Xe-133 Activity Evaluation of a Defective Fuel Rod Depending on Loading Cycle

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1. Introduction

Reliable performance of LWR fuels not only allows power plants to operate economically but also minimizes personnel radiation exposure, which may in turn contribute to convince the public of the viability of clean nuclear energy. Although KHNP's fuel failure rate has been remarkably decreased and it is excellent worldwide, one or two fuel rods have been damaged annually. Whenever fuel failure is occurred, KHNP engineers have to evaluate which FA(fuel assembly) is damaged by analyzing reactor coolant activity. It is important because they decide whether the FA with a damaged rod is the reload FA in the next cycle or not.

Recently, based on our operational experience and technical expertise, we analyzed the reactor coolant activity in order to identify FA's loading cycle with a damaged fuel rod. This paper suggests the knowledge about Xe^{133} activity level analysis.

2. Methods and Results

With the occurrence of a defective fuel, fission products (:such as I^{131}, I^{132}, I^{133}, I^{134}, I^{135}, Xe^{133}, Xe^{135}, Cs^{134}, Cs^{137}, Kr^{85}, Kr^{85m} etc.) are usually released into the primary coolant. Plant chemistry engineer analyzes the activity levels of the fission products respectively once or twice a day. This paper includes the results that analyzed only the Xe^{133} activity level because it is usually released into the primary coolant more easy than other nuclides. It keeps the constant activity level if the additional defective fuel is not occurred in the core.

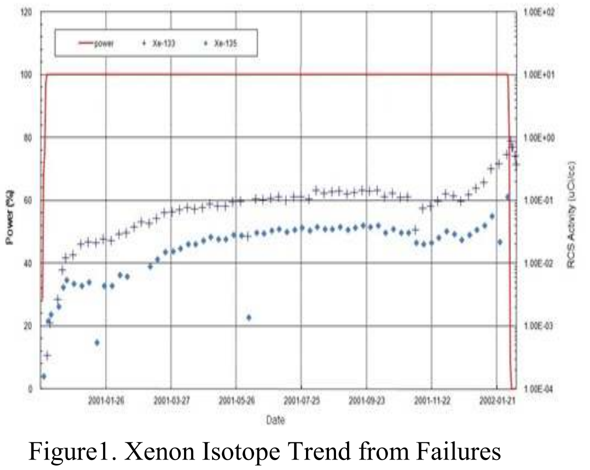

Figure1. Xenon Isotope Trend from Failures

The trend in Xe-133 activity has been used as an indicator of fuel integrity. Any step increase in Xe-133 activity in excess of about 0.025 μCi/g, especially if the increase is sustained for more than about a week, suggests the possibility of the existence of a fuel failure. Figure 1 shows the general noble gas release into the primary coolant during a single fuel rod failure. The sudden increase in Xe^{133} (and Xe^{135}) activity clearly indicates the occurrence of the fuel failure.

2.1 Analysis Scope

The paper includes the analysis results for the cases that only one defective fuel is occurred. Especially, Xe^{133} activity level is analyzed. Xe^{133} usually is detected the most easily because it is noble gas with proper half life and has the high fission yield relatively among the fission products. Table 1 shows the specifications of xenon isotopes.

Table1. Nuclear Data for Xenon Isotopes

Nuclide	$t_{1/2}$	λ sec-1	Cumulative Fission Yield U-235 % Yield	Pu-239 % Yield
Xe-l33	5.243 d	1.53E-06	6.7	7.016
Xe-l33m	2.19 d	3.66E-06	0.189	0.229
Xe-l35m	15.3 m	7.55E-04	1.102	1.714
Xe-l35	9.10 h	2.12E-05	6.539	7.608
Xe-l37	3.82 m	3.02E-03	6.129	6.01
Xe-l38	14.1 m	8.19E-04	6.297	5.171

In this paper, Xe^{133} activity levels are analyzed for total 14 cases. Table 2 shows the domestic cases which are analyzed. The cases that a defective fuel is occurred among the first loading FAs are 5(Plant A~E), the cases a defective fuel is occurred among the second loading

Table2. The domestic cases with a defective fuel rod

Plant	Loading Cycle	Root Cause
Plant A	Once Burned	Grid Fretting
Plant B	Once Burned	Debris
Plant C	Once Burned	Welding Defect
Plant D	Once Burned	Debris
Plant E	Once Burned	Debris
Plant F	Twice Burned	Debris
Plant G	Twice Burned	Debris
Plant H	Twice Burned	Unknown*
Plant I	Twice Burned	Unknown*
Plant J	Twice Burned	Debris
Plant K	Third Burned	Corrosion
Plant L	Third Burned	Debris
Plant M	Third Burned	Grid Fretting
Plant N	Third Burned	Debris

Unknown* : The case that A defective fuel was confirmed by UT but wasn't confirmed by VT

FAs is 5(Plant F~J), and the cases that a defective fuel is occurred among the third loading FAs is 4(Plant K~N). All of them are the cases that a defective fuel rod is confirmed by Ultrasonic Test. Most of them also are the cases that fission gas is released into the primary coolant immediately after a defective fuel is occurred because the defective size is large.

