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Charles A. Gentile, Erik Perry, Keith Rule, Michael Williams,
Robert Parsells, Michael Viola, and James Chrzanowski

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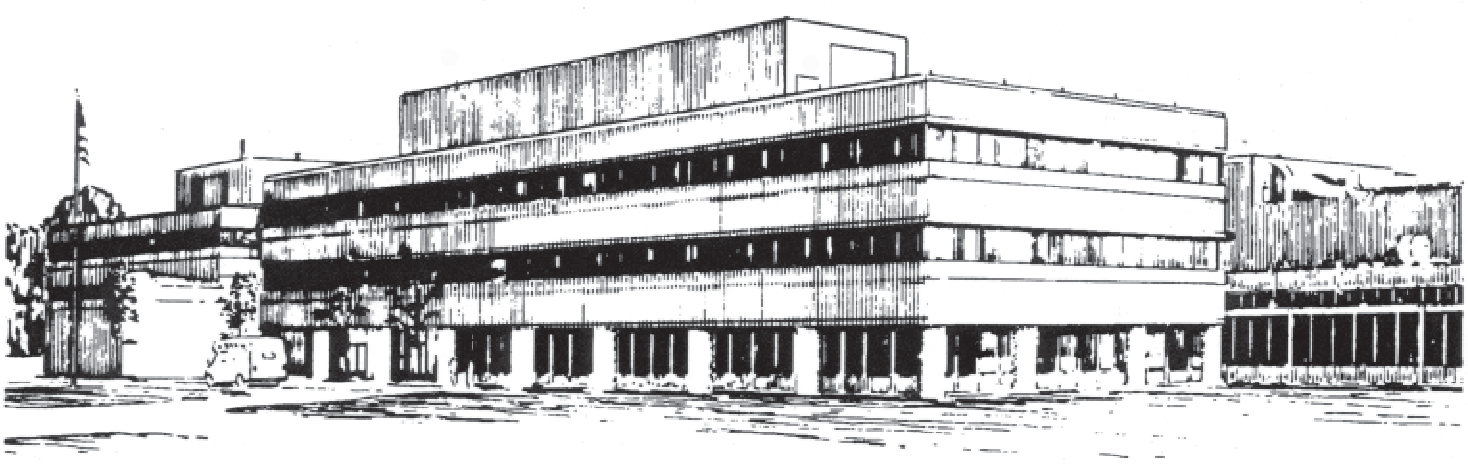
PHYSICS LABORATORY



PRINCETON PLASMA PHYSICS LABORATORY
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THE FIRST DECOMMISSIONING OF A FUSION REACTOR FUELED BY DEUTERIUM-TRITIUM

Charles A. Gentile / Princeton University, Plasma Physics Laboratory

Erik Perry / Princeton University, Plasma Physics Laboratory

Keith Rule / Princeton University, Plasma Physics Laboratory

Michael Williams / Princeton University, Plasma Physics Laboratory

Robert Parsells / Princeton University, Plasma Physics Laboratory

Michael Viola / Princeton University, Plasma Physics Laboratory

James Chrzanowski / Princeton University, Plasma Physics Laboratory

ABSTRACT

The Tokamak Fusion Test Reactor (TFTR), at The Plasma Physics Laboratory of Princeton University (PPPL) was the first fusion reactor fueled by a mixture of deuterium and tritium (D-T) to be decommissioned in the world. The decommissioning was performed over a period of three years and was completed safely, on schedule and under budget [1]. Provided is an overview of the project and detail of various factors which led to the success of the project. Discussion will cover management of the project, engineering planning before the project started and during the field work was being performed, training of workers in the field, the novel adaptation of tools from other industry, and the development of an innovative process for the use of diamond wire to segment the activated / contaminated vacuum vessel. The success of the TFTR decommissioning provides a viable model for the decommissioning of D-T burning fusion devices in the future.

