Safety Evaluation for the Proto-type Fast Breeder Reactor MONJU as a Japanese TSO

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Abstract.

In the safety field of fast breeder reactors (FBRs), JNES is conducting an evaluation work of the safety regulation by Nuclear and Industry Safety Agency (NISA) for the re-start of a prototype FBR MONJU. MONJU has been stopped over 14 years since 1995 due to a sodium leakage accident at a secondary heat transport system, and is now reached to the criticality on 8th of May, 2010. JNES is supporting the safety regulation work conducted by NISA based on the following activities: i) Support of the technical evaluation of the application for the establishment license prepared by Japan Atomic Energy Agency (JAEA), ii) Support of the description of the safety review report by NISA based on independent safety analyses for the major accident events such as unprotected loss-of-flow (ULOF) by employing the latest findings on the study of core disruptive accidents (CDAs) independently conducted by JNES, iii) Support of the risk-iformed-regulation (RIR) such as an accident management (AM) review, iv), and Consideration on the safety regulation policy from the points of severe accidents and source-term behaviors including the cesium (Cs). The objective of this paper is to introduce the major activities of JNES in the safety domain of MONJU regulations.

I. Introduction

In the field of the FBR safety JNES is conducting an evaluation work of the safety regulation by Nuclear and Industry Safety Agency (NISA) for the re-start of a fast breeder reactor MONJU. MONJU has been stopped over 14 years since 1995 due to a sodium leakage accident at a secondary heat transport system, and is now reached to the criticality on 8th of May, 2010. JNES is supporting the safety regulation work conducted by NISA based on the following activities:

i.) Technical evaluation of application document for alteration in establishment license prepared by Japan Atomic Energy Agency (JAEA) for the safety design of the MONJU core, fuel mechanics, and hydrodynamics of the plant system from the viewpoint of the composition change of fuel materials affected on the safety features of the re-starting plant, with paying attention that change of fuel materials are induced by an increasing of 241Am due to a decay of 241Pu caused by a long-term keeping over 20 years after the fuel manufacturing,

ii.) Support of describing the Safety Review Report by NISA based on independent safety analyses for the major accident events such as unprotected-loss-of-flow(ULOF) by employing the latest findings on the study of core disruptive accidents conducted by JNES,

iii.) Support of the risk-informed-regulation (RIR) on MONJU such as the confirmation of the accident management (AM), and confirmation of the allowable outage time (AOT) required for the limiting-condition-of-operation (LCO) described in the safety preservation rules, and iv.) Consideration on the safety regulation policy from the points of severe accidents and source-term behaviors including the cesium (Cs), and preparation of the technical standards for fuel and structures for the future commercial FBRs such as Japanese Sodium Fast Reactor (JSFR) concept.

2. Out-line of the MONJU safety regulation

MONJU has been stopped over 14 years since 1995 due to a sodium leakage accident at a secondary heat transport system, and is now reached to the criticality on 8th of May, 2010. JNES is supporting the safety regulation work conducted by NISA, and the out-line of the MONJU safety regulation works is summarized as follows:

- 1995.12~2010.3: Suspending and waiting for restart after the sodium leakage accident on Dec. 8, 1995.

- 2006.11-2008.3: Licensing work by NISA and Nuclear Safety Commission (NSC) has been conducted for the new core configuration with increased 241Am and decreased 241Pu due to the long-time storage over 15 years. JNES has made the technical investigation against JAEA applications for the alteration in establishment license under the direction by NISA. JNES has also conducted the cross-check analysis for the core performance and for the core disruptive accident, which were reported NSC in the second stage of the licensing procedure on 2008.1.

- 2008.3~continued: As in the case of LWRs in Japan, an accident management guideline (AMG) of MONJU has been prepared by JAEA and presented to NISA and related committee AM working group (AMWG) on 2008.5, with JAEA evaluation results of the effectiveness of the AMG by using level 1 and lvel 2 PSAs. The accident management review (AMR) has been conducted by NISA based on the independent PSA performed by JNES. The AMR, however, is currently interrupted by the inspection work due to miss-warnings of the Na leakage detection system. The AMWG will restart after MONJU criticality and the discussion will be transferred to NSC.

- 2008.09~2010.3: A seismic back-check has been conducted by NISA and JNES based on the systematic calculation of seismic capability.

- 2010.2.10: JAEA confirmed the “Over-all safety inspection report No.5” prepared by JAEA on 2010.2.10 according to the independent evaluation report by JNES, including the inspection importance analysis based on FV/RAW and impact evaluations of the ACS/VCB failure on the core damage frequency (CDF<1E-9) using the level 1 PSA.

