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The Innovations, Technology and Waste Management Approaches to Safely Package and Transport the World's First Radioactive Fusion Research Reactor for Burial

by

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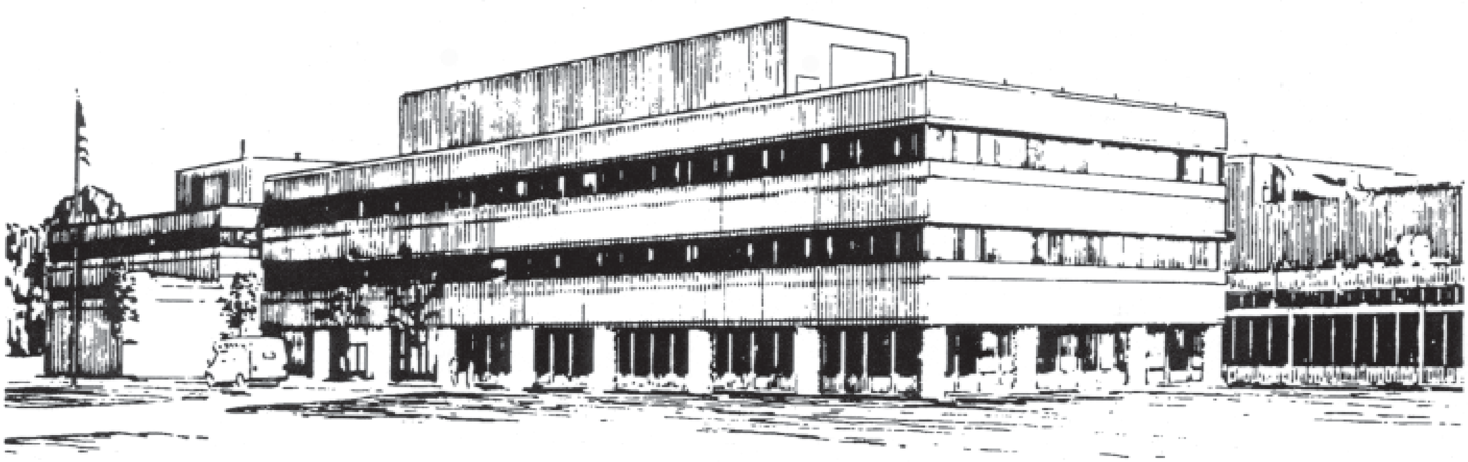

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THE INNOVATIONS, TECHNOLOGY AND WASTE MANAGEMENT APPROACHES TO SAFELY PACKAGE AND TRANSPORT THE WORLD'S FIRST RADIOACTIVE FUSION RESEARCH REACTOR FOR BURIAL

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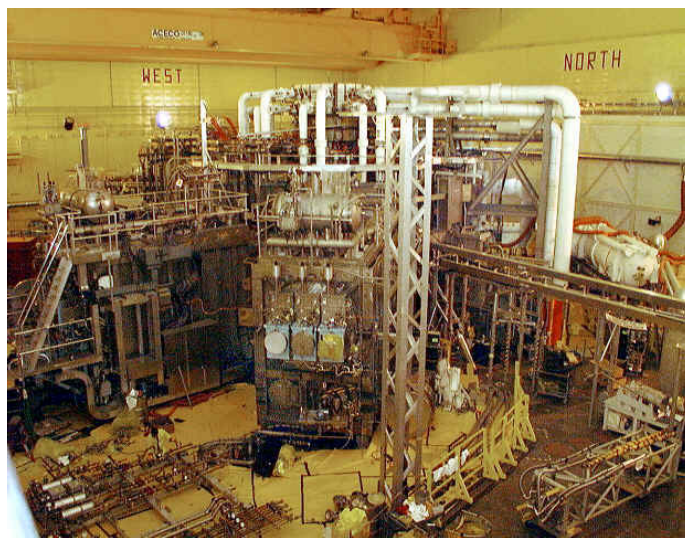
ABSTRACT
Original estimates stated that the amount of radioactive waste that will be generated during the dismantling of the Tokamak Fusion Test Reactor will approach 2 Million Kilograms with an associated volume of 2500 cubic meters. The materials were activated by 14 Mev neutrons and were highly contaminated with tritium, which present unique challenges to maintain integrity during packaging and transportation. In addition, the majority of this material is stainless steel and copper structural metal that were specifically designed and manufactured for this one-of-a-kind fusion research reactor. This provided further complexity in planning and managing the waste.

