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LAWRENCE LIVERMORE LABORATORY

SMS-209

August 3, 1979

Mr. Howard A. Levin
Systematic Evaluation Program Branch
Division of Operating Reactors
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington DC 55

Dear Howard:

Enclosed for your re w is our summary and questions concerning the document: "San O fre uclear Generating Station Unit 1, NRC Docket 50-206, Seismic Reevaluation and Modification," April 29, 1979. This material was a emoled from independent reviews conducted by EDAC, EGG, and LLL.

If you need ny additional information or further clarification, please call either Tom Nelson (FTS) 532-0306 or me at (FTS) 532-0308.

Very truly yours,

Robert C. Murray

Robert C. Murray
Structural Mechanics Group Leader
Nuclear Test Engineering Division

RCM/cam
Enclosures

cc: T. A. Nelson

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SUMMARY

The report was submitted to NRC at the end of Phase I of the San Onofre Unit No. 1 (SO-1) seismic reevaluation program. In Phase I, several reactor coolant system (RCS) component supports have been modified to provide the desired safety margins for these components to resist the greater loadings associated with a 0.67 g Safe Shutdown Earthquake (SSE). The report described the seismic reanalysis of the containment, the concrete structure inside containment and the reactor coolant system for such an earthquake. NRC has promised to review the report and also enclose a list of items (questions and comments) to be addressed for the Phases II and III Balance of Plant (BOP) seismic reevaluation.

The presentation of the SO-1 seismic reanalysis followed closely the NRC Regulatory Guide 1.70 format (or NRC SRP recommended format). The analysis effort was shared by Bechtel and Westinghouse companies, with Bechtel's emphasis on containment, reactor building and soil foundation analysis and Westinghouse, on RCS or NSSS system and components analysis (see the attached summary table). In each of the first three analyses listed in the table, the models of the containment, reactor building, NSSS system and soil foundation were all included to account for the possible dynamic interaction among them. A detailed model was used for each system being analyzed, and the remaining systems were represented by simplified models. The analysis of NSSS components, i.e., reactor vessel, pressurizer, reactor coolant pumps (RCP), and steam generators took two steps: NSSS system analysis was first performed using simplified component models, then a detailed component model was analyzed using the boundary displacement time history from NSSS system analysis as the input.

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SUMMARY - San Onofre Unit No. 1 Seismic Reanalysis (April 29, 1977)

Sheet 1

Structure Items	Investigator	Computer Program	Method of Analysis	Input	Consideration of 3 Components	Modal Combination

SUMMARY - San Onofre Unit No. 1 Seismic Reanalysis (April 29, 1977)

Sheet 1

Structure Items	Investigator	Computer Program	Method of Analysis	Input	Consideration of 3 Components of Motion	Modal Combination
Steel Containment Sphere	Bechtel	ASHSD	Response Spectrum	Housner's Spectra Horiz=2/3g Vert=2/3Horiz	2 Components*, SRSS on Responses	SRSS
Reactor Building	Bechtel	SAP 1.9	Response Spectrum	Housner's Spectra Horiz=2/3g Vert=2/3Horiz	3 Components, SRSS on	SRSS
NSSS (RCS) System	Westinghouse	WECAN	Time History (Direct Integration)	Synthetic Accel. Time History from Housner's Spectra	3 Components	N/A
NSSS Component	Westinghouse	WECAN	Time History (Direct Integration)	Support Displacement Time History from NSSS System	3 Components	N/A
Component Supports	Westinghouse	WESAN STRUDL NASTRAN	Static Analysis	Reaction Loads from NSSS System Analysis	N/A	N/A

*Vertical and horizontal

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SUMMARY - San Onofre Unit No. 1 Seismic Reanalysis (April 29, 1977)

Sheet 2

Structure Items	Soil-Structure Interaction Analysis	[illegible]	Load	Acceptance Criteria

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SUMMARY - San Onofre Unit No. 1 Seismic Reanalysis (April 29, 1977)

