Identification and Assessment of Recent Aging-Related Degradation Occurrences in U.S. NPP

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1. Introduction

Aging-related degradation of structures and passive components (SPCs) is an important aspect in assessing the seismic safety of new and existing nuclear power plants (NPPs), especially in the process of periodic safety reviews and license renewal application reviews. To advance the related technology, KAERI and BNL are collaborating to develop seismic capability evaluation technology for degraded SPCs. As the first step in this multi-year research effort, to better understand the status and characteristics of degradation of SPCs in NPPs, degradation occurrences of SPCs in the U.S. NPPs were identified by reviewing recent publicly available information sources and the characteristics of these occurrences were evaluated and compared to the observations in the past. The aging characteristics considered in this effort included the component type, aging effects, aging mechanisms, identification method, evaluation method, plant name, date of occurrence, etc.

Ten categories of SPCs that are of high risk significance in Korean NPPs were identified, comprising of anchorage, concrete, containment, exchanger, filter, piping system, reactor pressure vessel, structural steel, tank, and vessel. The documents reviewed included the NPP Licensee Event Reports (LERs) for the period of 1999 to present, recent NRC generic communications (Generic Letters, Bulletins, and Information Notices), and recent license renewal applications (LRAs) for a similar period of time [1]. In this paper, only the results regarding a review of recent LERs are presented.

2. Reviewed Components

The ten categroies of SPCs selected by BNL and KAERI were established as a combination of a list of structure and components provided by KAERI and a list of 18 components reported in NUREG/CR-6679 [2]. Eight component categories from NUREG/CR-6679, namely the cable tray systems, conduit systems, cooling tower, electrical conductors, HVAC duct, insulation/seal, structural seismic gap, and water-control structures, are not included in this search effort because they are not considered to be risk significant according to the component list provided by KAERI. The ten categories selected for this study are as follows:

1. Anchorage
2. Concrete
3. Containment
4. Exchanger
5. Filter
6. Piping system
7. RPV (Reactor Pressure Vessel)
8. Structural steel
9. Tank
10. Vessel

3. Review of Recent LERs

A total of 223 DORs (degradation occurrence records) were identified from the LERs for the period of 1999 to the present (4/16/2008), including a few from 1998 as well. Figure 1 shows the distribution of the SPC degradation occurrences by component categories, with the number of the degradation occurrences annotated over the bars. As would be expected, the piping systems have the most degradation occurrences reported in the LERs, about 36% of the total DORs. Exchangers and RPVs have the next two largest number of degradation occurrences, representing about 22% and 17% of the total DORs, respectively. The other seven component categories represent less than 25% of the total DORs; they are vessels, filters, containments, structural steel, tank, concrete, and anchorage in descending order of the number of degradation occurrences. It should be noted that the number of degradation occurrences for a particular category is also a function of the quantity of components in that category that is present at a plant. So for example, the number of degradation occurrences for piping was expected to be large, because there are many piping systems at a NPP and many of these piping systems can be quite long.

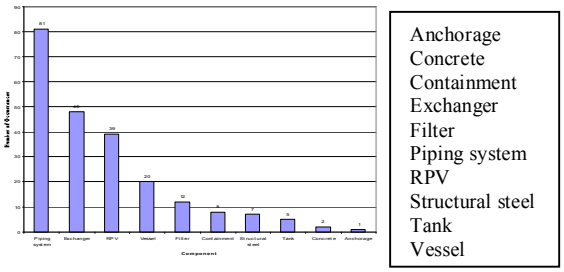

Figure 1 Distribution of SPC Degradation Occurrences over Component Category

Figure 2 shows the distributions of the degradation occurrences by components for three series of data: LER 1999-2008, NUREG/CR-6679, and LER 1985-1997, respectively. The bar chart is in the same order as reported in NUREG/CR-6679. Similarly, Figure 3 shows a normalized version of the same figure with the total numbers of DORS in each series as the basis. Considering LER 1999-2008 and NUREG/CR-6679, exchangers, piping system, and RPVs are the first three categories with the greatest number degradation occurrences. Since the piping system DORs for LER 1985-1997 were determined to be very large and did not include all of the occurrences in the NUREG/CR-6679 study, the actual number of DORs of piping system for LER 1985-1997 are artificially low. These figures also show that filters were the second largest category using LER 1985-1997. Both LER data series show that LERs do not report many structural DORs, especially containment, concrete, and anchorage.

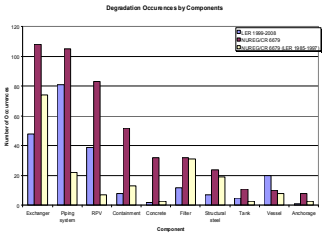

Figure 2 Distribution Comparison of SPC Degradation Occurrences over Component

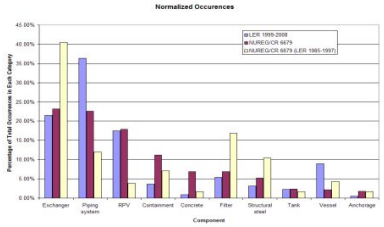

Figure 3 Comparison of Normalized Distribution of SPC Degradation Occurrences over Component

Figure 4 shows the distribution comparison of the SPC degradation occurrences over time, with the left figure showing the two series from NUREG/CR-6679 and with the right figure showing the series representing LER 1999-2008. First of all, the strong correlation over the years between the two series from NUREG/CR-6679 indicates that LER 1985-1997 represent a significant portion of the NUREG/CR-6679 data. Regardless of the partial years 1997, 1998, and 2008, the yearly DORs varies somewhat in cycles, which might correspond to inspection intervals that often are scheduled at refueling or are required by special NRC mandatory inspection requirements. On a yearly basis, there appear to be slightly more DORS from LER 1998-2008 than from LER 1985-1997. This observation may suggest that more degradation occurrences occured as plants are getting older, but may also be due to the differences in reviewing LERs.

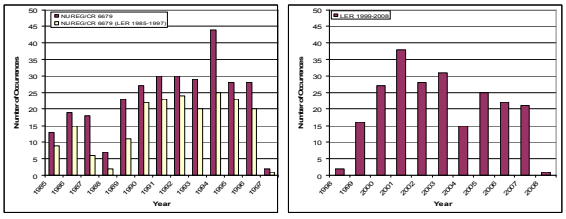

Figure 4 Distribution Comparison of SPC Degradation Occurrences over Time

4. Conclusion

A total of 223 recent DORs were identified for the ten component categories since 1999. Piping systems, exchangers, and RPVs have the most degradation occurrences reported in LERs, representing about 36%, 22%, and 17% of the total DORs, respectively. It was also found that LERs do not report a significant number of structural type components, such as containments, structural steel, concrete, and anchorages. However, this does not indicate in any way that structural degradations are of less significance to plant safety. The slightly higher degradation rate using more recent LERs reflects the fact that older plants show in general more degradation occurrences. Cracking was found to be the most predominant aging effect. Stress corrosion cracking was the most significant aging mechanism. The system that was most vulnerable to degradation is the reactor coolant systems.

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DISCLAIMER NOTICE

The findings and opinions expressed in this paper are those of the authors, and do not necessarily reflect the views of Brookhaven National Laboratory or the Korea Atomic Energy Research Institute.

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