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Measurement and evaluation of hydrogen yield in the transportation of the breached fuel with wet type transport cask

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Abstract

Wet type casks such as NFT type transport casks are mainly used for the transportation of spent fuel in Japan. The hydrogen yield within the cask due to coolant (water in the cask) radiolysis must be considered for these types of casks. In the past, we has measured hydrogen concentration in the gas phase part of the cask after the transportation of fuel with intact cladding, and it was verified that the hydrogen gas concentration in the cask is sufficiently lower than the 4% hydrogen gas concentration limit of flammability.[1)]

As we had an opportunity to transport a fuel assembly containing a breached fuel rod with Damaged Fuel Can (DFC) in NFT type transport cask, the concentration of hydrogen in the gas phase part of the DFC after transportation was measured. The measured concentration of hydrogen gas in the DFC (approx. 0.2%) was sufficiently lower than the 4% hydrogen gas concentration limit of flammability. Moreover, these measured values were equivalent to results of calculation based on previous study.

Introduction

Wet type casks such as NFT type transport casks are mainly used for the transportation of spent fuel in Japan. The hydrogen yield within the cask due to coolant (water in the cask) radiolysis must be considered for these types of casks. Water radiolysis continuously produces oxygen, hydrogen and hydrogen peroxide, and also results in the production of reactive radicals and molecular products, as well as chemical reactions between the radiolysis species. The radiolysis species concentration come to chemical equilibrium in a relatively short amount of time. This equilibrium concentrations depend on several factors, including irradiation dose rate and temperature. In the past, We has measured hydrogen concentration in the gas phase part of the cask after off-site transportation of fuel with intact cladding, and it was verified that the hydrogen gas concentration in the cask is sufficiently lower than the 4% hydrogen

gas concentration limit of flammability.[1)] However, the concentration of hydrogen gas after the transportation of fuel assemblies containing breached fuel rods had never been measured before, meaning that data must be acquired on this topic.

The concentration of hydrogen in the gas phase part in the DFC was measured after on-site transportation of fuel assembly containing a fuel rod with breached cladding using NFT type transport cask with DFC. This paper will introduce the valuable information gained on coolant (water in the cask) radiolysis after the transportation of breached fuel using a wet type cask.

Measurement of hydrogen gas concentration

(1) Transport cask subject to measurement

The NFT-12B type cask for BWR fuel transportation was subject to measurement, and this cask had the DFC which can load with breached fuel. The gas inside the DFC was collected and its concentration of hydrogen gas was measured. The contents of the DFC were breached fuel with low burnup and long cooling period, and analytical calculation of the absorbed dose rate of the water within the central portion of the DFC based on its specifications revealed it was 2.87×10^{1} Gy/h (neutron irradiation dose was ignored for the purposes of evaluation since it was 10^{-8} of the total irradiated dose). The specifications of breached fuel and transport conditions are shown in Table 1.

Table 1. Specifications of breached fuel and transport conditions

Items	Figures
Cask type	NFT-12B-#2 with DFC
Number of fuel assemblies contained	One breached fuel assembly in DFC
Breached fuel burnup	4,227 MWD/MTU
Breached fuel cooling period	6,621 days (as of the time when it was loaded within a cask)
Number of breached fuel rods	1 rod
Number of hours required for transportation	Approx. 91 hours (from adjustment of water levels within DFC to opening of DFC lid)

(2) Sampling of gases inside the DFC

The DFC of the NFT type transport cask is designed to be able to replace internal gas and water. During discharge of gases within the DFC prior to opening of the DFC lid after transportation, gases within the DFC were collected into a sampling bag via the sampling line connected to the lid coupler. The method by which gas was collected from the DFC is shown in Fig. 1.

