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Analysis of Regulatory Practices and Development of Regulatory Focuses on Passive Safety System

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Introduction

❖ Passive Safety Systems in Advanced New Reactors

- SMART100 in Korea
  - PRHRS(Passive Residual Heat Removal System), PSIS(Passive Safety Injection System), ADS(Automatic Depressurization System), CPRSS(Containment Pressure and Radioactivity Suppression System)
- NuScale in the United Sates
  - DHRS(Decay Heat Removal System), ECCS(Emergency Core Cooling System), NSSS(Nuclear Steam Supply System), Containment Vessel

❖ Regulatory Guidelines for Passive Safety System

- Emerging regulatory demand for the review of passive component and system
- KINS/RG-N07.12 [피동형 안전계통 설계 규제지침] was published at KINS in 2021, which was based on what had been discussed in the course of licensing for AP600 and AP1000.
- KINS/RG-N07.12 provides as follows:
  - Definition of terms of passive safety system – passive component, safety function, passive system, and passive safety system;
  - The endorsed technical standards;
  - The regulatory potions to the safe shutdown, single failure criteria, and In-Service Test.

❖ Motivation for the Present Study

- The regulatory guidelines need to be improved and to provide more specific regulatory positions as embracing up-to-date global regulatory focuses or discussions on newly emerging advanced reactors and SMRs with a wide variety of passive safety systems.
- In the present study, regulatory focuses applicable to domestic safety review on the passive safety system are identified over the through analyses on up-to-date international regulatory practices, as a part of the scope of the research project titled as "Study on Validation of the Consolidated Safety Analysis Platform for Applications of Enhanced Safety Criteria and New Nuclear Fuels".

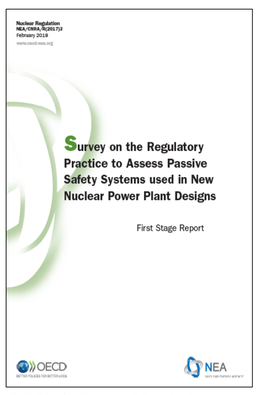
Analysis on Regulatory Practices

❖ Global Regulatory Practices

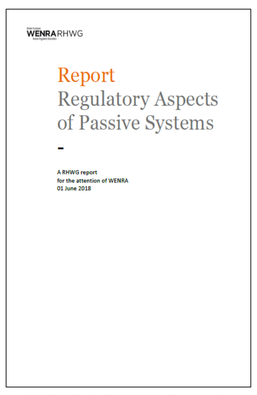
- To understand global regulatory practices on the passive safety system well, it is necessary to review individual country's regulatory practice. However, it is very formidable job to do so, therefore, we choose two recently published reports from international organizations

❖ Regulatory Practices of International Organizations

- OECD/NEA-WGRNR (Working Group on Regulations of New Reactors at Organization for Economic Co-operation and Development/Nuclear Energy Agency) and WENRA-RHWG (Reactor Harmonization Working Group at Western European Nuclear Regulators Association) have published the reports to share member stats' regulatory positions and practices and to improve the regulatory assessment of the passive safety system.
- The two reports deal with some of the key features of the passive system that the regulator should carefully review.



<OECD/NEA-WGRNR Report>



<WENRA-RHWG Report>

❖ OECD/NEA-WGRNR Report

- At the 15th Meeting of the Committee, WGRNR agreed to initiate a survey on regulatory practice to assess passive systems used in new nuclear power plant designs. Survey questions were grouped into five chapters:
  - Requirements for passive safety systems;
  - Testing and analyses of passive safety systems;
  - Regulatory review of passive safety systems;
  - Commissioning and periodic verification testing;
  - Experience with passive safety systems.
- We reviewed the report carefully and compiled seven regulatory practices needed to get our attention for the passive safety system over the active safety system. The summary of seven regulatory practices identified are shown below:

A. Use of Single Failure Criteria;
B. The Validation of Computer Codes and The Conduct of Testing Used to Demonstrate Safety Performance;
C. Concurrent Operation of Several Different Passive Safety Systems (Trains);
D. Concurrent Operation of Passive and Active safety systems;
E. Quantitative and Qualitative Analysis Results for Passive Safety Systems Reliability;
F. The Evaluation of The Impact of False Actuation (Starting) of Passive Safety System;
G. Commissioning And Periodic Verification Testing of The Passive Safety System.

❖ WENRA-RHWG Report

- The WENRA-RHWG report was prepared by experts from eighteen WENRA member states to supplement the safety reference levels applied to existing reactors for use in reviewing new reactors with wide application of the passive safety systems.

