Robert L. Cloud and Associates, Inc.

RLCA

# Interim Technical Report

DIABLO CANYON UNIT 1
IDVP VERIFICATION OF CORRECTIVE ACTION
-Containment Building-
ITR #54, Revision 1

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PROGRAM MANAGER'S PREFACE

DIABLO CANYON NUCLEAR POWER PLANT - UNIT 1

INDEPENDENT DESIGN VERIFICATION PROGRAM

INTERIM TECHNICAL REPORT

CONTAINMENT STRUCTURE

This Revision 1 to Interim Technical Report, ITR-54, is one of a series of ITRs prepared by the DCNPP-IDVP for the purpose of providing a conclusion to the program.

Revision 1 reports the completed IDVP-verification of the DCP corrective action to qualify the containment structure including the interior structure for both seismic and non-seismic loads. The IDVP review verification addressed EOI 1014 which was redefined to track the DCP reevaluation of the containment structure being performed as part of the Corrective Action Program, as well as EOI 3009. IDVP verification efforts related to the annulus structure are not included herein, but are reported in ITR-51. The results of the site verification of modifications are also reported herein. The IDVP verification results in this ITR will be reported in Section 4.4.4 of the IDVP Final Report.

As IDVP Program Manager, Teledyne Engineering Services has reviewed this Interim Technical Report. Prefessors J. M. Biggs and M. J. Holley, Jr., participated in the verification efforts underlying this report, as summarized in Appendix E, Program Manager's Assessment. Reflecting that participation, they are in agreement with the contents of this report.

ITR Reviewed and Approved
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IDVP Verification of Corrective Action

Containment Building

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# 1.0 INTRODUCTION

## Purpose and Scope

This interim technical report (ITR) summarizes the Independent Design Verification Program (IDVP) review of the Diablo Canyon Project's (DCP) corrective action to qualify the containment structure at Diablo Canyon Nuclear Power Plant, Unit 1 (DCNPP-1) for both seismic and nonseismic loads.

This ITR addresses both the interior and exterior concrete containment structures, including the polar crane. The interior structure consists of the reactor cavity wall, reactor support ring, crane wall, fuel transfer canal, and floor and structures supported at elevation 140 feet. The exterior structure is comprised of the containment shell and base slab. Important elements include the liner plate, slab/shell junction, and the access hatches. The polar crane is supported on the crane wall at elevation 140 feet of the interior structure. The containment building is a Design Class 1 structure. The IDVP verification of the DCP corrective action for the containment annulus, a steel-framed structure located between the crane wall and the containment shell, was presented in ITR #51.

The seismic load conditions for analyzing the containment structure consist of the Hosgri (both Newmark and Blume) Earthquake, Design Earthquake (DE), and the Double Design Earthquake (DDE). Nonseismic loads considered, if applicable, are thermal, pipe reaction, jet impingement, missile impact, and internal pressure.

The IDVP program for verification of the DCP corrective action with respect to Hosgri criteria (Phase I activities) was presented in ITR #8 (Reference 1). The IDVP program for non-Hosgri criteria (Phase II activities) was presented in ITR #35 (Reference 2).

The DCP Corrective Action Program for the containment building specified a complete review of the dynamic analyses and member qualifications. If the DCP review showed analytical changes, or if physical modifications were required, these were implemented.

In evaluating the DCP methodology, the IDVP examined scope, review, and reanalysis to ensure completeness and compliance with the licensing documents. These documents include the Final Safety Analysis Report (FSAR), Hosgri Report and Safety Evaluation Report (SER) Supplement No. 7 (References 3, 4, and 5).

In evaluating the DCP implementation, the IDVP compared the DCP's list of qualification analyses to the DCP scope. In addition, a sample of qualification analyses was selected and verified with respect to design criteria, as-built conditions, DCP analysis methods, and results. The IDVP examined the DCP analytical methods and models to ensure that proper engineering practice was used.

Summary

The IDVP conducted its verification of the containment structure at DCNPP-1 by examining the DCP Corrective Action Program methodology and implementation.

To evaluate the methodology, the IDVP reviewed the scope, criteria, and procedures described in the PGandE Phase I Final Report (Reference 6). To evaluate the DCP's implementation, the IDVP selected a sample of those calculations and computer files which comprised the qualification analyses for the structure and reviewed the sample for compliance with the DCP design criteria.

The IDVP found the DCP methodology and implementation to be complete as a result of the review of the sampled calculations.

The IDVP selected the polar crane as its sample for field verification of the containment building. The results of the field verification were satisfactory with the exception of two minor items as discussed in Section 4.3. These items had no significant impact on structural integrity nor was any generic concern identified.

## 2.0 INDEPENDENT DESIGN VERIFICATION METHODS

### 2.1 PROCEDURES

#### 2.1.1 IDVP Review of DCP Methodology

The scope of the DCP methodology is described in the PGandE Phase I Final Report. The IDVP compared the DCP scope to structural design criteria, as described in the FSAR, Hosgri Report, Safety Evaluation Report and Supplements, and other licensing documents.

The IDVP verified the DCP methodology by examining the PGandE Phase I Final Report to ensure that all criteria, assumptions, modeling techniques, and specific structural requirements were included. The calculations chosen for the IDVP sample were also reviewed for acceptable methodology.

The IDVP evaluated the three-dimensional models used by the DCP for structural evaluation of the containment exterior shell, equipment hatch, base slab/shell junction, and polar crane. The IDVP also reviewed the reactor cavity wall and reactor support ring evaluations, as well as the generation of response spectra for the interior structure. The IDVP did not review calculations for determination of the seismic loads from the models depicting the exterior and interior concrete structures as detailed in the PGandE Phase 1 Final Report. However, the methodology and procedures described therein were found to be acceptable. Mathematical models were examined with respect to assumptions, computation of mass and stiffness properties, boundary conditions, and representation of the physical structure by finite element modeling.

#### 2.1.2 IDVP Review of DCP Implementation

Appendix A, List of DCP Qualification Analyses, contains the calculation index as supplied by the DCP (Reference 7). The IDVP examined this index to ensure that all response spectra and member qualification analyses were included. The IDVP found the index to be complete and selected a sample of the qualification analyses for review in the areas of modeling, response spectra, and member evaluation. Specific technical checklists were used to document the IDVP review. (See Section 4.2.2 for the Design Review Checklist.)

The IDVP did not review the DCP calculations for generation of response spectra at the containment exterior shell. EOI 3009 addresses generation of response spectra for the containment interior structure.

Structural member evaluations were also reviewed (as described in Section 4.2) to ensure conformance with loading combinations and allowable stresses as specified in the DCP licensing criteria.

For the final segment of their review, the IDVP field verified a portion of the sampled calculations by comparing the as-built condition at the field site to the engineering drawings to ensure conformance.

## 2.2 CRITERIA

The IDVP assembled and reviewed the applicable licensing criteria. The major documents used in the IDVP review were:

- Final Safety Analysis Report for DCNPP
- Seismic evaluation for postulated 7.5M Hosgri earthquake
- Safety Evaluation Report and Supplements.

Also used were the U.S. Atomic Energy Commission Regulatory Guides and other references listed in Section 7.0.

## 3.0 IDVP REVIEW OF DCP METHODOLOGY

General DCP Methodology for Structures

The DCP Corrective Action Program is detailed in the PGandE Phase I Final Report. The DCP effort was undertaken to ensure overall adequacy of the analyses and design of the plant.

The DCP review methodology for structures in general is described in Section 1.5.4.1 of the PGandE Phase I Final Report. Included are the following:

- Comparison of as-built condition with design drawings; implementation of modifications required as a result of reanalysis
- Review of proper criteria utilization from FSAR and Hosgri Report
- Review of assumptions, input data, analytical models, computer codes, and calculation techniques; reanalysis performed as necessary.

## DCP Methodology for Containment Building

The DCP methodology is described in Section 2.1.1 of PGandE Phase I Final Report. Seismic review was performed using the FSAR and Hosgri Report criteria, with seismic input as detailed in those reports.

The DCP used seismic analysis results from the models described in the FSAR and Hosgri Report for the containment internal and external structures. An axisymmetric finite element horizontal model which included the exterior shell, internal structure, base slab, and rock was used for DE/DDE evaluation of the horizontal response. The interior and exterior structures were decoupled and fixed bases were used for the Hosgri evaluation. The Hosgri vertical model was identical to the Hosgri horizontal model for the exterior structure.

The vertical model of the containment internal structure for Hosgri assumed infinite rigidity of the concrete structure and included a lumped mass representation of the annulus structure. For the torsional response due to accidental eccentricity, lumped mass stick models of the interior structure were used. Response spectra were produced using these models.

The DCP reviewed the reactor cavity wall, reactor support ring, and other major sections of the internal concrete structure and found them to meet licensing criteria.

The DCP corrective action for the containment building included reevaluation of the exterior structure. The DCP assembled mathematical models to evaluate the base slab/shell junction and the equipment hatch region. An axisymmetric model using the FINEL computer code was used to investigate the base slab/shell junction, and stresses in the vicinity of the equipment hatch were determined with a model of the 90-degree sector of the shell including the hatch.

The DCP found the exterior shell, base slab/shell junction, and equipment hatch region to meet licensing criteria.

The DCP conducted a review of the polar crane and determined that modifications were required (Reference 6). These modifications included:

- o A constrained parking area to preclude exposure to jet impingement
- o Guide struts to prevent derailment
- o Reinforcement of gantry legs to eliminate occurrence of inelastic strain
- o Increase in depth of bridge trolley to withstand vertical dynamic loads.

An eigensolution was performed followed by a non-linear time history analysis which demonstrated the qualification of the polar crane.

## 4.0 IDVP REVIEW OF DCP IMPLEMENTATION

### 4.1 SELECTION OF IDVP SAMPLE

Basis for Selection of Calculations

The IDVP reviewed the List of DCP Qualification Analyses (Appendix A) to assess the entire seismic qualification of the containment structure for completeness, including implementation of design criteria, formulation of mathematical models, response spectra, and member evaluation.

To qualify the containment structure, the DCP reviewed a series of mathematical models used to analyze the structure. Several models were reviewed and results accepted by the DCP. Other models were newly formulated or revised.

The IDVP selected calculation files (Appendix B) to assess the following:

- o Evaluation of the containment exterior shell using seismic loads from the URS/Blume axisymmetric models (Hosgri) and the associated pressure and thermal loads. This included a review of all results for all loading combinations specified in the PGandE Phase I Final Report and a specific review of a computer run for one load case.
- o Modeling and evaluation of the equipment hatch region (Hosgri)
- o Modeling and evaluation of the base slab/shell junction (Hosgri)
- o Generation of response spectra for the containment interior structure.
- o Review of evaluation for the reactor cavity wall and reactor support ring
- o Review of the DCP analysis models and modifications used to qualify the polar crane (Hosgri).

