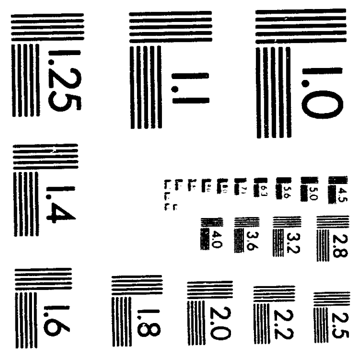
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GUIDELINES FOR SEISMIC QUALIFICATION BY EXPERIENCE IN ALWRs

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ABSTRACT

The methodologies and acceptance criteria for seismic qualification of equipment are provided in IEEE Std. 344 endorsed by the Nuclear Regulatory Commission (NRC) in the Standard Review Plan. The IEEE Standard allows seismic qualification by use of the similarity analysis method. Data available from past earthquake events or vibration tests can be used in this regard. The nuclear industry has collected a vast amount of earthquake experience and test data in the last decade, and is planning to use it for seismic qualification of equipment in advanced light water reactor (ALWR) plants. This paper discusses the existing data bases including their limitations and describes the ways these data bases can be used for equipment qualification in ALWR plants.

1.0 INTRODUCTION

Seismic qualification of a component demonstrates its ability to perform an intended function in a given vibratory environment. The science of seismic qualification provides reliable as well as cost-effective methods for implementation. The aim is to simulate the desired vibratory environment and operate the component to verify its functionality. The seismic qualification methods can be broadly divided into three groups: testing; dynamic and static analysis; and similarity analysis. In a test program, the component is tested under static or dynamic loads, and its performance is monitored. In a structural analysis, static or dynamic, a mathematical model is created to represent the component and the responses under the appropriate loads are analytically computed. In a similarity analysis, a component that has been already qualified (e.g., either by testing, or by dynamic or static analysis) is used as a reference and the target component is compared with the reference component to demonstrate similarity. The selection of one or more of the above methods depends on the qualification attributes such as functionality and structural integrity. The ultimate objective is to demonstrate that the component functions. For some components, a demonstration of structural integrity ensures their functionality. On the other hand, a component may be severely damaged but still performs its intended function. In order to avoid such occurrences, one may choose to demonstrate both functionality and structural integrity, especially since the damaged state of a component is extremely nonlinear and the functionality may not be repeatable. Thus, the selection and successful implementation of an appropriate qualification method depends on adequate knowledge of the use and function of the component.

So far in the above discussion, the term "component" has been used in a general sense such that either a structural member or an equipment item can be called a component. In a broader sense, the above discussion is equally applicable for a system which consists of a number of sub-systems or smaller items. An experimental program provides more reliable results but is typically more expensive than other means. Moreover, it may have limited use unless the results can be extended to other components. Thus, in an initial phase, an experimental approach is used, and when sufficient knowledge has been gained, the mathematical or similarity analysis method is employed. This has been the case with qualification of structural components. Basic parameters and validation of the analysis models are demonstrated by testing. Areas requiring further knowledge are still being addressed by testing (recent examples: validation of stiffness of shear walls, failure analysis of block walls, response in soil-structure interaction).

For the remaining discussions in this paper, the term "component" is used in a narrower sense to mean "equipment." Seismic qualification of equipment has been extensively performed in the last 25 years for nuclear power plants. A large number of dynamic test programs have been carried out using laboratory shake tables. On the other hand, several strong earthquakes occurred during this period and their consequences on equipment in industrial applications have been studied by the industry. This data base can also be used to verify seismic capability of equipment.

Recently, there have been several efforts to collect the existing test and earthquake experience data for nuclear power plant equipment [1,2]. Some of this information is currently being used for addressing seismic adequacy of equipment in existing older nuclear power plants under the scope of the NRC Unresolved Safety Issue A-46. An important conclusion of the above efforts is that certain equipment classes perform much better than others in a vibratory environment.

Currently, the industry is designing a new generation of reactors (Advanced Light Water Reactors or ALWRs) and attempting to use the experience data base for qualification of equipment in these plants. This paper discusses the strengths and weaknesses of these data bases, and describes the ways these data bases can be used for seismic qualification of equipment in ALWR plants. The approach that is employed to make use of an experience data base for qualification is the similarity analysis. Therefore, the method of qualification by similarity analysis is described first.

2.0 SIMILARITY ANALYSIS

An equipment item that is *similar* to one in the experience data base is expected to perform in a *similar* manner in a *similar* vibratory environment. In other words, if the equipment item can be shown to be similar to one that has successfully withstood a specified vibratory motion, it will be qualified up to that vibration level, typically measured in terms of a response spectrum. Thus, a similarity of both the equipment items and vibratory motions should be demonstrated.

