Calculations for Estimating the Tritium Generation and Distribution in a 600 MWt VHTR with TRITGO

Jong-Hwa. Park[a], Ik Kyu Park[a], Won-Jae. Lee[a]
a KAERI, 150 Dukjin-dong,Yusong., Taejon, 305-353, jhpark3@kaeri.re.kr

Abstract

In this study, the TRITGO code was introduced, which can predict the amount of tritium production, its transport, removal, distribution and the level of contamination for the produced hydrogen by the tritium in the VHTR (Very High Temperature Gas Cooled Reactor). The contamination level of the produced hydrogen by the tritium was predicted by an improved code for the VHTR with a 600 MW thermal power. The contamination level for the produced hydrogen by tritium was predicted as 0.56 Bq/H_2-g. This level is two orders lower than the regulation value of 56 Bq/H_2-g from Japan.

From the analysis of the calculation results, it is important that the fuel coating (SiC layer) should be kept intact to prevent the tritium from releasing. Also it is necessary that the level of an impurity such as ^{3}He and Li in the helium coolant and the reflector consisting of the graphite should be kept as low as possible. It was found that the capacity of the purification system for filtering the impurities directly from the coolant will be an important design parameter.

1. Introduction

Tritium is an isotope of the hydrogen, which consists of two neutrons and one proton. It exists as a gas under the atmospheric condition. The half-life is 12.32 years. The tritium emits low beta energy. Therefore, the external dose is not a problem. But in case of drinking or an inhalation or an absorption through the skin, it can make an effect on the internal organ.

In a VHTR, the tritium can be largely produced during the normal operation not only from the core but also from the coolant. In case of producing the hydrogen with using this hot helium gas from VHTR, the tritium can be easily permeated to the produced hydrogen and can be released to the atmosphere.

The available tool for analyzing the tritium behavior in VHTR is limited. TRITGO code to be used in this study was imported from GA company in the frame of the mutual collaboration between KAERI and GA. TRITGO was improved to be able to consider the permeation phenomena to the IS loop by KAERI.

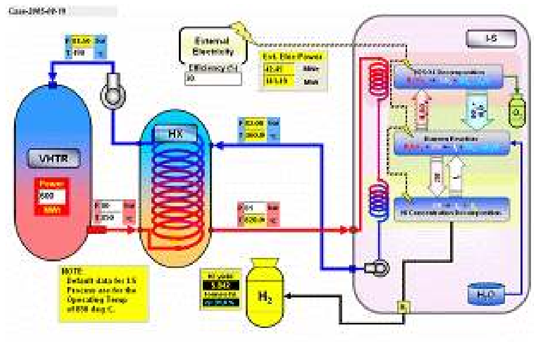

Figure 1. Conceptual VHTR system for producing H2

The Figure 1 is the conceptual VHTR system for producing the hydrogen that is under development by the KAERI. This figure1 showed that the hot helium gas from the core transfer its heat to the IS thermo-chemical processes through the heat exchanger for producing the hydrogen. The objective of this study is to identify the important control parameters on the tritium release from the VHTR with TRITGO code.

2. Description of the Actual Work

2.1 Review of the Tritium generation and distribution model in TRITGO

In the TRITGO code, the tritium can be generated from several sources. The first source is the ternary fission. Normally, two fragments, neutron and gamma ray emits during the fission. But rarely (one per billion) three fragments can be emitted at the fission. In this time, tritium is generated. The next can be produced from the activation reaction of the boron and beryllium with neutron. The third one is the 'Li' impurities within the graphite reflector. The last is the activation of ^{3}He.

The generated tritium is transported by a convection or a diffusion. The tritium generated from the ternary fission should be trapped within the SiC coating layer in the TRISO fuel particle. But some tritium can be diffused through the SiC layer and escaped to the coolant. The tritium in the coolant can be adsorbed on the porous graphite structures or bound in the nearest solid structures.

These adsorption phenomena play an important role in reducing the tritium release.