The IDVP selection of polar crane analyses for verification reflects the importance of the crane within the containment building and its importance as a major sample of DCNPP cranes. The polar crane is supported at elevation 140 feet on the crane wall and travels on a circular rail. It is used for maintenance operation on the reactor vessel and the surrounding support equipment.

The following guidelines were used by the IDVP as a basis for selecting the polar crane calculations:

- Evaluate changes to the mathematical model and subsequent eigensolution to ensure that physical modifications are included

- Review section properties, weights, and load capacities of critical members

- Review member qualification analyses for the prescribed loading combinations

Samples of the computer runs were selected to verify the DCP implementation. Various computer codes were used to perform the seismic analysis. This ITR does not examine these computer codes for quality assurance considerations such as benchmarking, revision number, etc. R.F. Reedy, Inc. has verified computer code quality assurance on a sampling basis as reported in ITR #41 (Reference 8). This ITR reviews the technical application and suitability of each code to the analysis of the containment building.

## 4.2 VERIFICATION OF DCP QUALIFICATION ANALYSES

### 4.2.1 Introduction to the IDVP Review

Using the DCP calculation files, the IDVP performed a review of specific DCP design assumptions, methods, and results for the containment building. The purpose of this review was to verify that DCP results were fully supported, accurate, and documented. These reviews of the sampled DCP calculation files are documented in the design reviews (References 9 through 14) as originated by Robert L. Cloud Associates, Inc. (RLCA). These design reviews were examined by Teledyne Engineering Services (TES) and Professors J. M. Biggs, and M. J. Holley, Jr., and serve as the technical basis for this ITR.

### 4.2.2 Design Review Checklist

The IDVP review of each particular calculation file was accomplished through the use of a checklist. Each checklist contains general technical items which ensure that all required areas are addressed.

The main checklist items and guidelines used to evaluate each item are as follows:

A. Use of Design Drawings

- o Proper transfer of data from construction (pour lift and shop drawings) to design drawings. Verification of field conditions versus drawings performed on a sample basis.

B. Validity of Assumptions

- o Limitations of formulas, mathematical models, etc. and impact on results. Degree of conservatism or unconservatism present, if any.

C. Methodology and Criteria

- o Formulation of mathematical models with respect to licensing commitments and required data. Use of proper seismic ground motion.

- o Inclusion of proper degrees of freedom, mass, stiffness, and boundary conditions.

- o Accuracy of results obtained and assessment of any method limitations.

- o Applicability of the time history and response spectrum analysis methods.

D. Use of Formulas/Accuracy of Calculations

- o Verification that proper formulas are used and applied.

- o Verification of the mathematical accuracy of selected calculations.

E. Completeness of Results/Data Transfer

- o Verification that all required loads, displacements and accelerations are obtained for member evaluation.

- o Review of all required loading combinations and resulting stresses against allowables as per the specified criteria.

- o Sample verification of data transfer for both hand calculations and computer runs. Reviews performed on computer run files, including sample reviews for accuracy of data transfer between calculation files and referenced computer run sequences.

F. Documentation

- o Verification that all calculation files sampled are properly signed, dated, referenced, labeled and approved.

The above checklist items are intended to provide, in summary form, the important topics and issues the IDVP addressed in reviewing the containment structure calculations.

A summary of the results for each DCP calculation file reviewed by the IDVP is presented in Sections 4.2.3 through 4.2.15.

4.2.3 <u>DCP Calculations #200C-1: Containment Shell, and #204C-1: Containment Shell Computer Output for 1.05D + P + Hosgri (1.0A + 0.4B + 0.4V) + T</u>

<u>DCP Analysis</u>

This DCP calculation provides the evaluation of the stresses in the liner, concrete, and reinforcement in the containment exterior shell. Stresses were analyzed at six sections along the height using the CECAP computer program.

Membrane forces due to dead loads and pressure were computed by hand. A thermal gradient across the shell thickness was determined from a thermal analysis.

Shell forces and moments were taken from the seismic analysis as given in the URS/Blume report (Reference 16). The three-dimensional SRSS values from the Blume earthquake controlled over Newmark; thus Blume shell forces and moments were used. Load combinations are specified in the PGandE Phase I Final Report, Sections 2.1.1.2.1 and 2.1.1.2.2. The DE and DDE vertical and one horizontal response were added on an absolute sum basis. The Hosgri earthquake seismic forces were combined according to:

(1) 1.0A + 0.4B + 0.4V
(2) 0.4A + 1.0B + 0.4V
(3) 0.4A + 0.4B + 1.0V

where:

A, B, and V are the total forces due to earthquakes in the North-South (N-S), East-West (E-W), and Vertical directions, respectively.

The CECAP models included representation of the liner, concrete, and reinforcement. The model at elevation 89 feet included the meridional steel beams. The CECAP program uses isotropic linear elastic material properties for concrete to compute stresses. An iterative procedure is used to obtain stresses considering the redistribution of forces due to cracking. The concrete is assumed to have no tensile strength.

The DCP determined the allowable concrete stress to be (0.9)(0.85)(f'c) = 0.765 f'c. Whenever the concrete stress computed by the CECAP model exceeded 0.7 f'c, the DCP considered the peak stress to be 0.7 f'c, the useful ultimate stress. The concrete stresses computed by the CECAP program exceeded the allowables at elevations 166 feet (Hosgri down) and 89 feet (Hosgri up and down) for the load case sampled by the IDVP. The maximum concrete stress computed by CECAP at these elevations for the load case sampled by the IDVP was 3.34 ksi compression, which is equal to .88 f'c. The value of f'c is the average compression strength of the concrete as determined by testing and as allowed for Hosgri evaluation.

For the load case D+NP+DE+To at elevation 89 feet, the diagonal rebar stress computed by CECAP exceeded the allowable by 10 percent. DCP performed hand calculations accounting for the shift in center of rigidity of the shell section due to cracking, which resulted in a total stress less than the allowable.

The DCP provided summary tables that presented all liner plate actual stresses. All stresses were within allowables for the required loading combinations.

IDVP Conclusions

The DCP qualification analyses and analytical models provided an acceptable representation of the exterior shell. The DCP analyzed the shell at six different elevations away from major discontinuities, which is adequate to capture locations where loads and stresses have significant variation. All loads and combinations required by the criteria were included. The DCP used an acceptable linear approximation of the thermal gradient curve to obtain nodal temperatures used in the CECAP model. Use of proper material properties as per the Hosgri Report was verified by the IDVP, as was the computer input and output for a specific load case (Calculation #204C-1).

Results of a study comparing dynamic characteristics of a similar pressurized water reactor (PWR) were provided by the DCP. This study illustrated that the presence of an opening (equipment hatch) was compensated for by the stiffness of the ring girder and two-way action of the shell. Thus, the axisymmetric model is acceptable for regions other than at the equipment hatch.

The DCP used moments obtained from the base slab/shell junction analysis to compute stresses at elevation 89 feet. This is acceptable since the base slab/shell junction model is more accurate in this region. The DCP also used hoop forces from the URS/Blume seismic analysis at elevation 92.58 feet for evaluation of the section at elevation 88.58 feet. This is conservative, since the hoop forces become lower closer to the base mat.

For the computer run examined by the IDVP, the concrete stresses computed by the CECAP program were nearly equal to the ultimate compressive strength of 0.85 f'c for reinforced concrete. The maximum strain computed was 0.00087, which is well below the ultimate strain capability of 0.003 to 0.004 for concrete. For load cases other than that sampled by the IDVP, maximum strain was 0.00125 (.95D + 1.5P + T", elevation 89 feet), with a stress of 4.59 ksi. A minimum specified compressive strength (f'c) of 3 ksi was used for the non-Hosgri load combinations. Even though the stress level computed by CECAP was above the allowable stress level, the low strain level indicates that the concrete has not failed. The use of 0.7 f'c as the useful ultimate stress is acceptable, given this strain level. The high concrete stress occurs within a limited range at the inside face of the shell, and is mainly due to the accident thermal load.

The DCP provided acceptable calculations demonstrating that the liner plate stresses and strains were within allowables when included in the CECAP model. The DCP then considered the additional stress in the reinforced concrete shell when the liner was not relied upon to act as a load-carrying element for the critical load cases. The total stress present in the reinforcement was verified to be less than the allowable stress. The IDVP concluded that the exterior shell meets licensing criteria.

4.2.4 DCP Calculations #210C-1: Containment Shell and Base Slab Juncture, and #213C-1: Computer Analyses of Stresses in Concrete, Steel, and Reinforcement Components at the Juncture of the Containment Shell and Base Slab for 1.05 DW + 1.0P + Thermal (Summer) + Hosgri Down

DCP Analysis

To qualify the containment shell and base slab juncture, the DCP formulated a mathematical model to evaluate the region at the juncture. The model was an axisymmetric finite element model that extended to elevation 200 feet on the containment shell and included portions of the interior structure and supporting rock foundation. Rotation of the cylinder edge relative to the base slab was allowed in any meridional plane with resistance provided against relative shell-to-slab radial and meridional displacements. The diagonal reinforcement was modeled using an element layer with equivalent orthotropic material properties. An artificially high pressure was applied to the diagonal reinforcement layer so that cracking would occur normal to the radial direction and the material would behave as a two-way membrane. The FINEL computer program accounted for cracking in the concrete through an iterative process which modified the element stiffness matrix when cracking occurred.

The temperature distribution was determined by an axisymmetric heat transfer program. The FINEL computer program used for member evaluation considered the cracking of concrete and yielding of reinforcing steel. The vertical membrane maximum force was conservatively applied as a uniform load around the circumference. Load combinations specified in the PGandE Phase I Final Report, Section 2.1.1.2.2, were considered.

Stresses were calculated for the diagonal and hoop reinforcement, vertical wide flange beams, and concrete. All stresses were shown by the DCP to be within allowables.

## IDVP Conclusions

The IDVP concluded that the DCP model was an acceptable representation of the base slab/shell junction with respect to the element mesh, boundary conditions, and applied loads.

The DCP derived an expression for the stress in the diagonal reinforcement based on strains from the FINEL output. The thermal strains were subtracted from these output strains, and a stress value was then computed. This is acceptable since the thermal strains are self-relieving.

The IDVP selected one loading combination and computer run (Calculation #213C-1) for review. The geometry and loadings were verified as corresponding to the model description given in #210C-1. The IDVP verified the source of the nodal temperature loads, but did not, however, review the calculation of nodal temperatures. The transfer of computed stresses from the computer output to Calculation #210C-1 was verified. The IDVP finds the slab/shell junction to meet licensing criteria.

4.2.5 DCP Calculations #250C-2: Containment Equipment Hatch Computer Analysis, and #250C-3: Stress Check According to ASME

DCP Analysis

Hand calculations performed by the DCP indicated the need for a more sophisticated analysis. A 90-degree sector, 60-foot high three-dimensional model was assembled. A pictorial representation of the model is given in Figure 1. The finite element mesh consists of three parallel surfaces, shown in the figure, and connected by transverse beam elements.