For equipment similarity, a knowledge of the equipment design, its functional mechanisms, weak links and dynamic responses is required. The equipment mass, mass distribution, size, stiffness, model numbers, etc. are frequently used for comparison.

On the other hand, a demonstration of similarity of the vibratory environment requires knowledge of the damage potential of the vibratory motions. This is accomplished by comparison of the response spectra, power spectral densities, frequency contents, peak-to-RMS ratios, etc.

If both the above similarity comparisons are established, the "similar" equipment item is qualified for the "similar" vibratory environment. Any extrapolation of "similarity" beyond the above definition will require further justifications.

3.0 EXPERIENCE DATA BASES

The experience data bases can be grouped into three major categories according to their sources: past qualification, earthquake events, and equipment development. The relative strengths and weaknesses of each data base are further discussed as follows:

Past Qualification - This type of data base is available with EPRI, NRC, vendors and testing laboratories. The strength of this data base is that the vibration data have been controlled and monitored, and therefore are reliable. The weakness is that often not enough details of equipment are available in the qualification documents. This is especially true for data bases with EPRI, NRC and testing laboratories.

Earthquake Experience - EPRI and its consultants maintain a vast amount of earthquake experience data. The strength of this data base is that the information of equipment can be obtained to the desired details. Another attractive feature is that the data represent real earthquake events. But, the actual motion experienced by equipment in almost all cases is estimated and expected to be narrow-banded.

Equipment Development - As part of development of their products, the vendors most often performed testing that provides an in-depth knowledge about equipment performance including weak links. The vibratory motion is also well characterized. But, typically such information is proprietary to the respective manufacturers or vendors.

Regardless of the data bases, the following general observations can be made as a result of general discussions of these data bases available in the public domain:

- Certain equipment classes are by design simple *and* can sustain high seismic motions.
- For certain equipment classes, the weak links are well understood *and* the qualification levels are adequately known.
- Certain equipment classes are by design complex *and* sensitive to vibratory motions.

These observations provide the necessary inspiration for development of an approach for qualification by use of the experience data.

4.0 QUALIFICATION OF EQUIPMENT IN ALWR PLANTS

For ALWR plants, the experience data bases are given as described above but the equipment types to be qualified are unknown since they have not yet been designed and the design details are not known. Currently, the basic requirements for seismic qualification of equipment are documented in the IEEE Std 344 [3] and NRC Standard Review Plan [4]. In order to verify whether the experience data bases can be used for qualification of equipment in ALWR plants, the NRC has appointed an Expert Panel[1]. Using the following parameters, the Panel recommended categorization of equipment into three general groups and a graded approach for qualification of each group:

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[1]The Expert Panel consists of the author and Drs. Daniel Kana, Robert Kennedy and Anshel Schiff. The views expressed in this paper are not necessarily supported by other Panel members and the NRC.

- Excitation-related damage severity potential
- Degree of equipment malfunction sensitivity
- Uncertainty associated with identification of malfunction mechanisms.

4.1 Group 1 Equipment

The Group 1 equipment classes are those (a) that by design demonstrate sufficient resistance to seismic motion; (b) that are designed for special considerations, e.g., operating loads, mechanical vibration; and (c) whose function is insensitive to seismic motion. For this group of equipment, less rigors are required to demonstrate similarity of equipment and motion.

4.2 Group 2 Equipment

The Group 2 equipment classes are not fit for Group 1 categorization but their malfunction mechanisms are sufficiently known from past experience. A rigorous similarity analysis is required for this group with a particular emphasis on the malfunction mechanism.

4.3 Group 3 Equipment

The Group 3 equipment classes are not fit for Groups 1 and 2, and are typically complex equipment whose malfunction mechanisms are not well identified. Shake table testing or a combination of testing and analysis is the recommended qualification approach for this group.

5.0 RECOMMENDATIONS

The following are some general recommendations for the ALWR equipment design and qualification:

- Learn from past practices, e.g., design weaknesses and failure occurrences.
- Use broader data bases.
- Increase vendor participation.
- Eliminate past weak links with sound procurement specifications.
- Encourage known sound design practices through procurement specifications.

The single-most important point is that the industry should strive for improvement of products rather than expending resources on qualification of poorly designed equipment since unlike in the past the ALWR equipment can be procured as desired by writing appropriate specifications.

6.0 ACKNOWLEDGEMENTS

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REFERENCES

1. EPRI Report NP-5223, Rev. 1, "Generic Seismic Ruggedness of Power Plant Equipment in Nuclear Power Plants," February 1991.

2. Bandyopadhyay, K.K., et al., "Seismic Fragility of Nuclear Power Plant Components," NUREG/CR-4659, Vols. 1, 2, 3 and 4, 1986-1991.

3. IEEE Standard 344-1987, "Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations."

4. U.S. Nuclear Regulatory Commission Standard Review Plan NUREG 800, Section 3.10.

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