ON THE REASSESSMENT OF SAFETY ASSESSMENT REPORTS AND THE RESTART OF UNIVERSITY RESEARCH REACTORS IN JAPAN

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ABSTRACT

After the 2011 March 11 earthquake and the Fukushima Dai-Ichi nuclear power plant accident, operation of all nuclear power plants has been suspended for the reevaluation of safety assessment under the new safety requirements formed by the dedicated regulatory institution, the Nuclear Regulation Authority (NRA). For the research reactors and critical assemblies (RRCAs), temporary permission for operation until the next annual inspection was issued under the condition that the additional temporary safety requirements by NRA are met. Since 2013, all RRCAs have been temporary shut down and reassessment of the safety assessment reports. The new safety requirements for the RRCAs are basically based on those for the power reactors with partial exemption and/or graded approach. After more than three years of operation interruption, the three RRCAs owned and operated by Japanese universities have successfully achieved the renewed operation license from NRA and restarted their operation in 2017. This paper describes the overall structure of the renewed safety requirement for the RRCAs and the specific issues on the reassessment of the safety assessment reports of the two research reactors of Kyoto University, the Kyoto University Research Reactor (KUR) and Kyoto University Critical Assembly (KUCA).

1. Introduction

The 2011 March 11 earthquake and the subsequent Tsunami and the Fukushima Dai-Ichi nuclear power plant accident, operation of all nuclear power plants has been subsequently suspended as their scheduled periodic inspections for the reevaluation of safety assessment under the new safety requirements formed by the dedicated regulatory institution, the Nuclear Regulation Authority (NRA). As of May 2012, all power stations had suspended their operation

The NRA is formed as an external bureau of the Ministry of the Environment and is responsible of nuclear safety regulations and safeguards on the use of nuclear energy, nuclear emergency preparedness as well as nuclear and radiation security. These regulatory responsibilities were separately governed for power reactors and research reactors before the formation of NRA and the resulting integration of the nuclear regulation (Fig. 1).

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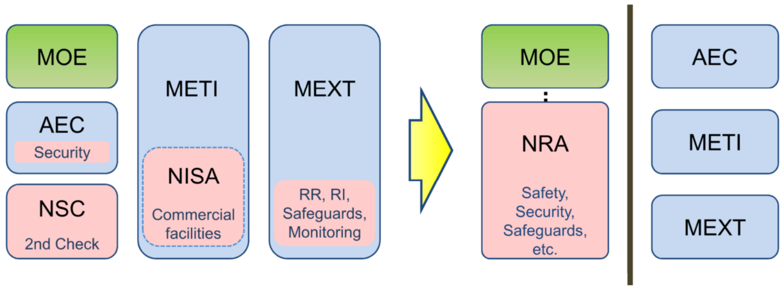

AEC : Atomic Energy Commission
METI : Ministry of Economy, Trade and Industry
MEXT : Ministry of Education, Culture, Sports, Science and Technology
MOE : Ministry of the Environment
NISA : Nuclear and Industrial Safety Agency (abolished)
NSC : Nuclear Safety Commission (abolished)

Fig 1: Restructuring of Nuclear Regulation and NRA [1]

The Reactor Regulation Act was amended based on the lessons learned from the Fukushima accident, the latest technical knowledge/information as well as overseas regulatory trends including the IAEA safety standards and best practices from other international organizations. Major requirements newly introduced in the revised Act includes the strengthening of measures against natural hazards, strengthening of measures against severe accidents and introduction of back-fitting rule to comply with the new regulations [2]. Through the lessons learned from Fukushima accident, emphasis are placed on Defense-in-Depth concept, prevention of common cause failures, preparation of multi-layered protection against severe accidents and introduction of measures against intentional aircraft crash [3], which are either reinforcement or new addition of safety requirements to the pre-existed ones. The overall structure of the new safety requirement is shown in Fig.2.

