DESIGN VERIFICATION PROGRAM

SEISMIC SERVICE RELATED CONTRACTS
PRIOR TO JUNE 1978

REVISION 1

Phase I

February 27, 1982

Project 105-4

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DESIGN VERIFICATION PROGRAM
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Phase I

1.0 Introduction & Scope

On September 28, 1981 Pacific Gas and Electric Co. reported that a diagram error had been found in a portion of the seismic qualification of the Diablo Canyon Unit 1 Nuclear Power Plant (DCNPP-1). This error resulted in an incorrect application of the seismic floor response spectra in the crane wall-containment shell annulus of the Unit 1 Containment Building.

The response spectra were thought to be computed correctly for Unit II, but as a result of the diagram error w -e applied to the opposite hand geometry of the Unit 1 building. The origin of the error was in the transmittal to a consultant of a sketch of the Unit 2 opposite hand geometry identified as Unit 1 geometry.

The effects of the error were being rectified and a re-verification program was initiated and underway during the months of October and November. The NRC Commissioners met during the week of November 16, 1981 to review the situation. On November 19 the Commission issued an Order Suspending License, CLI-81-30, which suspended License No. DPR-76 issued to the Pacific Gas and Electric Company to load fuel and conduct low power tests up to 5% of rated power at the DCNPP-1. In Attachment 1 to the order certain actions were specified that would be required before the suspension would be revoked. These actions consist primarily of an independent Design Verification Program and completion of a technical recovery program. The NRC Staff further clarified the required actions during a meeting in Bethesda on February 3, 1982.

This report presents Revision 1 of a description of the Design Verification Program on seismic work performed by service related contractors and PGandE prior to June 1978. This program is designed as Phase I of an overall Design Verification Program. Phase II of the overall program will include the remaining safety related work. This Revision 1 description includes modifications to the original program description to account for:

- Changes due to NRC meeting of Feb. 3, 1982,
- Comments of the program reviewer, Dr. W. E. Cooper of Teledyne Engineering Services, and
- Progress made to date. The present description is a picture of the program as of Feb. 27, 1982.

The Design Verification Program includes only the safety related Design Class I buildings, equipment, piping and components that were requalified considering the Hosgri 7.5M earthquake. Emphasis was placed on items important to public safety, as opposed to operational reliability. The scope of this Design Verification Program includes the design and analysis work performed associated with seismic-related service contracts in effect prior to June 1978. This date serves as a convenient separation point for the Quality Assurance portion of the design verification. Part of the engineering work done prior to June 1978 has been superseded, therefore the engineering verification for Phase I will involve review of some work performed after June 1978.

2.0 Development of the Seismic Design Chain

2.1 The Seismic Design Chain

The term "seismic design chain" designates the separate but linked process of providing seismic design for a nuclear plant. Each step in the process is usually linked to another step via flow of information. The design results obtained in one step may affect the design of systems or components in another step of the process. For example, the floor response spectra obtained in building analysis are used as input to the analysis of piping system of the particular floor. The piping analysis provides puping support loads which in turn are used for the design of piping supports. Figure 1 illustrates a typical seismic design chain for a nuclear power plant based on the site seismic design criteria.

2.2 Development of Seismic Design Chain

The seismic design chain applicable to the Diablo Canyon Nuclear Power Plant will be developed by the following approaches:

2.2.1 Information to Seismic Design Chain

The information necessary to develop the seismic design chain for the Diablo Canyon Nuclear Power Plant is as follows:

- Names of PGandE's contractors involved in the seismic safetly-related work prior to June, 1978.
- Work scope of each contractor.
- Commencement and ending dates of each contractor's

work.

- Design groups within PGandE responsible for the work of contractors.

- Interfaces of design groups within PGandE.

2.2.2 Seismic Design Chain Map

The map of the seismic design chain involving service-related contractors prior to June 1978 will be developed using information described in Section 2.2.1. This map will illustrate all interfaces (both with and within PGandE), describe the information passing between interfaces, and list the responsibilites of all contractors at each step of the seismic design process. When the entire chain has been mapped, it will facilitate the review of interfaces when design information was transmitted between PGandE internal design groups and between PGandE and each contractor.

3.0 Quality Assurance Program Review

The objective of this portion of the Design Verification Program is to evaluate the appropriate QA Programs against all eighteen criteria of 10CFR50, Appendix B and the applicable ANSI Standards. All 18 criteria of 10CFR50 Appendix B were considered and applicable criteria for each contractor were selected (Table III).

3.1 Controlling Documents

The review team of R. F. Reedy, Inc. shall collect controlling Quality Assurance related documents associated with each of the organizations identified in the seismic design chain in Section 2.0. These documents shall include the applicable revisions during the period prior to June 1978.

3.1.1 Specific Documents to be Reviewed

The specific documents to be reviewed during this phase of review shall, as a minimum, include:

a) The PGandE Diablo Canyon Safety Analysis Report
b) The Quality Assurance Manuals and Quality Assurance/Quality Control Procedures of each of the organizations in the design chain which were applicable during this design period.
c) The applicable procurement and design specifications used by each of the organizations in the design chain.

3.2 Review

The review team of R. F. Reedy, Inc. shall conduct the review of the documents listed in Section 3.1.1 for compliance with the requirements of 10CFR50, Appendix B, and the applicable ANSI Standards. In general, the immediate criteria applicable to design groups will include Instructions, Procedures and Drawings, and Document Control. However, there may be some organizations in the design chain, e.g. a test lab, whose design activities include functions such as testing, equipment calibration, and controlling material. When reviewing these types or similar organizations it will be necessary for the review team to include applicable Appendix B criteria in the review. Each such case will be evaluated to assure that all appropriate 10CFR50 Appendix B and ANSI criteria are included in the review and implementation audit.

3.2.1 Design Control

The Review of the Quality Assurance Manual and Procedures shall determine whether:

a) applicable regulatory requirements (and the design basis were correctly translated into specifications, drawings, procedures and instructions) and the appropriate quality standards were specified and included in the design process and that deviations from such standards were controlled;

b) the control of design interfaces and the coordination among participating design organizations was adequate and included the establishment of procedures among participating design organizations for the review, approval, release, distribution, and revision of documents;

c) control measures were provided for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculation methods, or by the performance of a suitable testing program and that the verifying or checking process was performed by individuals or groups other than those who performed the original design;

d) design changes were subject to design control measures commensurate with those applied to the original design and approved by the organization that performed the original design.

3.2.1.1 Design Input

The review team of R. F. Reedy, Inc. shall determine whether applicable design inputs, such as design bases, performance requirements, regulatory requirements, codes and standards were identified, documented, and their selection reviewed and approved, and whether the design input was specified and approved to the level of detail necessary to permit the design activity to be carried out in a correct manner and to provide a consistent basis for making design decisions, accomplishing design verification measures and evaluating design changes.

3.2.1.2 Design Process

The review team of R. F. Reedy, Inc. shall determine whether design control measures were applied to verify the adequacy of design, such as by one or more of the following: the performance of design reviews, the use of alternate calculations, or the performance of qualification tests.

3.2.1.4 Change Control

The review team of R. F. Reedy, Inc. shall determine whether changes to final design were justified and subjected to design control measures commensurate with those applied to the original design and approved by the same affected groups or organizations which reviewed and approved the original design documents.

3.2.1.5 Interface Control

The review team of R. F. Reedy, Inc. shall determine whether design interfaces were identified and responsibility defined, lines of communication established and the design efforts coordinated among the participating organizations.