The liner plate, sleeve, and hexagonal plate are modeled by isotropic elements, and reinforcement by orthotropic elements. The transverse beam elements represent the transverse normal and shear stiffnesses of the concrete shell. Membrane stiffness of the concrete is not included.

Boundary conditions were provided based on the application of symmetrical or nonsymmetrical loads. These boundary conditions and locations are summarized in Table 1. For seismic induced overturning moment, the structure remains symmetrical about the y-z plane. The vertical boundary is not allowed to displace. For seismic induced shear loads, the shear deformation in the x-direction is symmetrical about the x-y plane at boundary 3, and antisymmetric about the y-z plane at boundary 2. The vertical displacement is constrained at all boundaries.

Dead and internal pressure loads are applied as nodal forces. The thermal gradient is represented by the corresponding element temperatures. The overturning moment is defined by a cosine distribution of vertical stresses at the top boundary. Horizontal tangential shear forces are applied as nodal forces at the top boundary and also distributed as a cosine function.

Selected stresses and isostress plots were presented by the DCP in the PGandE Phase I Final Report. Local yielding was noted in small areas of the hexagonal plate near the penetration sleeve. Computed stresses were stated to closely match values from strain gage measurements taken during the structural integrity test.

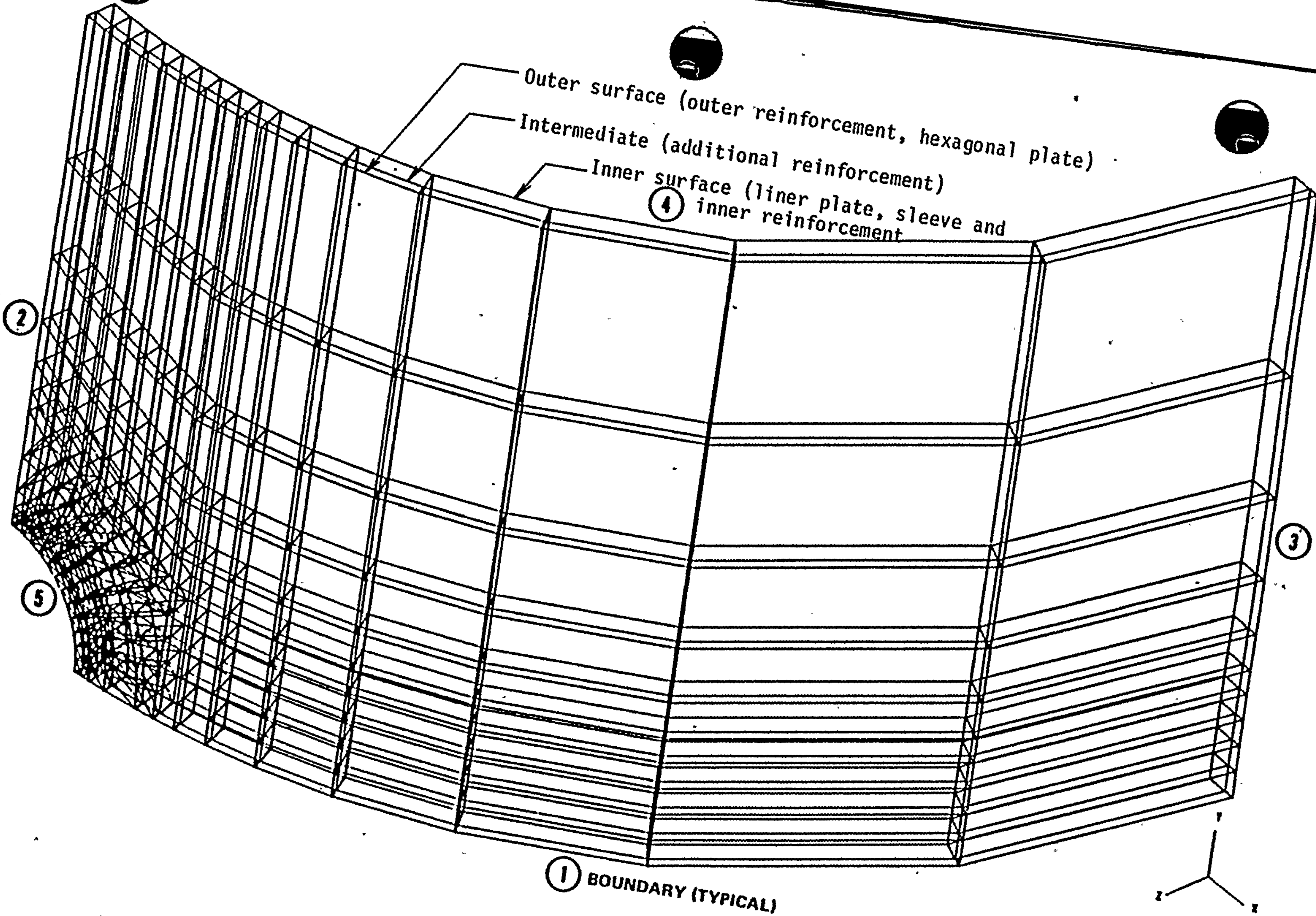



Figure 1

Equipment Hatch Analytical Model - Isometric View (Reference 6)

| AXISYMMETRIC LOADING | | | | | | |
|---|---|---|---|---|---|---|
| Boundary[(a)] | X | Y | Z | RX | RY | RZ |
| 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 2 | 1 | 0 | 0 | 0 | 1 | 1 |
| 3 | 0 | 0 | 1 | 1 | 1 | 0 |
| 4<br>Outside Layer Only | 1 | 0 | 1 | 0 | 0 | 0 |
| **MOMENTS DUE TO SEISMIC LOADS** | | | | | | |
| Boundary[(a)] | X | Y | Z | RX | RY | RZ |
| 1 | 0 | 1 | 0 | 1 | 1 | 1 |
| 2 | 1 | 0 | 0 | 0 | 1 | 1 |
| 3 | 1 | 1 | 0 | 0 | 0 | 1 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| **SHEARS DUE TO SEISMIC LOADS** | | | | | | |
| Boundary[(a)] | X | Y | Z | RX | RY | RZ |
| 1 | 1 | 1[(b)] | 1 | 0 | 1 | 0 |
| 2 | 0 | 1 | 1 | 1 | 0 | 0 |
| 3 | 0 | 0 | 1 | 1 | 1 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 |

0 = Free, 1 = Restrained

NOTE:

(a) - See Figure 1 for Boundaries

(b) - Restrained, except for the nine nodes nearest to the edge of the equipment hatch opening, allowing for variable vertical deformation.

Table 1

EQUIPMENT HATCH BOUNDARY CONDITIONS
(Reference 6)

The DCP then compared stress intensities computed using results of the analytical models according to the ASME code, Section III, Division 1, Subsection NE. Four locations encompassing the perimeter of the 90-degree modeled opening were examined. The DCP evaluated the stresses near the opening, and at .5 RT from the opening.

IDVP Conclusions

The DCP model of the hatch region was acceptable in order to compute the gross forces and moments acting on the structural elements. The boundary conditions specified by the DCP allow an adequate representation of the expected deformation pattern under the imposed loadings. The DCP simplifications used in the modeling of the neck are acceptable, since the primary load-carrying components are the hexagonal plate and reinforcement around the hatch opening. DCP provided calculations demonstrating that the stress intensification at the junction of the liner plate and neck was not significant. Thus the IDVP concludes that the computed stresses are acceptable.

The DCP evaluated the equipment hatch for the D + 1.5P + T" load case discounting the liner as a load carrying element. Small increases in stress occurred, with actual stresses still below allowable stress.

There is no single appropriate ASME or ACI code requirement that pertains to the evaluation of the equipment hatch at DCNPP. There are specific requirements for evaluating reinforced concrete and steel pressure vessel shells. The DCP chose to evaluate the hexagonal plate and surrounding reinforcement according to ASME Section III, Division 1, Subsection NE. The IDVP found this to be acceptable as the most applicable code presently available. The evaluation at the four locations of the hatch was acceptable. One load combination (1.05D + 1.5P) and its corresponding stress exceeded the ASME allowable, but since the computed stress was only 3% over allowable, the IDVP considers the effect to be negligible. The IDVP concludes that the qualification analyses for the hatch are acceptable.

### 4.2.6 DCP Calculation #300C-1: Reactor Cavity Wall

DCP Analysis

This calculation describes the reactor cavity wall qualification. The wall is at the center of the containment building and supports the reactor vessel. The wall extends from the base mat to the top of the fuel transfer canal at elevation 114 feet.

Seismic loads were obtained from the URS/Blume seismic analysis. Shears from the interior structure seismic analysis were distributed according to the relative rigidity of the walls. Shear stresses were computed and compared against the allowables as specified in the licensing criteria. The net overturning moment, including the effect of seismically excited equipment supports, jet impingement force, and pipe rupture loads, was computed for the interior structure. Section properties were computed and the total overturning moment was distributed according to flexural stiffnesses of the crane and cavity walls. Stresses resulting from the overturning moment were computed. The DDE event controlled over Hosgri for the abnormal loading condition.

The compartment pressurization dynamic load factor was computed using the time history pressure curves. Stresses in the walls were computed for the pressure load.

The steam generator support and anchorage into the reactor cavity wall was investigated and found to be satisfactory.

Pipe rupture loads were imposed on the nozzle area of the cavity wall. Stresses were computed and shown to be less than allowables.

IDVP Conclusions

The IDVP concluded that data used in the DCP analyses corresponded to the design drawings. Seismic shear loads were properly distributed to the interior walls based on relative rigidities. Overturning moments due to earthquake-induced steam generator support loads and the DDE condition were combined on an SRSS basis and are acceptable, since the support natural frequency is over twice that of the internal structure. Distribution of the overturning moments by the ratio of flexural stiffnesses was also acceptable.

The DCP cracked section analysis to determine concrete and reinforcement stresses was found to be satisfactory.

Pipe rupture loads were properly distributed as compressive and shear forces on the nozzle area.

The IDVP performed alternate calculations which verified the wall stiffness values. The IDVP also verified the mathematical formulas used to determine the section properties of the cavity wall to evaluate stresses due to bending.

#### 4.2.7 DCP Calculation # 300C-2: Reactor Support Ring

DCP Analysis

The steel reactor support ring bears on a reinforced concrete wall for the full depth of the ring. Vertical loads are resisted by bearing, and lateral loads are resisted by bearing and punching shear in the cylindrical cavity wall.

The DCP calculated critical loading conditions for the reactor support ring based on operating and accident condition loading information supplied by Westinghouse. The loading directions considered were normal (or radial), tangential, and vertical. The loading combinations which were checked were accident (A), dead load plus double design earthquake (DL+DDE), and accident plus dead load plus double design earthquake (A+DL+ DDE), in addition to Hosgri.

