Robert L. Cloud and Associates, Inc.

RLCA

Interim Technical Report

DIABLO CANYON UNIT 1
IDVP VERIFICATION OF CORRECTIVE ACTION

Turbine Building

ITR #56, Revision 0

Docket No. 50-275
License No. DPR-76

Vince M. Stephens 9/19/83
Project Reviewer/Date
Technical Review

Edward Denison 9/19/83
Project Manager/Date
Approved P 105-4-839-056

TELEDYNE
ENGINEERING SERVICES

PROGRAM MANAGER'S PREFACE

DIABLO CANYON NUCLEAR POWER PLANT - UNIT 1

INDEPENDENT DESIGN VERIFICATION PROGRAM

INTERIM TECHNICAL REPORT

TURBINE BUILDING

This Interim Technical Report, ITR #56, is one of a series of ITRs prepared by the DCNPP-IDVP for the purpose of providing a conclusion to the program.

This report summarizes the IDVP verification of the DCP corrective action to qualify the Turbine Building for both seismic and non-seismic loads. This report also summarizes the results of the IDVP site verification of Turbine Building modifications. One minor issue related to torsional effects remains unresolved and will be reported on in Revision 1 of this ITR. The IDVP verification results in this ITR will be reported in Section 4.4.8 of the IDVP Final Report.

As IDVP Program Manager, Teledyne Engineering Services has reviewed this Interim Technical Report. Professors 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 Review and Approved
IDVP Program Manager
Teledyne Engineering Services

R. Wray
R. Wray
Assistant Project Manager

J M Biggs
for J. M. Biggs and
M. J. Holley, Jr.

IDVP Verification of Corrective Action

Turbine 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 turbine building at Diablo Canyon Nuclear Power Plant (DCNPP) for both seismic and nonseismic loads (Reference 1).

Description of Structure

The turbine building is a Design Class 2 structure which contains some Design Class 1 equipment; primarily the emergency diesel generators, associated switchgear, and component cooling water heat exchangers. The building also contains some Design Class 1 piping, raceways, and ductwork. The turbine building is a combined steel frame and concrete structure. Vertical cross-bracing and reinforced concrete walls provide lateral force resistance. A single building houses the Unit 1 and Unit 2 turbine generators and associated equipment.

The seismic load conditions are the Hosgri (both Newmark and Blume) earthquake, Design Earthquake (DE), and the Double Design Earthquake (DDE). Nonseismic loads considered are dead and live loads.

Figures 1 through 6 illustrate elevations, plans, and sections of the turbine building. Figures 7 through 10 illustrated details of the physical modifications.

Four working floor levels of the turbine building are located at elevations 85, 104, 119, and 140 feet, respectively. A turbine pedestal supporting the turbine generator is located in the center of the building and is structurally isolated from the building floors, but shares a common foundation mat.

The turbine pedestal consists of six transverse frames connected by longitudinal beams. Twelve piers provide vertical support. Selected piers are post-tensional by steel strands anchored to either the foundation mat or rock, depending on the pier location. Gaps of 3-1/2 inches on the east-west sides and 1-1/2 inches on the north-south sides are present between the pedestal and operating deck at elevation 140 feet.

The roof of the turbine building is supported by trusses spanning in the east-west direction. These trusses are connected to columns and together they form rigid bents. The columns extend to the base mat.

The crane was assumed to be unloaded and parked at column line 9 for the fuel load licensing case. The operating case analyses address the loaded crane placed anywhere in the structure.

The east-west lateral force resisting system consists of the lower chord bracing, rigid roof truss/column bents, and vertical cross-bracing at column Line 1 above elevation 140 feet. At or below elevation 140, the seismic forces are resisted by concrete diaphragms at elevations 140, 119, and 104 feet, by interior concrete walls, and by exterior concrete buttresses. The concrete walls and buttresses are anchored to the foundation mat and rock.

The north-south lateral resisting system is similar. Vertical cross-bracing is present at Lines A and G. Additional resistance is supplied by the frame action of exterior columns and spandrel beams with moment-resisting connections at elevations 159, 140, 119, and 104 feet.

<u>Background</u>

The turbine building was originally designed using static equivalent loads. The NRC then required that the building be dynamically analyzed and reviewed for seismic loads. The building was reevaluated and upgraded to withstand the Hosgri seismic loads. The Hosgri modifications included the addition of buttresses and concrete walls, reinforcing main columns, strengthening floor diaphragms, and the addition of roof and wall braces.

The IDVP program for verification of the DCP corrective action with respect to Hosgri criteria (Phase I activities) was presented in ITR #8 (Reference 2), the IDVP program for non-Hosgri criteria (Phase II activities) was presented in ITR #35 (Reference 3).

Summary

The DCP Corrective Action Program for the turbine building specified a complete review of the DE, DDE, and Hosgri response spectra to provide a basis for Design Class 1 equipment qualification. The turbine building pedestal and crane were reviewed against the postulated Hosgri earthquake to ensure that these structures would not fail or impair the function of Design Class 1 equipment.

The DCP review resulted in revision of the analytical models for the building and crane. In addition, physical modifications were found to be required, primarily in the switchgear area; these were incorporated into the analytical models.

In evaluating the DCP methodology, the IDVP examined the DCP's scope, review, and analysis to ensure completeness and compliance with the licensing documents. These documents included the Final Safety Analysis Report (FSAR), Hosgri Report, and Safety Evaluation Report (SER), Supplement No. 7, (References 4, 5, and 6).

In evaluating the DCP implementation, the IDVP compared the DCP's list of qualification analyses (see Appendix A) to the DCP scope. In addition, a sample of qualification analyses was selected and verified with respect to licensing criteria, DCP analysis methods, and results.

The IDVP found the DCP methodology and implementation for the turbine building to meet licensing criteria with the following limitations. The IDVP will address EOI 1026, use of 10% increase in translational response to account for accidental eccentricity, and complete design reviews as noted in Section 4.2.7, 4.2.8, 4.2.9, and 4.2.16, and present its results in Revision 1 of this ITR.

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 (Reference 7). The IDVP compared the DCP scope to the 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.

2.1.2 IDVP Review of DCP Implementation

Appendix A, List of Qualification Analyses, contains the calculation index as supplied by the DCP (Reference 8). 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, using sampling criteria which considered 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 reviewed the horizontal model used for the east-west (E-W) and north-south (N-S) analysis and the vertical model for Lines 1-5. Models were reviewed to ensure proper mass and stiffness properties as well as boundary conditions and designation of degrees of freedom.

Response spectra generated by the DCP were examined to ensure that the proper spectra were determined for all required locations and that spectral acceleration values were correctly enveloped. These spectra were required for analysis of the equipment, piping, and components supported by the structure.

A sample of the structural member evaluations was also reviewed (see individual discussions in Section 4.2) to ensure conformance with loading combinations and allowable stresses as specified in the DCP licensing criteria.

2.2 CRITERIA

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

- o Final Safety Analysis Report for DCNPP
- o Seismic evaluation for postulated 7.5M Hosgri earthquake
- o 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 for structures in general is described in the PGandE Phase I Final Report. The DCP effect was undertaken to ensure 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 PGandE's Phase I Final Report. Included are the following procedures:

- o Comparison of as-built condition with design analysis to ensure compliance with criteria; analysis and modifications made as necessary
- o Review of proper criteria utilization from the FSAR and Hosgri Reports
- o Review of assumptions, input data, analytical models, computer codes, and calculation techniques; reanalysis performed as necessary.

DCP Methodology for the Turbine Building

The DCP methodology for the turbine building is described in Section 2.1.4 of PGandE's Phase I Final Report. Review was performed using the FSAR and Hosgri Report criteria.

The DCP review resulted in new analytical models for the turbine building and crane. The existing turbine pedestal model was found to be adequate for evaluation.

The horizontal model for E-W and N-S analyses consists of beam, plan stress, and truss elements. The roof truss was represented by an equivalent stiffness matrix added to the overall stiffness matrix of the structure at the appropriate locations. The matrix was calculated by applying a unit displacement in the direction of the selected degree of freedom (DOF) and computing the forces needed to restrain the other five DOFs. Six DOFs can be used because of symmetry. The mass of the roof truss was lumped at the three nodes of the equivalent member. To ensure accuracy, both static and dynamic behavior comparisons were made between tne actual roof truss and its equivalent member representation.

A similar method was used to develop equivalent members to represent the roof lower chord horizontal bracing system. The equivalent model consisted of truss elements spanning in the east-west direction from the center of the building to column lines A and G, and another set of truss members running north-south the full length of the building along column line D.

The lower chord horizontal bracing of the roof was modeled as an equivalent two panel cross-brace system, using truss elements to represent the bracing members. The area of the equivalent truss elements was calculated by equating displacements obtained from static analyses of a six-panel single-bay frame to a two panel single bay (equivalent member) for equal loads through an iterative process.

Columns were modeled as prismatic beam elements, and concrete walls by plane elements. Outside buttresses and the concrete wall along column line 11 were modeled as equivalent columns.

The floor diaphragm at elevation 104 feet was modeled as an equivalent beam while diaphragms at elevations 119, 123, and 140 feet were modeled with plane stress elements to represent in-plane stiffness of the floor.

Exterior chords along column lines A, G, and 1 at elevations 119, 123, and 140 feet were modeled with beam elements, while interior chords were modeled with truss elements.

Figures 11 through 18 show details of the horizontal analytical model (FS12) used for qualification of the turbine building.

Equal magnitude crane loads were applied at column lines A and G. Crane inertia loads were limited in the north-south direction by the crane brake capacity and the friction force between the crane wheels and rail.

A response spectrum analysis was performed for the postulated Hosgri earthquake to determine member forces. Time history analyses were performed to determine response spectra for the Hosgri DDE, and DE earthquakes.

Modifications were found to be necessary in the switchgear area in order to reduce the horizontal and vertical response spectra. These modifications included the addition of new members in horizontal and vertical planes as well as stiffening of existing members.

Evaluation of the roof lower chord bracing system showed design forces on some connections which exceeded the allowable bearing values given in Part 2 of the 1969 AISC specification. The DCP noted several conservatisms and supporting test data which showed that the design forces remained within the ultimate bearing strength.

Four models were formulated to represent the turbine building in the vertical direction. The areas represented are from column lines 1 to 5, 5 to 15, 15 to 17, and 17 to 19. The DCP chose the corresponding model separation lines because of the large openings in the floors due to the presence of the turbine pedestal. The DCP also stated, as further justification for the model separation, that a vertical load applied to a given point would affect a small horizontal area as well.

The floor diaphragms of the four models were represented by plate and beam elements. Beam checkered-plate floors and concrete slab/steel beam floors were modeled as equivalent beams using AISC requirements.

A DCP study of the floors in the area of Model 1 showed that a model extending from column line 1 to line 3.5 was sufficient to calculate representative responses. The model is illustrated in Figures 19 and 20. All nodes above elevation 140 feet had vertical displacement and two horizontal rotational DOFs. The only exceptions were the interface boundary nodes along column line 3.5, which were restrained for north-south translations and rotations about the east-west axis.

IDVP Assessment

The DCP used a number of horizontal analytical models in an iterative process which led to the final horizontal model for qualification (Model FS12). These models included A, B, C, D, E, F, and FS. Successive models differed for a variety of reasons, such as:

- o Refinement of finite element representation for more accurate determination of response spectra and member forces
- o Discrepancies found in some mass and stiffness property determinations as found by the DCP were corrected
- o Refinement of analytical model to reflect physical modifications in the switchgear area

Model A reflected the basic geometry, stiffness and mass properties. Each successive DCP model calculation file contained only the changes made to the previous model; thus it was necessary for the IDVP to evaluate each model to verify the final horizontal model. The IDVP evaluated a sample of the calculations performed for Models A to FS12 for mass and stiffness calculations.

The IDVP selected the DCP vertical model for lines 1 to 5 as their sample for review of the vertical models because of the model's proximity to the switchgear area. The DCP identified additional modifications to column lines 3 and 4, as detailed in their analytical Models N5 and N6. The IDVP has reviewed these models, whose enveloped results represent the qualification analyses.

In summary, the IDVP agrees with the DCP methodology as described in the PGandE Phase I Final Report, and as applied in the DCP program. The use of the Hosgri event only for member qualification is acceptable. Collapse is shown not to occur for the Hosgri earthquake, as required for Design Class 2 criteria. The Hosgri event controls over DE and DDE with regard to member evaluation for equal damping and material properties. Response spectra were produced for the DE, DDE, and Hosgri earthquake for equipment and piping qualification. The results of IDVP reviews of specific DCP calculation files are presented in Section 4.2. The IDVP review focused on the Hosgri earthquake for the above reasons.

4.0 IDVP REVIEW OF DCP IMPLEMENTATION

4.1 SELECTION OF IDVP SAMPLE

Basis of Selection of Calculation Files

The IDVP reviewed the List of IDVP Qualification Analyses (Appendix A) to assess the entire qualification process for completeness, including implementation of design criteria, formulation of analytical models, generation of response spectra, and member evaluation.

The IDVP then selected a sample of calculations and computer runs (see Appendix B) in order to assess:

- o Evaluation of mass properties used in the models, specifically at elevation 140 feet. Also, mass changes for elevation 140 in Models A to FS12 were reviewed.
- o Determination of stiffness properties for Models A to FS12. All element types were reviewed.
- o Incorporation of the final geometry, mass, and stiffness properties into the horizontal and vertical model (lines 1 to 5) eigensolutions
- o Generation of response spectra for the horizontal model
- o Determination of the bottom chord roof bolt-bearing capacity
- o Evaluation of steel bracing on lines 1, A, and G, and concrete shear wall on line A
- o Evaluation of beams and diaphragm at elevation 140 under vertical loading
- o Evaluation of modifications at elevations 104 and 119 (north end) as required for the switchgear area.

Samples of the computer runs used to qualify the turbine building 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 9). The technical application and suitability of the codes used in the analysis of the turbine building are reviewed in this ITR.

4.2 VERIFICATION OF DCP QUALIFICATION ANALYSIS

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 turbine building. The purpose of this review was to verify that the DCP results were fully supported, accurate, and documented. The design reviews (References 10 to 23) originated by Robert L. Cloud Associates, Inc. (RLCA) document the review of the sampled DCP calculation files. 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 contained general technical items which ensured that all pertinent areas are addressed.

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

A. Use of Design Drawings

- Proper transfer of data from design drawings to construction (shop drawings). Sample verification of field conditions versus design drawing was performed.

B. Validity of Assumptions

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

C. Methodology and Criteria

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

- 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 analysis method.

D. Use of Formulas/Accuracy of Calculations

- o Verification that proper formulas were 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 were obtained for member evaluation.

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

- o Performance of 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 computer runs.

F. Documentation

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

The above checklist items were intended to provide, in summary form, the important topics and issues the IDVP addressed in reviewing the turbine building calculations.

A summary of results for each DCP calculation file reviewed by the IDVP is presented in Sections 4.2.3 through 4.2.16.

4.2.3 DCP Calculation #64-T-204: Mass Calculation, Elevation 140 Feet

DCP Analysis

This calculation determined masses tributary to the nodal points at elevation 140 feet for the seismic models. The masses represent dead loads due to block and concrete walls, slabs, steel floor beams, siding, equipment, stairs, catwalks, trenches, hatch covers, and pipe hangers, etc. A 2 psf uniform load was assigned to represent raceways, ducts, and miscellaneous items.

Nodes were defined along column lines A, G and 1 for Model A, for which these calculations were tabulated. Revisions resulted in the node definition for Model FS12, as shown in Figure 14.

IDVP Conclusions

The IDVP reviewed the mass calculations on a sample basis for the concrete slabs, steel floor beams, and shear walls and found the DCP calculations to be acceptable. Tributary areas were properly defined for the nodal points selected. The IDVP noted several numerical differences which had no significant impact on results. The IDVP verified that block walls were sufficiently anchored to allow lumping of mass associated with half the wall height above and below elevation 140 feet. The IDVP review of the mass revisions from Models A to FS12 is presented in Section 4.2.7.

4.2.4 DCP Calculation #64-T-215: Hosgri Horizontal Models A to FS, Description

DCP Analysis

The DCP provided summaries of the geometry changes from Models A to FS. Diagrams of plan and elevation views were included which showed node and element numbers. The mass and stiffness computations detailing changes from Models A to FS were included in other calculations.

IDVP Conclusions

DCP provided an acceptable summary detailing the geometry, mass and stiffness changes for models A to FS. The plots and diagrams presented gave a satisfactory overview of the history of changes from models A to FS.

4.2.5 DCP Calculation #64-T-216: Hosgri Horizontal Model A, Stiffness

DCP Analysis

The section properties for elements defined in Model A were determined. The model was divided into element groups consisting of:

(a) Bracing at lines A, G, and 1

(b) Roof bracing

(c) Shear walls

(d) Floor diaphragms at elevations 104, 119, and 140 feet and beams at 159 and 165 feet

(e) Beams at elevations 179-6 and 193 feet

(f) Columns and buttresses at lines A, G, and 11

(g) Columns and shear walls at line 1

(h) Equivalent roof truss.

All diagonals in compression on lines 1,A, and G were assumed to buckle; therefore one-half the actual axial area was used for each cross-brace to represent the stiffness of only the tension brace for each panel. Truss elements (axial load only) were used.

The roof truss was represented by an equivalent beam and a matrix addition to the overall structure stiffness matrix.

