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DESIGN OF THE TARGET FABRICATION TRITIUM LABORATORY

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ABSTRACT

The design of the Target Fabrication Tritium Laboratory for deuterium-tritium fuel processing for laser fusion targets has been accomplished with the intent of providing redundant safeguard systems. The design of the tritium laboratory is based on a combination of tritium handling techniques that are currently used by experienced laboratories. A description of the laboratory in terms of its interrelated processing systems is presented to provide an understanding of the design features for safe operation.

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129

Introduction

With the increased complexity of the Nova targets, Fusion Target Fabrication has been faced with developing unique processing and construction schemes to meet design specifications. One area that is under investigation is the development of techniques for deuterium-tritium (D-T) fuel processing. Procedures for target fill, target fuel containment, and target fuel solidification are processes that are being studied to achieve a fabrication capability for Novette and Nova targets. A tritium laboratory (TL) has been designed and is currently being built for the new Fusion Target Development Facility (FTDF), Building 298, to permit experimentation with D-T fuel processing.

To acquire current technology on safeguards for handling tritium, a number of Laboratories were visited which have tritium facilities: Sandia (Livermore), Mound Laboratory (Ohio), LANSL, and LLNL. Common to each was the general approach of providing systems for tritium containment, recovery, gas purification, and monitoring and accountability. Although these facilities have a common philosophy for handling tritium, their techniques differ. In the case of tritium containment, glove boxes are used for most tritiated processes. Yet by using localized containment around critical pressurized areas, experiments with tritium have been performed in laminar flow hoods.* Likewise, recovery and gas

* LLNL, Tritium Facility, Building 331 has been using the approach of localized containment in a laminar flow hood to D-T fill laser fusion targets.

purification systems for cleaning-up residue tritiated gas or reducing tritium concentration levels are generally accomplished by a replaceable holding tank arrangement or by a gettering technique.* However, monitoring and accountability procedures are basically the same for each facility. Tritium monitors are positioned in strategic locations to permit determination of both concentration levels and environmental release.

In the design of the TL to supply fuel for laser fusion targets, a combination of approaches have been utilized to maintain the basic considerations expressed by the above facilities in handling tritium. On October 23, 1980 a design review of the laboratory was presented to LLNL personnel involved in the operation of the Tritium Facility, Building 331. The consensus of the review was that the basic design met the safe-guard criteria for handling tritium.¹ In addition, the design of the TL was reviewed by SAN safety as part of the FTDF and was given a low risk category.² A description of the TL is presented to provide an understanding of the design features employed for safe operation.

Tritium Laboratory Approach

The confinement of tritium begins with a primary containment system utilizing certified high pressure stainless steel tubing, vessels, and

* Gettering of tritium can be achieved by reacting tritiated gas with moisture and trapping the vapor in a catalyst-molecular sieve bed or by a tritiated gas-metal reaction forming a metal hydride.

valves. A stainless steel autoclave is used as the tritium source vessel in which the tritiated fuel is absorbed on granular vanadium metal forming vanadium hydride. The target fill section of the primary is composed of individual beryllium pressure cells that contain the targets during the fuel fill process. Localized secondary containment is provided for both the autoclave and beryllium pressure cells to insure, in the case of possible leaks, the entrapment of the tritiated gas.

The primary containment system with its localized secondary containment sections is redundantly contained by installing the system in a sealed stainless steel glove box. Any leak development from the primary due to a mechanical failure or operator error is thus enclosed within the box. The pressure inside the glove box is maintained slightly less than one atmosphere of argon and has an air lock chamber for accessibility.

Recovery of the tritiated gas from the primary containment system is accomplished by both a gettering and a holding tank approach. Initial recovery is performed by gettering the primary gas back on the vanadium bed. The remaining gas residue in the primary system is then gettered on granular uranium metal in a secondary contained autoclave. In addition, a holding tank is used to collect primary flushing gas in the event that traces of tritium might still be present. The holding tank and uranium bed are each designed to contain the total primary tritiated gas supply.

Tritiated gas in the holding tank, secondary containment vessels, and the glove box itself is purifiable by a titanium reactor gettering system housed inside the glove box. In this gas purification system (GPS), localized secondary containment is included for the titanium reactor, pumps, and blower.

Before the purified gas from the GPS leaves the glove box and enters the stack, it travels through a catalyst-molecular sieve unit. This redundant purification approach is to insure that the tritium concentration level in the stack is below the acceptable tritium concentration that can be released to the environment.