We will discuss the engineering concepts, innovative practices, and technologies that were utilized to size reduce, stabilize and package the many unique and complex components of this reactor. This waste was packaged and shipped in many different configurations and methods according to the transportation regulations and disposal facility requirements. For this particular project we were able to utilize two separate disposal facilities for burial. This paper will conclude with a complete summary of the actual results of the waste management costs, volumes, and best practices that were developed from this groundbreaking and successful project.



TFTR in first year of dismantling

INTRODUCTION
The Princeton Plasma Physics Laboratory (PPPL) is home to the Tokamak Fusion Test Reactor which ceased operation in April 1997. The Tokamak Fusion Test Reactor (TFTR) began operation in 1982. After many years of deuterium-tritium fusion experiments, resulted in the contamination of the vacuum vessel with tritium and activation of structural materials by 14-mega-electron-volt neutrons. The total tritium content within the vessel was in excess of 7000 curies, while dose rates approached 50 millirems per hour (0.5 mSv/hr). These radiological hazards, along with the size of the Tokamak (100 cubic meters), presented a unique and challenging task for dismantling.

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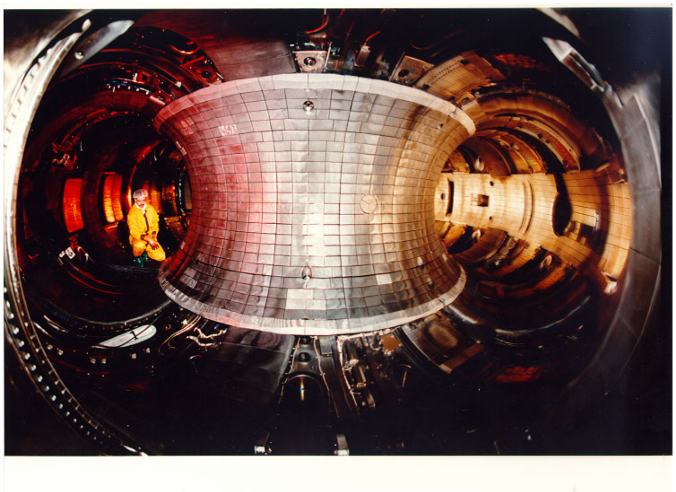
In 1991, prior to the final years of fusion experiments on TFTR, decontamination and decommissioning (D&D) planning began and continued until the commencement of D&D in October 1999. The TFTR D&D Project was originally estimated to generate 85, 000 cubic feet of radioactive waste. The primary goal of the project is to complete the dismantling and decontamination of the facility in three years within the established cost and schedule, while achieving an excellent safety record.



Interior of TFTR Vacuum Vessel

PLANNING

Several years of planning and engineering were necessary to detail the requirements and associated cost and schedule of this unprecedented dismantling. During this effort, planners integrated health and safety requirements into the cost and schedule and subsequently into the actual dismantling procedures. Specifically, a joint effort among the planning engineers and waste management engineers led to a detailed and flexible profile of the radioactive waste generation over the project duration. This effort consisted of a line by line evaluation of the project schedule to identify the various characteristics of the waste generated by a particular task. Each task was characterized by dimension, weight, type, and capability to be packaged. The latter is particularly important because is will place waste materials in categories. Some waste can be placed in drums, while other in standard boxes, and other larger items that require specific containers.

The "radioactive waste" project task characteristics were integrated into the actual computer planning database program known as "Primavera". The project planner imported the characteristic information into the line items identified to generate radioactive waste. As with most database programs if the information is properly joined with a line entry this can be a powerful tool. The successful completion of this effort provided an accurate view and report of any particular characteristic. This also provides for the line times and associated characteristics to be moved in unison with any schedule changes. The program can then generate a new report of your waste generation for any requested time frame. A very powerful and helpful tool if the up-front effort is performed accurately.

Many of the other more specific issues with regard to the unique design of this reactor led to additional evaluations that were integrated into the basic aforementioned planning effort. These are explained briefly:

Tile Removal Tool - Design and use of this tool will help determine the worker protection requirements for vessel dismantling and will also help determine the sizing and segmenting scheme for the vessels. This results in determining the package design, construction, use, required equipment, void space determination, transportation and disposal.