The lower chord roof bracing was represented by equivalent truss elements. One panel each from lines A and G to the centerline of equivalent bracing was used to represent the stiffness of the three existing panels. The compression brace was assumed to buckle. The average stiffness for the E-W and N-S deformation patterns was used.

Areas were first computed by an iterative process using identical loads and boundary conditions for the actual and equivalent bracing configuration. Areas were then computed which yielded the same displacements for the two configurations. N-S loads were applied at the centerline, while one-half the E-W loads were applied at the centerline and one-fourth at the ends, corresponding to mass percentages at these nodes.

Plane stress elements were used to represent the shear walls. Equivalent thicknesses were determined to account for openings in the walls. Flexural deformations were neglected.

For simplification, the slab at elevation 107 feet was modeled at elevation 104, and the slab at elevation 123 was modeled at elevation 119 feet. Equivalent beam properties were determined to represent the floor diaphragms. Where openings existed in the floor diaphragms, an equivalent thickness of the diaphragms was first calculated. Composite steel and concrete sections were considered.

An equivalent beam was used to model the upper chord, lower chord, and bracing of the truss system at elevation 193 feet. Equivalent beams were used to model the steel and concrete columns, buttresses and out-of-plane properties of the shear walls at lines A, G, and 11, and also for the steel columns and shear walls at line 1 below elevation 104.

IDVP Conclusions

The stiffness property calculations performed by DCP for model A were acceptable for the type of elements designated. The use of one-half the brace area to account for the buckling of the compression brace is acceptable. The DCP properly computed the equivalent beam properties to represent roof truss and roof chord bracing by equating the static and dynamic characteristics of the physical structure to the simplified idealization. Equivalent beams used to represent the diaphragms give an acceptable representation of the gross behavior. The DCP later refined the horizontal model to include plane stress elements at various locations in order to obtain a higher degree of accuracy, which is acceptable.

4.2.6 DCP Calculations #64-T-226, -227, -229, -230 and -231: Hosgri Horizontal Models B to FS, Stiffness

DCP Analysis

These calculations pertain to the stiffness calculations for models B to FS in the iterative process leading to the final horizontal model FS12. The DCP provided a summary of changes introduced to each successive new model.

Model B used plane stress elements to represent the floor diaphragm at elevation 119 feet, lines 1-4.8 instead of equivalent beams because of a large floor opening which resulted in a nonsymmetric stiffness distribution. This stiffness distribution could not be adequately represented by an equivalent beam. Geometry, mass, and stiffness adjustments were made to the model as required. Model C included an increased stiffness of the steel beam at elevation 119, line G, bents 3.5-4.8. This increase was incorporated (as a modification to the axial area of the beam) to reduce the torsional response of the diaphragm.

Model D incorporated several refinements. Plane stress elements replaced the equivalent beams at elevations 119 and 123, lines 15-17, in order to better represent the checkered plate diaphragm. An equivalent column was used to represent the local behavior of the shear wall at line 11 (elevation 85 to 119) instead of adding its properties to the columns at lines 10.6 and 12.2. The lever arm tie beam elements connecting the plane stress elements at elevation 119 feet, lines 1-4.8 to the checkered plate (plane stress) elements was modified for compatibility. Superelement stiffnesses representing the roof trusses were revised to reflect tapered column properties. Finally, some mass calculations were updated.

Model E was formulated to account for revisions in mass calculation assumptions. The only stiffness change was for the lever arms at elevation 119, line 15 for reasons similar to those described for model D.

Results of previous models illustrated that the panel loads at lines A and G (all elevations) and line 1 (below elevation 140 feet) were not high enough to buckle the compression brace. Thus the stiffness was revised to include the full area of the diagonals in Model F instead of the one-half area previously used. Axial stiffnesses of the equivalent beams at elevation 193 feet were revised to correspond to calculation assumptions; only the axial areas of the chords were used in model F with no inclusion of internal chord areas. Lever arm stiffnesses used as tie beam elements at line 48, elevation 119, were also revised for reasons previously discussed.

Model FS incorporated changes in order to more explicitly model the floor diaphragms at elevations 119, 123, and 140 feet and modeling of internal columns and shear links between elevations 119 and 123 feet.

IDVP Conclusions

The DCP use of iterative models reflected changes in modeling methodology consistent with obtaining increased accuracy in the areas of interest. The IDVP verified, on a sample basis, that appropriate stiffness and mass changes were incorporated into the model when new element types were used to better represent an area of the structure. The use of the full brace area was verified to be acceptable, since the compression loads in the diagonal did not result in buckling of the diagonal.

Use of plane stress elements to replace the simplified equivalent beam to represent the diaphragms provides more accurate results and is acceptable. The DCP properly corrected the tie beam element properties and other modeling refinements. Model FS provided an acceptable mathematical representation of the structure prior to the inclusion of physical modifications for Model FS12.

4.2.7 DCP Calculation #64-T-258: Hosgri Horizontal Model FS12, Geometry, Mass and Stiffness

DCP Analysis

This calculation contains the computations and description of changes for the final horizontal Model FS12. Modifications used to lower the response in the switchgear area were incorporated into this model. The modeling refinements included the addition of internal chords and shear links. Structural modifications were made as indicated in Figures 7 through 10. Mass and geometry changes were also included as required, as well as plots, which detailed the geometry of the analytical model. The eigensolution was then performed and results saved for the response spectrum and time history analyses.

IDVP Conclusions

The IDVP verified that the structural modifications represented in the design drawings were reflected in the FS12 analytical model. The above results are based on a complete, but not finalized, IDVP review of the DCP analysis. This IDVP review will be finalized and confirmation of the conclusions reported in Revision 1 of this ITR.

4.2.8 DCP Calculation #64-T-259: Hosgri Horizontal Model FS12, Member Forces

DCP Analysis

This calculation presents the computer run flow charts used to produce member forces using the response spectrum analysis. Displacements and a summary of selected element stresses at elevations 119 and 123 feet were presented. The element stresses are used to qualify members (as presented in other qualification analyses) together with the forces resulting from the response spectrum analyses. Both SRSS and DAS modal combination results are included in the computer output for the envelope of Blume and Newmark earthquake, SRSS of directions. A 10% increase in seismic input was used to account for accidental eccentricity.

IDVP Conclusions

The IDVP verified that the proper eigensolution results were used as input to the response spectrum analysis and that the computer run sequences (input and output files) were appropriate.

The DCP evaluated all members for the SRSS modal combination forces, as required by the licensing criteria. The resolution of the use of a 10% increase in seismic input to account for accidental eccentricity will be addressed in Revision 1 of this ITR.

4.2.9 DCP Calculation #64-T-260: Hosgri Horizontal Model FS12, Response Spectra

DCP Analysis

The DCP computed the horizontal spectra (Hosgri) for Model FS12 and included response spectra plots in this calculation.

Floor spectra were generated for both Newmark and Blume input time histories. The E-W response due to E-W and N-S input was computed as well as the N-S response to E-W and N-S input. The codirectional responses from the two horizontal seismic inputs were combined on an SRSS basis. The Blume and Newmark spectra were then enveloped for each node. Groups of nodes were in turn enveloped to represent the raw spectra in a specific area. The enveloped raw spectra were smoothed and broadened according to the Hosgri criteria. Spectra will be included in DCM C-17 (Reference 24), which represents the horizontal design spectra for elevations 104, 119, 140, 159, 165, 179.5 and 193 feet, plus the switchgear (119 feet), chlorine monitor, and diesel generator stack. A 10% increase was applied to the input time histories to account for accidental torsion.

IDVP Conclusions

The DCP provided acceptable explanation and flow charts detailing the process used to generate design response spectra. The IDVP verified that the proper eigensolution results and time histories were used. The computer run sequence for response spectra at one elevation was verified by the IDVP to correspond to the computer run index.

The IDVP reviewed the calculations which resulted in selection of nodes. The selection and enveloping of nodes was found to give an acceptable representation of the areas where response spectra were required.

The horizontal response spectra were properly generated, enveloped, broadened, and smoothed according to criteria. The use of a 10% increase in translational spectra to account for accidental eccentricity will be reviewed and results reported in Revision 1 of this ITR.

4.2.10 DCP Calculations #64-T-305, -306, -307: Vertical Model Lines 1-5: Description, Stiffness, and Mass; #64-T-334, -342: Modified Vertical Models N5 and N6, Spectra Lines 1-5

DCP Analysis

The DCP analysis of the turbine building under vertical excitation from lines 1-5 (Model 1) included all of the major structural elements in that area. Concrete slab/steel floor beams were modeled as composite beams whenever they satisfied AISC code requirements. Plate elements represented the concrete slabs, and the equivalent beams were modeled as edge beams around the plate elements. Beam elements represented parts of the exterior framing, roof trusses, and columns. Truss elements were used to represent the braces. The single DOF oscillators representing the crane were placed at line 3.5. Nodes were assigned mass values determined by procedures similar to those used in the horizontal model mass determination. Computer plots were presented of the various finite element types. Figures 19 and 20 illustrate portions of the DCP vertical model.

Nodes above elevation 140 feet (steel superstructure) have six DOFs, while nodes below elevation 140 feet have one vertical and two horizontal rotational DOFs. The exceptions are the boundary nodes along line 3.5, which were restrained for N-S translation and rotations about an E-W axis.

The DCP subsequently proposed physical modifications to stiffen the structure and lower the response of the switchgear area at elevation 119 feet. Models N5 and N6 were formulated to analyze the modified structure. Model N5 included the modification of connections to vertically tie floors at elevations 119 and 140 along line 3. Model N6 included the modification of connections as previously described, and the addition of a new column at line 4. Mass and stiffness properties of the previous Model 1 were modified to incorporate these changes. Results of Models N5 and N6 were enveloped with regard to member forces and response spectra in another calculation. Spectra plots resulting from Models N5 and N6 were included in the calculations.

IDVP Conclusions

The IDVP found the mass and stiffness calculations for Model 1 to be acceptable. Minor differences were noted as having no significant impact on results. The designation of element types and degrees of freedom was acceptable, since the steel superstructure was allowed to respond with all 6 DOFs, while the concrete slabs were assigned DOFs consistent with vertical excitation only. At line 3.5 below elevation 140, north-south restraint of nodes properly reflected the resistance provided by the remaining bays, and restraint of the east-west rotation reflected the essentially symmetric boundary condition at line 3.5. Above elevation 140 feet, at line 3.5, the E-W translation of the steel superstructure is allowed, properly reflecting its flexibility.

The IDVP finds the use of four vertical models to represent the turbine building structure to be acceptable.

The DCP noted that some columns modeled in N5 and N6 as axially active load-carrying members per the proposed modified connections were not modified in the field. This artificial increase in stiffness in the models was partially offset by not modeling the stiffening effect of block walls. Furthermore, the small increase in axial area of the models was not significant compared to the area of existing and added columns in the nearby area.

The IDVP verified, on a sample basis, the input data required for the eigensolution of models N5 and N6. All values were properly input into the computer program as described in the appropriate calculation files.

4.2.11 DCP Calculation #65-T-004: Bottom Chord Roof, Bolt-Bearing Capacity

DCP Analysis

The DCP computed allowable bearing capacities based on the AISC 7th and 8th editions, Part 2 (Reference 25) and the ultimate allowable. DCM C-42 (Reference 26) specifies Part 2 of the AISC 7th edition as the applicable criteria. The 3-bolt connection was analyzed using average test strengths for materials with the following capacities:

AISC 7th Edition, Part 2	151.4 k
AISC 8th Edition, Part 2	195.2 k
Ultimate	229.5 k

The capacities were based on edge distance, material strength, and bolt spacings. The ultimate capacity values were determined from the the AISC 8th Edition capacity formulas with no factor of safety.

IDVP Conclusions

Since the AISC code allowables are based on finger-tight bolts, the values are conservative. The bolted connections in the turbine building were installed to a minimum tension equal to 70% of the minimum tensile strength of the bolts; therefore, additional tension in the joints would increase the bearing capacity by a minimum of 10%. The IDVP found the use of the ultimate capacity value determined by the DCP to be acceptable, since collapse (ultimate condition) due to failure of the bolt bearing applied for the controlling Hosgri seismic event.

4.2.12 DCP Calculation 65-T-151: Bracing on Lines 1, A, and G

DCP Analysis

Members comprising the lateral load-resisting braces were evaluated for loads using the SRSS modal combinations from horizontal Model FS12. The braces consist of double angles. Connections were evaluated considering the gusset plate, weld, and bolt capacities. A 1.7 factor was applied to the AISC code allowables when computing allowables for the Hosgri event. Certain braced panels were demonstrated to possess adequate capacity in tension or compression with respect to applied loads.

The braced panel with the highest demand/capacity ratio of 0.92 was analyzed considering the compression brace to carry a combined axial and bending moment. The bending stress was computed by considering that the compression brace bowed due to the shortening of the compression member imposed by the frame displacements.

IDVP Conclusions

The DCP properly computed the connection allowables and demonstrated their qualification. Panels with adequate tension or compression capability to carry the full panel load were properly evaluated.

The IDVP used alternate methods to evaluate the critical brace members and determined a demand to capacity ratio of 0.94 versus the DCP value of 0.92. The use of a 1.7 factor applied to the elastic allowable stress for compression members is acceptable as per the AISC Code Part 2. Thus, the IDVP concluded that the bracing members meet licensing criteria.

4.2.13 DCP Calculation #65-T-208: Shear Wall Line A

DCP Analysis

The shear wall along column line A is evaluated for the combined effects of the horizontal and vertical Hosgri seismic forces. The shear walls were originally analyzed for loads from horizontal model F. The new load from the final model FS12 were then compared to the model F forces and were found to be lower. Vertical seismic forces were determined by estimating the vertical accelerations. These vertical seismic forces were compared to those found using the response spectrum analysis of vertical model lines 5-15. A summary table was presented that presented shear and overturning moment demand/capacity ratios for elevations 85, 104, and 114 feet, all ratios were below 1.0.

The shear capacity was taken as specified in the SEAOC code. Flexural yielding and diagonal shear modes were evaluated.

IDVP Conclusions

The IDVP verified, on a sample basis, the proper transfer of loads from the computer analyses results to the calculation file. The average shear capacity of all piers sharing a common lateral force was shown to be less than required by the criteria, and was verified by the IDVP.

The DCP calculations for overturning capacity assumed tht the concrete strain reached its maximum strain of .003 simultaneously with the extreme reinforcing steel strain level of six times yeild strain. The DCP analyzed the walls as being similar to deep beam flexural members. A linear strain distribution would require larger steel strains than allowed by the ductility ratio of six in order to satisfy the concrete ultimate strain value. The IDVP computed the ultimate capacity using the maximum ductility ratio of six, the concrete stress distribution, and used an iterative procedure to determine the forces such that equilibrium was satisfied. Moment capacities were reduced from the DCP values by less than 2%, which is expected since litle additional capacity is gained by additional strain beyond yield in the tension reinforcement. The IDVP finds the shear walls at lines A, G, and 1 to meet licensing criteria.

4.2.14 DCP Calculation #65-T-352: Diaphragm Slab, Elevation 140 feet

DCP Analysis

Floor diaphragm members were evaluated against Hosgri earthquake horizontal and vertical loads. Members were evaluated against loads from models FS and later checked for model FS12 loads. These members frame the inner and outer perimeters of the floor slabs. All demand capacity ratios were shown to be less than 1.0, the highest value being .94. The vertical loading includes dead load, equipment loads, and vertical seismic loads (ZPA). Steel members were evaluated according to Part 2 of the AISC 7th Edition for combined axial and bending moment loads. The effect of the concrete encasement around the steel beams was ignored.

The concrete diphragms were evaluated according to ACI 318-71. The diaphragms act as a series of adjacent beams with the shear walls as supports. The diaphragms are subjected to both axial and shear loads due to the E-W and N-S seismic exciation. Shear stresses are tabulated in the computer run for the horizontal model. These stresses are multiplied by the cross sectional area and then forces are summed across a section for evaluation against capacity. The allowable shear stress takes into account the value of the normal tensile force acting on the section. In sections where shear demand/capacity was high, the DCP performed additional calculations to better assess the magnitudes of axial force and bending moment acting on the section. Time history plots of the axial forces were tabulated in another calculation file. This resulted in a lower axial force than that computed from the response spectrum analysis.

The diaphragm panels were then investigated with respect to diagonal tension (shear) and found to be qualified. Out of plane loads due to dead and vertical seismic loading were shown to have small demand/capacity ratios. Concrete slab/steel beam composite action was also evaluated to ensure adequate shear transfer capability.

IDVP Conclusions

The IDVP verified a sample of the chord elements evaluated by the DCP for proper determination of capacity and comparison to demand. The IDVP found the sample members selected to be qualified for combined axial and bending stress. Total forces across a section used for evaluation were properly determined from the stress results of individual elements as taken from the response spectrum analysis. The use of a time history analysis to obtain more exact axial forces when computing shear capacity of the diaphragm is acceptable.

4.2.15 DCP Calculation #65-T-370: Beams, Elevation 140 feet, Area AX

DCP Analysis

These calculations contain the Hosgri sesimic evaluations of the floor at areas AX (lines 1-5-D-G) and DX (lines 15-17-D-G). Calculations were only performed for area AX because it was determined to be the critical area. Vertical load was stated to consist of dead load (including equipment) and the vertical seismic load acting at the ZPA of the floor response spectra. Horizontal loads resisted by the slab and steel encased chord beams were evaluated in other calculations. Beams were evaluated for the seismic load up or down. The difference in evaluation is that the compression flange has lateral support provided by the concrete slab for seismic down, and is unsupported between framing points for seismic up. Allowable stresses were based upon Part 1 of the AISC 7th edition increased by a factor of 1.7, but not to exceed the material tested yield strength.

