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TRITIUM TECHNOLOGY PROGRAMS IN THE UNITED STATES

by

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Abstract

Tritium technology in the United States has advanced considerably since the 1988 Tritium Conference in Toronto. This advance has come in facilities, processing and safety related technologies and in an ever increasing commitment to compliance related issues. The major laboratories in the U. S. tritium programs continue to be (Westinghouse)_ Savannah River Site, EG&G Mound, Lawrence Livermore National Laboratory, Sandia National Laboratory and the Los Alamos National Laboratory. Each of these Laboratories have made some significant changes in their programs and/or facilities in the past four years.

Introduction

"It was the best of times, it was the worst of times....."¹ Dickens' words from 1859 could certainly apply to the tritium activities in the United States during the past few years. These years have seen an increase in the interest and support for tritium research related to the fusion energy program, the new production reactor, reconfiguration activities within the Department of Energy (DOE) Weapons Complex, and the DOE Nuclear Weapons Testing Program. The fusion program is moving into the Engineering Design Activity for the International Thermonuclear Experimental Reactor (ITER) program. This world-wide activity will focus, for the next 5-6 years, on the design of a large Deuterium-Tritium burning fusion machine. The tritium technology requirements for this device will drive the tritium technology programs in many new and exciting directions. At the same time, many of the DOE tritium facilities have fallen behind the times with regard to Environmental, Safety, and Health (ES&H) rules, regulations and compliance requirements. As a result of these changing times, several of the DOE's tritium facilities have suffered shutdowns and stand downs during this period. Included in this list are the tritium production reactors at Savannah River; a major tritium laboratory at the Mound Plant; the Tritium Systems Test Assembly (TSTA), the Tritium Salt Facility (TSF), and the High Pressure Tritium Laboratory, at Los Alamos National Laboratory; and the Tritium Facility at Lawrence Livermore National Laboratory. Of these, the TSTA, TSF and Mound facility are now back on-line and in operation. The Savannah River reactors, the High Pressure Tritium Laboratory at LANL and the LLNL Tritium facility are still shutdown.

Additionally, these have been difficult times to bring new facilities on-line. The Weapons Engineering Tritium Facility (WETF) at Los Alamos has now received

approval for full operation. Securing all of the necessary approvals was a 3-4 year effort at WETF. The Replacement Tritium Facility (RTF) at Savannah River is not yet operational and will face ever increasing pressures as the facility moves toward an Operational Readiness Review and operating approval.

In May 1991, the Secretary of Energy, Admiral James Watkins formed a Tritium Operations Task Group to investigate the overall management of the DOE tritium facilities. His level of concern had been raised by a continuing number of tritium releases at the DOE tritium facilities. The Task Group was charged with taking a close look at the operation of these facilities including mechanisms for sharing design and operational information and measures for reducing actual and potential tritium releases. A summary of the Task Groups findings will be presented by Dr. J. E. Fitzgerald, Jr., Deputy Assistant Secretary, Safety and QA, U. S. Department of Energy, at the Conference luncheon, October 3, 1991.

A brief summary of the current status of tritium operations at the major tritium facilities within the DOE follows. This summary is necessarily brief. However, many technical papers expanding on this summary are being presented at this Conference by personnel from each of these facilities. Additional information on tritium technology programs in the United States fusion energy programs (and in fact, for the international fusion-related tritium technology programs) can be found in Fusion Engineering and Design, Volume 12, June 1990. This is a special issue of the journal Fusion Engineering and Design on Fusion Tritium Facilities and Tritium Technology R&D.

Status of Tritium Activities at the Major DOE Tritium Facilities

Savannah River Site

Tritium technology activities at the Savannah River Site (SRS) include the tritium production reactors, and facilities for extraction of tritium from irradiated Li-Al reactor targets; purification and enrichment of tritium; facilities for loading and unloading the tritium product shipping containers (PCs); regeneration facilities for zeolite beds; and facilities for packaging and unloading tritium reservoirs for specific DOE programs; and, a Materials Test Facility where operations include reservoir functionality testing, metallurgical examination of tritium contaminated samples, measurements of tritium and deuterium pressure and isotherms of different metal hydride beds, Scanning Electron Microscopy and Auger Scanning Microprobe capability.

