Regulatory Perspective on ECCS Sump Blockage Issue

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1. INTRODUCTION

In the event of a loss-of-coolant accident (LOCA) of a nuclear power plants (NPP), piping thermal insulation and other materials in the vicinity of the break will be dislodged by the pipe break and steam/water-jet impingement. A fraction of this fragmented and dislodged insulation and other materials, such as paint chips and concrete dust, will be transported to the containment floor by the steam/water flows induced by the break and by the containment sprays. Some of this debris eventually will be transported to and accumulated on the recirculation sump suction screens in pressurized-water reactor (PWR) containment or on the pump suction strainer in CANDU-type reactor containment. Debris accumulation on the sump screen or strainers could challenge the plant's capability to provide a long-term cooling water to the emergency core cooling system (ECCS) and the containment spray system pumps [1].

The present paper summarizes the safety issue related to the sump blockage and its historical background, layouts the applicable regulatory guide to this issue, and briefs the current status in Korean NPP. Based on those aspects, a perspective on future regulation of the sump blockage issue is suggested

2. BACKGROUND AND ISSUE

Originally this issue was a part of containment emergency sump performance issue designated as Unresolved Safety Issue (USI) A-43 by United States Nuclear Regulatory Commission (USNRC) in 1979 and a huge amount of research effort had been devoted. Result of the USI A-43 study indicated that the sump screen blockage by the debris could be greater than 50 % that had been a basis on sump screen design and that air ingestion to the sump outlet could be protected by a proposed hydraulic design guide (Regulatory Guide (RG) 1.82 Revision 1 and NUREG-0897 [2] in 1982). Since then, however, a lot of boiling water reactors (BWR) have frequently experienced incidents of ECCS suction strainer clogging. Especially the event of Barsebäck Unit 2 in Sweden at 1992 revealed the debris behavior was under-estimated using the previous guide and that the more extensive and systematic researches were needed to reach a reliable design, which resulted in a world-wide study on BWR strainer clogging issue [1]. For the potential to PWR sump blockage, Generic Safety Issue (GSI) 191 study was also conducted under sponsorship of USNRC, which were to find a reliable prediction of the debris behavior for the various insulation materials and sump designs including unidentified phenomena such as thin-bed-effect. Results from the study have been available since 1998 including huge amount of experimental data of head loss across the debris beds [3]. The RG 1.82 was also changed to Revision 3 (Nov. 2003) such that emphasize more conservative consideration of the debris sources including latent debris, transport calculation, etc. [4].

Based on those studies and the related regulation on sump blockage, the issue can be summarized as follows :

(1) Source of debris: how much debris can be generated by LOCA in plants with various insulations and coatings?
(2) Debris transport: how much and which kind of debris (sizes, material, and shapes) can be transported in containment pool and be available to block the sump screen?
(3) Debris accumulation and Impact on Net Positive Suction Head (NPSH): how much the sump screen will be blocked by debris? what is the effect on hydraulic head loss by the debris bed?

3. APPLICABLE REGULATORY GUIDE

As described previously, the important result obtained from the various researches has been reflected in the USNRC RG 1.82 Revision 3. From the review of the RG 1.82 and supporting documents, the important features of debris source and generation includes

(1) Evaluation of the entire LOCA break spectrum
(2) Use of Zone-of-influence (ZOI) model in NUREG/CR-6224 [3]
(3) Analysis on various break location,
(4) Consideration of thin-bed-effect (NUREG/CR-6224),
(5) Consideration of all sources of debris including particulate materials within ZOI.

For the debris transport, the followings are emphasized:

(6) Basic element of transport calculation including buoyancy of debris and pool turbulence
(7) Consideration of debris type and size with decomposition
(8) Consideration of bulk flow velocity and hydrodynamic forces
(9) Use of CFD in NUREG/CR-6772 [5] or alternatives
(10) Credit of curb around the sump, and
(11) Conservative assumption in lieu of transport analysis.

For the debris accumulation and head loss, the followings are included:
(12) Consideration of available screen area and uniform distribution of debris (NUREG/CR-6224)
(13) Pump failure criteria
(14) Use of conservative head loss correlation, and
(15) Calculation of head loss for different combination of fiber and particulate.

4. CURRENT STATUS OF KOREAN NPP

Currently, 19 operating plants in Korea have sump(s) in their containments for a common purpose of ECCS recirculation. In general, five categories can be deduced from the review of sump and containment floor layout design: Category 1 (Kori 1 and 2), Category 2 (Kori 3,4 and YGN 1,2), Category 3 (UCN 1 and 2), Category 4 (KSNP), and Category 5 (CANDU-type plant). It was basically due to difference in timing of construction and difference in applicable design or regulatory guide. RG 1.82 Rev.1 was applied only to the KSNP's that started to construct in 1990's.For the insulation, tt is not easy to characterize the features of insulation and coating used in each plants due to the limited information. And it is not clear whether the systematic debris behavior analysis requested even in RG 1.82, Rev. 1 was carried out especially for the older plants.For those reasons, it is difficult to describe the status of the capability of Korean plants in terms of the elements in Rev. 3 of RG 1.82.

5. PERSPECTIVE ON REGULATORY DIRECTION

Based on the previous evaluation, it is found that the sump blockage issue is important to safety and that the applicable regulatory guide and technical standards are available. However it is seen that the plant specific capability of ECCS recirculation and/or vulnerability for the blockage are not clearly identified for the most of the Korean NPP. Thus one can conclude a preliminary evaluation is required prior to enforce the requirements of RG 1.82, Rev. 3 to the existing plants to get an idea on how much impact of the issue on safety in Korean NPP and how to resolve (hardware or software) if vulnerable. Such an evaluation can be used to determine the method of implementation (scope and depth) and its timing.

From the review of the available information, it can be concluded that the method of evaluation should be the followings:
(1) Collection of design information on containment layout, sump, insulation, coating, etc
(2) Survey of plant-specific design basis and supporting information
(3) Preliminary evaluation of debris generation (spherical ZOI model or alternative one)
(4) Survey of plant survey or walk-down to determine the latent debris
(5) Debris transport analysis (CFD and/or alternative method)
(6) Evaluation of debris accumulation and head loss (NUREG/CR-6224 or other method), and
(7) Evaluation of impact on NPSH.(RG 1.82 Rev. 3)

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