SEISMIC QUALIFICATION OF NUCLEAR POWER PLANTS BY INSPECTION

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SUMMARY

In Canada, seismic surveys of CANDU-PHW Nuclear Power Plants are now a pre-requisite to licensing. Such surveys provide greater confidence that nuclear plants can safely survive a Design Basis Earthquake.

In the U.S.A., there is no mandatory requirement for such surveys. However, such surveys have been used to qualify nuclear facilities where the original design did not consider current seismic design levels or methods of analysis. The paper considers the possible application of this approach to the seismic requalification of existing U.S. nuclear power plants for higher earthquake levels or analytical techniques different from those originally specified.

INTRODUCTION

In Canada, part of the licensing process involves the inspection of the entire CANDU Nuclear Power Plant in order to establish that the as-built, as-installed condition of the facility and its equipment can safely survive a Design Basis Earthquake (DBE). It is not only essential to examine the adequacy of construction of major structures, such as the containment building, but to ensure that all of the process and special safety-systems contained within the containment and associated service building are properly constructed and installed. In addition, it is essential to inspect for possible failure of or damage to safety-related structures or equipment from cascading effects due to collapse, failure or dislodgement of nearby structures or equipment not specifically designed for high earthquake resistance.

In the U.S.A., similar field inspections or seismic reviews have been used on a limited number of existing nuclear power plants (Dresden-2, Oyster Creek, Falisades, Ginna and Millstone station), to evaluate seismic backfit potential on the plant survey.

The seismic review was undertaken at the request of the U.S. NRC by a Seismic Review Team composed of recognized seismic design experts. The review by the Seismic Review Team was considerably different in scope and depth from current U.S. construction permit and operating license reviews, because it is designed to focus only on pertinent matters of significance in an effective manner, sufficient to identify safety issues and to provide

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an integrated and balanced approach to backfit considerations in accordance with current, applicable U.S. regulations. These regulations specify that backfitting will be required only if substantial additional protection can be demonstrated for public health and safety.

In addition to the application of such seismic review teams by the U.S. NRC, to a limited number of operating nuclear power plants, similar surveys have been performed on other types of nuclear facilities to permit seismic qualification for continued operation or start-up.

**SEISMIC SURVEYS**

In Canada, such an inspection program is called a 'Seismic Survey' and has the following purposes:

1. To ensure that all structures are built and equipment installed in accordance with drawings and specifications.

2. To ensure that there are no loose, unrestrained, improperly anchored, or inadequately constructed or reinforced systems or structures which could become a safety hazard in the event of a DBE.

3. To ensure, by proper inspection, that containment integrity will be preserved in the event of such an earthquake.

4. To determine that systems important to safety will preserve their safety function following a DBE.

5. To ensure that there is unobstructed access to areas essential for safe operation and maintenance of the Nuclear Power Plant (NPP) following a DBE.

The overall concern is for proper operation of safety-related systems and components during/after an earthquake and the risk of cascading effects from collapse or failure of unqualified systems affecting safety-related areas.

**Seismic Survey - Stages**

Ideally, a site seismic survey should be carried out when construction is well advanced, the plant is fully accessible, and construction platforms and the like are still in place. It is usually conducted in three stages, as follows:

1. A check by the Owner or major contractor that everything has been built and is in accordance with the drawings and specifications.

2. A follow-up site survey by a team of experts, not involved with the construction or installation of the plant, to provide an unbiased opinion as to the adequacy, not only of the construction and installation of the plant, but of its design and layout as well.

3. Finally, a follow-up survey involving the Owner, selected experts and, if possible, a representative of the regulatory body responsible for licensing the plant for operation.
Between each of these stages, suitable corrective actions, if any, are undertaken and reported. The final step is to have a representative expert or inspection team issue a statement to the Owner or licensee that the plant, when placed in operation, is in an acceptable condition to safely survive a Design Basis Earthquake.

**Previous Seismic Surveys**

Table 1 lists some of the seismic surveys which have been conducted. The requirement for such a survey as a pre-requisite for issuance of an operating license commenced with the Pt. Lepreau-1 NPP (See Fig. 1).

**Seismic Survey - Approach**

For the surveys conducted by outside inspectors, a suitably-expert team is assembled, including plant personnel with a wide knowledge of the plant layout and the purpose and function of each piece of equipment. This usually requires personnel covering at least mechanical, electrical and civil engineering disciplines.

The experts conducting the survey must have a good knowledge of the systems, items and functions important to overall plant safety. They must also be aware of the seismic design approach which has been applied to the plant and the earthquake accelerations which are expected at each level and in each part of the NPP. In addition to a thorough inspection of structures, systems and components and consultation with plant experts, some ad-hoc, in-situ vibration tests are conducted including:

- jumping, kicking, swinging from pipes and cable trays, striking pipes and components with a rubber mallet, twanging small tubes,
- pull-back or snap-back tests, shaking by hand, or setting a system into resonance by gripping it and swinging back and forth, using body mass only.