An AISC beam evaluation program which automatically accounts for beam self weight was employed to calculate stresses. The highest member bending stress/capacity ratio was noted as 0.63.

IDVP Conclusions

The IDVP verified, on a sample basis, the beam section properties, spans, and loading data for the beams evaluated which showed the DCP input data into the computer program to be acceptable. The ZPA values for the modified vertical model were compared to the values used for member evaluation and found to be similar by the DCP. The IDVP verified this by examining a sample of the modified model response spectra plots. The AISC beam evaluation program is applicable for evaluation of the steel beams.

4.2.16 DCP Calculation #65-T-441: Floor Modifications, Elevations 104 and 119 feet (North End)

DCP Analysis

This calculation contains the qualification analyses for the structural modifications required to stiffen the area near the switchgear at elevation 119 feet in order to lower the response. Spectral values used in this calculation for loads imposed on members (i.e. vertical seismic loads on lateral load resisting members) were compared with the response spectra generated from the modified model. These members were found to still be qualified.

The main modifications designated for the turbine building switchgear area are shown in Figures 7 through 10. A new beam is added at elevation 119 to transfer load through an opening in the diaphragm. An existing beam below the floor diaphragm is strengthened by the addition of plates. These plates contain shear studs used in turn to transfer the horizontal load into the concrete floor diaphragm. This strengthened beam is connected to the beam spanning the opening in the diaphragm. Members and connections are evaluated. Bending loads due to vertical seismic plus dead load are considered. Horizontal loads are taken as the SRSS modal combination from the horizontal model analysis.

Members were evaluated for combined axial and bending loads. The allowable stress as specified by Part 1 of the AISC code was increased by 1.7 to determine the allowable for the Hosgri earthquake load combinations. If this allowable was greater than the yield stress, the yield stress was specified as the allowable stress.

IDVP Conclusions

The DCP qualification analyses were verified with respect to the design modification drawings and found to be acceptable. Beam interaction formulas reflecting moment magnification effects were not used when adequate lateral support was provided, which is acceptable. Welds were verified to be adequate for transfer of the horizontal shear loads imposed. DCP used peak spectral accelerations when computing bending moments due to the inertia load of the beam, which is conservative. The IDVP verified the spectral acceleration values and found them to correspond to the response spectra for the modified models. Bending moments induced by eccentric axial loads were properly determined and considered as part of the total load.

The use of a 1.7 factor applied to the AISC Part 1 allowable bending stress is not specified in Part 2 of the AISC. Part 2 does allow a 1.7 increase for axial compression members and connections. However, since the DCP used an allowable stress of 1.7 times AISC Part 1 (elastic) allowables or the yield stress, whichever was lower, the IDVP concludes that the allowables specified by the DCP meet the licensing criteria for Class 2 structures. Qualified members were verified as not exceeding yield stress, thus no collapse would occur. In addition, no ductility factors, as allowed by the licensing criteria, were used to qualify the members. If ductility factors were used, additional local deformation could be sustained by the members.

The above results are based on a complete, but not finalized, IDVP review of the DCP analysis. This IDVP review will be finalized and confirmation of the conclusions reported in Revision 1 of this ITR.

4.3 VERIFICATION OF AS-BUILT CONDITION

The IDVP field verified the as-built condition of portions of the modifications described in Section 4.2.16. The as-built conditions agreed with the design and modifications used as the basis for calculations (Reference 27).

5.0 Error and Open Item Reports

The IDVP issued six EOI reports relating to the turbine building area. These EOIs were all issued during the RLCA preliminary report and initial sample stages of the program. No EOI reports have been issued as a result of the verification of the current DCP qualification.

EOI 1026 was issued to note several regions in the turbine building for which response spectra or scaling criteria were not defined. Design Class I electrical raceways are supported in these regions. The current DCP qualification now includes these response spectra.

This EOI is classified as an Error Class A or B due to the corrective action undertaken by the DCP. Files 982, 984, 1010, 1025, 989, and 1028 have been combined into this EOI for tracking purposes.

EOI 982 notes that the original design transmittals between URS/Blume and PGandE were not examined for the RLCA preliminary report. These transmittals are no longer significant since the turbine qualification has been reanalyzed by the DCP. This EOI was combined with EOI 1026 and was closed.

EOI 984 notes that the interface procedures between URS/Blume and PGandE were not examined for the RLCA preliminary report. These transmittals are no longer significant since the turbine building qualification has been redone by the DCP. This EOI was combined with EOI 1026 and was closed.

EOI 1010 was issued to note that response spectra or scaling criteria were not defined for turbine building locations above elevation 140 feet. Design Class I electrical raceways and HVAC Duct are supported in this region. The current DCP qualification now includes these response spectra. This EOI was combined with EOI 1026 and was closed.

EOI 1025 was issued to note that response spectra or scaling criteria may not be defined for the entire region defined by bents 16-20 at elevation 104 feet. Design Class I piping is supported in this region. The current DCP qualification now includes these response spectra. This EOI was combined with EOI 1026 and was closed.

EOI 989 notes that the construction modifications made to the turbine building crane as part of the original Hosgri evaluation were not examined for the RLCA preliminary report. As-built analysis of the crane is within the scope of the DCP corrective action program. The IDVP has field verified as-built conditions and modifications on a sampling basis for the overall turbine building. This EOI was combined with EOI 1026 and was closed.

EOI 1028 was issued to note differences in torsional combination methodologies. This question remains open for the turbine building. EOI 1028 was combined with 1026 and was closed.

6.0 CONCLUSIONS

The IDVP has reviewed the DCP Corrective Action Program Methodology for the turbine building as detailed in the PGandE Phase 1 Final Report and found it to be acceptable, with two limitations. These limitations are the resolution of the use of a 10% increase in the seismic time history to account for accidental eccentricity and finalization of the IDVP design reviews.

The IDVP found the DCP list of qualification analyses to be acceptable. The IDVP found its sample of selected qualification analyses to be acceptable, with the limitations described in Sections 4.2.7, 4.2.8, 4.2.9 and 4.2.16, which concern the finalization of the IDVP design reviews. These issues will be addressed in Revision 1 of this ITR. The IDVP has performed field verification for a sample of the modifications and the results were acceptable.

7.0 Reference No.	Title	RLCA File No.
1	Independent Design Verification Program (IDVP), Diablo Canyon Nuclear Power Plant, Unit 1, Phase I Program Management Plan, Revision 1, July 6, 1982.	
2	ITR #8, Verification Program for PGandE Corrective Action, Revision 0, October 5, 1982.	P105-4-839-008
3	IDVP ITR #35, Verification Plan for Diablo Canyon Project Activities, Revision 0, April 1, 1983.	P105-4-839-035
4	Diablo Canyon Site Units 1 and 2, Final Safety Analysis Report, USAEC Docket Nos. 50-275 and 50-323.	P105-4-200-005
5	Seismic Evaluation for Postulated 7.5M Hosgri Earthquake, USNRC Docket Nos. 50-275 and 50-323.	P105-4-200-001
6	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
7	Pacific Gas and Electric Company (PGandE) Phase 1 Final Report Independent Design Verification Program, Diablo Canyon Nuclear Power Plant, June 21, 1983.	P105-4-200-117

Reference No.	Title	RLCA File No.
8	Diablo Canyon Project (DCP) Calculation Index, Turbine Building	P105-4-431-511
9	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
10	IDVP Design Review of DCP Calculation #64-T-204, Revision 0.	P105-4-506-095
11	IDVP Design Review of DCP Calculation #64-T-215, Revision 0.	P105-4-506-075
12	IDVP Design Review of DCP Calculation #64-T-216, Revision 0.	P105-4-506-100
13	IDVP Design Review of DCP Calculation #64-T-226, 227, 229, 230, 231, Revision 0.	P105-4-506-165
14	IDVP Design Review of DCP Calculation #64-T-258, Revision 0.	P105-4-597-279
15	IDVP Design Review of DCP Calculation #64-T-259, Revision 0.	P105-4-597-291
16	IDVP Design Review of DCP Calculation #64-T-260, Revision 0.	P105-4-506-183
17	IDVP Design Review of DCP Calculation #64-T-305, 306, 307, 334, 342, Revision 0.	P105-4-506-178

Reference No.	Title	RLCA File No.
18	IDVP Design Review of DCP Calculation #64-T-004, Revision 0.	P105-4-506-077
19	IDVP Design Review of DCP Calculation #64-T-151, Revision 1.	P105-4-506-122
20	IDVP Design Review of DCP Calculation #64-T-208, Revision 1.	P105-4-506-107
21	IDVP Design Review of DCP Calculation #64-T-352, Revision 0.	P105-4-506-181
22	IDVP Design Review of DCP Calculation #64-T-370, Revision 1.	P105-4-506-152
23	IDVP Design Review of DCP Calculation #64-T-441, Revision 0.	P105-4-597-245
24	Diablo Canyon Project (DCP), Design Criteria Memorandum (DCM) C-17, Hosgri Response Spectra for Structures, Systems, and Components, Revision 7.	P105-4-200-100
25	American Institute of Steel Construction, Manual of Steel Construction, 7th and 8th Editions.	
26	DCP, DCM C-42, Turbine Building, Revision 0.	P105-4-200-164
27	Field Verification Notes for Turbine Building Modification Sample	P105-4-591.5-320 through -323

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Section 8.0

Figures

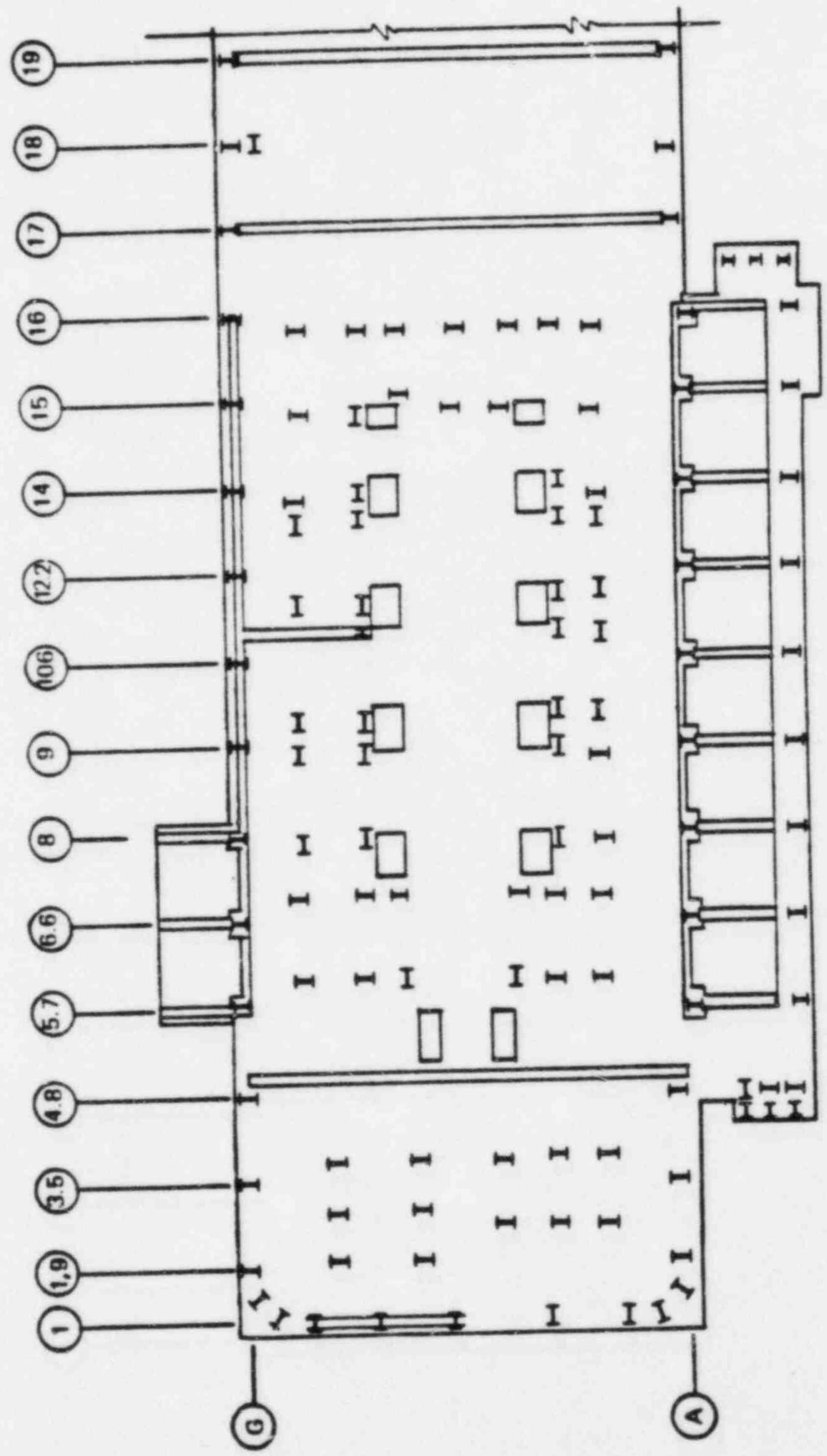


Figure 1
Turbine Building Plan at El. 85'-0"

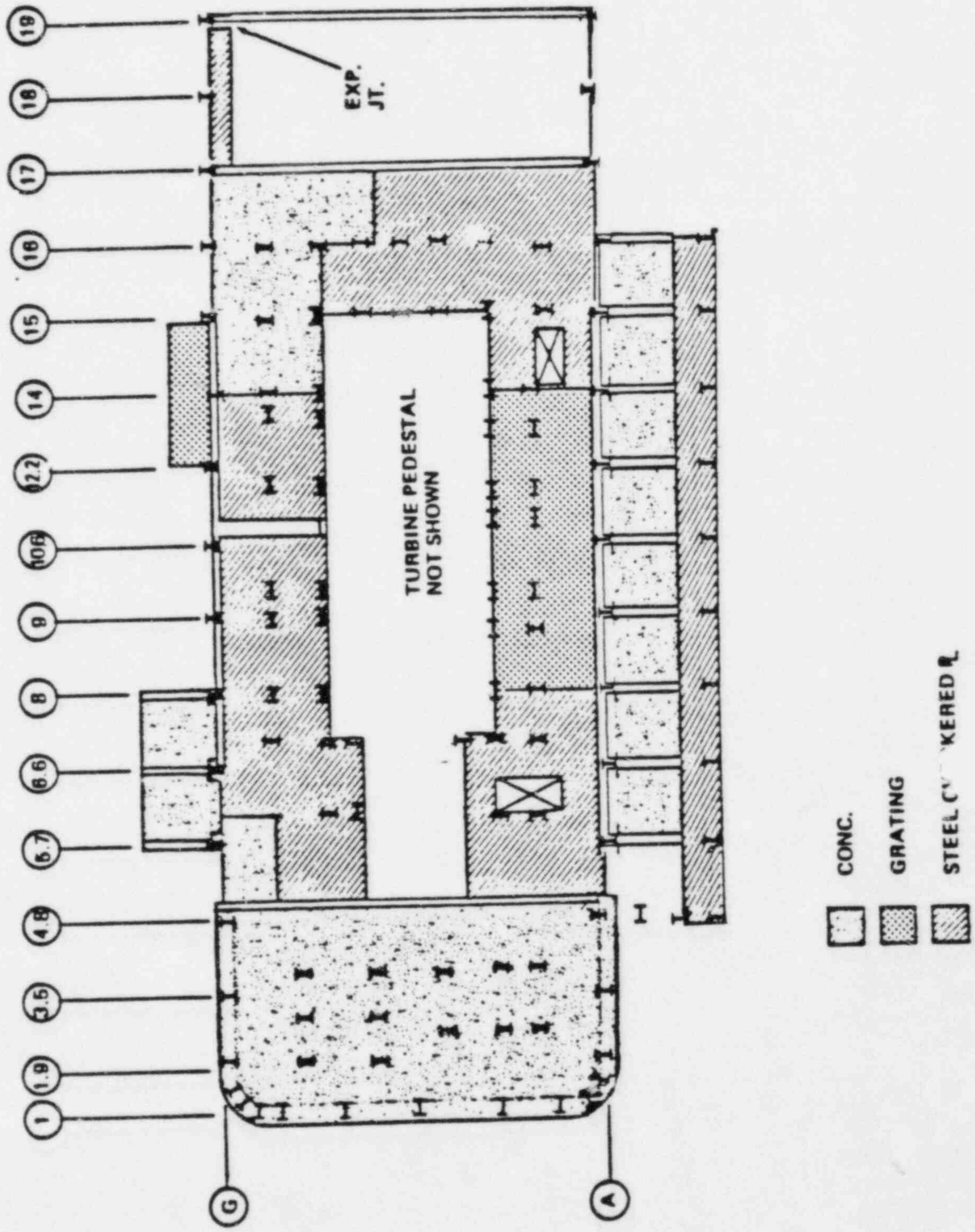


Figure 2
Turbine Building Plan at El. 104'