IDVP Conclusions

The actual bearing stress due to the vertical loading was verified by the IDVP to be less than the allowable (based on AISC code criteria for plastic deformation). Also, the actual value of punching shear due to lateral loading was verified to be less than the allowable (based on ACI code criteria). Bearing stress and hoop stress in the steel reactor support ring due to radial and tangential loads were less than AISC code allowables (calculated based on plastic design criteria).

### 4.2.8 DCP Calculation #320C-1: Polar Crane Gantry Leg Section Properties

DCP Analysis

The DCP review showed that modifications were required to eliminate the occurrence of inelastic strain in the gantry legs. The required section properties were determined, and plate size increased, to preclude the need for another iteration of capacity versus demand.

IDVP Conclusions

The DCP computed the new section properties correctly and the modifications were included in the appropriate drawings.

### 4.2.9 DCP Calculation #320C-2: Polar Crane - Hold-Down Capacity of Rail Clips

DCP Analysis

The capacity of the rail clip anchorage system was investigated by the DCP to find the controlling component in the resistance of horizontal forces. The components considered were the anchor bolts, clamp assembly, and the grout-bearing material. Tensile capacity of the anchor bolts was computed as well as pullout capacity of the bolts anchored in concrete. Plastic moment capacity of the clamp assembly was calculated both with and without the grout considered as a competent bearing medium. The DCP found that a small compressive stress existed in the grout when the tensile strength of the anchor bolt was developed. When the effects of the grout were conservatively ignored, the rail clip capacity was determined by flexure in the rail clip, and was slightly less than capacity when the grout was intact.

The rail clip anchorage system is illustrated in Figure 2. Applied loads and reaction components and surfaces are detailed.

IDVP Conclusions

The results of these computations for DCP Calculation #320C-2 were used in the polar crane guide strut analysis (Calculation #320C-4), where capacity versus demand comparisons were made. These comparisons show that the tensile capacity of the anchor bolts was properly computed and stated as controlling over the plastic moment capacity of the rail clip assembly. The IDVP verified the values as being acceptable. Appropriate consideration was given to the possible failure of the grout-bearing surface.

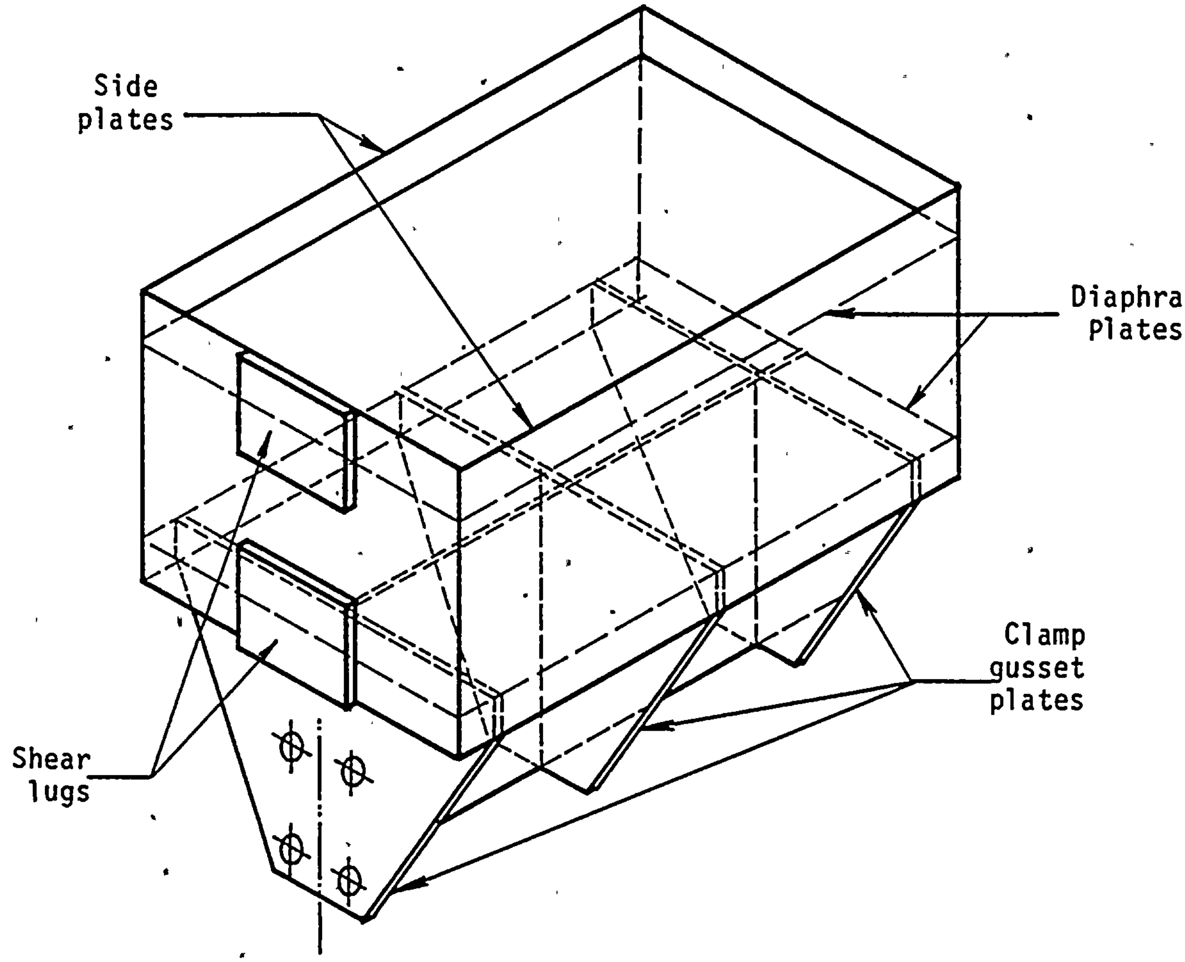
4.2.10 DCP Calculation #320C-3: Polar Crane - Review of Crane Weights for Analysis

DCP Analysis

In this calculation, the DCP listed all weights used to determine the nodal masses in the mathematical models. Agreement with the manufacturing company drawings was noted.

IDVP Conclusions

The listed weight distributions corresponded to those listed in Design Criteria Memorandum (DCM) C-57 (Reference 18) and in Calculation #501C-1, and are acceptable.




Guide Strut Inner Box

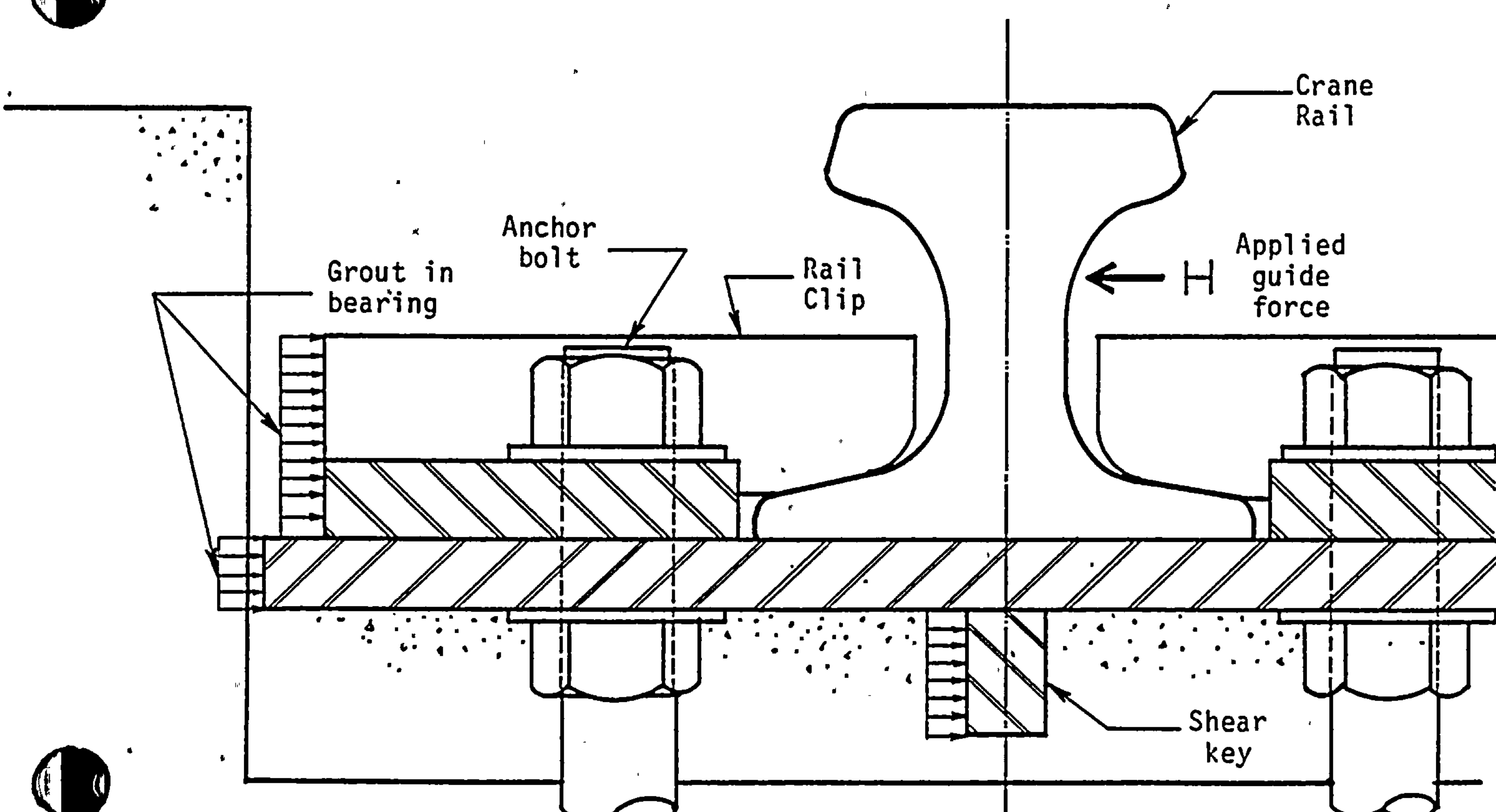



Figure 2
Polar Crane Rail Clip Anchorage System and Guide Strut Inner Box

### 4.2.11 DCP Calculation #320C-4: Polar Crane - Guide Strut Stress Calculations

DCP Analysis

In this analysis, a comparison of capacity and demand for the guide strut and rail anchorage system was presented. The purpose of the guide strut is to prevent derailment when the crane wheels lift off during a seismic event. In the anchorage system, the load transfer mechanism involves:

- o Application of horizontal load to the rail web
- o Load resistance by bearing against the grout or via an alternate path through the shear in the anchor bolts and shear key
- o Rail overturning moment resistance by bearing of the sole plates against the bottom flange of the rail and rail clip capacity.

In the guide struts, the load transfer mechanism involves:

- o Application of horizontal load at the rail head/web interface to the guide strut angles
- o Transfer of load to the gusset plate and inner box section
- o Reaction of the loads by the shear lugs
- o Distribution of load to the outer box section and the sill beam.