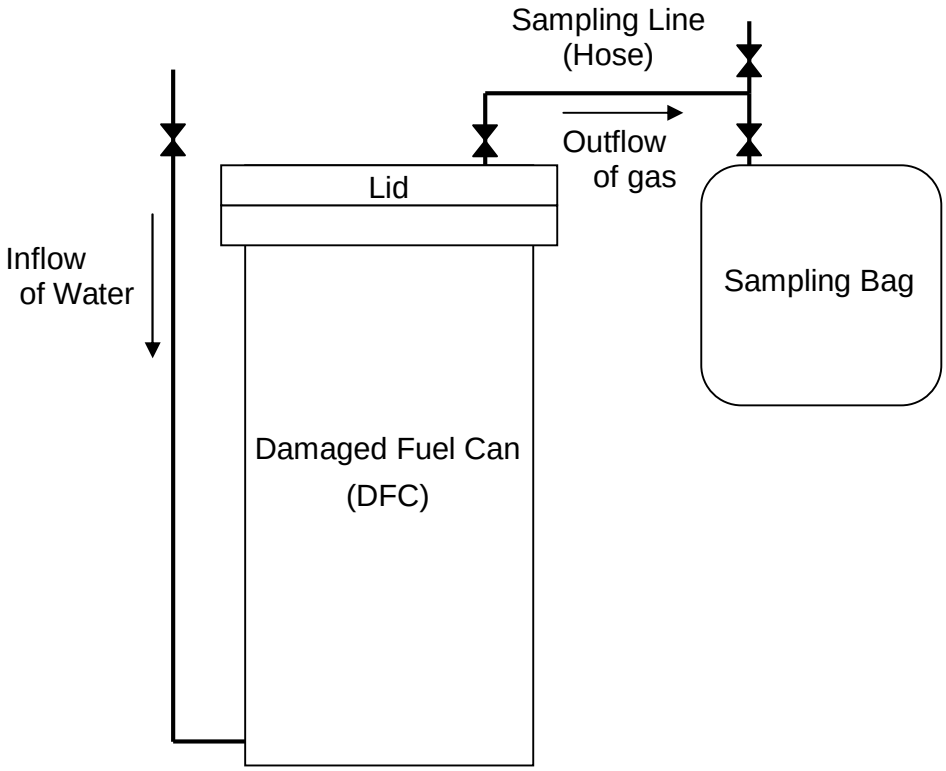

Fig. 1. Method by which gas was collected from the DFC

(3) Measurement of hydrogen gas concentration

The hydrogen gas concentration was measured with the gas detecting tube. The gas collected in the sampling bag was extracted with the glass injector, then injected into the gas detecting tube for measurement. The gas sample was measured three times, and the results of hydrogen gas concentration measurement are shown in Table 2.

The hydrogen gas concentration in the DFC was sufficiently lower than the 4% hydrogen gas concentration limit of flammability.

Table 2. Results of hydrogen gas concentration measurement

Cask type	Date	Gamma absorbed dose (Analysis evaluation value)	Hydrogen gas concentration
NFT-12B-#2	Jan. 2013	28.7Gy/h	0.2%

Evaluation of hydrogen gas concentration

Next, the steady-state hydrogen gas concentration of the absorbed dose during the transportation of DFC was evaluated. A previous study of water radiolysis suggested that the steady-state hydrogen gas concentration was proportional to the second root of the absorbed dose rate via evaluation of product generation amount due to coolant (water in the cask) radiolysis using numeric simulations and actual experimentation.[2)] Although evaluation was performed taking this relationship into consideration, the absorbed dose rate was outside the scope of data provided within previous study. Therefore, linear extrapolation was performed so that set the concentration of hydrogen gas at 0 at the origin point. Results of calculation revealed that hydrogen gas concentration was 0.19%, which was a figure very close to actual measured values.