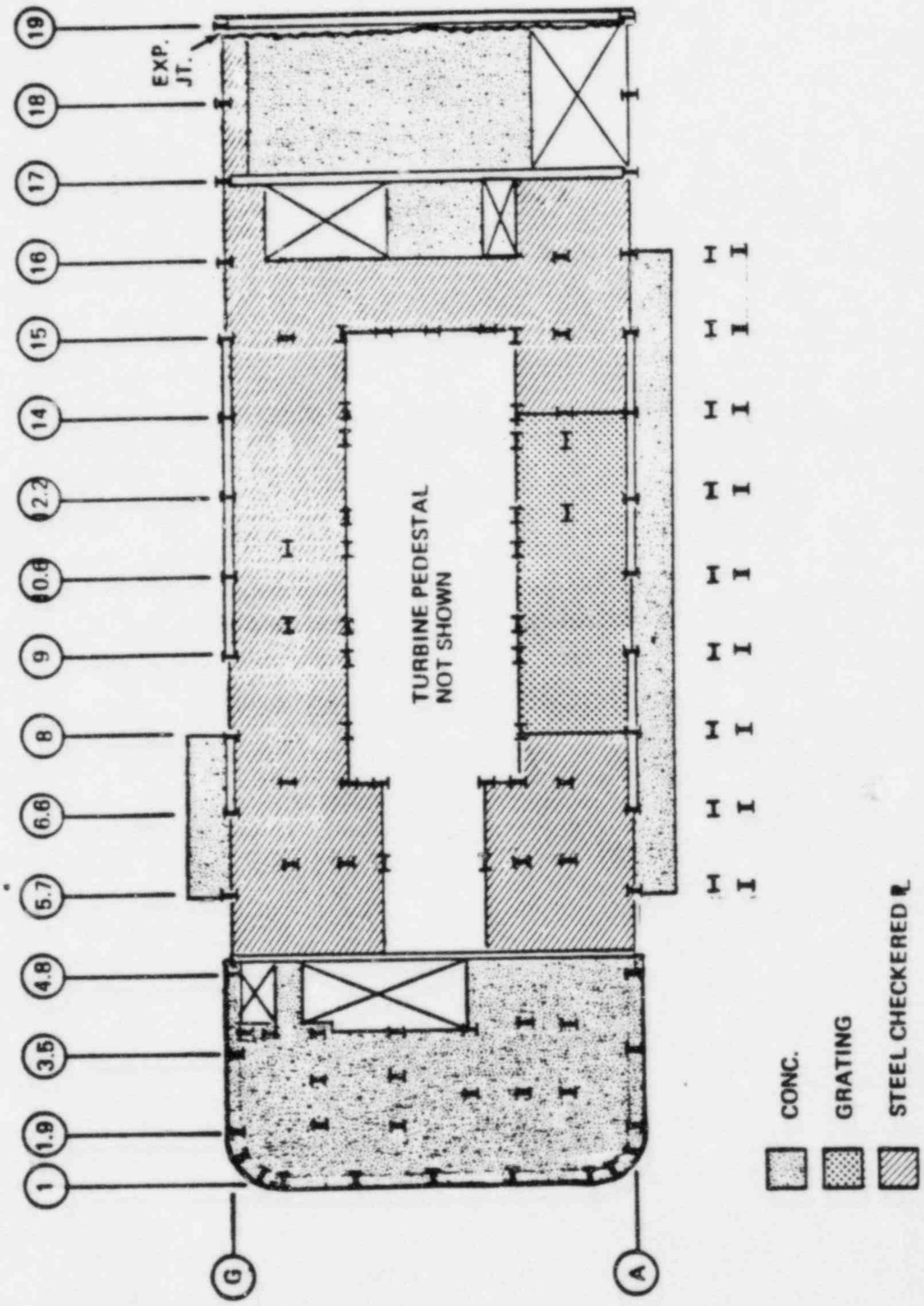


Figure 3
Turbine Building Plan at El. 119'

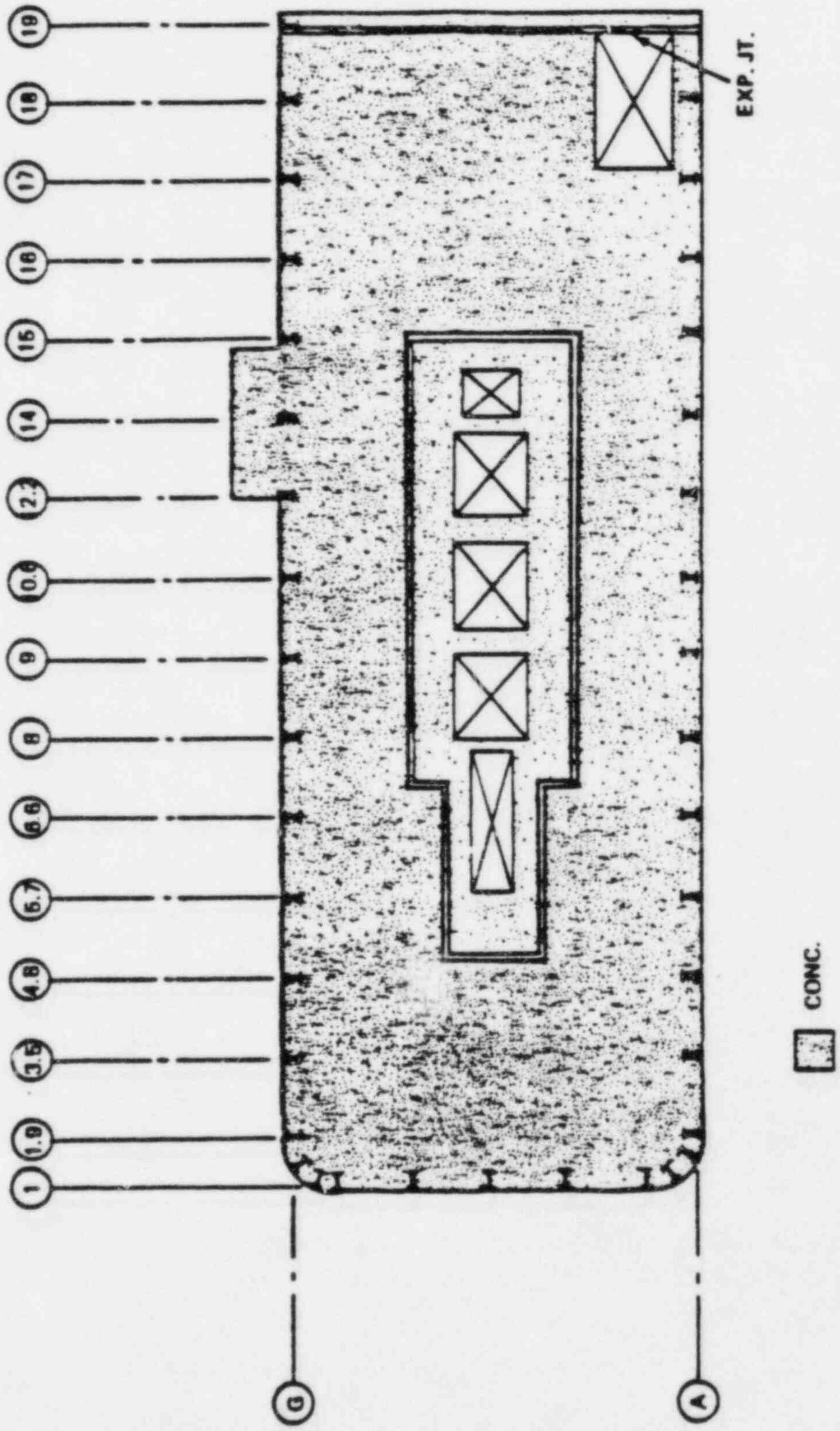


Figure 4
Turbine Building Plan at El. 140'

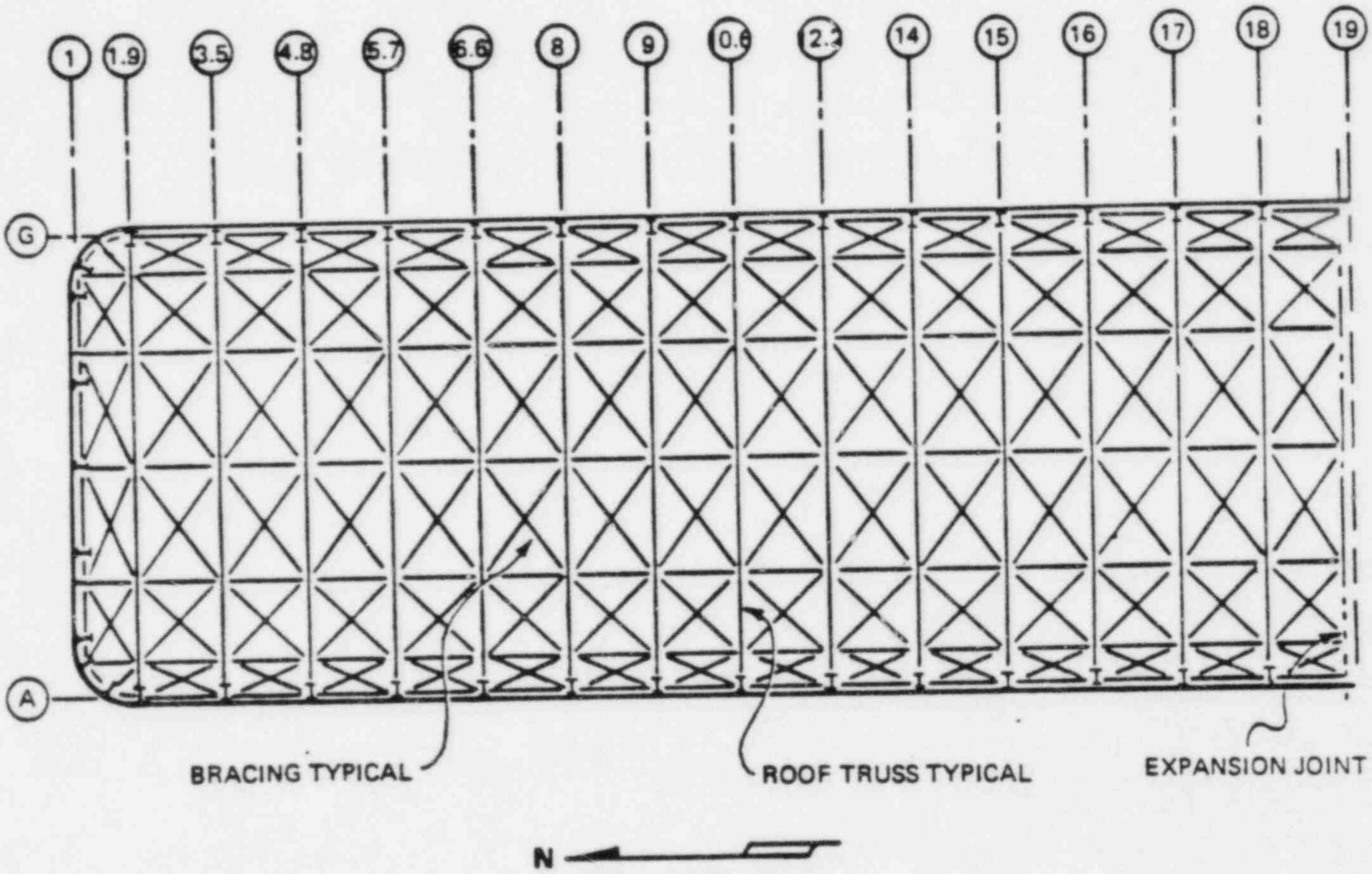


Figure 5
Turbine Building Plan
Lower Chord of Roof Trusses at El. 193'

