ENCLOSURE 3

TENNESSEE VALLEY AUTHORITY
SEQUOYAH NUCLEAR PLANT (SQN)
UNITS 1 AND 2

Relevant Sections of SQN Calculation SCG2S90088
and
ABS Consulting Report Number 116518-R-002, "Seismic Qualification of SQN Main Control Room Suspended Ceiling and Air Delivery Components."

TVAN CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
B87 90 0320 010	calculations(nuclear)	

Calc Title: Control Room Suspended Ceiling, Light Fixture, and Air Distribution Duct I(L) Supports

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	SQN	CEB	SCG2S90088	6	7	Entire calc ☐
NEW	CN	NUC						Selected pages ☒

ACTION	NEW ☐ REVISION ☒	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)

UNITS	SYSTEMS	UNIDS
0, 1, 2	247 31	0-LIGI-247-MACR 0-LGT-247-1000, 0-DUCT-031-1000, 0-PNLD-247-0659

DCN,EDC,N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION
D21359	005-073-02-A 005-073-01-B 46W402-3 55N416-3 629811-1, -2, and -3	E

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS AFFECTED
Yes ☒ No ☐	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
RDGISH	843-8918	CEB	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
RDGish *[signature]*	2/24/04	DSRyder/JKRochelle per E-mail *[signature]*	2/26/04
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
DSRyder/JKRochelle per E-mail *[signature]*	2/26/04	PDOsborne *[signature]*	2/27/04

STATEMENT OF PROBLEM/ABSTRACT

Revisions 7:
Revision 6 added, as Attachment 9, an "early version" (before submittal to the NRC) of the WBN response to the NRC Request for Additional Information.

Revision 7 replaces the "early version" with the "final version".

The NRC RAI includes changes and annotations, as needed, to make the WBN response applicable to SQN.

MICROFICHE/EFICHE Yes ☐ No ☒ FICHE NUMBER(S) N/A

☐ LOAD INTO EDMS AND DESTROY
☒ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS: ERCU O&PS-1 SQN
☐ LOAD INTO EDMS AND RETURN CALCULATION TO:

SCG-2590-088 R4 F4/F190

B39 030208 002 QA Record

ABS Consulting

REPORT COVER SHEET

Report No:	1116518-R-002
ABS Project No:	1116518
Report Title:	Seismic Qualification of SQN Main Control Room Suspended Ceiling and Air Delivery Components
References:	See Page 27
Attachments:	NONE

APPROVED
This approval does not relieve the Contractor from any part of his responsibility for the correctness of design, details and dimensions.
B39030208001
Date 2/8/03
TENNESSEE VALLEY AUTHORITY
SQEP By: Engineering Manager

Total Number of Pages (Including Cover Sheet): 187

Revision Number	Approval Date	Prepared	Checked	Reviewed	Approved
0	2/8/03	N. Doumbalski	J. Arros	Roger Mick, Jim Rochelle by telecon	

Record of Revisions

Revision No.	Description
0	Original Issue

ABS Consulting

Refer to Att #9 WBN RAI #6 RG 9/13/03

Summary

Seismic qualification of the suspended ceiling and air delivery components at 742' elevation at the main control room of the Sequoyah Nuclear Plant was established by performing detailed time history analyses of the system consisting of these components. Both the suspended ceiling and the air delivery components have been classified as Seismic Category I(L) with special requirements on position retention, structural integrity and maintaining flow delivery function. The qualification analyses demonstrated compliance with these requirements when subject to SQN SSE loading.

The suspended ceiling grid consists of north-south running extruded aluminum "airbars" at nominal 4 ft spacing and east-west running T-bars at 2 ft spacing connecting the airbars. Supported in each "cell" of this grid are "luminous panels" that consist of a thin plastic plate and an aluminum louver. The luminous panels are secured in place at each grid intersection with an assembly of plates and nylon bolts. The grid is vertically supported by nominal 2 ft long wire supports in a nominal 4 ft by 4 ft grid pattern. The ceiling grid is surrounded along its perimeter by a ¾" thick plaster panel, with a small clearance (zero to 1/8") between the grid perimeter and the edge of the plaster panel. During oscillatory seismic motion, the plaster panel will push on the ceiling perimeter at different locations at different times and "drive" the ceiling seismic response. Given such a loading mechanism, the significant loading to both the airbars and the T-bars is compressive, tensile and bending effects being insignificant.

Refer to Att #9 WBN RAI #7 RG 9/17/03

During the level of seismic response implied by the Sequoyah Safe Shutdown Earthquake (SSE), with a peak ground acceleration of 0.18 g horizontal and 0.12 g vertical, the response of the ceiling structure will involve significant nonlinear behavior resulting in damping in excess to the levels, e.g., 5% or 7%, typically used in structural design. For example, the luminous panels will undergo some amount of sliding relative to the aluminum grid members they are mounted on. Given that the mass of the luminous panels constitutes about 70% of the total mass of the suspended ceiling, it is evident that such sliding against a level of friction can result in significant energy dissipation, i.e., damping. Nonlinear time history analyses were performed to incorporate these effects and to obtain more accurate representation of the actual seismic response than achievable using elastic linear analysis. In addition to the beam and shell structural elements, nonlinear elements between the joining elements at the intersections were incorporated to allow modeling of sliding of these elements relative to each other. The model reflected the as designed ceiling grid except that a further assumption was made that spacer bars (minor modifications) are added between the plaster panel and the perimeter airbar at the north and south ends of the control room to prevent significant deformation of the perimeter air bar at these locations.

Time histories matching SSE response spectra at the slab above the control room were generated for use in the analyses. To address frequency uncertainty, time history runs were made, in addition to the "nominal" case, also for two additional cases: (1) time scale accelerated by a factor of 1.10 and (2) time scale decelerated by a factor of 1.10. Since SQN criteria also require a factor of safety of 1.3 for seismic qualification by analysis, the acceleration histories were amplified by a factor of 1.3 in all the analyses performed.

The results indicated (a) no buckling in the suspended ceiling grid members, (b) axial and bending stress less than 30% of allowable establishing position retention and structural integrity and thereby seismic qualification of the suspended ceiling grid. The results confirmed the conclusions of the analyses performed earlier as part of the ceiling grid functionality evaluation using hand calculation methods. However, minor modifications (spacer bars and connection screws) have been defined by TVA-SQN to prevent localized distortion of suspended ceiling perimeter bars at the north and south ends of the MCR. These modifications reduce north-south displacements of the suspended ceiling and enhance qualification of the air delivery components.