Sheet 2

Structure Items	Soil-Structure Interaction Analysis: Model	Soil-Structure Interaction Analysis: Soil Damping	Damping	Load Combination	Acceptance Criteria
Steel Containment Sphere	Axisym Finite Element	4% Critical	4% Critical (all modes)	DW + Pressure + DBE	$P_m < 1.2 S_m$ $P_1 + P_b$, $P_1 < 1.8 S_m$ Table 3.8.2-1 (P.3.8.2-7)
Reactor Building	6 Equivalent Springs	10% Rocking 12% Transl. 16% Vertical	Composite Modal Damping	DW+L+DBE	ACI 318-71 Code (P. 3.9.1-8)
NSSS (RCL) System	6 Equivalent Springs	10% Rocking 12% Transl. 18% Vertical	Viscous Damping (Rayleigh) Sect. 3.7.2-15	DW + Pressure + DBE	Coolant loops: ASA B 31.1 Piping Reactor Internals: ASME-III, 1965 (P.3.9.1.5)
NSSS Component	N/A	N/A	Viscous Damping (Rayleigh) Sect. 3.7.2-15	DW + Pressure + DBE	(Table 3.9.1-1) $P_m <$ Smaller of $2.4 S_m$ & $0.7 S_u$ $P_1 + P_b$, $P_1 <$ Smaller of $3.6 S_m$ & $1.05 S_u$
Component Supports	N/A	N/A	N/A	DW + DBE	(Table 3.9.1) $P_m <$ larger of ($1.5 S_m$, $1.2 S_y$) $P_1 + P_b$, $P_1 <$ larger of ($2.25 S_m$, $1.8 S_y$)

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TECHNICAL QUESTIONS

- The seismic response of NSSS system and components was predicted by a nonlinear step-by-step dynamic analysis via the Westinghouse computer code WECAN. The nonlinearity considered was related to gap effects, lift-off, and the behavior of special types of component supports. As the validity of the results very much depends on the step-by-step solution procedure employed, a description should be provided discussing the convergence of the solution at each time step (i.e., the iteration scheme and convergence criterion used) in the sense that the internal resisting forces deriving from material laws are in equilibrium with external forces.

- We feel further justification of the analysis results from the nonlinear models of the NSSS and concrete internals (RB) is also needed.

1) One set of synthesized earthquakes, one for each orthogonal direction, was used for seismic input (page 3.7.1-7). The NSSS nonlinear model is expected to be sensitive to earthquake characteri-tics such as "phasing". Therefore, more than one time-history should be used to assess the effect of earthquake input characteristics on the system response.

2) A set of "gap conditions" (Section 3.7.2.1.3.1 SYSTEM MODEL) were assumed in the NSSS model. However, the equivalent analytical model (Appendix A) and UCLA vibration tests indicated

that the NSSS was sensitive to gap conditions. It is also possible that the gaps might change because of operation. The magnitude of impact or "banging" (closing of stops) may be significantly affected by the assumed gap conditions. Therefore, the nonlinear model analysis should include the variability of gaps.

3) The Westinghouse modified, nonlinear model predicted displacements in the range of 0.40 to 0.95 inches at the top of the pumps and at the top of the steam generators (Table 3.7.2-4). These were 2 or more times bigger than measured clearances at seismic stops. Reference 50-206-146, Effects of Earthquake Stresses on Primary Cooling System, UCLA-7151-(1971). The deformed shapes of the SG and pump are not given. However, given the geometry of the seismic stops, it would appear that deformation this large could produce large deflections at the nozzles of SG and pump, and consequently, large stresses. Therefore, additional data in the form of displacement time-histories, assumed gap values, deformation shapes, etc., or other justification should be requested.

4) The linear Bechtel model response was used to calculate loads on the concrete structures and anchors (page 3.7.2-45). If impact occurs as was evident in the Westinghouse nonlinear model, the box section beams (associated with stops and bumpers) may transfer loads significantly higher than those predicted by the linear model. Also, the characteristics of the earthquake

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time-history and gap conditions (see discussions 1 and 2 above) would affect the loading on the anchors and to a lesser extent of the structures. Therefore, further justification is required for this approach.

- It is inferred that the stress criteria were met for the system. However, <u>functionability</u> of the SG, pump, and pressurizer were <u>not</u> shown. As a minimum, bearing loads and gaps of the pump should be presented to assure <u>operability</u> (similar to Section 3.7.3.14.7), since this is an active component. Also, further details and comparison of modified and unmodified pump responses are required to justify the factor (10.0) used in the pump component analysis (page 3.9.1-22).

<u>Points of Clarification</u>

- The effects of the concrete containment shell added in 1977 have not been included in the Phase I analysis. We feel the through-soil coupling between the new concrete shell and older structures must be considered.

- A comparison of measured earthquake responses with computed values may be desirable for linear systems which have not subsequently been modified. Although significantly higher damping could be expected for the SSE, a verification of some frequencies and mode shapes may be valuable.

- Input motion used in this evaluation was 0.67 g Housner spectra for Horizontal and 0.44 g Housner spectra for Vertical.

  All results will have to be reevaluated in light of the site specific spectra being developed.

  Are "fault simulation studies" an acceptable methodology to determine seismic input? Apparently TERA, Del Mar, is assisting SCE in this area. It is planned to be a deterministic analysis instead of a "risk" (Hazard) study.

