Conf-950506--2

WSRC-MS-95-0083P

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A document prepared for FIFTH TOPICAL MEETING ON TRITIUM TECHNOLOGY IN FISSION FUSION AND ISOTOPIC APPLICATIONS at Lake Maggiore from 05/28/95 - 06/03/95.

DOE Contract No. DE-AC09-89SR18035

TRITIUM PROCESSING AND CONTAINMENT PRACTICES AT THE SAVANNAH RIVER SITE

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ABSTRACT

This report emphasizes the features of the United States Tritium Facility operation at the Savannah River Site. It outlines the buildings that represent the facility operating basis. It explores areas where new technology and proven methods of operation developed at the site have made dramatic environmental and facility worker enhancements over the last several years. These enhancements should be consideration for future facility designs and for any current tritium missions.

I. INTRODUCTION

For the past 40 years, the Savannah River Site (SRS) has produced nuclear materials for the national defense of the United States. The mission of SRS's Tritium Facility is to provide tritium for U.S. Departments of Energy and Defense. Technologies used to accomplish this mission are: vacuum furnace melting of lithium aluminum targets, gas separation to remove impurities, hydrogen isotope separation , filling transportable reservoir containers with tritium, and reclaiming the transportable reservoirs. These missions have largely been reduced over the peak years of the past, but the facility still processes thousands of grams of Tritium annually. Today, a much greater emphasis is being placed on process control, tritium containment and preventive maintenance. The process and maintenance experience and the applied containment of the processing buildings is the focus of this report.

II. FACILITY HISTORY

The Savannah River Site has five tritium processing buildings with unique operations and capabilities. These are : Extraction and Recycle, Building 232-H; Loading, Unloading and Recycle, Building 233-H; Reservoir Handling, Building 234-H; Helium Recovery and Reservoir Burst Testing, Building 236-H; and Reservoir Reclamation, Building 238-H.

Building 232-H has three levels covering 4,800 square meters of floor area. Beginning operation in 1955, it is the oldest of the five buildings. Building 232-H houses approximately 30 large air ventilated hoods, one extraction furnace room, two Control Areas, a support service area, and 20 offices. Building 232-H is the location of the equipment to perform the functions of vacuum furnace extraction of tritium from the irradiated lithium aluminum targets, purification and enrichment of tritium, and loading and unloading low pressure product containers. Personnel are protected in the tritium processing areas by once-through ventilation.

Building 233-H is a seismically qualified, underground structure with a floor area of 3,100 square meters. Beginning operation in 1994, it is the newest and most technologically advanced of the five buildings. Building 233-H houses 26 airtight, nitrogen filled gloveboxes and is controlled from one centralized control area. Building 233-H is the location of the equipment to perform the functions of loading and unloading reservoirs, purification and enrichment of tritium, and initial separation of the He-3 from the gas stream.

Building 234-H has one level covering 1,700 square meters of floor area. It began operation in 1957. All tritium processing areas have once-through ventilation. Building 234-H is the location of the equipment to perform the functions of receiving new manufactured reservoirs and inspecting, testing, packaging, and shipping loaded reservoirs. Returned reservoirs are also accounted for through this building.

Both Buildings 236-H and 238-H provide a support mission to the other three primary structures and both are an order of magnitude smaller in surface area than the previous buildings discussed. Building 236-H began operation in 1964 and occupies 100 square meters. Building 238-H began operation in 1969 and occupies 700 square meters, respectively. Building 236-H provides Helium-3 recovery and reservoir pneumatic burst test capability. Building 238-H provides reservoir reclamation capability.

III. TRITIUM PROCESSING

In past years, the primary Tritium source for the United States was generated from irradiated lithium aluminum target rods. These rods, approximately 6 meters in length, were irradiated at the Savannah River Site's Heavy Water Reactors. The irradiated rods were then transferred to Building 232-H for tritium gas extraction via a vacuum furnace operation. Existing tritium supplies are being recycled to support current programs. Due to the decay of the tritium, total quantities are gradually being depleted: therefor plans are being developed to build another tritium generation source after the turn of the century.

Tritium gas processing at the Savannah River Site is divided into five main areas: separation, purification, compression, pumping, and storage. Separation is the process of removing unwanted gas impurities from hydrogen isotopes. This operation is accomplished using a commercially available palladium diffuser which is designed similar to a tube/shell heat exchanger. The process is supported by mechanical and hydride pumping, and storage equipment. The system has worked well for several years.

The purification process involves taking a hydrogen isotope stream and dividing the hydrogen isotopes, i.e. tritium, deuterium and hydrogen. This is performed by two methods - Cryogenic Distillation and the Thermal Cycled Absorption Process. The latter uses thermal cycling of a palladium hydride to perform the gas separation. Cryogenic distillation uses the difference in boiling points to facilitate the separation of isotopes. Both of these methods are effective and produce purity levels greater than 99%. With the development of the hydride based process, lower inventories can be used to perform the purification step and thus has increased the margin of operating safety.

The compression and pumping processes are mechanical operations. In Building 233-H diaphragm compressors produce the numerous atmospheres of pressure desired for filling reservoir containers. Positive, displacement bellows pumps in series with orbiting, scroll pumps produce from full vacuum to the 2 - 3 atmospheres positive pressure needed for gas movements. These systems have totally eliminated oil and mercury pumping mediums in Building 233-H; and, thus handled a major liquid waste generation and worker tritium exposure hazard.