Refer to Att #9 of RAI #8 11/13/1 RG 8/1/03

The air delivery components that are supported by the main control room suspended ceiling are (a) the airbars, (b) the triangular fiber board ducting, (c) the flex ducting connecting to the triangular fiber board ducting. The air bar is qualified based on ceiling grid analysis results. The triangular fiberboard duct is qualified based on (1) being subject to low seismic inertial forces due to its very light weight and low effective acceleration demonstrated by the grid time history analysis, (2) solid continuous mounting, over its total length, with additional restraint from the eye bolt that runs through the duct top panel, and (3) the duct fiber board material not being subject to brittle failure modes. On this basis, the triangular duct structural integrity and functional capability will remain intact during the SQN SSE. The 10 inch diameter flexible ducts are qualified based on (1) being attached firmly to the triangular duct and to outlets in the Category I sheet metal duct mounted to the overhead reinforced concrete slab, (2) being subject to very low inertia force and relative displacement demands due to very light weight and flexibility by design. Duct position retention is based on the continuous (over the length) secure mounting on the sheet metal channel adapter and additional lateral support from the eyebolt shanks. With this configuration, a ship-lap connection between two adjacent sections is not subject to relative displacements and the connection, with special reinforced tape wrapped over the connection area, will maintain integrity and functional capability.

The SQN suspended ceiling and air delivery components with minor modifications to the original design meet the applicable position retention, structural integrity, and functionality criteria requirements when subjected to the SQN SSE.

Table of Contents

1. Purpose and Scope

This calculation documents seismic qualification analyses of the SQN Main Control Room (MCR) suspended ceiling and the attached air delivery components. Finite element models incorporating nonlinear features to realistically represent the response of the various components of the ceiling were developed and nonlinear time history analyses performed. The results of these analyses verify the conclusions of the Functionality Evaluation (included as Appendix D) derived from analyses using hand calculation methods and establish that the subject components maintain integrity during the safe shutdown earthquake in accordance with special SQN Category I(L) criteria requirements, including position retention, structural integrity and functionality requirements for the air delivery components (air bars, triangular duct, and flexible duct). The analysis considers effects of minor modifications defined by TVA-SQN in Reference 5.13. These modifications (spacer bars and connection screws) enhance seismic qualification of the air delivery components by reducing north-south displacements of the ceiling and removing analytical uncertainty due to plastic deformation of the perimeter bars at the ends of the MCR. The special criteria requirements and qualification methodology are applied in this calculation pending NRCs review and approval of TVAs associated licensing submittal.

2. Methods and Models

Figure 2.1 shows a diagram of the suspended ceiling.

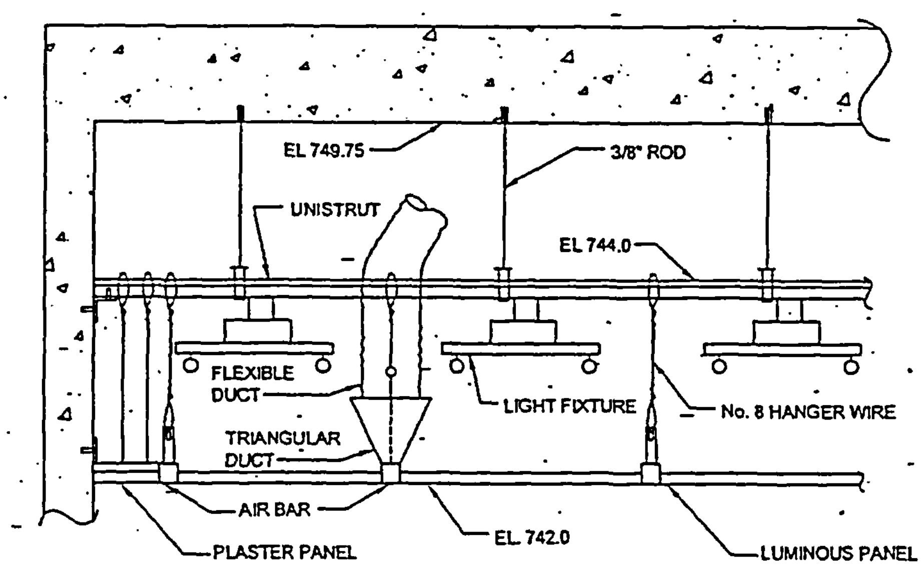


Figure 2.1 Diagram of SQN main control room suspended ceiling, looking north

East-west running unistrut beams at nominal 4 ft intervals are suspended with rods from the reinforced concrete slab at elevation 749.75'. The ends of these unistrut beams are rigidly anchored to the north-south running walls and support the grid structure that is the subject of the current analyses with nominally 8 Gauge wire hangers. (The rod hung unistrut grid supporting the light fixtures and the suspended ceiling was seismically qualified in Calculation SCG-2S90-088, Reference 5.1.) The subject suspended ceiling grid consists of north-south running extruded aluminum "airbars" at nominal 4 ft spacing and east-west running "T-bars" at 2 ft spacing connecting the airbars. Supported in each "cell" of this grid are "luminous panels" that consist of a thin plastic plate and an aluminum louver. The luminous panels are secured in place at each grid intersection with an assembly of plates and nylon bolts (SQN drawing 46W402-3, Reference 5.2). The ceiling grid is surrounded along its perimeter by a ¾" thick plaster panel, with a small clearance (zero to 1/8") between the grid perimeter and the edge of the plaster panel. The grid is vertically supported by nominal 2 ft long thin wire supports in a nominal 4 ft by 4 ft grid pattern. If the ceiling was supported only by the wires, with nothing preventing a range of lateral motion along the perimeter, the natural frequency of lateral oscillation would be very low and the whole ceiling could swing "freely" during seismic excitation. In this condition, the ceiling elements would be subject to very low accelerations and internal forces.

However as the range of displacement due to seismic loading would clearly exceed the width of the clearance between the ceiling perimeter and the plaster panel, the plaster panel will impact the ceiling perimeter and "drive" the ceiling seismic response. During the oscillatory seismic motion, the plaster panel will push on the ceiling perimeter at different locations at different times. Given such a loading mechanism, it is clear that the significant loading to both the airbars and the T-bars is compressive, tensile effects being insignificant.

During the level of seismic response implied by the Sequoyah Safe Shutdown Earthquake (SSE), with a peak horizontal ground acceleration of 0.18 g, the response of the ceiling structure will involve significant nonlinear aspects resulting in damping in excess to the levels, e.g., 5% or 7%, typically used in structural design. For example, the luminous panels will undergo some amount of sliding relative to the aluminum grid members they are mounted on. Given that the mass of the luminous panels constitutes about 70% of the total mass of the suspended ceiling, it is evident that such sliding against a level of friction can result in significant energy dissipation, i.e., damping.

Evaluation of this type of structure using the standard linear elastic equivalent static method of seismic analysis leads typically to conservative results as the energy dissipation associated with the small continuous relative motions with friction are not accounted for. To be able to account for these effects and to obtain more accurate representation of the actual seismic response of the suspended ceiling structure, nonlinear time history analyses were performed.

For this purpose, a 3-D model of the ceiling, shown in Figure 2.2, was developed using ANSYS general purpose finite element software (Reference 5.3). Input data used in the development of the model was based on information in references 5.1, 5.2, 5.4, and 5.5 (Reference 5.5 is included in Appendix D).