The Gas Extraction process recovers tritium from irradiated target elements which have been removed from the Production Reactors, cleaned and stored for decay of short-lived activation products. The recovered tritium and other isotopes of hydrogen are separated from other gases present by diffusion through the wall of a hot palladium/silver alloy tube. The diffused mixture of hydrogen isotopes is further processed in cryogenic distillation columns to provide the concentration of tritium in deuterium needed by the customer.

Tritiated water in the SRS systems is adsorbed on zeolite beds at many locations in the plant. After loading, the zeolite bed is moved to the Recovery System where the water is desorbed from the zeolite and cracked, releasing the hydrogen isotopes. Nearly all of the protium is efficiently separated from tritium by cryogenic distillation and is discarded to the atmosphere.

A new tritium facility, the Replacement Tritium Facility (RTF) is under construction at SRS. When fully operational it will replace most of the existing tritium processing facilities. The RTF design incorporates state-of-the-art hydride technology. Secondary containment is attained via inerted glove boxes. The glove box atmosphere can be processed to recover tritium losses from the primary containments. The RTF is scheduled to be operational in late 1992. The RTF will be described in detail in the paper "The Replacement Tritium Facility," by T. Motyka², SRS, in a paper at this Conference. Table 1 is a summary of the tritium technology improvements that will be introduced in the RTF.

Table 1. Tritium Technology Improvements at Savannah River within the RTF.

<u>CURRENT FACILITIES</u>	<u>REPLACEMENT TRITIUM FACILITY</u>
<u>Tritium Releases/Personnel Protection</u> provided by exhaust of control hoods to 200 ft stack	<u>Nitrogen atmosphere gloveboxes</u> with tritium removal to meet all current and future emissions requirements
<u>Gas Storage</u> above atmospheric pressure in stainless steel tanks	<u>Hydride Beds</u> provide compact subatmospheric storage
<u>Process pumping</u> via oil free bellows pumps, mercury diffusion pumps and diaphragm pumps	Oil and mercury free pumping via bellows pumps, <u>scroll pumps</u> , and <u>hydride beds</u>
<u>Isotope Separation</u> via Cryogenic Distillation	Cryogenic Distillation and <u>Thermal Cycling Absorption Process</u>
<u>Unload Gas</u> using Mechanical Shearing of Reservoir Stem	<u>Laser</u> Unloading of Reservoir
<u>Process Control</u> via Graphic Panel Board	<u>Distributed Control System</u> with CRT Operator Interface
<u>Loading Gas</u> via Diaphragm Compressors	^g Diaphragm Compressor with <u>Hydride^d Beds</u> for Specialized locations

It is expected that the introduction of these new state-of-the-art facilities and operations at SRS will greatly reduce the tritium emissions from the SRS Tritium Processing Facilities. These releases typically have been of the order of 200,00 Curies per year. The RTF will replace tritium facilities than have been in operation for some 35 years at Savannah River.

EG&G Mound

The Mound Facility, located in Miamisburg, Ohio is operated by EG&G Mound Applied Technologies. The Mound Plant provides production, development, and research support for DOE weapons and energy related programs.

Tritium activities at the Mound Plant include performance evaluation of gas transfer systems, production of tritium-bearing components for DOE programs, loading and shipping tritium for commercial customers, recovery and enrichment of tritium from tritium-bearing scrap materials, and process development studies for DOE programs. Mound recovery and enrichment facilities are used to process scrap materials from internal operations and from operations at LLNL, SNLL and LANL. The recovered tritium is shipped to Savannah River for reuse and the residual waste is packaged and shipped for burial.

A major activity at Mound is the tritium enrichment and filling of containers for commercial customers. The enrichment facilities include a modern cryogenic distillation system and a gas phase thermal diffusion cascade. The DOE transferred its tritium loading, sales, and distributions operations to the Mound Plant in July 1990. Mound loads hydride traps that contain up to 29,000 Curies of tritium and gas shipping cylinders for shipment to commercial customers. The total annual sales are approximately 600,000 Curies of tritium gas.