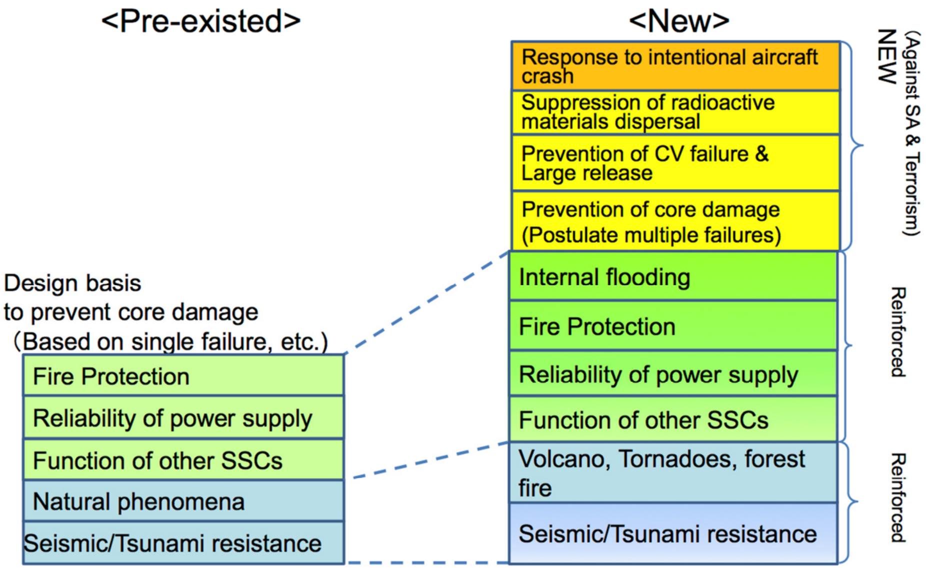

Fig.2: Structure of New Safety Requirements for Power Reactors [3]

Based on these requirements, the specific regulatory requirements for establishment permit and technical standards were first developed for power reactors, and the requirements for other types of reactors including research reactors and critical assemblies (RRCAs) were designed basically based on those for the power reactors, with partial exemption and/or graded approach.

As for RRCAs, temporary permission for operation until the next periodic inspection was issued under the condition assuring the additional temporary safety requirements by NRA meet the renewed safety standards. Since the first quarter of 2013, all RRCAs have been temporary shutdown, and the reassessment of the safety assessment reports was commenced. Table 1 and 2 show the present status of the research reactors in Japan and their categorization on the renewed safety standard. Currently eight out of nine RRCAs have submitted the request for safety review, and among them three RRCAs have successfully passed the review and restarted, including the Kyoto University Research Reactor (KUR) and Kyoto University Critical Assembly (KUCA).

Tab 1: List of Current Research Reactors in Japan

Reactor	Operator	Thermal Power	First Criticality	Status (as of Feb 1, 2018)
UTR-KINKI	**Kindai Univ.**	1W	1961	**Restarted Mar 2017**
KUR	**Kyoto Univ.**	5MW	1964	**Restarted Aug 2017**
KUCA*	**Kyoto Univ.**	10W	1974	**Restarted June 2017**
NSRR	JAEA	300kW / peak pulse 23GW	1974	Safety review request submitted March 2015
JRR-3	JAEA	20MW	1990	Safety review request submitted Sep. 2014
STACY*	JAEA	200W	1995	Safety review request submitted March 2015
HTTR	JAEA	30MW	1998	Safety review request submitted Nov. 2014
JOYO	JAEA	140MW	1977	Safety review request submitted Mar 2017
NCA*	Toshiba	200W	1963	Safety review schedule TBD

*critical assembly

Tab 2: Categorization of Research Reactors

Category	Reactor Power	Reactor
High-Power Reactors	over 10MW	JOYO, HTTR, JRR-3
Mid-Power Reactors	from 500kW to 10MW	KUR
Low-Power Reactors	up to 500kW	NSRR, KUCA, STACY, UTR-KINKI, NCA

2. Key Modifications of Safety Analysis Report of KUR and KUCA

The safety analysis reports of KUR and KUCA were thoroughly reevaluated based on the requirements as described in the “Ministerial Ordinance for the Technical Standards on Siting, Structure and Facilities of Research and Test Reactors”, issued on November 2013. The renewed safety analysis requirements for the two reactors are summarized in Table 3.

Tab 3: Safety Analysis Requirements under New Safety Regulation for KUR and KUCA

Article title of "Ministerial Ordinance for the Technical Standards on Siting, Structure and Facilities of Research and Test Reactors"	KUR	KUCA
General Conditions	X	X
Definitions	X	X
Site foundation	X	X
Prevention of Damage by Earthquake	X	X
Prevention of Damage by Tsunami	X	X
Prevention of Damage by External Shock	X	X
Prevention of unauthorized or inadvertent entry to facilities	X	X
Prevention of Damage by Fire	X	X
Prevention of Damage by Flooding	X	X
Prevention of Erroneous operation	X	X
Safety Evacuation Path	X	X
Safety facilities	X	X
Prevention of abnormal transient during operation and design basis accident	X	X
Fuel element handling and storage facilities	X	X
Safety protection circuit	X	X
Reactivity control system	X	X
Radioactive waste management system	X	X
Radioactive waste storage facility	X	X
Protection from direct gamma ray	X	X
Protection of workers from radioactive rays	X	X
Reactor containment facility	X	X
Security power facilities	X	X
Experimental facilities	X	X
Communication facilities	X	X
Facilities for loss of external power supply	X	X
Reactor core and related facilities	X	X
Primary cooling system	X	Not Required
Residual heat removal system	X	Not Required
Heat transfer system to final heat sink	X	Not Required
Measurement and Control system	X	X
Reactor Shutdown system	X	X
Control room and related facilities	X	X
Monitoring system	X	X
Prevention of accident associating significant release of radioactive material	X	Not Required

The key issues on the revised safety analysis for KUR and KUCA were the following four categories.