Gas movement is also provided by metal hydride beds. These beds serve primarily as tritium storage but also provide the energy to evacuate and move low pressure tritium gas. The storage capability is a more efficient use of process space. It provides a large size advantage over low pressure gas vessels. It also provides a safer medium to contain tritium since its operation chemically converts the tritium gas into a solid form. This makes the process less susceptible to leaks and accidental loss of significant tritium volumes.

Overall these five processing areas, when correctly coordinated, offer a very effective tritium handling system. They have evolved over many years with emphasis on improving worker safety, reducing environmental impact and effectively meeting the production mission.

IV. TRITIUM CONTAINMENT CONCEPT

The containment of large tritium processes, due to the small molecular size, is very challenging. Original plant design was single containment piping as the primary control. Ventilation provided a secondary control for personnel protection. This combination was thought, at the time, to be the safest design for facility personnel. Improvements in design provided capabilities to capture air ventilation exhaust for tritium recovery. This helped mitigate large accidental releases. Today, secondary containment concepts have been researched and some successfully employed. The advantage of secondary techniques used at the Savannah River Site Tritium Facilities is the use of air tight glovebox technology, which is generally passive, and requires little activation at the time of an incident. This method has worked well in containing the low levels of tritium that escape the primary piping.

The primary tritium containment is predominantly stainless steel piping, valves and vessels. Three hundred series stainless steels are used which provide service for the full vacuum to the hundreds of atmospheres of pressure used at our site. In the past gasket materials have been polymeric. Over the last ten years more soft metals have been used, i.e. nickel alloys, copper, gold and silver. The entire system, as a result, provides greater than 10^{-6} atmospheric cubic centimeters per second leak tightness, routinely. Other test systems have better leak rate capabilities. Instruments and process equipment must meet these same containment standards as they also form part of the system barrier.

Secondary confinement and containment at the site has also evolved greatly in the last decade. The 1950's through the early 1970's designs provided secondary confinement, which by our definition is controlling the atmosphere around the primary containment equipment so it does not expose the worker. This concept, however, does not process the surrounding air it only channels it to and through exhaust stacks, where it is ultimately discharged 200 ft. above the plant. Thus the secondary confinement design is ventilated lexan and stainless steel or aluminum air hoods that surround the primary processes. These hoods are connected to exhaust air ducts routed to building exhaust fans that are connected to the exhaust stacks. Any tritium leaks from the primary containment, accidental or maintenance related, are vented to the atmosphere.

The secondary containment concept came on the scene in the 1980's when more engineered control of environmental releases was needed. A capture system was designed for air exhaust from high risk process hoods that would enable recovery of rapid tritium accidental releases. This system is no longer in service. With the construction of the 233-H building airtight gloveboxes with 99% nitrogen atmospheres were introduced. The glovebox system provides several orders of magnitude reduction in atmospheric releases, and it deals with both accidental and routine operational losses of tritium. The implementation of the glovebox and tritium recovery equipment in the 233-H building has not only reduced atmospheric losses but enabled improvements that have lowered employee tritium exposure and environmental concerns. This comes at a time when both were generating higher and higher operating costs.

At the Savannah River Site we employ a term As Low As Reasonably Achievable when addressing tritium or radioactive controls. Any large scale tritium handling mission should very carefully consider all options before employing a triple containment concept.

V. TRITIUM MAINTENANCE

Maintenance of tritium systems is a key element to their smooth operation. No system can function well without the important parts being pre-staged and in some cases qualified. Good configuration control in the beginning of a project saves operating cost over trying to build one after the fact. A regular maintenance schedule and work planning for critical components is an absolute requirement. Savannah River Site's experience with maintenance staffing is that it is almost equal to the operating staff (excluding technical engineers and general support personnel). Effective training and close interface with radiological controls expertise is needed to achieve the results expected in today's nuclear safe operating world. Overall maintenance effectiveness cannot be achieved without good implementation of the above areas.

The Savannah River Site's Tritium Maintenance group is organized to parallel the various building operating structures. It provides a maintenance section for each of the larger buildings and one overall auxiliary equipment group. Training is performed for specific tasks and involves both written tests and/or on-the-job evaluation. Status of qualified personnel are maintained and used to control who works on key equipment. All work is assigned and pre-scheduled, except for emergency repairs. Difficult or involved tasks are preplanned to ensure safety and efficient completion.

Work planning activities are at the heart of the program. The main elements of the program are: a comprehensive database is used to follow work, record work performed and provide a technical baseline; all maintenance deficiencies are formally identified, all work is formally released and technical reviewed before release; and finally, work is formally returned to service after post maintenance testing. The current program handles approximately 400 preventative maintenance tasks per month. The current ratio of preventative to corrective maintenance tasks is 60% versus 40%, respectively. The site goal is to reach 80% preventative versus 20 corrective. This is an ambitious goal for structures as old as ours, but one that is felt attainable. The maintenance program has improved greatly in the last 5 years. Mechanic qualification and more formalization have been the key.

VI. SUMMARY

The tritium mission at the Savannah River Site has the goal of advancing Safety, Cost Effectiveness, Disciplined Operations and Continuous Improvement. These building blocks provide the basis for a nuclear site like the US Tritium Facility to evolve and keep pace with the new and improving world technology. The concepts presented in this paper involving the processing, containment and maintenance of a large tritium installation can be applied anywhere, but they especially should be considered when expanding or making a major change to tritium related system.

ACKNOWLEDGMENTS

I would like to extend my appreciation to Bernice Rogers and Chuck Campbell who assisted in the collection of information for this manuscript.