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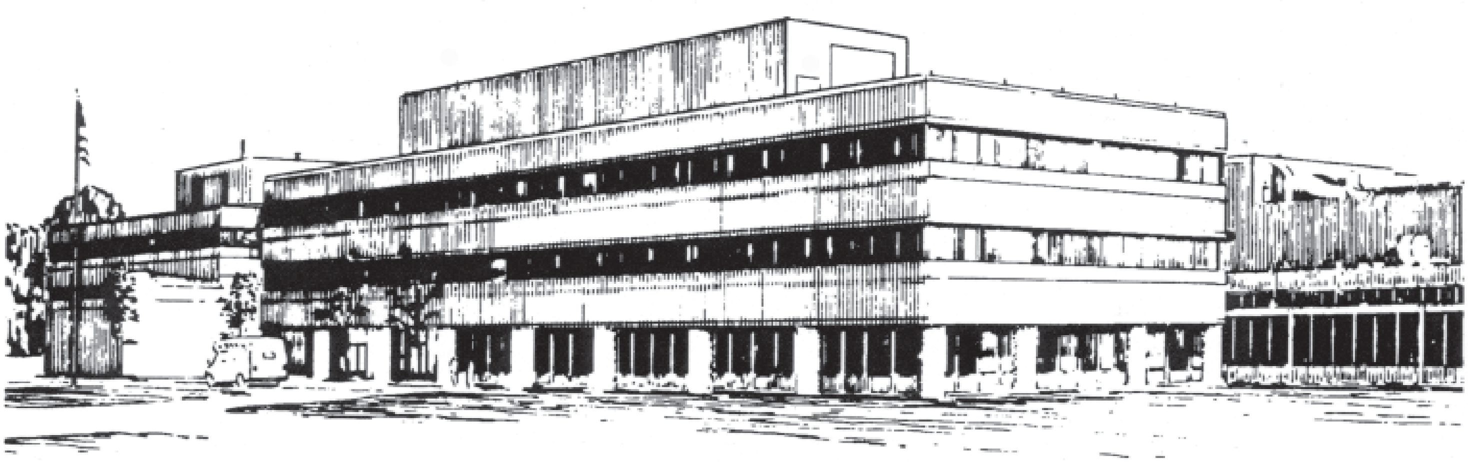

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Comparison and Evaluation of Various Tritium Decontamination Techniques and Processes

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In support of fusion energy development, various techniques and processes have been developed over the past two decades for the removal and decontamination of tritium from a variety of items, surfaces, and components. The motivational force for tritium decontamination by chemical, physical, mechanical, or a combination of these methods, is driven by two underlying forces. The first of these motivational forces is safety. Safety is paramount to the established culture associated with fusion energy. The second of these motivational forces is cost. In all aspects, less tritium contamination equals lower operational and disposal costs. This paper will discuss and evaluate the various processes employed for tritium removal and decontamination.

I. INTRODUCTION

Tritium Decontamination of various materials and components associated with fusion energy development has proceeded forward over the past twenty years. The motivation for tritium removal, in pursuit of fusion energy, falls into four categories. The first of these is to remove tritium from components in a manner to reduce tritium contamination for radiological protection purposes. The second is to remove tritium in a fashion such that an item can be reused in a non-tritium environment. This is typically defined as "free releasing" components for use in non-radiological areas. The third is to remove tritium in a manner such that a specific inventory limit can be maintained. This is critical in maintaining site limits in compliance with regulatory requirements, or for maintaining operational control of material (tritium) in-process by reducing inventory "bottlenecks" in the system. The ability to move tenaciously held tritium to a more useful area within the tritium boundary has additional value. The fourth category is to remove tritium from items such that they may be disposed of in a less restrictive fashion. The underlying common factor for the removal of tritium in all four of these categories is safety and cost. The need to remove or reduce tritium for radiological protection purposes, in addition to personnel safety, is in part to attenuate the cost of operating a facility due to increased engineering and radiological controls. The motivation for removing tritium from a component, which can be "free released" and employed in a non-tritium environment, is to conserve resources by using a device/component over again in a less restrictive, non-radiological, or low radiological environment. The motivation for the removal of tritium associated with inventory control, in addition to technical safety concerns, is to reduce site costs related to engineering controls, site boundary doses, environmental impacts, mitigating systems, and facility design. The driving force associated with the removal of tritium for the purpose of disposal is directly related to the cost of regulatory compliance, transportation, packaging and handling requirements. In countries where fusion energy is being developed, regulatory compliance and disposal cost of tritiated items/components can comprise a significant fraction of the operating budget of the facility. In addition, costs associated with transportation and disposal typically outpaces the rate of inflation.