Torroidal Field Coil Disposition - A number of questions revolve around the TF coils and their disposition. This also ties in with the vessel segmenting and/or tile removal tool. Questions/Considerations: method for removal of coils, subsequent cutting, packaging, lifting, decontamination, recycling, transport, re-use, radiological conditions, packaging, storage, potential waste generation scenarios and disposal.

Container Study - A detailed study is needed to identify the specialized sizing for waste containers. TFTR is a one-of-a-kind reactor facility with unique equipment which will require a great deal of cutting in order to place in standard containers. There is a significant waste generation and radiation exposure associated with material cutting.

Transportation Study - This should be performed in parallel with the container study to evaluate the cost differences associated with transport of waste containers according to their physical dimensions and weight.

Research Technology Development - Effort should be devoted toward advancing technology in waste minimization and management. In particular, the areas of metal recycling, waste reduction and facility dismantling should be examined.

Release of Radioactive Material - The application of impending guidance from 10CFR834 along with site background determination will most likely place us in a situation to use RESRAD, which exists as NUREG and DOE publication, to justify the release or recycling of material from the Test Cell Basement and Hot Cell. This has a huge impact on S&R schedule and waste generation.

Machine Activation Study - Study needs to be continued to project the nuclide production and radiation levels from the TFTR. This will affect the ALARA calculations for vessel dismantling and TF coil disposition. The nuclide distribution could affect the LSA and Type A designations with regard to packaging, transport and disposal.

OPTIONS FOR BURIAL

There are two disposal facilities operated for the U.S. Department of Energy (DOE) that are available for DOE sites to utilize for burial of radioactive waste. These sites are located at the Nevada Test Site (NTS) in Nevada and Hanford

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Reservation in Washington State. Both of these locations are arid climates with desert characteristics which are desirable for land burial of radioactive waste. A third site is available for burial of waste that is operated by Envirocare of Utah, Inc., a private concern. The DOE has initiated a large scale contract with the latter as an option for burial of mixed waste and large quantities of soil/debris radioactive waste.

In the U.S.A. we are fortunate to have options for burial of low-level radioactive waste. When considering your options the burial cost is usually the primary factor, followed by transportation. Due to our geographic location on the eastern coast of the U.S., the difference in transportation costs was inconsequential. However, the disposal costs and acceptable burial configurations were significant. At the Hanford burial ground the disposal costs average \$20 per cubic foot (~355 £/m3) while the NTS averages \$6/ft3 (106 £/m3). If you are packaging and transporting waste in metal containers you would select the NTS for burial but when considering other options we chose to ship dump trailers with approx. 40 m3 of activated, non-contaminated waste to Hanford. The costs savings were significant due to the absence of labor for size reduction.

INITIAL APPROACH

There was a considerable amount of aluminum that was utilized as support for the many diagnostic and operational equipment. This non-ferrous material was selected due the high-strength magnetic fields present during operations. A secondary benefit is that aluminum has a very small profile for neutron activation with a short 2.5 minute half life of Al-28. For the first year of the project we focused on the removal of the non-activated and non-contaminated materials such as structural aluminum, peripheral wiring, lead and poly shielding, and other miscellaneous peripheral systems. This approach is quite logical, in that, you usually need to start disassembly from the perimeter and work your way in, but there is also the added benefit of minimizing radioactive waste. If you were to disassemble a tritium contaminated system and contaminate adjacent equipment that could have been previously removed, you would create radioactive waste that might have otherwise been recycled. This approach also provide for the "easier" work to be accomplished by the new work force which enhanced the learning and created confidence to begin more difficult tasks.

TECHNOLOGY–DISMANTLING & SIZE REDUCTION

A Wachs Guillotine cutter is a powered reciprocating saw, powered by electric, hydraulic or pneumatic means and can cut through large metal objects such as pipe, tanks, or structural steel. They are similar in work to a hacksaw without the person doing the operations. They clamp onto the object to be cut and the cutting rate can be manually or automatically controlled. These cutters were instrumental for the size reduction of the 90 ton stainless steel umbrella structure and the copper poloidal field coils.

A Wachs Clamshell cutter utilizes a tool steel blade to cut through piping using an electric, pneumatic or hydraulic motor. The cutting support frame is in pieces which are easily joined and mounted around the pipe. The cutting bled is then inserted and rotated around the pipe by the motor and gear assembly. This system is shaves pieces of metal around the pipe and continues at a gradual depth until breakthrough is achieved. The work is conducted in a controlled manner while generating a small amount of metal shavings instead of fumes, vapors, or particulates.

