DEVELOPMENT OF A STORAGE VESSEL AND SHIPPING PACKAGE FOR TRITIUM

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ABSTRACT

Tritium must be safely stored in a stable form for a long time due to its radiological hazard. And, if necessary, it must be safely transported to a desired location for industrial use or research for peaceful purposes because it is a very useful resource. For these purposes, the Korea Atomic Energy Research Institute (KAERI) has been developing a storage vessel and shipping package for tritium. The storage vessel was designed to store the tritium (T_2) in the form of metal tritide. Titanium was selected as a medium suitable for forming the metal tritide. Tritium reacts with titanium and is converted to titanium tritide ($Ti_{1.0}T_{0.83}$). The storage capacity of the vessel is 0.5 MCi of tritium. The shipping package to transport the storage vessel containing 0.5 MCi of tritium was designed as a B type-shipping package. The designed shipping package consists of two parts: the main drum and the secondary container. The main drum is made of stainless steel and its inside is packed with a special impact absorber and an insulator to protect the storage vessel from a fire and being dropped. The secondary container which is also made of stainless steel supplies the space to house the storage vessel and, in the case of a leakage, the gas from the vessel can be captured. The prototype-shipping package was fabricated and subjected to several tests involving a 9 m free drop test, 1 m puncture test and a thermal test (800°C, 30 min.) in accordance with the regulations. The integrity and safety of the shipping package could be verified through these tests.

INTRODUCTION

Tritium which is one of the hydrogen isotopes in heavy water systems is a major source of radiation exposure to operators in CANDU (CANadian Deuterium Uranium) reactors. To minimize the exposure by recovering the tritium, the Korea Hydrogen & Nuclear Power (KHNP) is committed to the construction of the Wolsong Tritium Removal Facility (WTRF) at the Wolsong Nuclear Power Station where four CANDU reactors are operating. The TRF is now under construction and will be completed by the end of 2005. This facility will reduce both the operator’s exposure and tritium emission from the operating reactors.

The tritium is recovered in the form of T_2 gas at the WTRF. To safely store this form of tritium for a long time, it is preferred that the tritium be converted to a stable form such as metal tritide because of the possibility of a gas leakage. It is known that a solid metal tritide can bind the tritium tightly into a stable chemical compound suitable for a long-term storage. Various metals such as a titanium, uranium, zirconium, erbium, and yttrium have been evaluated as a tritium storage media[1]. Out of these metals, titanium of a metal sponge type has been selected as the storage medium for the tritium at the WTRF because, with its use, the tritium can be recovered at a somewhat lower temperature[2]. Using this material, the storage vessel was designed and fabricated to contain 0.5 MCi of tritium in this study.

In some cases, the shipping package is required to safely transport the storage vessel to a location for industrial use or research for peaceful purposes because it is very useful resource. The shipping package to transport the storage vessel containing 0.5 MCi of tritium must be categorized and licensed as a B type-shipping package. Because the B type-shipping package has to protect the contents under an accident condition, very rigid test requirements are imposed on the licensing. In this study, a B type shipping package was designed to transport the storage vessel for tritium and the prototype package fabricated by the design was subjected to several tests under an accident condition involving a 9 m free drop test, 1 m puncture test and a thermal test (800°C, 30 min.) in accordance with the regulations to verify its integrity and safety.

STORAGE VESSEL FOR TRITIUM

The tritium in the form of T_2 gas reacts with titanium of a metal sponge type and is converted to solid titanium tritide ($Ti_{1.0}T_{0.83}$) as follows.

$$T_2(g) + Ti(s) \rightarrow Ti_{1.0}T_{0.83}$$

Based on this reaction, the amount of titanium was determined to store 0.5 MCi of tritium. Because He-3 is produced during storage by the decay of the tritium in the titanium tritide and it exists in the gas form inside the vessel, the maximum pressure of the vessel after a 50-year storage was calculated. And operation conditions such as an activation, tritiding and recovery were also considered in the design of the storage vessel. After the design was completed, the storage vessel was fabricated according to the design specification. The storage vessel contains 1kg of titanium and its internal volume is about 6.5 L. The vessel can endure an internal pressure of 7.4 MPa. The material of the main body is made of stainless steel SUS 316L. Inspection of the vessel was performed according to ASME section II part A, ASME section VIII division 1 and ASME section V.