3.2.1.6 Documentation and Records

The review team of R. F. Reedy, Inc. shall determine whether design documentation and records, which provide evidence that the design and design verification processes were properly performed, were collected, stored, and maintained in accordance with documented procedures.

3.2.2 Instructions, Procedures and Drawings

The review team of R. F. Reedy, Inc. shall determine whether activities affecting seismic deaign were prescribed by documented instructions, procedures, or drawings of a type appropriate to the circumstances and accomplished in accordance with these instructions, procedures, or drawings.

3.2.3 Document Control

The review team of R. F. Reedy, Inc. shall determine whether measures were established to control the issuance of documents, such as instructions, procedures, and drawings, including changes thereto, which prescribed activities affecting quality and that documents, including changes, were reviewed for adequacy and approved for release by authorized personnel and are properly distributed.

4.0 Review of Implementation of Quality Assurance Controls

The objective of this portion of the Design Verification Program is to evaluate the implementation of the appropriate QA Programs assessed in Section 3.0.

4.1 Development of Audit Plan

The review team of R.F. Reedy, Inc. shall develop and conduct on-site verification audits to assess the design control implemented by each contractor and PGandE.

Where the review of Section 3.0 shows a method of controlling design activities in an organized and documented manner which meets the requirements of 10CFR50, Appendix B, and the applicable ANSI standards, the audit will consist of a review of objective evidence to verify that the program was adequately implemented and documented. Where the program review team considers that the contractor's program does not contain the controls of 10CFR50, Appendix B, and the applicable ANSI standards, the audit will consist of a determination whether the design activities were controlled in a manner consonant with the criteria requirements of Appendix B and the applicable ANSI standards.

4.2 Audit Scope and Depth

The scope of these audits will include a review of the implementation of Quality Assurance Procedures and controls used by and for:

a) PGandE internal design groups that interfaced with the seismic contractor;

b) each contractor's design group;

c) transmittal of information between PGandE and each contractor;

d) transmittal of contractor developed information within PGandE;

e) and contractor internal interfaces and interfaces with subcontractors when applicable.

Qualified engineers will be used to review at least some of the calculations and analysis of PGandE and each design contractor. The review may consist of reviewing design input and output for consistency, or a check review by use of simple calculations to approximate results, or a detailed check of a portion of the calculations for analysis to assure the results are correct. The results of each audit will have a direct bearing on the type and depth of additional verification. See also last paragraph, Section 5.2.

If any contractors sublet design activities, it will also be necessary to review that subcontractor and his interfaces with others. Design interfaces will be reviewed whether they are internal or external to the group. Again, the depth of additional verification will depend upon the results of the implementation audit.

Some of the specific items to be addressed during these audits are:

- Correct application of design input data
- Documentation of design assumptions
- Applicability of quality requirements
- Identification of applicable codes, standards, and regulatory requirements
- Adequacy of design interfaces

- Appropriateness of design methods
- Verification that acceptance criteria was met

4.3 Quality Assurance Results

The results of the program reviews and audits of PGandE and each contractor will be presented in a report.

Quality Assurance Findings, together with the results of the independent sample calculations, will form a basis for determination of the need for additional verification.

5.0 Independent Sample Calculations

5.1 Types of Samples

The sample of equipment, piping, buildings, and components to be design verified by independent calculations is shown in Table 1. This sample is termed generic and covers the entire plant. The generic sample will cover the significant design activities of PGandE and the seismic-safety related contractors.

However, to provide for the case where deficiencies are found by means of either the Quality Assurance review or independent sample calculations, provisions have been made for additional verification. (See Section 5.3).

5.2 Sampling Philosophy and Criteria

Since the current effort is a review of engineering work, the objective will be to perform enough independent calculations to ensure no significant errors are propagated through any parts of the work. This will be done by determining the sources of errors, whether due to method, mathematics, incorrect input data, omission of information or other. In cases of discovery of errors, additional verification will be required to determine the nature and quality of the engineering work, so that a clear statement can be made on the need for improvements or modifications.

The size of the sample, and the buildings, piping, equipment and components contained in the sample have been chosen on a judgement basis. Judgement sampling is discussed in "Sampling Manual for Auditors", The Institute of Internal Auditors, New York, N.Y., where it is noted that certain types of auditing are best done using judgement sampling. In the current situation, substantially more assurance can be gained by the development of an informed understanding of the engineering work and a follow-through to determine the possibility of error propagation, than would be gained by an attempt to apply formal statistical procedures, which would be difficult in any case due to the diversity of the work.

The specific items of buildings, piping, components and equipment were chosen:

- to obtain a sample from all seismic-safety related contractors

- to obtain a sample significant to Public Safety

- to obtain a sample from all areas of the plant

- to obtain a sample analyzed by means of different methodologies.

The size of the sample was determined on the basis that the cross-section of the total engineering work provided is more than sufficient to establish the adequacy of the seismic design or indicate if significant errors exist. Additional verification will be required if errors or QA deficiences are determined.

5.3 Additional Verification

Additional verification is performed if deficiencies are found by means of either the QA review or the Independent Calculations

5.3.1 Additional Verification Resulting from Quality Assurance Reviews

Deficiencies in the Quality Assurance Program adequacy or implementation of PGandE or service related contractors will be cause for additional technical verification of design work. This review will cover the technical work done under the deficient QA program. QA deficiencies are reported as findings or observations. For present purposes these are defined as :

<u>Finding</u>: A nonconformance with respect to the Quality Assurance Program adequacy or implementation that requires corrective action due to potential impact on quality.

<u>Observation</u>: A noncomformance which does not require corrective action. This nonconformance does not have an apparent impact on quality.

Additional technical verification of the subject design work will be performed for all Findings as defined above. (Observations will not require additional verification).

5.3.1.1 Criteria

Depending upon the nature of the design work done under inadequate Quality Assurance, one of the following approaches will be taken.

<u>Design Review</u>

Technical work of a qualitative nature will be verified by review, by means of the following steps:

-Define scope of work.
-Establish an independent review program.
-Perform review to establish whether work is satisfactory based upon state-of-the-art methods applicable to the original design work.
-Write review report and draw conclusions as to whether work is satisfactory or not.

Independent Calculations

Technical work of a quantitative nature will be verified by means of independent calculations. The following steps will be followed:

-Establish scope of work.
-Develop a verification program based upon independent calculation of a suitable sample of the work, based upon state-of-the-art methods applicable to the original design work.
-Perform verification program to establish whether work is satisfactory.
-Write verification report.

An example of this verification that covers both qualitative and quantitative review is given below.

Deficiency: The Harding-Lawson QA Report by R. F. Reedy, Inc. contained three Findings (QA Findings 968, 969, and 970).

Additional Verification: RLCA and Robert McNeill are currently assessing the scope of the Harding-Lawson work. A program will be developed to verify this by design review, independent calculations or a combination of the two.

5.3.2 Additional Verification Resulting from Independent Calculation Program

The independent calculation program entails four categories of verification:

1. Field inspection to determine whether the as-installed configuration conforms to the design configuration.

2. Independent calculations to determine the correctness of the design calculations.

3. Verification that applicable seismic design input was employed.

4. In certain cases, design methodology is separately verified.

Deficiencies identified by any of the above will result in additional verification.