- 2008.3-2010.5: NISA and JNES has conducted various inspections such as sodium detection system due to miss-warning, the safety protection structures and organization of JAEA, violence of the LCO (Limiting Condition for Operation) at the miss-warning of sodium detection system on 2009.7, a failure of the vacuum circuit breaker (VCB) of the air cooling system (ACS) of the secondary heat transport system on 2009.12, and confirmation of the start-up test.

- 2010.5.6: Re-starting of the MONJU operation and criticality is reached on 8th of May, 2010.

- 2010.5~2010.7: NISA and JNES are conducting an “on-the-spot” inspection for the whole area of the conduction of the core performance test to confirm the excess reactivity and control rod worth,

Fig.1 Inspection view at MONJU control rooom

plant operation during the tests, trouble events such as obstacles of the failed fuel detection sysrem. Figure 1 shows the inspection view by NISA at the MONJU control room.

3. Technical evaluation of the application document for alteration in establishment license prepared by JAEA

JNES has conducted the technical evaluation of application document for alteration in establishment license prepared by JAEA for the safety design of the MONJU core, from the viewpoint of the composition change with attention that change of fuel materials are induced by an increasing of 241Am due to a decay of 241Pu caused by a long-term keeping over 20 years after the fuel manufacturing(1, 3).

For the restart of MONJU, a number of initial MOX fuels were replaced by those with higher plutonium enrichment. However, replaced MOX fuels were also produced by using the same plutonium powders stored since fourteen years ago. Therefore, replaced MOX fuels also contain the same fraction of 241Am as the fuels remained in the core.

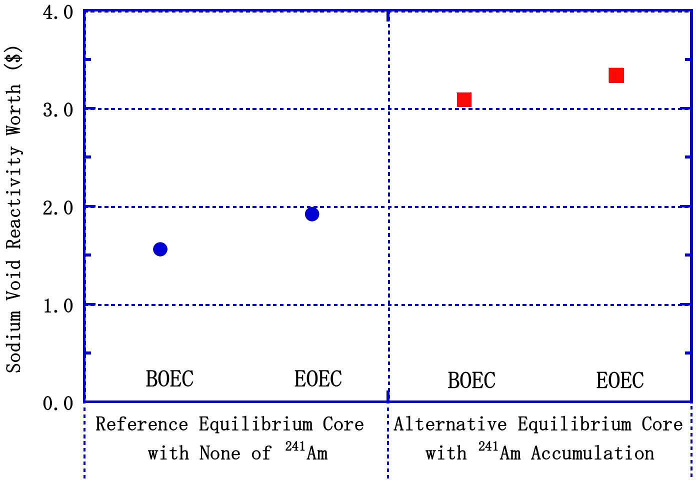

Fig.2 Comparison of sodium void reactivity worth between two MONJU cores

The sodium void reactivity worth, which is a most important core characteristic from the view point of safety evaluations of the MONJU core, is strongly affected due to the accumulation of 241Am. Therefore, the effect of 241Am accumulation on the sodium void reactivity worth was evaluated by comparing the results of two MONJU equilibrium cores.

The results of neutronic calculations of the sodium void reactivity worth for two different MONJU cores indicated that the neutron spectra of the voided core are shifted harder due to voiding. This spectral shift causes the increase of the positive reactivity, and this spectral effect due to voiding is much larger in the 241Am accumulated core compared to the no 241Am accumulated core. The sodium void reactivity worth of the 241Am accumulated core is almost twice of that of no 241Am accumulated core as shown in Fig. 2. As a result of the calculation, it was confirmed that the accumulation of 241Am significantly influences on the sodium void reactivity worth and hence on the safety analysis for the core disruptive accidents such as an Unprotected Loss-of Flow (ULOF), which is positioned as “section 5 event” in the construction permit application in Japan.

4. Independent safety analyses

From the viewpoint of the safety design of FBRs, it is preferable to prevent the core disruptive accidents (CDAs) or to eliminate energetic induced by a severe re-criticality during the CDAs, because the FBR core is not in the maximum reactivity configuration. The positive sodium void reactivity is thus playing an important role especially for the power transient of the ULOF initiating phase.

Once a super-prompt criticality occurs during the ULOF, the core fuel will begin to melt and vaporize. The expansion of the fuel vapor drives the upper sodium slug to strike the reactor vessel head and generates a mechanical consequence as to threaten the vessel integrity. Thus, the evaluation of the characteristics re-criticality during CDAs is one of the important issues for the licensing procedure of

FBRs. In the case of the safety evaluation in the construction permit application of MONJU, the ULOF is typical “section 5 events.”

