EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

1.0 PURPOSE

The purpose of this Technical Information Document (TID) is to provide procedural and technical requirements for evaluating safety related systems, structures and components (SSC) for seismic effects when SSC are subject to a temporary condition. These requirements are to ensure that temporary conditions are evaluated consistently, and that temporary condition evaluations are well documented.

This document also includes Exhibits A, B and C. Exhibit A describes the procedure; Exhibit B describes the methodology for developing this procedure. Exhibit C describes the methodology application to obtain site-specific parameters that are used in this procedure.

2.0 SCOPE

2.1 This document is applicable for planned temporary conditions at all Commonwealth Edison Company (CECO) nuclear stations. Station-specific information provided in work packages will be used to implement the procedure for each station.

3.0 REFERENCES

1. "NOD-MA.6 Requirements for Scaffold Erection and Barriers."

2. "ZAP 902-01, Zion Station Administrative Procedure, Use of Scaffolding and Ladders."

3. "QAP 1500-7, Quad Cities, Administration of Scaffolding; QAP 1100-12, Quad Cities, Screening; QCGM 307-01 Erecting Scaffolding."

4. "BAP 499-3, Byron, Station Requirements for Erecting Scaffolding and Ladders."

9408150292 940808
PDR ADOCK 05000237
P PDR

3.0 REFERENCES (Continued)

5. "LAP-900-28, LaSalle Station, Erection, Inspection, and Use of Scaffolding and Ladders."

6. "DAP 4-12, Dresden Station, Erection, Inspection, and Use of Scaffolding and Ladders."

7. "BWAP 400-21, Braidwood Station Erection, Inspection, and Use of Scaffolding and Ladders."

8. "Quad Cities Seismic Considerations for Scaffolds in the Vicinity of Safety-Related Components, Draft. November 1988."

9. "Primera Engineers, Ltd. Calculation 91-002 Rev. 3 Seismic Qualification of Scaffolding. Calculation 91-003 Rev. 1, 91-004 Rev. 2, and 93-001 Rev. 1."

10. "TID-MS-02 Seismic Analysis of Scaffolds, Rev. 0."

11. "OSHA Standard, 2A CFR part 1910.28 and 1926-451."

12. "Sargent and Lundy Calculation 8.35.0-9, Rev 2."

13. "Sargent and Lundy Calculation 8.11.7-1 Rev. 1, 1-28-94, Seismic Consideration of Temporary Structures in CECo BWR Units."

14. "Sargent and Lundy calculation 19.14.0.4 Rev. 1, 2-10-94, Seismic Consideration of Temporary Structures in CECo PWR Units."

4.0 DEFINITIONS

See Exhibit A

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

5.0 EXHIBITS

Exhibit A Procedure

Exhibit B Technical Methodology

Exhibit C Methodology Application to CECo Nuclear Stations

Authorized by: David L. Shamell
Nuclear Engineering and Technology Services Manager

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

PROCEDURE

TABLE OF CONTENTS

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

TABLE OF CONTENTS (cont'd)

LIST OF TABLES

LIST OF FIGURES

1.0 RESPONSIBILITIES

1.1 Procedure Development and Revision

The Mechanical/Structural Engineering Group is responsible for development and revision of this procedure

1.2 Procedure Implementation

This procedure will be used by M&S Group to determine seismic accelerations applicable for evaluation of the temporary conditions typically present at CECO nuclear sites. The existing nuclear station's procedures are adequate for documentation of temporary conditions.

The minimum information required for evaluation of temporary conditions are: start date, completion date, and the system/component impacted by temporary condition. As an alternative to work packages the stations may enter the information on the Electronic Work Maintenance System (EWMS) or equivalent in lieu of the Temporary Condition Evaluation Form , provided the same information can be searched and retrieved from these data bases. PRA/M&S is also responsible for searching and collecting the information on the Temporary Condition Evaluation Form from the EWMS or by logging the Temporary Condition Evaluation Form in the Station Temporary Condition Log. As a minimum, this log shall list the information similar to that in Figure 2.

2.0 DEFINITIONS

2.1 Temporary Condition

A temporary condition refers to planned changes to safety-related SSC or to erection of temporary structures near safety-related SSC in order to support maintenance/modification activities in the plant. Changes to SSC may be in the form of imposing masses/boundary conditions different from those used in design-basis evaluations.

Several examples of temporary condition follow:

- Rigging loads on in-place structural members
- Placement of lead blankets on components for temporary radiation shielding
- Removal of snubbers from a piping or component for purposes of testing and repair
- Erection of temporary structures to support specific maintenance/modification activities
- Freeze plugs to isolate piping segments

2.2 Temporary Condition Identification

Temporary condition is identified by reference to either the (SSC) item that it affects or by the safety related area in which it is present.

2.3 Planned Temporary Duration (PTD)

This is the planned time period (including appropriate contingency) for each identified temporary condition to be in effect to support maintenance/ modification activities. For a condition to be identified as temporary, PTD must be less than or equal to one year.

2.4 Start Time (ST)

This is the actual time when PTD begins. Start time can be any time during the year that is suitable to begin the temporary condition.

2.5 Planned Completion Date (PCD)

This is the first planned completion date of a temporary condition, i.e., PCD = ST + PTD.

2.6 Revised Completion Date (RCD)

This is any revised completion date, due to unforeseen conditions in planning the work, after work begins at ST.

2.7Actual Completion Data (ACD)

This is the actual time when the temporary condition ends.

2.8 Revised Temporary Condition Duration (RTD)

For any revised completion date, RCD, this is calculated as the difference between RCD and the Start Time, ST, i.e.,

RTD = RCD - ST

2.9 Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE)

For each CECO nuclear station, these design-basis earthquakes are given in the applicable Updated Final Safety Analysis Report (UFSAR).

2.10 Initial OBE and SSE Scale Factors for Temporary Conditions: SFO (OBE) and SFO (SSE)

Each OBE and SSE in-structure response spectrum is modified by a frequency-independent scale factor to obtain the seismic accelerations applicable to a temporary condition evaluation. Scale factors depend on the duration of temporary condition being considered. Initial scale factors are determined using duration equal to PTD.

2.11 Revised OBE and SSE Scale Factors for Temporary Conditions: RSF (OBE) and RSF (SSE)

These scale factors are determined using the revised duration RTD in place of PTD.

2.12 OBE and SSE Allowables

These are the force, displacement, and stress limits defined in the station-specific design criteria for the purpose of evaluating SSC for load combinations that include OBE and SSE.

2.13 <u>No-Seismic-Limit-Duration (NSLD)</u>

This is a time limit to define a very short-duration temporary condition. It applies only to the initial duration. If PTD is shorter than NSLD, seismic effects need not be evaluated.

When PTD of a very short duration temporary condition needs to be revised, as a minimum, RTD shall be taken as one month and scale factors corresponding to one month shall be specified.

3.0 PROCEDURE

3.1 General

Temporary conditions are in place for brief periods of time. Therefore, temporary conditions are less likely to be exposed to an earthquake of the same intensity as the design-basis earthquakes (OBE and SSE), specified for permanent plant installations. This procedure specifies duration-dependent scale factors to modify design-basis in-structure response spectra in order to evaluate temporary conditions for load combinations that include OBE and SSE. SSC are evaluated using the OBE and SSE allowables, in the UFSAR.

The scale factors specified in this procedure are determined so that the probability of exceeding the reduced seismic acceleration, within the temporary condition duration, is the same as the probability of exceeding the plant design-basis acceleration in one year.

The site-specific scale factors to be used with SSE allowables are summarized in Table A-1. The scale factors for OBE evaluation are given in Table A-2. Exhibit B describes the methodology used for determining the scale factors. Exhibit C summarizes the methodology application to determine the scale factors for the six stations.

