Enclosure 1

SAFETY EVALUATION OF CONFIRMATORY ANALYSIS
DIABLO CANYON LONG TERM SEISMIC PROGRAM
STRUCTURAL AND GEOSCIENCES BRANCH

BACKGROUND

In Supplement 34 to the Safety Evaluation Report (SSER 34) for the Diablo Canyon Nuclear Power Plant (Ref. 1), the staff concluded that the licensee, Pacific Gas & Electric (PG&E), essentially satisfied all of the four elements of the license condition that led to the extensive seismic reevaluation program called the Long Term Seismic Program (LTSP). However, in reviewing PG&E's final report on LTSP (Ref. 2), the staff found that its estimates of the site-specific ground motion spectra exceeded PG&E's estimates over a part of the frequency range. PG&E performed preliminary evaluations and concluded that the plant seismic margin was not affected by such exceedances in the ground motion spectra (Refs. 3 and 4). The staff reviewed these preliminary evaluations and generally agreed with PG&E's conclusion. However, the staff stated in SSER 34 that PG&E should perform detailed confirmatory analyses to demonstrate that these spectral exceedances could be accommodated by the plant seismic margins that were reported in the LTSP Final Report (Ref. 2). In response to this requirement, PG&E performed the required confirmatory analyses to show that the overall plant seismic margin reported in Ref. 2 is not affected by the increased ground motion estimates made by the staff, and submitted the results of the confirmatory analyses for the staff's review (Ref. 5). The staff has reviewed the confirmatory analyses and its evaluation is provided below.

EVALUATION

In its confirmatory analyses, PG&E considered the LTSP 84th percentile site-specific ground motion augmented by the staff's estimated increases in certain frequency ranges. The simultaneous effects of both horizontal and vertical components of earthquake motions on the responses of the structures and equipment were considered in these analyses.

1. Analyses for Horizontal Spectral Amplitude Increase:

The LTSP horizontal acceleration spectrum (5% of critical damping) completely envelops the staff's (SSER 34) estimate of the corresponding spectrum at frequencies greater than 1 hertz (Hz), (Ref. 1). Below 1 Hz, however, the SSER 34 spectrum shows an increase in spectral amplitudes of about 10 to 20 percent over the LTSP spectrum. PG&E has determined (Ref. 3) that no essential equipment or components have natural frequencies below 1 Hz, and that only the sloshing modes of the outdoor water storage tanks have low frequency responses in the 0.2 to 0.4 Hz range. As a typical example of such outdoor tanks, PG&E analyzed the Refueling Water Storage Tank (RWST) and made revised fragility estimates, considering the increased ground motion effect on the tank sloshing mode. This analysis showed that the 84th percentile High-Confidence-of-Low-Probability-of-Failure (HCLPF) value was slightly reduced from 4.08g to 3.92g. Thus, the scale factor, based on the demand of 1.94g in the 3 to 8.5 Hz range (Ref. 1), is only slightly reduced from 2.10 to 2.02. Since the seismic margin of the RWST (which is a typical example of the structures affected by the increased ground motion at frequencies less than 1 Hz) remains high, the staff agrees with PG&E's conclusion that the overall plant seismic margin is not affected by the staff's estimate of increased ground motion at frequencies below 1 Hz in the horizontal direction.

2. Analyses for Vertical Spectral Amplitude Increase:

a) Equipment/Components

Figure 2.5 in Ref. 1 shows that the staff's 84th percentile vertical acceleration response spectrum (5% of critical damping) exceeds the corresponding LTSP spectrum in the frequency range of 1 to 10 Hz by about 15%. In May, 1991 (Ref. 4), PG&E provided a general discussion on the adequacy of plant seismic margins assuming an increase in amplitude of the LTSP vertical ground motion in the frequency range from 2 to 10 Hz. In response to the SSER 34 requirement, PG&E performed the necessary confirmatory analysis in which it used the following screening criteria to determine the equipment and components that were affected by the vertical spectral increases: 1) components having vertical natural frequencies in the 1 to 10 Hz range; and 2) components supported at locations where the structural floor slab vertical frequency falls within the 1 to 10 Hz. The following nine components were identified for evaluation based on the above screening criteria: 1) NSSS Piping; 2) Main Steam PORV; 3) Diesel Generator Fuel Oil Day Tank; 4) 4.16 kV switchgear; 5) 4.16 kV Potential Transformer 6) Safeguard Relay Panel; 7) Impulse Lines; 8) BOP Piping and Supports; and 9) Conduits, Cable Trays, and Supports.

