Development of the Packaging for Tritium Transport

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INTRODUCTION

For the purpose of establishment of the Fusion Fuel Cycle, research and development using tritium has been carryied out by Japan Atomic Energy Research Institute (JAERI).
In order to procure tritium for R&D, development a of tritium transport package is necessary. This paper describes an overview of the package developed by JAERI, which is designed to comply with the Japanese domestic transport regulations revised on the basis of the 1985 edition of the IAEA Safety Standards No. 6 [1].
It took approximately 4 years to develop the package. The schedule of development is as follows;

JFY 1989: Conceptual design
JFY 1990: Basic design and investigation on chemical and physical property of tritium getter
JFY 1991: Demonstration tests for verification of compliance with the requirement of the regulation and licensing effort
JFY 1992: Fabrication of the actual package

DESIGN PHILOSOPHY AND SPECIFICATION REQUIREMENTS

Design Philosophy

The design philosophy of the package is:
- Minimized when possible.
- Possible to transport large quantity of tritium safely.

Specification Requirements

To meet the above philosophy, the specification requirements of the package are:
- The package shall be satisfied with the requirement of the type BU package stipulated in the transport regulation in order to employ it for the international tritium transport.
- It shall be possible to transport large quantities of tritium whose state is chemically stable during transportation.

- It shall be easy to operate the package and possible to both charge tritium gas into the package and discharge from it safely.
- Taking into account the characteristics of tritium gas, the package shall be capable of restricting tritium permeation through the wall of the package as little as possible and has a high-performance containment system.

OUTLINES OF THE PACKAGE'S SPECIFICATION

To comply with the above specification requirements, the package shown in Figure 1 has been developed. The package has the following characteristics:

- Package is designed to comply with not only requirements for type BU package, but also the additional requirements for package transportation.
- In the viewpoint of sealability for tritium, capability that chemical state is stable during transportation and minimizing the packaging size in transportation, the state of tritium is in the form of metallic hydrogen compound by absorbing it to getter (Zirconium-Cobalt compound approximately 1 kg of which, more than 100 liters of tritium can be absorbed in stable).
- Packaging is composed stainless steel cylindrical "primary container" which is containment boundary and "protective container" functioned as a shock absorber which is made of balsa wood covered with thin steel plate.
- Primary container, of the containment boundary of the package, has a sufficiently thick wall in order to restrict the permeation of accommodated tritium and to maintain its integrity in the event of the accident conditions of transport and metal gaskets are employed as containment system of packaging to minimize the permeation of gaseous tritium.
- Radioactive contents of the package is contained in a "capsule" inside which a layer of getter (Zirconium-Cobalt compound) to absorb tritium is placed . The capsule has a couple of highly leak-tight valves which absorb and discharge of tritium gas.

STRUCTURE OF THE PACKAGING

The packaging is a cylindrical shape of 620 mm in outer diameter and 1,200 mm in height. The primary container, which is the containment boundary of the package, is contained in the protective container possessing the function of a shock absorber. The primary container consists of a primary container body and a primary container lid. The protective container consists of a protective container body and a protective container lid. During transport, an aluminum spacer is installed into the space between the primary container and the protective container.

Primary Container Body

The primary container body is made of stainless steel. The top of it is a flange, which comprises the containment boundary by means of being fastened with a primary container lid. There are 20 bolt holes through which the capsule is fixed by bolts to the inside of the top-surface, and there are 16 bolt holes to fasten the primary container lid at the outside of the top surface. Helium is filled in the primary container during transport in order to dissipate the decay heart of tritium. On the hull part, there are two valves for the gas purge and ventilation inside the primary container. And during transport, the valves are covered with a valve cover.

Primary Container Lid

The primary container lid is made of stainless steel and is a structure welded a cap on a flange. The lid is to be fastened with the primary container body by 16 tie-down bolts. The surface of flange is designed to maintain the containment of the primary container by a metal O-ring and an elastomer O-ring installed outside of it, in order to accommodate the containment test by using a testing hole provided in the space between the two O-rings.

Protective Container Body

The protective container body has a double wall cylindrical shape. It is a weld construction of external plate (both hull and bottom) and internal plate. In the space formed between the external and the internal plate, balsa wood is filled in to absorb the energy imposed by drop impact. In order to dissipate the decay heat by tritium, it is required to provide a heat removal path, so that there are eight copper inner fins on the hull part, connecting the external and internal side plates.