The cost of tritium is relatively inexpensive at several dollars per Curie. However, the cost of disposal and management of tritiated items can be as much as several orders of magnitude higher in fusion facilities, thus costing many thousands of dollars to dispose of the same Curie which cost only several dollars to procure.

II. TRITIUM REMOVAL

The removal of tritium from components is typically performed by chemical, physical, and/or mechanical techniques.

Chemical techniques include oxidative decontamination processes, or chelating agents, which work by combining with tritium in a fashion that is effective in reducing surface and near-surface tritium [1]. Figure 1 depicts a chemical oxidative system for removing tritium from "soft waste" items [2]. Empirical measurements (ΔT^2 concentrations) employing this system have achieved a tritium Decontamination Factor (DF) of greater than 100. This system is capable of processing up to 20 kg of soft waste in a batch mode. The process container is loaded with various components of Personal Protective Equipment (PPE). The device rotates the reaction chamber at approximately 10 rpm while ozone gas is fed into the stainless steel container. An additional feature of the device is that, in addition to reducing tritium from these soft wastes, is a size reduction due to the interaction of ozone with various plastic and polymer-based materials resulting in a shredding effect.

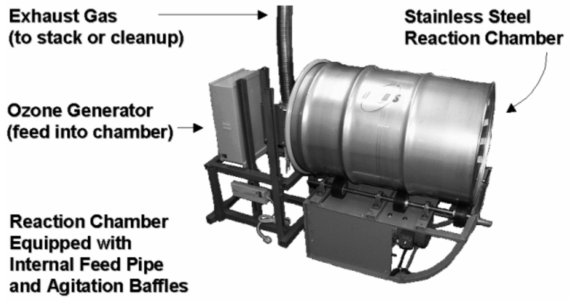

Fig. 1. Rotary Oxidative Tritium Decontamination System

Similar results have been achieved with hydrogen peroxide (H_2O_2) solutions at concentrations of 3% at room temperature [2,3]. In these applications components are immersed in a hydrogen peroxide bath and are subjected to a several hours of immersion in the H_2O_2 decontamination cocktail. Table I depicts survey results prior to and after H_2O_2 decontamination of TFTR RF feed-throughs. These devices, which consist of stainless steel, copper, and ceramic material, were successfully decontaminated for use in a non-tritiated environment. The cost savings associated with reusing these components in another (non-tritium environment) fusion energy device at PPPL saved the laboratory approximately $500,000.

TABLE I. H_2O_2 Decontamination of TFTR RF Feed-through Components

RF Feed-through Survey Location	**Before Decon Bq/100cm^2**	**After Decon Bq/100cm^2**
Outside Ctr. Cond.	16973.90	0.85
Inside Ctr. Cond.	1355.85	1.08
Outside Outer Cond.	44.97	0.50
Conductor Area	15481.93	0.80
Main Body Seal Area	1393.50	0.65

Physical decontamination methods include ovens , lasers, and burners to remove surface and near-surface tritium contamination by raising the surface and bulk temperature of the material being decontaminated. This technology works for a variety or materials and geometries in a fashion to remove tritium from a large distributed surface to a more concentrated area where it can be disposed of or redeployed after processing. These technologies are useful in the removal of tritium from first wall materials and have been shown to be highly effective for the removal of tritium from co-deposited and imbedded tritium in graphite tiles. The use of bake-out ovens provides a powerful tool for removing tritium from various metal, ceramic components and graphite tiles. These types of ovens typically are operated at nominal temperatures of 350 – 500 ºC. Bake-out ovens for tritium decontamination use have been very successful (for small components) in removing tritium from surface and the near-surface matrices.