A Marvel 25 vertical band saw was purchase and utilized for cutting of the large 25 ton toroidal field coils. These coils were custom manufactured out of Nitronic-33 stainless steel, copper and epoxy. The Nitronic-33 is 50% by weight. This large throat saw with a 25" depth and 22 inch height allowed for the cutting of these 14 foot diameter coils with dimensions approaching the limitations of the saw. The saw utilized carbide tipped cutting bands and were able to make both cuts of the circular coil in 8 hours. This provide for a simpler packaging scheme using fabrics and plastic instead of large metal containers.

The Burndy crimping tool is a battery powered electro-hydraulic crimping tool normally utilized for electrical wire connector assembly. This tool die was modified at PPPL to provide for crimping of capillary tubing containing high concentrations of tritium. By crimping the tubing with the new die, a two-point crimp was obtained by the 12 tons of hydraulic force which provide for mechanical cutting of the tubing with bolt cutters. This provide for an extremely safe method of size reducing tubing for packaging in metal boxes or drums.

The Champion hydraulic plunging blade cutter utilizes a hydraulic pump cart with hoses and end effectors to cut various sizes of conduit, tubing, piping and structural metals. The various end-effectors have the ability to cut up to 6 inch diameter piping. This tolling is also intrinsically safe, in that, any misuse or exceedance of force will cause the blade to bend rather than quickly shear which creates a projectile. This tooling was also instrumental in size reduction of various metal piping and structures for packaging.

The Holmatro hydraulic scissor blade cutters also utilize a hydraulic pump cart and hose with end effectors for cutting of metals. This manufacturer has a large selection of end-effectors which usually has greater capability however it can be less safe due to the hardened scissor-type blades.

The Trumpf Nibbler is manufactured in Europe and is a an electric powered nibbler which punches small metal chips out of piping or sheet steel during operation. This tooling has the capability to cut up to 3/8" carbon steel and was instrumental in cutting large diameter piping lengthwise for size reduction and packaging.

All of the aforementioned technology performed the dismantling and size reduction of metal structures without the generation of radioactive particulate, fumes or other hazardous exposures to workers or the environment.

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DECON AND PACKAGING TECHNOLOGY

A strippable coating manufactured by Bartlett Nuclear in the US was utilized for contamination control of radionuclides. This was accomplished in different applications. The coating can be applied prior to work in order to protect clean items from contamination. The coating can also be applied after work to trap and remove contamination or in several applications which traps contamination in layers. No matter the preference the coating becomes rubbery and elastic after it cures. It can be removed by peeling the rubbery layer(s) from the surface and then packaging as waste. This product is quite effective and eliminates the need for typical solutions and mop/rag decon.

An amino-plast resin based foaming agent was instrumental in the removal of our 24 inch diameter vacuum pumping ducts. This foam, Core-Fill 500, is delivered through a multi part hose system to a mixing valve control and then through a poly tube to the desired location. The foam is three part: water, air and the resin, and weighs less than 1 pound per cubic foot. This foam was injected into the ducts prior to removal which trapped the contaminants within the duct. The ducts were then unbolted into segments while the foam was cut with a diamond abraded piano wire. The foam filled the entire void space within the ducts which enabled immediate packaging into a specially designed container.

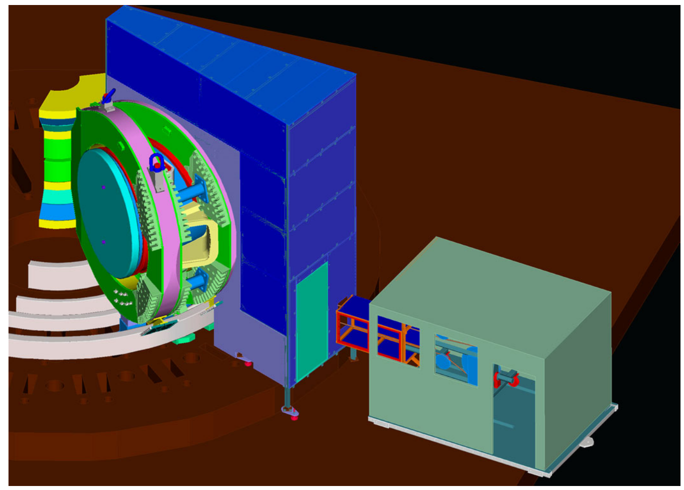
In preparation for the eventual diamond wire cutting of the vacuum vessel, the Geocell® foamed lightweight concrete product was pumped into the vessel for stabilization. The material is an aerated low-strength concrete with a weight of approximately 35 lbs/ft3. This concrete performed four different functions for this critical phase of the project. The concrete provides: 1) additional shielding which reduced dose rates, 2) void space filling in preparation for packaging, 3) containment of tritium contaminates/dust, and 4) a mechanism for wire support during diamond wire cutting. The concrete was pumped through 3 inch hose into the vessel to a total volume of 100 cubic yards in three separate lifts. This enabled the concrete to cure and release heat in between lifts which eliminated any potential for slumping or voids.