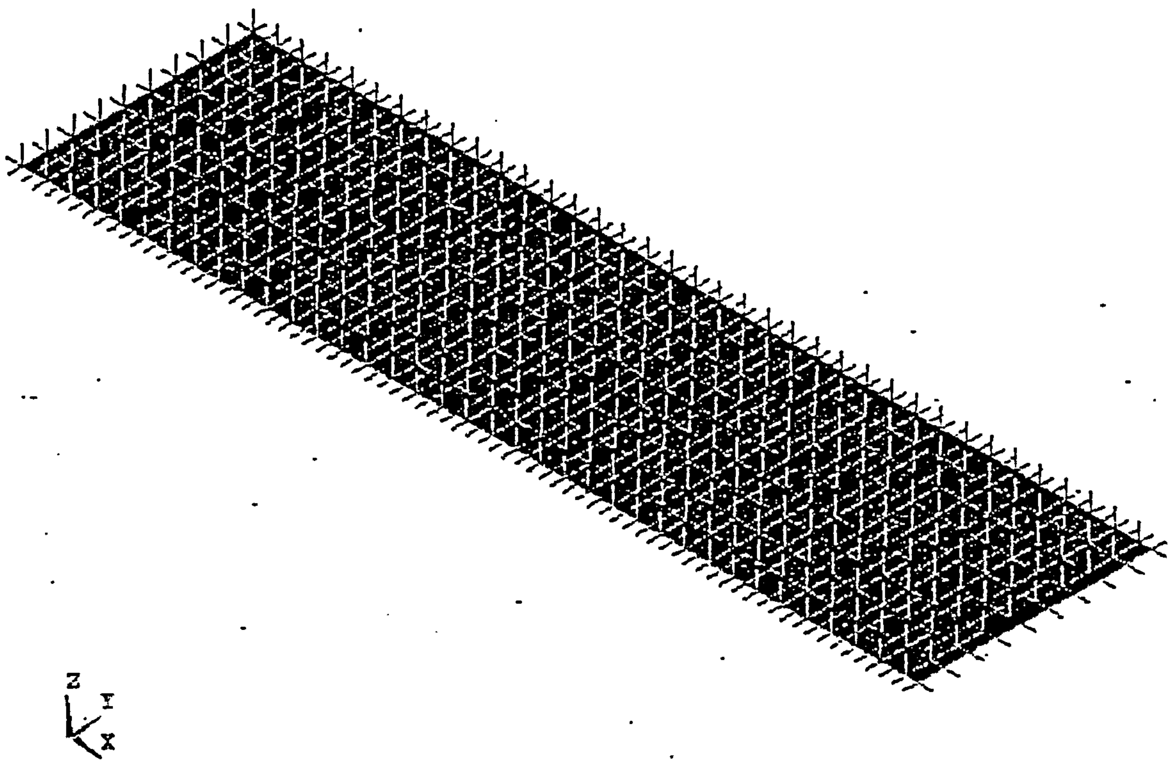


Figure 2.2 3-D model of SQN MCR suspended ceiling. (Y axis points to the west)

All the airbar and T-bar sections as well as the luminous panels are represented with discrete elements in the model. The close-up plot in Figure 2.3 shows just the beam elements representing the air bars and the T-bars and the tension-only links representing the wire hangers, while Figure 2.4 shows the shell elements representing the luminous panels.

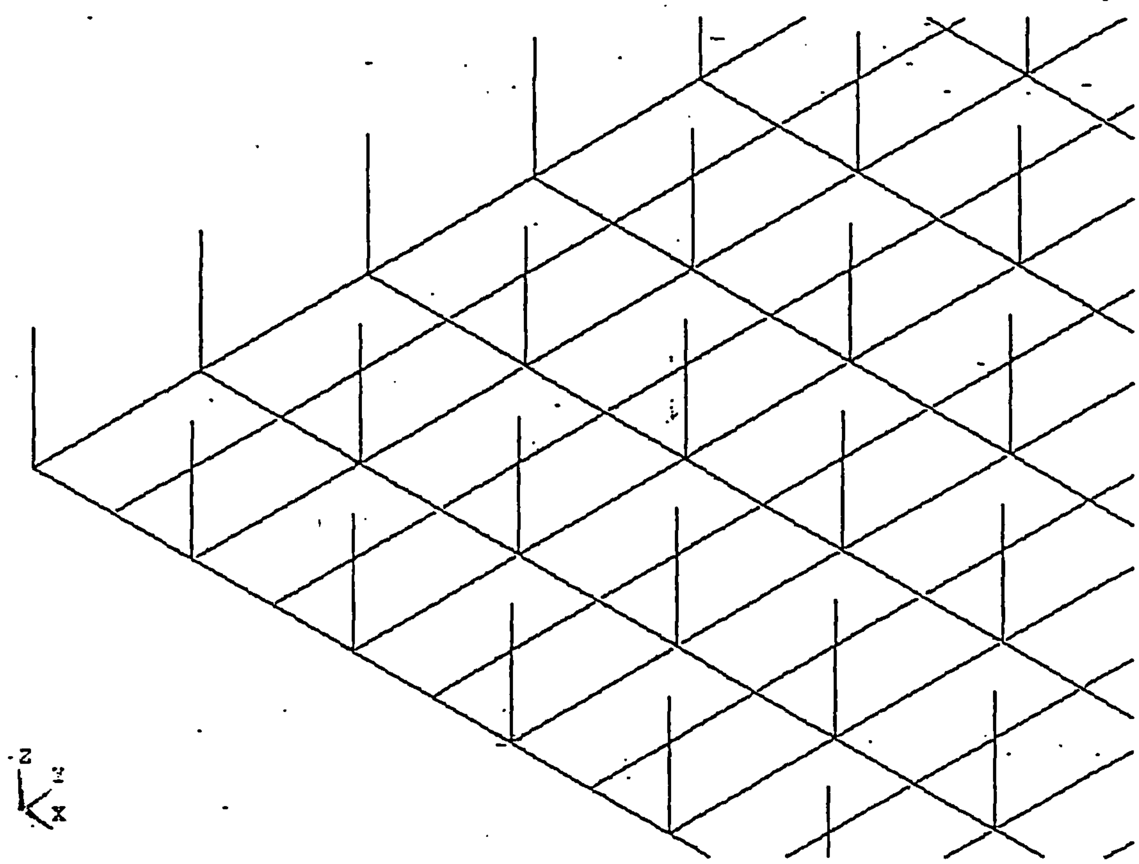


Figure 2.3 Full model, beam elements for airbars and T-bars as well as tension-only links for wire hangers shown. South-West corner. (Y axis points to the west)

