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Laser Leak Detector for Fuel Channel Closer Plug in PHWR Nuclear Power Plant

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1. Introduction

In a pressurized heavy water reactor (PHWR), heavy water (D_2O) is essentially utilized as a neutron moderator and a coolant. Although a lot of safety technologies have been implemented in those nuclear reactors, there are still some risks that the coolant (D_2O) can be leaked out of the pressure boundary (PB) due to the corrosion or the cracking in several reactor components such as valves, pumps, or fuel channels. Since these coolant leaks can induce sudden shutdowns of a nuclear reactor as well as a radioactive contamination of the environment, the nuclear industry needs strongly a reliable detection system to continuously monitor the coolant leaks during a normal operation of the reactors.

Up to now, many methods have been developed and employed for the detection of coolant leaks in the nuclear power plants. Among them, radiation detection, acoustic emission detection, and humidity detection are widely used in both the PWR and the PHWR. However, those methods have been found to have some drawbacks through practical applications in the current power plants.

Recently, we developed a new method as an effective tool for detecting a coolant leak by using a tunable diode laser spectroscopy (TDLS), which can be directly applicable to detect the coolant leak in the PHWR. Through some feasibility test in the laboratory, the newly developed leak sensor was shown to operate successfully to monitor the coolant leak, having several advantages over the conventional techniques such as radiation monitoring, humidity monitoring and FT-IR spectroscopy [1].

In this paper, we report on the real field test, which was performed at Wolsong-4 PHWR plant. The test was performed for the leak detection of the fuel channel closer plug. In PHWR, 380-fuel channels at Calandria tube have some possibility that the coolant can be leaked through closer plug (CP) in operation or after the replacement of the nuclear fuel. Up to now, although camera or fueling machine has been used to monitor the leak at the closer plug, there has been no reliable method for the leak detection.

2. Brief Description of the Laser Leak Detector

As reported earlier, our new leak detector use laser absorption spectroscopy based on the off-axis integrated cavity output spectroscopy [2]. As shown in Fig. 1, if the heavy water (D_2O) is leaked from valve, pipe or fuel channel in PHWR, the D_2O molecule is converted into the HDO molecule by the isotope exchange reaction. In order to detect the leaks with a very low rate, it is more effective to measure HDO molecules rather than D_2O.

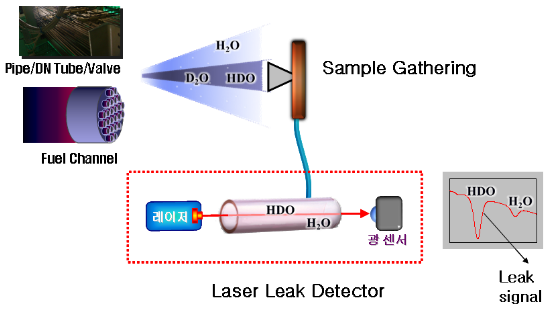

Fig. 1. Basic principle of laser leak detector

After the HDO molecule is collected by some specific tools, they are sent to laser leak detector consisted of a laser sensor, absorption cell, and a photo detector. If the HDO molecule which was originated from leaked D_2O is inserted in the absorption cell, the laser through the cell is absorbed by the HDO molecules. When we detect the transmitted beam with a photo detector, we can know whether some leaks happen in the component of the PHWR.

3. Real Performance Test at Fuel Channel Closer Plug

After we finished the feasibility test on the laser leak detector at the laboratory, we performed the real field test for fuel channel closer plug at Wolsong-4 PHWR. The overall scheme is shown in Fig. 2.

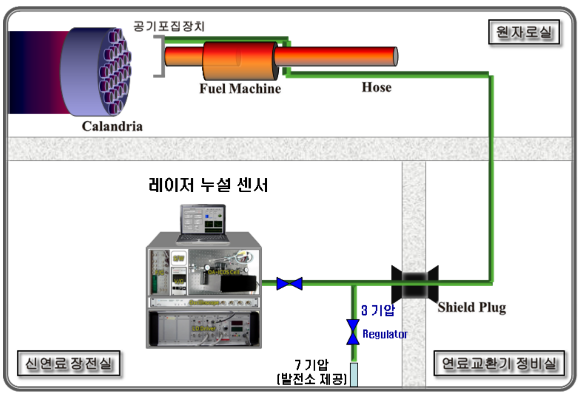

Fig. 2. Overall test scheme for detecting leak at fuel channel closer plug

The Calandria tube consist of 380 fuel channels and each fuel channel has closer plug to protect the leakage of heavy water. In order to collect leaked heavy water from each fuel channel, we attached cylinder-shape collector in front of fueling machine which can move vertically and horizontally near fuel channels. The collected air sample sent to the laser leak detector using venturi tube. If we use venturi tube to send sample to detector, we can decrease detection time, compared with the use of only vacuum tube. When we use the hose with the length of ~70 m, the detection time was measured to be within 20 s.

In real test, we tried to measure the leak of heavy water for 5 channels. Each channel was chosen randomly. Since the fuel channels are maintained to protect the leakage in normal operation, it is very rare to observe the leakage at the fuel channel. However, we can detect a small leak signal at some channels. To estimate the leak rates for the channels from the measured leak signals, we acquired calibration curve in the laboratory as shown Fig. 3

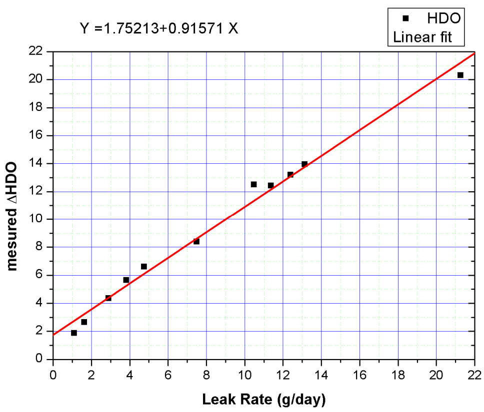

Fig. 3. Measured calibration curve for determination of the leak rate at fuel channel closer plug.

Using the calibration data in Fig. 3, we can estimate the leak rates of some channels to be 0.2 g/day ~ 7g/day. The detailed test result will be presented in the conference. The FSAR(Final Safety Analysis Report) suggest that the permissible leak rate of each channel is 10 g/day. Considering FSAR, the leak of some channel has no influence on the operation of the power plant and safety. However, the test results showed that our newly developed leak detector can measure leak at a very low rate lower than the permissible value suggested in FSAR.

4. Conclusions

A new leak detector based on laser absorption spectroscopy was developed for a detection of coolant leakage which may happen in pressurized heavy water reactor (PHWR). Using the detector, we can monitor a leak event at a very low rate. After finishing the feasibility test in the laboratory, we performed the real field test at Wolsong-4 for monitoring the leak of fuel channel closer plug. At the field test, we can measure leak with a very low rate at some channels. The measured leak rate was estimated to be lower than 10 g/day allowed in FSAR. In conclusion, our developed laser leak detector can be very useful to detect the leakage of the heavy water in PHWR.

REFERENCES

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