Status of JRR-3 After Great East Japan Earthquake

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JRR-3 at Tokai site of JAEA was in its regular maintenance period, when the Great East Japan Earthquake took place on 11th March 2011. The reactor building with the solid foundations and the equipment important to safety have survived the earthquake without serious damage, and no radioactive leakage has been occurred. Recovery work, check and test of the integrity for all components have been carried out. In response to the accident at Fukushima Daiichi NPS, the new safety standards for research and test reactor facilities came into force on December 18, 2013. The evaluation of natural disasters and prevention of spread of accidents beyond design basis mainly were enhanced in the standards. We have completed the necessary checks and assessments, and submitted an application for reviewing if JRR-3 complies with the new standards to the Nuclear Regulation Authority on September 26, 2014.

Key Words: JRR-3, Great East Japan Earthquake, new regulatory requirements.

1. Introduction

JRR-3 (Japan Research Reactor No.3) is a light water cooled and moderated swimming pool type research reactor with nominal thermal power of 20MW. The reactor building contains reactor facilities such as a reactor pool, cooling system, instrumentation and control system, etc. Neutrons coming from the core are transported to a beam hall and many of neutron beam experiments are carried out in the hall. The secondary cooling tower receives heat generated in the core and emits it to the atmosphere. Air with minor radioactivity in the reactor building is filtered and exhausted to the atmosphere through an exhaust stack.

JRR-3 has suffered the great earth tremor not previously experienced when the Great East Japan Earthquake with the seismic energy of magnitude 9.0 has occurred on March 11, 2011. At that time, JRR-3 was undergoing regular periodical inspection and the reactor was not operated. Although commercial electric supply was stopped, necessary minimum facilities were continuously operated with emergency electric generators. It is very important to confirm immediately whether nuclear fuel materials and reactor containment system are damaged or not. During the aftershocks for a few hours, the reactor pool, nuclear fuels and their storage facilities were checked visually and confirmed to keep their soundness. Although several small cracks were shown on the inside of the walls of the reactor building, they did not result in adverse effect on the integrity of containment and there was no release of radioactive materials to environment.

2. JRR-3 works after the Great East Japan earthquake

2.1. Recovery works

The buildings themselves did not sink since they are built on the bedrock, but ground around the buildings was sunk about 40cm. According to the ground sinking, an exhaust duct led from the reactor building to a stack was slightly damaged at a connection. A liquid nitrogen

storage tank, used for feeding liquid nitrogen to experimental facilities, and electric transformers for secondary cooling system were also damaged and leaned. Some of the ceiling panels in the reactor building were dropped.

Cracks of reinforced concrete were investigated with the installation of a scaffold (see *FIG.1*). Although the cracks were mostly less than 1mm in width, several cracks over 1 mm in width were found. These cracks of concrete were repaired by injecting the epoxy resin. Exfoliation/falling were not found.

All recovery works have already been completed.

FIG.1. Repair of reactor building and cooling tower.

2.2. Verification of the Integrity

As the Great East Japan earthquake measured larger seismic acceleration than that of seismic design of JRR-3, regulatory body has demanded us to evaluate soundness of reactor facilities and report it for reactor re-operation. Several evaluation have been required such as (1) the impact in the event of station blackout, (2) check and test of all of the SSCs (structure, systems and components), and (3) seismic analysis in the light of the knowledge obtained from the earthquake.

(1) When station blackout occurs, the reactor is shut down automatically. The decay heat of JRR-3 is the thermal power of 1.4 MW that is 1/100 of power rector. The maximum fuel surface temperature after the auto shutdown by station blackout reaches to about 120 degrees Celsius, and then decreases gradually by natural circulation of the cooling water. This shows that integrity of core is kept if station blackout occurs.

(2) Deformation, buckling or crack of the structure was confirmed by visual observation, and deformation, loosening or the lack of a bolt and a nut was also checked. Soundness of the cooling system, instrumentation and control system etc. needed for reactor re-operation were confirmed by the performance inspection. All of the check and test have been completed.