2.2 Analysis Result

Figure 2 shows the Xe^{133} activity levels for the cases that a defective fuel is occurred among the first loading FAs. As you see in the figure 2, Xe^{133} activity level is about 1.5 X 10^{-2} µci ~ 7.8 X 10^{-1} µci.

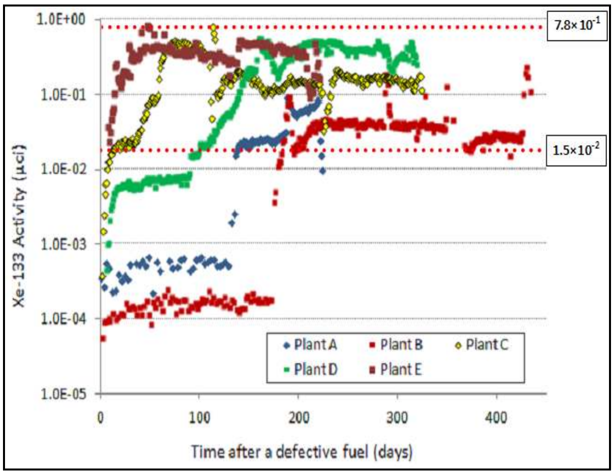

Figure2. Xe^{133} Activity Level of A Defective Fuel Rod Among the first loading FAs

Figure 3 shows the Xe^{133} activity levels for the cases that a defective fuel is occurred among the second loading FAs. As you see in the figure 3, Xe^{133} activity level is about 1.6 X 10^{-2} µci ~ 1.0 µci.

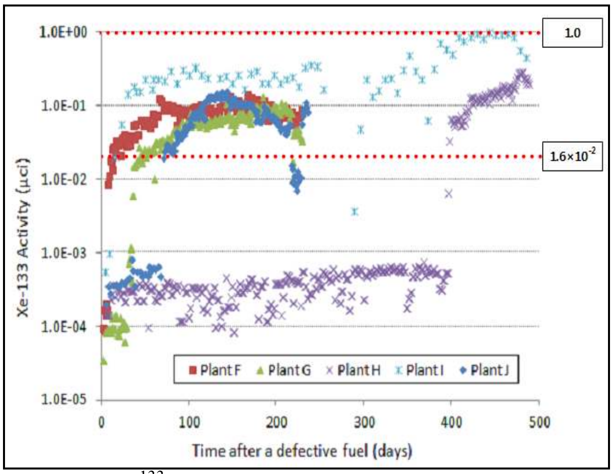

Figure3. Xe^{133} Activity Level of A Defective Fuel Rod Among the second loading FAs

Figure 4 shows the Xe^{133} activity levels for the cases that a defective fuel is occurred among the third loading FAs. As you see in the figure 3, Xe^{133} activity level is about 3.8 X 10^{-4} µci ~ 3.1 X 10^{-3} µci.

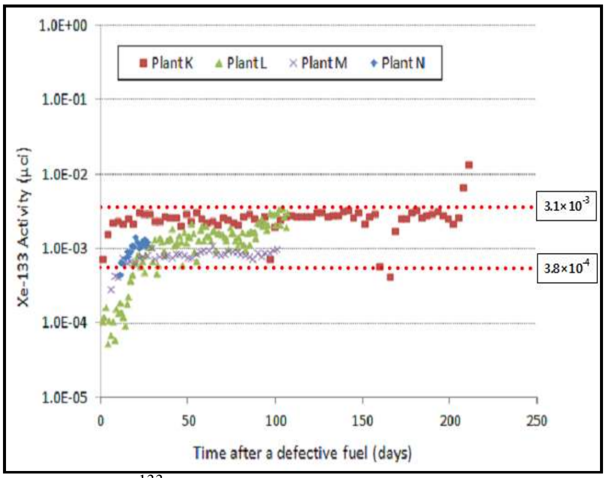

Figure4. Xe^{133} Activity Level of A Defective Fuel Rod Among the third loading FAs

As the result, Xe^{133} Activity Level is similar if a defective fuel is occurred among the first or second loading FAs. It is why the first and second loading FAs generate the similar relative power. Therefore, we can estimate that the FA with a defective fuel rod is one of the first or second loading FAs if Xe^{133} Activity Level is over 1.0 X 10^{-2} µci.

We can also estimate that the FA with a defective fuel rod is one of the third loading FAs if Xe^{133} Activity Level is less than 1.0 X 10^{-2} µci. It is why the third loading FAs generate much less power than the first and second loading FAs. It is important to know that the FA with a defective fuel rod is one of the third loading FAs because the third loading FAs are discharged in the next cycle.

3. Conclusions

Xe^{133} activity level is analyzed in order to identify FA's loading cycle with a defective fuel rod. As the result of them, we can estimate that the FA with a defective fuel rod is one of the first or second loading FAs if Xe^{133} activity Level is over 1.0 X 10^{-2} µci. We can also estimate that the FA with a defective fuel rod is one of the third loading FAs if Xe^{133} activity Level is less than 1.0 X 10^{-2} µci. It is why Xe^{133} activity Level is sensitive to the FA's relative power.

REFERENCES

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[2] PWR Fuel Follow from Coolant Activity Analysis, ABB Combustion Engineering Nuclear Power Windsor, Connecticut,1991. pp.3-1 - 3-19 l