1) Renewal of safety classification of structures, systems and component (KUR, KUCA)

The safety classification of structures, systems and components (SSCs) were thoroughly reviewed and reclassified from seismic classification and their safety function. The C/R system, biological shield, fuel element, core support structure, core tank outlet primary coolant pipe system, beam tube and spent fuel pond were identified as Class S SSCs for KUR, so the reevaluation of design-basis ground motion (Ss) was required (described in section.3)). Furthermore, the adequateness of the design and construction of the existing systems and components were examined through additional inspections and modifications according to the result of new classification.

2) Beyond-DBA analysis to ensure the effectiveness of fuel damage prevention or its mitigation scheme (KUR)

Severe accident conditions exceeding the assumptions of design-based accident were analyzed to evaluate the fission product (FP) release mitigation measures. In the analysis, fuel damage caused by coolant channel blockage and large scale LOCA followed by FP was set as the accident condition, assuming hypothetical multiple failures (e.g. simultaneous loss of reactor shutdown, cooling and containment capabilities) triggered by severe earthquake. Additional mitigation schemes were introduced including coolant water supply by emergency fire pumps, fission gas containment by sealing reactor top structure and evacuation of personnel from the facility. In addition, the review of preparedness of these mitigation schemes was incorporated in the regular emergency training and drills.

3) External hazard analysis based on methodology established for power plants (KUR, KUCA)

The external hazard analysis was significantly reinforced in the renewed safety requirement for both power reactors and RRCAs, aiming to a) prevent common cause failures by introducing accurate approaches in assessment of earthquake and tsunami and measures against tsunami inundation, b) introduction of assessment of volcano, tornado and forest fire, and c) enhancement of measures against fire, internal flooding and loss of power.

As for the earthquake assessment, reevaluation of design-basis ground motion (Ss) were performed in a manner to greatly expand the range of potential active faults in the vicinity of the site and to take into account the inter-plate earthquake (e.g. Nankai trough earthquake, M9.0) and intra-plate earthquake, and also to consider the associated uncertainties in a conservative manner. The integrity of SSCs was then analyzed using the updated Ss, which showed the required safety performances are ensured. The impact of tsunami caused by those earthquakes was evaluated to be insignificant to the reactors, due to the relatively high altitude of the site.

The external hazards other than earthquakes and tsunami were also analyzed on a conservative manner to consider the possible uncertainties, such as the probability of tornado attack and its magnitude. Together with risk assessment of external and internal fire, additional measures including reinforcement of buildings and installation of safety equipment were required as described in Section 3.

4) Renewed quality management system and activities for design and construction

The quality management system (QMS) has been thoroughly reevaluated and redesigned to cope with the reinforced requirement, where the overall structure of QMS was strengthened to the level equivalent to that of power reactors.

3. Key Modifications of Safety Installations of KUR and KUCA

In order to meet the safety requirements described in the previous section, modifications of safety equipment and systems were performed.

As for beyond-DBA situation, additional emergency coolant supply system composed of external water storage tank, portable generator, emergency fire pump and dedicated supply pipeline.

The modifications of safety installations associated with external and internal hazard assessments include the following actions;

1) Tornado: reinforcement of outer wall structure of EG related facility buildings to prevent damage by design-based tornado, installation of tornado forecast system, emergency reactor shutdown and evacuation of vehicles under tornado warning conditions (Fig. 3),
2) Volcanic impacts: emergency removal of volcanic ash and emergency reactor shutdown,
3) External fire: installation of outdoor fire hydrant system and fire isolation area (Fig. 4), additional training and drills,
4) Internal fire: additional installation of fire detector, fire preventive shutter and fire extinguish system, protection of equipment and cables using insulator materials, renewal of cables, restriction and control of carry-in combustible materials

