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COMMON POSITION ON THE FUEL THERMAL CONDUCTIVITY DEGRADATION

Participation

Countries involved in the MDEP working group discussions:	South Korea, United Arab Emirates and the United States
Countries which support the present common position	South Korea, United Arab Emirates and the United States
Countries with no objection:	
Countries which disagree	
Compatible with existing IAEA related documents	

Multinational Design Evaluation Program

APR1400 Working Group

APR1400 Accidents and Transients Technical Experts Subgroup

COMMON POSITION ON THE FUEL THERMAL CONDUCTIVITY DEGRADATION

Purpose

To identify common position 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,
4. Support standardization of new reactor designs, and
5. Ensure new plant designs to have minimum risk of experiencing fuel failure due to the thermal conductivity degradation of fuel pellet with burn-up.

Discussion

The MDEP APR1400 Technical Expert Subgroup on Accidents and Transients has chosen to prepare a common position on the Thermal Conductivity Degradation (TCD) of nuclear fuel with the increase of fuel burnup. Although the issue is, in nature, not an APR1400 design specific one, this issue and the effect on safety analysis have been extensively reviewed among the regulators of three member countries and discussed with the APR1400 reactor vendor or licensee, KHNP/KEPCO, thus, a design specific common position applicable to the APR1400 plants and the related safety analysis can be established.

It is well understood that irradiation damage and the progressive buildup of fission products in fuel pellets by reactor operation result in reduced thermal conductivity of the pellets. However, it was known that this reduction in thermal conductivity with increasing irradiation was not included in some fuel thermal performance analysis codes because earlier test data were inconclusive as to the significance of the effect. This was issued as Information Notice 2009-23 by U.S. Nuclear Regulatory Commission (NRC). Measurements collected from an instrumented assembly at the Halden high-burnup experiment during the 1990s have indicated steady degradation in the thermal conductivity of uranium fuel pellets with increasing exposure. These data indicate a degradation of approximately 5 to 7 percent for every 10 gigawatt-days per metric tonne of exposure. NRC has stated that this reduction was not included in the codes approved before

1999 and that models that do not account for the effect of degradation are still used to perform safety analyses.

Licensees use a series of computer codes to calculate the plant response in the safety analyses they perform to demonstrate compliance with the regulatory requirements. The simulation of the fuel element is an integral part of the safety analysis. Within the analysis, the fuel pellet thermal conductivity model determines the rate at which heat is transferred from the fuel pellet, first to the gas gap, then to the fuel cladding, and subsequently to the coolant. A lower fuel pellet conductivity results in higher fuel temperatures at a given linear heat generation rate. Therefore, the analytical prediction of the fuel thermal conductivity will affect the results of several types of safety analyses. Any codes used for safety analyses that do not consider the reduction of conductivity may mischaracterize the expected plant performance.
A fuel rod performance code, FATES3B, has been used for APR1400 safety analysis, which did not include the degraded conductivity as a function of burnup. Therefore, an appropriate action is required to resolve the issue, especially to exclude any adverse effect from the use of the code for safety analysis including non-conservatism in prediction of fuel centerline temperature, cladding temperature, and peak local oxidation. This situation may be significant in realistic emergency core cooling system (ECCS) evaluation model.

In order to resolve the issue and to demonstrate the compliance with the acceptance criteria of ECCS evaluation model, the reactor vendor or licensee of APR1400 is developing a new model implementing the fuel thermal conductivity as a function of burnup and working for large break LOCA calculation. However, the action considering the TCD issue is being required since the existing codes were used in the current licensing calculations.

Background

Since the PLUS7 fuel has been commonly adopted in APR1400 and the maximum burnup of the discharged fuel at 60,000 mega-watt-day per metric-tonne-uranium (MWd/MTU) has been approved, the TCD issue should be resolved. For this resolution, there has been a minor difference between countries as discussed in the below section. As the result of these differences in different countries, MDEP participants have established a common position on high level regulatory requirements about the resolution of TCD issue.

Common position

The TCD issue needs an analysis and evaluation specific to the plant design and fuel design. The analysis should be done to determine the effect of the TCD on the existing analyses of accidents and transients of interest. The deterministic evaluation results related to the issue resolution can be further assessed according to country specific regulatory practices.

<u>General position</u>
For all anticipated operational occurrences (AOO) and design base accidents (DBA) of APR1400 in which the fuel pellet thermal conductivity was considered as an important factor, the degradation of the thermal conductivity with fuel burnup should be taken into account in an appropriate manner and in compliance with the acceptance criteria based on the evaluation should be confirmed.

Fuel rod performance with burnup

In this aspect, a new fuel rod performance code to calculate the burnup related phenomena should be used replacing the FATES3B code to provide the initial fuel rod condition of each accident and transient. The codes should have a capability to account the burnup effect and to predict the important parameters including, but not limited to, fuel and cladding temperatures and rod internal pressure. The specific material properties for the PLUS7 fuel pellet and ZIRLO cladding at a certain burnup state which have been currently used for APR1400 design should be implemented into the code. Also the uncertainties of the calculated parameters describing the initial condition including fuel and cladding temperatures, rod internal pressure, gap conductance, dimensions of pellet, cladding and gap should be evaluated.

Calculation of accident considering the burnup effect

The calculated initial condition of the fuel rod at a certain burnup together with the most relevant uncertainties should be consistently incorporated into the subsequent accident and transient calculations. The system thermal-hydraulic codes should be capable to describe the burned-down fuel behaviour by the important parameters. For the large break LOCA, the peak cladding temperature (PCT) and peak local oxidation (PLO) should be calculated accounting the uncertainties related to the burnup effect and other sources of calculation uncertainties.

Interim alternatives

As an interim alternative to the approach using a new fuel rod performance code capable of addressing the fuel burnup effect, an approach to add a penalty to the safety parameters such as PCT and PLO can be considered. The penalty should be determined to cover the effect of use of the code which did not address the degraded thermal conductivity and the scheme to determine the penalty is specific to the regulation of each country.

Regulatory Resolutions

For regulatory and licensing reviews of APR1400 in Korea and United Arab Emirates, a penalty has been imposed on the calculated PCT. The PCT penalty was conservatively derived from the calculation using the thermal conductivity data for the burned fuel of 30,000 MWd/MTU and the geometric condition of fresh fuel.

For the APR1400 Design Certification in United States, a penalty, based on the Halden test data, is imposed on the calculated fuel centerline temperature.

This completes the first version of the common position paper.