Ultrasonic Cleaning for Reloaded Nuclear Fuel in Domestic NPP

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1. Introduction

When Zn injection is performed to reduce the Ni elution after replacing the steam generators, corrosion product, which is called crud, is accumulated on the reloaded nuclear fuel cladding by the substitution reaction with existing substances (Ni, Co, Fe). It can cause AOA (Axial Offset Anomaly) which is one of the CIPS (Crud Induced Power Shift) and define as a significant negative axial offset deviation from the predicted nuclear design value. In order to prevent the AOA and secure the safety of the core, ultrasonic cleaning operation is performed on the reloaded nuclear fuel.

KNF (KEPCO Nuclear Fuel) developed ultrasonic cleaning technique some years ago, and apply it in domestic reloaded nuclear fuel. For this paper, crud cleaning was performed about PLUS7 fuel designed in KNF. This paper introduces about efficient of crud cleaning, mass of collected crud.

2. Performance and Result

2.1 Performance

KNF performed crud cleaning for 27 days including installation and disassemble. KNF installed ultrasonic cleaning equipment which including filtration skid, visual inspection device, chamber, and control system in CLP (Cask Loading Pit). In filtration skid, there are radiation measuring instruments to measure the difference in radiation dose before and after cleaning. This makes it possible to examine process of cleaning.

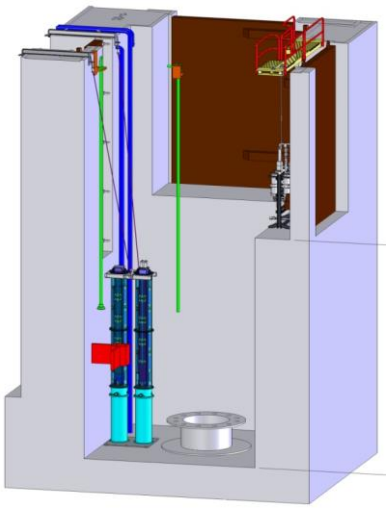


Fig. 1. Outline of ultrasonic cleaning equipment

Normally, ultrasonic cleaning took 6 minutes per assembly, and most of crud was cleaned in 2minutes and after cleaning it needs 1 or 2 minutes waiting to collect crud in filtration skid.

Before and after cleaning, visual inspection was performed to inspect defects or other unusual case. In overseas companies, usually, analyze ultrasonic cleaning efficiency through visual inspection. KNF analyzes the ultrasonic cleaning efficiency by visual inspection and measures the weight of the crud to ensure cleaning properly.

While cleaning, the system was calibrated pressure differential and radiation dose rate in filter to decide replacement of the filter. Unlike other form of filtration skid type which contains 8 filters and 2 pumps, KNF operated compact type which consists of 2 filters and 1 pump.

This campaign completed crud cleaning on 108 assemblies which consist of 68 first burned fuels and 40 second burned fuels and preferred to predict high cumulated crud without defective symptom.

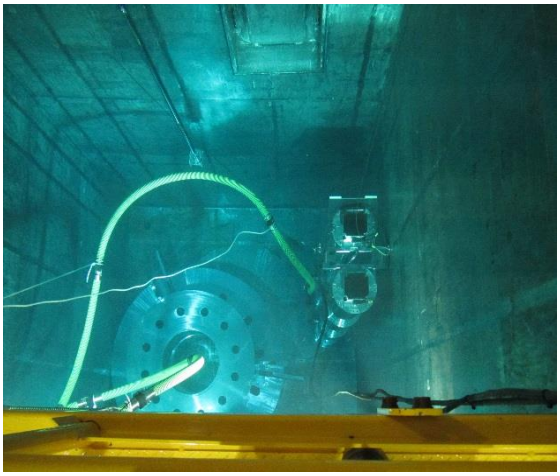


Fig. 2. Installation of ultrasonic cleaning equipment

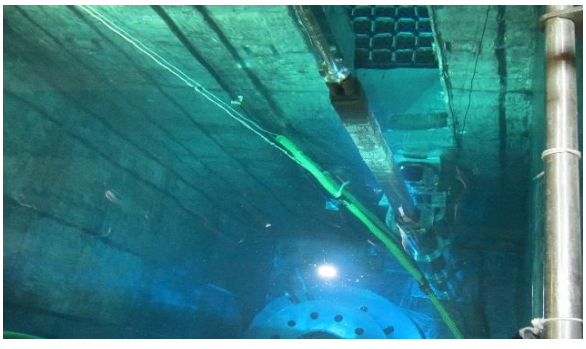


Fig. 3. Reloaded nuclear fuel after ultrasonic cleaning

2.2 Measuring weight of cleaned crud

Once measuring weight of filter before and after ultrasonic cleaning, it is possible to know weight of cleaned crud. The weight can be determined from two measurements. As fig. 4 shown, one is performed "up" position (4ft) and the other is performed at a "down" position (38ft).

The filter weight (W_0) can be calculated following formula[2]

$$W_0 = W_{up} + \frac{\Delta W}{1 - \frac{P_{up}}{P_{down}}} \qquad (1)$$

Measuring weight of filter before and after cleaning, the weight of crud would be differences of this weight. However, it is recommended to considering calibrated in water.

There must be measurement uncertainty, such as scale accuracy and variation in measurement depth, however, for this paper, it can be ignorable.

