Multinational Design Evaluation Programme
Design Specific Common Position
APR1400 No 04

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Related to : APR1400 Working Group activities

COMMON POSITION ON IRRADIATION EFFECT ON THE APR1400 FUEL BUNDLE SPACER GRID STRENGTH

Participation

Regulators involved in the MDEP working group discussions:	KINS (South Korea), FANR (United Arab Emirates) and NRC (the United States)
Regulators which support the present common position	KINS (South Korea), FANR (United Arab Emirates) and NRC (the United States)
Regulators with no objection:	
Regulators that disagree:	

Purpose

To identify common positions among the regulators reviewing the APR1400 accidents and transients in order to:

1. Promote understanding of each country's regulatory decisions and basis for the decisions,
2. Enhance communication among the members and with external stakeholders,
3. Identify areas where harmonization and convergence of regulations, standards, and guidance can be achieved or improved, and
4. Supports standardization of new reactor designs.
5. Ensure fuel for new plant designs to have minimum risk of experiencing spacer grid crushing during seismic / LOCA transients.

Discussion

Operating experience regarding the effects of in-reactor service on fuel assembly component response to externally applied forces challenge existing regulatory guidance. Operating experience from US operating nuclear power plants and other relevant information show that the crush strength of fuel assembly spacer grids may decrease during the life of a fuel assembly; whereas, the review guidance currently used is based on an assumption regarding the combined effects of operating conditions on grid strength. It is assumed that the overall spacer grid crush strength would increase due to the irradiation induced material hardening. The latest information obtained by US Nuclear Regulatory Commission and elsewhere has shown that the irradiation hardening also relaxes the coupling between the spacer grid and fuel rods. The combined effects of hardening and relaxation could lead to the reduction of the crush strength of fuel bundle spacer grids throughout the life cycle of the fuel.

Although the issue is, in nature, not specific to the APR1400 design or to its fuel, regulators of the three member countries have extensively reviewed the effect of irradiation on the fuel bundle spacer grid strength on seismic / LOCA analyses and discussed with their reactor vendor, fuel manufacturer or licensee an approach for resolution. This paper presents the common position that has been established among Korea, USA and UAE.

Common position

The APR1400 design currently relies on the PLUS7 fuel assembly, which consists of 236 fuel rods and burnable rods, 4 guide thimbles, an instrument tube, 12 spacer grids, a top nozzle and a bottom nozzle. The fuel spacer grids are designed to withstand the impact force during the postulated design basis seismic event and loss of coolant accident so that CEA insertability and fuel bundle coolable geometry are maintained during such an event. Therefore, an evaluation of the spacer grid strength shall appropriately address the potential degradation of the spacer grid crush strength due to irradiation throughout the lifetime of a fuel bundle.

Consistent with the review guidance in use, the initial evaluations provided by licensee / applicant in support of the regulatory reviews in Korea, USA and UAE only contemplated BOL conditions. Regulators from the

three member countries therefore requested complementary demonstration of the structural adequacy of the PLUS 7 fuel assemblies during a seismic / LOCA at EOL conditions.
The methodology of demonstration approved by Korea, USA and UAE regulators included a series of tests on spacer grid and fuel assembly together with a re-analysis of the seismic/ LOCA response of the fuel based on licensed methodology. The methodology is described below:

1. Fuel assembly and grid tests

In order to obtain the dynamic characteristics of fuel assemblies and grids at EOL conditions during seismic / LOCA event, a number of tests are required on EOL grids and fuel assemblies. Since it is not possible to perform direct tests on irradiated grids and fuel assemblies, tests are carried-out on simulated EOL grids and simulated EOL fuel assemblies. EOL fuel assemblies are manufactured from BOL grids with an increased cell size to reflect the dimensions obtained from measurements in hot cell facility with irradiated grids.

1.1 Typical tests undertaken on simulated EOL grids include the following

- Static compression test to generate the static stiffness and static buckling load of the grids,
- One-sided grid crush test to determine the strength and coefficient of restitution of the grids resulting from grid to barrel impact
- Through-grid crush test to determine the strength of the grids resulting from grid to grid impact.

All tests being performed at room temperature, test results must be corrected to reflect operating temperatures

1.2 Typical test undertaken on simulated EOL fuel assemblies includes fuel assembly mechanical tests and flowing water damping test:

1.2.1 Fuel assembly mechanical tests

Due to the highly complex features of the fuel assemblies characteristics, a mechanical model of a fuel assembly is required for seismic and LOCA analyses in the core. This model shall have the equivalent characteristics as actual fuel assemblies. A number of static and dynamic tests are to be carried out to develop the BOL and EOL models:

- Fuel assembly lateral stiffness test, to verify the static lateral characteristics of the fuel assembly modes,
- Fuel assembly lateral free / forced vibration tests, to determine the natural frequencies and mode shapes.
- Fuel assembly lateral impact test, to simulate the fuel assembly to core shroud impact

1.2.2 Flowing water damping test

A series of flowing water damping test shall be carried out in order to measure the damping coefficients for the fuel assembly in flowing water conditions considering the actual operating condition.

2. Seismic / LOCA analysis

Due to irradiation effects, fuel assembly natural frequencies and grid crush strength are reduced at EOL conditions. By using the fuel assembly flowing water damping value (higher damping value) in seismic and LOCA analyses at EOL condition, it is possible to regain some of the margin lost due to irradiation effects.

A series of detailed analyses shall be performed to obtain the response of fuel assemblies to seismic and LOCA excitation. First, the seismic/LOCA responses of the reactor containment building and reactor coolant system (RCS) must be calculated, and then, the responses of the reactor vessel internals (RVI) will be determined using the motion of the reactor vessel from the previous RCS analysis. The response of fuel assemblies shall be analysed using detailed core models and core plate motion (CPM) which is obtained from the RVI structural analysis. Finally, the maximum responses from the detailed core analyses shall be used to evaluate the structural integrity of the fuel assemblies.

To predict the fuel assembly stress during seismic / LOCA events, a fuel assembly model is needed. This model shall be developed based on the results of the static and dynamic tests discussed above. As a result, the model will enable to obtain the axial and lateral loads as well as the deflection shape. From these results, it is then possible to evaluate the stress applied on various structural components of the fuel assembly.

The fuel assembly structural components, including four guide thimble and one instrument tube, shall support the axial and lateral loads occurring during seismic / LOCA events. The principle of the stress analysis method is that there is a direct relationship between the deflection shape of the fuel assembly core model and the stresses/strains in the fuel assembly structure for lateral deflections. Based on the analysis, the stresses of fuel assembly structural components shall be evaluated by using the deflection and axial loads on fuel assembly during seismic/LOCA events.

Conclusion

The methodology of evaluation described above has been reviewed and approved by regulators from Korea, USA, and UAE. It is the common position of the APR1400 Working Group that the application of this methodology is adequate in demonstrating that the PLUS7 fuel of the APR1400 would not experience spacer grid crushing during seismic / LOCA transients at EOL conditions.