The methodology assumes that the occurrence of seismic events is random in time, and separate events occur independently of each other -- a common assumption in seismic risk analysis. This implies any revision of the temporary condition duration, after the work has started, can be treated without regard to the consumed part of the previous duration. In order to avoid an intentional misuse of this concept, this procedure imposes a penalty by using durations cumulatively, if an extension of a temporary duration is required. For example, if PTD is two months and an extension of another two months is needed, a total duration of four months shall be used to determine the scale factors.

When the PTD is very short, the scale factors become small. This implies seismic event need not be considered for such a very short duration. Exhibit B discusses a basis for determining a duration limit -- No-Seismic-Limit-Duration (NSLD) -- in order to determine if the initial duration is very short. Table A-3 provides station-specific NSLD values in hours. Exhibit C describes methodology application to calculate NSLD. If the PTD of a very short duration needs to be revised, the revised duration shall be one month, as a minimum.

The PRA/MS engineers will review the work packages to obtain the duration, temporary condition type and location information for each application. If the information in the work packages is not complete,The PRA/MS engineers may initiate and complete the Temporary Condition Evaluation Form , shown in Figure 1. Upon completion of this form, PRA/MS engineers log the temporary condition in the station specific Temporary Condition Log Form.

Figure 2 provides the minimum information that should be included in the log form for each Temporary condition.

The following section provides instructions for Temporary Condition Evaluation Form.

3.2 Instructions for Temporary Condition Evaluation Form (TCEF)

This section contains instructions for Sample Temporary Condition Evaluation Form. If a station specific form is used, the instructions provided in this section shall be used as a guide to fill out such form. A Sample Temporary Condition Evaluation Form is provided in Figure 1. Upon completion of temporary condition, PRA/MS engineers will enter the information in the Temporary Condition Log and will file the TCEF.

he Temporary Condition Evaluation Form contains Sections A through J. Guidance for ompleting these sections are given below:

Section A - Description of Condition

This information is obtained from the Work Request that identifies the maintenance/modification activity requiring temporary condition evaluation.

Section B - Location

This information is obtained from the Work Request of the activity being planned.

Section C - Work Schedule

This information is obtained from the Work Request of the activity being planned.

Section D - Selected PTD

Planned temporary duration (PTD) is a basic parameter. A realistic upper bound value, including any contingency, should be used to establish this parameter, considering the nature of the planned work and its schedule.

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

Section E - List Scale Factors for PTD

The scale factors for SSE and for OBE, i.e., SFO (SSE) and SFO (OBE), are obtained from Tables A-1 and A-2, respectively, by entering these tables with the planned PTD between 1 month to 12 months. Linear interpolation between tabulated information can be used, if necessary.

If using Table A-3, PTD is found to be very short, use SFO (SSE) and SFO (OBE) equal to zero. For values of PTD greater than NSLD but less than one month, use values from Tables A-1 and A-2 for PTD = 1 month.

Section F- Start Time (ST)

This is the actual start time of the temporary condition. For example, if a sling is used to lift a valve, the Start Time corresponds to the clock time that the valve is lifted.

Section G - Planned Completion Date (PCD)

This is computed by adding the planned temporary duration (PTD) to start time (ST) of the temporary condition

Section H - Revision of Completion Date

Unforeseen conditions in planning may require revision(s) of completion date. For each revised completion date (RCD), one line in the Duration Revision Log shall be completed. Note that the revised temporary condition duration (RTD) is calculated from the following equation:

RTD = Greater of (1 month) or (RCD - ST).

The following comment applies to this equation: One month serves the purpose of avoiding to consider a very short duration for the second time. If a temporary duration, based on PTD was considered to be very short with zero scale factors, any revision of duration shall be considered as at least one month.

Revised scale factors for SSE and OBE, i.e. RSF (SSE) and RSF (OBE), are calculated using Tables A-1 and A-2, respectively, by entering these tables with duration equal to RTD. Linear interpolation of tabulated information may be used, if necessary.

Section J- Actual Complete Date (ACD)

This is the actual time that the temporary condition requiring evaluation is completed. The ACD is entered to complete the Temporary Condition Evaluation Form. The MS or PRA engineer completes and files the Temporary Condition Evaluation Form. The MS or PRA engineer also enters the temporary condition information in the Temporary Condition Log Form, Figure A-2.

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

Table A-1

Values of Scale Factor for SSE

Duration PTD or RTD	Byron	Braidwood	Zion	LaSalle	Dresden	Quad Cities
12 months	1.00	1.00	1.00	1.00	1.00	1.00
6 months	0.78	0.77	0.67	0.77	0.77	0.82
4 months	0.65	0.64	0.53	0.64	0.64	0.71
2 months	0.45	0.46	0.39	0.44	0.46	0.53
1 month	0.31	0.33	0.26	0.34	0.32	0.38

Note:For SFO (SSE), use duration = PTD
For RSF (SSE), use duration = RTD

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

Table A-2

Values of Scale Factor for OBE

Duration PTD or RTD	Byron	Braidwood	Zion	LaSalle	Dresden	Quad Cities
12 months	1.00	1.00	1.00	1.00	1.00	1.00
6 months	0.67	0.75	0.70	0.74	0.76	0.73
4 months	0.53	0.59	0.55	0.62	0.60	0.59
2 months	0.40	0.45	0.27	0.41	0.43	0.41
1 month	0.26	0.33	0.11	0.20	0.33	0.32

Note: For SFO (OBE), use duration = PTD
For RSF (OBE), use duration = RTD

Table A-3

Values of No-Seismic-Limit-Duration (NSLD) (Hours)

Byron	Braidwood	Zion	LaSalle	Dresden	Quad Cities
72	72	72	72	72	54

Note: The actual No-Seismic-Limit-Duration (NSLD) (Hours) are higher for all stations except Quad Cities than shown above. For additional conservatism and consistency, the above NSLD values are recommended.

Figure 1
(Sheet 1 of 4)

Sample Temporary Condition Evaluation Form

MS or PRA engineer shall complete this form for each temporary condition identified in the work package. The acronyms in this form are defined at the end of the form.

A. Description of Condition: ______________________________

____

____

____

____

____

B. Location: ______________________________

____

____

____

____

____

Figure 1

(Sheet 2 of 4)

PLANNED:

C. Work schedule: ______________________________

D. Selected PTD for work schedule: ______________________________

E. List scale factors for PTD:

SFO (OBE) = ______________________________

SFO (SSE) = ______________________________

ACTUAL:

F. Start Time ST= ______________________________

G. Planned Completion Date (PCD):

PCD = ST + PTD = ______________________________

H. Extension of Completion Date

If PCD has to be extended, for each revision, fill out one line in the table below.
If no revision, complete Item J below:

Figure 1

(Sheet 3 of 4)

Duration Revision Log

Rev. No.	Revised Completion Date RCD	Reason	Revised Duration PTD (cumulative)	Revised Scale Factor RSF	
				OBE	SSE
1					
2					

Note: RTD = Greater of 1 month or (RCD-ST)

Figure 1

(Sheet 4 of 4)

J. Actual Completion Date (ACD):

Actual Completion Date: ______________________

MS/PRA Engineer: ______________________

Signature: ______________________

Date: ______________________

Definition of Acronyms in This Form

ACD	=	Actual Completion Date
PCD	=	Planned completion date
PTD	=	Planned Temporary Duration
RCD	=	Revised Completion Date
RTD	=	Revised Temporary Duration
RSF (OBE)	=	Station-specific revised scale factor for OBE, based on RTD. Use Table 2
RSF (SSE)	=	Station-specific revised scale factor for SSE, based on RTD. Use Table 1
SFO (OBE)	=	Station-specific scale factor for OBE, based on PTD. Use Table A-2
SFO (SSE)	=	Station-specific scale factor for SSE, based on PTD. Use Table A-1
SSC	=	Systems, structures, and components
ST	=	Start Time

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

Figure 2
Sample Temporary Condition Log

STATION:________________________ UNIT: 1____ 2____ 0____

Sequence#	Temporary Condition Evaluation Form	Actual Completion Date	Description	Total Duration

Prepared by: S. Bakhtiari
S. Bakhtiari
Senior Engineer

Reviewed by: R. Janowiak
R. Janowiak
Staff Engineer

Approved by: B. Rybak
B. Rybak
MS Design Supervisor

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

EXHIBIT B

TECHNICAL METHODOLOGY

The methodology used is described in the attached paper by M. Amin and L. V. Jacques.

