Applicability Review of Safety Function for Kori NPP Unit 1 after shutdown permanently

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1. Introduction

In 1978, Kori unit 1, which had been operating as the first commercial nuclear power plant in South Korea and contributed to the domestic economic growth for 40 years, was decided to be permanently shutdown (June 2015) in accordance with recommendation of the Energy Commission. Article 21 of the Nuclear Safety law requires operating license change for permanent shutdown. For this purpose, operating license change documents for permanent shutdown (operating technical specification, final safety analysis report and quality assurance plan) are required to be submitted. However, absence of experience in permanent shutdown, insufficient understanding of the difference between operating units and permanently shutdown units, and lack of detailed applicable law and guidelines all led to a great deal of difficulties in determining the direction of revising the documents that are required to be submitted. Most of all, whether to maintain the safety functions required for safety related structures, systems and components has become an important current issue. This is due to the change in the operating condition of the plant where all fuel is permanently unloaded from the core to Spent Fuel Pool (SFP) with the unit permanently shutdown. In this paper, the aim is to perform accident analysis for permanent shutdown of the Kori unit 1 and based on the results, to review if the safety functions would require to be applied to structures, systems and components (SSC) classified as safety class so that it could be used for exemption of design requirements such as single failure criterion and amendment of documents requiring submission for operating license change.

2. Methods and Results

The regulations for US and domestic 'safety functions' [1, 2] were investigated, and US permanent shutdown nuclear power plants and related EPRI and NRC documents [3, 4, 5, 6] have been reviewed. Based on the review results, the approach (to reviewing safety functions applicability) was determined, and new accident analysis for the existing design basis accident (DBA; FSAR, chapter 15) and beyond-DBA (loss of SFP cooling and inventory) was carried out for permanent shutdown of Kori 1.

2.1 Safety Function and Safety Class

The safety related SSC should perform at least one of the following functions [1]. The first is to ensure the integrity of the reactor coolant pressure boundary, the second is to shutdown the reactor and to maintain the shutdown condition, and the third is to prevent or mitigate the situation of concern that may lead to exceeding the offsite dose limits. These are referred as safety functions and they are a concept that considers DBA. The safety classes are assigned to the equipment of the reactor installations according to their safety functions and are classified as safety classes 1, 2 and 3 [2]. Among the safety class SSCs, no SSCs are considered as safety class 1 and 2 for permanent shutdown condition, but there exists those SSCs that are classified as safety class 3 in this condition (e.g. function of maintaining cooling for spent fuel stored in wet storage). Therefore, DBA and beyond-DBA accident analysis was performed to review whether the safety functions would apply to Kori unit 1 with consideration of the permanent shutdown condition.

2.2 Accident Analysis Results

Based on the accident analysis of DBA (FSAR chapter 15) for permanent shutdown, it was determined that most limited accident would be fuel handling accident (FHA) since most of the accidents are eliminated because all fuel is removed from the core. Dose assessments [7, 8] for exclusion area boundary (EAB), low population zone (LPZ) and main control room (MCR) revealed that the exposure limits would be satisfied without placing charcoal filter in service after 20 days from reactor shutdown, and thyroid exposure would be reduced below 1 rem after 60 days, indicating safety standards are met with sufficient margin.

Sensitivity Analysis of Air Conditioning System with Elapsed Time
(Condition in which the air conditioning system does not work)

Elapsed Time	EAB(rem)			LPZ(rem)		
	Thyroid	Gamma (Whole body)	Beta (Whole body)	Thyroid	Gamma (Whole body)	Beta (Whole body)
20 days	3.13e+1	9.82e-2[2]	2.01e-1	2.08e+0	6.53e-3	1.34e-2
25 days	2.04e+1	5.19e-2	1.42e-1	1.35e+0	3.45e-3	9.45e-3
30 days	1.32e+1	2.77e-2	1.11e-1	8.80e-1	1.84e-3	7.42e-3
34 days	9.373e+0[1]	1.69e-2	9.80e-2	6.24e-1	1.13e-3	6.52e-3
40 days	5.58e+0	8.33e-3	8.72e-2	3.72e-1	5.54e-4	5.80e-3
50 days	2.36e+0	2.95e-3	8.06e-2	1.57e-1	1.96e-4	5.36e-3
55 days	1.53e+0	1.96e-3	7.93e-2	1.02e-1	1.30e-4	5.28e-3
60 days	9.96e-1	1.42e-3	7.87e-2	6.63e-2	9.45e-5	5.23e-3
68 days	4.99e-1[2]	1.02e-3	7.81e-2	3.33e-2	6.81e-5	5.19e-3
90 days	7.50e-2	7.87e-4	7.76e-2	4.99e-3	5.23e-5	5.15e-3

[1] : Within Red Emergency limits. [2] : Within Blue Emergency 12 limits.