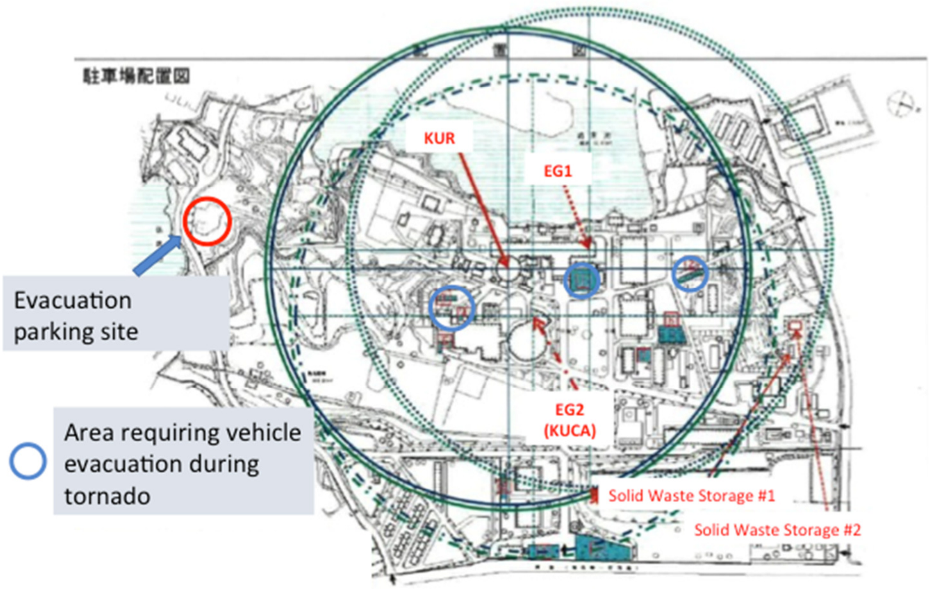

Fig 3: Vehicle evacuation area under tornado warning conditions

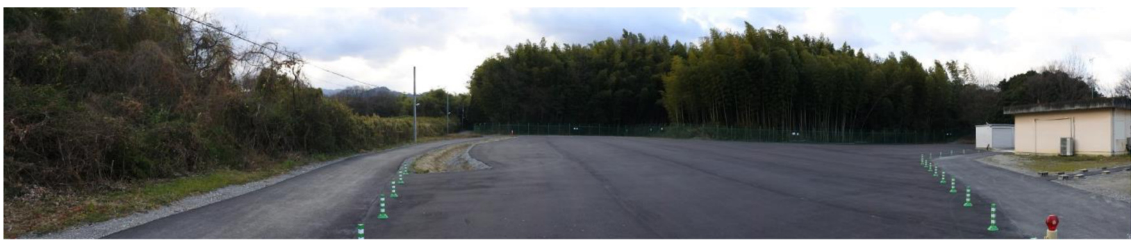

Fig 4: Fire prevention zone for External Fire Hazard Prevention / Mitigation

4. Review by NRA and the Road to Restart

The request for renewal license of KUR and KUCA including the renewed safety analysis report described above was submitted to NRA on September 2014. Five amendments of safety analysis report were submitted during 2016 for KUR and three amendments were submitted during 2015 and 2016 for KUCA.

After the completion of review and approval of the safety analysis on 2016, the operational safety program was approved on August 2016. The review of design and construction for the required safety installations has commenced since then, and after the reinforcement and additional installation of the safety equipment, the restart of KUCA and KUR has been approved by NRA in June 2017 and August 2017, respectively.

5. Summary and Concluding Remarks

Many lessons have been learnt through the long course of the safety review of KUR and KUCA, for both the operator and the regulator. As described in the introduction, the safety regulations for RRCAs were based on those for the power plants, and the graded approach as recommended by IAEA was not sufficiently incorporated in the design of the safety regulations for RRCAs. Based on the experience of the safety review of KUCA and UTR-KINKI by NRA, the NRA commissioner board has requested the NRA to summarize the graded approach for safety review of RRCA in order to efficiently promote the review and ensure the safety. Based on this request, NRA has released their plan for the graded approach for safety review of RRCA on June 2016, which summarized and clarified the basic philosophy of the graded approach and its application to external hazard analysis. The plan also mentions the importance of survey on the individual facilities and to further understand their characteristics, and mentions that the graded approach be further discussed to be reflected in the regulatory system.

The improvement of safety capabilities has effectively leaded to enhance the multi-layered protective measures of KUR and KUCA based on the defense-in-depth concept, and has accounted to ensure the diversity and independence of the safety measures. We believe that our experience, together with the anticipated progress of the adaptation of graded approach in the safety regulation, would serve to effectively accelerate the review of the safety analysis of the remaining research reactors in Japan.

References

[1] Toyoshi Fuketa, “Proposed Regulatory Requirements in Japan”, presentation at the 25th Annual Regulatory Information Conference, Bethesda North Hotel and Conference Center, March 13, 2013.

[2] The Secretariat of Nuclear Regulation Authority, "Outline of Nuclear Regulation of Japan - Reference documents for the IAEA IRRS Mission -", Reference documents for IRRS Japan 2016, Nov. 2016.

[3] Toyoshi Fuketa, “Topics on Current Nuclear Regulation in Japan”, presentation at the 26th Annual Regulatory Information Conference, Bethesda North Marriott Hotel and Conference Center, March 11, 2014.