SEISMIC LOADING FOR EVALUATION OF TEMPORARY CONDITIONS IN NUCLEAR POWER PLANTS

Mohammad Amin[1] and Lawrence V. Jacques[2]

ABSTRACT

A quantitative procedure for using available site-specific annual seismic hazard curves to determine the acceleration level for evaluation of a temporary condition of known short duration (several days or months in a year) is described. The results are relatively insensitive to the choice of hazard curves for sites in the eastern United States since the procedure depends on the shape of the curves rather than on the probability values. The use of the procedure for determining a short duration limit for not considering seismic effects as a load case is also described and the results obtained for a site are presented and discussed.

Introduction

Nuclear power plants are designed for two levels of seismic load: Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE). The design-basis qualification of components and structures considers resulting seismic effects in various combinations with other significant parameters, such as dead load, operation effects, and accident effects. Conditions of predicable short duration (several days or months) often require evaluation to support maintenance activities or modifications during refueling cycles. Examples are temporary rigging loads, placement of lead blankets on components for temporary radiation shielding, and modification of boundary conditions for testing and repair as in a steam generator snubber removal. Detailed structural analysis for full seismic effects on structures, systems, or components for temporary conditions can result in costly modification work. In order to properly account for such conditions, it is appropriate to include the duration effect on seismic load when structures and components are evaluated for a temporary condition.

[1]Engineering Supervisor, Structural Analytical Division, Sargent & Lundy, 55 East Monroe St., Chicago, IL 60603

[2]Associate and Senior Structural Project Engineer, Sargent & Lundy, 55 East Monroe St., Chicago, IL 60603

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

This paper discusses a quantitative procedure for considering the duration effect of short-term loads when seismic loading is being considered. The procedure uses available annual seismic hazard curves to obtain the acceleration level applicable to a prescribed load duration. The derived acceleration, expressed as a fraction of design-basis SSE or OBE acceleration, is relatively insensitive to the specific hazard curve, from among those available for use in this type of calculation. Approach and reasoning are also provided to determine a very short duration limit for not considering seismic as a load case. The implementation issues related to the procedure are also discussed.

Duration-Dependent Site Acceleration

The calculation of site acceleration as a function of a prescribed short duration utilizes site-specific annual hazard curves (plots of the probability of exceedance per year against peak horizontal ground acceleration). The availability of annual hazard curves for nuclear plant sites, the distribution function of site acceleration, and selection of an acceleration level from the distribution function are described below.

Availability of Annual Hazard Curves

Most nuclear plant sites in the United States have recently developed annual hazard curves available either because of studies related to their response to Individual Plant Examination for External Events (IPEEE) or because of resolution of the eastern seismicity issue related to the Charleston Earthquake. For sites east of the Rocky Mountains, the annual hazard curves are available from two sources:

- Lawrence Livermore National Laboratory (LLNL) Study (Bernreuter et al., 1989)
- Electric Power Research Institute (EPRI)/Seismic Owners Group (SOG) Study (McGuire et al., 1989)

Three items are noteworthy regarding the LLNL and EPRI/SOG hazard curves relative to this paper: (1) these curves were developed through extensive studies involving groups of seismicity and ground motion experts, and formal procedures for considering the experts' judgement; (2) both procedures used a Poisson process for the occurrence of earthquakes in each seismic zone; and (3) the hazard curves from these studies were used by the United States Nuclear Regulator Commission (USNRC) and the industry to formulate solutions to seismic issues in nuclear power plants (e.g., the USNRC used LLNL and EPRI/SOG curves to put 69 plants in the eastern United States into two seismic bins for the purpose of addressing the seismic portion of IPEEE).

Figure 1 shows seismic hazard curves for a specific site from LLNL and EPRI/SOG studies. It is well-known that for the same acceleration value, the probability of exceedance from the curves of the two studies vary widely. The procedure to be discussed depends on the shape of hazard curves rather than on absolute probability values. For this reason, the results tend to be less sensitive to the source of the hazard curve that is used in the calculation.

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

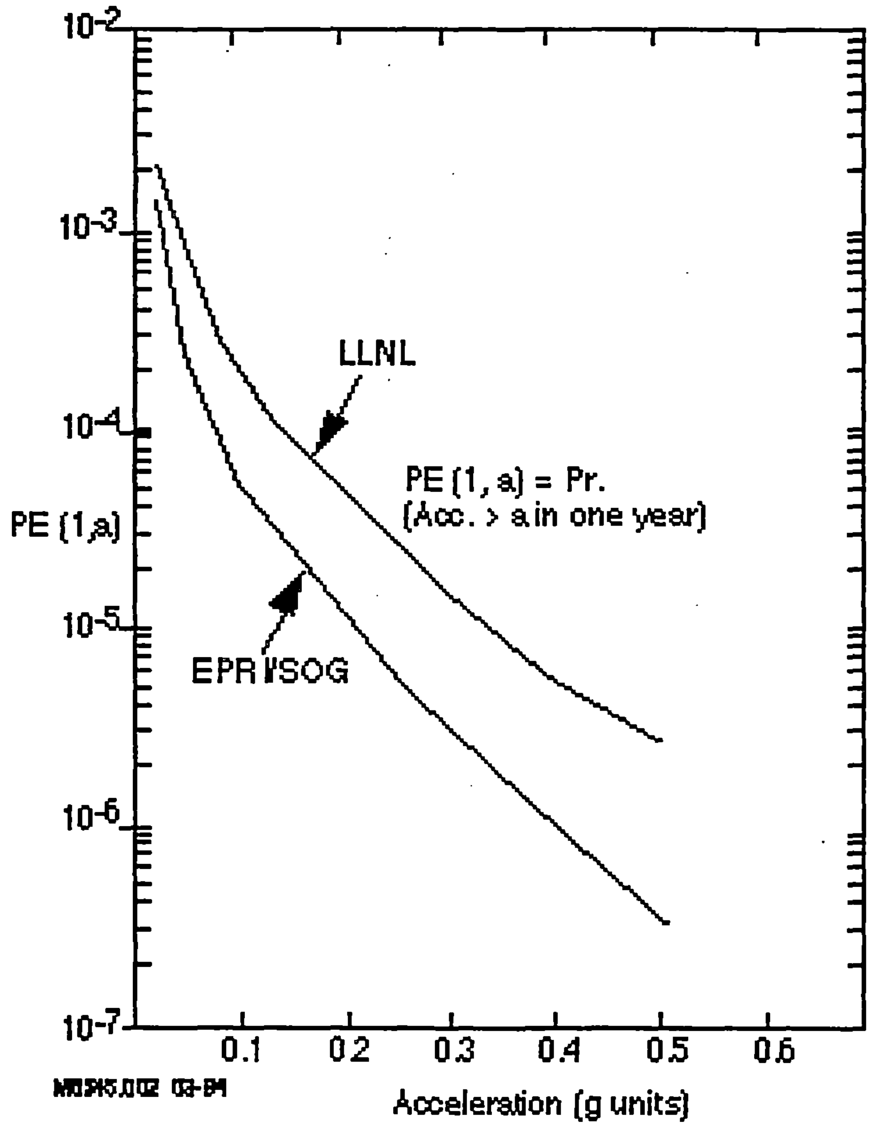

Figure 1. Sample median annual hazard curves for a site.

Distribution Function of Site Acceleration in t_d

Consider a short duration t_d (fraction of a year), and adopt the following assumptions:

1. Seismic acceleration at the site has a probability distribution function

$$F_A(a) = \text{Pr.}\,[A \le a] \tag{1}$$

where A = random site peak horizontal acceleration, a = a specific value of acceleration, and Pr. [.] denotes the probability of the event described within the bracket.