The structural components used to transfer the load are illustrated in Figures 2 and 3.

The DCP computed capacities considering shear and bearing in the rail web, and included the capacities for the rail anchorage system determined in Calculation #320C-2. Values are presented in Table 2.

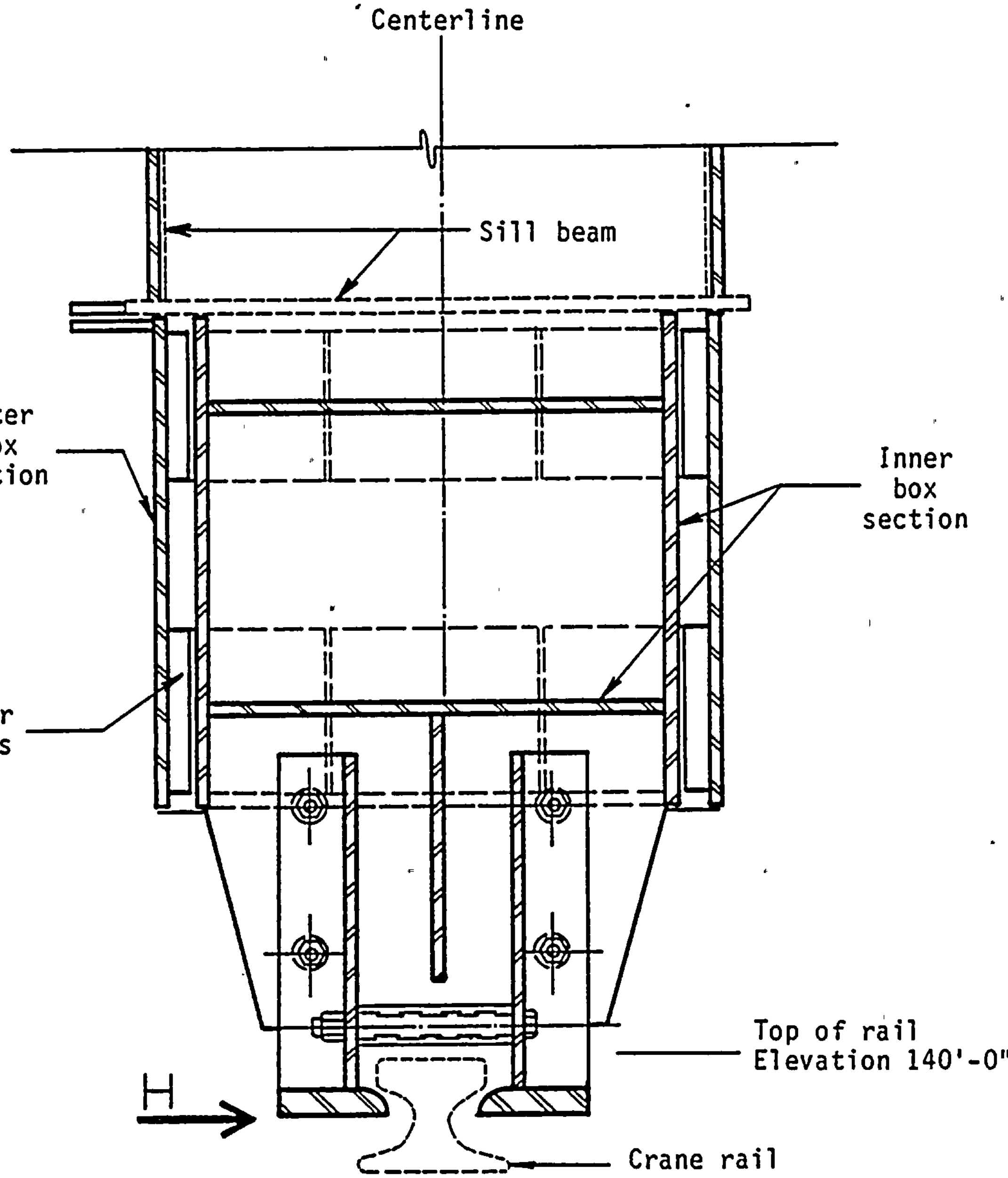



Figure 3

Polar Crane Guide Strut

| GUIDE STRUT CAPACITY | | |
|---|---|---|
| Bending in outside box section | | $317^K$ |
| Bending in guide clamp | $(388^K)^{(1)}$ | $329^K$ |
| Shear lug welds - no uplift | | $273^K$ |
| Shear lug welds - 2 in. uplift | | $214^K$ |
| **RAIL (Controlled by Bending in Web)** | | |
| Grout effective | | $445^K$ |
| Grout over Rail Flange spalled | | $417^K$ |
| **RAIL ANCHORAGE** | | |
| Grout effective - bolt tension controls | | $480^K$ |
| Grout over Rail Flange spalled | | $333^K$ |
| **TRUCK CAPACITY** | | |
| Side plates bending | | $216^K$ |
| Wheel rim shear | | $390^K$ |

Notes

(1). DCP capacity of $329^K$ is based on post first yield but not fully plastic section. IDVP capacity of $388^K$ is based on a fully plastic section.

(2). These values are component capacities as determined by the horizontal reaction load present at the guide strut/rail interface.

TABLE 2

POLAR CRANE COMPONENT CAPACITIES

The DCP examined all elements of the rail anchorage system to determine the controlling element and resulting horizontal load capacity. The DCP conservatively used 36 ksi as the yield stress for the rail material. The horizontal load was assumed to be spread out through five rail clips and anchorages in order to determine total horizontal load capacity. This is acceptable, given the stiffness of the rail and the supporting foundation. A total tributary width of 54 inches was considered.

The guide strut was originally intended as a device to limit lift off. However, the DCP found it to possess sufficient stiffness and strength to act as a primary structural element in resisting horizontal loads. The guide strut capacity was determined from the post-yield but less than full plastic moment capacity of the guide strut assembly. Capacities of the inner box section and shear lugs between the inner and outer box sections were determined from the weld allowables. The outer box section was analyzed using a computer program with plate elements. Shear lug bearing pressures were converted to nodal loads.

The sill beam was analyzed and shown to safely transfer loads from the guide struts to the crane legs. The truck capacity was determined with respect to out-of-plane bending of the side plates and shear on the wheel rims.

IDVP Conclusions

The IDVP concludes that the DCP gave an acceptable description of the guide strut and rail anchorage system load transfer mechanisms. The IDVP performed alternate calculations using the full plastic moment capacity of the guide struts. This value exceeds the DCP calculated capacity as expected. The IDVP finds the summary of DCP demand versus capacities for the guide strut, rail, rail anchorage, and truck components to be acceptable.

Inside box sections and shear lug capacity calculations were found to be acceptable. The outer box section finite element model gave a satisfactory representation of the expected behavior of that section.

Bending and shear (torsional and direct) stresses were properly computed for the sill beam section with the result that both combined and principal stresses were less than allowables. The truck capacity calculations considering bending in the side plates and shear in the wheel rim were also acceptable.

### 4.2.12 DCP Calculation #320C-5: Polar Crane - Determination of Maximum Load on Guide Struts

DCP Analysis

The DCP computed the distribution of the horizontal radial demand load to the components of the polar crane. Time histories of the radial shear loads at the four gantry legs were presented. The radial shear was divided between the truck and guide strut when the uplift was less than 0.75 inches, and taken entirely by the guide strut when the uplift was 0.75 inches or more. A table of maximum wheel uplift versus radial shear was presented in the DCP calculation file.

The possibility that wheels might overcome friction and slide, which would result in a pinching effect and additional horizontal load, was addressed. The longitudinal stiffness of the polar crane was determined and multiplied by the maximum relative ground displacement (20 inches for 2% damping). This yielded a pinching load of 66 kips for the zero-uplift condition. This horizontal load was combined with the pinned support analysis results on both an absolute sum and an SRSS basis.

In the DCP analysis, the horizontal stiffness of the guide strut was stated to consist of the lateral deflection of the sill beam and deformation of the outer box section. The rail clamp stiffness was also included. Unit loads were applied and the total stiffness value determined.

The truck stiffness was determined from the plates, gussets, and pins of the system. A description was given of the load path and transfer mechanism from the horizontal load at the crane wheels into the crane legs. A unit load was applied at the rail/wheel interface and deflections at various portions of the system were computed and accumulated. Both bending and shear deformations were included in determining guide strut and truck stiffness values.

The radial shear was distributed between the truck and the guide struts on the basis of relative rigidities. The guide strut was also assumed to carry additional load due to a 3/16-inch displacement from clearances. The guide strut and truck radial load demands were then tabulated for the zero uplift, 0.1 inch uplift, and maximum uplift conditions.

IDVP Conclusions

Maximum radial shears were read from the time history plots corresponding to the times where uplift exceeded selected values. This method was acceptable to use for determining distribution of load to the truck and guide strut.

The IDVP performed alternate calculations to determine the distribution of load to the truck and guide struts. The loads were similar to the DCP results. A demand versus capacity summary is shown in Table 3. The IDVP finds the DCP qualification analyses for the guide strut and associated components listed in Table 3 to be acceptable.

4.2.13 DCP Calculation #320C-6: Polar Crane - Guide Strut Stresses - Computer Output

DCP Analysis

The outer box section was analyzed to determine its maximum capacity and the associated horizontal load at the wheel/rail interface. Plate elements were used to represent the box section. A unit load was applied to the model and multiplied by the ratio of the allowable/unit load stress to determine the maximum horizontal load the section is capable of resisting.

IDVP Conclusions

Model loads applied to the shear lugs were properly determined from the bearing pressure distribution and tributary area of the nodes. The IDVP verified a sample of the computer output and the final maximum element output stress used to determine the box section capacity and found the sample to meet licensing criteria.

| Condition | Capacity | Demand | Demand / Capacity Ratio |
|---|---|---|---|
| Maximum Horizontal Shear - No Uplift | Guide: $273^k$ | Absolute Sum: $252^k$ | .92 |
| | | SRSS: $216^k$ | .79 |
| | Truck: $216^k$ | Absolute Sum: $101^k$ | .47 |
| | | SRSS: $81^k$ | .38 |
| Uplift less than 0.1 inches | Guide: $273^k$ | Absolute Sum: $231^k$ | .85 |
| | | SRSS: $195^k$ | .71 |
| | Truck: $216^k$ | Absolute Sum: $90^k$ | .42 |
| | | SRSS: $70^k$ | .32 |
| Maximum Uplift - 1.35 inches | Guide: $214^k$ | Absolute Sum: $149^k$ | .70 |
| | | SRSS: $106^k$ | .50 |
| | Truck: None | Absolute Sum: $0^k$ | N/A |
| | | SRSS: $0^k$ | N/A |

Table 3
Polar Crane Component Demand Versus Capacities

### 4.2.14 DCP Calculation #501C-1: Hosgri Analysis and Design Evaluation of the Containment Polar Crane with Modification of Gantry Legs

DCP Analysis

This calculation consisted of an overview of the input data, dynamic analyses, and member evaluation (Hosgri) of the polar crane. DCP Calculations #501C-2 and #501C-3 contain the computer runs used in this analysis.