Tritium gas is introduced in to the storage vessel by a batch-wise operation. Ten batch operations are needed to satisfy the storage capacity of the vessel. Tritium content (T/Ti) in every batch operation is 0.08 and the final content is 0.83 after the 10th batch operation. Hydrogen is used instead of tritium since the chemical properties of the tritium are virtually identical to that of hydrogen. The performance test was then conducted on the storage vessel. The result is shown in Figure 1. A maximum of about 30 minutes is required for each batch to be stored by the titanium in the vessel. There were no significant differences in the hydriding phenomena from the batches. The hydrogen contents (H/Ti) in the titanium sponge were about 0.08 after each batch operation. After the 10th batch operation, the total hydrogen contents (H/Ti) reached 0.83 which is the storage capacity of the vessel.

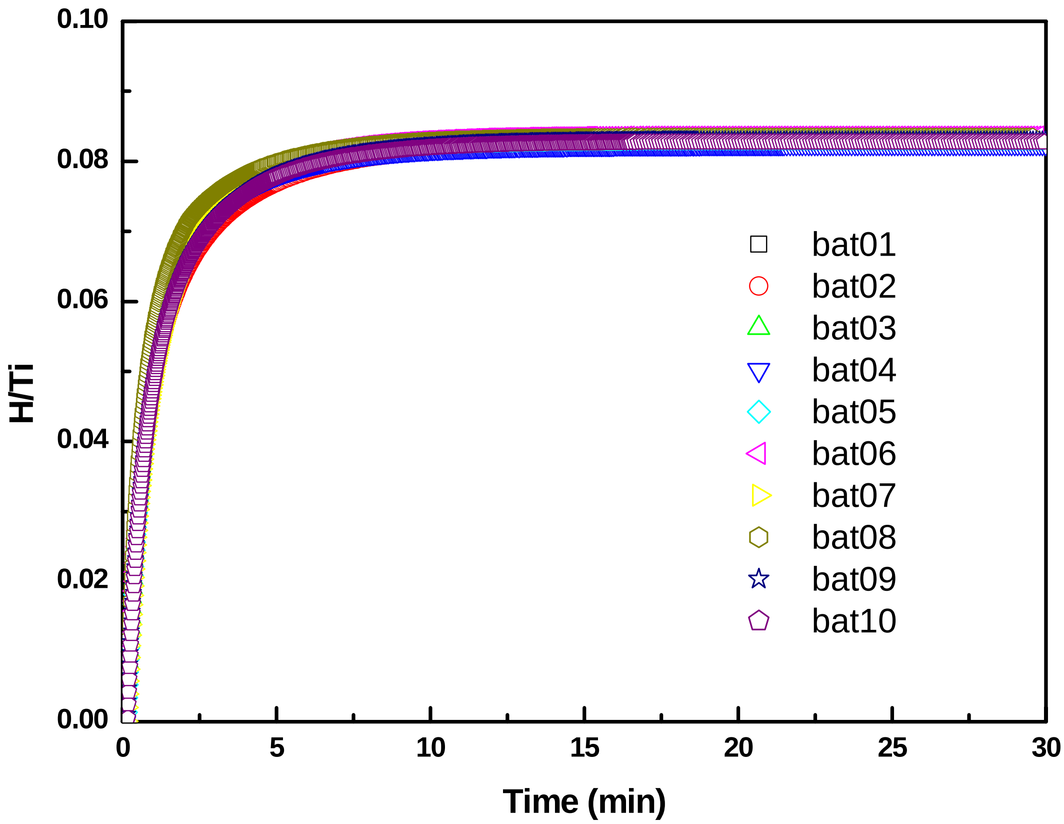

Fig. 1. Hydrogen content (H/Ti) of the storage vessel at each batch operation.

