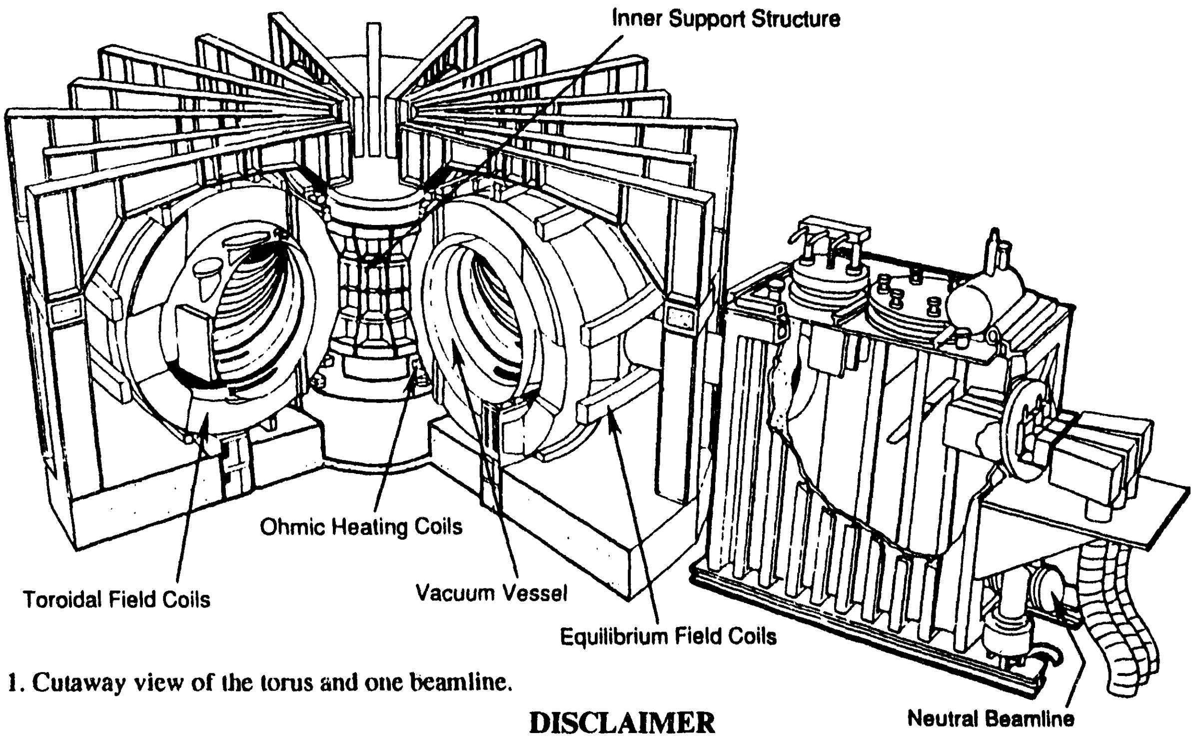

Figure 1. Cutaway view of the torus and one beamline.