2. The earthquakes at the site occur in accordance with a stationary Poisson process at a yearly rate ν (average number of earthquakes per year).

Define duration-dependent hazard curve (PE) as

$$\begin{aligned} PE\,(t_d,a) &= \text{Pr.}\,[A_{max} > a \text{ within } t_d] \\ &= 1 - \text{Pr.}\,[A_{max} \le a \text{ within } t_d] \end{aligned} \tag{2}$$

where A_{max} = maximum site acceleration during t_d. Based on assumptions 1 and 2, the hazard function is (Cornell, 1968)

$$PE\,(t_d,a) = 1 - e^{-\nu t_d[1 - F_A(a)]} \tag{3}$$

Since νt_d = average number of earthquakes affecting the site in duration t_d (Cornell, 1968), it is usually much smaller than unity. Also since $F_A(a)$ is a probability distribution function, 1 - $F_A(a)$ is smaller than unity. It follows that

$$PE\,(t_d,a) \approx t_d\nu\,[1 - F_A(a)] \tag{4}$$

Equation 4 implies

$$PE\ (t_d,a) = t_d\ PE\ (1,a) \tag{5}$$

where PE (1,a) = annual hazard curve. Consequently, by specifying a short duration t_d as a fraction of a year, the duration-dependent hazard curve can be constructed by scaling the annual hazard curve according to Equation 5. Figure 2 shows hazard curves constructed from the

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

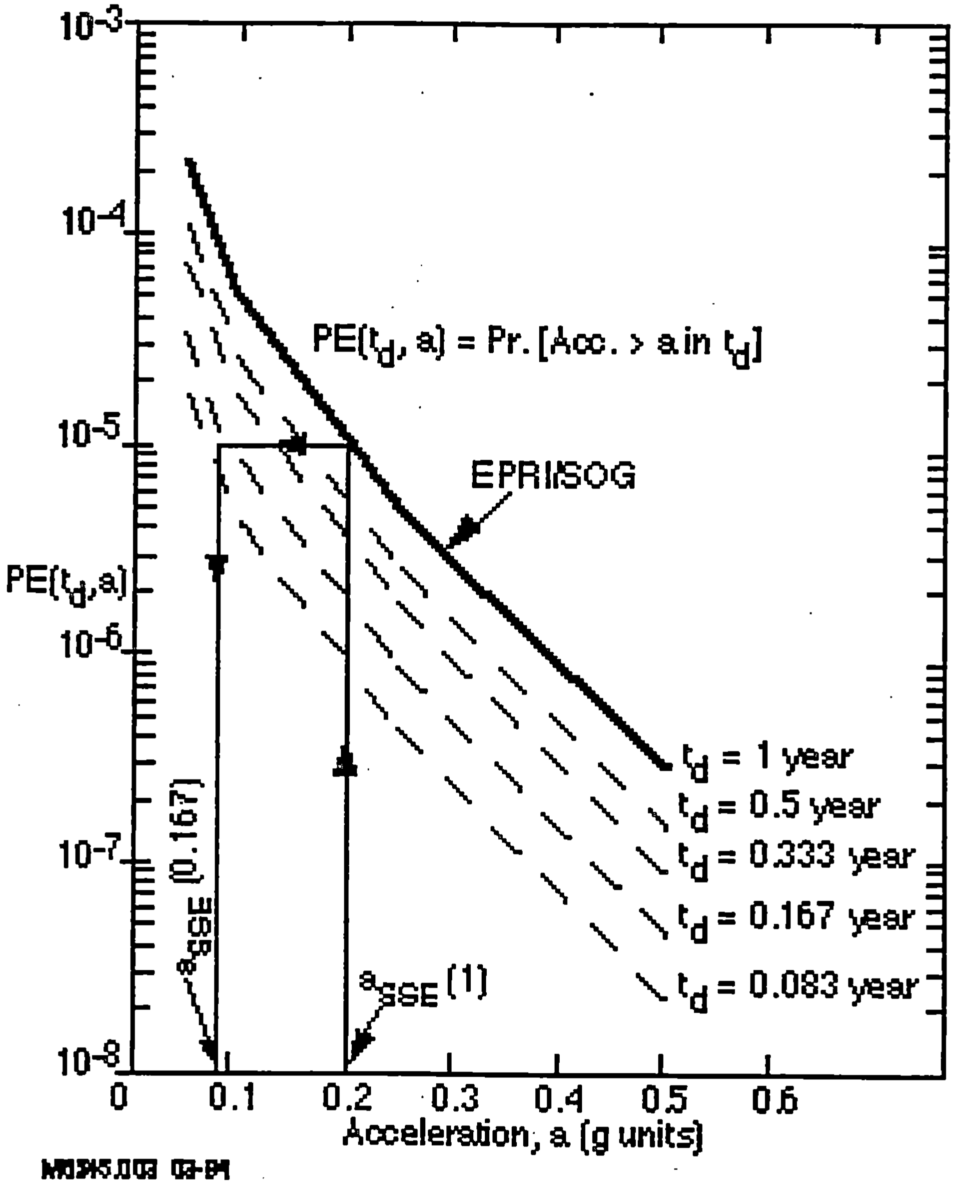

Figure 2. Duration-dependent hazard curves for EPRI/SOG curve in Figure 1 and construction of a_{SSE} (t_d) using a_{SSE} (1).

EPRI/SOG curve of Figure 1 for t_d = 0.5 (6 months), 0.333 (4 months), 0.167 (2 months), and 0.083 (1 month).

Site Acceleration for t_d

The specification of an acceptable probability level for selecting an acceleration from the hazard function and the choice of a unique hazard curve given this selected probability are controversial. In order to circumvent these difficulties, plant design basis accelerations [i.e., $a_{SSE}(1)$ = for SSE peak ground acceleration and $a_{OBE}(1)$ = for OBE peak ground acceleration] and their corresponding annual probabilities are used.

Consider $a_{SSE}(1)$, for example. Given a specific annual hazard curve, the ordinate at this acceleration, i.e., PE $(1,a_{SSE})$, yields the probability of exceeding this acceleration. Since the plant is *deterministically* designed for $a_{SSE}(1)$, it is logical to treat PE$(1,a_{SSE})$ as an acceptable probability of exceedance. This probability is used to determine $a_{SSE}(t_d)$ from the associated duration-dependent hazard curve. The construction for t_d = 0.167 is shown in Figure 2, assuming $a_{SSE}(1)$ = 0.2 g. The value of $a_{(SSE)}$ (0.167) is read as 0.09 g.

In summary, the acceleration value corresponding to short duration t_d (for SSE or OBE evaluation) is the acceleration value that will have the same probability of being exceeded during t_d as the design value [$a_{SSE}(1)$ or $a_{OBE}(1)$] has in one year. Note that a year is used as a base period because of the way hazard curves are now available to the plants. Any duration other than a year could be used for the base period. A more directly relevant value would be the duration of a refueling cycle. Any such choice is not expected to affect the results significantly.

Table 1 summarizes the ratio of SSE acceleration for t_d, $a_{SSE}(t_d)$, to SSE acceleration for one year, $a_{SSE}(1)$, for the two site hazard curves of Figure 1. For this comparison $a_{SSE}(1)$ = 0.2 g. Considering the appreciable difference in the ordinates of the two hazard curves in Figure 1, the acceleration ratios in Table 1 from the LLNL and EPRI/SOG are very close. This table shows the relative insensitivity of the procedure to the choice of LLNL or EPRI/SOG hazard curves.

$$t_d(0.02) = \frac{PE(1, a_{SSE})}{PE(1, 0.02\ g)} \quad \text{(in years)} \tag{6a}$$

$$= \frac{8760\ PE(1, a_{SSE})}{PE(1, 0.02\ g)} \quad \text{(in hours)} \tag{6b}$$

When Equation 6b is evaluated using $a_{SSE}(1) = 0.2$ g and the annual hazard curves in Figure 1, the resulting values of $t_d(0.02)$ are 69 hours for EPRI/SOG hazard curves and 206 hours for LLNL curves. The application of this procedure to the curves of several stations shows the following:

- The shortest duration is always calculated from the median hazard curves of EPRI/SOG.
- The calculated duration t_d (0.02) always exceeds 24 hours, which implies that a 24-hour duration is conservatively short enough so as not to require evaluation of seismic effects; duration longer than 24 hours may be acceptable at specific sites.