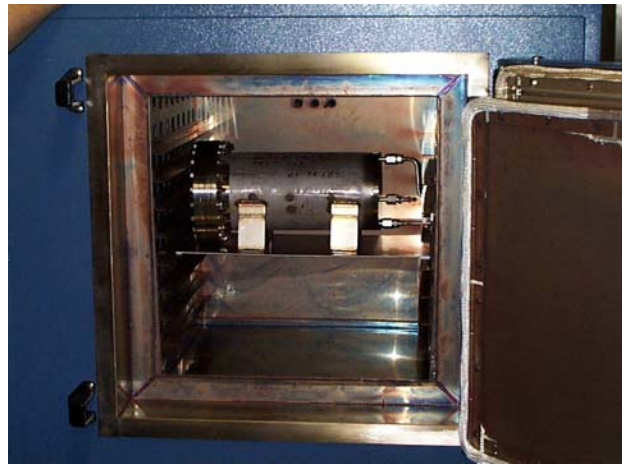

Fig. 2. Tritium Decontamination Bake-out Oven

The Nd:YAG laser configuration shown in Figure 3 was deployed at PPPL and was successful in removing up to 87% of tritium from TFTR and JET co-deposited layers from graphite tiles [4,5]. In addition to rapidly heating the surface of the tile to approximately 2000 ºC, in a rastering fashion, this process does not produce tritium oxide (HTO) and can be completely performed in vacuum.

Fig. 3. Detritiation of TFTR Tile with Nd:Yag Laser

A developing technique for the removal of tritium from graphite tiles is the use of a oxygen-methane burner. In this application a open flame is deployed on the surface of the tile raising the temperature of the heated material to approximately 1000 ºC. Empirical measurements collected at PPPL during these experiments, which were performed in collaboration with United Kingdom Atomic Energy Authority (UKAEA) and Tritium Laboratory Karlsruhe (TLK), have resulted in DF's on JET tile surfaces greater than 1000, and within the tile bulk greater than 60 was realized.

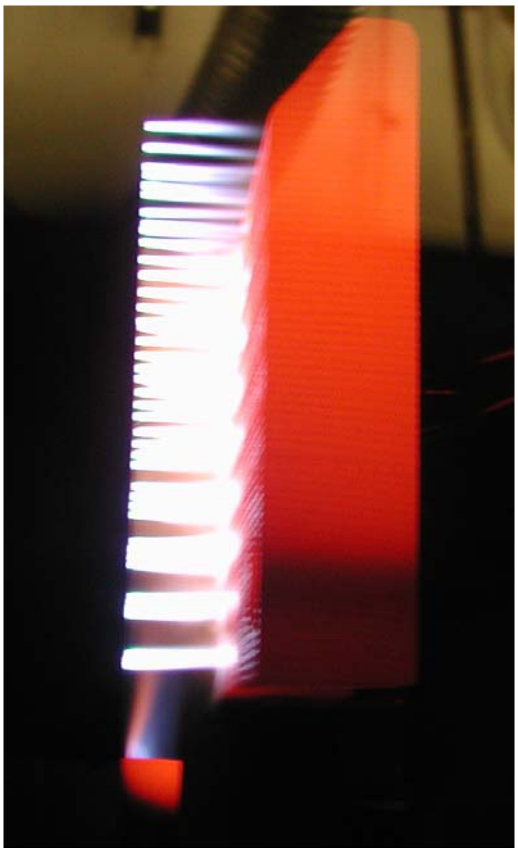

Fig. 4 JET Tile Oxy-Methane Burner Experiment

Mechanical methods include the removal of tritium contamination which includes cutting devices, CO_2 pellet ablation, shredders, grinders, and other tools where contaminated surfaces or part of a component is mechanically removed.

A system for processing large streams of tritium waste has been proposed.

The systems depicted in Figure 5 employs mechanical and physical processes for size reduction and tritium decontamination. This industrial sized system is designed to remove tritium, to background and near-background levels, for a variety of soft housekeeping components at the rate of tens of kg per hour. In this system tritium is removed from the effluent waste stream and concentrated in a collection system which can be either disposed of or processed for reuse.

