THE INSTALLATION OF THE DEFECTIVE IDENTIFICATION DEVICE FOR IRRADIATED FUEL IN NUCLEAR POWER PLANT

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1. INTRODUCTION
The fission products may leak out through the clad of the defective fuel and contaminate the reactor parts. The defective fuel should be detected, identified and isolated. During reactor operation the tightness of the fuel clad is detected by monitoring the activity of the nuclide of fission products in reactor coolant sampling. During refueling outage the defective fuel assemblies are identified by the in-mast sipping. After refueling the defective fuel assemblies are identified further and evaluated the size of leakage by the poolside sipping. The localization of the leaky fuel rod in the fuel assembly is done by the ultrasonic system. The extraction of defective rod from the fuel assembly and replacement with dummy is done by the special repair system. To localize the defect on the clad of the fuel rod the eddy current system and the special hot cell techniques are used. The defective rod can be repaired and reused. For the commercial nuclear power plant the sipping test devices are more useful.

2. THE SIPPING TEST TECHNIQUE
The sipping test devices are used to identify the defective fuel. By isolating the fuel assembly to be tested in the isolator and increasing the pressure inside the fuel or decreasing the pressure outside the fuel, the release of the fission products from the defective fuel will be accelerated. The defective fuel can be identified by detecting the occurrence of the fission products entrained by the medium rising around the fuel rods. There are two kinds of sipping test device to inspect the tightness of the irradiated fuel assembly from nuclear power plant (NPP). For the NPP with two units one set of in-mast sipping test device is shared by two units and two sets of poolside sipping test device are installed at the fuel storage pool of each unit.

The in-mast sipping taking the mast as the isolator, the air as the medium, and the $^{133}$Xe as the indication nuclide is used for qualitative tightness test of each fuel assembly during refueling operation above the reactor. This device consists of the gas system, the $\gamma$ activity detection and measurement system, the power supply and signal system, and the mechanical component and parts.

The poolside sipping taking the sipping cell as the isolator, the air and water as the medium is used for quantitative confirming the diagnosis of the in-mast sipping and identifying the tightness of the fuel at the side of the fuel storage pool after refueling. This device consists of the fluid system, the control command system, the cabinets, and the mechanical components.

The design manufacture and calibration of three devices were successfully completed domestically step by step with serious quality assurance and quality control.

3. THE RESEARCH AND DEVELOPMENT OF THE IN-MAST SIPPING TEST DEVICE
The in-mast sipping is used for examination of every fuel assembly at reactor operation outage time.

4. THE INSTALLATION OF THE POOLSIDE SIPPING TEST DEVICE
For the good quality of the fuel assemblies the poolside sipping is not useful.

5 CONCLUSIONS
The defective fuel assembly identification devices are well installed. For the good quality of the fuel assemblies only the in-mast sipping is very useful for qualitative identification of every fuel assemblies.

REFERENCES
ABSTRACT

The sipping test devices are used to identify the defective fuel. The defective fuel can be identified by detecting the occurrence of the fission products entrained by the medium rising around the fuel rods.

There are two kinds of sipping test device to inspect the tightness of the irradiated fuel assembly from nuclear power plant (NPP).

The in-mast sipping taking the mast as the isolator, the air as the medium, and the Xe 133 as the indication nuclide is used for qualitative tightness test of each fuel assembly during refueling operation above the reactor. The poolside sipping taking the sipping cell as the isolator, the air and water as the medium is used for quantitative confirming the diagnosis of the in-mast sipping and identifying the tightness of the fuel at the side of the fuel storage pool after refueling. The design manufacture and calibration of three devices were successfully completed domestically step by step with serious quality assurance and quality control.

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There are two kinds of sipping test device to inspect the tightness of the irradiated fuel assembly from nuclear power plant (NPP). For the NPP with two units one set of in-mast sipping test device is shared by two units and two sets of poolside sipping test device are installed at the fuel storage pool of each unit.

The in-mast sipping taking the mast as the isolator, the air as the medium, and the Xe 133 as the indication nuclide is used for qualitative tightness test of each fuel assembly during refueling operation above the reactor. This device consists of the gas system, the γ activity detection and measurement system, the power supply and signal system, and the mechanical component and parts.

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The design manufacture and calibration of three devices were successfully completed domestically step by step with serious quality assurance and quality control.

3. THE RESEARCH AND DEVELOPMENT OF THE IN-MAST SIPPING TEST DEVICE

3.1 The Option Selection

In-mast sipping test device is used to identify the tightness of the irradiated fuel assembly during refueling campaign. The gas is selected as the medium and the Xenon 133 is selected as the indication nuclide. The device consists of the gas system, the γ activity detection and measurement system, the power supply and signal system, the mechanical components and parts. There are satisfactory functions in the device e.g. easy operation, indication in instrumentation, chart record and acoustic alarm which can meet the operation demand of the nuclear reactor.