(3) The earthquake registered 9.0 on the Richter scale, and the intensity was a lower 6 at Tokai. The maximum ground accelerations of 11.83 m/s^2 in horizontal and of 5.12 m/s^2 in vertical were observed at JRR-3. Those are larger seismic acceleration than that of seismic design of JRR-3. Seismic analysis has been carried out in order to confirm the JRR-3 would have been resistant to the earthquake adequately.

The seismic safety for components and their supporting structure were evaluated by the response magnification method. Table 1 shows result of evaluation. The initiation stress is very smaller than the evaluation criterion, because each component is designed with margin. We confirmed that each component had enough strength to be proof against the Great East Japan earthquake.

The results of the integrity were reported to regulatory body on November 2, 2012.

TABLE 1: RESULTS OF EVALUATION.

Kind of components	**Initiation stress (N/mm^2)**	**Evaluation criterion (N/mm^2)**
Standard Fuel Element	4	54
Follower Fuel Element	18	74
Beryllium Reflector	3	112
Heavy Water Tank	13	58
Neutron Absorber	571	1272
Control Rod Guide Tube	6	123
Horizontal Beam Tube	59	135

2.3. Work in reactor shutdown

Four years from the Great East Japan Earthquake, and the so long reactor shutdown is our first experience. During the shutdown term, main facilities have been kept the integrity by checking operation regularly once in a month. These main facilities are shown in Table 2.

In addition to keeping reactor facilities in a good condition, we feel strongly the importance of keeping motivation and skills of operators. Therefore, we come up with effective management methods such as (1) operating the main facilities and safety protection system and evaluating their integrity monthly, and (2) operating the most of reactor facilities (the cooling system, instrumentation and control system, etc.) for a whole week and confirming the integrity once a year. And we carry out them.

TABLE 2: MAIN FACILITIES.

Period of operation	Once a month
Cooling system	Primary cooling system
	Secondary cooling system
	Heavy water cooling system
	Spent fuel cooling system
Safety protection system	Reactor scrum circuit

3. Work for Re-operation

3.1. About New Regulatory Requirements

In response to the accident at Fukushima Daiichi NPS, Japanese government revised the Reactor Regulation Act, for the purpose of introducing new regulation system based on lessons learned from the accident and the latest technical findings. And new regulatory requirements for research and test reactor facilities were enforced on December 18, 2013. In the Act, it is stipulated the introduction of back-fit system that is a system for adopting the latest technological findings and obligating approved nuclear facilities to conform to the new requirements.

The main requirements in new regulatory requirements for research and test reactor are shown Table 3.

TABLE 3: MAIN REQUIREMENTS.

Item		Requirement
Basic Design for Earthquake and Tsunami		SSCs with safety functions shall be designed to sufficiently withstand appropriate design basis earthquake and tsunami.
External Events	Natural Phenomena	The evaluations and design to be based on the latest findings related to natural disasters such as volcanic eruptions, tornados, and forest fires, etc.
	Man-Induced Events	The safety of facility will not be impaired by airplane crash, dam break, explosion, fires in neighboring factories, toxic gas, collision ships, electromagnetic interferences, etc.
Fire Protection		The safety will not be impaired by fire considering protective measure for preventing, detecting and extinguishing of fire, and mitigating its effect.
Internal Flooding		The safety of the facilities will not be impaired by postulated internal flooding that may take place within the facilities.
Communication Systems		The communication system can give necessary information and instructions to the person inside and outside the facilities when design basis accident occurs.
Loss of External Power Supply		The facilities shall be so designed that safe shutdown and proper cooling of reactor after shutdown can be ensured in case of the station blackout for a given time.
Radiation Monitoring		The facility shall be designed to enable proper radiation monitoring and surveillance against the release of radioactive materials during design basis accidents.
Prevention of Spread of Accidents		The evaluation against accidents beyond design basis (BDBA) must be conducted.

3.2. Applications for Review to Verify Conformity to New Regulatory Requirements

We have conducted the necessary checks and reassessments of JRR-3, and completed the preparations for the relevant applications. We then submitted the application document to change the current reactor establishment permission to the Nuclear Regulation Authority (NRA) for their review to verify conformity to new regulatory requirements on September 26, 2014.