Table 2 in Ref. 3 compares the revised median spectral acceleration capacities of the above equipment / components with the previously determined capacities. It is seen from that comparison that, except for the 4.16 kV switchgear, the others have sufficient seismic margins against the increased vertical spectral amplitude in the 1 to 10 Hz range. The 84th percentile HCLPF capacity of the 4.16 kV switchgear (in its functional failure mode) is 1.37 g which is less than the demand of 1.94 g. However, as stated in SSER 34, the functional failure of the 4.16 kV switchgear is recoverable by operator action, and therefore, the staff concludes that the increase in the vertical acceleration spectrum has no adverse impact on the seismic margin of the above components. (Note: PG&E has given only median capacities in Table 2 in Ref. 5 because it considered this table to be a supplement to Table 6.24 in the LTSP Final Report).

b) Structures and Structural Elements

b1) Structures

References 1 and 4 established that shear walls, which are primarily horizontal-earthquake resisting elements, control the seismic capacities of major civil structures at the Diablo Canyon power plant. These walls, being rigid in the vertical direction, have frequencies much greater than 10 Hz. Therefore, PG&E has concluded, and the staff agrees, that the seismic capacity of major civil structures will not be affected by the increase in vertical ground motion. However, parts of some structures, such as flexible floors and floor beams, may be affected by the increased vertical earthquake ground motion. The capacity of these structural elements is usually controlled by ductile bending behavior which is accompanied by a large inelastic energy absorption capability. Although such elements are highly unlikely to fail, it is necessary to evaluate the effects of increased ground motion on the supported equipment important to plant safety. On this basis, PG&E has identified two vertically flexible slab systems for analysis as discussed below.

b2) Structural Elements

Items 4, 5, and 6 of the nine components listed earlier that are affected by the increased vertical ground motion are supported on vertically flexible floor slabs having vertical frequencies less than 10 Hz. Therefore, PG&E analyzed the effects of the increased vertical ground motion on two vertically flexible slab systems, i.e. 1) Auxiliary Building Control Room Roof Slab; and 2) Turbine Building Floor System at elevation 119 feet.

b2.1) Auxiliary Building Control Room Roof slab:

Out of 11 vertically flexible slabs in the Auxiliary building, only the control room roof slab has a fundamental frequency in the range of 1 to 10 Hz in the vertical direction. This roof slab system consists of a 3 feet 4 inch thick reinforced concrete (RC) slab which is supported by 57 foot long embedded structural steel beams with end moment restraints provided by RC shear walls. Light-weight lighting fixtures and ceiling tiles are suspended from the underside of the roof slab via a grid of unistrut steel channels welded to insert plates embedded in the slab. A few HVAC ducts are also attached to the slab by concrete expansion anchors.

PG&E evaluated the seismic margin of this slab using the Conservative Deterministic Failure Margin (CDFM) approach that was used in the LTSP Final Report (Ref. 2).