INTRODUCTION

The Tokamak Fusion Test Reactor commenced operation in 1982 and was operated until 1997. From 1993 through 1997 TFTR was operated with tritium, a component of fusion fuel. During this four year period TFTR successfully completed > 1,000 D-T shots and processed ~ 1 M Ci of tritium of which approximately 53,000 Ci were delivered into the 80,000 liter TFTR vacuum vessel in support of fusion energy development. The employment of tritium during the last 4 years of TFTR operation presented several challenges for the successful D&D of the project. In addition to the 7,000 Ci of tritium remaining in the vacuum vessel, predominately in the co-deposited layer within the graphite tiles, a relatively high concentration of surface tritium contamination (10 M to 40 M dpm / 100 cm2 for surface smears) existed. The vacuum vessel and support structures were activated to levels ranging from approximately 50 mRem/hr (on contact with the vessel) to approximately 2 mRem/hr on ancillary equipment. At the end of the 3 year TFTR D&D project approximately 52,000 cubic feet of radioactive and tritium contaminated waste would ultimately be disposed of. The deployment of novel technologies during D&D led to an approximate 63% reduction in the amount of radioactive and contaminated waste materials that was initially estimated to be generated using conventional tooling and procedures [2]. In addition to the 63% reduction of radioactive and contaminated waste the project came in under budget with a completion cost of $36.8 M. This is approximately 9.5% under the original estimated cost. The major elements associated with this savings was; the deployment of novel technologies employed during the project, a well trained staff, appropriate allocations of funds, and diligent scheduling and reporting which quickly identified work slippage which prompted reaction in a positive manner to get the task back on schedule and completed in accordance with project requirements.

SAFETY CULTURE

The single most important aspect of the successful D&D of TFTR was (and still is) PPPL's commitment to safety. Safety considerations in the performance of low, medium, and high risk tasks has been a corner stone of the successful operation of the facility since the establishment of the laboratory and is prevalent throughout PPPL. The safety culture at the laboratory is nurtured throughout the organization and recognized by senior management down the reporting chain to the workers in the field as a critical aspect in the fulfillment of the laboratory's mission. As PPPL's most valuable tool in the development of fusion energy all elements of the D&D project were built upon a culture which supported a safe work environment. One of the tenants of an effective safety culture is the pre engineering planning that goes into a task and analysis of completed tasks received from workers after a job is complete. This information was collected during post-job briefs which were then integrated into a lessons learned data bank. This data was then used to provide improvement and refinement to future jobs to be performed during the D&D project. Discussing and reviewing tasks with workers immediately prior to a job in the form of a pre-job brief was a crucial element of maintaining safety and efficiency at the job site. Engineers, supervisors, and workers would come together to discuss various details of the work. Workers were encouraged to ask questions and to discuss any concerns they may have. The purpose of this activity prior to a specific job was to ensure that workers in the field were fully aware of the hazards, had a clear understanding of how to safely perform their task, to ensure that the proper controls were in place to support a successful conclusion, and to integrate knowledge learned from past tasks into current and future activities associated with the project.

DOCUMENT CONTROL

Document control provided considerable cost savings with the establishment of a Document Control Center (DCC) near the work site. The fundamental function of the DCC was to maintain applicable documentation near the work site such that workers would have easy access to controlling documentation. The Document Control Center established a system of work packages which included; specific task procedures, work planning forms, hazard analysis, safety reviews, work permits, pre-job briefs and post-job briefs. Maintaining and keeping all of the job specific documents available to workers in a single file package saved considerable time and significantly increased productivity. Immediate field supervisors and workers were available to spend more time at the work site since comprehensive work packages germane to specific tasks were readily available to workers in the field. In addition the work packages provided a method of detailing the engineering planning that went into preparing for the job. This information was readily available to all working on these specific tasks. In several instances when new workers were assigned to a task already in progress the worker could review the job work package material in the field with the job supervisor and could safely commence work in accordance with established procedures. This process kept workers fully aware of job specifics while maintaining safety and efficiency. At the conclusion of a specific task the work package file would be closed out, reviewed by project management and forwarded to the PPPL Operations Center where the document package would be archived. Employing this system of document control provided a comprehensive record of all aspects of the completed task which included hazards analysis, those persons working on the task, and conditions at the final conclusion of the job.