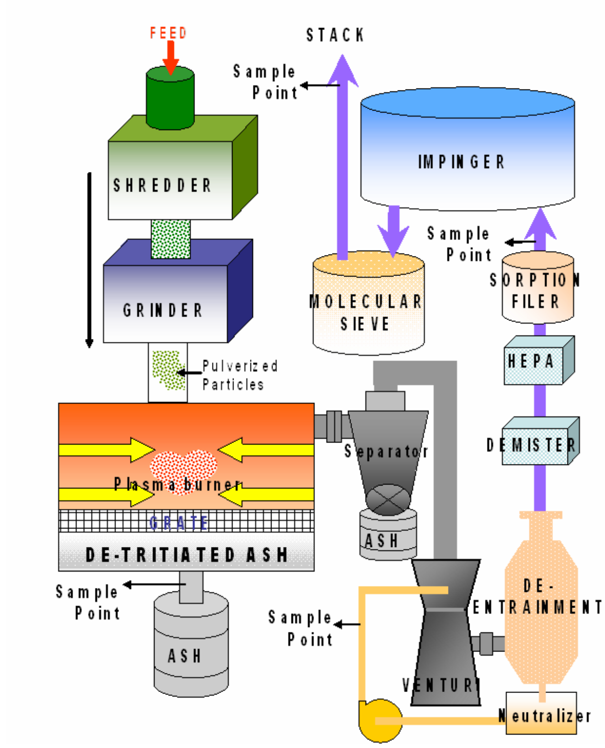

Fig. 5 Soft and Semi-Soft Tritium Decontamination Processing System

The three major categories of tritium decontamination/removal which include; chemical, physical, and mechanical (or combinations of the three methods) are effective, but are highly dependent on the type item and acceptable end condition of the item.

For small to medium components with irregular shapes (small tools, diagnostic equipment, etc), chemical, physical, and mechanical techniques which include oxidative chemistry and heat appear to be most effective for tritium decontamination or in some instances the removal of highly tritiated sub-components from the object.

For flat surfaces such as first wall materials in fusion energy devices (vacuum vessels or chambers), physical removal by means of a Nd:YAG laser appear to be rapid and cost effective. In areas where walls or floor surfaces need to be decontaminated, CO_2 ablation has been effective. For items that need to be disposed of in the most economically efficient way, mechanical (shredding) followed by intense heat can effectively remove tritium from the waste stream and jointly reduce volume.

For purposes associated with the removal of tritium for disposal a system is required for complete or nearly complete removal of tritium from a variety of components and multiple processes need to be employed.

Table II details the various methods in a comparison and evaluation format. Each tritium decontamination method has specific advantages germane to the material or component that requires tritium removal. In all listed cases, good tritium DF's are realized. The decontamination methodology is primarily determined by the material requiring decontamination, and the required condition of that material after the decontamination process. None of these methods can truly be classified as non-destructive. Although the level of disrepair during the decontamination process for the various components may be considered insignificantly low from the point of material damage.

TABLE II. Comparison and Evaluation Table

Method	**Chemical**	**Physical**	**Mechanical**
Type	Oxidative Chemistry, Chelating Agents	Lasers, Ovens, Burners	CO_2 pellets, cutting devices
Application	Hydrogen Peroxide, Ozone	Nd:YAG, UV, Oven Heating	Ablation removal
Cost	Low	Medium/ High	Low/ Medium
Deployment Material	Metal, ceramics,, Flat Surfaces, Soft Waste	First wall materials (graphite, stainless steel)	Walls, Floors, Building Compounds
Effectiveness	Good	Very Good	Good

III. CONCLUSIONS

A variety of technologies exist for the removal of tritium contamination. The method or technique employed is highly dependent on the type of material to be decontaminated, the distribution of tritium contamination, the concentration of tritium, and the final acceptable condition of the item. No single technology will serve as a method for efficient and cost effective tritium decontamination of all items. The deployment of a combination of the described methods provides a powerful synergy for tritium decontamination/removal in support of fusion energy development.

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