By this approach, it is possible to determine the approximate frequency characteristics, the maximum amplitude of vibration under low excitation, damping characteristics, areas of impact, missing or loose brackets, anchors and supports, and large amplifying effects in the system under test by excitation of attached equipment to much higher levels of motion. Where frequencies were high, amplitudes low or damping adequate, it was generally considered that the system had been well designed and properly installed. Where such ad-hoc tests and visual examinations were unsatisfactory, the adequacy of any suspicious structure or equipment was referred back to the designer, certain dynamic tests were called for, either in-situ or away from the plant, re-analysis or an alternative dynamic analysis was carried out or another opinion was sought, generally with reference to a similar, successful installation elsewhere.

**Seismic Survey - Problem Areas**

A number of problems were identified which made these seismic surveys particularly difficult. These included:

- installation of equipment and systems by a wide variety of suppliers
and sub-contractors with varying approaches; field runs of piping, tubing and conduits, cables, etc, by a number of sub-contractors, some of whom were following their own practices, rather than specific installation guides (including 'short cuts' which violated the Group 1 and Group 2 separation philosophy – see Fig. 2); field modifications made during construction or commissioning, which might not have received adequate seismic re-qualification.

75% of the problems disclosed were related to construction or installation errors or difficulties. At off-shore sites, some of the difficulties were related to the practices of indigenous contractors and the use of substitute materials and methods. There is no doubt that greater feedback between the designer and site during all stages of construction, installation and commissioning would avert many of the problems that were disclosed during some of these surveys. This, however, is particularly difficult to control at off-shore sites, which are far removed from the originating design office. In some cases, design concepts initiated by one consulting engineer were detailed by another and installation and construction carried out by still another group at the site. Interface control among the groups, would avoid many of the problems that were disclosed during the seismic surveys.

Seismic Surveys – Results

Table 2 gives examples of typical areas which were examined, the concerns which were expressed in relation to earthquake performance, and some of the proposed solutions. Not all of these were found in any one plant, but represent a typical range of findings and some of the actual solutions employed.

Advantages of a Seismic Survey

A Site Seismic Survey performed at an advanced stage of construction of an NPP, offers an excellent opportunity to perform an independent and overall evaluation of the plant design, layout, construction, installation, field modifications and general suitability for safe survival in the event of an earthquake. In addition, it provides excellent support to Probabilistic Risk Assessments which are carried out separately in conjunction with licensing activities; offers a chance to independently inspect for loose, missing or improperly-installed items of equipment; allows for simple but effective corrective actions to be undertaken at a time when important systems and equipment are readily accessible and there is sufficient time to carry out any necessary remedial actions.

In almost every case, the corrections, repairs, fixes or modifications which were proposed, as a result of such seismic surveys, were readily undertaken, in-situ, were generally inexpensive, and did not seriously affect the schedule for start-up of the plant.

The most important function of a seismic survey of a Canadian NPP is to permit certification of the plant from the safety standpoint in terms of seismic risk, as a definite pre-requisite for licensing such an NPP for operation.
CONCLUSION

The use of seismic survey teams, composed of recognized seismic experts, as a significant part of the seismic qualification procedure in nuclear power plant facilities in Canada and with limited application in the U.S. has been shown to be an extremely efficient and cost-effective method for developing overall assurance of seismic design adequacy. It is hoped that this favourable experience to date can be applied more broadly to nuclear-power-plant seismic qualification world-wide, as a means of reducing the design and/or analytical effort required and to better identify important interfaces and interactions which are essential for assuring overall nuclear safety.

REFERENCES


TABLE 1 - CANADIAN SEISMIC SURVEYS

<table>
<thead>
<tr>
<th>Name of Reactor</th>
<th>Location</th>
<th>Power (Mw(Gross))</th>
<th>Type of Survey</th>
<th>Date of Survey</th>
<th>First Power</th>
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<tbody>
<tr>
<td>Pickering-1</td>
<td>Ontario</td>
<td>542</td>
<td>Reactor vault only</td>
<td>1969</td>
<td>1971</td>
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<tr>
<td>Pickering-2</td>
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<td>Reactor vault only</td>
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<td>1971</td>
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<td>Bruce-1</td>
<td>Ontario</td>
<td>826</td>
<td>Walk through</td>
<td>1976 May</td>
<td>1977</td>
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<tr>
<td>Bruce-2</td>
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<td>826</td>
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<tr>
<td>Gentilly-2</td>
<td>Quebec</td>
<td>685</td>
<td>1st walk through</td>
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<td>Cordoba</td>
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<td>2nd full survey</td>
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<td>Wolsung-1</td>
<td>Korea</td>
<td>679</td>
<td>Full survey</td>
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3.3 Material Provisions