Fig. 2 shows a comparison between this above-mentioned calculated value, the actual concentration of hydrogen gas measured after on-site transportation of breached fuel, and the actual concentration of hydrogen gas measured after off-site transportation of fuel with intact cladding using a NFT-38B type cask. It is predicted that the difference between the linear projection based on the actual measured concentration of hydrogen gas after the transportation of fuel with intact cladding using a NFT-38B type cask and the actual measured concentration of hydrogen gas after the transportation of breached fuel was the portion caused by the effect which the breached fuel had on hydrogen gas concentration. However, since there is little measurement data at this time, further knowledge on the concentration of hydrogen gas after transportation of breached fuel will continue to be gathered into the future.

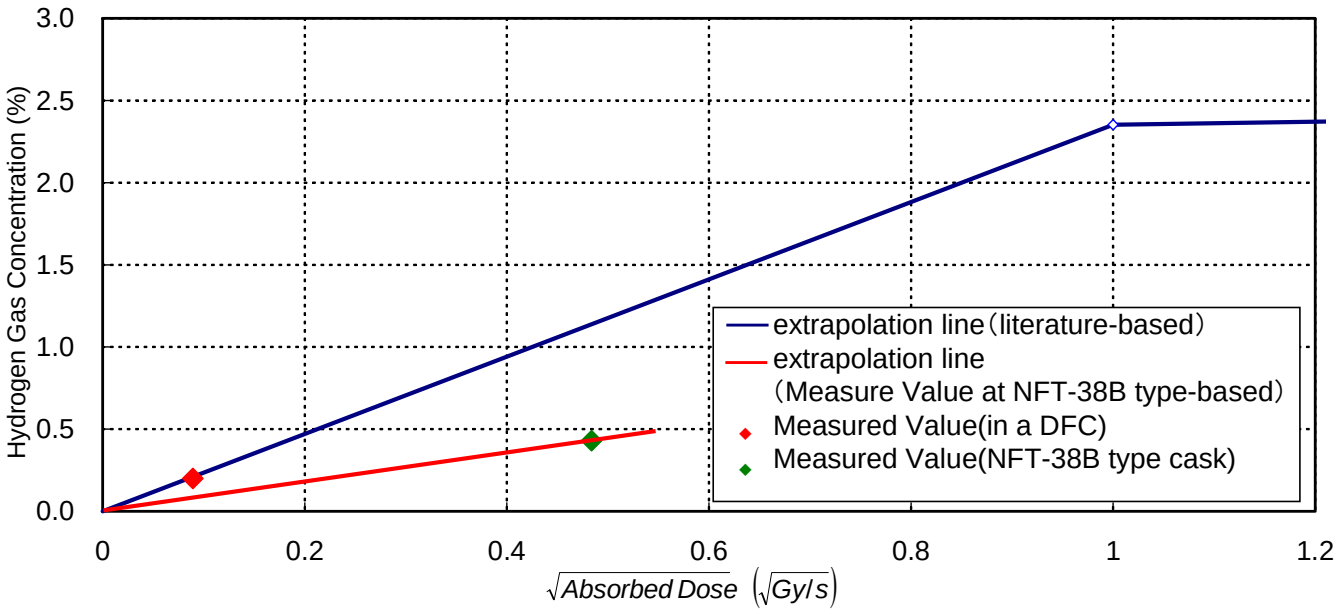

Fig. 2. The difference between hydrogen gas concentration after transportation of intact fuel and transportation of breached fuel

Conclusions

Collection of the gas inside the DFC afer transportation of breached fuel and measurement of the concentration of hydrogen within said gas revealed that the concentration of hydrogen gas was approx. 0.2%, which is sufficiently lower than the 4% hydrogen concentration limit of flammability. Moreover, comparison of the actual measurement value of hydrogen gas concentration and the concentration of hydrogen gas predicted from absorbed dose rate showed there was little difference between the two values. Knowledge regarding the hydrogen gas concentration after transportation will continue to be accumulated into the future.

References

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2) Snaryo, 1993, “A Study on Yields and Chemical Behavior of Radiolysis Products of High Temperature Water”, University of Tokyo.