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Fuel CRUD Cleaning Using Ultrasonic Wave

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Replacing steam generators or injecting zinc in PWR Nuclear Power Plant may cause substitution reaction with radioactive materials presenting in the oxide layer of the system, which increases corrosion products in the fuel, this may result in AOA(Axial Offset Anomaly). CRUD cleaning of nuclear fuel using ultrasonic wave can prevent such problems and ensure core safety.

Description

● Background

- AOA is a phenomenon where the axial power distribution of upper core is abnormally distorted during the plant operation. AOA occurs when the neutron absorbing material(LiBO₂) is deposited in fuel as a form of CRUD(Chalk River Unidentified Deposit), which leads reduction of thermal conductivity in the cladding tube. CRUD is a corrosive product and mainly consists of metal oxide such as iron, nickel and chromium.
- This phenomenon can be further intensified by the replacement of steam generator, zinc injection, and long-term/high burn-up fuel, and if AOA occurs, actions such as power run back, plant shutdown, early release of fuel may be required. In addition, radiation exposures to workers due to increased radiated CRUD in the system can greatly affect the safety and economics of the plant.

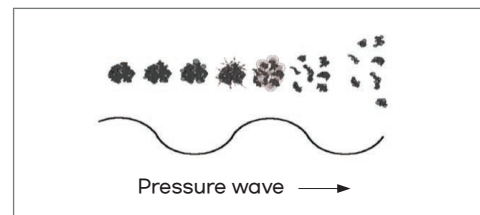
● Purpose and Necessity

- Many researches are being conducted to predict, mitigate and prevent the occurrence of CRUD as a precaution against AOA. As one of them, CRUD cleaning technology which physically removes CRUD by using ultrasonic waves has been developed, and core safety

can be ensured by preventing AOA through CRUD cleaning of reloaded core fuel by using ultrasonic waves.

● Principle of Ultrasonic Fuel Cleaning

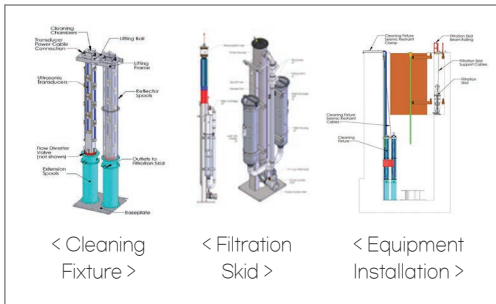
- Ultrasonic waves generated in water are repeatedly compressed and decompressed which make cavitation and generate micron-size vacuum bubbles. At this time, micron-size vacuum bubbles generated inside the CRUD are burst at a certain pressure. Thus, CRUD is crushed into small pieces, detached from the fuel surface then the detached CRUD pieces are trapped on the filter restraining them from flowing into system.



● Composition of Ultrasonic Fuel Cleaning Equipment

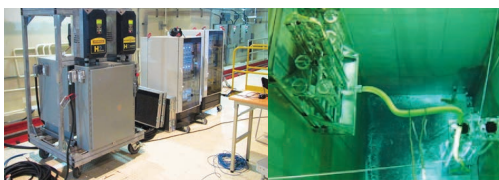
- The Ultrasonic Fuel Cleaning Equipment consists of the cleaning fixture and filtration skid. CRUD is removed by ultrasonic waves generated from the transducer system in the cleaning fixture, and removed CRUD pieces are transferred to the filtration skid through the connected hose between cleaning fixture and filtration skid.
- Cleaning fixture consists of two chambers and each chamber is designed to clean CRUD by loading one nuclear fuel assembly. In addition, the control module is composed of dual system so that it is designed to be able to clean by another system without a certain delay even if one of the CRUD cleaning fails during the cleaning performance.

- Filtration skid is connected to the cleaning fixture with a hose, and CRUD removed by ultrasonic waves is collected in the filter. Filtration skid consists of pump, filter housing and sensors(temperature, pressure, flow). Radiation dose of the filter can be measured by gamma detectors.

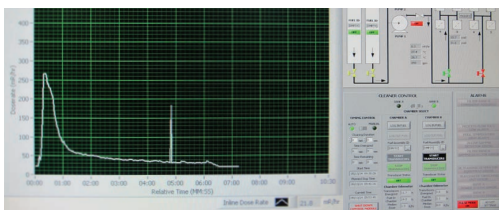


● Control System of Ultrasonic Fuel Cleaning Equipment

- The control system of CRUD cleaning equipment includes a program which controls the cleaning fixture and filtration skid. The CRUD cleaning program is designed to allow operator to check the temperature, pressure and flow in real time. Operating conditions can be changed by adjusting the above variables as needed, and the radiation dose of the collected CRUD of each fuel assembly can be checked through the radiation dose increase in the filter. Additionally, the fuel assembly cleaning can be maintained by controlling ultrasonic transducer.



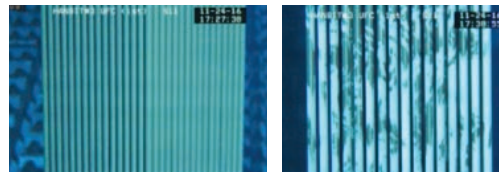
< Cleaning Equipment on ground and underwater >



< Ultrasonic Fuel Cleaning Program >

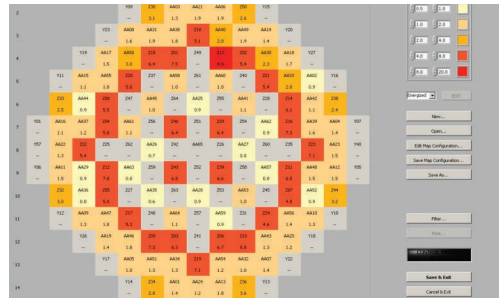
● Results of CRUD Cleaning

- Using underwater cameras, it can analyze the state of before and after the CRUD cleaning and the efficiency of the CRUD cleaning. In addition, quantitative results can also be verified by analyzing collected CRUD, radiation dose of the filter and radiation dose by nuclear fuel, and the results can be used to predict whether AOA occurs or not.



< Before cleaning >
Crud is uniformly deposited on fuel

< After cleaning >
Crud removed by ultrasonic cleaning



< Core CRUD Map(Filter dose rate of each fuel) >

Distinctiveness

● Characteristics

- Satisfy the requirements of the mechanical integrity of the nuclear fuel
- Stability is ensured through dual system equipment operation and cleaning can be conducted without delay of over hole process
- Possible to connect with work such as replacing steam generators in Nuclear Power Plants or injecting zinc
- Safety and cleaning effectiveness of the equipment operation is verified through a number of CRUD cleaning experience.

● Benefits

- Reduction of AOA occurrence in PWR Nuclear Power Plant
- Improvement of nuclear fuel integrity
- Reduction of exposure dose to radiation workers in the system

Experience

- A total of 19 CRUD cleaning campaign are carried out on domestic PWR power plants (as of June 2021)
- Same technology is applied in the United States of America, Spain, etc.

Deliverables

- Performance of CRUD cleaning service
- Evaluation report on CRUD cleaning
- Evaluation report on core safety

Technology Readiness Level (TRL)

Actual system proven through operation

Business Model

Technology Transfer

Licensing

Joint Search

Service Execution

Others