Development of tritium transport package for ITER SDS supply

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1. Introduction

ITER is the next generation fusion machine with the fuel of deuterium and tritium [1]. The transport of large amounts of tritium is an important issue from viewpoints of fuel supply and safety. For the shipment of tritium to the ITER site, a transport container needs to be developed and licensed as type B(U) package [2]. It is an ITER requirement to transport tritium as metal tritide, which has been considered to be the safest way for tritium transport. There are not many available licensed packages on the market today. Examples are the WSRC Hydride Transport Vessel (HTV)[3], which can be loaded with up to 18 g tritium in uranium tritide powder and JAERI Type B(U) package with capacity up to 25 g tritium in ZrCo tritide material. JAERI (now JAEA) has proposed a 250 g capacity tritium transport package for future fusion reactors [4]. The design would utilize ZrCo to form the metal tritide to store the tritium. This new package would have a volume of only approximately 50% more than that of the 25 g capacity package and would be capable of repeated use.

The tritium will be transported from tritium production sites, mainly the CANDU type reactor sites to ITER tritium plant building. According to the tritium supply plan derived from the operation and experiment plan of ITER, it is necessary to develop a large capacity tritium transport package which is licensed for international transportation. In 2009, Korea Atomic Energy Research Institute (KAERI) was commissioned the work of developing the tritium transport package from ITER Organization and the first stage of the development has been just finished. The interfaces of the package with related equipments/facilities were identified and the basic design and preliminary safety analyses were successfully performed. This paper describes the design requirements, basic design and the structural and thermal evaluation results of the developed package under the hypothetical accident conditions.

2. Transport Package Design

2.1 Design requirements

The design requirements of the ITER tritium transport package can be classified into three categories: functional requirements, interfacial requirements, and safety/regulatory requirements. The functional requirements given by the ITER Organization are as follows: The capacity of the package is 70 g and tritium should be stored in the form of metal hydride for safe transportation [5]; The package would be stored in fully loaded state for up to 5 years; The package would be reused and should provide additional contamination control for repetitive usage. The interfacial requirements of the package are as follows: The package should be equipped with appropriate interfacial apparatus such as valves and connectors compatible with equipments in both ITER tritium plant building and tritium production sites; The package should be size such that the modification of equipments currently in operation such as the glovebox at the tritium production sites would be minimized. Lastly, the safety/regulatory requirement of the package are as follows: The package design should comply with the IAEA regulation for safe transportation of radioactive materials; Also domestic regulations of countries related with the transportation like France should be considered.

2.2 Proposed design

The ITER tritium transport package consists of four components: the primary container (storage vessel), aluminum container (contamination control vessel), secondary container (containment vessel) and overpack. The proposed package design is illustrated in Fig. 1. The primary container store tritium in metal hydride (UT2.7) and is equipped with inlet and outlet valves compatible with the WTRF (Weolsong tritium removal facility) which is a potential source of tritium supply to ITER. The secondary container provides a strict containment to the primary container and the aluminum container assembly which is a minimal handling unit is ITER.

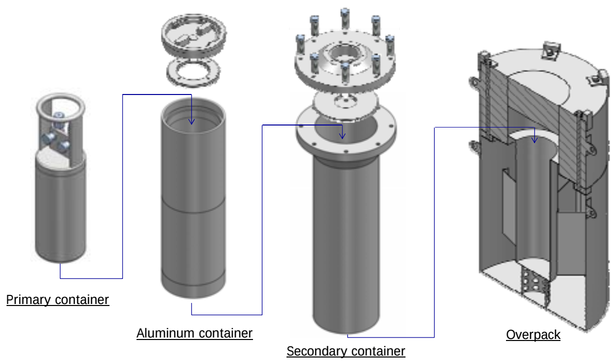

Fig. 1 Assembly drawing of tritium transport package

The overpack provides thermal and structural protection to the package under normal condition of transportation and accident conditions.

3. Safety Assessment

3.1 Requirements

The radioactivity of 70 g tritium is 686,000 Ci which is equivalent to 635 A_2. Thus, the package for transporting 70 g tritium should be a type B(U) package [6] and meet the requirements for type B(U) package stipulated in the IAEA regulations for safe transport of radioactive materials.

