Development of Evaluation Method Applying the RIA New Acceptance Criteria

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1. Introduction

As the results of RIA (Reactivity Initiated Accident) experiments performed in France, Japan and Russia since 1990s, it was confirmed that the fuel failure phenomena were observed in fuels with high burnup below the current acceptance criteria (Ref. 1). In 2007, the US NRC (Nuclear Regulatory Commission) issued interim acceptance criteria and guidance (SRP 4.2 Appendix B, Ref. 2) for the RIA based upon an assessment of the empirical data. However, the current RIA analysis method for operating and new plants didn't consider the interim RIA acceptance criteria by US NRC. In this study, the new RIA analysis method was developed to comply with the interim acceptance criteria for RIA and the RIA analyses were performed using iSAM (integrated Non-LOCA Safety Analysis Methodology).

2. Interim RIA Acceptance Criteria

The US NRC interim acceptance criteria published in 2007 are summarized as below.

2.1 Fuel Cladding Failure Criteria

The total number of fuel rods that must be considered in the radiological assessment is equal to the sum of all of the fuel rods failed each of the criteria below:

Case	Failure Criteria
A-1 High Cladding Temperature Failure	A-1-1 : HZP Case Peak radial average fuel enthalpy > 170 cal/g (Prod < P_{RCS}), or Peak radial average fuel enthalpy > 150 cal/g (Prod > P_{RCS}) A-1-2 : Power > 5% Case minimum DNBR < DNBR Limit
A-2 PCMI Failure	Radial average fuel enthalpy rise > Corrosion-dependent limit (Fig.1)

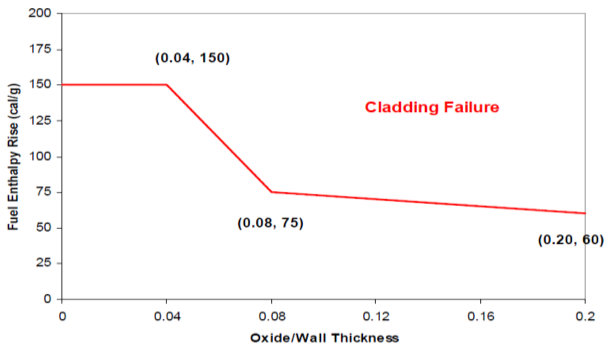

Fig. 1. PWR PCMI Fuel Cladding Failure Criteria

2.2 Coolable Core Geometry Criteria

Acceptance criteria for demonstrating that the coolable core geometry is maintained during the RIA are shown below:

Case	Acceptance Criteria
B-1 Enthalpy	Peak radial average fuel enthalpy < 230 cal/g
B-2 Fuel Melting	Peak fuel temperature < incipient melting conditions
B-3 Mechanical Energy	Mechanical energy generated as a result of (1) non-molten fuel-to-coolant interaction and (2) fuel rod burst must be addressed with respect to reactor pressure boundary, reactor internals, and fuel assembly structural integrity
B-4 Coolable Geometry	No loss of coolable geometry due to (1) fuel pellet and cladding fragmentation and dispersal and (2) fuel rod ballooning.

2.3 Radiological Fission Product Inventory

The total fission-product gap fraction available for release following any RIA would include the steady-state gap inventory (present prior to the event) plus any fission gas released during the event.

Case	Acceptance Criteria
C-1 Fraction of Fission Product Inventory for Release from RIA	Total FGR = Steady-state Gap Release Fraction + Transient Fission Gas Release Transient Fission Gas Release = [(0.2286*ΔH – 7.1419] ΔH : increase in radial average fuel enthalpy, cal/g

3. Analysis Method

In this section, the computer codes and detailed analysis method in compliance with interim RIA acceptance criteria are described.

In this study, iSAM is applied to perform detailed calculations of fuel temperature, fuel enthalpy and enthalpy rise during RIA.

3.1 Fuel Cladding Failure Calculation

The fuel cladding failure can be occurred due to cladding temperature increase or instantaneous enthalpy rise during RIA. The cladding failure due to cladding temperature increase is analyzed to evaluate DNBR (Departure from Nucleate Boiling Ratio) above 5% power and to evaluate the peak radial average fuel enthalpy at HZP (Hot Zero

Power) condition. Also, the enthalpy rises of entire core are compared with the PCMI (Pellet Cladding Mechanical Interaction) failure criteria shown in Fig. 1 to determine PCMI failure caused by instantaneous enthalpy rise.

3.2 Coolable Core Geometry Criteria

First, to ascertain the satisfaction of the acceptance criteria B-1 and B-2 in Section 2, the fuel temperature and fuel enthalpy are calculated. Second, the evaluation of mechanical energy as a result of non-molten fuel-to-coolant interaction among acceptance criteria B-3 is not performed unless the PCMI failure is occurred. The mechanical energy due to fuel rod burst in acceptance criteria B-3 doesn't threaten the coolable geometry if the peak fuel enthalpy is less than 230cal/g. In the last, no loss of coolable geometry due to ballooning among acceptance criteria B-4 is only evaluated to perform cladding strain calculation considering the increase of internal fuel rod pressure due to enthalpy rise during RIA.

3.3 Radiological Fission Product Inventory

The total fission-product gap fraction should include the steady-state gap inventory plus any fission gas released during the RIA. To assess the offsite dose during RIA, the steady-state gap inventory fraction in a gap described in RG 1.l95 (Ref. 3) and the transient fission gas release suggested in SRP 4.2 Appendix B (Ref. 2) are assumed. In terms of the transient FGR (Fission Gas Release) in SRP 4.2 Appendix B (Ref. 2), an arithmetic mean of the each fuel node's maximum enthalpy rise is used as a representative value for transient FGR calculation of a particular fuel rod.

4. Results and Conclusions

A spectrum of RIA analysis was performed using developed analysis method for Shin Kori 5&6.

According to the analysis results, there was no PCMI fuel cladding failure, no maximum enthalpy limit (230 cal/g) violation, and no fuel centerline melting. For HZP case, the hot spot peak fuel radial average enthalpy was well below the high cladding temperature failure criterion. As to the core coolability, there was no non-molten fuel-to-coolant interaction because there is no cladding failure such as PCMI fuel cladding failure, cladding ballooning or burst. Therefore, there was no loss of core coolable geometry either.

The assessment of offsite dose was done by considering the transient FGR. The offsite dose results were within the 25% of 10CFR100 limits specified in SRG (Safety Review Guidelines, Ref. 4).

In conclusions, the interim acceptance criteria for RIA described in SRP 4.2 Appendix B were met.

Acknowledgments

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