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Fuel Failure Detection Using IMS (In Mast Sipping)

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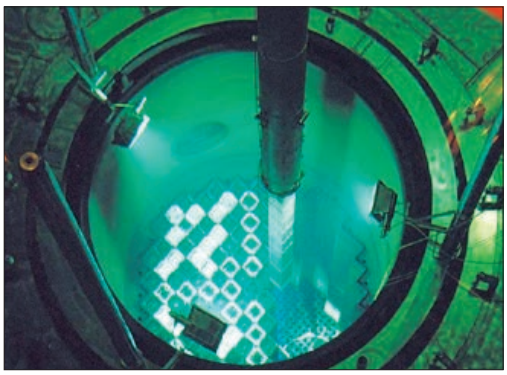
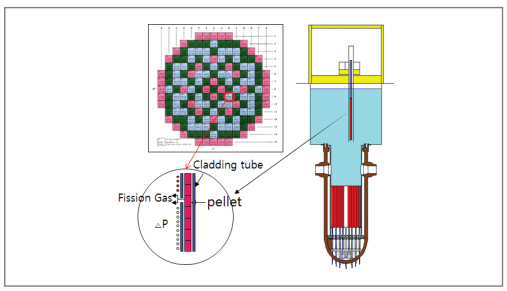
IMS(In Mast Sipping) is a technology to detect the leakage by collecting and analyzing fission gas that leaks from inside of the fuel rod in the event that nuclear fuel is failed. When fuel is extracted from the reactor, it vertically rise about 10 m generating 15 psig water pressure difference. This pressure drop causes the fission gas inside of the fuel rod to leak out of the fuel rod. Fission gas has a variety of nuclide such as Xe-133 and Kr-85, etc. IMS technology enables us to detect and analyze these nuclides.





Description

● Background

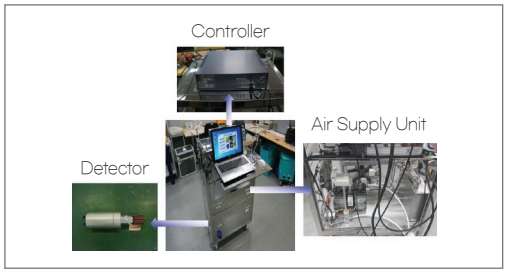
- Domestic nuclear power plants relied on the VT(Visual Testing) and UT(Ultrasonic Testing) to detect the leakage in nuclear fuel in the past. Since VT and UT can be carried out separately after the fuel is withdrawn first which means there is a time gap between the actual leakage event and detecting it. Moreover, it is difficult to detect the leakage inside the fuel with VT, and with UT, it is impossible to detect the leakage if there is no water inside the leaking fuel rod. For this reason, KEPCO NF developed IMS equipment that can perform a reliable test.

● Purpose and Necessity

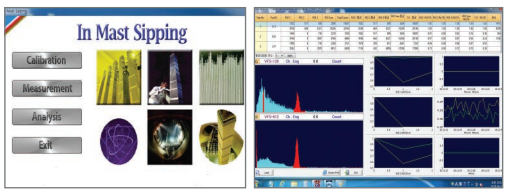
- Since IMS is performed simultaneously as fuel is unloaded from the core, there is no additional fuel transfer for the inspection minimizing the possibility of damaging the fuel. Fuel that is determined to have leakage defects can be repaired and reloaded into core or safely stored in the nuclear fuel pool. In addition, inspection results can be reflected in redesigning the core.
- IMS can detect leaking fuel even if there is no water inside the fuel rod unlike UT. In addition, since IMS is completed during the fuel withdrawal process, the leaking fuel can be classified as a assembly group before the UT. The UT will be executed on the classified assembly group to find which fuel rod is leaking. This process improves the accuracy of detecting leaking fuel than the UT does.

● System Configuration

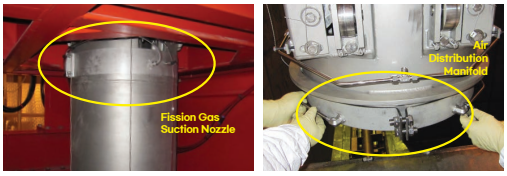
- **IMS Equipment**
  - The control system controls MCA(Multi Channel Analyzer), vacuum pump, solenoid valve, humidity sensor, pressure sensor and flow sensor. It consists of a DAQ(Data Acquisition Board) which acquires signals and data, digital system which simultaneously controls air supply devices and detection analysis device, and a laptop to process the acquired signals, display them on screen and make database out of them.
  - The air supply system captures the fission gas inside the mast, sends it to the detection analysis device, and discharges the gas back to the atmosphere. It consists of vacuum pump, valve, air dryer, regulator, gauge, air transfer tube and various sensors and connectors.
  - The detection analysis system analyzes the fission gas captured from the mast to determine whether the fuel is leaked or not. It consists of detector, MCA, lead shield, and laptop.



- **IMS Program**
  - All devices installed on IMS device can be controlled by IMS program. The program provides calibration, leaking fuel inspection and analysis services. Using 1,024 channels of MCA, a various nuclide in the range of radioactive energy from 10 ~ 1,000 keV can be analyzed. Not only the radiation measurement value of the detector but also the pressure and flow of the inhale line in real time can be checked.



- **Mast Fixing Device**
  - Mast fixing device is an auxiliary device installed on the outer mast of the reactor for IMS, consisting of suction nozzle installed on the upper part of the mast and an air distribution manifold installed on the lower part of the mast. The suction nozzle is connected to the detector of the IMS device by an air hose and the vacuum pump starts to inhale the fission gas when the inspection is started.
  - The air distribution manifold is connected to the service air line of the power plant. From the beginning of the inspection, service air is injected into the bottom of the fuel assembly to activate the collection of leaking gas.



Distinctiveness

● Characteristics

- Reduce the fuel transfer and fuel damaging factors
- Various nuclide in the range of radioactive energy from 10 ~ 1,000 keV can be analyzed by using 1,024 channels of MCA
- Identify leaking fuels in real time while the inspection is executed at the same time
- Improve resolution by blocking noise from natural radiation and electromagnetic waves
- Increase reliability of leaking fuel detection by simultaneous analysis of gamma and beta energy

Experience

- 7 times IMS inspection for domestic pressurized water reactor(as of June 2021)

Deliverables

- Design and manufacture of IMS equipment
- IMS service performance for power plant
- IMS training and manual