Protective Container Lid

The protective container lid comprises welded structure of double layer cylindrical shape, the external and internal sides which are made of stainless steel (both the hull and upper plate). Within the cylinder, balsa wood is filled in as a shock absorber. The fastening of protective container and the lid is made with eight bolts.

Material to Be Stored

The content of this packaging is the capsule which contains getter (ZrCo) where tritium, in a chemical state of metallic hydrogen compound, is absorbed. This capsule is filled with ZrCo which is capable of absorbing large quantities of tritium.
The capsule is composed mainly of stainless steel.

During transport, the capsule is to be fixed to the primary container body by means of 20 fixing holes provided on the capsule flange. There are two lines on the upper part of the capsule. The method of absorption of tritium is made to fill tritium gas into capsule under room temperature conditions and absorb it to Zirconium-Cobalt compound, then that of discharging tritium is made to heat the capsule and release tritium from the compound.

SAFETY ANALYSIS OF THE PACKAGE

The safety analysis has been performed in order to verify that it complies with the requirements for the Type BU package stipulated in the transport regulations.

Structural Analysis

The evaluation of the portions which consist of the containment boundary has been made in accordance with the philosophy of ASME SECTION Ⅲ Class I components. Thus the design criteria of Level A Service Limit has been employed in evaluating the integrity of the package in the event of normal conditions of transport and that of Level D Service Limit has been employed in evaluating in the event of accident conditions in transport.

The evaluations of the lifting and tie down devices have been made by establishing appropriate load factors. The generating accelerations and deformations in 1.2-m and 9-m drop tests have been evaluated based on the Volumetric Displacement Method (VDM). The load combinations have been defined appropriately taking into account of pressure and temperature condition.

Thermal Analysis

In order to correspond the transport of the large quantity tritium, the evaluation has been performed under the condition that the decay heat has been assumed to be 25W. The evaluation has been made by using TRUMP, which is 3-D finite difference method unsteady heat transfer analysis code.

In evaluating the temperature distribution in the package under normal conditions of transport, compliance with the requirement for the package transported by air has been confirmed. The results of the evaluations are shown in the following table. According to the evaluations, it has been confirmed that the package complies with the requirements stipulated in the transport regulations and the temperature of the containment systems as lower than the maximum service temperature of the materials.

Normal conditions of transport					Accident conditions of transport	
Solar heat		with	without	without	800	amb. for 30 min.
Ambient temperature		38	38	55**	Temp.	Time*(h)
Portions	Surface of the package	59	44***	61	794	0.5
	Containment systems · Primary contain lid O-ring	64	48	64	129	1.7
	· Valve cover O-ring	66	50	67	123	4.0
	Surface of the capsule	61	77	77	133	4.0

* Time since the fire accident started. (unit : ℃)

** Additional requirement for the package transported by air.

*** Taking in into account of transported by air; the maximum allowable temperature is 50 ℃.

Containment Analysis

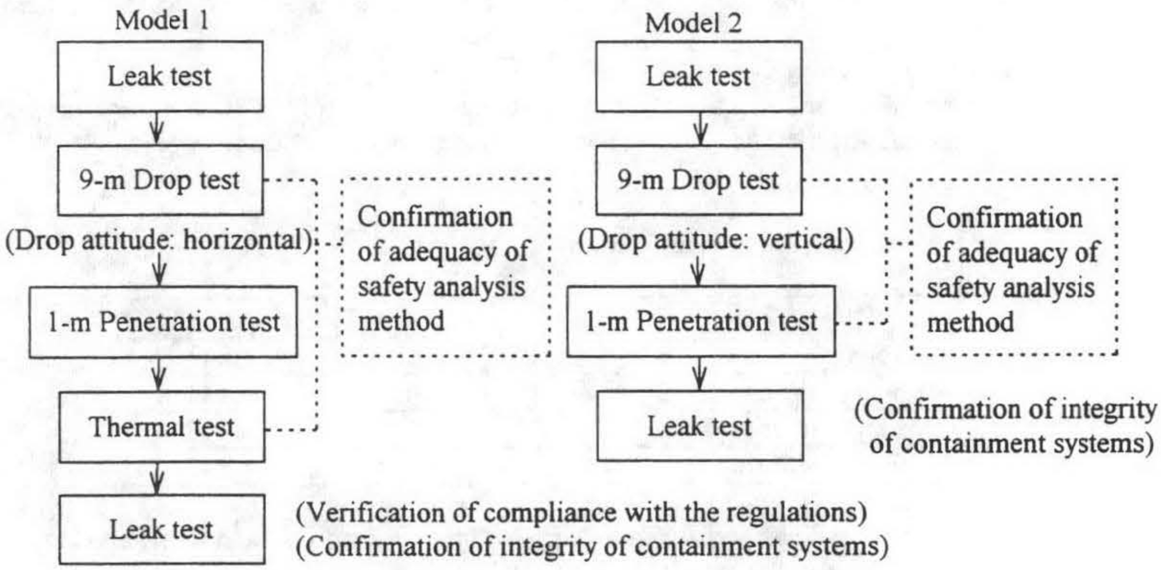
As a result of structural and thermal analysis, the primary container and lid, the containment boundary, and the capsule keep their integrity in both normal and accident conditions of transport, however, containment evaluation has been performed under conditions that the sealability of the capsule was ignored.