Sipping technique is used to identify the tightness of the fuel. By isolating the fuel assembly to be tested and increasing the pressure inside the fuel (by heating) or decreasing the pressure outside the fuel, the fission products release from the defective fuel will be accelerated. The tightness of the fuel can be identified by detecting the fission products.

The sipping technique has been developed since 1960’s up to date there are the sipping taking the water as the medium, Iodine and Cesium isotopes as the indication nuclide; and the sipping taking the gas as the medium, Krypton and Xenon as the indication nuclide; the poolside sipping using the sipping cell as the isolator; and the in-mast sipping using the mast of the refueling manipulator as the isolator.

The objective of this subject is to set up a detection device to identify the tightness of the irradiated assembly for NPP. The device should be more sensitive and easy to operate.

It was learnt from the literature that the escape factor of fission gas Krypton and Xenon from the defective fuel into the coolant are about five times the factor of soluble fission products Iodine and Cesium, the activity of Kr85 and Xe133 in the coolant are higher than that of I113 and the activity of Xe133 in the coolant is about 150 times that of Kr85, the Xe133 has the more portion of γ activity with high peak which is easier to detect, Xe133 with a
shorter half life can be detected during refueling operation. For the more sensitive device the Xe133 is the best indication nuclide.

The in-mast sipping used the mast as the isolator is simpler than the sipping with the special sipping cell, and it is easy to operate only a bit more operation time is necessary without special operator.

The in-mast sipping with gas medium and Xe133 indication nuclide was selected.

### 3.2 In-Mast Sipping Test Device

As the fuel assembly gripped by the gripper raises inside the mast of the refueling manipulator from the reactor core to the top gripper position for about 9m, The Xe133 release through the defective clad of the fuel will be accelerated. The compressed air injected into the mast at the bottom rising along the fuel rods will carry the Xe133. The air will be detected and measured by the γ activity detection and measurement system to identify the tightness of the fuel assembly.

The sipping device consists of the gas system; the γ activity detection and measurement system; the power supply and signal system; the mechanical components and parts.

#### 3.2.1 Gas system

The gas system is used for the compressed air supply; the air injection and the air attraction to the counting chamber.

The compressed air flow is divided into two ways, one of them supply the injection air in certain pressure and flow rate to the bottom of the mast, the another way supply the air in certain pressure to a vacuum generator to attract the air from the mast through the counting chamber in certain flow rate.

The calibration of the gas system is done in two steps: the tightness test of the whole circuit section by section; the adjustment of pressure and flow rate to the value.

#### 3.2.2 The γ activity detection and measurement system

The γ system is used for detection, measurement and record of the γ activity of the gas inside the counting chamber. The system consists of a series of Nuclear Instrument Module (NIM); the detector and the recorder.

The calibration of this system is done in three more steps: the adjustment of the NIM; the drawing of a curve in cps - threshold with standard solid γ source; the setting of the threshold corresponding to the cps peak of the indication nuclide.

#### 3.2.3 The power supply and signal system

The power supply and signal system is used for supply the power to the NIM rack, the recorder and the signal light. The system consists of the breaker, the timer, DC power source and signal light.

#### 3.2.4 The mechanical components and parts

The mechanical components and parts are: the counting chamber, the lead cask, the source holder and cabinet. All of these matters are out of vendor catalog. The design, manufactory and quality assurance should be done specially.

#### 3.2.5 The key behavior of the device

The key behaviors of this device are:

- The sensitivity of the γ system
- The tightness and attraction ability of the gas system
- The calibration parameters if the system in the device
- The indication and record functions of the device.

#### 3.2.6 The approach to the goal

The subject was successfully completed step by step as following:

- The investigation done by consulting the information about existing sipping device worldwide from the experts and literature;
- The option selection based on the investigation;
- The engineering work;
- The procurement of the standard parts within the vendor catalog;
- The manufactory of the special parts;
- The assembling and calibration of individual system outside the cabinet separately;
- The assembling and calibration of whole device inside the cabinet;
- The acceptance of the key behavior.

### 3.3 The Performance of The Device

There are satisfactory functions in the device e.g. easy operation; indication in the instrumentation; chart record and digital indication alarm etc. The calibration parameters are as they should be. The in-mast sipping is used for examination of every fuel assembly at reactor operation outage time.

### 4. THE INSTALLATION OF THE POOLSIDE SIPPING TESE DEVICE

#### 4.1 The Principle

The poolside sipping is used for quantitative confirming the diagnosis of the in-mast sipping and sizing up the failures. After quick detection of failed fuel assembly in term of “untight” by in-mast sipping the failed fuel is enclosure by sipping cell of poolside sipping device, the water and gas are circulated in their circuits. On-line γ counting with record and curve drawing is performed continuously on the γ ray of Xe133 (81keV) in a special counting pot inserted in the gas circuit. As temperature of water and gas circulated in the sipping cell are elevated to the certain plateau by the electric heater and cooler, the activity of Xe133 γ ray will be follow up to reach the equilibrium in a certain kinetic. This kinetic is different and directly dependant of the defect size. The evaluation of the defect size can be done by comparison this kinetic with the reference curve.

