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Application of Correction Factors to the Coolant Flow Rate Differences for Enhancing the Precision of the Failed Fuel Identification Criteria

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1. Introduction

The delayed neutron monitoring system (DN) of CANDU-6 has two basic functions: the first one is to locate the fuel channel containing the defected fuel, and the second one is to locate the position of the defect within the fuel column1). The failed fuels need to be replaced immediately with the intact ones to protect the heat transport system (See Fig.1) from the radioactive contamination due to the defective fuels. But it is generally known that the failed fuel identification is very difficult even in the cases that the gaseous fission product monitoring system (GFP) of Wolsong nuclear power plant detected some typical defect signals. In this study, a new method for enhancing the determination capabilities of the failed fuel discrimination ratio was introduced and reviewed to increase the precision of the failed fuel identification criteria.

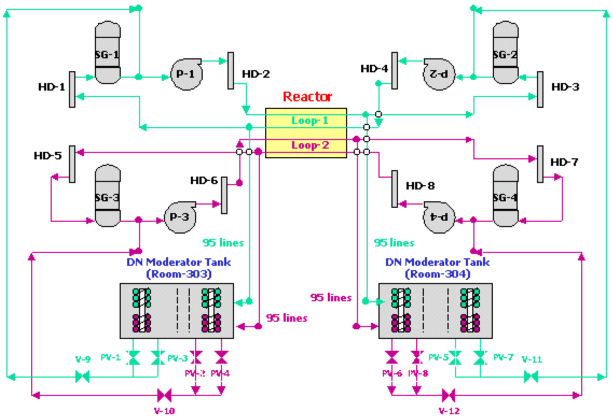

Fig. 1. Coolant flow diagram of heat transport system in CANDU-6.

2. Theoretical Background

2.1. Discrimination ratio

The parameters A and B stand for the average DN signal count rates obtained from each of the loop-halves of the channel, and S represents the DN signal count rate for single channel. In estimation, S value is normalized to the loop-half average value and represents the discrimination ratio (DR) of a fuel channel2):

$$DR = \frac{S}{A} \quad \text{or} \quad \frac{S}{B} \tag{1}$$

In the case of the 2N channel loop as shown in Fig. 2, radioactivity concentrations measured by the neutron detector are expressed as follows:

(1) Activity concentration of the failed fuel channel of the loop-half A:

$$S' = \frac{\lambda R}{F}\left(1 + \frac{r}{N}\left[\frac{1}{1-r}\right]\right) \tag{2}$$

where λ is decay constant, R is fission product release rate from the defect, F is channel flow, r is activity concentration reduction factor, and N is the number of channels. The activity concentration of the neighbor channel is expressed as below.

$$S_A = \frac{\lambda R}{F}\left(\frac{r}{N}\left[\frac{1}{1-r}\right]\right) \tag{3}$$

(2) Activity concentration of the non-failed fuel channel of the loop-half B:

$$S_B = \frac{\lambda R}{F}\left(\frac{r^{1/2}}{N}\left[\frac{1}{1-r}\right]\right) \tag{4}$$

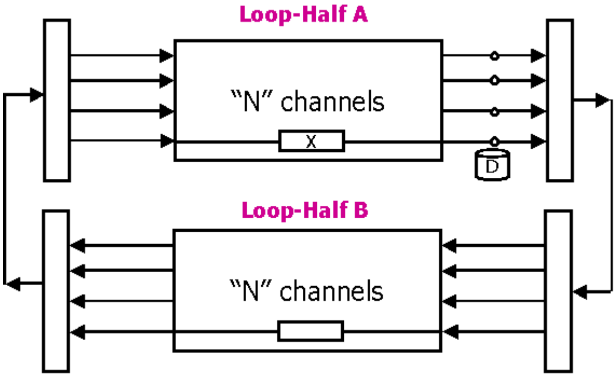

Fig. 2. 2N-channel model for the activity concentration calculation of failed fuel channel.

(3) DR in this loop-half:

$$DR = \frac{S'}{S} = 1 + \frac{N}{r}(1+r) \tag{5}$$

2.2. Necessity of correction factor

As shown in the equation (1), F is a constant, but it is not a constant in practice. The 380 coolant sampling lines corresponding to each fuel channel have different flow rate. It is guessed that the causes of coolant flow rate difference are due to the small particles like welding debris accumulated in the particular position of sampling lines in the DN monitoring system. In this context, the flow correction factors are introduced to determine the discrimination ratio more precisely.

2.3. Identification Criteria

In Canada, an identification criterion that each sampling line contains a failure indication if the DR is higher than 1.3 in CANDU-6 reactors has employed. But this criterion is not applying to the Wolsong nuclear power plants because of coolant flow rate differences in the sampling lines. For that reason, the coolant flow rate correction factors are required to determine the discrimination ratio more precisely.

3. Results

The coolant flow rate in each sampling line can be measured by the high temperature ultrasonic sensors. If an average value of coolant line measurements (F_i) is F_{av}, and normalized in 1, the coolant flow rate correction factor in each sampling line is represented by

$$C_i = \frac{F_i}{F_{av}} \qquad (6)$$

And the equations (2), (3), (4) and (5) can be replaced by the equations reflecting the correction factors:

$$S' = \frac{\lambda R}{C_i}\left(1 + \frac{r}{N}\left[\frac{1}{1-r}\right]\right) \qquad (7)$$

$$S_A = \frac{\lambda R}{C_i}\left(\frac{r}{N}\left[\frac{1}{1-r}\right]\right) \qquad (8)$$

$$S_B = \frac{\lambda R}{C_i}\left(\frac{r^{1/2}}{N}\left[\frac{1}{1-r}\right]\right) \qquad (9)$$

$$DR = \frac{S'}{S} = A\left(1 + \frac{N}{r}(1+r)\right) \qquad (10)$$

where A is a new constant due to the introduction of correction factor.

4. Conclusions

The coolant flow rate correction factors was introduced to reduce the uncertainty in determining the failed fuel discrimination ratio to mitigate the coolant flow rate differences in the DN sampling lines. It is expected that the precision of failed fuel identification would be improved if the flow rate correction factors are applied to the determination of the failed fuel discrimination ratio at the Wolsong nuclear power plant in the future.

References

[1] A.M. Manzer, “In-Core Assessment of Defective Fuel in CANDU-600 Reactors”, Presentation at the IAEA Specialists Meeting on PIE and Experience, Tokyo, Japan, Nov., 1984.

[2] R.D. MacDonald et al., “Detecting, Locating and Identifying Failed Fuel in Canadian Power Reactors,” AECL-9714, 1990.