3.2 Structural Evaluation

The structural integrity of the ITER tritium transport package was evaluated considering the drop test conditions stipulated in IAEA safety series ST-1 paragraph 727 (a), (b). The drop test conditions include 9 m free drop on unyielding surface and 1 m free drop on puncture bar. Since it is not straightforward to find the drop posture that causes the maximum damage to the containment boundary, we considered several candidate drop postures which are known to cause severe damages to the packages of cylindrical shape in most cases [7].

The half model of the package was built using about 190,000 finite elements as shown in Fig.2 and the structural analyses were performed using the explicit dynamic analysis code ABAQUS/Explicit. The evaluation criteria and procedure follow the ASME Boiler and Pressure Vessel Code Section III div. 3 [8, 9]. The results show that the proposed design is intact under all the drop conditions, satisfying all the stress requirements at the evaluation points (stress classification lines: SCLs).

3.3 Thermal evaluation

The IAEA safety series ST-1 imposes requirement on the thermal performance of the package under normal condition of transportation and hypothetical accident condition. We carried out analyses under various conditions including 800°C fire condition with duration of 30 min using FLUENT code and it was demonstrated that the package design is intact under such conditions. Fig. 3 shows the temperature contour under hot condition.

4. Conclusions

The first phase of ITER tritium transport package was successfully completed. The developed package utilize metal hydride (uranium bed) for the storage of tritium and provides containment for transportation and temporary storage up to 5 years before tritium is deloaded in ITER tritium plant building. By adopting an additional container within the package, the aluminum container, this package provides contamination control after the primary container is used and contaminated by the permeated tritium during the deloading operation. The structural and thermal integrity of the package have been demonstrated through a series of analyses under the conditions stipulated in the IAEA regulation for safe transportation of radioactive materials. Also, the integrity of primary container during the deloading operation was checked considering two possible deloading furnace designs.

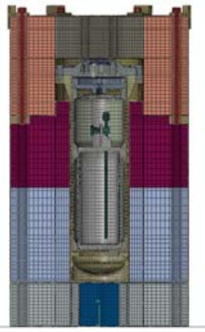

Fig. 2 FEM model

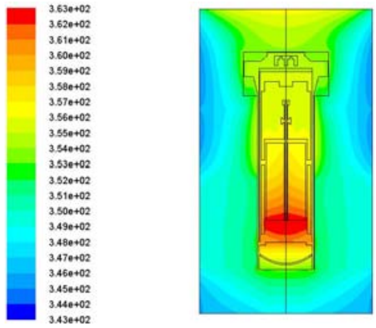

Fig. 3 Temperature contour (HOT)

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References

[1] http://www.iter.org

[2] International Atomic Energy Agency, IAEA Safety Standards Series No. TS-R-1: Regulations for the Safe Transport of Radioactive Material, Vienna, 2009.

[3] L. K. Heung, Design of metal hydride vessels for processing tritium, WSRC-MS-2001-00179, Westinghouse Savannah River Company, 2001

[4] S. O'hira, et al., Design Study of a Tritium transport package for future fusion reactors, Fusion Engineering and Design, 45(1999) 187-195.

[5] D. Murdoch and M. Glugla, Tritium Plant Building Layout and General Systems Footprins, DesRev7-02, ITER Design Review Meeting, July 16-19, 2007, Cadarache, France.

[6] US NRC 10 CFR Part 71, Packaging of Radioactive Material for Transport and Transportation of Radioactive Material under Certain Conditions, 2005.

[7] US NRC Regulatory Guide 7.6, Design Criteria for Structural Analysis of Shipping Cask Containment Vessels, US NRC, 1978.

[8] ASME Boiler and Pressure Vessel Code Section III Div. 3, Containments for Transportation and Storage of Spent Nuclear Fuel and High Level Radioactive Material and Waste, ASME Press, 2007.

[9] ASME Boiler and Pressure Vessel Code Section II, Materials, ASME Press, 2007.