#### 4.2 The Function Requirement

- During operation the water and gas circuits are circulated simultaneously, the fluids come in from cell bottom, pass the fuel assembly and flow out through cell top;
- The fuel assembly in sipping cell is heated as certain rate and stabilized at certain temperature plateau by the heater and cooler in water circuit;
- During temperature elevation the activity of fission gas is measured continuously by γ activity measurement channel;
- The sample of water circuit and gas circuit taken from the glove box are sent to radiochemical laboratory to measure the activity of certain radionuclide of fission product;
- The sipping cell is of double housing, before temperature elevation in cell water the thermal barrier is created by injection of air to the space between the inner can and the external vessel;
- The cell lid is actuated by the lid cylinder control loop; the hydro pneumatic pump is installed for that when the water pressure is not sufficient;
- The cell top, cell bottom and glove box can be washed;
- Before the gas sample taken the air exhauster is used;
- The leak tight of gas and water circuits should be check carefully; the flow rate, the temperature and the cell lid actuation should be monitor and control precisely to meet the requirement for fuel identification;
- For the higher density and higher cell water temperature elevation rate the cross section of the cell inner can should be close to the fuel assembly, the manufacture should be carefully control;
- The volume of the piping in the electromechanical module should be less and the lead bold be installed to reduce the dose rate of the personal radioactive exposure;
- The filter is installed at the cell bottom used for filtration of solid particle in circuit;
- The shutters are installed to prevent the counting pot contaminate by water penetration;
• There are the filter handling tool and lid handling tool.

4.3 The Components
4.3.1 Base plate, radial arm and control panel

The base plate is used to fix the sipping and filter storage stand in the bottom of the pool; the radial arm is used to fix the sipping cell in the side wall of the pool; the control panel is used to fix the cable, hoses and the tools for filter and lid handling in the side wall of the pool.

4.3.2 Sipping cell

The cell is of double housing, inner can and outer vessel, the thermal barrier is between them. There are two temperature detecting point at the middle and the top of the cell. The filter is at cell bottom. The cell lid can be actuated by cylinder, hydro pneumatic pomp and tool handling.

4.3.3 Hoses

The hoses are the flexible shielded piping to carry fluid and electrical cable used to connecting sipping cell and control cabinet. The interconnectors are at control panel

4.3.4 Control and measurement units

- The instrumentation and control cabinet;
- The electromechanical module;
- The γ activity detection unit;
- The glove box;
- The γ activity measurement channel.

4.3.5 Fluid systems

- The water loop is used to transport and homogenize the fission products, maintain the temperature stages by means of actions of heater and cooler, get liquid samples in glove box;
- The cell washing loop is used to wash cell with clean water in case of contamination by fission products and corrosion products;
- The glove box washing loop is used wash glove box and sampling container;
- The cooling loop is used to maintain temperature stages with cooler by temperature regulation channel;
- The lid cylinder control loop is used to actuate cell lid by pressure water or by hydro pneumatic pump;
- The gas loop is used to carry the gaseous fission products, prevent the counting pot pollution by water penetration with shutter and condenser, take gas sample in glove box. It can be cleaned by injecting clean gas;
- The thermal barrier circuit can create a thermal insulation of the fuel assembly toward the pool water by injection of air into the double housing formed between the inner can and the outer vessel;
- The condenser circuit is used to collect the water of the vapor coming from the cell;
- The drawing off circuit.

4.3.6 Handling tools

- The tool for lid handling;
- The tool for filter hanging;
- The tool for cell handling.

4.4 Tests and Calibrations

4.4.1 Calibration of nuclear measurement part with standard radioactive sources

4.4.2 Dry (pool without water) test

- Test in mechanical parts;
- Test in electrical parts.

4.4.3 Wet (pool with water) test

- Test in thermal barrier circuit;
- The leak tightness test in cell top gas circuit;
- The leak tightness test in cell bottom gas circuit;
- Test in water loop;
- Test in gas loop;
- Test of glove box washing;
- The alarm test;
- The combination test of water loop and gas loop.

4.5 The Performance of the Device

The quality of the installation and calibration are well completed as the certain requirement, the performance is good. For the good quality of the fuel assemblies the poolside sipping is not useful.

5 CONCLUSIONS

The defective fuel assembly identification devices are well installed. For the good quality of the fuel assemblies only the in-mast sipping is very useful for qualitative identification of every fuel assemblies.

REFERENCES