Justification for 0.02 g

Two generic justifications that support 0.02 g as being a low enough acceleration not to require a seismic evaluation are provided below.

Reference to Correlation of MM Intensity with Peak Ground Acceleration

Figure 3 shows correlation of Modified Mercalli (MM) intensities with peak horizontal ground accelerations provided by a number of investigators (Murphy and O'Brien, 1977). For intensity V, acceleration varies from 0.012 g to 0.07 g. For intensity VI, the corresponding acceleration range is from 0.024 g to 0.12 g. The 0.02-g ground acceleration is near the low end of acceleration for intensity V, and it is less than the low point acceleration for intensity VI. Recalling that intensity V shaking is felt and small unstable objects get displaced, but damage to structures or movement of large objects does not occur, it follows that 0.02-g acceleration is sufficiently low enough as to not require a

(6b)

When Equation 6b is evaluated using $a_{SSE}(1) = 0.2$ g and the annual hazard curves in Figure 1, the resulting values of $t_d(0.02)$ are 69 hours for EPRI/SOG hazard curves and 206 hours for LLNL curves. The application of this procedure to the curves of several stations shows the following:

- The shortest duration is always calculated from the median hazard curves of EPRI/SOG.
- The calculated duration t_d (0.02) always exceeds 24 hours, which implies that a 24-hour duration is conservatively short enough so as not to require evaluation of seismic effects; duration longer than 24 hours may be acceptable at specific sites.

Justification for 0.02 g

Two generic justifications that support 0.02 g as being a low enough acceleration not to require a seismic evaluation are provided below.

Reference to Correlation of MM Intensity with Peak Ground Acceleration

Figure 3 shows correlation of Modified Mercalli (MM) intensities with peak horizontal ground accelerations provided by a number of investigators (Murphy and O'Brien, 1977). For intensity V, acceleration varies from 0.012 g to 0.07 g. For intensity VI, the corresponding acceleration range is from 0.024 g to 0.12 g. The 0.02-g ground acceleration is near the low end of acceleration for intensity V, and it is less than the low point acceleration for intensity VI. Recalling that intensity V shaking is felt and small unstable objects get displaced, but damage to structures or movement of large objects does not occur, it follows that 0.02-g acceleration is sufficiently low enough as to not require a specific seismic calculation to show acceptability.

Reference to Threshold of Damage from Construction Vibrations

Wiss provides information on the threshold of possible damage to buildings caused by construction activities (Wiss, 1981). In terms of peak ground velocity, this threshold for residential buildings is 2 in./sec. The velocity threshold for commercial buildings is higher (4 in./sec). Values to correlate peak ground velocity to peak ground acceleration for seismic motions are 48 in./sec/g for competent soil and 36 in./sec/g for rock (Newmark and Rosenblueth, 1971). Combining this information to obtain a lower bound for damaging acceleration level yields

$$a_{\text{lower bound}} = (2 \text{ in./sec}) \div (48 \text{ in./sec/g}) = 0.042 \text{ g} \qquad (7)$$

This lower bound value justifies using 0.02 g as the acceleration level that requires no specific seismic qualification.

Implementation Issues

The following two issues are of particular interest when the described procedure is applied to the evaluation of a specific temporary condition.

Duration, t_d, and Start Time

A conservative duration (t_d) for each temporary condition should be estimated to preclude future reevaluation, should the anticipated duration of the activity be exceeded; this t_d should be used to determine the applicable acceleration for making the necessary evaluations. The start time of this duration can be any time in a given year or in a refueling cycle. Because the procedure is based on the Poisson process for occurrence of earthquakes and since the Poisson process is a memoryless process, if in a given application (due to unforeseen factors) the estimated duration expires before the work is completed, the evaluation remains valid for a subsequent duration equal to t_d. However, this Poisson assumption should not be misused by underestimating the duration t_d when the work is being planned.

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

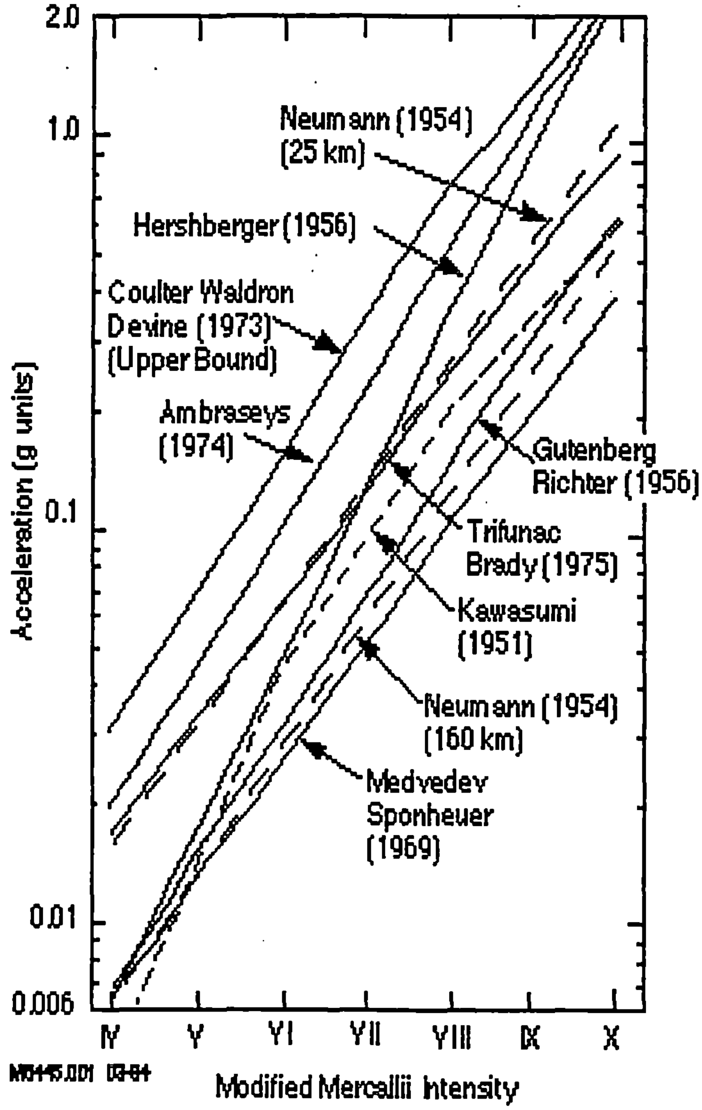

Figure 3. Selected intensity/acceleration correlations from Murphy and O'Brien, 1977.

Applicability of Poisson Assumption

As noted earlier in this paper, modern site-specific annual seismic hazard curves are determined by utilizing considerable expert studies and judgment. These studies all use the Poisson assumption as a suitable and convenient tool to provide data for engineering evaluations. The resulting hazard curves are considered to provide stable estimates of site seismicity. On this basis, using the annual hazard curves to consider duration-dependent acceleration seems to be reasonable without becoming concerned with the invalidity of the Poisson assumption during foreshocks and aftershocks of a main seismic event. It is presumed that significant changes in seismicity will be appropriately incorporated in the future seismic hazard curves.

Summary and Conclusions

This paper discusses a quantitative procedure for using available site-specific annual seismic hazard curves to determine an acceleration level for evaluating a temporary condition of known short duration (several days or months in a year). The plant design basis SSE or OBE acceleration is used to determine the acceleration for a short duration from the annual hazard curves. The results depend on the shape of the hazard curves rather than on absolute probabilities. The results are insensitive to the choice of hazard curves from LLNL and EPRI/SOG studies for sites in the eastern United States.