The polar crane is a gantry crane with a trolley, and it supports a dome service crane. The DCP analysis incorporated the modifications described in the PGandE Phase I Final Report, Section 2.1.1.5.2.

Section properties and lumped mass values were computed by the DCP as input for the computer model to obtain eigenvalues. To reflect the modifications, the gantry leg section properties were revised. Mass and stiffness proportional damping values were used.

The DCP model used pinned supports at all four gantry legs. Natural frequencies and participation factors were obtained.

A nonlinear time history analysis was then performed. Gap elements with compression stiffness-only represented the truck wheel and rail assembly. The hook cable was represented by a tension-only element.

Three statistically independent time histories which correspond to the longitudinal, transverse, and vertical directions and matching the design spectra at elevation 140 feet in the containment interior structure were applied. The gap element forces were obtained and time history plots of forces and displacements were produced. The gantry legs, sill beams, bridge girders, tie beams, trolley, connections, and gantry truck members were evaluated. The crane stabilization system was evaluated in other calculation files (see Section 4.2.11). Plate buckling was considered and stresses checked against allowables as specified in the licensing criteria.

IDVP Conclusions

The IDVP determined that the DCP eigensolution model gave an acceptable representation of the polar crane. The IDVP verified, on a sample basis, weight and section property calculations that were based on design drawings. Minor calculational errors were noted which had no significant impact on results. The IDVP verified, on a sample basis, the eigenvalue extraction computer program input. Even though the damping values computed were based on frequencies slightly different than the final frequency values, the resulting damping values were not significantly changed.

The time history input was conservative since it was developed from the broadened floor spectra and not the raw spectra at elevation 140 feet. The use of pinned supports did not take into account any possible excursions of the crane and associated sliding and friction phenomena. The DCP performed a hand analysis to evaluate these effects and included them in the evaluation of the stabilization system. The IDVP verified the computer program input for the loaded case with free uplift, and the bridge trolley at the center of the crane. Transfer of member forces from the computer output for member evaluation was also verified on a sample basis. Member stresses were verified as being within allowables. In certain cases, moments and forces were combined on a concurrent time basis to yield a more accurate combined stress, which is an acceptable procedure.

## 4.2.15 Containment Interior Response Spectra

### DCP Analysis

The DCP used an axisymmetric, fixed base model for the Hosgri evaluation of the containment structure. Translational response spectra were produced using this model at elevation 140 feet and below. The time histories developed at elevation 140 feet were used as inputs to a decoupled model representing the structures (steam generators and pressurizer walls) supported at elevation 140 feet. Response spectra were then generated. This addressed EOI 1009, which noted that previously no spectra or scaling criteria had been defined above elevation 140 feet.

Eigensolution results were then obtained from axisymmetric models representing the E-W and N-S directions stiffness properties with the same analytical procedures used in the 1978 Hosgri analyses as part of the DCP review process. The DCP computed response spectra for the E-W and N-S directions.

The IDVP developed response spectra for the same E-W and N-S models using the eigensolution results supplied by the DCP but using a different integration routine. These results showed frequency shifts and amplitude changes in the response spectra. These spectra were not enveloped by the DCP Hosgri response spectra recorded in DCM C-17. These findings resulted in the issuance of EOI 3009.

The DCP investigated the parameters involved which contributed to the difference in spectra produced by the DCP and IDVP. The first factor was features of the Hosgri time history acceleration seismic input. The second factor was the integration routine. The design spectra was produced using the Wilson theta method with theta=2.0. Accuracy has been shown to be better for a smaller value of theta=1.4. Period elongation and amplitude decay occur due to the combined influence of the ratio of the time step to natural period and theta value. The effect of the integration routine parameters coupled with the particulars of the time history resulted in the difference in response spectra.

The DCP then used a refined lumped mass stick model representing the interior structure in the N-S and E-W directions which included the structure above 140 feet. A current integration routine was used and response spectra were generated using the same Hosgri acceleration time history. The study model response spectra showed results more similar to the design response spectra. The IDVP found the horizontal design spectra to be acceptable for elevations 140 feet and below. The IDVP found the spectra differences above elevation 140 feet warranted further review.

The DCP then formulated a revised mathematical model which employed a rigid foundation with soil-structure interaction. The foundation medium was represented by impedance functions that reflected stiffness and radiation damping. These impedance values were frequency dependent. Frequency domain analysis techniques were used to calculate the nodal acceleration time histories and subsequent response spectra.

The response spectra obtained were then compared to the design response spectra. The study model response spectra were enveloped by the design response spectra at elevations 151 and 175 feet for both the E-W and N-S directions. The study model response spectra had a significantly higher amplitude than the design response spectra at 20 hertz for elevation 184 feet. The DCP evaluated the piping and components above elevation 140 feet and found a maximum of 10% increase in stress (Hosgri) with stresses still below allowables.

IDVP Conclusions

The IDVP found the use of the refined model with rigid foundation and impedance functions to represent the foundation medium to be acceptable. The foundation properties and equations used to determine the impedance functions were satisfactory. The DCP compared response spectra (at elevation 184 feet) produced from the frequency domain versus the time history for the fixed base model. Response spectra were similar, thus use of the frequency domain analysis for the rigid foundation/ impedance function model yields satisfactory results and is acceptable.

Since there are few components affected by the higher study model response spectra (at elevation 184 feet, 20 hertz) and the DCP demonstrated that these components remain qualified, the IDVP finds the design response spectra to meet licensing criteria. EOI 3009 has been closed.

## 4.3 VERIFICATION OF AS-BUILT CONDITION

The IDVP has field verified the as-built condition of portions of the containment structure sample described in Section 4.1. This sample consisted of portions of the polar crane. The as-built conditions were checked against the design drawings used as the basis for calculations.

The IDVP found two minor instances where the as-built condition did not match the design drawings. The first case concerned the clearance of the crane wheels and guide struts versus the crane rail. Plates were modified to allow the proper clearance, and these modifications had no impact on the structural integrity. Secondly, a nonstructural plate was welded to the outer box instead of the inner box of the guide strut. This discrepancy will be resolved by the DCP for the final resolution of the operational capability of the polar crane. All other field verification review results were satisfactory.

The IDVP finds their field verification review results to be satisfactory. The two minor discrepancies had no impact on structural integrity nor were any generic concerns identified.

## 5.0 ERROR AND OPEN ITEM REPORTS

EOIs 1014 and 3009 have been issued concerning the containment building.

EOI 1014 is a consolidation of EOI files which addresses certain areas for which neither response spectra nor scaling criteria had been defined, and the structural evaluation of the annulus.

The DCP has now defined response spectra at the areas above elevation 140 feet. In addition, the annulus analysis has been revised and was verified by the IDVP. EOI 1014 was resolved as an Error Class A/B.

EOI 3009 states that the Hosgri horizontal design response spectra for the interior structure does not envelop the raw spectra developed independently by the IDVP. As reported in Section 4.2.15, the DCP has performed additional analyses. These analyses have been reviewed and accepted by the IDVP. EOI 3009 was therefore resolved as an Error Class C.

## 6.0 CONCLUSIONS

The IDVP has reviewed the DCP Corrective Action Program methodology for the containment building (excluding the annulus, which is reported in ITR #51) as detailed in the PGandE Phase I Final Report and found it to be acceptable.

The DCP supplied the IDVP with a list of qualification analyses (Reference 7, detailed in Appendix A) which the IDVP found to be acceptable. The IDVP selected a sample from this list in order to verify the DCP implementation.

The IDVP found the components selected in its sample of qualification analyses to meet licensing criteria. Field verification results were found to be satisfactory.

## 7.0 REFERENCES


| Reference No. | Title | RLCA File Number |
|---|---|---|
| 1 | Independent Design Verification Program (IDVP), Interim Technical Report (ITR) #8, Verification Program for PGandE Corrective Action, Revision 0, October 5, 1982. | P105-4-839-008 |
| 2 | IDVP, ITR #35, Verification Plan for Diablo Canyon Project Activities, Revision 0, April 1, 1983. | P105-4-839-035 |
| 3 | Diablo Canyon Site Units 1 and 2, Final Safety Analysis Report, USAEC Docket Nos. 50-275 and 50-323. | P105-4-200-005 |
| 4 | Seismic Evaluation for Postulated 7.5M Hosgri Earthquake, USNRC Docket Nos. 50-275 and 50-323. | P105-4-200-001 |
| 5 | Supplement No. 7 to the Safety Evaluation Report, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, In the Matter of Pacific Gas and Electric Company, Diablo Canyon Nuclear Power Station, Units 1 and 2, Docket Nos. 50-275 and 50-323. | P105-4-100-013 |
| 6 | Pacific Gas and Electric Company (PGandE), Phase I Final Report - Independent Design Verification Program, Diablo Canyon Nuclear Power Plant, June 21, 1983. | P105-4-200-117 |
| 7 | DCP, Calculation Index, Containment Building, Revision 6, August 16, 1983. | P105-4-431-425 |

| Reference No. | Title | RLCA File Number |
|---|---|---|
| 8 | IDVP, ITR #41, Corrective Action Program and Design Office Verification Performed by R.F. Reedy, Inc., Revision 0, April 13, 1983. | P105-4-839-041 |
| 9 | IDVP Design Review of DCP Calculations #200C-1 and #204C-1, Revision 0. | P105-4-506-197 |
| 10 | IDVP, Design Review of DCP Calculations #210C-1 and #213C-1, Revision 0. | P105-4-506-198 |
| 11 | IDVP Design Review of DCP Calculations #250C-2 and #250C-3, Revision 0. | P105-4-506-195 |
| 12 | IDVP Design Review of DCP Calculations #300C-1 and #300C-2, Revision 1. | P105-4-506-092 |
| 13 | IDVP Design Review of DCP Calculations #320C-1, #320C-2, #320C-3, and #501C-1, Revision 1. | P105-4-506-099 |
| 14 | IDVP Design Review of DCP Calculations #320C-4, #320C-5, #320C-6, and #501C-2, Revision 1. | P105-4-506-145 |
| 15 | Diablo Canyon Project (DCP), Design Criteria Memorandum (DCM) C-17, Hosgri Response Spectra for Structures, Systems, and Components, Revision 7. | P105-4-200-100 |
| 16 | URS/John A. Blume and Assoc., Diablo Canyon Nuclear Power Plant, Unit 1, Containment Structure Dynamic Seismic Analysis for the 7.5M Hosgri Earthquake, May 1979. | P105-4-441-002 |
| 17 | DCP, DCM C-47, Containment Exterior Structure, Revision 0. | P105-4-200-127 |
| 18 | DCP, DCM C-57 Containment Polar Crane, Revision 0. | P105-4-200-107 |

| Reference No. | Title | RLCA File Number |
|---|---|---|
| 19 | DCP response to RFI #1102, resolution package for EOI 3009. | P105-4-3009-002 |
| 20 | Supplemental response to resolution package for EOI 3009. | P105-4-431-531 |
| 21 | DCP computer verification of containment interior soil structure interaction model. | P105-4-431-514 |
| 22 | DCP evaluation of piping above elevation 140 feet - supplemental response for EOI 3009. | P105-4-611-1208 |
| 23 | DCP Calculation 250C-2, Revision 1 and computer run 259C-2. | P-105-4-431-550 |