Since 1969 Mound has been among the leaders in the DOE complex in adopting the philosophy of minimizing both normal and abnormal release of tritium to the environment. Effluent releases to the environment in 1990 were less than 1 percent of 1970 releases in terms of total Ci. This reduction occurred even though the inventory of tritium had doubled in the same time period. Strong emphasis is placed on reducing the effluents through a combination of procedural and technological improvements. The Effluent Recovery System (ERS) was the first such system installed at a DOE facility. Subsequently Mound has added additional systems including the Tritiated Aqueous Waste Recovery System, the Tritium Recovery Column, the Hydrogen Isotope Separation System, and the Thermal Diffusion Facility. The Thermal Diffusion Facility has the ability to recover tritium to over 99% purity. The above processes employ, respectively, electrolysis and catalytic exchange, cryogenic distillation, and thermal diffusion techniques. A replacement for the ERS, the Tritium Emissions Reduction Facility (TERF) is scheduled to begin operation in 1992. The TERF will have a larger throughput, higher oxidation temperature, and a higher capture efficiency than the ERS. This will result in approximately a ten-fold reduction in tritium emissions below current

ERS emission levels. The TERF is further described in a series of papers from Mound 3,4,5 at this Conference.

Many of the tritium systems at Mound employ the triple containment philosophy to further minimize accidental releases to the environment. The three barriers consist of the primary system such as piping and vessels, the secondary system such as a glovebox or double piping, and the tertiary or Emergency Containment System, ECS. The ECS isolates the affected room by diverting the ventilation into the ECS system. The ECS is a capture system that operates on a catalyst and exchange process.

Lawrence Livermore National Laboratory

The Tritium Facility at Lawrence Livermore National Laboratory (LLNL) has, throughout its history, conducted research and development on metal hydrides, tritium gas pumping and transfer, support for the Inertial Confinement Fusion program, and cryogenic studies on hydrogen isotopes. This facility has been in operation since about 1956. In 1989 the tritium inventory in the facility was about 200 grams. In 1990 the management of LLNL made the decision to downsize the tritium operations considerably. The decision was made to reduce this to no more than 5 grams. The inventory at the LLNL facility had been reduced to about 40 grams in April 1991. At that time, an Unusual Occurrence, resulting in a release of approximately 150 Curies to the atmosphere, and a personnel exposure of slightly more than 1 rem, resulted in a DOE mandated shutdown of the facility. The facility remains in this shutdown mode at this time. Lawrence Livermore Laboratory and the DOE are working together to define the conditions for restart of the facility. At the time of restart LLNL will continue operations to reduce the inventory at the facility. Future programmatic activities at the LLNL tritium facility are undecided at this time.

Sandia National Laboratory, Livermore

Tritium operations at Sandia National Laboratory, Livermore, SNLL, are conducted in the Tritium Research Laboratory, TRL. The TRL is a unique facility in which tritium compounds are handled in a variety of research and development activities. Personnel safety, property and environmental protection are provided by glove boxes, connected to a central decontamination system. The research and development tasks conducted at TRL are variable. The associated processes and process variables are changed to meet the requirements of the research and development going on at any time. Operations conducted at the TRL include: studies on metal hydride/tritides; high pressure tritium pumping; first wall fusion reactor materials studies, tritium diffusion/permeation studies; functional testing of components for the DOE weapons program; tritium assay/accountability and control studies; scanning electron microscopy and transmission electron microscopy studies; and, tritium contaminated waste handling/packaging and disposal activities.

The TRL includes a modern containment system, including a Vacuum Effluent Recovery System, VERS, for reducing tritium emissions. All work involving more than 0.1 gram

of tritium is done in a glovebox whose atmosphere is circulated through a tritium recovery system, the Glovebox Purification System, GPS. The GPS removes tritium contaminants from the glovebox atmosphere. The VERS removes tritium contaminants from gases exhausted from the glovebox pressure control systems, and the laboratory vacuum systems before the residue gases are vented to the stack. Both systems are designed to reduce tritium concentrations to a few parts per billion by oxidation on a precious-metal catalyst and collection of the oxide on molecular sieve dryers. The tritium removed by the cleanup systems is contained, either for recovery or for disposal, as solid waste on type 4A molecular sieves.⁶

Only work involving small quantities of tritium, experiments such as metallographic sample preparation and study, tensile tests, and some maintenance operations are conducted in ventilation hoods. This mode of operation has resulted in safe operation of the facility since it became operational in 1977.