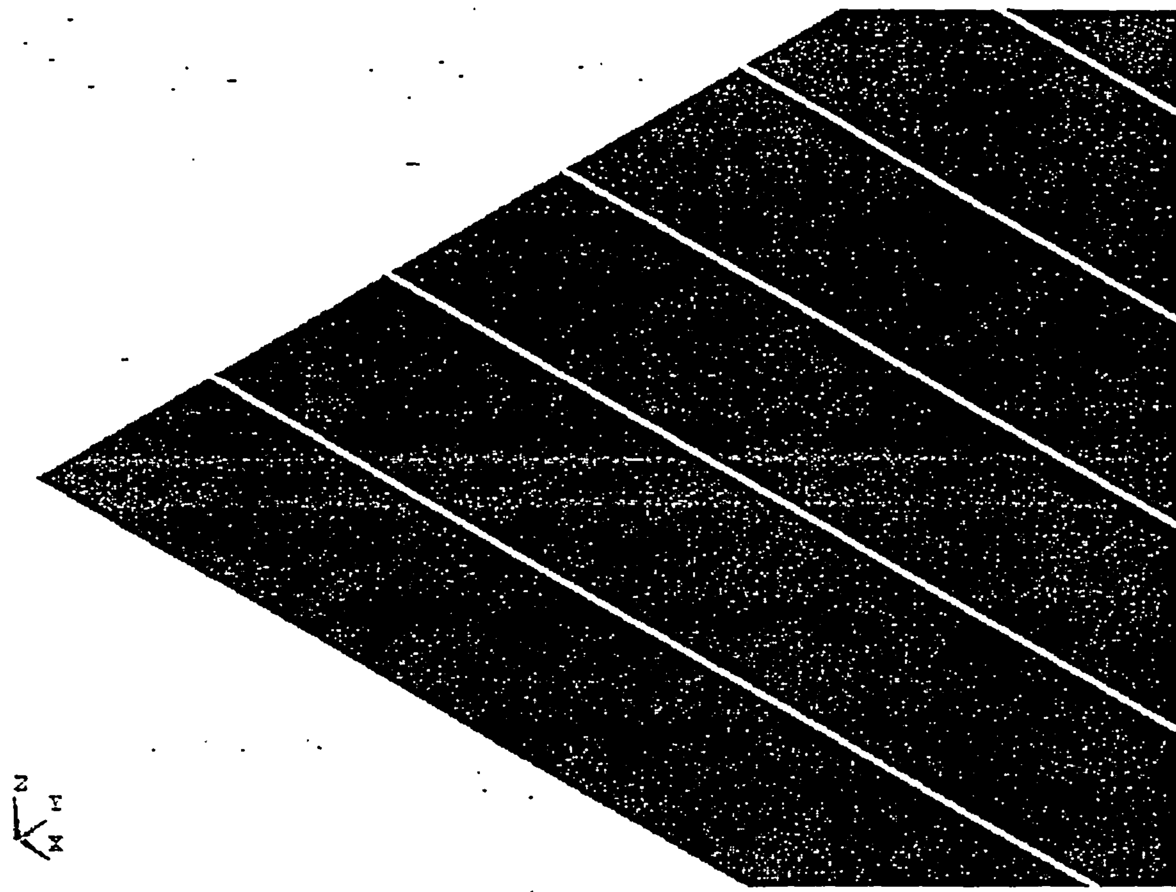
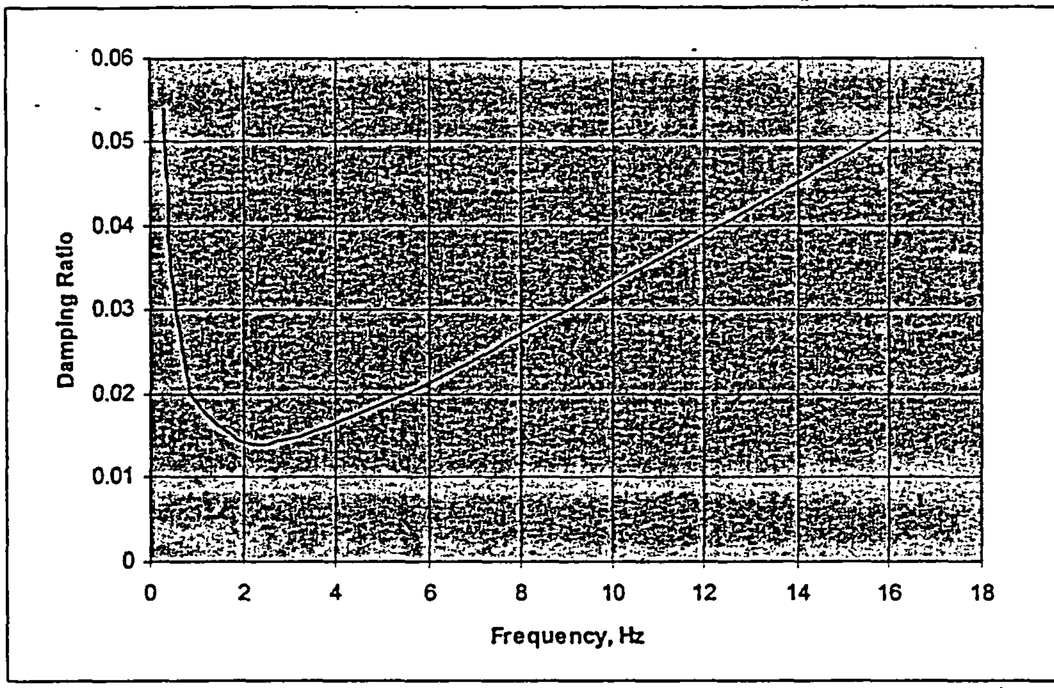


Figure 2.4 Full model, luminous panel elements shown. South-West corner. (Y axis points to the west)



Refer to Att. #9, WBN RAI #11 RG 9/27/03

Figure 2.5. Raleigh proportional damping with $\alpha = 0.2$ and $\beta = 0.001$.

Raleigh proportional damping was applied with the mass proportional coefficient equal to 0.2 and stiffness proportional damping equal to 0.001. This results in frequency dependent damping shown in Figure 2.5 for linear elastic systems. At the frequency of ideal pendulum with wire length of 24" of 0.64 Hz, the above results in less than 3% damping, and the damping remaining below 5% up to about 16 Hz. Use of linear elastic damping of 5% would be consistent with the SQN FSAR requirements for linear elastic analysis of the suspended ceiling.

In addition to the beam and shell structural elements, several nonlinear elements between the joining elements at the intersections were incorporated to allow modeling of sliding of these elements relative to each other, e.g., sliding of the luminous panels relative to the supporting grid members. For the panels, based on field observation a range of sliding of 1/8" was modeled, with a "hard stop" at this limit preventing further sliding. At the perimeter, contact elements with compressive stiffness specified to model that of the plaster panel were included to represent the constraint by the panel with a gap of 1/8" between the panel and the ceiling perimeter member. Details of the nonlinear elements are provided in Attachment A. (Time history runs of the N-S and E-W submodels were also made assuming zero clearance between the plaster panel and the ceiling perimeter.)

As stated previously, the significant loading to the suspended ceiling structure is in the form of compression of the airbars and the T-bars. As the air bars and the T-bars are perpendicular, with the airbars running north-south and T-bars running east-west and the ceiling is essentially doubly symmetric relative to lines through the ceiling center north-south and east-west, there is very little cross coupling between the north-south and east-west responses. As the run times with the "full" model (Figure 2.2) would be very long (prohibitive), the low level of cross coupling was taken advantage of by dividing the full model to two submodels: (1) north-south submodel, and (2) east-west submodel, shown in Figures 2.5 and 2.6, respectively.