The tritium inside the primary container in a gaseous state whose existence is equal to equilibrium partial pressure has been assumed to be the radioactive material concerned with leakage. Then, as the evaluation of radioactive leakage, both "leakage" due to pressure differential between the inside of the primary containers and the atmosphere and "permeation" via adsorption, dissolution, and diffusion through the primary container wall materials [2] have been evaluated.

As a result of the evaluation, the leakage of the radioactive materials (sum of "leakage" and "permeation") was confirmed not to exceed the criteria in the transport regulations.

DEMONSTRATION TESTS

The demonstration tests using two prototype models have been performed in order to verify that the package complies with the criteria stipulated in the transport regulations and to confirm that the method of safety analysis employed in the safety analysis report (SAR) is adequate.
The Strength test (9-m drop test and 1-m penetration test) and the Thermal test (800 ℃ ambient for the period of 30 minutes) have been performed.
The tests sequences are as follows.



Specifications of the Prototype Model

Two prototype models were manufactured. As for the whole weight, dimensions, and employed materials both models are the same as the actual package. The difference between the two are as follows;

Model 1: the material to be stored (capsule) the outlook is same as the actual beat in order to simulate the decay heat, it accommodates heater system instead of Zirconium Cobalt compound.

Model 2: the capsule is the same as the actual in order to provide it to the handling test for the purpose of confirming the ability of Hydrogen isotope absorption to ZrCo compound.

Results of the Test and Comparison with the Analysis

Drop Test

Model 1 was dropped from a height of 9 m and then dropped onto mild steel bar from a height of 1 m horizontally taking into account of the effect of the thermal test.
On the other hand, model 2 was dropped vertically.

The test results are shown as follows:

		Horizontal		Vertical	
		Test	Analysis	Test	Analysis
9-m Drop test	Accelerations (G)	575	610	304	370
	Deformation* (mm)	32	66	34	143
1-m Penetration test	Occurrence of Penetration**	No.		No.	

* It is confirmed that the deformation occurred only in the protective container.

** External plate of the protective container and lid.

According to the above table, it is confirmed that the analysis method leads to conservative result, therefore, the employed one is justified adequate as a safety analysis method.

Thermal Test

Using model 1, thermal test (800 ℃ ambient for the period of 30 minutes) was performed. Concerning the method, furnace test #2 defined in The IAEA Safety Standards S. S. No. 37.

The test results are shown as follows:

Portions	Maximum Temperature (℃)	
	Test	Analysis
Surface of the capsule	101	131
Primary container O-ring	126	137
Valve cover O-ring	102	122

(Remarks)

The analysis was performed by employing the relation between time and ambient temperature in the test as an input condition.

According to the above table, it is clarified that the employed analysis method leads conservative result, therefore the one employed is justified as an adequate safety analysis method.

Leak Test

Before and after each test, in order to confirm the integrity of containment systems, leak tests of the O-ring portions of both primary container and valve cover were performed by the Helium Leak method. Concerning the capsule, after all of the tests were finished, the tests were performed by the same method as above. All of the test results were below the helium detection limit (10^{-10} MPa·cm^3/sec. order); therefore, the integrity of the containment system and the capsule was verified and the package's compliance with the criteria of the transport regulation was also verified.