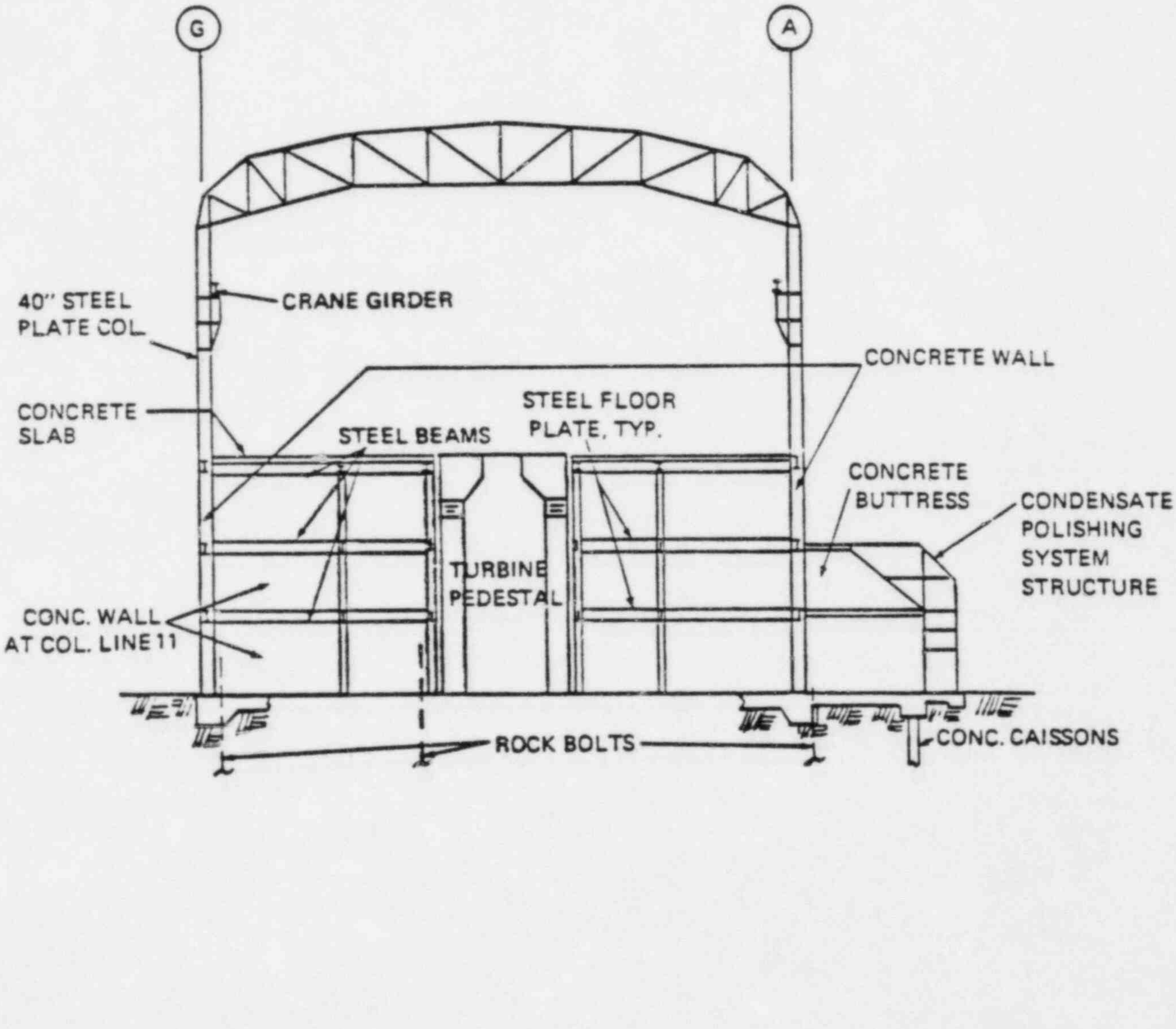


Figure 6
Turbine Building Typical Section

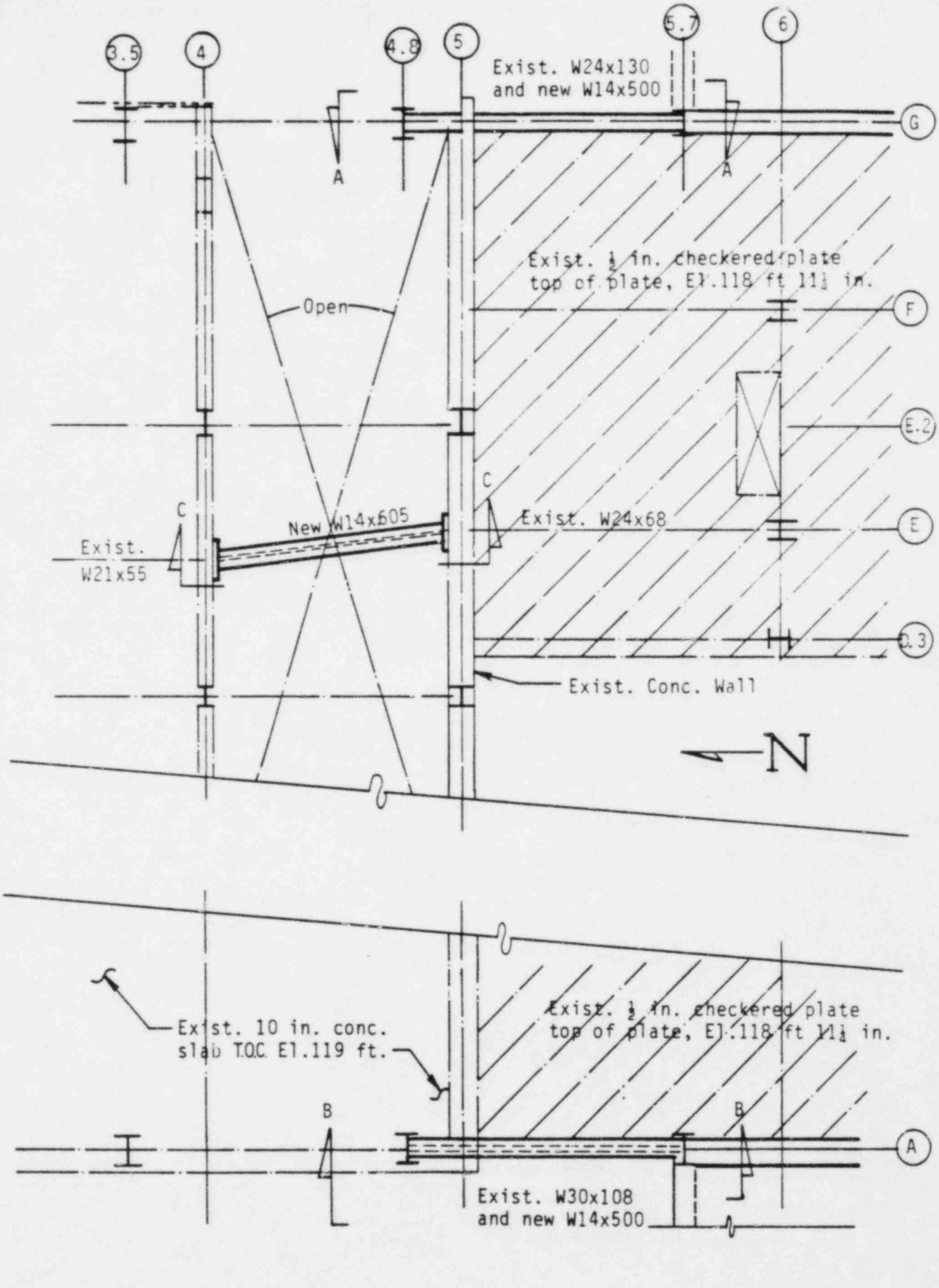
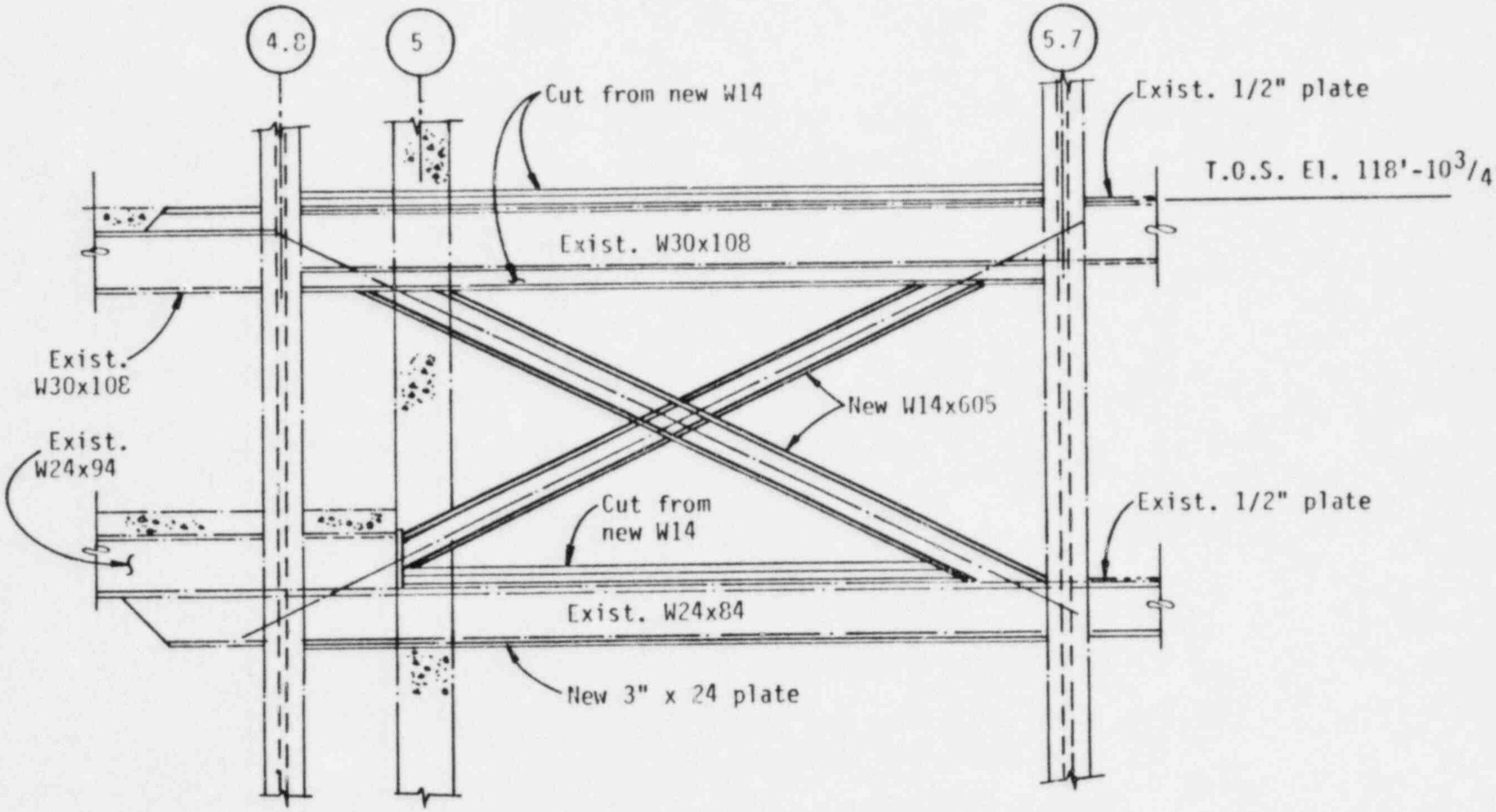


Figure 7

Modifications - Partial Plan
at Elevation 119.0 Ft



Section B-B

Figure 8

Modifications - Elevation along Column Line A (Looking East)

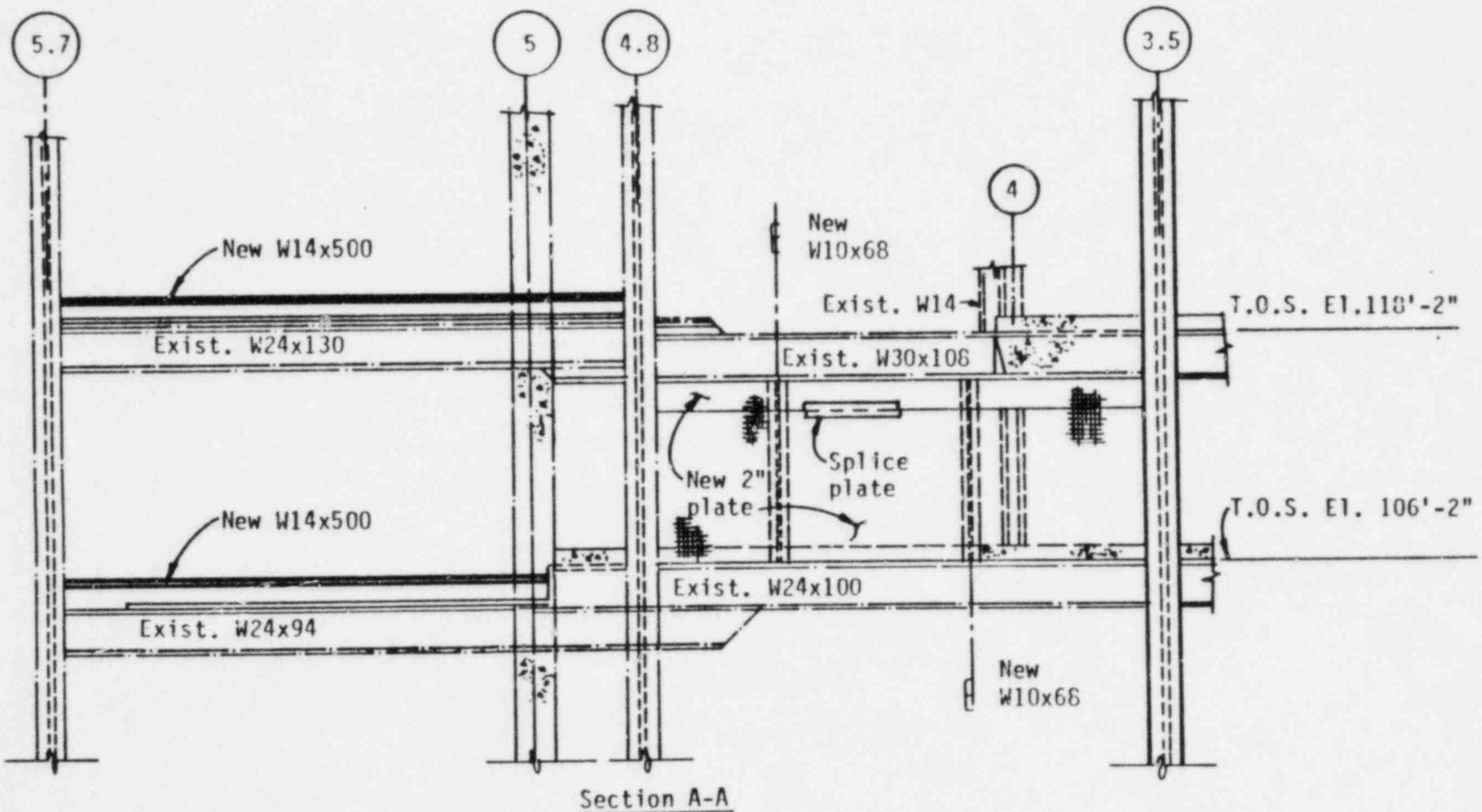


Figure 9

Modification - Elevation along Column Line G (Looking West)