The seismic margin factor, determined by the CDFM method, represents the amount by which the deterministic spectrum can be scaled to produce a demand equal to the HCLPF capacity of a structure or component; it is obtained by multiplying the elastic scale factor by the CDFM inelastic energy absorption factor, Fm. The elastic scale factor is the factor which can be used to scale the deterministic spectrum to produce a demand equal to the yield capacity of the structure or component. PG&E computed the elastic scale factor from the slab response just before a 'mechanism' is formed. The inelastic energy absorption factor, Fm, was determined as a function of the target displacement beyond yield displacement (i.e., ductility, m). The ductility of the control room roof slab system is directly related to the ultimate displacement of the slab near midspan. The HCLPF value of the ultimate displacement of the slab is based upon structural capability considerations. PG&E considered the inelastic rotation capacity limit specified in the ACI 349 code to be a HCLPF value. For floors subjected to a significant gravity load, PG&E has accounted for the ratcheting behavior of the slab or beam when estimating the system ductility. 'Ratcheting' here refers to the progressive downward displacement that occurs following multiple seismic load reversals in the inelastic range and reduces the available ductility of the system. A reduced effective ductility value was used in determining the inelastic energy absorption factor to account for the effect of ratcheting (Appendix A in Ref. 5). It must be noted here that the failure mode considered in this analysis is the elasto-plastic flexure mode only, since the combined axial and flexure behavior does not apply to this case.

To determine the seismic margin of the control room roof slab, PG&E performed a sensitivity study. This study showed that, corresponding to the Auxiliary Building seismic margin of 1.64 reported in the LTSP final report, the displacement of the control room roof slab is only about 4 inches at the center of the 57 ft span, as shown in Fig. 5 of Ref. 5. This displacement corresponds to a member ductility of 3 which is acceptable in this case, according to the ACI 349 code. This deflection being less than about 0.6 % of the slab span, it is judged that the capability of the anchored components (described earlier) will not be degraded significantly (Ref. 6). Therefore PG&E has concluded, and the staff agrees, that the increased SSER 34 vertical ground motion has not adversely affected the seismic margin of the control room roof slab given in the LTSP report.

<u>b2.2) Turbine Building (TB) Floor System at Elevation 119 feet:</u>

Of the three safety-related systems housed in the Turbine Building, the 4.16 kV switchgear is located at elevation 119 feet on floor systems consisting of RC slabs supported by structural steel beams. PG&E has analyzed this slab because of its higher elevation, and consequent higher response amplification.

The switchgear slab also supports equipment that are more displacement sensitive, more massive,and thus subjected to larger seismic demands. The switchgear slab consists of a 10-inch thick RC slab supported by compact wide flange structural steel beams and columns. Certain structural modifications (i.e., connection of certain columns to the slabs at the top and bottom) were made during the Hosgri reevaluation in order to connect the two floors and thus reduce the response of the slab at elevation 119 feet (Ref. 5).

The CDFM approach was used to confirm the adequacy of the seismic margin of the TB floor slab at elevation 119 feet. After determining the controlling structural steel beam elements by this method, PG&E evaluated the seismic margin of these beams, and consequently the switchgear floor system, by performing a sensitivity study. In this study, the seismic margin factors corresponding to specific target displacement (or pre-assigned ductilities) were calculated, considering the ratcheting effect due to dead load. The results of such a sensitivity study showed that, for a seismic margin of 1.45 (reported for the TB in Ref. 7), the maximum displacement of the switchgear slab was about 1.7 inches. By subtracting the dead load deflection of 0.3 inch of the switchgear slab, PG&E determined a differential displacement of 1.4 inches. Combining the effects of this differential displacement with other loads including the horizontal and vertical seismic loads, PG&E calculated the stresses in the switchge anchorage, and found that they were within allowable limits. Thus PG&E concluded, and the staff agrees, that acceptable margins exist for the switchgear under the increased loading due to SSER 34 seismic spectra (Ref. 6).

c) Fuel Handling Building (FHB) Crane:

PG&E reevaluated the FHB crane for the SSER 34 vertical ground motion spectra, since the crane response is primarily governed by the vertical component of ground motion. As described in Refs. 1 and 7, the crane system had four failure modes within the frequency range of 1 to 10 Hz, and the lowest seismic margin factor obtained was 1.55 for one of the four failure modes, namely, the bridge girder failure mode. The reevaluation showed that this factor is reduced to 1.35 which is acceptable to the staff, since PG&E's analysis conservatively assumes that the crane will lift a maximum load of 125 tons (equal to its rated capacity) concurrently with the maximum magnitude earthquake event.

d) Structural Steel Frame and Truss Systems:

Pipeway Structure

From among the class of structures composed of structural steel framing and truss system that could be affected by the increased vertical ground motion in the 1 to 10 Hz frequency range, PG&E selected the pipeway structure because it supports certain safety-related systems (Ref.5). Examples of such systems are: auxiliary feedwater pipe line; certain smaller piping and instrumentation tubing and conduits; main steam and feedwater pipe lines; and pipe whip restraints. The pipeway structure is a three dimensional structural steel frame attached to the outside of the containment shell, the auxiliary building and the turbine building.