Refer to Att. #9, WBN RAI #12 RG 9/27/03

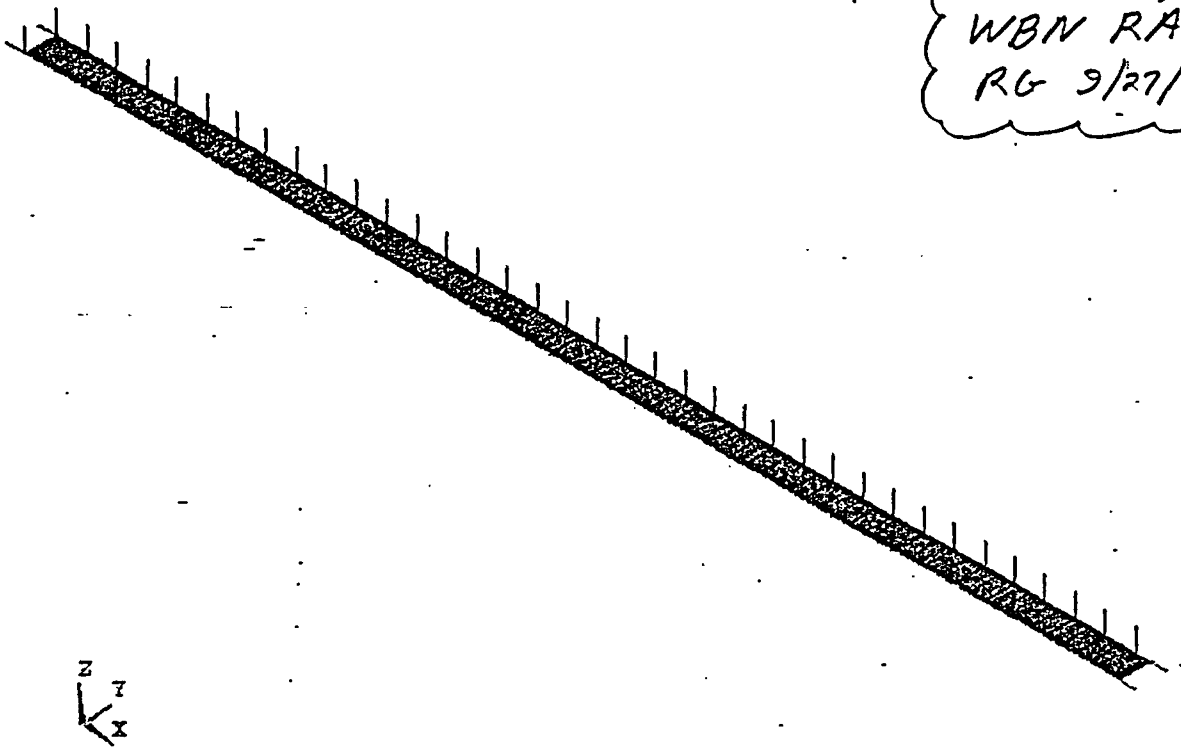


Figure 2.5 North-south submodel. (Y axis points to the west)

These models were created by starting from the full model and "isolating" representative strips limited by two adjacent rows of wire hangers.

The north-south submodel consists of two airbars from the center portion of the ceiling (with both bars supporting a triangular duct), the luminous panels between these airbars, and wires supporting the two airbars. The portion of the ceiling tributary to the two airbars and two rows of wires actually includes, in addition to the luminous panels between the air bars, also a half width of the luminous panels "outside" the two airbars. The additional tributary mass from panels outside the two airbars was accounted for in the model by doubling the mass density of the luminous panels included in the model. Correspondingly, the nonlinear element initial stiffness and friction force were also doubled.

The east-west submodel consists of three T-bars from the center portion of the ceiling, the two 2 foot wide rows of luminous panels between these T-bars, and the two rows of wires supporting the two outermost T-bars. (Note that the middle T-bar is not supported by wires.) The portion of the ceiling tributary to the two lines of wires actually includes, in addition to the luminous panels between the three lines of T-bars, also one 2-foot wide row of luminous panels "outside" both the outermost T-bar lines. The tributary mass from the panels outside the three T-bars included in the model, was accounted for by doubling the mass density of the two rows of luminous panels in the model. Correspondingly, the nonlinear element initial stiffness and friction force were also doubled. Similarly, the mass density of the airbars with and without triangular ducts attached is doubled in the model. Per drawing 46W402-3 (Reference 5.2), five of the airbars have triangular ducts attached and five do not.

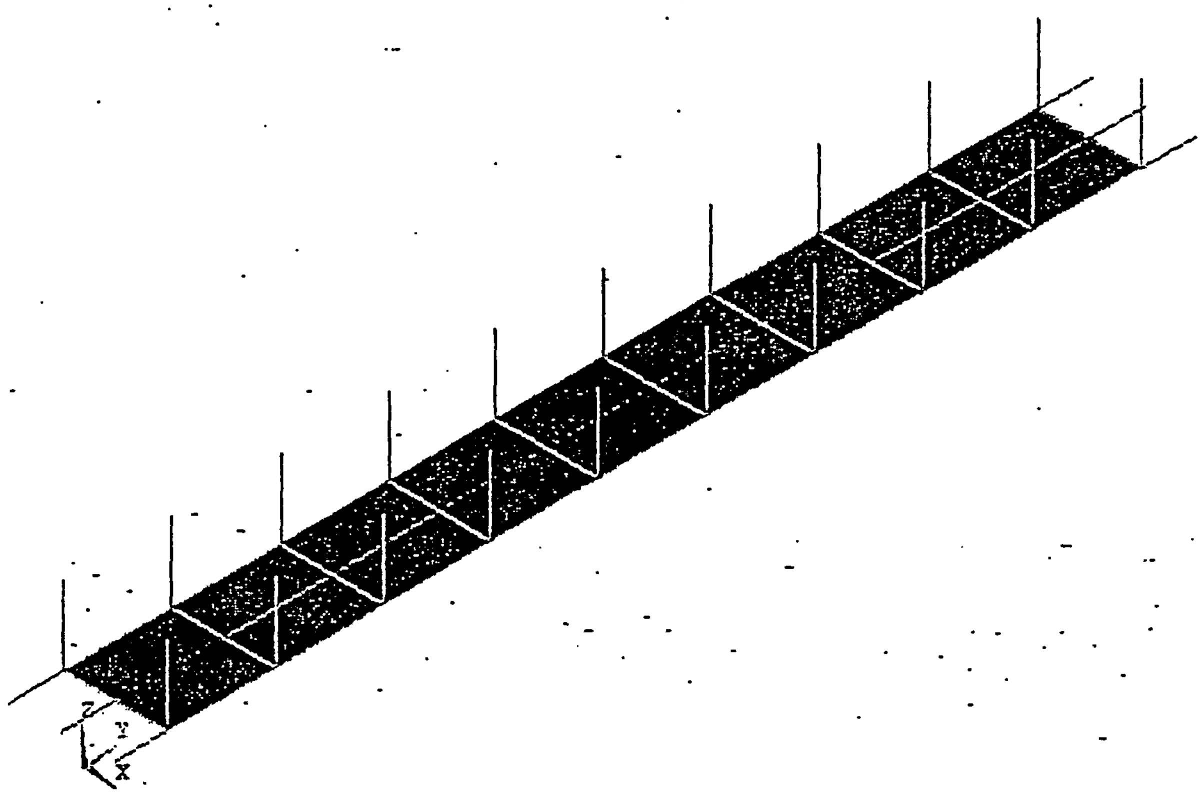


Figure 2.6 East-west submodel. (Y axis points to the west)

The north-south submodel was run for an input consisting of the combination of north-south and vertical acceleration histories and the east-west submodel was run for the combination of east-west and vertical acceleration histories.