The existing tritium in the coolant can be permeated to the secondary loop through the primary pipe wall such as the HRSG (Heat Recovery Steam Generator), which consist of the evaporator, economizer and heaters and the heat exchanger tubes. Also in case of producing the hydrogen, the tritium in the coolant can be permeated to the IS loop.

The primary objective of this study is to identify the important control parameters to reduce the tritium release from the VHTR. Another purpose is to estimate the capability of the TRITGO code to simulate the overall tritium behavior in the VHTR.

2.2 Simulation of H-3 behavior in 600MWt VHTR

The 600 MWt VHTR was simulated with the TRITGO code. The input deck was prepared based on the GTMHR-350 data for a normal operation [1]. Figure 2 shows the total generation of tritium, the amount bound in a solid, the amount of generation by fission and the activation from the 600 MWt VHTR.

Figure 3 shows that the generation rate by the activation started to decrease according to the time. It was because the impurity was depleted by the activation reaction. Although the amount of tritium being generated by the fission continued to increase, it showed that most of it was bounded within the Sic coating layer (~95%). It means that the fabrication of fuel particles without any defects is important to arrest the tritium release.

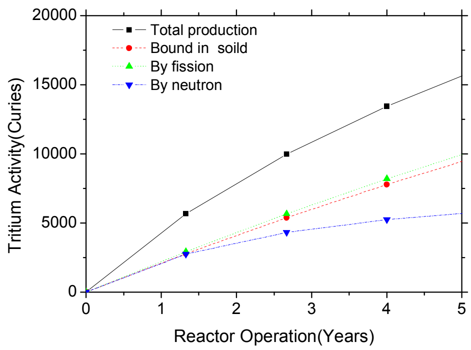

Figure 2. Total tritium generation and bound in solid

From figure 4, the permeation rate remains the highest level for 1.5 years. The tritium that permeate to the IS loop can contaminate the produced hydrogen and it can release to the atmosphere. Therefore it is necessary to define the regulation limit for the contamination level of the produced hydrogen by the tritium. The only available regulation limit is 56 Bq/H_2-g from Japan [2].

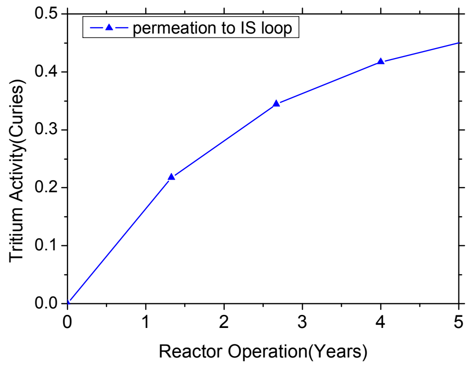

Figure 3. The Amount of permeation to the IS loop

The hydrogen production for one year was assumed as 1.0×10^{10} g and the amount of permeation for one year was predicted as 0.15 Ci. Therefore, the contamination level of the produced hydrogen by the tritium turned out to be 0.56 Bq/H_2-g. This level is two orders lower than the regulation value of 56 Bq/H_2-g from Japan.

3. Conclusion

In this study, the contamination level for the produced hydrogen by tritium was predicted as 0.56 Bq/H_2-g. This level is two orders lower than the regulation value of 56 Bq/H_2-g from Japan. From the analysis of the calculation results, it is important that the fuel coating (SiC layer) should be kept intact to prevent the tritium from releasing. Also it is necessary that the level of an impurity such as 3He and Li in the helium coolant and the reflector consisting of the graphite should be kept as low as possible. It was found that the capacity of the purification system for filtering the impurities directly from the coolant will be an important design parameter.

ACKNOWLEDGEMENTS

Authors would like to thank MOST for supporting this research with the frame of MOST long term R&D program.

REFERENCES

1. "GT-MHR Conceptual Design Description Report," GA project 30103 GA/NRC-337-02,August 2002.
2. Tetsuaki Takeda et.al," Study on Tritium-Hydrogen Permeation in the HTTR hydrogen production system, " JAERI-TECH 98-044, JAERI,1998.