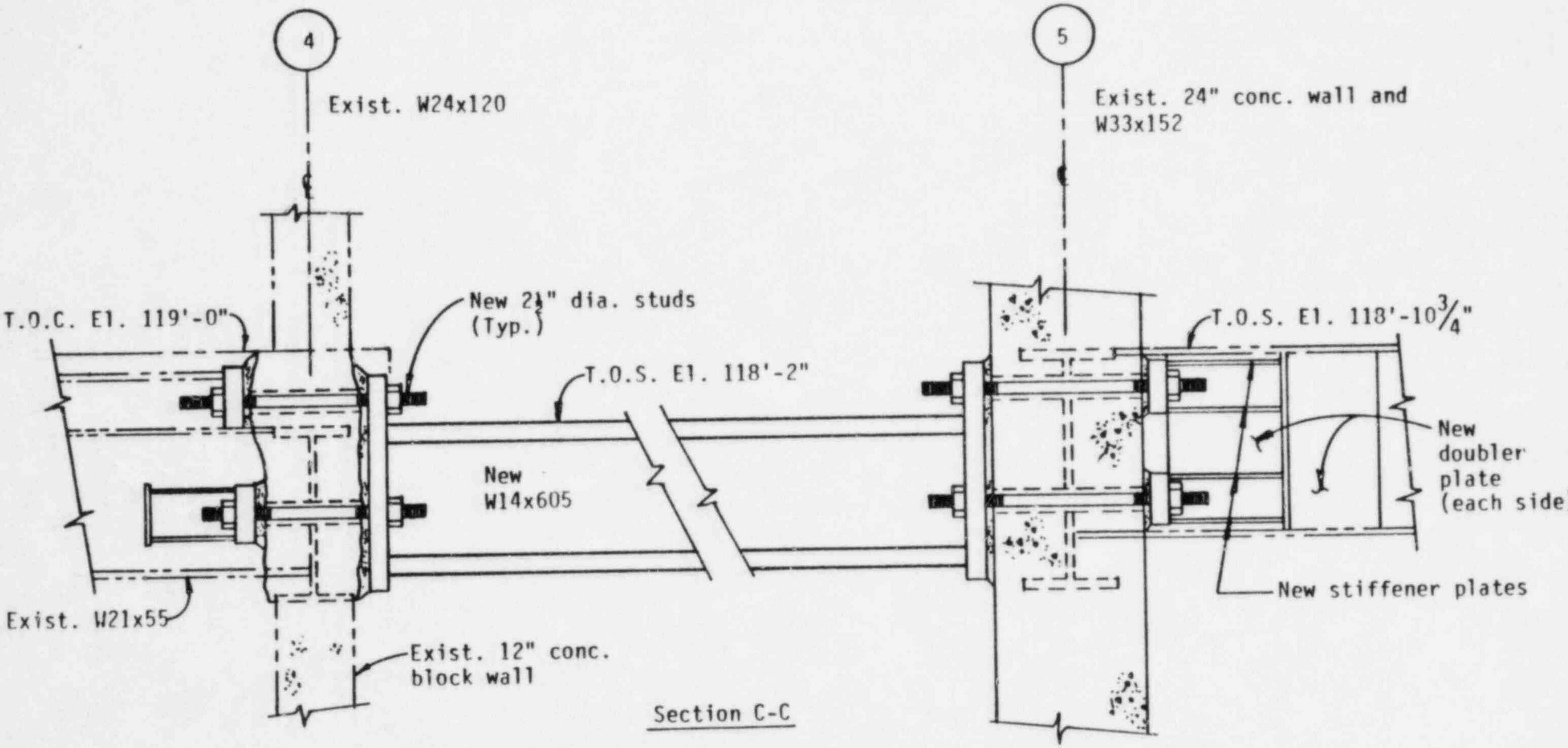


Figure 10

Modifications - Elevation, New Tie Beams

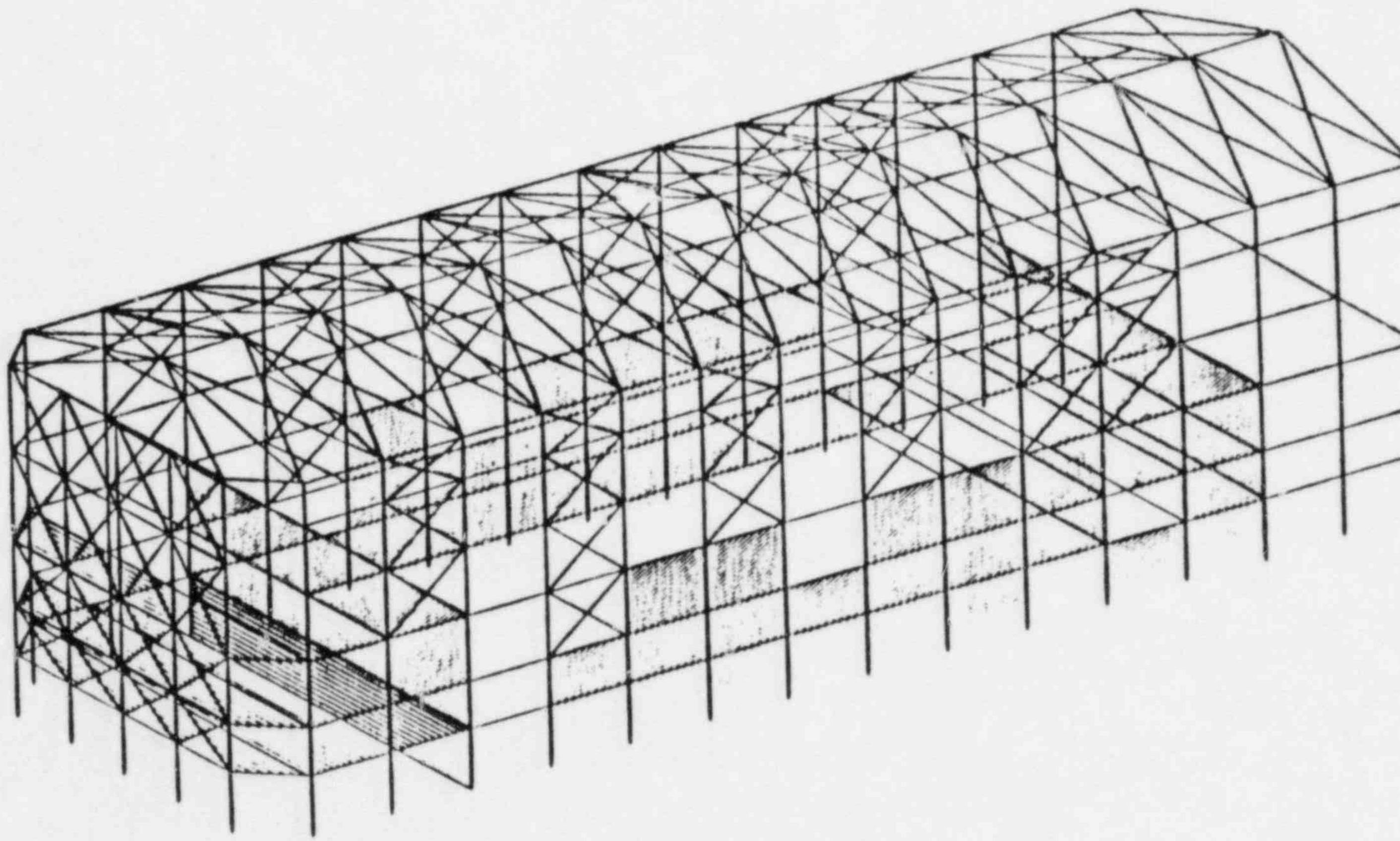


Figure 11

Turbine Building Horizontal Model

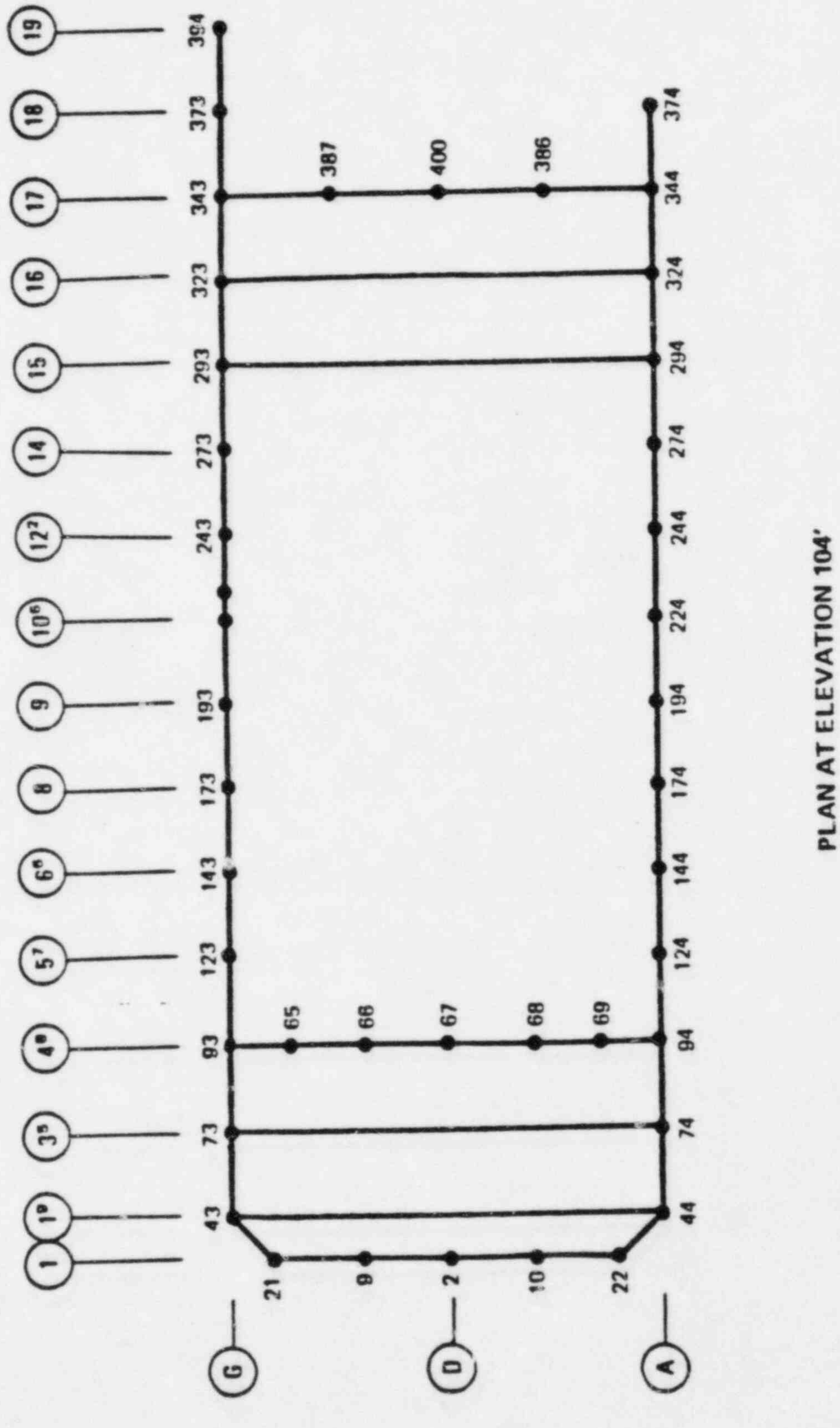


Figure 12
Turbine Building Horizontal Model
Plan at El. 104'-0"

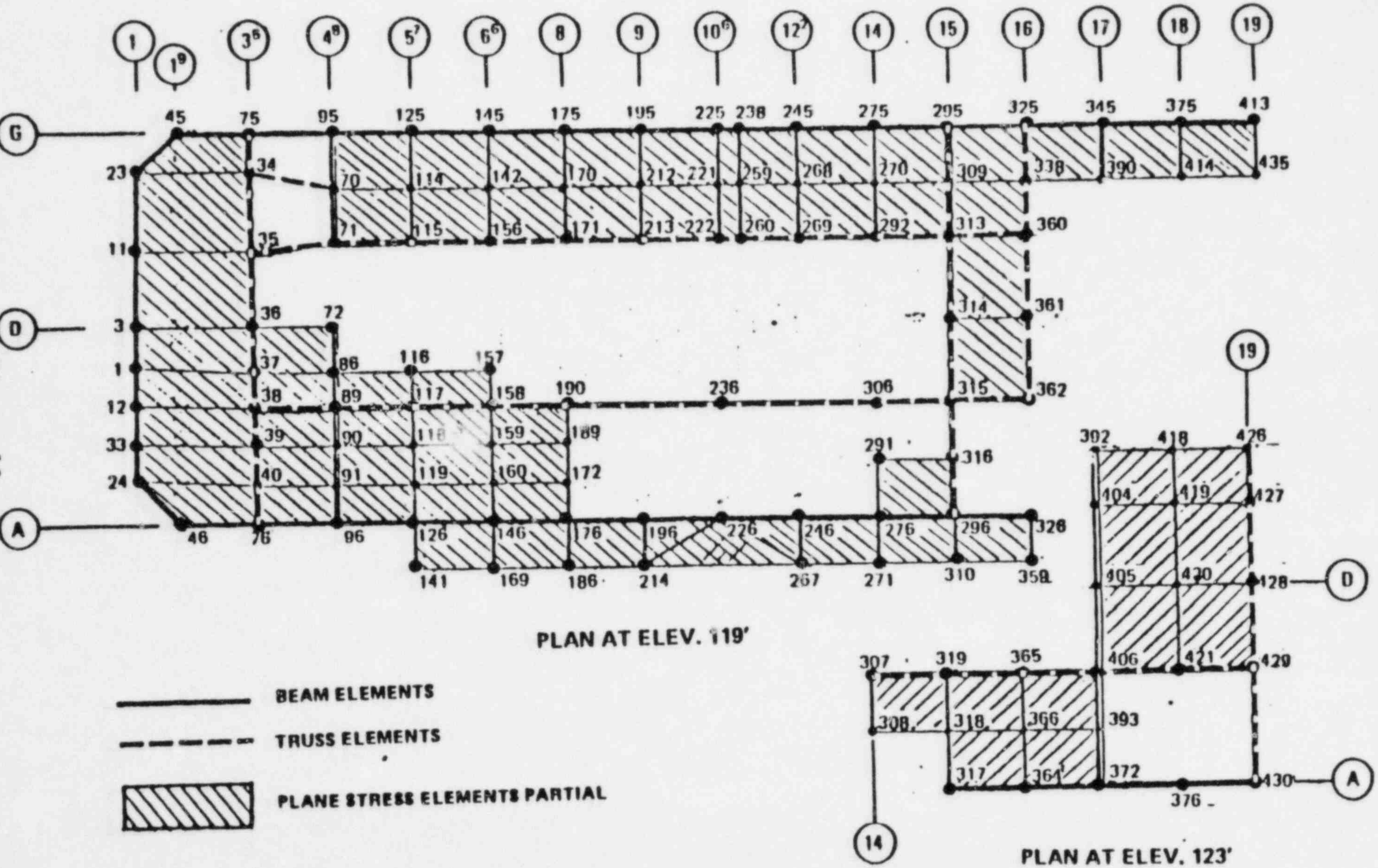


Figure 13
Turbine Building Horizontal Model
Plan at El. 119'-0" & 123'-0"

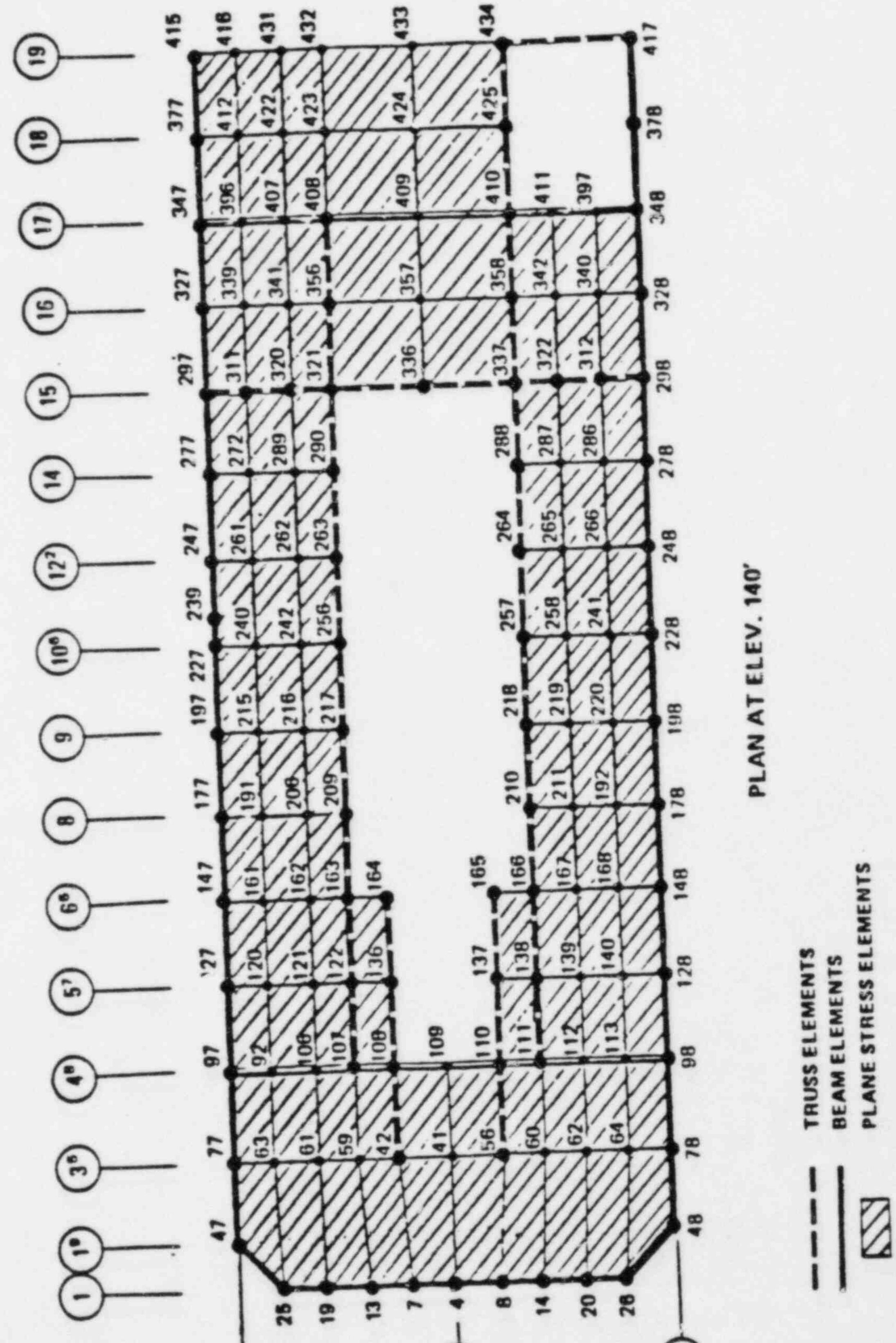


Figure 14
Turbine Building Horizontal Model
Plan at El. 140'-0"