The specific results for a given site presented in the paper show that for the SSE conditions and durations of 6 months and 1 month in a year, the corresponding acceleration values are 0.77 and 0.33 times the SSE ground acceleration, respectively.

Given an acceleration level that is low enough as not to require a specific seismic evaluation, the use of the procedure is described to determine short-duration limits such that durations less than this limit do not require considering seismic effects as a load case. Generic information is presented to consider 0.02 g as a reasonable threshold under which detailed seismic evaluation is not required. For the example worked here, the "no seismic limit" duration is calculated as 69 hours. Studies with seismic hazard curves for several sites show that a 24-hour duration is a conservative duration for which seismic effects need not be considered as a load case.

Finally, two items of interest for implementing the procedure are discussed and recommendations for each are provided.

References

Bernreuter, D. L., J. R. Savy, R. W. Mensing, and J. C. Chen. "Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains," NUREG/CR-5250, UCID-21517, November 1989.

Cornell, C.A. "Engineering Seismic Risk Analysis," *Bull. Seismological Soc. of America*, 58, no.5, (October 1968): 1583-1606.

McGuire et al. "Probabilistic Seismic Hazard Evaluations at Nuclear Plant Sites in the Central and Eastern United States: Resolution of the Charleston Earthquake Issue," EPRI NP-6395-D, April 1989.

Murphy, J. R. and L. J. O'Brien. "Correlation of Peak Ground Acceleration Amplitude with Seismic Intensity and Other Physical Parameters," *Bull. Seismological Soc. of America*, 87, no. 33, (June 1977): 877-915.

Newmark, N. M., and E. Rosenbleuth. *Fundamentals of Earthquake Engineering*, Englewood Cliffs, N.J., Prentice-Hall, Inc., 1971.

Prepared by: NA

Reviewed by: R. Janowiak
R. Janowiak
Staff Engineer

Approved by: B. Rybak
B. Rybak
MS Deisgn Supervisor

Wiss, J. F. "Construction Vibrations: State-of-the-Art," *Proc. ASCE*, 107, no. GT2, (February 1981): 167-181.

EXHIBIT C

METHODOLOGY APPLICATION TO CECo NUCLEAR STATIONS

GENERAL

This Exhibit describes how the site-specific values listed in Tables A-1 and A-2 of for the scale factors and in Table A-3 for the No-Seismic-Limit-Duration were determined. The methodology used is that of Exhibit B. The use of specific annual hazard curves to obtain the scale factors and the No-Seismic-Limit-Durations is explained in detail in this Exhibit.

SCALE FACTORS IN TABLES A-1 & A-2

These scale factors are calculated using the station specific median annual seismic hazard curves of EPRI/SOG, Reference 1. The methodology of Exhibit B was used to calculate the information for all six CECO nuclear plants.

For each site, the annual seismic hazard curves are available from EPRI/SOG, and the Lawerence Livermore National Laboratory, LLNL 1993, References 1&2. Note that the LLNL data referenced here corresponds to the recent revision of LLNL curves.

The approach used to determine the scale factors depends on the shape of the hazard curves, rather on than the absolute values of the probability of exceedance. Therefore, as demonstrated in Exhibit B, Table 1, the use of specific hazard curves is not expected to significantly affect the value of scale factors for a given duration.

In order to further illustrate the above scale factor insensitivity, the mean and median annual hazard curves from Reference 1 and 2 for the Braidwood Station is considered. The determined scale factors from these curves for SSE evaluation are compared in Table C-1 for several values of the temporary condition duration, t_d. This table shows that the scale factors determined from different hazard curves are indeed close. The table also shows that the results from EPRI/SOG median hazard curves envelope the results from the other three hazard curves for each duration.

The scale factors in Table 1 were determined soon after the information in Reference 1 became available. In view of the relative insensitivity of the scale factors to the hazard curves, these earlier results have been retained in Tables A-1 & A-2.

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

NO-SEISMIC-LIMIT-DURATION(NSLD) IN TABLE A- 3

The NSLD values calculated using the methodology in Exhibit B, are more sensitive to the annual hazard curve being used than the scale factors. Table C-2 compares the NSLD values determined from the mean and median curves of EPRI/SOG and LLNL(1993).

If a single hazard curve of a seismic hazard study were to be used for a station, the mean hazard curve is more representative. This logic is used to select the results from the mean hazard curves. It is not, however, possible to discriminate between the EPRI/SOG and LLNL(1993) results for the mean curves. Practically, the smaller of the results from the two mean hazard curves for each site is considered. This approach leads to the results listed in Table C-3.

Considering the results in Table C-3, Table A-3 was formulated as follows: The NSLD is kept limited to 72 hours unless the station-specific value in Table C-3 is less than 72 hours. In this case the value from Table C-3 is used. For this reason, for five of the six CECO sites, Table A-3 uses NSLD of 72 hours. For Quad Cities the value of 54 hours is used.

REFERENCES:

1. McGuire, R. K., et al. "Probabilistic Seismic Hazard Evaluation at Nuclear Plant Sites in the Central and Eastern United States: Resolution of the Charleston Earthquake Issue", EPRI NP 6395-D, April 1989

2. Sobel, P., "Revised Livermore Seismic Hazard Estimates for 60 Nuclear Plant Sites East of Rocky Mountains", MUREG-1448, October 1993.

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

TABLE C-1

Comparison of Scale Factors SFO(SSE), Determined from Different Annual Hazard Curves (Braidwood Station)

Duration t_d (Year)	Mean Hazard Curve		Median Hazard Curve	
	EPRI/SOG	LLNL(1993)	EPRI/SOG	LLNL(1993)
1.000	1.00	1.00	1.00	1.00
0.500	0.75	0.70	0.77*	0.74
0.333	0.60	0.58	0.64*	0.61
0.167	0.42	0.36	0.46*	0.40
0.083	0.29	0.24	0.33*	0.27

* Envelopes values for the duration

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

TABLE C-2

Comparison of Values of No-Seismic-Limit-Duration (NSLD), Determined from Different Annual Hazard Curves (Braidwood Station)

Hazard Curve	NSLD(Hours)
EPRI/SOG, Mean	83
LLNL (1993), Mean	108
EPRI/SOG, Median	62
LLNL (1993), Median	81

EVALUATION OF SEISMIC LOADING FOR TEMPORARY CONDITIONS

TABLE C-3

Least Value of NSLD From the Mean Hazard Curves of EPRI/SOG and LLNL

Station	Byron	Braidwood	Zion	LaSalle	Dresden	Quad Cities
NSLD (Hours)	108	83	375	175	80	54

Prepared by: S. Bakhtiari
S. Bakhtiari

Reviewed by: R. J. Janowiak
R. Janowiak

Approved by: B. Rybak
B. Rybak
MS Design Supervisor

RPK
Robert P. Kennedy
Structural Mechanics Consulting
18971 Villa Terrace, Yorba Linda, CA 92686 • (714) 77

March 23, 1994

Mr. Darrell Taylor
Commonwealth Edison
1400 Opus Place
Suite 400
Downers Grove, IL 60515

Subject: Review of Report Entitled "Seismic Loading for Evaluation of Temporary Conditions in Nuclear Power Plants"

Dear Mr. Taylor:

As per your request, I have reviewed the Sargent & Lundy subject report.

I found this report to be excellent. I wholeheartedly support both the philosophy and the technical approach recommended therein. I concur that:

1. For conditions of predictable short duration (less than a few months per year), it is appropriate to reduce the design seismic loading so as to maintain a consistent annual probability of unacceptable performance.

2. If the reduced site acceleration is less than 0.02g, seismic evaluation is unnecessary.

3. Situations which exist for a cumulative time of less than 24 hours per year and which are not caused by a seismic event don't warrant seismic evaluation/design.