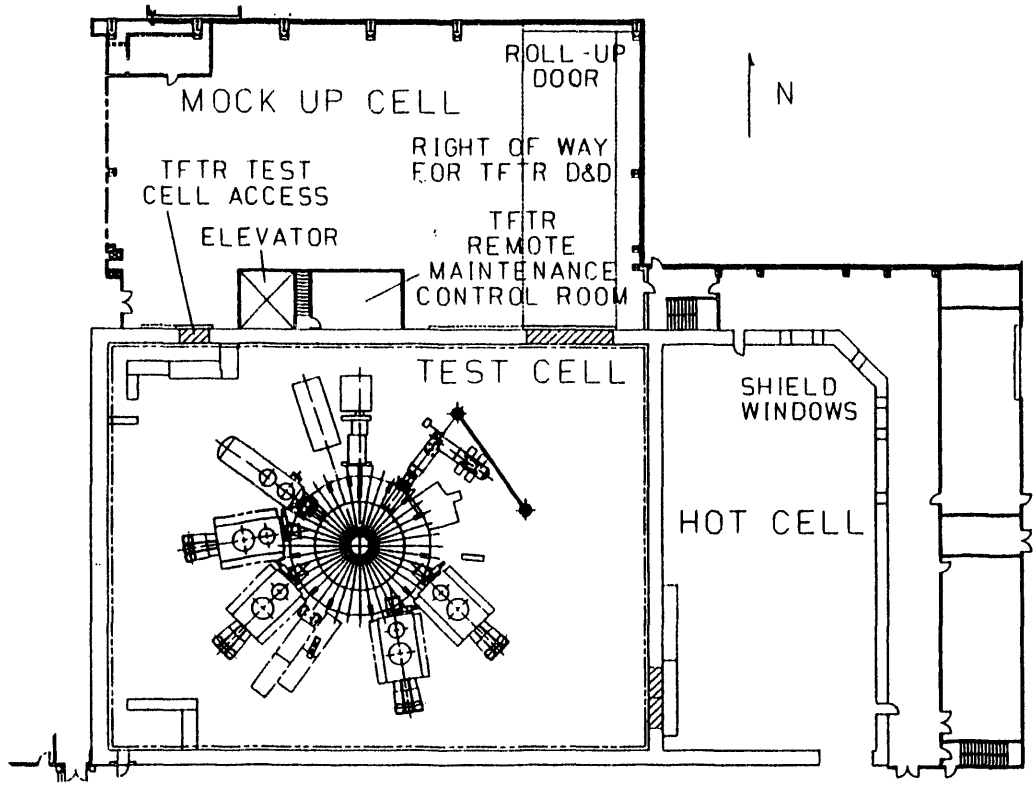

Figure 2. Plan view of the test cell complex.

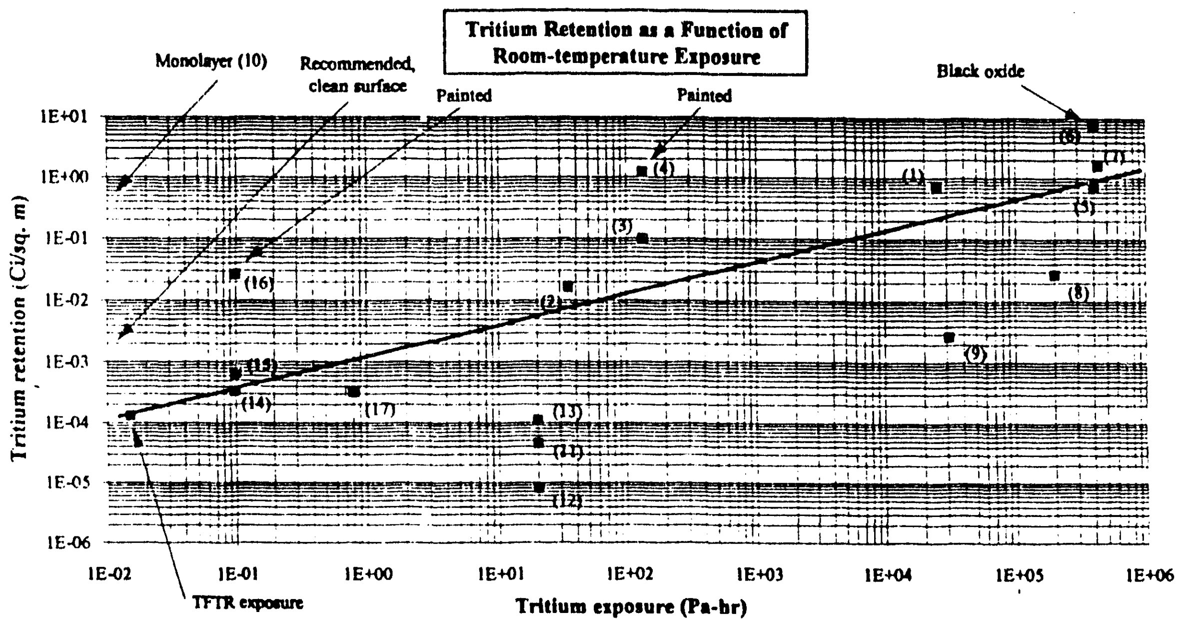

Figure 3. Tritium surface retention as a function of pressure and exposure time for room temperature, clean stainless steel.

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