Tritium and Coolant Leak Evaluation for Fuel Channel Closure Plug in Heavy Water Reactor Using Multiple Acoustic Sensors

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1. Introduction

An AE sensor and MEMS type microphone has been used to detect the leakage sound with the equivalent leak flow rate of 20 ml/min above from the closure plug on the fuel channels of 380. The test results showed that the influences of background noise were smaller at the high frequencies where leak location could be estimated with the moving of sensors. This accuracy is within the localization accuracy required for the leak detection system. We conformed that the cumulative signal level and voltage amplitudes versus test time obtained from microphone and AE sensor during normal operation varied regularly. And also, leakage or abnormal condition in fuel channels could be detected by field test using the fuel channel leakage detection system. Therefore, it was suggested that AE and microphone analysis is a useful method for the detection of leakage of tritium or coolant from closure plug of fuel channel in heavy water reactor.

2. Methods and Results

The sensor assembly consists of a MEMS microphone and an AE sensor. This system provides faster and reliable detection of tritium and coolant leak and also human safety.

2.1 Design of Fuel Channel Leakage Detection System

The fuel channel leak detection system consists of sensor unit, amplifier unit, sensor assembly drive unit, signal processing unit, monitor, control unit, power supply and cables etc. And also, sensor unit are composed of AE sensor to detect a leak signal of high frequency and microphone to detect a leak signal of low frequency respectively. AE sensor is used for diagnosing leak symptom propagated from the channel closure plug inside by contacting on its surface and microphone is used for diagnosing leak symptom propagated from the channel closure plug outside by keeping its distance.
Bandwidth of AE sensor and resonant frequency is 50~650 kHz and 150 kHz, respectively. It is designed for operation in very high temperature (up to 540 ℃) and radiation environments (up to 1000 MRADs). Amplification is achieved in four stages of 30, 40, 50, 60 dB. A/D converter for signal digitizing has data acquisition circuits of 4 channels and sampling frequency of 40 MHz. Operating frequency of microphone is 0~70 kHz and microphone of MEMS type. Fig.1 shows AE sensor, microphone and cables of the fuel channel leakage detection system. The block diagram of fuel channel leakage detection system for data acquisition is shown schematically in Fig. 1.

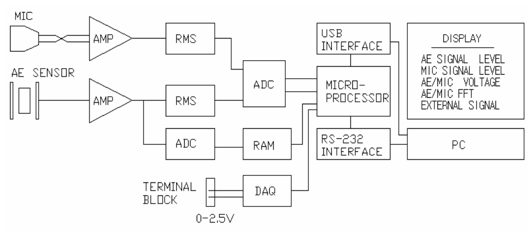


Fig. 1. Block diagram of fuel channel leakage detection system

2.2 Field Test Results

Fig. 2 shows fuel handling machine during leak field test using tritium leak detection system as indicated in. Head of sensor assembly of tritium leak detection system as indicated in B is located in front of antenna plate as shown in C and connected at clamping piston as indicated in D. Body of it containing preamplifier, microphone and driving unit located near location between C and D, where cooling water pipes and oil channels are located.

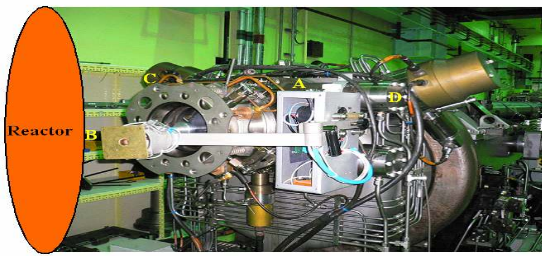
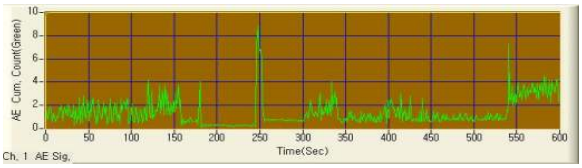


Fig. 2. Fuelling machine during field leakage test.

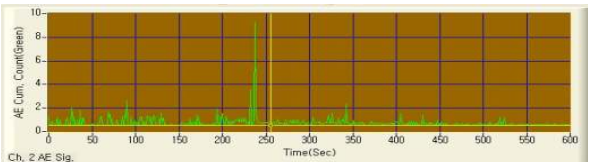
A horn and pipeline is used to transfer leak sound to microphone located in body remotely from sensor head. The sensor assembly is designed to fit without contact or disturbing operation of fuel handling machine. Fig. 3 shows the variation of signal level expressed in terms of

RMS amplitude versus test time obtained from microphone and AE sensor during normal operation. Fig. 3(a) shows the measurement results of the cumulative signal level versus test time obtained from microphone. From Fig. 3(a), it was conformed that all values of the cumulative signal level versus test time exist within 4 counts level in condition of normal operating conditions and these values correspond to background noise reactor around. Higher signal level than those at other test time was observed at test time of 250 sec, it was estimated that higher signal level due to the occurrence of small leakage in fuel channel or abnormal movement of heavy water toward fuel channel outside.

Fig. 3(b) shows the measurement results of the cumulative signal level versus test time obtained from AE sensor. From Fig. 3(b), it was conformed that all values of the cumulative signal level versus test time exist within 2 counts level in condition of normal operating conditions. Higher signal level than those at other test time similar to result of microphone test was observed at test time of 230 sec, it was also estimated that higher signal level due to the occurrence of small leakage or abnormal movement of heavy water toward fuel channel outside.



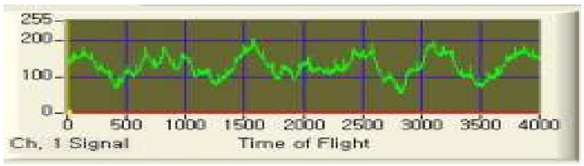
(a)



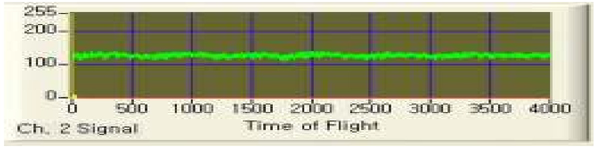
(b)

Fig. 3. Variations of cumulative RMS amplitudes versus test time.

Fig. 4 shows the voltage variation versus the test time elapsed obtained from microphone and AE sensor during normal operation. Fig. 4(a) shows the measurement results of the voltage amplitude versus test time obtained from microphone. From Fig. 4(a), it was conformed that all values of the voltage amplitude versus test time exist within 200 mV in condition of normal operating condition. These values correspond to background noise reactor around. And also, Fig. 4(b) shows the measurement results of the voltage amplitude versus test time obtained from AE sensor. From Fig. 4(b), it was conformed that all values of the voltage amplitude versus test time exist within about 120 mV in condition of normal operating conditions. These values correspond to background noise reactor around.



(a)



(b)

Fig. 4. Voltage signals during normal operation.

3. Conclusions

Methodology to simulate leak condition for fuel channel closure plug could be established to accomplish sensitivity test using high temperature-pressure fluid test loop and the tritium leak detection system developed in this study. We conformed that the cumulative signal level and voltage amplitudes versus test time obtained from microphone and AE sensor during normal operation varied regularly. And also, leakage or abnormal condition in fuel channels could be detected by field test using the fuel channel leakage detection system.

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