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RLCA

Appendix A

List of DCP Qualification Analyses

(7 pages)

Appendix A

List of DCP Qualification Analyses

| Calc. No. | Revision | Calculation Description |
|---|---|---|
| 200C-1 | 0 | Containment Shell |
| 200C-2 | 1 | Containment Displacements due to LOCA loads for Table in DCM C-28 |
| 201C-1 | 0 | Containment Shell (CO*) (1.05D + To ± DE + NP) |
| 201C-2 | 0 | Containment Shell (CO*) ((1.0 ± 0.05)D + 1.5P + T 2) |
| 202C-1 | 0 | Containment Shell (CO*) (1.05D + 1.25P ± 1.25DE + T 1) |
| 202C-2 | 0 | Containment Shell (1.05D + P ± DDE + T) |
| 203C-1 | 0 | Containment Shell (CO*) El. 89' |
| 204C-1 | 0 | Containment Shell (CO*) (1.05D ± Hosgri (1.0A + 0.4B + 0.4V) + T |
| 204C-2 | 0 | Containment Shell (CO*) (1.05D + P ± Hosgri (0.4A + 1.0B + 0.4V) + T) |
| 204C-3 | 0 | Containment Shell (CO*) (1.05D + P ± Hosgri (0.4A + 0.4B + 1.0V) + T) |
| 205C-1 | 0 | Containment Shell (CO*) (D + T + P) El. 301' |
| 205C-2 | 0 | Containment Shell (CO*) (D + T + P) El. 281.64' to 166' |
| 205C-3 | 0 | Containment Shell Displacement (CO*) (D + T) |
| 205C-4 | 0 | Containment Shell Displacement (CO*) (D + P) |

CO* - Computer Output

Appendix A

List of DCP Qualification Analyses (Continued)

| Calc. No. | Revision | Calculation Description |
|---|---|---|
| 210C-1 | 0 | Containment shell and base slab juncture |
| 211C-1 | 0 | Computer analysis for 0.95DW + 1.5 PT + Thermal (Winter) |
| 211C-2 | 0 | Computer analysis for 0.95DW + 1.5P + Thermal (Summer) |
| 212C-1 | 0 | Computer analysis for 1.05DW + 1.0P + Thermal (Winter) + Hosgri Down |
| 212C-2 | 0 | Computer analysis for 0.95DW + 1.0P + Thermal (Summer) + Hosgri Up |
| 213C-1 | 0 | Computer analysis for 1.05DW + 1.0P + Thermal (Summer) + Hosgri Down |
| 213C-2 | 0 | Computer analysis for 0.95 DW +1.0P + Thermal (Summer) + Hosgri Up |
| 214C-1 | 0 | Computer analysis for 1.05DW + 1.25P + Thermal (Winter) + 1.25 DE Down |
| 214C-2 | 0 | Computer analysis for 0.95DW + 1.25P + Thermal (Winter) + 1.25 DE Up |
| 215C-1 | 0 | Computer analysis for 1.05DW + 1.25P + Thermal (Summer) + 1.25 DE Down |
| 215C-2 | 0 | Computer analysis for 0.95DW + 1.25P + Thermal (Summer) + 1.25 DE Up |

Appendix A

List of DCP Qualification Analyses (Continued)

| Calc. No. | Revision | Calculation Description |
|---|---|---|
| 216C-1 | 0 | Computer analysis for 0.95DW + 1.5P (No liner plate) |
| 216C-2 | 0 | Computer analysis for 1.0DW + 1.15P |
| 217C-1 | 0 | Computer analysis for 1.05DW + 1.0P + Thermal (Summer) |
| 217C-2 | 0 | Computer analysis for 0.95DW + 1.0P + Thermal (Summer) |
| 218C-1 | 0 | Computer analysis for inclined reinforcement stresses and nodal temperatures |
| 218C-2 | 0 | Computer analysis - Nodal Temperatures |
| 225C-1 | 0 | * Containment base slab calculations |
| 250C-1 | 0 | Containment equipment hatch - hand calculations |
| 250C-2 | 1 | Containment equipment hatch (computer analysis) |
| 250C-3 | 0 | Equipment hatch stress check according to ASME Section III Division 1, Subsection NE |
| 251C | 0 | Computer analysis of:<br>(i) Dead load (D)<br>(ii) Pressure (P)<br>(iii) Thermal corresponding to 1.5P(T")<br>(iv) Thermal corresponding to 1.0P(T)<br>(v) Thermal corresponding to 1.25P(T')<br>(vi) 1.0D + 1.15P<br>(vii) 1.05D + 1.5P + T" |

* The IDVP has not listed the associated computer calculation numbers.

## Appendix A

### List of DCP Qualification Analyses (Continued)

| Calc. No. | Revision | Calculation Description |
|---|---|---|
| 252C-1 | 0 | Computer analysis of maximum overturning moment - HE |
| 252C-2 | 0 | Computer analysis of maximum shear force - HE |
| 253C-1 | 0 | Computer analysis of maximum overturning moment - DE |
| 253C-2 | 0 | Computer analysis of maximum shear force - DE |
| 254C | 0 | Computer output for load combinations:<br>(i) D + 1.5P<br>(ii) 1.05D + 1.5P + T" |
| 255C | 0 | Computer output for load Combinations:<br>(i) 1.05D + 1.25P + T' + 1.25 (DEm + DEv)<br>(ii) 0.95D + 1.25P + T' - 1.25 (DEm + DEv)<br>(iii) 1.05D + 1.25P + T' + 1.25 (DEs + DEv)<br>(iv) 0.95D + 1.25P + T' + 1.25 (DEs + DEv) |
| 256C | 0 | Computer output for load combinations:<br>(i) 1.05D + T + 2.0 (DEm + DEv)<br>(ii) 0.95D + T - 2.0 (DEm + DEv)<br>(iii) 1.05D + T + 2.0 (DEs + DEv)<br>(iv) 0.95D + T + 2.0 (DEs + DEv) |

Appendix A

List of DCP Qualification Analyses (Continued)

| Calc. No. | Revision | Calculation Description |
|---|---|---|
| 257C | 0 | Computer output for load combinations:<br>(i) 1.05D + P + T + (HEm + 0.4HEs + 0.4HEv)<br>(ii) 0.95D + P + T + (-HEm + 0.4HEs - 0.4HEv)<br>(iii) 1.05D + P + T + (0.4HEm + HEs + 0.4HEv)<br>(iv) 0.95D + P + T + (-0.4HEm + HEs - 0.4HEv) |
| 258C | 0 | Preparatory computer run for:<br>(i) Thermal expansion corresponding to 1.0P<br>(ii) Thermal expansion corresponding to 1.25P |
| 259C-2 | 0 | Load case 1.05D + 1.5P +T" (without liner) |
| 259C | 0 | Preparatory computer run for thermal expansion corresponding to 1.5P |
| 320C-1 | 0 | Section properties of gantry legs |
| 320C-2 | 2 | Hold-down capacity of rail clips |
| 320C-3 | 0 | Review of polar crane weights to be used in analysis |
| 320C-4 | 1 | Guide strut stress calculations |
| 320C-5 | 1 | Determine maximum load on guide struts |
| 320C-6 | 0 | Guide strut stresses computer output |

Appendix A

List of DCP Qualification Analyses (Continued)

| Calc. No. | Revision | Calculation Description |
|---|---|---|
| 501C-1 | 0 | Hosgri analysis and design evaluation of the containment polar crane with modification of the gantry legs |
| 501C-2 | 0 | Hosgri seismic analysis runs of the polar crane with modification of the gantry legs |
| 501C-3 | 0 | Hosgri design analysis runs of the polar crane with modification of the gantry legs |
| 501C-4 | 0 | Hosgri analysis runs of base shear of polar crane modification of the gantry legs |
| 502C-1 | 0 | DE/DDE horizontal acceleration spectra of containment shield walls above El. 140 feet |
| 502C-2 | 0 | DE/DDE horizontal acceleration spectra of shield walls above El. 140 feet |
| 503C-1 | 0 | 7.5M Hosgri Newmark acceleration time history |
| 504C-1 | 0 | Maximum displacement of shield walls above El. 140 feet |
| 504C-2 | 0 | Computer output of maximum displacement of shell walls above El. 140 feet |

Appendix A

List of DCP Qualification Analyses (Continued)

| Calc. No. | Revision | Calculation Description |
|---|---|---|
| 505C-1 | 0 | DE analysis and design evaluation of the containment polar crane with modification of the gantry legs |
| 505C-2 | 0 | DE seismic analysis runs of the polar crane with modification of the gantry legs |
| 505C-3 | 0 | DE design analysis runs of the polar crane with modification of the gantry legs |
| 506C-1 | 0 | DDE analysis and design evaluation of the containment polar crane with modification of the gantry legs |
| 506C-2 | 0 | DDE seismic and thermal analysis runs of the polar crane with modification of the gantry legs |
| 506C-3 | 0 | DDE design analysis runs of the polar crane with modification of the gantry legs |
| 511C-1 and 511C-2 | 0<br>0 | Spectra generation @ Node 48 of containment polar crane for Hosgri loaded and unloaded case (computer output also) |

Note: This list is excerpted from Reference 7. Calculation numbers pertaining to the annulus, pipeway, and platforms were not listed.