- Clarify discussions on page 3.7.2-66 concerning damping.

MINOR CONCERNS

- An equivalent, six node (24 DOF) RB model was used in the NSSS model. The Bechtel model of the building indicates several structural modes below 33 hz. Some of these modes are shear deformation of SG concrete compartments (page 3.7.2-35) and torsional mode of RB (page 3.7.2-37). The SG and pump are attached to these compartments at more than one location and, therefore the adequacy of the 6 node, RB model should be discussed in regard to effects of end point movement for multiply supported items.

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- The reported seismic analysis examines the safety margin (surplus margin) against catastrophic membrane failure under a postulated 0.67 g earthquake (DBE or SSE), when the plant is in normal operating condition. The possible cyclic failure covered by ASME code fatigue and stress range evaluations has not been analyzed. Buckling instability was only examined in the case of containment (in table 3.8.2-4). The instability analysis should also cover other structural components and their supports (including linear type and plate and shell type supports).

CONTAINMENT ANALYSIS

- Show the method of deriving simplified containment models from ASHSD analysis results.

REACTOR BUILDING ANALYSIS

- Show the method of deriving the six equivalent foundation springs for the building analysis.

- Has the effect of relative displacement among supports (if any) been considered in the response spectrum analysis of RPV lifting rig, reactor service crane and feedwater penetration? Also describe for each item the method of calculating local responses from modal analysis results and show the input spectra at the supports.

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- Add an explanation of how the operation $\sum_{i=1}^{nelem} E_i K_i$ was accomplished in Equation 3.7.2-1, Page 3.7.2.57.

<u>NSSS SYSTEM (WECAN) ANALYSIS</u>

- Discuss in detail the method of establishing the viscous matrix C (used in the dynamic equilibrium equations) for the component (element) damping characteristics (given in terms of modal damping). The discussion should include soil damping, damping in components, damping due to impact in gaps, and any other damping considered in the NSSS system and component analysis models.

- Describe the location and the magnitude of the peak vertical and lateral displacement and acceleration responses in each NSSS component. Describe the history of response at the places where lift-off of equipment has occurred. Show the force response history at the constant-force pump support points.

- Describe the difference between a gap element and a dynamic element, and the theory for the fluid element.

- Show samples of displacement response history obtained at gap elements of each NSSS component model and indicate the periods of gap closing and the peak resisting forces.

- Describe the method of tying the NSSS system including coolant loops and components to the six nodes (24 d.o.f.) of the reduced reactor building (consider both modified and unmodified NSSS support configurations). Explain why this method is adequate as far as modeling transmission and amplification of all the components of seismic motion coming from the foundation, through the building, to the NSSS. Has the structural flexibility between some supports been ignored?

- Were the auxiliary lines, i.e., safety injection system, RHR system, secondary coolant piping and surge lines (P 3.7.2-17) seismically analyzed? Are they not classified as seismic category I lines?

NSSS COMPONENT (WECAN) ANALYSIS

- Describe the vertical support for the reactor pressure vessel (RPV) head lifting rig and its attachment structures.

- The discussions in Section 3.9.1.5.5 seem to indicate that the pump response spectral values generated from the modified NSSS support configuration analysis can be ten times that from the unmodified support configuration analysis. This result should be explained.

Provide a detailed description of the approach presented in Sections 3.9.1.5.4 to 3.9.1.5.7 of modifying detailed component analysis stress results by comparing spectra generated from NSSS system model with and without support modifications. Justify the basis for

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comparison considering the fact that the component could have a different boundary condition in the modified support configuration versus in the unmodified support configuration.

ACCEPTANCE CRITERIA AND LOAD COMBINATIONS

- Describe the jurisdiction of class MC components, Class 1, 2 and 3 components, and NF and NG supports.

- Show the definition of stress quantities P_m, P_l and P_b for the cases of the nozzles, and various plates and shells in the NSSS system.

- Table 3.8.2-1 indicated that the allowable stresses used for all the critical regions of the containment under Design plus DBE or SSE (a faulted condition) were 1.2 times those for the design condition allowables. However, according to ASME III NE-3131 (c) (2) the factor of 1.2 should only be used as the increase of allowable for materials in the integral and continuous region of the vessel (containment).

- Did the stresses listed in Table 3.8.2-3 for containment shell at feedwater penetration include those produced by reaction loads from feedwater piping?

- Have mechanical loads from moving and rotating parts of the

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equipment, hydrodynamic loads due to fluid flow, transient loads from normal start up and shut down and other operating loads been considered in the load combination with DBE?

Show the method of deriving the rebar stress in Table 3.8.5-1 from the finite element analysis results.

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