SHIPPING PACKAGE FOR TRITIUM

Shipping Package

The shipping package to transport the storage vessel containing 0.5 MCi of tritium is shown in Figure 2.

The shipping package consists of two parts: the main drum and the secondary container. The main drum is made of stainless steel and its inside is packed with a special impact absorber and insulator to protect the storage vessel from a fire and being dropped. The secondary container which is also made of stainless steel supplies the space to house the storage vessel and, in the case of a leakage, the gas from the vessel can be captured. Total weight of the shipping package containing the storage vessel is about 130 kg and it has a cylindrical shape with dimensions of 420 mm in diameter and 840 mm in height. The apparent density of the package is approximately 1.056 g/cm^3.

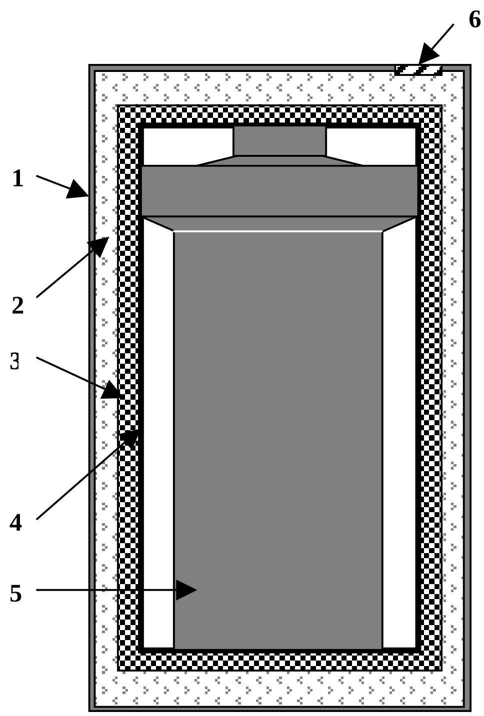

Fig. 2. Schematic of the Shipping Package
1: Drum Vessel, 2: Impact Absorber, 3: Insulator,
4: Insulator Support, 5: Secondary Vessel, 6: Vent

Performance Tests

The shipping package to transport the storage vessel containing 0.5 MCi of tritium must be categorized and licensed as a B type-shipping package. Because this shipping package has to protect the contents under an accident condition, very rigid test requirements are imposed on the licensing. These required test conditions and criteria for the package are summarized in Table I.

Two prototype packages named KT500A and KT500B were fabricated to have the same structure and they were subjected to the performance tests involving a 9 m free drop test, 1 m puncture test and a thermal test (800°C, 30 min.) in accordance with the regulations of Korea which are related to the transportation of radioactive materials (the Ministry of Science and Technology Notice 2001-23)[3]. The integrity and safety of the shipping package could be evaluated through the measurement of the helium leakage and a visual inspection after the performance tests.

Table I. Design and Test Requirements for the Transport of the Tritium Storage Vessel

Requirements		Test Condition	Criteria
Normal Conditions	Water Spray	50 mm/hr	- Leakage of Radioactive Materials Per Hour: Less than 10^{-6}× A2
	Free Drop	1.2 m	
	Stacking	5 times of its weight	
	Penetration	1 m	
Accident Conditions	Free Drop I	9m	- Surface Dose Rate (1m): Less than 10 mrem/hr - Leakage of Radioactive Materials Per Week: less than A2 (A2 value of Tritium: 1,000 Ci)
	Free Drop II	1 m Puncture	
	Thermal	800°C, 30 min.	
	Immersion	15 m, 8 hr	

Helium leakage of the packages prior to the tests

Helium leakage rates were measured for the KT500A and KT500B which have the storage vessels filled with 0.2 MPa of helium prior to performance tests. The leakage test was done in accordance with ANSI N14.5-1997 A.5.4[4] and ISO 12807-1996 A.3.4[5]. The helium leakage rates of the packages were 1.8×10^{-6} cm^2/s and 1.9×10^{-6} cm^2/s, respectively.