The seismic margin of the pipeway structure was determined using the CDFM approach. Critical structural elements for margin assessment were identified on the basis of the seismic capacity-to-demand ratios determined during the Hosgri reevaluation. The CDFM capacities of most of these elements were calculated using the Load and Resistance Factor Design specification of the AISC, while those of some elements were based on 1.7 times the AISC allowable stresses.

For ductile structural systems the seismic margin can be assessed by limiting the ultimate target displacement based on the functionality of supported systems and components. However, for the pipeway structure, PG&E determined the displacement corresponding to a seismic margin factor of 1.76 (which is the seismic margin for the balance of plant piping determined in LTSP). It was found that beams in two bents of the pipeway structure that could become inelastic, displace vertically by up to about 1 inch. Based on its evaluation, PG&E concluded, and the staff agrees, that long-span, flexible piping systems that are attached to the pipeway structure (as described earlier) will withstand the effects of such small displacements.

CONCLUSION

Based upon a review of the confirmatory analysis submitted by PG&E as required in SSER 34 (Ref. 1), the staff concludes that the seismic margins of the structures, and equipment / components at the Diablo Canyon plant reported in the LTSP final report (Ref. 2) are adequate even after considering the staff's estimates of increased seismic ground motions. This closes out the only confirmatory item contained in the SSER 34 that dealt with the results of Diablo Canyon Long Term Seismic Program. PG&E has agreed that, for future plant design modifications, the LTSP spectra given in Ref. 2 would be increased to envelope the exceedances in the vertical and horizontal spectra discussed in SSER 34 Section 2.5.2.3, and then used to verify that the plant HCLPF values remain acceptable (Ref. 8).

References:

1. Safety Evaluation Report related to the operation of Diablo Canyon Nuclear Power Plant, Units 1 & 2, NUREG-0675, Supplement No. 34, June 1991.

2. Pacific Gas & Electric Company, Final Report of the Diablo Canyon Long Term Seismic Program, Docket Nos. 50-275 and 50-323, July 31, 1988.

3. Letter No. DCL-91-108 from J. D. Shiffer of PG&E to USNRC dated May 1, 1991. Subject: Adequacy of seismic margins assuming an increase in amplitude of the Diablo Canyon LTSP horizontal ground motion in the frequency range below 2.5 hertz.

4. Letter No. DCL-91-131 from J. D. Shiffer of PG&E to USNRC dated May 17, 1991. Subject: Adequacy of seismic margins assuming an increase in amplitude of the Diablo Canyon LTSP vertical ground motion in the frequency range from 2 to 10 hertz.

5. Letter No. DCL-91-313 from Gregory M. Rueger of PG&E to USNRC, dated December 26, 1991. Subject: Diablo Canyon Long Term Seismic Program - Confirmation of Plant Seismic Margins

6. Letter No. DCL-92-077 from Gregory M. Reuger of PG&E to USNRC, dated April 3, 1992; subject: Diablo Canyon Units 1 and 2 Long Term Seismic Program - Supplement Information for Confirmatory Analysis Report.

7. Letter No. DCL-90-226 from J. D. Shiffer of PG&E to USNRC, dated September 18, 1990. Subject: Additional Deterministic Evaluations Performed to Assess Seismic Margins of the Diablo Canyon Power Plant, Units 1 and 2

8. Letter No. DCL-91-143 from J.D. Shiffer of PG&E to USNRC, dated May 29, 1991. Subject: Long Term Seismic Program - Implementation of the results in the future modifications at Diablo Canyon