However, I wish to emphasize two cautions. First, the proposed approach is vulnerable to being misused. I have observed non-nuclear power industry situations where the duration of a condition has been underestimated and this underestimated duration was used to justify a reduced seismic design. Then at the end of this time, the memoryless aspect of the Poisson process was used to justify the continued lesser seismic design for an additional duration. Carried to an extreme, a condition could be estimated to last one day so as to justify no seismic design. At the end of that day it could be estimated to continue for another day. This subterfuge could conceivably be extended for years, each time invoking the memoryless aspect of the Poisson process. To win acceptance of the approach, I believe you need to insure that either realistic or conservative durations are used. Furthermore, there should be a penalty if the situation lasts longer than the estimated duration used to establish the reduced seismic design load. Users should not be allowed to invoke the memoryless aspect of the Poisson process. Based on our telephone conversation of today, I understand that you agree with this concern and that you are putting measures in place to address this concern.

Secondly, for an intermittent condition that occurs multiple times or is replaced by an equivalently hazardous condition, the duration to be used should be the total cumulative times per year that the condition or conditions exist. For example, if temporary rigging is moved around in the plant, the duration to be used for seismic evaluation should be the cumulative time per year that either this rigging or similar rigging is in critical locations, and not just the time that the rigging is at one location.

Again, with the above two cautions, I wholeheartedly support the proposed approach.

Sincerely,

Robert P. Kennedy

Robert P. Kennedy

DR. C. ALLIN CORNELL

P. O. Box 9260
Stanford, CA 94305

110 Coquito Way
Portola Valley, CA 94028
Phone/Fax: (415) 854-8053

April 25,1994

Mr. Darrell Taylor
Commonwealth Edison
1400 Opus Place
Downers Grove, Illinois 60515

Subject: Seismic Loads for Temporary Conditions

Dear Mr. Taylor:

I reviewed your March 23 submittal to NRC and the attachments.

For reasons I shall explain below:

1. I support the concept and, with the reservations to follow, the general levels of reduction of seismic load levels for temporary conditions.

2. The restrictions are:

(a) One should not <u>simultaneously</u> compromise (i.e., permit seismic capacity reduction of) safety-related components in both of the two dedicated seismic success paths* in the plant. Note that no restrictions need apply to components not contained in one of the two success paths.

(b) If, in any one calendar year, both success paths are compromised, the <u>total</u> or accumulated temporary duration of both paths shall be used in ascertaining the permitted reduction. For example, if each is compromised for two months, four months temporary duration shall be used.

(c) Effective management and review procedures should be implemented to control the application of this relaxation; the bases are subtle and could easily be misused.

---

*These are paths such as those that would be defined for IPEEE in an application of the EPRI Margins procedure.

(d) Both CECO and the NRC should consider whether there should be some lower limit placed on this reduction. One reason is that one might wish to place an upper limit on the frequency of exceedance of the reduced capacity during the temporary period. Such a limit might be, for example, 100 times the SSE exceedance frequency. If set at a low enough level, such a limit would interfere with the relaxation discussed in Item 3 below.

Note carefully the word "frequency"; this is a mean rate per unit time. For example, if the frequency of exceeding a 0.2g SSE is 10^{-5} per year, and the seismic criterion for a one month temporary condition is reduced to, say, 0.05g, the frequency of exceedance of 0.05g during this month increases to about 10^{-4} per year, even though the probability of such an exceedance during this one month is only about $(1/12)(10^{-4})$ or about 10^{-5}. Note, too, that during any one month period, the frequency of exceeding the SSE remains 10^{-5} per year, and the probability of exceeding it during that one month is 10^{-6}. While these may seem like obvious observations, they are critical to the discussion below.

To my knowledge, there is no precedent or theoretical basis for setting such a (short-term) frequency limit. Any suggestion I might make for a value for such a limit would be only a personal opinion. The question needs more consideration. Perhaps no limit is appropriate.

3. I concur that it is reasonable to recognize, without any required formal analysis, some minimum inherent seismic capacity of items such as temporary scaffolding, etc., and (within limits) of SSCs with temporarily altered supports, boundary conditions, etc. This capacity does imply to me (for reasons outlined below) that there can be some temporary duration such as a day to a week for which no formal analysis of the temporary seismic capacity need be required.

Without being personally familiar with the spectrum of such situations that arise during the operation of your plants, I am not prepared to categorically say, however, that there should not be at least a qualitative evaluation and judgment made by a "seismically sensitive" engineer. I am sure it would be cost-effective and operationally feasible to "pre-qualify" in a qualitative manner certain commonly recurring situations, and/or to prepare and provide written guidance to the engineer with respect to satisfactory and unsatisfactory examples and conditions.

As mentioned in Item 2(d), above, there is a potential for conflict if this presumed minimum capacity (e.g., 0.02g) corresponds to a spectrum reduction ratio (e.g., 0.02g/0.2g = 0.1) that is in turn associated with a "permitted" temporary duration (e.g., one week), that implies a temporary frequency of exceedance frequency) that is greater than the limit that might have been set under Item 2(d). Recall such a limit may not be appropriate. There is an inter-relationship, therefore, between the resolution of this limit and the possibility of permitting a consistent maximum duration (e.g., one day to one week) for which no quantitative seismic evaluation is needed.

DISCUSSION OF THE QUANTITATIVE REDUCTION BASIS: The basis stated for the determination of the accelerations (or SSE reduction factors) for durations shorter than a year is (top of page 2 of the March 23 submittal) "maintaining the same level of safety during a seismic event (sic) as the plant licensing design basis". I believe "during a seismic event" was intended to be "during a temporary condition". In any case, this "same safety notion has been interpreted (in your attachments 1 and 2) as maintaining the same probability of (reduced spectrum) exceedance during the temporary condition as the probability of SSE exceedance during one year. I do not believe this is a proper interpretation of "same safety". Quantitative safety goals associated with worker and public safety are stated in frequency (per unit time) terms. This interpretation is consistent, for example, with maintaining a given FAR (Fatal Accident Rate) or AIR (Average Individual Risk), which are common life safety measures (see Reference 1, attached). I also believe the frequency interpretation is consistent with the NRC Quantitative Safety Goals. Presumably the reason for looking at SSE exceedance frequencies as a basis for this reduction is because they are correlated implicitly with core damage and severe accident frequencies.

As stated above, the frequency of exceeding the SSE is constant no matter what the duration. The implication to me is that we must seek another basis for calculating the reduced, seismic accelerations for temporary durations. As confirmed by Reference 1 (the only reference I am aware of dedicated to the temporary duration problem), there is virtually no literature, research, or formal precedent addressing the problem (See, also

Reference 2, which calls for research on the topic). As both these authors suggest, one reasonable alternative safety criterion that permits such an acceleration reduction is a limit on time-averaged frequency. This permits temporary frequency increases to be averaged versus extended periods of smaller frequency. Because this approach does provide a formal basis for what makes good common sense, and because it has apparently not been worked through before, I will take the liberty of expanding on the notion below. The bottom line is that, for what seems to me to be reasonable assumptions, the acceleration reductions versus temporary duration are quite similar in numerical value to those proposed in the attachments to your submittal.

Some Calculations; Suppose we reduce the acceleration capacity from a_0 (the SSE level) to a_1 for a fraction t_d (e.g., 10%) of the averaging period* T. Then, $\overline{H}$, the time average frequency of exceeding the (varying level capacity) is

$$\overline{H} = t_d H_1 + (1-t_d) H_0$$

where H_0 is the SSE exceedance frequency (e.g., 10^{-5} in the example above) and H_1 is the frequency of exceeding the temporarily reduced capacity (H_1 might be 10^{-4}).

We might consider requiring that $\overline{H}$ be kept below some specified absolute value. But this value would be difficult to decide upon and the fixed value would lead to major variations in the permitted reductions because the SSE frequencies, H_0, vary rather widely plant-to-plant. Consider instead permitting an increase in the time-averaged frequency to $R \times H_0$, where R might be** 2 or 3. Then the temporary increase in H_1 would be

---

*The averaging period T might be one year (or perhaps longer). The longer the more relaxed the procedure. A long period could be justified if the compromising situation were done only once and if only off-site public living in the area (typically for 5 to 10 years or more) were considered. But on-site worker safety and the need to take advantage of the rule multiple times in the plant life suggest to me the one-year period is appropriate. This number deserves more thought.