The time history analyses were run in "large deformation" mode including geometric nonlinearity effects. Should the compressive force state and deformations cause buckling in the airbars or the T-bars, the analysis would indicate this through development of rapidly increasing displacements. (No buckling was indicated in the runs performed.)

For the purpose of the analyses, time histories were generated based on the response spectra provided for the slab above the control room, at elevation 748.50', in report CEB-80-20-C (Reference 5.4). Documentation of the time history generation is provided in Appendix C, and the three generated component acceleration time histories are shown in Figures 2.7, 2.8, and 2.9.

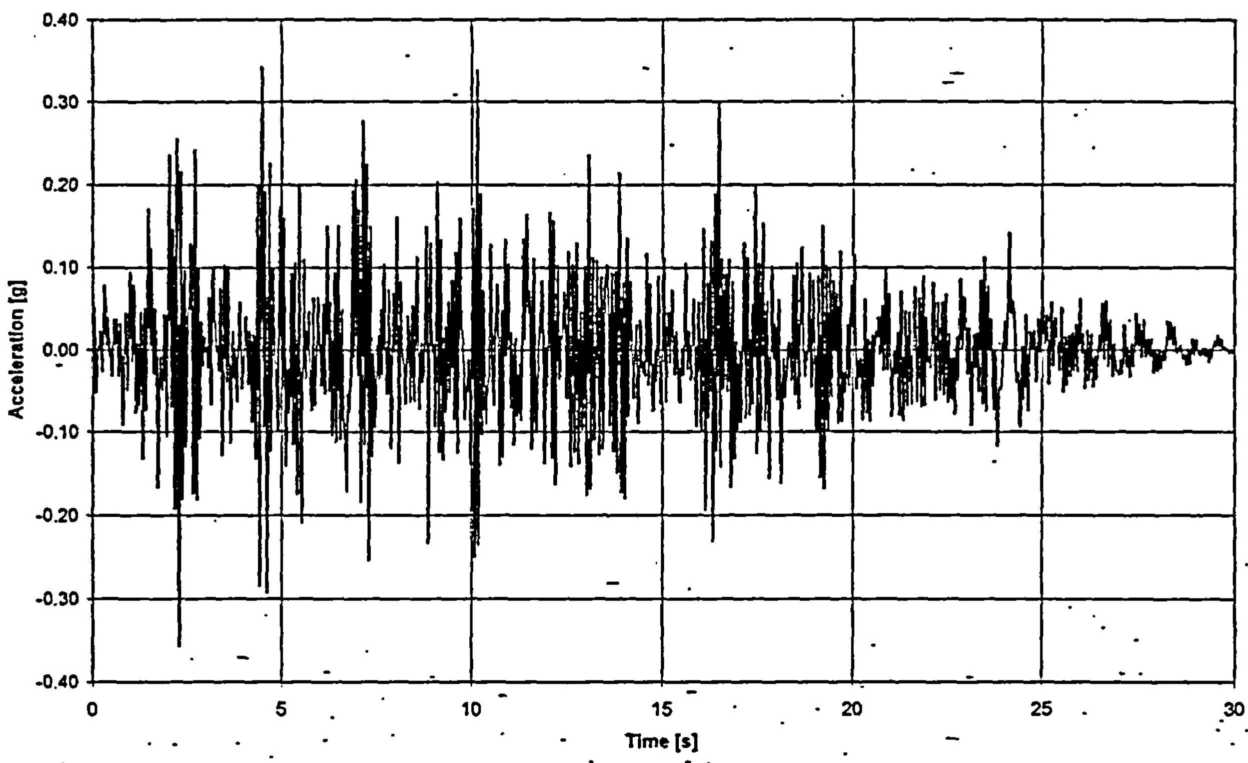


Figure 2.7 North-south acceleration time history

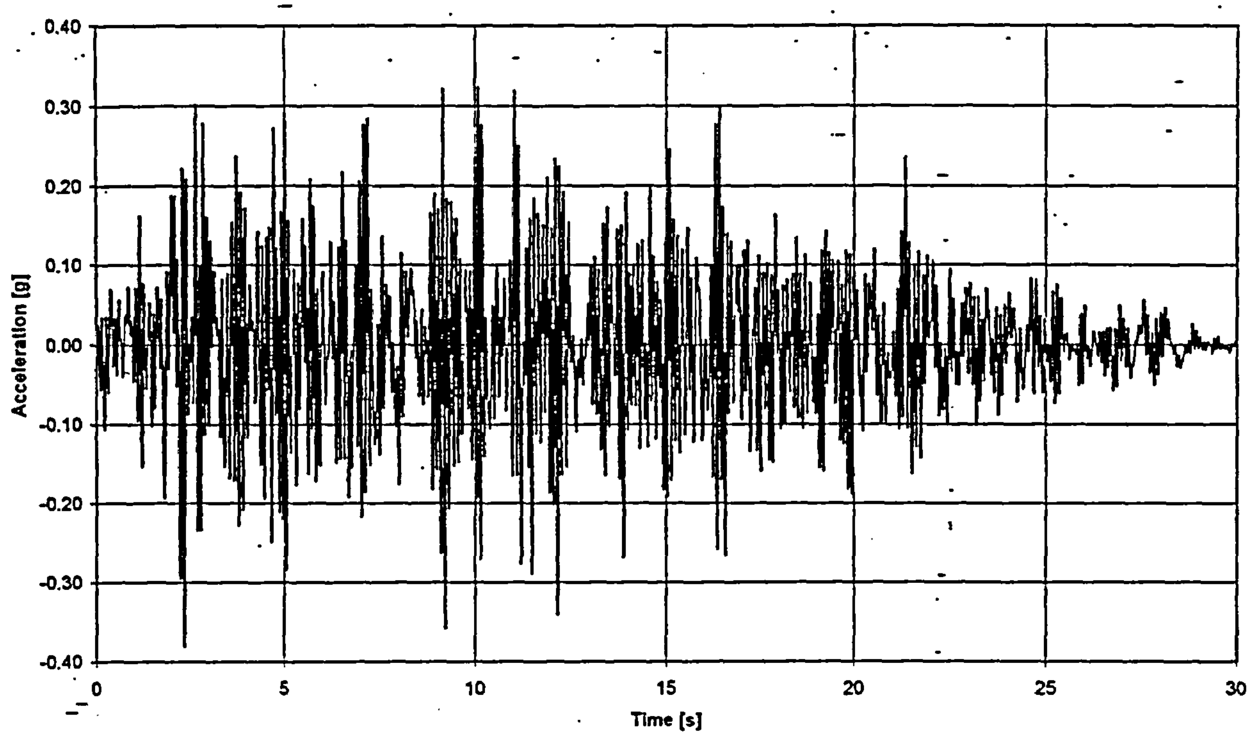


Figure 2.9 East-west acceleration time history

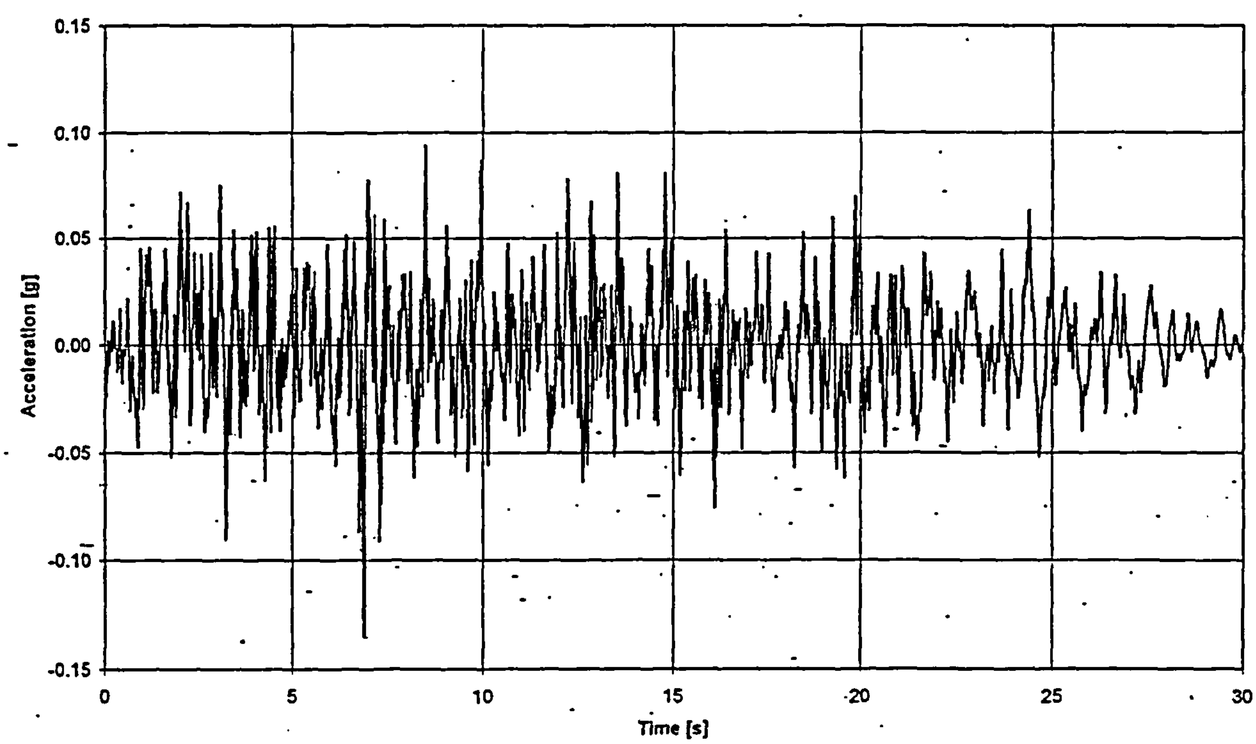


Figure 2.8 Vertical acceleration time history

To address frequency uncertainty, two time history runs were made in addition to the "nominal" case (i.e., as generated in Appendix C): (1) time scale accelerated by a factor of 1.10 (event duration = 27.3 seconds) and (2) time scale decelerated by a factor of 1.10 (event duration = 33.0 seconds). This is a way of achieving "peak shifting" by a factor of 1.10. Per existing TVA criteria described in Reference 5.5, a factor of safety of 1.3 on the nominal seismic loading in the seismic qualification for structural integrity is required. To meet this criterion, the three component acceleration histories were multiplied by 1.3 in all the analyses performed.

3. Qualification - Suspended Ceiling Components

Seismic qualification of the suspended ceiling components is based on results and conclusions from the time history analyses. The key results from the time history analyses of the suspended ceiling are the following:

- Compressive force in the air bars and in the T-bars
- Tension (or slack) in the wire hangers
- Non occurrence of global buckling modes