DEPLOYMENT OF NOVEL TECHNOLOGIES

Several novel technologies were deployed during TFTR D&D which significantly reduced cost and risk associated with the project.

Diamond wire cutting provided a method of cutting the TFTR vacuum vessel into 10 pieces which were able to be placed in Type A shipping containers for shallow land burial disposal. Prior to TFTR D&D diamond wire cutting was typically used in stone quarries or in environments where concrete blocks needed to be cut. Prototype testing at PPPL proved that diamond wire cutting could be used effectively to cut the stainless steel vacuum vessel when the vessel was filled with a light weight concrete. A cable fitted with small sleeves incorporating industrial diamonds was used to effectively cut the vacuum vessel. The employment of diamond wire cutting saved both resources and radiological exposure to personnel who were mainly outside of the 25 mRem /hr general area radiation field that existed on and near most of the vacuum vessel components.

Crimping ends of tritiated pipes and lines proved to be an effective method of safely dismantling tritiated components for disposal. The use of industrial crimpers provided a method for isolating tritium contaminated surfaces in a manner which protected the workers and mitigated tritium off-gassing. In addition pieces of pipes and lines could be crimped and cut in a fashion to reduce dismantling labor cost while optimizing the size of the component that could fit into the waste disposal package. The deployment of crimpers significantly reduced the quantity of removable tritium contamination at the work site. Which led to a reduction in the quantity of radiological waste that needed to be disposed of.

The employment of large industrial power saws provided for an efficient means of cutting large metal components such as the toridal field coils. Saw technology has advanced significantly over the past several years and provided an effective cutting platform for large irregular pieces of hard metals (stainless steel, inconel) that needed to be reduced in size in order to fit into the appropriate waste packages. In several saw cutting configurations, workers would set up the saw cutting geometry, lock the pieces in place and the saw would perform the cut while the worker was observing the cut at a location outside of the radiological area. This also lead to maintaining worker exposures in accordance with ALARA considerations.

RADIOLOGICAL EXPOSURES AND RELEASES

During the course of TFTR D&D Health Physics and Radiation Control practices were instrumental in maintaining doses to workers to at ALARA levels. Each D&D task associated with work which included a radiological component was reviewed and an appropriate Radiation Work Permit (RWP) was established. Workers were required to read and sign the RWP to ensure understanding of the radiological conditions at the job site and to declare that they understood and would comply with the controls in the RWP. During the TFTR D&D project total radiological exposure for all workers for the course of the entire project was determined (by dosimetry) to be 10.97 Person Rem. Stack releases to the environment during the time of D&D project were determined to be 446.62 Ci of tritium as measured by passive stack monitors. The use of engineered containment's to isolate tritium, activated metal particles, and dust was also instrumental in maintaining exposure ALARA while minimizing the quantity of radioactive waste associated with D&D. Another powerful tool employed to maintain contamination levels to a minimum was the employment of negative pressure trunks. Three and six inch diameter trunks ranging in lengths of up to 50 ft were readily available during D&D to provide negative pressure in a fashion that would direct contaminated air and dust away from workers. These trunks were configured to direct flow to the facility (negative pressure) HVAC system which was continuously monitored via real time tritium detectors which provided data to site supervising personnel.

CONCLUSION

The commitment to strong safety culture, establishment of a comprehensive single documentation folder in the form of a Work Package System (available at the work site), and the deployment of novel tooling for TFTR D&D established a platform for a safe, efficient, and economical project. These elements of the successful TFTR D&D can serve as a model for future D&D projects not limited to fusion reactors.

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Information Services
Princeton Plasma Physics Laboratory
P.O. Box 451
Princeton, NJ 08543

Phone: 609-243-2750
Fax: 609-243-2751
e-mail: pppl_info@pppl.gov
Internet Address: http://www.pppl.gov