Appendix B

List of IDVP Sample

Containment Building

(2 pages)

Appendix B

List of IDVP Sample - Containment Building

| Calculation No. | RLCA File P105-4- |
|---|---|
| 200C-1 | 431-131,380 |
| 210C-1 | 431-133 |
| 250C-1 | 431-136,449 |
| 250C-2 | 431-287 |
| 250C-3 | 431-433 |
| 300C-1 | 431-140,471 |
| 300C-2 | 431-141,471 |
| 320C-1 | 431-103,449 |
| 320C-2 | 431-103,452 |
| 320C-3 | 431-103 |
| 320C-4 | 431-324,432 |
| 320C-5 | 431-167,199,325,432 |
| 320C-6 | 431-167 |
| 501C-1 | 431-107,449 |
| 501C-2 | 431-104 |

Appendix B

List of IDVP Sample - Containment Building (Continued)

Description of IDVP Selected Computer Runs

| Computer Run No. | RLCA P 105-4- | Description |
|---|---|---|
| 203C-1 | 431-380 | See Appendix A |
| 204C-1 | 431-380,449 | See Appendix A |
| 213C-1 | 431-134 | See Appendix A |
| 251C | 431-406 | See Appendix A |
| 252C-1 | 431-405 | See Appendix A |
| 252C-2 | 431-407 | See Appendix A |
| 257C | 431-307 | See Appendix A |
| 501C-2-17 | 431-104 | Polar crane eigensolution |
| 501C-2-18 | 431-104 | Polar crane nonlinear time history analysis |
| 501C-3-01 | 431-105 | Bridge girder stresses |
| 501C-3-02 | 431-105 | Gantry leg stresses |
| 501C-3-05 | 431-105 | Bridge girder shear time history |
| 501C-3-06 | 431-105 | Crane leg shear time history |
| 501C-3-10 | 431-106 | Gantry leg extreme fiber stress |

# Appendix C

## EOI Status - Containment Building

(1 page)

Appendix C

EOI Status - Containment Building

| EOI File No. | Subject | Rev. | Date | By | Type | Action Required | Physical Mod. |
|---|---|---|---|---|---|---|---|
| 1014 | Containment - Generic EOI | 0 | 2/09/82 | RLCA | OIR | RLCA | |
| | | 1 | 3/22/82 | RLCA | PPRR/OIP | TES | |
| | | 2 | 4/17/82 | TES | PRR/OIP | PGandE | |
| | | 3 | 9/03/82 | TES | OIR | RLCA | |
| | | 4 | 9/07/82 | RLCA | PPRR/OIP | TES | |
| | | 5 | 9/09/82 | TES | OIR | RLCA | |
| | | 6 | 9/09/82 | RLCA | PER/AorB | TES | |
| | | 7 | 9/10/82 | TES | ER/AorB | PGandE | |
| | | 8 | 11/13/82 | TES | ER/AorB | PGandE | |
| | | 9 | 1/05/83 | TES | ER/AorB | PGandE | |
| | | 10 | 9/8/83 | TES | OIR | RLCA | |
| | | 11 | 10/3/83 | RLCA | PPRR/CI | TES | |
| | | 12 | 10/3/83 | TES | PRR/CI | TES | |
| | | 13 | 10/3/83 | TES | CR | NONE | NO |
| 3009 | Containment - Internal spectra (E-W and N-S) | 0 | 8/16/83 | TES | OIR | TES | |
| | | 1 | 10/3/83 | TES | ER/C | PGandE | |
| | | 2 | 10/3/83 | TES | CR | NONE | NO |

STATUS: Status is indicated by the type of classification of latest report received by PGandE:

- OIR - Open Item Report
- PPRR - Potential Program Resolution Report
- PRR - Program Resolution Report
- PER - Potential Error Report
- OIP - Open Item with future action by PGandE
- ER - Error Report
- CR - Completion Report
- CI - Closed Item
- DEV - Deviation
- A - Class A Error
- B - Class B Error
- C - Class C Error
- D - Class D Error

PHYSICAL MOD: Physical modification required to resolve the issue. Blank entry indicates that modification has not been determined.

*Robert L. Cloud and Associates, Inc.*

RLCA

# Appendix D

## Key Term Definitions

(8 pages)

## Appendix D

## Key Term Definitions

(The definitions in this glossary establish the meanings of words in the context of their use in this document. These meanings in no way replace the specific legal and licensing definitions.)

As-Built

- Present configuration of DCNPP-1 as shown by IDVP field verification; same as in-service.

Axial Load

- Load acting on a member along an axis.

BNL

- Brookhaven National Laboratory.

Bedrock

- General term applied to the solid rock underlying soil or any other ground surface.

Blume Spectra

- Hosgri response spectra generated for DCNPP-1 by URS/Blume.

Calculation Files

- DCP term for set of individual, numbered design calculations.

Closed Item

- A form of program resolution of an Open Item which indicates that the report aspect is neither an Error nor a Deviation. No further IDVP action is required.

Completion Report

- Used to indicate that the IDVP effort related to the Open Item identified by the File Number is complete. It references either a Program Resolution Report which recategorized the item as a Closed Item or a PGandE document which states that no physical modification is to be applied in the case of a Deviation or a Class D Error.

Corrective Action

- Response of the Diablo Canyon Project to concerns related to the Hosgri qualification which were identified either by the IDVP or by the DCP Internal Technical Program.

Crosshole

- Seismic refraction test performed between adjacent boreholes.

Damping

- The measure of energy dissipation in a system.

DCNPP-1

- Diablo Canyon Nuclear Power Plant, Unit 1.

DDE

- Double design earthquake.

DE

- Design earthquake.

Dead Load

- A constant load exerted by the weight of a mass at rest; also known as static load.

Design Analysis

- Work performed by or for PGandE.

Design Codes

- Accepted industry standards for design (e.g., AISC, AISI, ANSI, ASME, AWWA, IEEE).

Dynamic Load

- A force exerted by a moving body on a resisting member, usually in a relatively short time interval; also known as energy load.

Eigenanalysis/Eigensolution

- Defines frequencies of vibrations, mode shapes, and participation factor for a math model.

Elements

- Mathematical computer representation of stiffness connections between node points (e.g., a beam).

EOI

- Error and Open Item Report.

Error Report

- An Error is a form of program resolution of an Open Item indicating an incorrect result that has been verified as such. It may be due to a mathematical mistake, use of wrong analytical method, omission of data, or use of inapplicable data.

  Each Error shall be classified as one of the following:

  - Class A: An Error is considered Class A if the design criteria or operating limits of safety-related equipment are exceeded and, as a result, physical modifications or changes in operating procedures are required. Any PGandE corrective action is subject to verification by the IDVP.

  - Class B: An Error is considered Class B if the design criteria or operating limits of safety-related equipment are exceeded, but are resolvable by means of more realistic calculations or retesting. Any PGandE corrective action is subject to verification by the IDVP.

  - Class C: An Error is considered Class C if incorrect engineering or installation of safety-related equipment is found, but no design criteria or operating limits are exceeded. No physical modifications are required, but if any are applied, they are subject to verification by the IDVP.

  - Class D: An Error is considered Class D if safety-related equipment is not affected. No physical modifications are required, but if any are applied, they are subject to verification by the IDVP.

Field Verification

- The process of verifying actual configuration of equipment, buildings, and components at the installation site against PGandE drawings.

Finite Element Method

- Idealization of a structure with representation of members and masses by nodes, beams, plates, etc.

FSAR

- PGandE's Final Safety Analysis Report.

Hertz

- Unit of frequency; also known as cycles per second (cps).

Hosgri Criteria

- Licensing criteria referring specifically to the postulated 7.5M Hosgri earthquake.

Hosgri Report

- A report issued by PGandE that summarizes their evaluation of DCNPP-1 for the postulated Hosgri 7.5M earthquake; includes seismic licensing criteria.

Hosgri 7.5M Earthquake

- Maximum intensity earthquake for which the plant is designed to remain functional.

IDVP

- Independent Design Verification Program undertaken by R. L. Cloud Associates, Teledyne Engineering Services, Stone & Webster Engineering Corporation and R. F. Reedy to evaluate Diablo Canyon Nuclear Power Plant for compliance with the licensing criteria.

Internal Technical Program

- Combined Pacific Gas and Electric Company and Bechtel Power Corporation project formed for Diablo Canyon completion.

Interim Technical Report

- Interim Technical Reports are prepared when a program participant has completed an aspect of their assigned effort in order to provide the completed analysis and conclusions. These may be in support of an Error, Open Item or Program Resolution Report, or in support of a portion of the work which verifies acceptability. Since such a report is a conclusion of the program, it is subject to the review of the Program Manager. The report will be transmitted simultaneously to PGandE and to the NRC.

Licensing Criteria

- Contained in PGandE licensing documents; includes allowable criteria (see Hosgri Report).

Load

- Consists of forces, moments, accelerations, and displacements which are applied to piping, attached equipment, or supports.

Member Qualification

- Consists of allowable loads for a particular structural member at DCNPP-1 as specified in the design criteria.

Modal Superposition Method

- Dynamic analysis method whereby responses are calculated separately on a mode-by-mode basis and then combined.

NRC

- Nuclear Regulatory Commission (formerly the Atomic Energy Commission).

Open Item

- A concern that has not been verified, fully understood, or its significance assessed. The forms of program resolution of an Open Item are recategorized as an Error, Deviation, or a Closed Item.

PGandE Design Class 1

- PGandE engineering classification for structures, systems, and components which corresponds to NRC Regulatory Guide 1.29 Seismic Category I classification.

Phase I Program

- Review performed by RLCA, TES and RFR, restricted to verifying work performed prior to June, 1978 related to the Hosgri reevaluation design activities of PGandE and their service-related contractors.

Phase II Program

- Work performed by RLCA, TES, Stone & Webster, and RFR; includes non seismic-related contracts prior to June 1, 1978, PGandE internal design activities and all service-related contracts after January, 1978.

QA Review

- Quality Assurance review.

Response

- The motion resulting from an excitation of a device or system under specified conditions.

Response Spectra

- A plot, for all periods of vibration, of the maximum acceleration experienced by a single degree of freedom system during a particular earthquake.

RLCA

- Robert L. Cloud and Associates, Incorporated.

Shear

- Parallel to the plane of reference.

Spectral Input

- Acceleration value taken from response spectra for input into seismic analysis.

SRSS

- Square root of sum of the squares.

SSE

- Safe Shutdown Earthquake: Maximum intensity earthquake for which the plant is designed to remain functional.

Time History Analysis

- Used to determine the dynamic response of a system excited by accelerations as a function of time.

Torsion

- The in-plane rotation of a point or body about an axis perpendicular to that plane.

Verification Analysis

- Work performed by RLCA as part of the IDVP.

Appendix E

Program Manager's Assessment

(1 page)

# APPENDIX E

## PROGRAM MANAGER'S ASSESSMENT

As Program Manager of the Independent Design Verification Program, TES has reviewed the verification work as described herein.

The program management fuction was performed by TES in accordance with the Phase I Program Management Plan. The task of verification of corrective action of the containment structure which is part of the management function was carried out through several steps:

1. Meetings were held with RLCA and the DCP to review and discuss technical assumptions and results.

2. Calculations and reports performed by RLCA were reviewed. The underlying DCP documents were utilized in this review.

3. TES and RLCA personnel, along with J. M. Biggs and M. J. Holley, Jr. had an opportunity to view the containment structure during a visit to the Diablo Canyon Nuclear Power Plant.

4. The TES Team Leader with other team members participated in the IDVP field verification of modifications.

Professors J. M. Biggs and M. J. Holley, Jr. were involved in all aspects of the review with the exception of the field verification of modifications. Their involvement included participation in open meetings in which the containment structure was a topic of discussion and review of material generated by RLCA supplemented, as needed, with material generated by the DCP.