These lighter weight fillers provided contamination control, increased worker protection and turn-key packaging of large, highly contaminated objects in preparation for disposal.

DIAMOND WIRE CUTTING OF THE VACCUUM VESSEL AND PACKAGING OF THE SEGMENTS.

Diamond wire cutting is a mature technology for concrete cutting applications. As a result of R&D at PPPL and the subsequent successful cutting, the technology has also proven to be applicable to size-reduction of large metal vessels such as reactors, heat exchangers, and tanks, when combined with some form of concrete matrix. The technology is particularly advantageous when there are significant health and safety concerns. This technology was selected as the only viable, safe, and proven method for segmenting the large donut-shaped vacuum vessel.

An automated pulley system was installed at the selected cut location around the vacuum vessel, along with the particulate collection shrouds and apparatus. Several pulleys were mounted and positioned to transition the diamond wire from the automated pulley system to the saw. With these systems in place, the main containment and saw containment were installed, sealed, and joined. The cryogenic cooling system was strategically positioned to cool and clean the diamond wire. An 11-mm-diameter diamond wire was used to begin and perform most of the cutting. When a new wire needed to be installed, because of smaller kerfs due to bead wear, a 10-mm wire was sometimes needed.



Isometric Drawing of DWC Arrangement

The first of 10 cuts began in late August 2001; all cuts were completed in late February 2002. The average cutting time to completely sever the segment was 15 hours, with all cutting taking place without personnel in the containment. All 10 cuts were performed as planned. The "pull cut" method was utilized for the majority of cutting, while the "push cut" was used to complete the cut and free the segment. While there were instances of wire failure due to binding of the wire from stresses and fixtures within the vacuum vessel, a minimal number of entries into the containment were necessary to correct these conditions.

The contamination control systems, procedures, and radiation protection practices complemented the engineering controls to prevent the spread of contamination beyond the planned control areas and containments. No unplanned personnel exposures occurred, and all cutting was performed without any occupational injury.

These individual segments, ten in total, were each package within a specially designed container. This design accounted for the necessary geometry, transportation constraints, and weights of the packaging mechanisms. Each segment was lifted and rotated to lie flat on the cut surface. A one foot layer of cement was poured into the container for stabilization and bracing. The remainder of the container was filled with radioactive waste to fill voids and utilize the empty space. Each container had a gross weight restriction of 53,500 pounds. With the vessel weight at 22,000 pounds and concrete at and container weight combing for 17,000 pounds, an estimated

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14,000 pounds of other radioactive weight to be added. While the container design cost was slightly greater due to the increase weight capacity, this was easily off-set by the increased capacity for radioactive waste.

Initial segment removal

LESSONS LEARNED

While no two projects are the same, many of the general principles, processes, and lessons learned from this D&D project can be related to others. The importance of planning cannot be stressed enough. It is also important that the planning involve each organization that will be involved with the execution. Outside input can be invaluable.

Selection of the proper disposal containers, vendors and product delivery is essential to compliance and schedule. The designs must allow for contingency and should be developed with peer review. Selecting more than one vendor can also provided needed flexibility for fabrication and on-time delivery. Quality control, testing and inspection is critical to compliance and prevention of container leaks or weld failures.

Research into existing or near market technology can significantly improve safety, cost and schedule. Most technology can yield cost benefit in less than one year if it is applied properly. There has been a wider application of technology into D&D projects over the past 5 years with an ample supply of lessons learned. It is also essential to involve the hands-on technicians when evaluating and selecting technology.

SUMMARY

The TFTR D&D project was completed in September of 2002. The project team completed this under budget and on – schedule. Due to the extensive planning, use of technology and creativity of the personnel, this project generated 52,000 cubic feet of radioactive waste as compared to the original estimates of 85,000 ft3.

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