Analysis on Regulatory Practices (continued)

❖ WENRA-RHWG Report (continued)

- The WENRA–RHWG report consists largely of three safety assessment areas for the passive safety system review, which can be further divided into several smaller topics as shown in Table 1.

Table 1: WENRA–RHWG report contents

Area 1. Actuation of a passive system	Topic 1. Assessment of actuation of passive safety system Topic 2. Inadvertent actuation of passive safety system
Area 2. Performance of safety function	Topic 1. Specific range of conditions and consequences on safety analysis Topic 2. Performance demonstration Topic 3. Internal and external hazards consideration for passive system Topic 4. Consideration of human actions Topic 5. Probabilistic Safety Assessment
Area 3. Operating experience feedback	Topic 1. Implementation of operating experience feedback

- We have summarized the regulatory positions of the report into the eight major regulatory focuses as follows:

A. Assessment of Actuation of Passive Safety System;
B. Inadvertent Actuation of Passive Safety System;
C. Specific Range of Conditions and Consequences on Safety Analysis;
D. Performance Demonstration of Passive Safety System;
E. Internal and external hazards consideration for passive systems;
F. Consideration of Human Actions;
G. Probabilistic Safety Assessment;
H. Operating experience feedback.

Identification of Additional Regulatory Focuses and Their Evaluations

❖ Identification of Additional Regulatory Focuses and Their Evaluation

- From the analysis of regulatory practices in OECD/NEA and WENRA reports, we have drawn largely ten different areas of requiring additional regulatory focuses and developed evaluation plan for the regulatory focuses as follows in Table 2.

Table 2: Identification of Additional Regulatory Focuses and Their Evaluations

A1. Considerations for validation of performance E1. Are the coverage of the models and correlations included in the thermal-hydraulic system code appropriate for analyzing the target passive safety system? (Has the PIRT been prepared and used to evaluate the code?)
A2. Weak driving force E1. Has the safety analysis been performed, including the effects of non-condensable gas and system leakage? E2. Has the safety analysis been performed considering the effects of atmospheric heat sink (temperature)? E3. Has the safety analysis been performed considering the effects of the aging, such as reducing the diameter of pipes due to contamination? E4. Considering that the performance degradation of the passive safety system over time, has the safety analysis been conducted for a sufficiently long time to draw conclusions on the passive safety system performance? E5. Has the safety analysis been demonstrated that there is sufficient margin to avoid cliff- edge effects that may be caused by uncertainties included in the performance evaluation of the passive safety system? (The safety analysis should reflect the uncertainty in the factors that are expected to change in relation to performance and the potential causes of the change in that factor.)
A3. Operability E1. Considering the weak driving force of the passive safety system, is the appropriate check valve model used for the safety analysis?
A4. Internal and external hazards E1. Has the safety analysis been performed assuming the worst atmospheric heat sink conditions (temperature, humidity and particle concentration) after the accident? E2. Has the safety analysis been performed assuming that the temperature distribution of circulation loop of the passive safety system became the weakest condition to impede natural circulation due to fire? E3. Has the safety analysis been performed assuming that the piping shape of the passive safety system was deformed due to the earthquake and became the weakest condition to impede natural circulation?
A5. Reliability E1. Has the reliability model of the passive safety system been reflected assuming the root causes in consideration of functional failure?
A6. Simultaneous operation of multiple systems E1. Has the safety analysis been performed considering the effect of simultaneous operation of multiple (or multiple train) passive safety systems?
A7. Simultaneous operation of active & passive systems E1. Has the safety analysis been performed considering the simultaneous operation of the passive safety system and the active system (non-safety system)?
A8. Evaluation of the effect of malfunction E1. Has the safety analysis been performed considering the effects of malfunction and inadvertent actuation of the passive safety system?
A9. Considerations for human actions E1 Has the safety analysis been performed considering the effects of operator intervention and measures?
A10. Reflection of operating experience N/A

※ A: Area, E: Evaluation Plan for the Additional Regulatory Focuses

Summary

❖ The advanced reactor and SMR, which are recently being developed domestically or abroad, are widely adopting the passive safety system.

❖ Regulatory focuses applicable to the passive safety system are identified embracing up-to-date regulatory practices of international organizations, which are the reports of OECD/NEA-WGRNR and WENRA-RHWG in addition to the existing regulatory guidelines.

❖ We think that the results of this study can be used to resolve the performance and reliability issues of the passive safety system from the safety analysis perspective and for the development of the regulatory positions and the domestic safety review on the passive safety system.