5.3.2.1 Deficiencies resulting from field inspection

The objective of performing additional verification as a result of identified deficiencies in the as-built configurations will be to discover the extent of such deficiencies. One of the two following methods will be used for such additional verification.

- Repeated field inspections of additional sample configurations.

- Establish the cause or reason for the dsicrepancy; then trace down other discrepancies that could possibly result from such cause or reason.

An example of this verification is given below:

Deficiency: An ambiguous design note led to a communication problem between engineering and the field concerning additional tubing weight on raceway supports (EOI 910).*

Additional Verification: PGandE has set up a program to examine all raceway supports with attached tubing. Preliminary indications show attached tubing on about 100 of the 20,000 class IE raceway supports.

5.3.2.2 Deficiencies resulting from the independent calculation program

The objective of performing additional verification as a result of identified calculational deficiencies will be to discover the extent of such deficiencies. This will be accomplished by one of the following means.

- Performance of additional independent calculations until the reasons for discrepancies are understood and a clear basis exists for all remaining safety-related discrepancies to be remedied.

- Determination of the cause or reason for the discrepancy; then trace down other discrepancies that result from such cause or reason.

An example of this verification follows:

* Error and Open Item Report. These reports are being sent semi-monthly to PGandE and the NRC as of January 1982.

Deficiency: The buckling of the tank skirt and sloshing loads on the rood were not evaluated by PGandE for the Boric Acid Tank (EOI 1030).

Additional Verification: RLCA will verify that other Hosgri tanks are not affected by the above items.

5.3.2.3 Deficiencies resulting from inapplicable seismic input

The objective of performing additional verification as a result of the use of inapplicable seismic input will be to discover the extent and significance of such deficiencies. This will be accomplished by one of the following means:

- Determination of the cause or reason for the discrepancy; then trace down other discrepancies that result from such cause or reason.

- Performance of additional checking of seismic inputs.

An example of this verification is given below.

Deficiency: Nine of twenty electrical raceway support calculations checked for the Preliminary Report used inapplicable spectra (EOI 983).

Additional Verification: PGandE is currently reviewing all the class IE electrical raceway support calculations. RLCA will select a sample of these re-done supports for independent calculations to close out EOI 983.

5.3.2.4 Deficiencies in design methodology

The objective additional verification will be to identify and correct all deficiencies in design that result from faulty methodology. This will be accomplished by two methods:

- A critique of the methodology in question will be issued.

- When the methodology has been improved or justified, the design work will be re-verified relative to the new or revised design methods.

5.4 Independent Requalification

In this phase of the program the seismic qualification of the sample (buildings, piping, components and equipment) will be performed on an independent basis. In each case, the starting point will be the engineering drawing which will be field checked. All data required for the qualification will be obtained or calculated independent of the PGandE analysis to guard against common data errors. Verified computer codes different from those used by PGandE will be used.

The verification of buildings represents a special case, as described below.

5.4.1 Buildings

5.4.1.1 Sample

There are four safety-related structures: Intake Structure, Turbine Building, Containment and Auxiliary Building. RLCA decided to independently verify the seismic design of the Auxiliary Building. This building includes the Fuel Handling Structure and the control room.

Except for the Containment Building, The Auxiliary Building is the most important structure with regard to overall safety. The choice of a structure for independent calculation logically was between the Containment and Auxiliary Building. The latter was chosen for the following reasons:

- The Auxiliary Building contains the largest amount of safe shutdown piping, equipment and components.

- The building itself involves the Fuel Handling Structure and the control room.

- The structure is quite complex with both a concrete shear wall section and a steel frame section.

- As discussed in the preliminary report on the review of the URS/Blume-PGandE interface, there appeared to be some controversy on one mass point in the seismic model of the building (EOI 985).

- The Containment Building is under separate scrutiny due to the error discovered in the annulus model.

5.4.1.2 Methodology

The plan for verification of the Auxiliary Building follows.

a. Review the model used by URS/Blume for the dynamic analysis of the building.

b. Independently calculate the building properties using field verified drawings including weight, moment of inertia, etc.

c. Independently calculate the modes and natural frequencies.

d. Independently perform the time-history analyses and calculate the floor response spectra.

e. Independently analyze a sample of the building members.

The independent results will be compared with the PGandE results for b, c, d, and e above.

5.4.1.3 Acceptance Criteria

Additional verification will be required if the results vary by more than:

- 15% for the building dimensions and properties.

- For the building, 15% for the frequencies, provided the mode shapes agree.

- For the response spectra 15% in peak accelerations and 15% for the peak frequencies

5.4.2 Piping

5.4.2.1 Sample

Table II contains the piping problems chosen for independent verification. This sample of 10 piping analyses were chosen on the following basis:

- Obtain a sample from all buildings
- Obtain a sample from all elevations
- Obtain a sample from a diversity of systems
- Obtain samples from lines most important to safety (risk of radiation release).

This sampling strategy is based on the fact that each piping analysis is a lengthy and complex undertaking that requires examination and verification of a large body of data. In addition, consistent with the overall plan, if discrepancies are found, additional verification will be required.

5.4.2.2 Methodology

The methodology for the verification is based on the following points:

- A field verification of installation of the sample lines will be performed.

- Models will be developed from field verified drawings.

- The methods used for the analysis will in general parallel those used for the Hosgri analysis of the piping. The applicable Hosgri criteria are included in Attachment III.

- The analysis will consider deadweight, pressure and seismic loads.

- The verification analyses will be done using ADLPIPE, a different computer program than was used for the Hosgri analysis.

- ADLPIPE has been benchmarked against standard problems.

5.4.2.3 Acceptance Criteria

Upon completion of the independent analysis of the 10 piping runs, the results will be compared with the design analysis. The following procedure will be employed.

. Field tolerances are defined in PGandE's 79-14 program.

. For both the verification and design analysis, select all points in the line that are stressed to 70% of allowable stress or more. These are the reference location.

. If fewer than 5 such points are found, select the 5 most highly stressed points as reference locations.

. Compare design and verification stresses at the reference locations. If the stresses differ by more than 15% or exceed allowable stress additional verification is required.

. Compare all support loads to the design analysis results.

. Compare all equipment nozzle loads to the design analysis results.

. Compare all valve accelerations to the design analysis results.

Additional verification is required if differences greater than 15% result in the last 3 steps or if allowable values are exceeded.

5.4.3 Pipe Supports

5.4.3.1 Sample

Twenty pipe supports have been chosen from those associated with the 10 piping verification analyses. These supports were chosen from different locations and represent a cross section of the different types of supports: snubbers, rigid restraints and spring hangers.

5.4.3.2 Methodology

For the twenty supports chosen:

- A field verification will be performed.
- Calculate the first mode frequency.
- Calculate the stresses in the pipe supports, based upon loads calculated from the 10 piping analyses.

For the remainder of the supports included in the 10 piping analyses:

- Compare the loads calculated from the independent analyses with those in the qualification analyses as discussed previously.

5.4.3.3 Acceptance Criteria

The original design of pipe supports required each support to have a minimum natural frequency of 20 Hz considering the stiffness of the support and the mass of the supported pipe. For the twenty supports chosen;

- The field verification will compare as built to design utilizing PGandE's 79-14 tolerances.

- The first mode frequency must equal or be greater than 20 Hz.

- Compare the design and verification stresses on the pipe supports, based upon loads calculated from the piping analyses. Critical section stresses that differ by more than 15% will require additional verification action.

For the remainder of the supports included in the 10 piping analyses;

- Compare loads calculated from the independent analyses with the design loads. Loads differing by 15% or over allowable will require additional verification.