Los Alamos National Laboratory

There are several tritium facilities in operation at the Los Alamos National Laboratory, LANL. Tritium-related activities at the LANL encompass nuclear weapons component evaluation and development, fusion fuel handling and processing development, and many other research and development programs conducted in eight separate tritium facilities. This paper will discuss three of these facilities, with special emphasis on the fusion fuel processing technology development at the Tritium Systems Test Assembly.

Weapons Engineering Tritium Facility (WETF)⁷

The WETF construction was completed and the facility approved for tritium operation in 1991. This is the newest tritium facility in the DOE complex and was designed and constructed to meet all of the safety standards required under the DOE Design Criteria for Non-Reactor Nuclear Facilities. The major activities at WETF include: receiving and unloading tritium from shipping containers into the Tritium Gas Handling Subsystem (TGHS), which is located in the process room; repackaging tritium into smaller quantities; repackaging tritium and other gases to higher pressures; separating helium from tritium; mixing tritium with other gases; and, analyzing tritium gas mixtures.

The WETF contains several systems designed to enhance the safety of the facility. These include the Tritium Gas Confinement Subsystem (TGCS), consisting of glovebox sections that confine any tritium escaping from the Tritium Gas Handling Subsystem and minimize exposure of operating personnel to tritium; a Tritium Waste Treatment Subsystem (TWTS) that processes the Tritium Gas Confinement Subsystem exhaust to extract tritium for either recovery or disposal; an Emergency Tritium Cleanup Subsystem (ETC) that processes tritium releases to the process or recovery rooms that might result from an accident or other unplanned release; and, the Instrumentation and Control System (ICS) that provides the facility operator with real-time data, alarms, and control of process variables.

Although the WETF now has all approvals necessary for full operation, major tritium operations have not yet been initiated. It is expected that the WETF will become fully operational by early 1992.

Tritium Salt Facility (TSF)

The TSF at LANL provides a facility for working with very reactive metal tritides. The TSF includes a large, inert atmosphere glovebox and dry-train, an Effluent Treatment System (ETS) and associated hardware. The TSF is used to fabricate metal tritide components for the DOE nuclear weapons program; provides space for research into metal tritide systems; houses some research and development activities related to the DOE New Production Reactor program; and, provides some space for developing new analytical techniques such as laser induced Raman spectroscopy.

The TSF has been operational since 1974. In April 1991, a worker in the facility received a 20 mrem exposure when a valve replacement operation was being conducted. The management of the TSF immediately placed the facility in a "Stand Down" while the operators critically reviewed the Conduct/Formality of Operations, reviewed and revised key procedures at the facility, conducted refresher training courses, and generally evaluated the operations from an Environmental, Safety, and Health (ES&H) perspective. The facility went back into full operation at the end of June 1991.

Tritium Systems Test Assembly (TSTA)

The TSTA is designed to model, in full-scale, the deuterium-tritium (DT) fuel cycle of future fusion reactors. The TSTA built and completed in the early 1980s, consists of a number of systems arranged in a close-coupled, integrated processing loop to simulate the reactor torus and its associated gas pumping, fuel processing, and re-injection systems, Figure 1. At the TSTA facility, all of the components of this process loop, as well as the interconnecting piping, are confined in glove boxes or some other type of secondary confinement. Tritium releases into glove boxes or secondary containment piping are removed by the Tritium Waste Treatment System⁸. This system also removes tritium from vacuum pump effluents and purge gases used to clear out residual tritium from process lines and small experiments. Releases into the experimental hall or into either of the two, smaller tritium laboratories at TSTA can be processed by the Emergency Tritium Cleanup System⁹. The building provides a third level of containment to prevent tritium releases to the environment. The TSTA is a computer controlled and monitored system, and automatic actions are initiated by the computer software to mitigate the effect of system failure or abnormal conditions. The TSTA facility and programs were described in detail by Bartlit in 1990¹⁰.