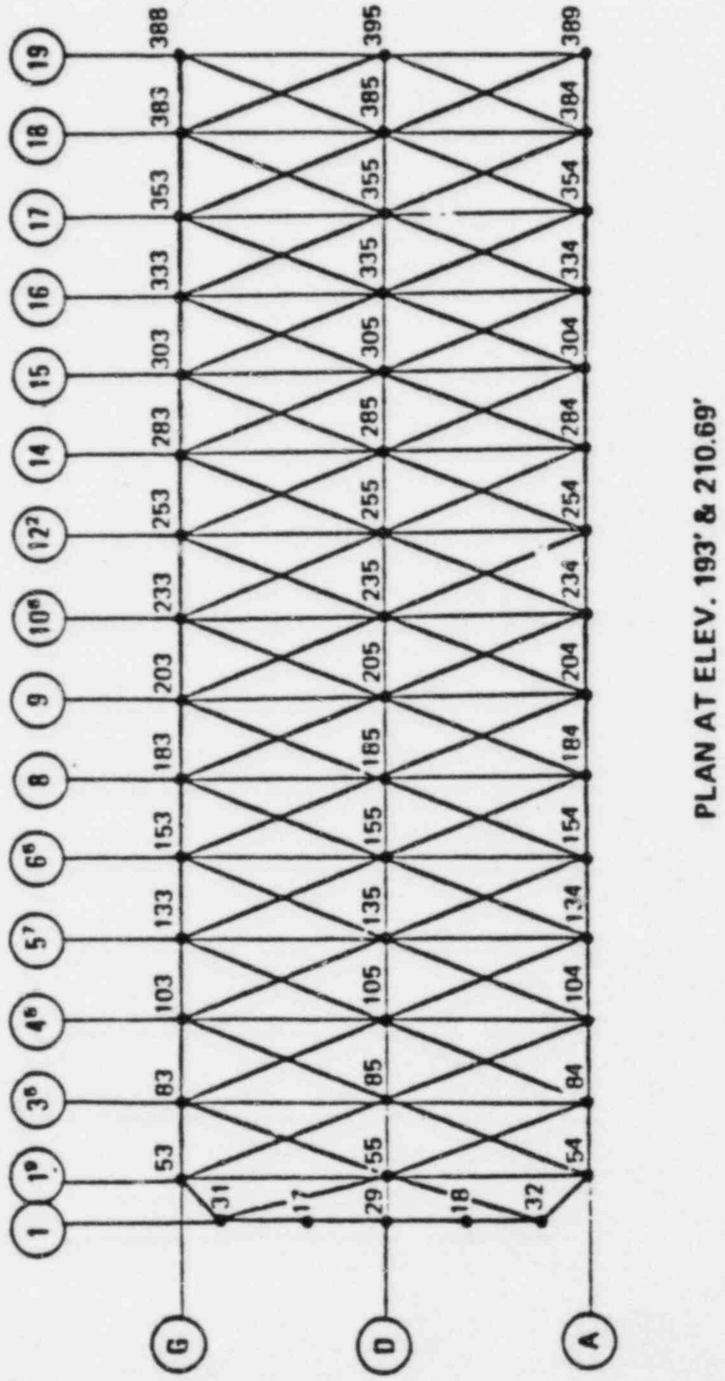


Figure 15
Turbine Building Horizontal Model
Plan at Roof Level

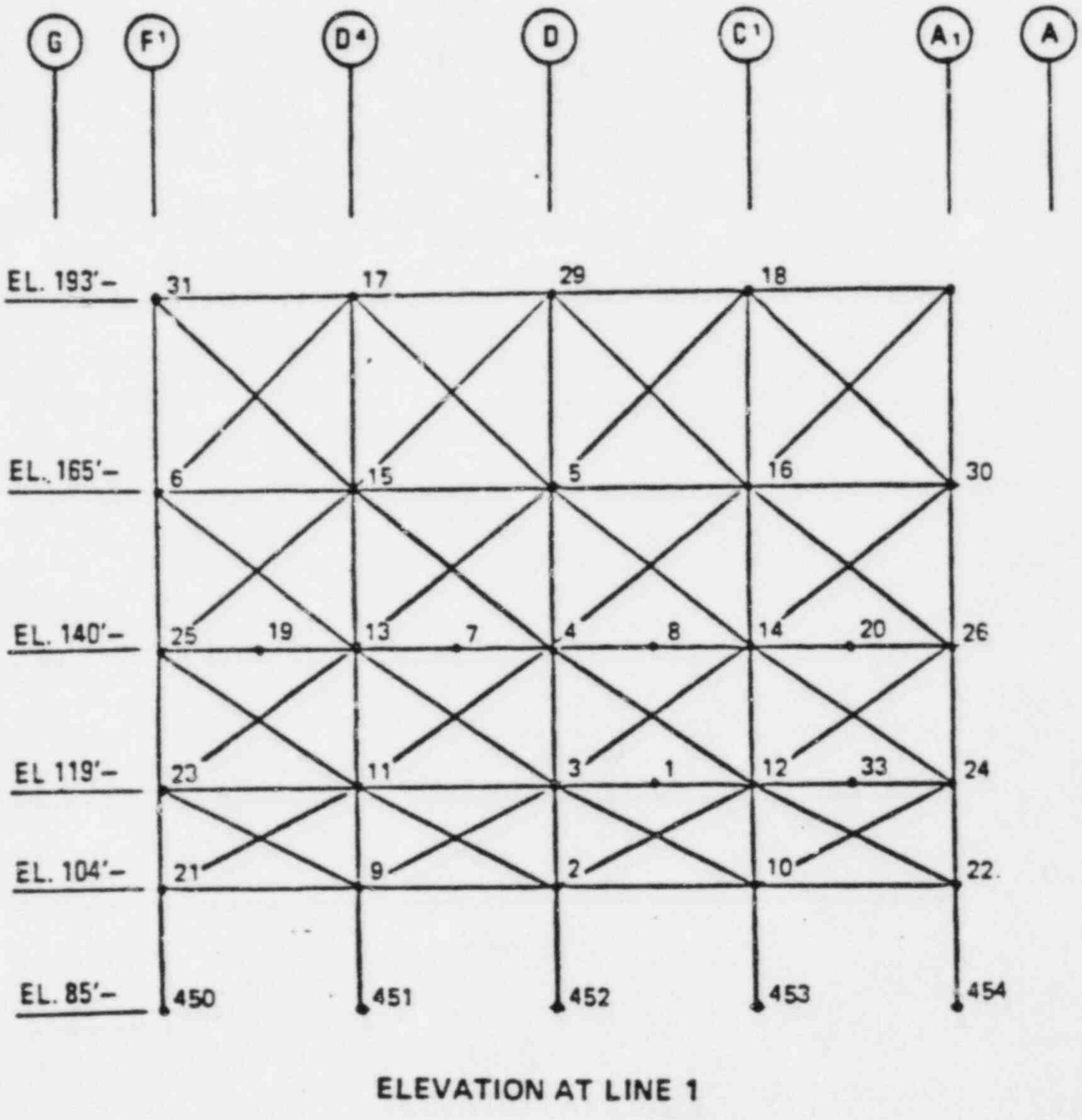


Figure 16
Turbine Building Horizontal Model
Elevation at Line 1

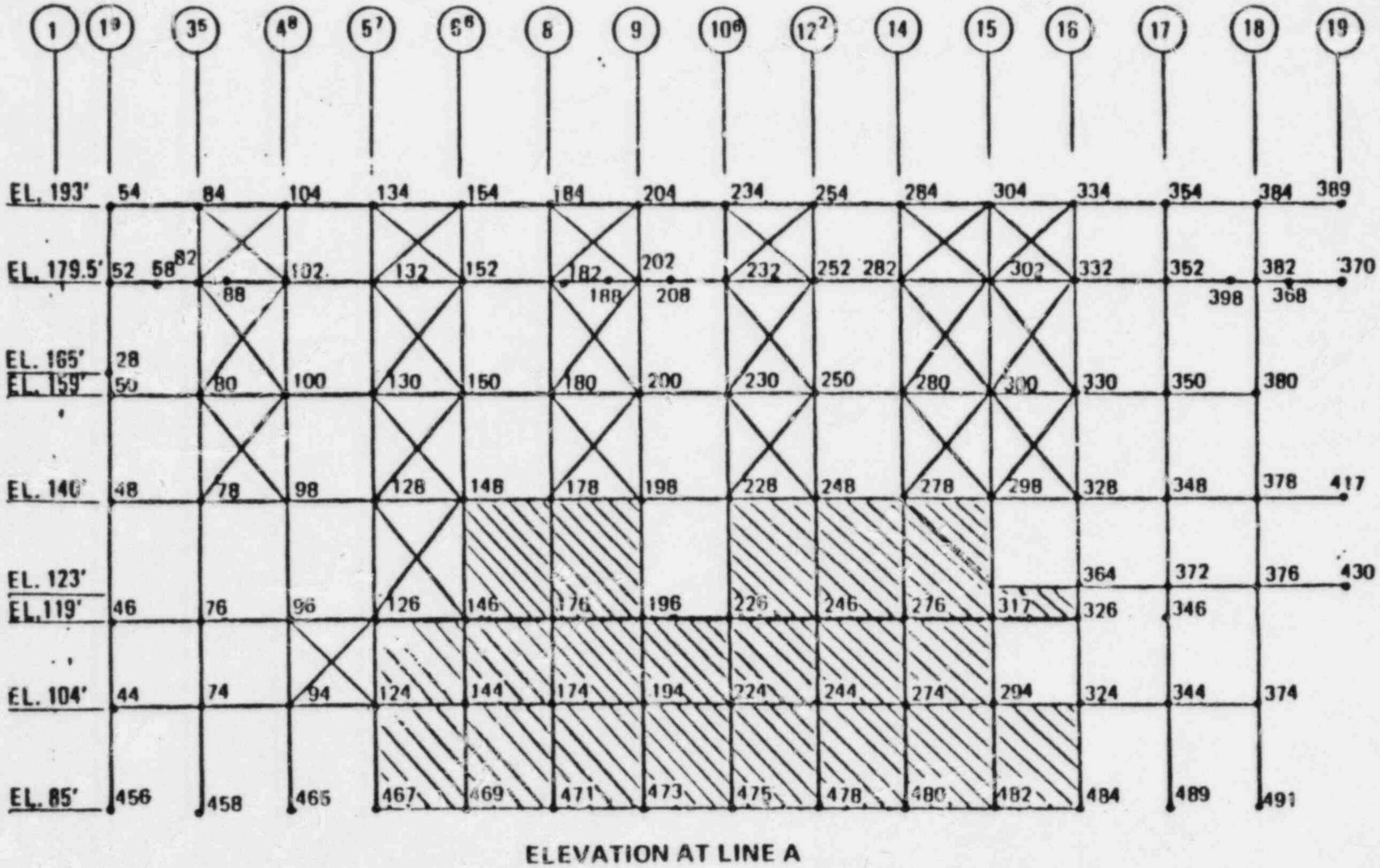


Figure 17
Turbine Building Horizontal Model
Elevation at Line A

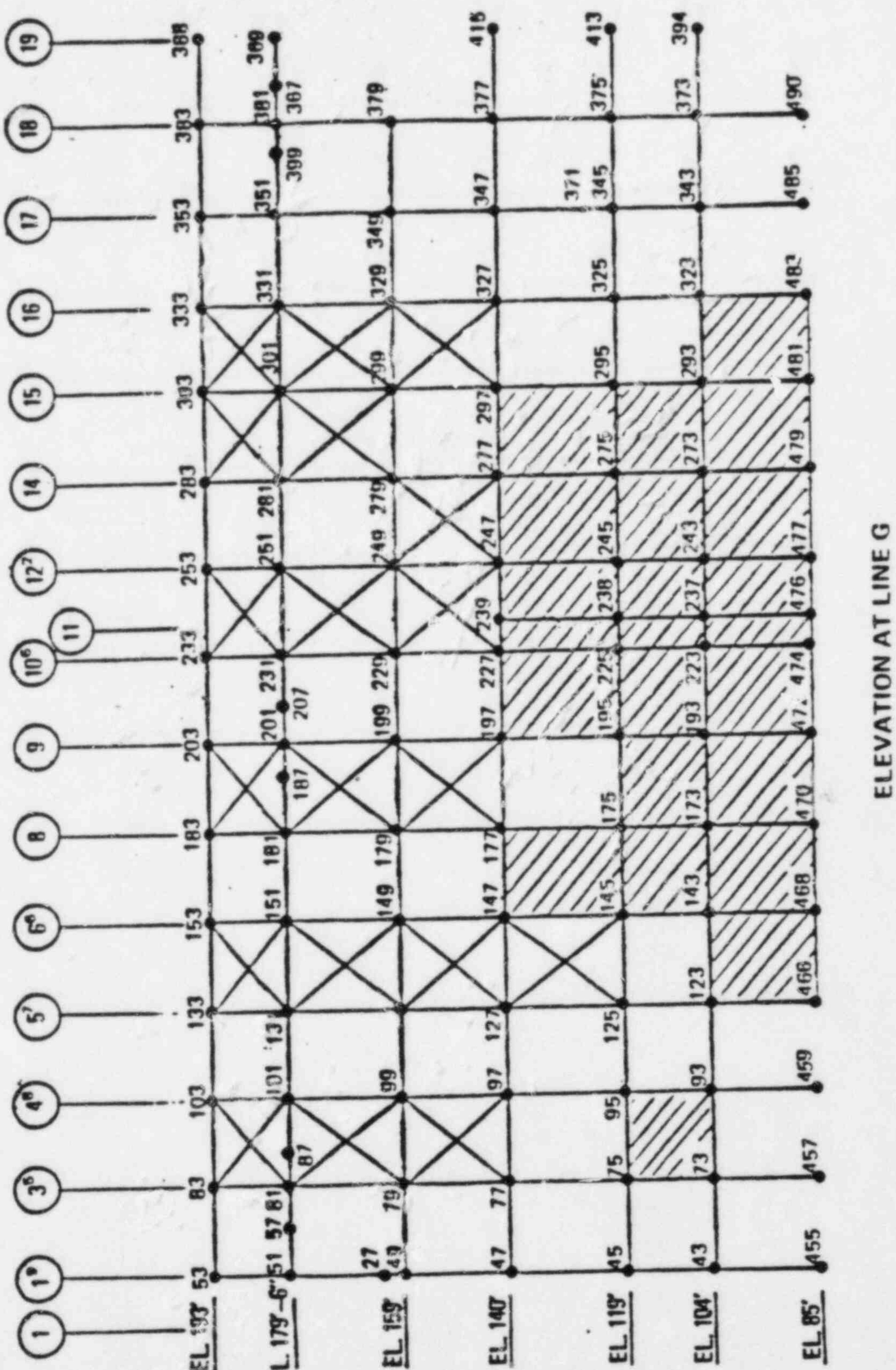


Figure 18
Turbine Building Horizontal Model
Elevation at Line G

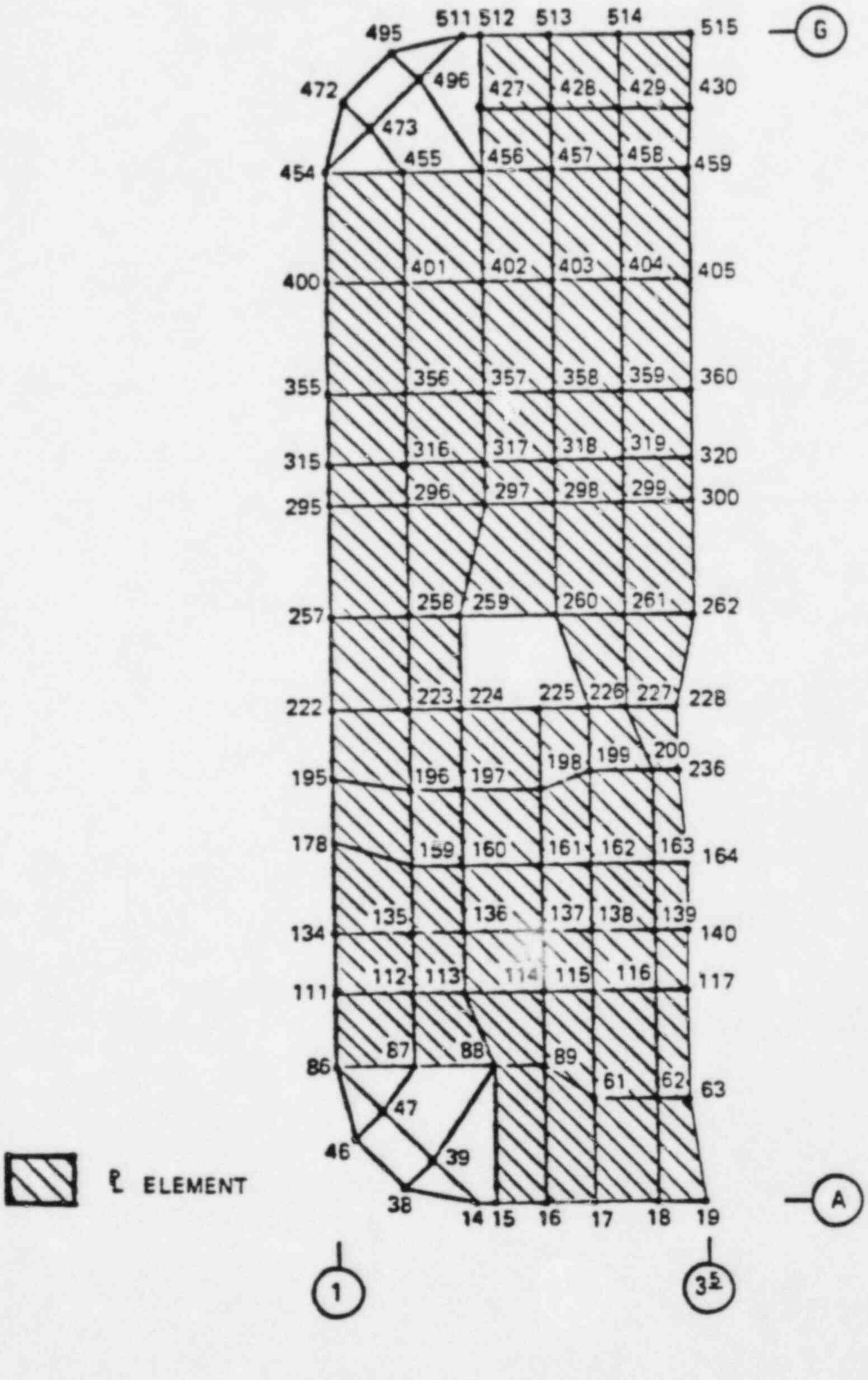


Figure 19
Turbine Building Vertical Model No. 1
Plan at El. 140'-0"

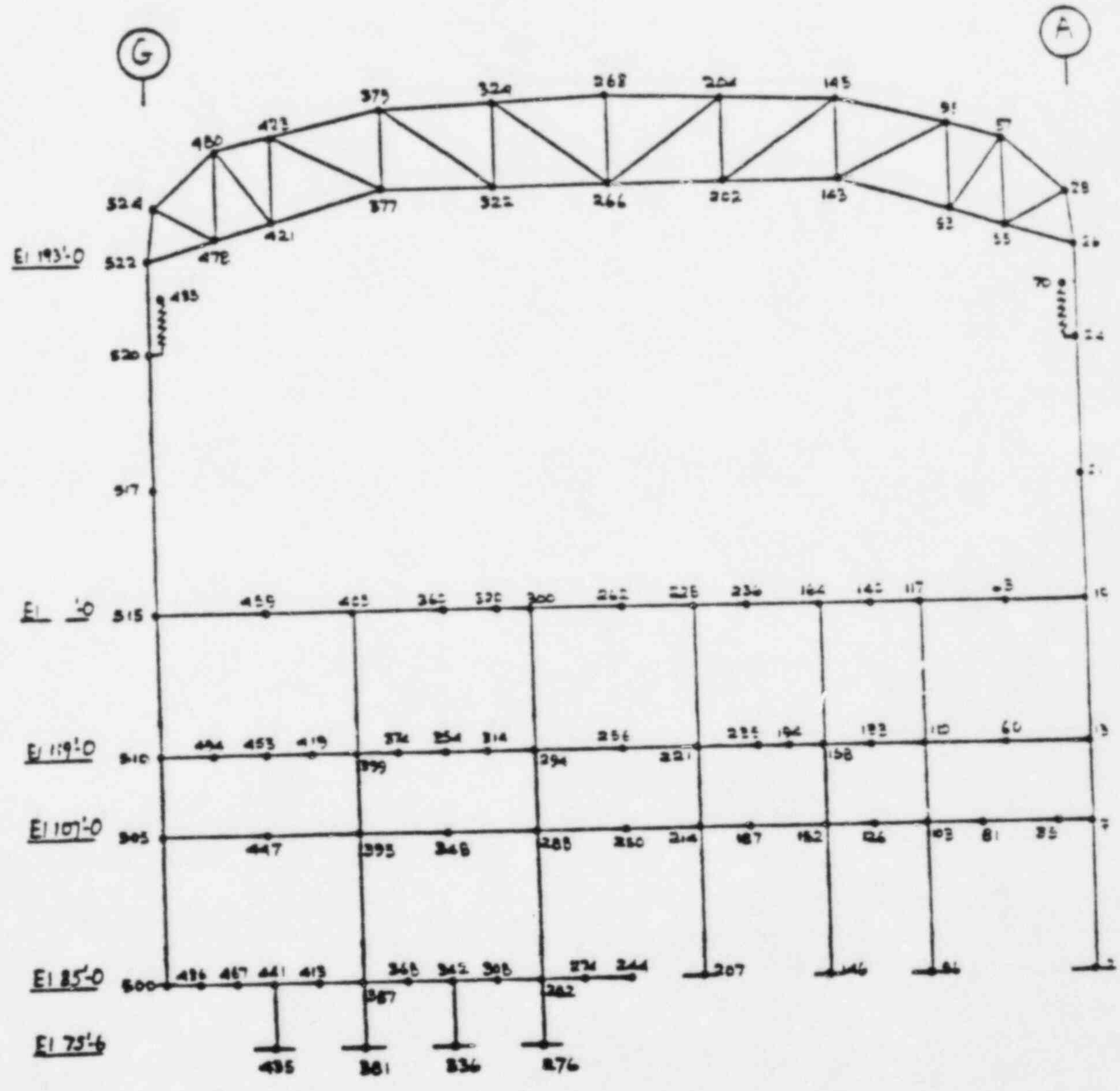


Figure 20

Turbine Building Vertical Model No. 1
Elevation at Line 3.5

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Appendix A

List of DCP Qualification Analyses

Turbine Building

(6 pages)

Appendix A
List of DCP Qualification Analyses
Turbine Building

Calculation No.	Rev. No.	Description
Unmodified* (Licensing)		
64-T-204	1	Mass Calculation Elevation 140
64-T-205	1	Mass Calculation Elevation 119
64-T-209	0	Elevation 180 Mass Calculation
64-T-210	0	Elevation 159 Mass Calculation
64-T-211	0	Elevation 193 Mass Calculation
64-T-212	0	Elevation 165 Mass Calculation
64-T-213	0	Elevation 104 Mass Calculation
64-T-214	0	Model A Mass Summary
64-T-215	0	Hosgri Horizontal Models A to FS Description
64-T-216	0	Hosgri Horizontal Model A Stiffness
64-T-219	0	DDE Horizontal Model F Stiffness Calculations
64-T-221	0	Elevation 119 Mass Calculation Lines 1-5
64-T-225	0	Hosgri Horizontal Model D Mass Calculation
64-T-226	0	Hosgri Horizontal Models B, C Geometry and Stiffness Calculations
64-T-227	0	Hosgri Horizontal Model D Geometry and Stiffness Calculations
64-T-229	0	Hosgri Horizontal Model E Stiffness Calculations
64-T-230	0	Hosgri Horizontal Model F Stiffness Calculations
64-T-231	0	Hosgri Horizontal Model FS Stiffness Calculations
64-T-232	1	Pipe Supports Distributed Weight Study
64-T-233	0	Hosgri Horizontal Model E Mass Calculations
64-T-234	0	Hosgri Horizontal Model F Mass Calculations
64-T-235	0	Hosgri Horizontal Model FS Mass Calculations
64-T-236	0	Hosgri Horizontal Models B to FS Mass Summary
64-T-237	0	DDE Horizontal Model F Geometry and Damping
64-T-255	0	Hosgri Model F&FS Line G. Study - Opening & CCW HtxBr Effect
64-T-302	0	Vertical Model Floor Composite Action Study
64-T-305	0	Vertical Model Description Lines 1-5
64-T-306	0	Vertical Model Stiffness Calculation Lines 1-5
64-T-307	0	Vertical Model Mass Calculation Lines 1-5
64-T-309	0	Vertical Model Description Lines 5-15
64-T-310	0	Vertical Model Stiffness Calculation Lines 5-15
64-T-311	0	Vertical Model Mass Calculations Lines 5-15

*These calculations may also apply wholly or in part to the modified building calculations.