Because the maximum permissible leakage rate of the package by the calculation was 2×10^{4} cm^2/s, it was evaluated that the packages are airtight enough to protect the leakage of tritium.

9 m free drop test

9 m free drop tests at vertical and horizontal positions were conducted for the package KT500B. After the tests, three of the four locks of the package cover were unfastened and it was found that the cover was not separated from the package. No severe damage was observed. The results are shown in Figure 3.

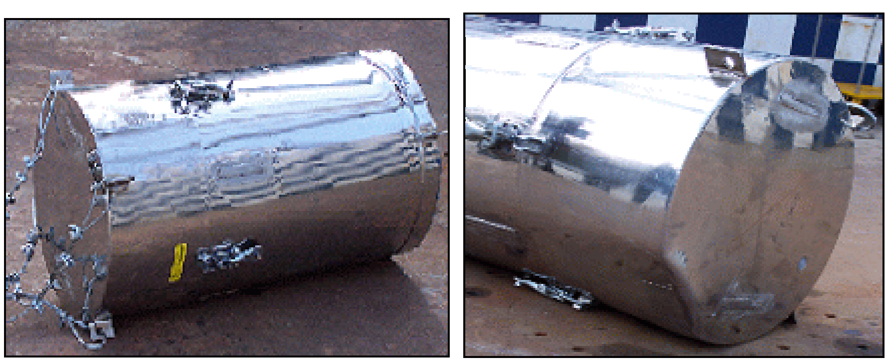

Fig. 3. Shipping Package KT500B after the 9 m Free Drop Test.
(Left: Drop at a Vertical Position; Right: Drop at a Horizontal Position)

1 m puncture test

After a visual inspection of the package dropped freely from 9 m was completed, the package was subjected to the 1 m puncture test. Several 1 m puncture tests were done at various positions. As a result, a part of the package was slightly crushed but it was not in a critical state.

Helium leakage of the packages after the drop tests

Helium leakage rates were measured for the package after a series of 9 m free drop tests and 1 m puncture tests were conducted for package KT500B. The helium leakage rates of the packages were $2.4x10^{-7}$ cm^2/s and it means that the air-tightness of the package could be maintained under a series of 9 m free drop tests and 1 m puncture tests.

Thermal test

A thermal test was performed under the conditions of 800°C and 30 min for the KT500A on which a 9 m free drop test (oblique) at an angle of 10° and a 1 m puncture test were consecutively done. After the thermal test, it was observed that most of the impact absorber made of polyurethane was burnt out and a part of the insulator was damaged by heat. However, the maximum temperature of the storage vessel in the package was merely 83°C. Helium leakage rate after the thermal test was $2.1x10^{-7}$ cm^2/s and the airtightness of the package could be maintained under the thermal test condition.

SUMMARY

KAERI has been developing a storage vessel and shipping package for tritium. The storage vessel was designed to store the tritium (T_2) in the form of tritium tritide ($Ti_{1.0}T_{0.83}$). The storage capacity of the vessel is 0.5 MCi of tritium. The shipping package to transport the storage vessel was designed as a B type-shipping package. The prototype-shipping package was fabricated and subjected to several tests involving a 9 m free drop test, 1 m puncture test and a thermal test (800°C, 30 min.) in accordance with the regulations. The integrity and safety of the shipping package could be verified through these tests. Currently the work for licensing as a B type-shipping package is underway for the package developed to transport the storage vessel containing 0.5 MCi of tritium

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