Recent major activities at TSTA include completion of several major experiments during which the processing loop was operated continuously for periods of a few days to more than a week. During these major tests the TSTA loop is operated around the clock, with a three-shifts per day schedule. These major tests provide the fusion program with

Figure 1. TSTA INTEGRATED FLOW LOOP

information on the efficiency and tritium inventory of the major subsystems in the TSTA gas processing loop; information on system dynamics, reliability and availability; operating procedures; and a cadre of trained, experienced operators.

In 1990 a major new subsystem, a Fuel Cleanup system designed and fabricated by the Japan Atomic Energy Research Institute (JAERI), was installed at TSTA. This system, the JFCU, was provided under the terms of the Cooperative Agreement between DOE and JAERI for the collaborative operation of TSTA. The JFCU is based on use of a palladium/silver membrane diffuser to remove impurities from a DT stream; oxidation of the separated impurities so that all hydrogen isotopes in the impurities are collected as water; recovery of the hydrogen isotopes from the water by electrolysis in a high-temperature, ceramic electrolysis cell; and, reintroduction of these hydrogens into the main feed stream to the JFCU. This system is discussed in detail by Konishi et al.¹¹ in a paper at this Conference. Los Alamos has just received final approval to do full scale tritium testing of the JFCU as an integrated component in the gas processing loop.

A new analytical tool, described in a paper by O'hira, et al.¹¹ at this Conference, has also been added to the TSTA during the past year. An on-line laser Raman spectroscopy system has been added. This analytical tool allows the operators to analyze the hydrogen isotope ratios and impurity species (except for the noble gases) in situ, rapidly and safely. A gas sample can be extracted from the processing loop, passed through the analytical cell, and returned to the processing loop quickly and efficiently. The analysis of this sample is completed within about two minutes. The sample lines can then be swept out and a new sample introduced within a few minutes. This analytical system is replacing the original gas analysis system which is based on gas chromatography. The new system ultimately will be used as part of an on-line feedback system as part of the automatic control of the loop operation. The implementation of this aspect of the LASER Raman system will occur over the next few years.

The TSTA project continues to accrue an impressive record of low exposures to personnel and low releases to the environment. However, in April 1991 a tritium release from a sample bottle into a glove box and subsequent escape of this tritium from the glove box into the room occurred. The quantity of tritium released to the room and subsequently out the stack, was about 0.4 Curies. No personnel exposures resulted from this release. The site-boundary dose calculated for this release was less than one billionth of the allowable. As a result of this release, the DOE mandated a shut down of TSTA while LANL conducted a complete investigation of the event, identified deficiencies, and corrected these deficiencies. The DOE conducted several investigations and reviews of the TSTA project during this period. Approval for a full restart of the TSTA programmatic activities occurred three months after the shut down. At this time the TSTA is in full operation. However, due to experimental time lost during this shut down, some experiments are behind schedule. This resulted in some papers planned for this Conference being withdrawn.

Summary

The development of tritium technology within the DOE complex is expected to proceed at a fast pace during the coming years. The current emphasis on establishing a new safety culture within all DOE operations is certainly a factor in the tritium area. Management at existing facilities will have to devote the time and resources to bring these facilities into the mainstream of the ES&H activities. Many of the existing facilities were built at a time when the codes, standards, and criteria were considerably different from what is accepted practice today. Retrofitting these facilities to the newer, more stringent requirements must be addressed for each facility.

New facilities such as the WETF at Los Alamos and the RTF at Savannah River have been constructed to the new criteria. These facilities will, therefore, provide demonstration of what modern tritium facilities should include and how they should be constructed.

Some of the existing facilities are not only aging, but are located in population centers that are growing rapidly. This creates additional pressures on DOE and the Laboratories to evaluate continuously the desirability of maintaining these facilities.

Programs like the International Thermonuclear Experimental Reactor program (ITER) will depend on existing tritium facilities to provide the data base for design, construction, licensing, and operation of these large fusion devices. The potential for tritium technology development and enhancement is great. It will be up to the engineers, scientist, and facility managers to demonstrate that we can continue to operate these facilities in a safe, responsible, manner, thus providing laboratories for the continuing development of this technology.

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