CONCLUSION

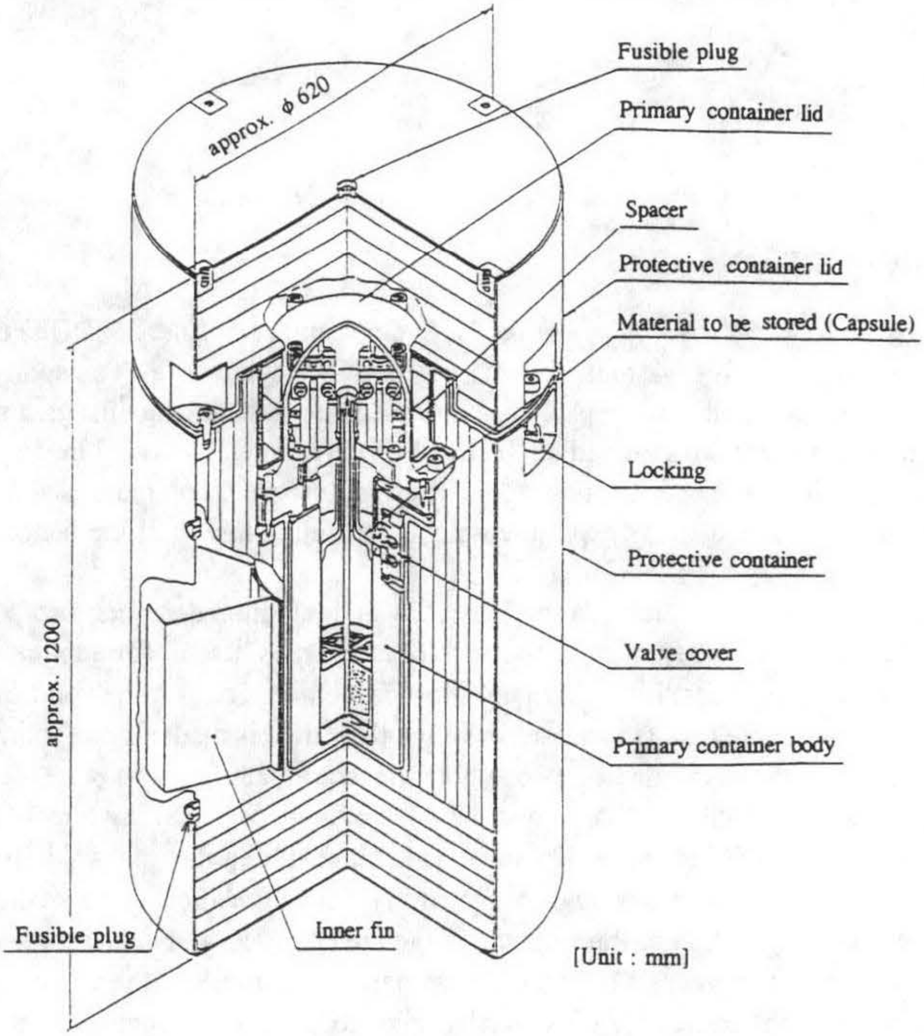
The package for Tritium transport whose characteristics are capability of transporting large quantities of tritium safely has been developed. As for the package, safety analysis and demonstration tests were performed and package's safety and compliance with the transport regulations were confirmed. The package has been certified as Type BU package by the

Competent Authorities of the relative nations. The actual package was manufactured and now is provided for international transportation of Tritium.

REFERENCE

[1] I AEA "Regulations for the Safe Transport of Radioactive Materials", 1985 Edition.

[2] Naruse, Y. et.al. *Equilibrium Hydrogen Pressure of ZrCo-H, etc., as materials for tritium getter*, Japan Atomic Power Association Subcommittee Transactions 1985.



	Specification
Dimensions	1.2 m 0.62 m
Weight	approx. 450 kg
Packaging	approx. 427 kg
Capsule	approx. 23 kg
Material: Primary container	Stainless steel
Protective container	Stainless steel, Balsa wood, Copper
Capsule	Stainless steel, Zirconium-Cobalt compound

Figure 1. Outline of the Tritium Transport Package.