5.4.4 SMALL BORE PIPING

5.4.4.1 Sample

The small bore piping at Diablo Canyon Unit 1 has been supported using standard criteria for the spacing of supports or spacing tables. This is a standard approach in the industry. A sample of 3 runs of approximately 150 feet each of small bore piping has been chosen for review. This sample of piping will include 20 supports or more. In view of the fact that a relatively simple standard methodology was employed in the design, the sample chosen is expected to permit a satisfactory verification of the design.

5.4.4.2 Methodology

The verification of the small bore piping will consist of two parts:

- Field verification of the sample to establish that the pipe installations conforms to the design criteria.

- Independent review of the design criteria to establish that the criteria satisfy the applicable stress limits and provide conservative support design loads using Hosgri seismic inputs. The Hosgri small bore piping criteria is included in Attachment II.

5.4.4.3 Acceptance Criteria

Acceptability of the field installation will be based upon the PGandE tolerances developed for the I&E 79-14 Bulletin review. Instances of violation of the criteria will require additional verification.

Review of the design criteria will consider the levels of seismic input throughout the plant together with the size and schedule of piping to ensure adequate margins are developed by use of the criteria. The criteria will be considered satisfactory if general stress levels satisfy the allowable stress criteria within ± 15% and support design loads are within ± 15% of conservatively calculated design loads.

If these criteria are not met, additional verification will be required.

5.4.5 Equipment Analysis

For purposes of the present discussion, the general category of equipment qualified by analysis includes the following classes:

- Heat exchangers
- Tanks
- Pumps
- Valves
- Certain electrical panels and cabinets

5.4.5.1 Sample

The equipment sample is identified in Table 1.

The samples have been chosen using the same guidelines as with the other samples. An attempt was made to choose equipment most important to public safety and from a diversity of locations.

5.4.5.2 Methodology

Design drawings will be field verified. Standard dynamic analysis and stress analysis methods are used in the verification of the equipment qualification. Hand calculations are used where possible, otherwise standard computer methods for dynamic analysis are employed. Standard, benchmarked computer codes are used for this work, ANSYS for example. A computer code different from that used by PGandE will be used in the independent calculation.

The verification analysis considers stresses in the equipment itself as well as the supporting structure including the anchorage. The Hosgri loading combinations and structural criteria for both the Mechanical Equipment and supports are included in Attachment 1.

In general, the different types of equipment are governed by different codes and standards. These governing criteria are listed for each type of equipment and supports in the Hosgri report. Field tolerances will be 15%.

The results from the verification analysis will be compared to the design analysis. Stresses from governing locations will be required to be within 15% and below allowable. If this level of agreement is not obtained, additional verification will be required.

5.4.6 Equipment Qualified by Test

5.4.6.1 Sample

Certain types of electrical equipment are more conveniently qualified by test than analysis. Electrical equipment qualified by test within the present scope has been segregated into 7 groups in the original design qualification. This segregation was based upon the location of the equipment in the plant and was done to permit one test spectra to envelop the floor spectra applicable to each group. The test qualification applied to each group will be reviewed.

5.4.6.2 Methodology

The review will consist of two steps:

- Verify that the equipment in each group is located such that the applicable floor spectra of each item of equipment does in fact fall within the envelope of the design spectra.

- Verify that the test response spectra, specifically response spectra associated with the motion of the test table, does in fact envelop the design spectra for each of the 7 groups of equipment.

- Verify that the seismic test procedure meets the required IEEE 344-1975.

5.4.6.3 Acceptance Criteria

The governing criteria applicable to electrical e uip- ment qualified by test, as specified in the Hosgı report is the IEEE 344 standard 1975 edition.

The seismic test procdure will be reviewed to verify that the requirements of the standard were met. Secondly, the test spectra will be required to envelop the design spectra.

5.4.7 Conduit Supports

5.4.7.1 Sample

The applicability of design spectra used in the qualification of conduit supports was reviewed as part of the preliminary study of the PGandE design interface with URS/Blume. As reported in the November 12, 1981 preliminary study, a substantial portion of the sample was qualified with either inapplicable spectra or acceleration values. PGandE undertook a program to requalify all conduit support designs.

The present verification effort will involve 20 different conduit supports.

5.4.7.2 Methodology

The methods to be employed for the verification of the conduit supports are:

- Verify that the sample supports were installed according to the design, loading, location, dimensions, etc.

- Using the PGandE design methodology, independently calculate stresses for the sample supports.

- Review the technical basis of the conduit design methodology employed by PGandE incoporating the requirements of IEEE 344-1975.

5.4.7.3 Acceptance Criteria

Acceptability of the field installation will be based on the PGandE tolerances in drawings 050029 and 050030.

Review of the design methodology will consider the effectiveness of the resulting design to resist loads from the total dynamic effects of an earthquake, i.e., longitudinal and transverse motion, differential stiffness etc., as well as the applicability of the methodology throughout the plant. The seismic stress allowables in the AISC and AISI manuals are the governing

Criteria.

5.4.8 HVAC Supports

5.4.8.1 Sample

Two sections of HVAC duct have been selected for independent verification. One section is located in an area of high torsional accelerations in the building, and the other is attached to a floor with high peak horizontal response spectra.

5.4.8.2 Methodology

The methodology for the verification is based on the following points:

- A field verification of installations will be performed.
- Independent analysis of the duct supports

5.4.8.3 Acceptance Criteria

Acceptability of the field installation will be based on a tolerance of 15% in dimensions. Additional verification will be required for stress differences greater than 15% or above allowables at governing locations.

6.0 Field Verification

In order to ensure that the building, piping, equipment and components are built and installed in the manner for which they were qualified, an independent field verification will be made.

7.0 Hosgri Spectra

The spectra used in the verification program will be the docketed Hosgri Spectra with two exceptions. Turbine Building spectra included in the March 1980 Blume Turbine Building Report but not abailable in the Hosgri Report will be used (EOI 1029). The revised annulus spectra (curves dated 10/30/81-Equipment Loads) will be used in place of the Hosgri annulus spectra.

Seismic inputs into the qualification calculations for all the samples will be checked against the above spectra.

In addition the verification program will identify the latest and most current seismic data developed by Blume.

8.0 Seismic Service Related Activities of NSSS Vendors

The seismic design chain will be mapped to show all NSSS endors who supplied service for Diablo Canyon. The inerface between PGandE and the NSSS vendor will be checked for transmittal of Hosgri spectra. On a sampling basis NSSS vendor calculations will be checked to verify that the applicable seismic input spectra were actually used for qualification calculations.

9.0 Program Approach

The review team(s) shall establish review plans, checklists, schedule(s), and priorities for accomplishing the Design Verification Program.

10.0 Reporting Procedures

R.F. Reedy, Inc. QA Reports will be sent simultaneously to the NRC and R.L. Cloud Associates.

R.L. Cloud Associates' semi-monthly, interm and final report will be sent simultaneously to the NRC and PGandE.

Deficiencies identified in the QA reviews will be noted on sequentially numbered, "QA Findings and Observations" forms. Deficiencies identified by means of the independent calculations will be noted on sequentially numbered, "Error and Open Item (EOI)" forms. These will be attached to the R. L. Cloud Associates semi-monthly reports.

11.0 Conclusion

The Design Verification Program presented in this report is designed to be responsive to each point of the request for information listed in Attachment 1 to the NRC order suspending license, CLI-81-30, for DCNPP-1, dated November 19, 1981.