- The results support the basic conclusions reached based on the hand calculations in Reference 5.5 (included as Appendix D)

The peak forces in the airbars, T-bars, and wires are summarized in Table 3.1.

Table 3.1 Peak forces in the airbars, T-bars, and wires

	N-S SubModel			E-W SubModel		
	Max airbar compr. [lb]	max wire tension [lb]	min wire(3) tension [lb]	Max T-bar compr. [lb]	max wire tension [lb]	min wire(3) tension [lb]
Nominal Event	810.1	32.28	13.28	148.0	29.24	10.97
Accelerated Event (1)	667.5	31.11	13.25	140.3	27.24	12.30
Decelerated Event (2)	764.5	33.68	10.87	183.0	29.22	10.94
Nominal Event (No Gap)	761.5	33.81	11.38	97.8	29.24	10.93

(1) Peaks shifted up in frequency by a factor of 1.10
(2) Peaks shifted down in frequency by a factor of 1.10
(3) Minimum values shown are for wires not located at the ends, where tributary mass is lower. The minimum wire tension at end location is 6.68 lb.

Comparison of the above peak forces in the airbars, T-bars, and the wire hangers to the forces in the hand calculation of Reference 5.5 (included in Appendix D) results in the following conclusions:

- The highest peak force in the airbar of 810 lb is only 46% of the comparable value 1777 lb [= (1367)(1.3)] in the hand calculation, indicating higher safety factors than reported in Reference 5.5.

- The highest force in the T-bar of 183 lb is 68% of the comparable value 269 lb [= (207)(1.3)] in the hand calculation, indicating higher safety factors than reported in Reference 5.5. The indicated safety factor is more than 2.

- The time history analyses indicate that the wires remain in tension. The overall minimum value of 6.68 lb occurs at wires located at ends, i.e., with a low tributary mass (see e.g., curve "W-South" in Figure 3.3). In typical wires supporting airbars with triangular ducts attached, the minimum is 10.9 lb (see Table 3.1) demonstrating that the airbars do not lift up and buckle. [The comparable minima in Reference 5.5 for wires not at the ends is 5.1 lb.] The maximum wire tension of 32.8 lbs is much less than estimated capacity of 1032 lb [= $(\pi/4)(0.148)^2(60{,}000)$].