JNES is preparing and studying the techniques to evaluate the core disruptive accidents of the FBR core for the preparation of the cross-check analysis required as a safety inspection by the national regulatory authorities. In this study, we have concentrated on the evaluation of the mechanical energy released in the initiating phase of the EOEC core of MONJU by using SAS4A code borrowed from JAEA under the permission of US. DOE.

Based on the analysis on the ULOF initiating phase of the MONJU core, no mechanical energy release was confirmed based on the systematic parametric analyses using SAS4A code independently verified by JNES using in-pile experiments such as CABRI project. Most of parametric cases within the realistic uncertainty conditions indicate that the maximum fuel temperature is lower that that of the boiling point of about 3800K at the atmosphere pressure indicating no fuel vapor expansion to be converted to the mechanical energy(2).

5. Risk-informed-regulation of the MONJU

An accident management guideline (AMG) of MONJU has been prepared to NISA by JAEA with an evaluation result of an effectiveness of the AMG by employing level 1 and level 2 PSAs. JNES carried out the PSA from the viewpoint of an accident management review(AMR).

This evaluation, independently of JAEA, conducted a level 2 PSA of MONJU to evaluate containment failure frequencies (CFF) and evaluated changes in CFF before and after the preparation of the AM measures. A comparative analysis was carried out on JAEA’s and JNES’s principles and methods for the Level 2 PSA evaluation in order to evaluate the causes of differences in CFF and the degree of their impacts. Based on the results of these evaluations, the technical appropriateness of the effectiveness evaluation of the AM measures carried out by JAEA using the level 2 PSA approach is confirmed.

As the result, the total CFF, even before the preparation of the AM measures, was rated at 9.2E-9/reactor year (CDF at 2.7E-7/reactor year), and it has been confirmed that these numerical values are well below the power reactor performance goal indicator values (CDF: 10-4/year or so; CFF: 10-5/year or so) even before the preparation of the AM measures(4,5).

6. Code development for the level 2 PSA

Since several years ago, JNES has developed own safety analysis methods for LMFBR to make safety analyses independently from the applicant to support NISA. The area of these analysis code covers the plant response phase, the core disruption phase and the CV response phase of severe accidents as shown in Fig.3. In addition, the PRD method was figured out as a logical method to identify the probability distributions of blanching point of event tree for PSA. After validation of these computer codes using various experimental data and trial calculations to actual reactor system, the prepared tools were applied to level-2 PSA of MONJU (6).

Now, further efforts are being made to make analyses more realistic backed by experimental data to phenomena dealt in level-2 PSA for the MONJU with an advance core and the demonstration LMFBR, JSFR. Also, these improvements are very helpful in constructing databases of the Emergency Response Support System (ERSS) for MONJU by conducting

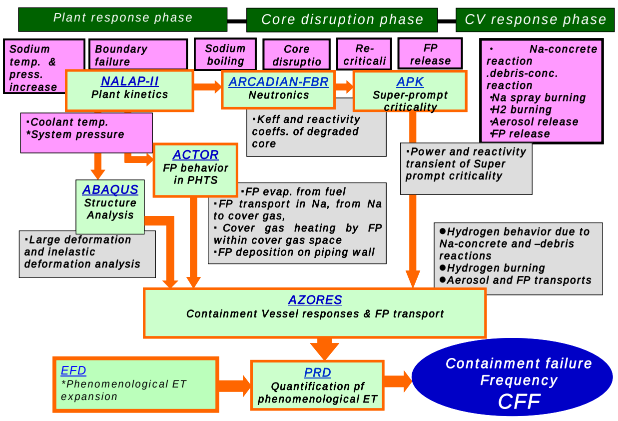

Fig.3 JNES code system applied to level-2 PSA

more reliable analyses to the conceivable scenarios after initiating events.

7. Consideration on the safety regulation policy

JNES is examining the future safety regulation polic**y** from the points of severe accidents evaluations such as section 5 events, source-term behaviors including the cesium (7), and preparation of the technical standards for fuel and structures for the future commercial FBRs such as Japanese Sodium Fast Reactor (JSFR) concept.

8. Conclusion

MONJU has been stopped over 14 years since 1995 due to a sodium leakage accident at a secondary heat transport system, and is now reached to the criticality on 8th of May, 2010.

JNES is supporting the safety regulation work conducted by NISA based on : i) technical evaluation of the application for the establishment license prepared by JAEA, ii) manufacturing the safety review report by NISA based on independent safety analyses, iii) risk-iformed-regulation such as an accident management (AM) review, iv) on-the-spot inspection works on the sodium detection system, the safety protection structures and organization of JAEA, violence of the LCO at the miss-warning of sodium detection system, and on the confirmation of the start-up test., and v) consideration on the safety regulation policy from the points of severe accidents and source-term.

9. References

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