This verification program is designed to establish the correctness of the seismic design. It will detect errors in the seismic design process that arise in the generation of data, in the transmission of data, or in the use of data. This will be accomplished by an in-depth review of Quality Assurance, independent sample calculations, and field verification of as-build conditions. A sampling approach employing engineering judgement will be employed which is designed to expand the scope of the program upon detction of an error.

Semi-monthly reports will be submitted as requested. A final report will be prepared and submitted upon completion of the program. The significance of errors found will be evaluated. If any errors are found to be significant, recommendations will be made. This will include a description of the error; correction, if required; implication to safety, if any; the cause of the error with a statement as to whether it is generic or not and a justification. Errors determined to be insignificant will be explained.

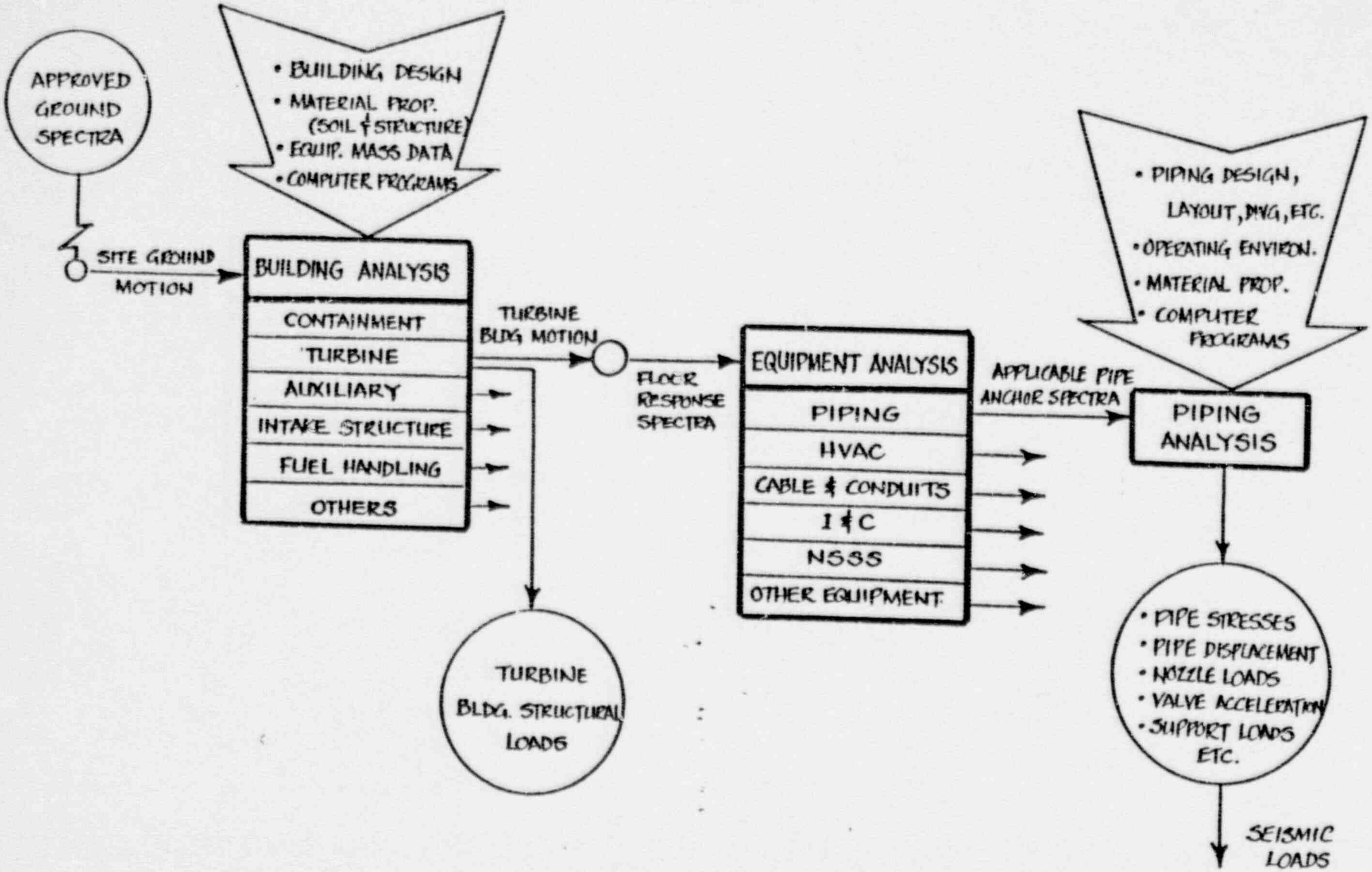

FIGURE 1. ILLUSTRATION OF A PORTION OF A SEISMIC DESIGN PROCESS

Table I

EQUIPMENT

Item	PGandE or Contractor Analysis
CCW Hx	Anco & PGandE
CCW Pump	Manufacturer & PGandE
Aux SW Pump	Manufacturer & PGandE
Turbine Driven Aux FW Pump	Manufacturer & PGandE
Diesel-Engine Starting Air Receiver Tank	Anco & PGandE
Diesel-Engine Oil Priming Tank	PGandE
Boric Acid Tank	PGandE
Main Annunciator Cabinent	Wyle & PGandE
Hot Shutdown Remote Control Panel	Manufacturer & PGandE
HVAC Supply Fan S-31	EDS Nuclear
HVAC Damper 7A	EDS Nuclear
7 Groups of Electrical. Equipment by Test	Wyle

Table I (continued)

EQUIPMENT

Valves

Independent calculations will be performed for:

FCV--41	EDS Nuclear Analysis
FCV--95	EDS Nuclear Analysis

Acceleration values will be checked for all the values included on the 10 piping analysis:

Westinghouse analyzed Valves

9001A	8804A	8700
9002A	8805A	8010A
8821A	8805B	8010B
8921A	8394A	8010C
8922A	8394B	9003A
	8473	

PGandE analyzed Valves

FCV355	FCV37	4 valves listed in PGandE specification 8729
FCV430	LCV113	
FCV431	LCV115	

TABLE II

PIPING SAMPLE

RLCA Analysis No.	Bldg.	Piping System	Piping Design Review Isometric
RLCA 100	Aux.	Containment Spray	446540 Rev.9
RLCA 101	Aux.	Safety Injection	446546 Rev.8
RLCA 102	Aux.	Chemical Volume Control	446544 Rev. 11 446542 Rev. 10
RLCA 103	Aux.	Residual Heat Removal	446541 Rev. 7
RLCA 104	Turbine Aux.	Component Cooling Water	449314 Rev. 3 449315 Rev. 3 449316 Rev. 3
RLCA 105	Cont.	Reactor Coolant System	437991 Rev. 16 445884 Rev. 8
RLCA 106	Cont.	Component Cooling Water	446491 Rev. 10
RLCA 107	Aux.	Containment Spray	446540 Rev. 9 446542 Rev. 10
RLCA 108	Aux.	Auxiliary Feedwater	445878 Rev. 14
RLCA 109	Aux.	Auxiliary Feedwater	447119 Rev. 12