Tritium concentration levels are determined by tritium monitors that are placed in various locations in the TL. Two monitors are positioned inside the glove box. One of them is set at a sensitive, low curie concentration range for the GPS while the other is at a higher range for detecting tritium levels in the secondary containment vessels and in the glove box. Others are strategically located outside the glove box to monitor the working environment. In addition, monitors are placed in the stack to determine the amount of tritium being released outside the building. By knowing gas flow rates or volumes and tritium concentration levels, accountability of tritium for the TL can be obtained.

Primary Containment System

The primary containment system as represented in Fig. 1 is basically composed of a high pressure gas manifold, a tritiated gas source autoclave, and beryllium pressure cells for fuel fill. The autoclave and pressure cells are each enclosed in a secondary stainless steel vessel. The high pressure manifold is constructed of 316 stainless steel tubing rated at 30,000 psi. The manifold valves and fittings are of the weld type and are, likewise, rated at 30,000 psi. The gas source autoclave is a 316 stainless steel vessel rated at 12,000 psi that is heated and temperature controlled to provide pressurized tritiated gas. Granular vanadium hydride is used as the source of tritiated gas because of its high equilibrium vapor pressure at low temperatures. The maximum amount of tritiated fuel that the vanadium source will store at any one time will be 2 grams of tritium (20 K Ci). The secondary vessel around the autoclave is a 304 stainless steel container enclosing a 5,000 psi pressure transducer, a redundant high pressure valve, and an automatic actuated seismic valve. The vessel has a volume that will contain the total tritiated gas fuel at a pressure less than two atmospheres.

The seismic valve is rigidly supported inside the autoclave secondary vessel. To meet the SAN safety analysis, the seismic valve is designed to operate in a closed position during a 0.03 g vertical and a 0.05 g horizontal disturbance.² The enclosure of the seismic valve in the secondary vessel is to contain any gas leaks from the valve packing while

it is in the open mode. Rigid attachment of the valve to the secondary vessel is to prevent, during a seismic disturbance, possible shear forces from rupturing the connecting tube between it and the autoclave. The seismic valve is automatically activated by a pneumatic actuator attached outside the secondary vessel. The mounting of the seismic valve and actuator is shown in both Fig. 2 and Fig. 3.

A deuterium or helium gas supply port is used to leak check the primary system before each fill and also to purge the system after each run. A gas sample bottle is also provided in the system for analysis of the tritiated gas mixture.

The beryllium pressure cells are used for pressurized gas fills into target fuel containers. The use of beryllium is due to its low hydrogen permeation property and its ability to maintain strength at permeation fill temperatures. Each of six cells are able to be heated and temperature controlled to provide a programable fuel fill process. The pressure cells are likewise enclosed in a 304 stainless steel secondary vessel to contain any gas leaks that may occur. The secondary containment vessel for the beryllium pressure cells is shrapnel designed having a volume that could hold the total tritiated gas fuel at less than 100 psi.

Recovery System

Recovery of tritiated gas from the primary system is initially begun by reabsorbing the gas on the granular vanadium material within the gas source autoclave. Due to the equilibrium vapor pressure of vanadium hydride at ambient temperature (approximately 2 atm at 25°C), not all of the gas can be absorbed. Consequently, a granular uranium material is utilized to complete the recovery process. The equilibrium vapor pressure of uranium hydride is very low (10^{-9} atm. at 25°C) and is thus used as a getter material for recovering the tritiated gas. The uranium material is located inside a 316 stainless steel autoclave similar to that of the vanadium source as shown in Fig. 4. The uranium autoclave is also secondary contained in a 304 stainless steel vessel and is designed to have, by the use of a secondary contained metal bellows pump, a gas flow through the uranium material. This design prevents the build-up of helium (tritium decay product) that if allowed would hinder the getter process. In addition, the uranium hydride autoclave can be heated and temperature controlled to permit reuse of excessive absorbed fuel. The uranium bed system is shown in Fig. 5.