**I shall discuss this number below.

$$H_1/H_0 = \frac{R-1+t_d}{t_d}$$
$$\cong \frac{R-1}{t_d} \qquad (for\ t_d<<1)$$

For example, if T = 1 year and R 2 and 3

Temporary Duration	t_d	H_1/H_0 R=2	H_1/H_0 R=3
6 months	1/2	3	5
2 months	1/6	7	13
1 month	1/12	13	25
1 week	1/52	53	105
1 day	1/365	366	731

The permitted temporary reduction in the acceleration capacity level can then be found by entering the annual hazard curve at level H_1 corresponding to t_d (and R). For example, in the EPRI/SOG median hazard curve shown in Fig. 2 of your attachment 1 to the March 23 letter, for $t_d = 0.167$ (2 months), the H_1 for $R = 2$ would be 7×10^{-5} and the temporary a_1 value would be about 0.10g (close to the 0.09g value the authors propose). Note that 0.10g is 50% of a_0, the SSE.

We can estimate the general implications of any proposal by assuming that the annual hazard curve $H(a)$ is of the form $H(a) = ca^{-k}$ (i.e., linear on a log-log plot) in the range of interest. Here that range is values between the reduced acceleration, a_1, and the SSE, a_0. (This assumed form has been used in may recent hazard-related studies; it more effective at the SSE and larger accelerations, but it serves here to obtain an estimate of the ratio of a_1/a_0 at least for values of that ratio of, say, 0.1 to 1.) For this assumption, it is easily shown that

$$a_1/a_0 = (H_1/H_0)^{-1/k}$$

or, combining,

$$a_1/a_0 = ((R-1+t_d)/t_d)^{-1/k}$$

Note the important conclusion that under these assumptions, the reduction depends only on the "slope" k of the (log-log) hazard curve. This slope has been found in recent DOE studies to be fairly stable site-to-site in the Eastern U.S. In this hazard range, a typical value might be 2.3. Then for R = 2 and 3, the following reductions would be permitted by this time-averaged frequency rule:

Temporary Duration	t_d	Reduction a_1/a_0 R=2	Reduction a_1/a_0 R=3
6 months	1/2	0.8	0.5
2 months	1/6	0.43	0.33
1 month	1/12	0.33	0.25
1 week	1/52	0.18	0.13
1 day	1/365	0.08	0.06

These a_1/a_0 values are, for R = 2, very close to proposed reductions you have shown me for several of your plant sites.

As for the appropriate value of *R*, there is again little guidance. DOE 1020 (formerly "15910") permits frequency increases of 2 for existing structures (subject to case-by-case review). I believe this is a reasonable number, especially because this component analysis basis does not explicitly account for the effect on the system. Subject to the "no simultaneous application" restriction (Item 2(a), above), the effect on system risk (e.g., core damage frequency, time-averaged now) will be less than that on the component. These statements about systems require some elaboration because they are the basis for my restrictions as well as for being less concerned about component (time averaged) frequency increases by factors of about 2.

It is not suggested the CECO conduct formal system PRAs to justify their proposed temporary reductions. I believe the quantitative basis for such reductions should continue to be the simple calculations like those above. A qualitative look at the system implications, however, is informative.

The EPRI margins procedure of focussing on two dedicated seismic success paths is very helpful here. First, it implies that the capacity reductions (frequency increases) on components not on these success paths have <u>no</u> effect on plant risk*. Second, it permits us to focus on these two paths, each containing multiple components necessary to its success. Assume for simplicity of the qualitative argument that each component, i, has common frequency, $f_i=f$, of failing due to an earthquake. Suppose there are n components in each path. Assuming (incorrectly, see below) independence of these failures the failure frequency of Path 1 (or 2) is about $\Sigma f_i=nf$. If we increase by a factor R the frequency of one component to $f_i=Rf$, then the path frequency increases to $(n+R-1)f$, an increase by a factor of only $(n+R-1)/n$. For $n=10$ factor is only 1.1 for $R=2$ (and 1.2 for $R=3$); this increase is at worst $(n-1)R$. This conclusion that the success path seismic failure frequency (or here time-averaged capacity exceedance frequency) will probably experience only a small increase if only one or a small fraction of its components are temporarily compromised (by degree R) remains true even for more realistic assumptions.

More realistically n is greater than 10, the frequencies are not the same, and the failures are not independent. This last assumption is the most critical. Indeed, due to the relative large variability in the (common) seismic load level, there is major "common cause" dependence. Therefore, the success path failure frequency is closer to the <u>maximum</u> of the f_i than to the sum. This implies a lower path frequency, but it also means that the effect of an increase by a factor R on a component's frequency <u>could</u> have a comparable increase on the path frequency, but only if that component's original frequency is at or near the maximum value of all the components in the path. If, incidently, the component in question is piping (e.g., if a temporary lead shielding load reduces the seismic capacity), the effect on success path frequency should be negligible because it is widely accepted that piping seismic failure frequencies are substantially less than those of other components. Altogether then it is clear that an increase by a factor R in the time-averaged seismic capacity exceedance frequencies for any one of the (or even multiple) components in a success path, will generally cause an increase of much less than R (closer to unity) in the corresponding success path frequency.

---

*This, is of course, not strictly true. Rather, one should say, it has no effect on the plant risk (or safety) as guaranteed by this two-path assessment. The actual plant risk is, of course, even less than the two-path basis. This actual risk is affected mildly by off-success-path component frequencies.

The situation is reversed, however, when one considers, not the multiple components in one path, but the two success paths. Using the original, naive assumptions above (for simplicity), if each path has failure frequency f, the frequency of seismic failure of the system of two parallel success paths is f^2 (assuming, recall, independence). In this case, an increase in a single path frequency by, say, R will cause a system failure increase to Rf^2, i.e., an increase factor equal to that of the path. But if both paths are compromised temporarily by a factor R, the system frequency increases to R^2f^2, i.e., by a factor R^2. Allowing for the actual lack of independence, the system failure frequency is not f^2, but perhaps 1.1f, i.e., slightly larger than the smaller of the two path frequencies. Therefore, increasing one (only) path by R will increase the system frequency to only, say, 1.03f. But increasing both will produce perhaps 3.1f. It is for these reasons that I believe that the no-simultaneous-path restriction (Item 2(a) above) should be instituted. With this restriction (especially after allowing for common cause dependence) we can say, again, that an increase of R on a component will have a significantly lessor effect on system safety. A proposed value of R of, say, 2 should be considered in this light.

Finally, with the time-averaged frequency basis, it is clear that one must accumulate the fractions, t_d, during the averaging period T, when making the allowances. For systems reasons discussed above, however, this accumulation need not apply (1) to components off the two success paths, nor (2) if there are multiple components compromised simultaneously on one path*. But the accumulation rule should apply to the total time either success path is compromised; hence the restriction in Item 2(b) above.

Yours very truly,

C. Allin Cornell

CAC:bb
Enclosure Reference Article (copy)

---

*Strictly, in the simple academic case, the path frequency will go up like $(n+m(R-1))/n$ where m is the number of simultaneously compromised components. More realistically in $\max(f_i)$ rule applies, however. Therefore, the effect is always R or less on the path.

Reference

[1] Vinnem, J.E., "Risk Acceptance Criteria for Temporary Phases", *Proceedings OMAE 1994*, Vol. II, pg. 1, ASME, NY, NY.

[2] Paté-Cornell, M.E., "Risk Management for Existing Energy Facilities: A Global Approach to Numerical Safety Goals", *Applied Mechanics Reviews*, 1993, ASME, NY, NY.

[wplet2.51\taylor.ltr]