TABLE III

QUALITY ASSURANCE

PROGRAM REVIEWS

CRITERIA	ORGANIZATIONS						
APPENDIX B	PG&E	EDS	EES	HLA	ANCO.	WYLE	URS/BLUME
I. ORGANIZATION	X	X	X	X	X	X	X
II. PROGRAM	X	X	X	X	X	X	X
III. DESIGN CONTROL	X	X	X	X	NA	NA	X
IV. PROCUREMENT DOC CONTROL	X	NA	NA	X	NA	NA	X
V. INSTR. PROCED. DRAWINGS	X	X	X	X	X	X	X
VI. DOC. CONTROL	X	X	X	X	X	X	X
VII. CONTROL OF PURCH. MAR'L SERVICES	X	NA	NA	X	NA	NA	X
VIII. IDEN & CONTROL OF MAT'LS,PTS, COMP	NA	NA	NA	NA	NA	NA	NA
IX. CONT.OF SPEC. PROCESS	NA	NA	NA	NA	NA	NA	NA
X. INSPECTION	NA	NA	NA	NA	NA	NA	NA
XI. TEST CONTROL	NA	NA	NA	X	X	X	NA
XII. CONTROL OF M & TE	NA	NA	NA	X	X	X	NA
XIII. HAND, SHIP & STORE	NA	NA	NA	NA	NA	NA	NA
XIV. INSP,TEST & OPER	NA	NA	NA	NA	NA	NA	NA
XV. NONCONF. MAT'L PTS, COMP	NA	NA	NA	NA	NA	NA	NA
XVI. CORRECTIVE ACTION	X	X	X	X	X	X	X
XVII. QA RECORDS	X	X	X	X	X	X	X
XVIII. AUDITS	X	X	X	X	X	X	X

NA - Not Applicable

X - Applicable

ATTACHMENT I

Table 7-1 Hosgri Seismic Evaluation--Loading Combinations and Structural Criteria--Mechanical Equipment

Table 7-2 Hosgri Seismic Evaluation--Loading Combinations and Structural Criteria--Mechanical Equipment Supports

TABLE 7-1

Hosgri Seismic Evaluations
Loading Combinations and Structural Criteria
Mechanical Equipment(1)

Component (2,3)	Loading Combinations (4)	Criteria (7,8,9,10)	
Tanks, Heat-Exchangers, Filters, Demineralizers	Deadweight + Pressure + Seismic + Nozzle Loads	σ_m $(\sigma_m \text{ or } \sigma_L) + \sigma_b$	$\leq 2.0S$ $\leq 2.4S$
Active Pumps	Deadweight + Pressure + Seismic + Nozzle Loads	σ_m $(\sigma_m \text{ or } \sigma_L) + \sigma_b$	$\leq 1.2S$ $\leq 1.8S$
Inactive Pumps	Deadweight + Pressure + Seismic + Nozzle Loads	σ_m $(\sigma_m \text{ or } \sigma_L) + \sigma_b$	$\leq 2.0S$ $\leq 2.4S$
Active Valves	Deadweight + Pressure + Seismic + Nozzle Loads	Extended Structure	: σ_m $\leq 1.2S$ $(\sigma_m \text{ or } \sigma_L) + \sigma_b$ $\leq 1.8S$
		Pressure Boundary	: ANSI B16.5 or MSS-SP-66
		Nozzle Loads	: (5)
Inactive Valves	Deadweight + Pressure + Seismic + Nozzle Loads	Extended Structure	: σ_m $\leq 2.0S$ $(\sigma_m \text{ or } \sigma_L) + \sigma_b$ $\leq 2.4S$
		Pressure Boundary	: ANSI B16.5 or MSS-SP-66
		Nozzle Loads	: (6)

NOTES FOR TABLE 7-1

(1) See Chapters 5 and 6 f reactor coolant system.

(2) Active : Mechanical equipment which is needed to go from normal full power operation to cold shutdown following the earthquake and which must perform mechanical motions during the course of accomplishing its design function.

(3) Inactive : Mechanical Equipment which is not required to perform mechanical motions in taking the plant from normal full power operation to cold shutdown following the earthquake.

(4) Nozzle loads shall include all piping loads transmitted to the component during the Hosgri earthquake.

(5) Piping loads at piping/active-value interfaces shall be limited such that maximum fiber stresses in the piping at the interface are less than the piping yield strength at temperature (S_y).

(6) Valves, being stronger than the attached piping and having a proven history without any gross failures of pressure boundaries, can safely transmit piping loads without compromising their pressure retaining integrity. Therefore piping integrity assures valve integrity.

(7) σ_m = general membrane stress. This stress is equal to the average stress across the solid section under consideration, excludes discontinuities and concentrations and is produced only by mechanical loads.

(8) σ_L = local membrane stress. This stress is the same as σ_m except that it includes the effect of discontinuites.

(9) σ_b = bending stress. This stress is equal to the linear varying portion of the stress across the solid section under consideration, excludes discontinuities and concentrations, and is produced only by mechanical loads.

(10) S = code allowable stress value. The allowable stress shall correspond to the highest metal temperature at the section under consideration during the condition under consideration.

TABLE 7-2

Hosgri Seismic Evaluation

Loading Combinations and Structural Criteria

Mechanical Equipment Supports(1)

Support	Loading Combinations(4)	Criteria (5,6,7,8)	
Linear Supports(3)	Deadweight + Seismic + Nozzle Loads	ASME Code Appendix XVII and Appendix F (Stresses not to exceed S_y for active components)	
Plate and Shell(2) (Active Components)	Deadweight + Seismic + Nozzle Loads	σ_m $(\sigma_m + \sigma_b)$	$\leq 1.2S$ $\leq 1.8S$
Plate and Shell (Inactive Components)	Deadweight + Seismic + Nozzle Loads	σ_m $(\sigma_m + \sigma_b)$	$\leq 2.0S$ $\leq 2.4S$
Bolts	Deadweight + Seismic + Nozzle Loads	ASME Code Appendix XVII and/or Code Case 1644 plus Appendix F	

60

NOTES FOR TABLE 7-2

(1) See Chapters 5 and 6 for reactor coolant system supports.

(2) Plate and Shell Type Supports: Plate and shell type component supports are supports such as vessel skirts and saddles which are fabricated from plate and shell elements and are normally subjected to a biaxial stress field.

(3) Linear Type Support: A linear type component support is defined as acting under essentially a single component of direct stress. Such elements may also be subjected to shear stresses. Examples of such structural elements are: tension and compression struts, beams and columns subjected to bending, trusses, frames, rings, arches, and cables.

(4) Nozzle loads shall be those nozzle loads acting on the supported component during the Hosgri earthquake.

(5) σ_m = general membrane stress. This stress is equal to the average stress across the solid section under consideration, excludes discontinuities and concentrations and is produced only by mechanical loads.

(6) Deleted 60

(7) σ_b = bending stress. This stress is equal to the linear varying portion of the stress across the solid section under consideration, excludes discontinuities and concentrations, and is produced only by mechanical loads.

(8) S = Code allowable stress value. The allowable stress shall correspond to the highest metal temperature at the section under consideration during the condition under consideration.

ATTACHMENT II

Hosgri Section 8.1 Spacing Criteria for Piping Seismic Restraints

8.1 SPACING CRITERIA FOR PIPING SEISMIC RESTRAINTS

For certain pipe sizes (described below) spacing criteria were developed for restraints to ensure that piping would be in the rigid region of the response spectra.