Sensitivity Analysis of Dose Evaluation on the Main Control Room

System	Condition of Analysis: Case	Decay Time (Elapsed Time)	Thyroid	Whole body	Remarks
HVAC operating	Comparative Data	Current FSAR	3.37 rem	3.73e-2 rem	
	Case 01	0 days	2.04 rem	2.26e-2 rem	Satisfied
HVAC not operating + Consider Decay + Apply ARCON96(Apply the latest spreading factor on the Main Control Room)	Case 02	0 days	139 rem	2.39e-2 rem	Excessed
	Case 03	10 days	57.9 rem	5.40e-3 rem	Excessed
	Case 04	15 days	37.7 rem	2.86e-3 rem	Satisfied
	Case 05	20 days	24.5 rem	1.52e-3 rem	Satisfied
	Case 06	30 days	10.3 rem	4.39e-4 rem	Satisfied
	Case 07	40 days	4.36 rem	1.32e-4 rem	Satisfied
	Case 08	50 days	1.84 rem	4.18e-5 rem	Satisfied
	Case 09	60 days	0.78 rem	1.40e-5 rem	Satisfied (Level of Natural Environment)
Acceptance Criteria			50 rem	5 rem	

Thus it was able to determine that if FHA were to occur, dose would be reduced to the extent that operation of Charcoal Air Purification System in the SFP area and Main Control Room Air Cleanup System that are used for mitigating exposure would no longer be necessary after 60 days from reactor shutdown. After permanent shutdown, all fuel is removed from the core and stored in SFP, and decay heat is reduced without additional generation of fission products.

The results [9] of new accident analysis (beyond-DBA) are calculations of available time needed for SPF level to decrease to 10 ft above the stored fuel (minimum level required for radiation shielding) which are as follows. The time available to take action in the event of loss of SFP cooling function after 10 days from reactor shutdown was 2.63 days with maximum evaporation rate of 2.19 kg/sec. For the case of SFP coolant inventory loss, the calculation showed that the time available to take action was 1.75 days with maximum evaporation rate of 2.19 kg/sec. Therefore the time available to take action for SFP coolant inventory loss was determined to be sufficient in resuming makeup to SFP. In addition, Kori Unit 1 has fixed makeup water supply source utilizing Refueling Water Storage Tank, Condensate Storage Tank and diesel-operated fire pump which can be used in the event of loss of SFP cooling. If all of these fixed makeup water supply are unavailable, mobile pump vehicle can be used as a makeup water supply.

Stress test for Kori Unit 1 revealed that in the loss of off-site power (LOOP) scenario, power can be supplied using backup diesel generator (manual startup) within 0.5 hour and if this diesel generator is inoperable, mobile generator vehicle can be used to supply power within 2 hours. Inability to supply power altogether would result in using diesel-operated fire pump to supply makeup water but if this was also rendered unavailable, mobile pump vehicle could be used to supply makeup water within 2.5 hours. All these could be achieved before fuel stored in SFP is exposed. Thus, in case of a beyond-DBA, approximately 5 hours are needed to supply power and makeup water to SFP before fuel stored in SFP is exposed.

3. Conclusions

3.1 Conclusions

The fuel handling accident (FHA) analysis showed that after 60 days from permanent shutdown, radiation dose for general public are reduced well below allowable limits even without placing heating ventilating and air conditioning system (charcoal filter) in service. This means that exceeding offsite dose limits is of no concern. Therefore, there are no SSCs classified as safety related after 60 days following permanent shutdown of Kori unit 1.

Furthermore, additional new accident analysis (beyond-DBA) concluded that 1.75 days (approximately 42 hours) are enough to employ actions to mitigate an accident by recovering power supply and on-site/off-site makeup water supply for loss of SFP cooling function. This available time will continue to increase over time following reactor shutdown.

This means that Kori unit 1 may maintain the safety functions until 60 days after permanently defueled condition where fuel is stored in SFP and after 60 days, these safety functions may not need be implemented. This brings changes in complying with design requirements including single failure criteria. Therefore, according to this accident analysis results, operating license change documents were revised and submitted to maintain one diesel generator for backup power supply and discard operating alternate alternating current diesel generators (AAC D/G). However, for those equipment that need be operational after permanent shutdown, inspections and tests will be performed in the equivalent manner as that of the operating units to maintain integrity in safe storage of SFP.

3.2 Limitations

Although the accident analysis performed for abovementioned DBA and beyond-DBA showed that implementation of the safety functions can be deferred after 60 day from permanent shutdown, there were limitations of moving beyond the Nuclear Safety and Security Commission (NSSC) Notice specifying current safety classes due to general public's acceptability following Daiichi Nuclear Power Station accident, lack of applicable law for permanent shutdown and lack of procedures

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