(1) Basic Design for Earthquake and Tsunami

The standard seismic motions and basis tsunami were newly formulated from the seismological and earthquake engineering point of view on geology, geological structure, seismicity, etc. of the site and its surrounding area based on the latest scientific and technological knowledge and finding. The standard seismic motions and maximum water reaching level are shown in Table 4.

SSCs having important safety functions of JRR-3 can keep their functions for seismic force due to the standard seismic motion, because they are designed with margin. In addition, they will not lose their safety functions even in the face of design basis tsunami. JRR-3 located at the altitude of 19 m prevents basis tsunami from directly reaching and intruding into them through land area.

TABLE 4: STANDARD SEISMIC MOTION AND BASIS TSUNAMI.

Standard Seismic Motion	Horizontal	7.96 m/s^2
	Vertical	5.77 m/s^2
Maximum Water Reaching Level		+13 m (sea water level)

(2) Evaluation of Beyond Design Basis Accidents (BDBA)

The prevention of fuel damage and the mitigation of the consequences shall be achieved even if BDBA occurs. The postulated events for the BDBA are selected and evaluated as shown in Table 5. Alternative measures or alternative equipment are designed as functions required with sufficient reliability under environmental during postulated BDBA.

TABLE 5: EVALUATION OF BDBA.

Conceivable event		Countermeasure
Loss of shutdown function	2 control rods insert failed	If 2 control rods are not inserted, JRR-3 can be shut down with 4 other control rods.
Loss of cooling function	Loss of commercial and emergency power supply (BLACKOUT)	JRR-3 is shut down automatically and removes its decay heat by the natural cooling circulation.
	Primary cooling water leakage (LOCA)	We can supply the reactor pool with alternative water by using mobile injection pumps, water injection lines or buckets.
Loss of containment function	Loss of emergency exhaust function in case of fuel failure accident	All ventilation equipment is stopped, radioactive materials are locked in the reactor building by the isolation valves.

(3) Other evaluations

- Natural Phenomena (tornados and Volcanic eruptions)

  Maximum wind speed of most powerful tornado in Japan is 92 m/s. The reactor building of JRR-3 would not be ruined by the tornado or flying objects.

  The nearest volcano is located 88km away from JRR-3. Safety functions would not be lost by the falling tephra (volcanic ash).

- Man-Induced Events (airplane crash and external fire)

  The probability of plane crash on JRR-3 is about 8.8×10^{-8} times/year. It is smaller than 10^{-7} that is reference value to require the design considerations.

  Even if forest fires or fires in neighboring factories occur, the temperature of an exterior wall would not be below allowable temperature 200 °C.

- Fire Protection

  Important cable e.g. signal cable, power supply cable and communication cable are flame resistant as a fire prevention.

- Internal Flooding

  Internal flooding that may take place within JRR-3 is caused by failure of equipment or piping, the operation of the fire protection system, or sloshing in the spent fuel pool or spent fuel pit. The safety function of shutdown system and cooling system will not be impaired by the internal flooding, even taking into account the secondary impacts. In addition, JRR-3 has a weir or a barrier to prevent water leakage from radiation controlled area.

- Communication Systems

  JRR-3 has a communications system that can convey instructions on operation, work, evacuation, etc. to all the people in JRR-3 from the control room or that can convey information of accidents to outside of JRR-3. In addition, the communications system have dedicated and diversified communication lines such as specific cable/wireless lines and satellite telephone, etc.

- Loss of External Power Supply

  When the power supply from off-site is lost, the reactor can safety be shut down automatically and the cooling after shutdown can be achievable by emergency AC power and natural circulation. If both off-site and on-site AC power are lost, the power for monitoring can be supplied by the emergency DC power of JRR-3.

- Radiation Monitoring

  The monitoring posts have emergency power to measure and monitor the concentration of radioactive materials and the dose rates during design basis accidents. And the transmission systems of the monitoring posts have diversity so that prompt countermeasures may be taken in case of accidents.

4. Conclusion

Damages by the earthquake have not impaired the safety of the JRR-3. Recovery work mainly for ground sinking has been carried out smoothly. The structure, systems and components needed for reactor operation have been checked to be reusable without major repair. We have

confirmed to conform to new regulatory requirements and have submitted an application document for re-operation. The over 10 review meetings were held by the NRA, and that is ongoing.