8.1.1 PIPING GREATER THAN TWO INCHES IN DIAMETER AND UP TO AND INCLUDING SIX INCHES IN DIAMETER

Spacing criteria for piping seismic restraints were developed by simplified dynamic analysis on a simple span, simply supported beam. The beam's first mode is away from the frequency where the spectrum peak value exists. The results from this simplified approach have been previously compared with detailed dynamic piping analysis and proven to be conservative[1]. This simplified approach does not represent the exact solution to the 3-D multi-degree-of-freedom piping system since the effect of the torsional moments and higher modes of vibration are neglected. Therefore, these design criteria were applied only to piping systems in the rigid region of the response spectra. A piping system was considered rigid if the first mode of vibration was less than 0.066 seconds.

A system restrained by these spacing criteria consists of spans of pipe supported by two mutually perpendicular restraints normal to the pipe; a) at all concentrated masses (e.g., valves), b) at all extended masses, c) at a maximum spacing on straight runs of piping defined by the formulas given below, and d) at elbows and tees. For elbows and tees, the maximum axially measured distance was 75% of the straight-run distance calculated by the formulas given below. The maximum distance between two seismic guides may be determined from the following equation:

$$L = 0.862\left[\left(\frac{T^2 EI}{Wp+Ww}\right)\right]^{1/4}$$

Where:

L = Maximum seismic span (maximum distance between two seismic guides for straight runs), ft

T = period (0.066 sec)

E = modulus of elasticity of piping material, psi

I = moment of inertia, in.^{4}

W_p = weight of pipe per foot, lb

W_w = weight of water per foot, lb (if applicable)

This equation was used in a Company computer program PIPROP12 to generate maximum allowable pipe spans for various sizes of pipes containing water or air. The results from this calculation are summarized in Table 8-1. The values in this table were used for the Diablo Canyon piping designs.

The above design criteria were limited to cold piping systems because the resulting restraints may not allow thermal flexibility of hot piping. Also, these spacing criteria normally were limited to pipes with diameters between two and six inches, because their use results in a large number of restraints. For piping larger than 6 in. in diameter, in the flexible region of the spectra, it is more economical to restrain the piping according to response spectrum modal superposition analysis described in Section 8.2.

8.1.2 PIPING TWO INCHES IN DIAMETER AND LESS

For both cold and hot piping, two inches in diameter or less, criteria for placing seismic restraints were also developed by the Company. These criteria deal primarily with two types of restraints:

1. A <u>bilateral restraint</u> holds the supported pipe in the planes normal to its longitudinal axis. The pipe is allowed to move axially and to expand radially within specified clearances.

2. An axial restraint holds the supported pipe axially and bilaterally. The pipe is allowed to expand radially within specified clearances.

These restraints are supplemented as necessary by unilateral restraints--for one direction only--to provide seismic restraint while allowing for thermal expansion.

Maximum spacing between successive bilateral supports is according to Table 8-2. If concentrated loads (valves, flanges, etc.) are not directly supported, the maximum allowable span is reduced by the length of piping equivalent to the weight of the concentrated load. Piping runs longer than one span length, and less than 100 ft long, are allowed only one axial restraint.

Spacing criteria were developed for seismic restraints on piping with offsets. For example, Figure 8-1 illustrates the maximum allowable pipe length without axial restraint--as a function of pipe size and offset. Other criteria cover spacing of bilateral restraints, as well as minimum and maximum pipe spans at corners.

8.1.3 REVIEW FOR HOSGRI CONDITIONS

The spacing criteria for piping restraints, as described in Subsections 8.1.1 and 8.1.2, have been reviewed with the working Hosgri acceleration response spectra (see Chapter 5) as input. 2% damping and maximum floor eccentricities (distance from the building center of mass) were used in developing the spectra for the review. The results of this study indicate the following:

1. Pipe stresses are within allowable limits.

2. The simplified model described in Section 8.1.1 was run using the final Hosgri spectra for all Class I portions of the power plant. The resulting load coefficients were found to be as shown in Table 8-10. A representative case model was developed and run with the final Hosgri spectra. The loads and stresses found with this model were less than the loads and stresses developed by the simplified model. Thus, the conservatism of the simplified model was verified. 56

ATTACHMENT III

Hosgri Section 8.2	Response Spectrum Modal Superposition Analysis
Hosgri Section 8.3	Analysis of Piping Six Inches and Greater Attached to Reactor Coolant Loop Piping

8.2 RESPONSE SPECTRUM MODAL SUPERPOSITION ANALYSES

For the seismic design of Class I piping systems not covered by restraint spacing criteria, response spectrum modal superposition analysis was used with computer programs PIPDYN and PIPESD(2). Analysis of piping six inches and greater attached to the reactor coolant piping is discussed in Section 8.3.

PIPDYN was written specifically for piping systems consisting of straight pipe and elbows. Input to the program consists of descriptions of the loads--horizontal and vertical acceleration spectra--and of the physical model. This model has lumped masses and one-dimensional elements: all physical properties of the real member can be concentrated on its elastic axis. The analysis is an eigenvalue of the reduced structure (consisting only of translational degrees of freedom). Results of the program are SRSS (square root of the sum of the squares) values of displacements, member end moments, effective stresses, stop forces and stop moments.

PIPESD is much more comprehensive than PIPDYN. It is designed to perform linear elastic analysis of three-dimensional piping systems subjected to static, thermal, and dynamic (earthquake) loadings. The results for a dynamic load case consist of values of displacements, support reactions, and member forces and stresses. The dynamic load case can be combined with static load cases to present combined stress results. The methods for combining modal responses and combining stresses in this analysis are described below.

The mass participation in each mode due to orthogonal components of motion (two horizontal and one vertical) was computed individually, and then added (one horizontal plus vertical) by absolute summation at the modal level. All modal responses were combined by Square-Root-of-the Sum-of-the-Squares to obtain the total response for all modes considered. 60

The total response was calculated twice: once with North-South Horizontal and Vertical Spectra, and second with East-West Horizontal and Vertical Spectra. The resultant total response used for design is the maximum of the two calculations. This approach of combined horizontal and vertical seismic response may be illustrated as follows: 60

Let F_A be a response quantity of interest, be it a displacement or a member force at some point in the structure. Let Fij be the maximum response in the jth mode due to ith component of excitation. Consider *n* modes (i.e., j = 1, 2 . . . n) and 2 components (i.e., i = 1, 2 for horizontal and vertical directions).

$$\text{Then } F_A = \left(\sum_{j=1}^{n} \left[\sum_{i=1}^{2} | F\,ij | \right]^2 \right)^{1/2}$$

Stresses resulting from the DE seismic analysis were combined with deadload stresses, pressure stresses, and other stresses caused by other sustained loads. The following equation in the ANSI B31.1 piping code was used:

$$\frac{PDo}{4t_n} + \frac{0.75i\,M_A}{Z} + \frac{0.75i\,M_B}{Z} \leq 1.2\,S_h$$

Where:

P = Internal pressure, psig.

Do = Outside diameter of pipe, in.

t_n = Nominal wall thickness of component, in.

M_A = Resultant moment loading on cross section due to sustained loads, in-lb.

M_B = Resultant moment (in.-lb.) loading on cross section due to occasional loads such as thrusts from relief/safety valve loads, from pressure and flow transients, and (DE) design earthquakes. For earthquake, use only one half the earthquake moment range. Effects of anchor displacement due to earthquake may be excluded.

S_h = Basic material allowable stress at operating temperature from allowable stress table of ANSI B31.1, psi.