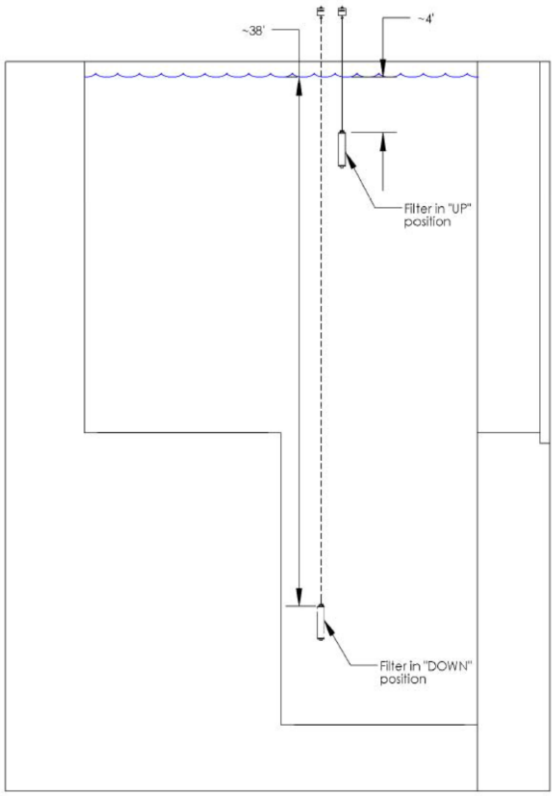


Fig. 4. Position of measuring weight of filter (4ft and 38ft)

Table I : Measured data in campaign

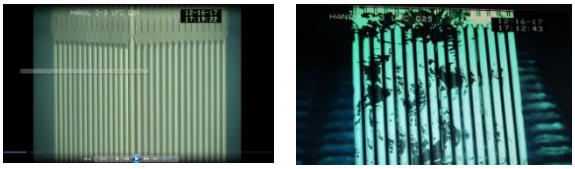
Weight	Filter #1(kg)	Filter #2(kg)
W_{up}	4.666	4.691
W_{down}	5.248	5.271
$W_{up-crud}$	4.840	4.895
$W_{down-crud}$	5.376	5.423

2.3 Result

The effect of ultrasonic cleaning can be seen in the upper of assembly because most of crud is stuck on there. The efficiency of cleaning is quite different between first burned fuel and second burned fuel. The result of visual inspection showed first burned fuel was 20% cleaned a crud, and second burned fuel was 80% (Refer Fig. 5).

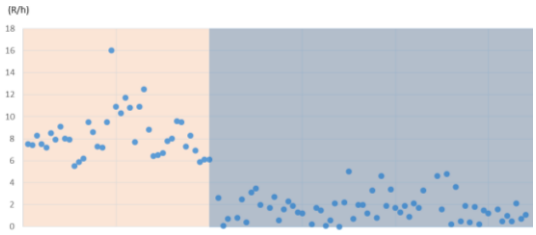
As shown fig. 6, the total rate of radiation dose reduction was 386R/hr which means 3.574R/hr per each assembly. This value is almost similar in last cleaning which value is 384R/hr. As fig. 6 shown, 1st burned fuel average is 1.47R/h, and 2nd burned fuel average is 9.14R/h. To confirm the reliability of the filtration skid radiation dose rate record, it was compared with computer log data. It showed that the difference was about 14.7 ~ 17.2%. The cause of this is analyzed as filter was contaminated due to the high water radiological contamination at the initial stage of the ultrasonic cleaning. And fig. 7 shows how much radiation dose is reduced for each assembly in the reactor core map.

Mass of crud was analyzed in water level 4ft and 38ft for reflecting buoyancy. The entire mass was 204g (1.89g per assembly) considering buoyancy. This result belongs to world average range (100g~1000g).



(Before cleaning) (After cleaning)

Fig. 5. Before and after ultrasonic cleaning



(2nd burned fuel) (1st burned fuel)

Fig. 6. Radiation dose differences at 1st and 2nd burnup fuel

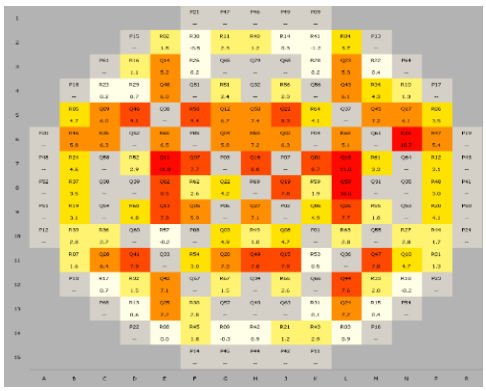


Fig. 7. Core crud map

3. Conclusions

The 108 reloaded nuclear fuels were cleaned and the result of visual inspection, weight of crud and radiation dose showed crud on the nuclear fuel cladding was reduced. In the visual inspection, first burned fuel was 20%, and second burned fuel was 80% of cleaning efficiency showed. The average of radiation reduction for each assembly is 3.574R/hr, which is same as cleaning in other plant except plant occurred AOA. The quantity of collected crud was 204g and it belongs to world average range. By accomplishing the project, KNF was able to gather data about result of ultrasonic cleaning and KHNP can produce electricity stably. Ultrasonic cleaning in all domestic nuclear plants makes it possible to reduce occurring possibility of AOA, and exposing radiation dose for human.

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