As indicated in Fig. 4, a 40 liter 316 stainless steel gas holding tank is employed in the system as a redundant recovery process. The function of the tank is to contain the gettered gas effluent from the primary containment system. Initially the tank is evacuated. It is then used after each fuel fill to collect the gettered primary effluent. This

process continues until the gas pressure in the tank approaches an atmosphere. When this occurs the effluent gas is pumped from the holding tank to the gas purification system. The tank is evacuated and again able to proceed to collect primary effluent. The volume of the tank is designed to contain the total tritiated gas source at a pressure less than one atmosphere. This provides an option for storing the fuel in the event that a need arises to deplete both the vanadium and uranium hydride from the autoclaves. An additional function of the tank is to collect any tritiated gas due to leaks in the vessels providing secondary containment including gas circulating vacuum pumps and blower. In this capacity, the recovery holding tank also acts as a vacuum effluent recovery system.

Gas Purification System

The gas purification system is designed to purify the atmosphere in the glove box and in the recovery holding tank. The operation of the purification system is based on a titanium reactor using a solid state gettering principle. Two titanium disposable cannisters are each held at different temperatures whereby the gettering of oxygen and the isotopes of hydrogen is thermodynamically favored. A 4 cfm secondary contained blower provides the gas circulation necessary for continuous processing. Fig. 6 indicates the flow diagram of the gas purification system in relation to the primary and recovery systems. The figure also shows two gas analyzers that are used along with a secondary contained metal

bellows pump to monitor the concentration level of oxygen and moisture in the circulated purified gas.

A secondary contained Alcatel vacuum pump is utilized in the system to perform the evacuation of the recovery holding tank. Both the input and output of the Alcatel pump has a molecular sieve trap to prevent any pump oil backstreaming or misting. Another secondary contained pump, a double metal bellows pump, is employed in the system to assist in circulating the gas effluent.

Two-way directional valves are used to control the purification flow process. Normally the titanium reactor is continuously purifying the glove box atmosphere. However, when the recovery holding tank approaches a pressure near an atmosphere or indicates a significant tritium concentration, the directional valves are positioned to purify the recovery system. In any case, purification of the recovery system continues until the tritium concentration reaches an acceptable release level. At this time the effluent is again redundantly purified by yet another purification system, a catalyst-molecular sieve. The catalyst-molecular sieve system is located outside the glove box enclosed in its own laminar flow hood. The effluent gas from the tritium laboratory travels through this redundant purification system before it is allowed to enter the stack and thus released to the outside environment.

Monitoring and Accountability

One of the most important aspects of operating a tritium laboratory is the responsibility of instituting a tritium monitoring and accountability system. A system for this purpose is provided for the TL by employing a number of Betatec 100 tritium monitors. These monitors are strategically located inside the glove box, in the stack, and in the laboratory working area.

Two tritium monitors, shown in Fig. 4, are used to determine tritium concentration levels in the glove box. One monitor is low concentration level sensitive, in the range of $1 \mu\text{Ci}/\text{m}^3$ to $20 \text{ Ci}/\text{m}^3$. The other operates in the range of $1 \text{ mCi}/\text{m}^3$ to $20 \text{ KCi}/\text{m}^3$. These monitors are used to indicate the tritium concentration levels in the various systems of the laboratory and are thus used to determine the initiation and completion process for effluent purification. Likewise, two tritium monitors are used to determine the concentration level of tritium that is released to the environment via the stack. These monitors are set to cover the range, in one case, from $1 \mu\text{Ci}/\text{m}^3$ to $20 \text{ Ci}/\text{m}^3$ and in the other, from $100 \mu\text{Ci}/\text{m}^3$ to $2 \text{ KCi}/\text{m}^3$. Accountability of how much tritium is released through the stack can be determined by the effluent flow rate. Other monitors will also be used in the TL area to provide a warning system if the tritium concentration in the working environment begins to approach an unacceptable level.

Summary

The design of the Tritium Laboratory has taken in consideration the necessary safeguards for handling tritium. These safeguards are a composite of handling techniques acquired by communicating with various experts in the field. A design review for the TL approach has indicated that system redundancy in containment, recovery, purification, and monitoring adequately meets the SAN Safety Analysis to permit a "low" risk category.

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FIGURE CAPTIONS

Figure 1. The primary D-T containment system has secondary containment for the vanadium fuel source and beryllium pressure cells.

Figure 2. A photograph showing the mounting of the seismic valve and actuator to the vanadium bed secondary containment vessel lid.

Figure 3. A photograph of the complete vanadium bed system.

Figure 4. Residual D-T recovery is accomplished by either a uranium getter or by a recovery tank.

Figure 5. A photograph of the complete uranium bed system mounted to the secondary containment vessel lid.

Figure 6. The gas purification system is based on a titanium reactor along with redundant purification using a catalyst-molecular sieve.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6