Calculation No.	Rev. No.	Description
64-T-312	0	Vertical Model Spectra Generations Lines 5-15
64-T-313	0	Vertical Model Description Lines 15-19
64-T-314	0	Vertical Model Stiffness Calculations Lines 15-19
64-T-315	0	Vertical Model Mass Calculations Lines 15-19
64-T-316	0	Vertical Model Spectra Generation Lines 15-19
64-T-317	0	Crane Vertical Model Description
64-T-318	0	Crane Vertical Model Stiffness Calculations
64-T-319	0	Crane Vertical Model Mass Calculations
64-T-320	0	Crane Vertical Model Force Calculations
64-T-322	0	Vertical Model, Frequency Study, Lines 5-15
64-T-323	0	Vertical Model, Parametric Study, Lines 15-17
64-T-324	0	Fire Piping Specific Vertical Displacements
64-T-336	0	Crane Vertical Model, Specific Programs
64-T-343	0	CCW Piping Specific Vertical Displacements
64-T-401	0	Turbine Pedestal Accelerations Calculations

Calculation No.	Rev. No.	Description
Licensing (Modified)		
65-T-003	0	Roof Lower Chord Bracing
65-T-004	1	Bottom Chord Roof, Bolt Bearing Capacity
65-T-051	2	Transverse Roof Trusses
65-T-053	0	Horiz. Seismic Forces Transverse Roof Trusses
65-T-103	2	Main Exterior Columns
65-T-104	2	Columns Line 1
65-T-151	2	Bracing on Lines 1, A and G
65-T-203	1	Concrete Shear Wall Line 1
65-T-204	0	Shear Wall Line 5
65-T-205	0	Shear Wall Line 11
65-T-206	0	Shear Wall Line 17
65-T-207	0	Shear Wall Line G
65-T-208	1	Shear Wall Line A
65-T-250	1	Turbine Pedestal Evaluation of Critical Members
65-T-251	1	Turbine Pedestal Separation Evaluation El. 140
65-T-252	0	Turbine Pedestal Separation Evaluation El. 119, 104
65-T-253	0	Turbine Pedestal Design Evaluation
65-T-301	1	Buttress Walls on LInes A and G
65-T-352	1	Diaphragm Slab El. 140
65-T-353	0	Diaphragm Slab Axial Forces Elevation 140
65-T-365	0	Beams Connection Capacities
65-T-370	1	Beams El. 140 Area AX
65-T-371	1	Beams El. 140 Area AY
65-T-372	1	Beams El. 140 Area BX
65-T-373	1	Beams El. 140 Area BY
65-T-375	1	Beams El. 140 Area CIY & CIIY
65-T-405	1	Diaphragm Floor at El. 119
65-T-420	1	Beams El. 119 Area AX
65-T-423	1	Beams El. 119 Area BY
65-T-424	0	Beams El. 119 Area CIX
65-T-425	1	Beams El. 119 Area CIY
65-T-426	0	Beams El. 119 Area CIX & CIIX
65-T-427	1	Beams El. 119 Area CIY & CIIY
65-T-428	1	Beams El. 119 Area DX
65-T-429	1	Beams El. 119 Area D(X-Y)
65-T-430	1	Beams El. 123 Area DY
65-T-431	1	Beams El. 119 Area DY
65-T-450	1	Diaphragm Floor El. 104
65-T-471	1	Beams El. 107 Area AY
65-T-472	0	Beams El. 104 Area DY
65-T-473	1	Beams El. 104 Area DYI
65-T-474	1	Beams El. 104 Area DXY
65-T-475	1	Beams El. 104 Area CIIY
65-T-476	1	Beams El. 104 Area DX
65-T-477	0	Beams El. 104 Area BY
65-T-501	1	Interior Columns Area A
65-T-504	1	Interior Columns Area D

Calculation No.	Rev. No.	Description
65-T-551	0	Foundation Beams Lines A & G
65-T-602	2	Crane Runway Calculations
64-T-603	1	Crane Bridge Calculations
65-T-701	0	Steel Test Strength, 1978 Hosgri Modifications
65-T-703	0	Reinforcing Steel Test Strength, 1978 Hosgri Modif.
65-T-704	0	Steel Test Strength, 1978 Hosgri Modifications
65-T-705	0	Checker Plate Steel Test Strength, 1978 Hosgri Modif.
65-T-706	0	Material Test Strengths, original construction
65-T-800	0	Bldg. Evaluation, Pipe Supports 2-1R to 14-79R
65-T-801	0	Bldg. Evaluation, Pipe Supports 18-1SL to 301-166V
65-T-802	0	Bldg. Evaluation, Pipe Supports 384-51R to 384-141R
65-T-803	0	Bldg. Evaluation, Pipe Supports 384-300R to 384-370R
65-T-850	0	CRPS Ductwork El. 140 and Above

Calculation No.	Rev. No.	Description
64-T-228	1	Crane Horizontal Analysis
64-T-245	1	Hosgri Horizontal Stiffness and Forces at Diesel Gen. Stacks
64-T-253	0	DDE Horizontal Model
64-T-254	0	DDE Time History Check
64-T-256	0	DDE Horizontal Model Response Spectra
64-T-257	0	DDE Horizontal Model Displacements
64-T-258	0	Hosgri Horizontal Model
64-T-259	0	Hosgri Horizontal Model Member Forces
64-T-260	0	Hosgri Horizontal Model Spectra
64-T-269	0	DDE Horiz. Model Local Response Spectra
64-T-272	0	Hosgri Horiz. Mdl. Time History Stresses at El. 140
64-T-273	0	Hosgri Horiz. Mdl. Node Selection for Spectra 1P
64-T-334	0	Vertical Modified Model N5 Spectra Lines 1-5
64-T-342	0	Vertical Modified Model N6 Spectra Lines 1-5
64-T-344	0	Vertical Modified Model N5-N6 Env. Spectra Lines 1-5

Calculation No.	Rev. No.	Description
Modifications Design		
65-T-441	1	Floor Modifications El. 119 & 104 (North-End)
65-T-442	1	Floor Modifications El. 119 & 123 (South-End)
65-T-511	1	Column Modifications Between El. 119 & 140
65-T-512	0	Roof Modifications for Diesel Gen. Stacks Supports
65-T-514	0	El. 140 Floor Beams Modification at Block Attachments
65-T-804	0	Wall A Reinforcing at 4.8 to 5.7 for Fire Piping Supports

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Appendix B

List of IDVP Sample - Turbine Building

(3 pages)

Appendix B
List of IDVP Sample
Turbine Building

Calculation No.	RLCA File No. P105-4-
64-T-204	431-172, 487
64-T-214	431-221, 475
64-T-215	431-173, 476
64-T-216	431-174, 477
64-T-221	431-364, 478
64-T-225	431-365, 479
64-T-226	431-366, 480
64-T-227	431-330, 481
64-T-229	431-300, 482
64-T-230	431-301, 483
64-T-231	431-256, 484
64-T-233	431-367, 484
64-T-234	431-368, 484
64-T-235	431-369, 484
64-T-236	431-230, 370, 485
64-T-258	431-415
64-T-259	431-416
64-T-260	431-417, 460
64-T-273	431-411
64-T-334	431-418
64-T-342	431-419

Calculation No.	RLCA File No. P105-4-
64-T-302	431-341
64-T-305	431-177
64-T-306	431-324, 486
64-T-307	431-334, 486
65-T-004	431-224
65-T-151	431-225,
65-T-208	431-226, 327, 424
65-T-352	431-421
65-T-353	431-510
65-T-370	431-222, 422
65-T-441	431-385, 459

Description of IDVP Selected Computer Runs

Computer Run No.	RLCA P105-4	Description
T0524	431-429	Model FS12 Eigenanalysis
T0535	431-461	Envelope of Blume and Newmark Response Spectrum Analysis (SRSS modes, SRSS directions) model FS12.
T0538	431-465	N-S Blume Response Spectrum Analysis (DAS modes) model FSR
T0546	431-462	Envelope (DAS modes) of Blume and Newmark Response Spectrum Analysis, SRSS directions, model FS12.
T0545	431-463	SRSS of E-W and N-S Newmark Response Spectrum Analysis (DAS modes) Model FS12.
T0542	431-464	SAPOST3 Reformat of E-W Newmark Response Spectrum Analysis (DAS modes) Model FS12.
T0547	431-458	Envelope (SRSS and DAS modes Blume and Newmark) Response Spectrum Analysis, SRSS directions, model FS12.
Computer Run Index	431-398	Horizontal Models
Computer Run Index	431-391	Vertical Models
T3401	431-428	Vertical Modified Model N6 Eigensolution

All models are for the crane parked with respect to the licensing condition.

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Appendix C

Error and Open Item Status - Turbine Building

(2 pages)

Appendix C
Error and Open Item Status - Turbine Building

EOI File No.	Subject	Rev.	Date	By	Type	Action Required	Physical Mod.
982	Turbine Building Design Interface (Preliminary Report)	0	2/6/82	RLCA	OIR	RLCA	
		1	6/18/82	RLCA	PPRR/OIP	TES	
		2	7/1/82	TES	PRR/OIP	PGandE	
		3	7/20/82	TES	OIR	RLCA	
		4	7/21/82	RLCA	PPRR/CI	TES	
		5	7/23/82	TES	PRR/CI	TES	
		6	7/23/82	TES	CR	NONE	NO
984	Turbine Building Design Interface (Preliminary Report)	0	2/6/82	RLCA	OIR	RLCA	
		1	6/18/82	RLCA	PPRR/OIR	TES	
		2	7/1/82	TES	PRR/OIP	PGandE	
		3	7/20/82	TES	OIR	RLCA	
		4	7/21/82	RLCA	PPRR/CI	TES	
		5	7/23/83	TES	PRR/CI	TES	
		6	7/23/83	TES	CR	NONE	NO
989	Turbine Building Crane Modifications (Preliminary Report)	0	2/6/82	RLCA	OIR	RLCA	
		1	6/28/82	RLCA	PPRR/OIP	TES	
		2	7/1/82	TES	PRR/OIP	PGandE	
		3	7/21/82	TES	OIR	RLCA	
		4	7/21/82	RLCA	PPRR/CI	TES	
		5	7/23/82	TES	PRR/CI	TES	
		6	7/23/82	TES	CR	NONE	NO
1010	Spectra not available above elevation 140 feet	0	2/9/82	RLCA	OIR	RLCA	
		1	3/22/82	RLCA	PPRR/OIP	TES	
		2	4/17/82	TES	PRR/OIP	PGandE	
		3	7/20/82	TES	OIR	RLCA	
		4	7/21/82	RLCA	PPRR/CI	TES	
		5	7/23/82	TES	PRR/CI	TES	
		6	7/23/82	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.

Appendix C
Error and Open Item Status - Turbine Building (Continued)

EOI File No.	Subject	Rev.	Date	By	Type	Action Required	Physical Mod.
1025	Spectra not available for bents 16-20 elevation 104 feet	0	2/20/82	RLCA	OIR	RLCA	
		1	3/22/82	RLCA	PPRR/OIP	TES	
		2	4/17/82	TES	PRR/OIP	PGandE	
		3	7/20/82	TES	OIR	RLCA	
		4	7/21/82	RLCA	PPRR/CI	TES	
		5	7/23/82	TES	PRR/CI	TES	
		6	7/23/82	TES	CR	NONE	NO
1026	Spectra not available for several areas	0	2/20/82	RLCA	OIR	RLCA	
		1	3/19/82	RLCA	PPRR/OIP	TES	
		2	4/17/82	TES	PRR/OIP	PGandE	
		3	7/20/82	TES	OIR	RLCA	
		4	7/21/82	RLCA		PER/AorB	
		5	7/23/82	TES	ER/AorB	PGandE	
		6	8/29/83	TES	ER/AorB	PGandE	
		7	9/8/83	TES	OIR	RLCA	
1028	10% Increase in Translational Spectra to account for Torsion	0	2/23/82	RLCA	OIR	RLCA	
		1	3/22/82	RLCA	PPRR/OIP	TES	
		2	4/17/82	TES	PRR/OIP	PGandE	
		3	5/24/82	TES	OIR	RLCA	
		4	7/2/82	RLCA	PPRR/OIP	TES	
		5	7/13/82	TES	PRR/OIP	PGandE	
		6	3/9/83	TES	OIR	RLCA	
		7	8/26/83	RLCA	PPRR/CI	TES	
		8	8/29/83	TES	PRR/CI	TES	
		9	8/29/83	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.

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Appendix D

Key Term Definitions

(10 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.)

Allowable Criteria

- Maximum stress or load provided by the licensing criteria.

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.

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.

Damping

- The measure of energy dissipation in a system.

DCNPP-1

- Diablo Canyon Nuclear Power Plant, Unit 1.

DCP

- Diablo Canyon Project: PGandE and Bechtel Power Corporation.

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).

Deviation

- A form of program resolution of an Open Item indicating a departure from standard procedure which is not a mistake in analysis, design, or construction. No physical modifications are required, but if any are applied, they are subject to verification by the IDVP.

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).

Envelop

- Response spectra "A" is said to envelop response spectra "B" if all the accelerations on "A" are higher than those of "B" for the same frequency region.

EOI

- Error and Open Item Report.

Equivalent Static Method

- Static analysis method whereby an acceleration applied to a system is treated as a static force.

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:

- o 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.

- o 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.

- o 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.

o 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

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

FSAR

- PGandE's Final Safety Analysis Report.

Generic

- Relating to or characteristic of a whole group or class; general.

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.

Independent Analysis

- Seismic analysis performed by Robert L. Cloud and Associates.

Inertial Loads

- Loads produced by inertial motion of a body.

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.

KSF

- Kips per square foot.

Licensing Criteria

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

Lithology

- Descriptions of physical characteristics of rock determined by eye or low-power magnifier. Includes color, structures, mineral components, and grain size.

Load

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

Member Qualifications

- 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.

Moment

- A rotational load about a point produced by applying a force at the end of a lever from that point.

NRC

- Nuclear Regulatory Commission (formerly the AEC).

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.

Operating Basis Earthquake (OBE)

- The earthquake which could reasonably be expected to affect the plant site during the operating life of the plant.

PGandE

- Pacific Gas and Electric Company.

PGandE Design Class I

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

PGandE Technical Program

- Verification program undertaken by PGandE to evaluate DCNPP for compliance with licensing criteria.

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.

Qualification

- The final step in the process of evaluating plant buildings, systems and components, and confirming that they comply with the plant licensing criteria.

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 single degree of freedom system during a particular earthquake; used in seismic analysis. Types of spectra include both vertical and horizontal.

Response Spectra Modal Superposition

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

RFR

- Roger F. Reedy, Incorporated.

RLCA

- Robert L. Cloud and Associates, Incorporated.

Sample

- Initial sample stipulated in Phase I Program of equipment, components, and buildings to be design verified by independent analysis.

Shear

- Parallel to the plane of reference.

Spectra

- Graph showing relationship between acceleration and time; used in 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.

Static Load

- See Dead Load.

TES

- Teledyne Engineering Services.

Time History Analyses

- 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.

Translation

- The linear movement of a point in space without any rotation.

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Appendix E

Program Manager's Assessment

(1 page)

TELEDYNE ENGINEERING SERVICES

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 function was performed by TES in accordance with the Phase I Program Management Plan. The task of additional verification of the Turbine Building 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 Professors J. M. Biggs and M. J. Holley, Jr. had the opportunity to view the Turbine Building during a visit to the Diablo Canyon Nuclear Power Plant.

Professors J. M. Biggs and M. J. Holley, Jr. were involved in all aspects of the review. Their involvement included participation in open meetings in which the Turbine Building was a topic of discussion and review of material generated by RLCA, supplemented with material generated by the DCP.