For DDE stresses, the following formula was applied:

$$\frac{PDo}{4t_n} + \frac{0.75\ i\ M_A}{Z} + \frac{0.75i\ M_C}{Z} \leq \underline{1.8}\ S_h$$

Where:

M_C are DDE values corresponding to M_B for DE.

Earthquake stresses due to the DDE were not calculated directly; instead the results from the DE piping analysis were doubled to represent the DDE. This approach was chosen because review of the design spectra showed that the DDE acceleration did not exceed twice the DE acceleration and in some cases was less than twice as large. Since pipe stress is linear with acceleration, this approach is conservative.

Linear interpolation was used to generate the spectra at the intermediate elevations. Each seismic analysis deals with a section of pipe which lies between two or more anchors. These anchors may represent equipment connections, containment penetrations, or supports which restrict any translational and rotational movements of the pipe. Supports in the seismic analysis may be located at various elevations of the structure. Therefore, different response spectra at the corresponding support elevations are enveloped to obtain the final design spectra. In most cases, the highest elevation response spectrum will govern and the low elevation spectra are ignored. In situations where the piping systems run between two buildings, all support elevations are considered. Figure 8-2 illustrates the combination of spectra.

One half percent damping was used throughout for DE and DDE analysis.

The frame supports and snubbers in the seismic analyses are modeled as infinitely stiff elements. This modeling method is slightly less conservative than the actual situation. Since the supports are designed with the first mode of frequency above 20 Hz, the slight deviations in support modeling do not significantly affect the results of the seismic analyses.

All piping designed by the response spectrum modal superposition analysis was found to exhibit acceptable pipe stresses under DE and DDE conditions.

Piping systems seismically qualified by response spectra modal superposition methods for the DE/DDE were reanalyzed using the Hosgri spectra, described in Chapter 5. For Class A, B, and C piping (as defined in FSAR Section 3.2), other than the reactor coolant loop, the specific differences in other criteria were as follows:

1. The damping was 2% for pipes equal to or less than 12 inches in diameter and 3% for lines greater than 12 inches in diameter. As discussed in Chapter 5, these values are in accordance with Regulatory Guide 1.61.

2. The Hosgri earthquake loads or stresses were combined with normal operating loads or stresses--pressure plus deadload. The allowable combined stresses were currently accepted values for faulted conditions--2.4 S_h for Class B and C piping (per ASME Code Case 1606-1) and 3.6 S_h for Class A piping (unchanged from the FSAR, Table 5.2-13).

3. The allowable stress on all seismic supports was 1.2 S_y, based on ASME Section III NF criteria. Table 8-9 lists the maximum allowable stresses for various loading combinations on hangers.

The results of the evaluation are shown in Table 8-3. This table compares the highest seismically induced stress and the maximum allowable seismic stress for each piping component in each section. The allowable seismic stresses were obtained by subtracting the dead weight and longitudinal pressure stresses from the total 2.4 S_h allowable. 56

The table is organized on the basis of the major systems included and lines are given in numerical order within each system. Modifications were made where seismic stresses exceeded allowable stresses, but some lines which were not over allowable stresses have also been affected. Some lines in the table are not represented by specific stress values but have the note "See 8.1.1." This indicates that these lines were qualified by the seismic restraint spacing criteria described in Sections 8.1.1 and 8.1.3. A few lines in the table have the note "N.R." This stands for, "Not Required", and means that these lines are extremely short, embedded in concrete, or otherwise obviously adequately supported to assure low seismic stresses. Lines in this category have been re-reviewed to verify this conclusion. Piping in the reactor coolant loop is discussed further in Section 8.3. 72

8.3 ANALYSIS OF PIPING SIX INCHES AND GREATER ATTACHED TO REACTOR COOLANT LOOP PIPING

Piping models were constructed for the WESTDYN computer program. This special purpose program is designed for the static and dynamic analysis of redundant piping systems with arbitrary loads and boundary conditions. The lumped-mass models represented ordered sets of data that numerically described the physical systems to the WESTDYN program.

The spatial geometry of the piping models was based on the piping isometric drawings. The node point coordinates and the incremental lengths of the elements were calculated from these drawings.

The lumping of a distributed mass of a piping segment was accomplished by the following:

1. For straight pipe between rigid restraints separated by length L, one half the total mass was located 1/4 L from each rigid restraint.

2. For pipe segments with valves, flanges, manifolds, etc., the piping mass was located along the centerline of the pipe at the location of the component.

3. For components, valves, flanges, manifolds, etc., the total mass was located at the center of gravity of the component.

Each piping model was coupled to a model of the appropriate reactor coolant loop which included the mass and stiffness characteristics of the steam generator, reactor coolant pump, reactor vessel and core internals. The remaining reactor coolant loops were modeled as a 6x6 stiffness matrix applied at the reactor vessel centerline. The influence of the auxiliary piping supports on the piping model was considered by applying each support in the form of a 6x6 matrix representing the stiffness and directionality in the plant coordinate system. Support types and directionality were obtained from the applicable support detail drawings. In general, support 60 spring rates used in the analyses were calculated from the support detail drawings. Snubber spring rates were assumed to be the average of the manufacturer supplied tension and conversion values. Loads acting on supports were computed by multiplying the support stiffness matrix, by the displacement vector at the support point. 50

A sketch of a typical piping model is shown in Figure 8-3. The reactor coolant loop model to which the piping model was coupled is shown in Figure 8-4.

Analysis of the auxiliary piping was performed for the Hosgri earthquake horizontal floor response spectra discussed in Chapter 5 of this report. The analysis was performed using the three dimensional lumped mass model described above and the response spectrum method also discussed in Chapter 5.

The horizontal response spectrum used in the analyses was the envelope of floor response spectra curves for the interior containment at elevation 140 ft. and, if applicable, the exterior containment at the elevation of the containment penetration of the specific piping under consideration. The interior containment 140 ft. elevation represents the highest elevation for attachment of the piping supports or components and also maximum horizontal seismic excitation.

The vertical response spectrum used in the analyses was the envelope of floor response spectra curves for the interior containment at elevation 140 ft. and, where applicable, the exterior containment at the elevation of the containment penetration of the specific piping under consideration and also, where applicable, the containment annulus structure (envelope of curves dependent upon actual location of support attachment to the annulus structure). The interior containment 140 ft. elevation represents the highest elevation for attachment of the piping supports or components and also maximum vertical seismic excitation. 60

Within each mode, the results due to the vertical shock were added absolutely to the results of the horizontal shock directions. The modal contributions were then added by the SRSS method.

Two seismic cases were considered; north-south plus vertical and east-west plus vertical. The worst combined response was used in the evaluation of the system.

The following loading combination was considered:

$$S_{\ell p} + S_{DW} + S_{HOSGRI} \leq 3.6\ S_h$$

Where:

$S_{\ell p}$ = longitudinal pressure stress as defined by Paragraph 102.3.2 of the ANSI B31.1 code, 1973.

S_{DW} = an assumed maximum stress of 1500 psi due to deadweight moment.

S_{HOSGRI} = stress due to the Hosgri earthquake inertial moment as defined by Paragraph 104.8.2, equation 12, of the referenced code.

S_h = piping material allowable stress at maximum temperature from Appendix A of the referenced code.

Summary results are given in Table 8-3 and compare the calculated stresses resulting from the Hosgri earthquake to the allowable seismic stresses. The allowable seismic stresses were obtained by subtracting the deadweight and longitudinal pressure stresses from the total 3.6 S_h allowable. 66