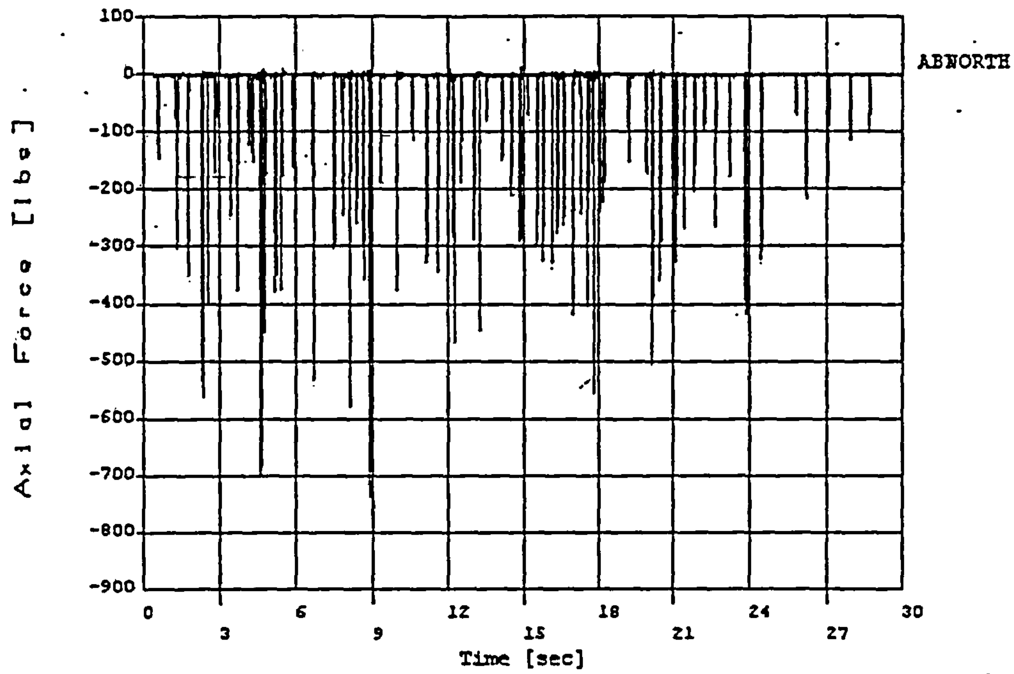


Figure 3.1 Airbar compression North end, N-S Response, Nominal Event.

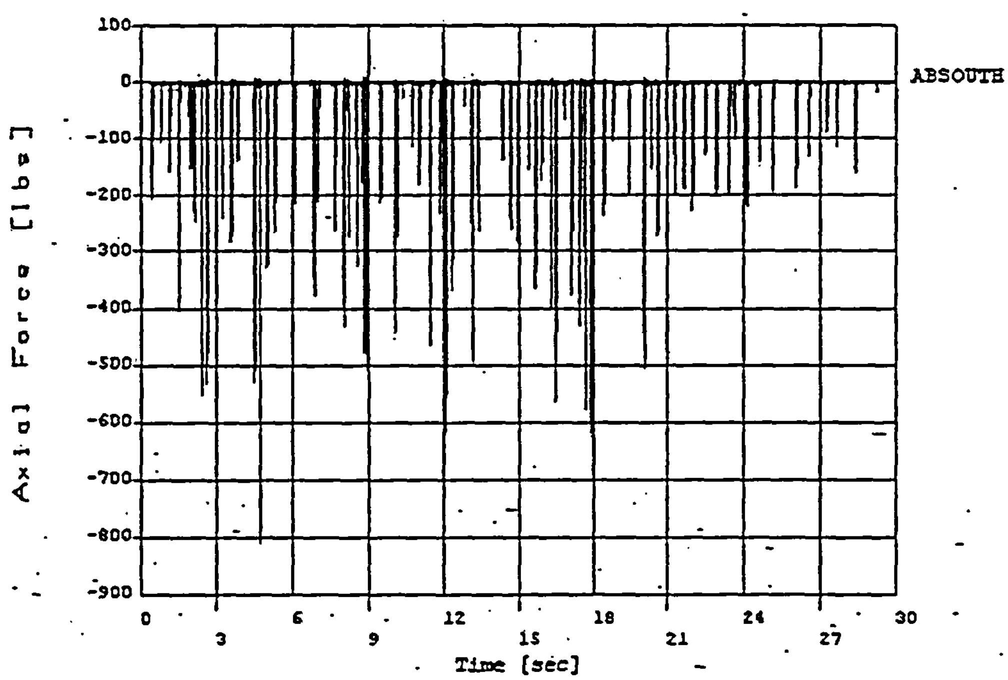


Figure 3.2 Airbar compression South end, N-S Response, Nominal Event.

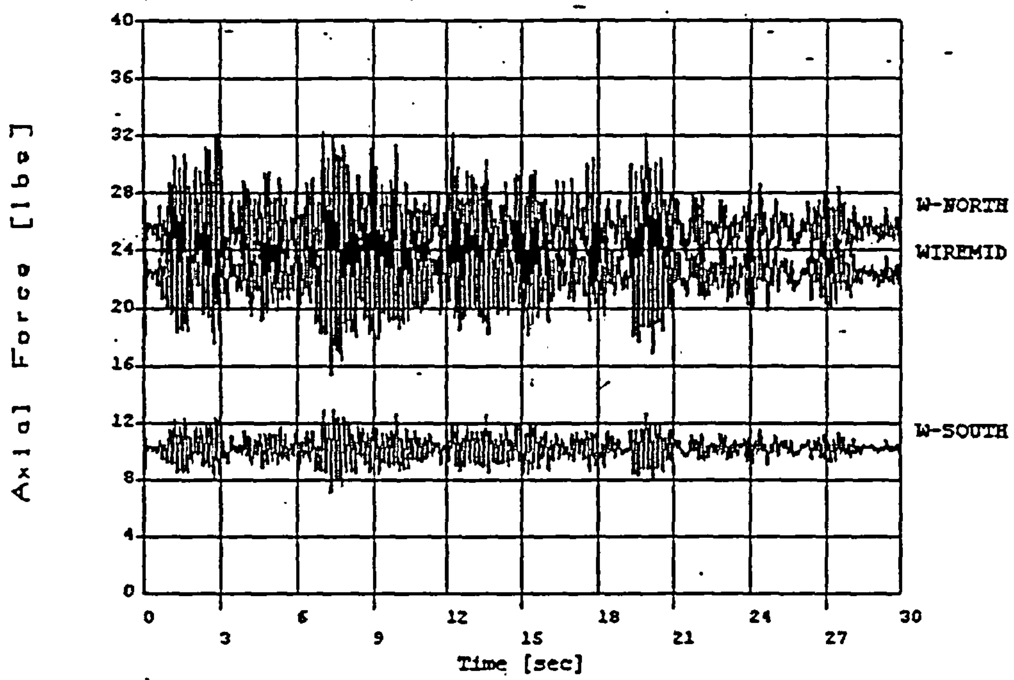


Figure 3.3 Wire Tension, N-S Response, Nominal Event. Lower level curve for wires at end with lower tributary mass.

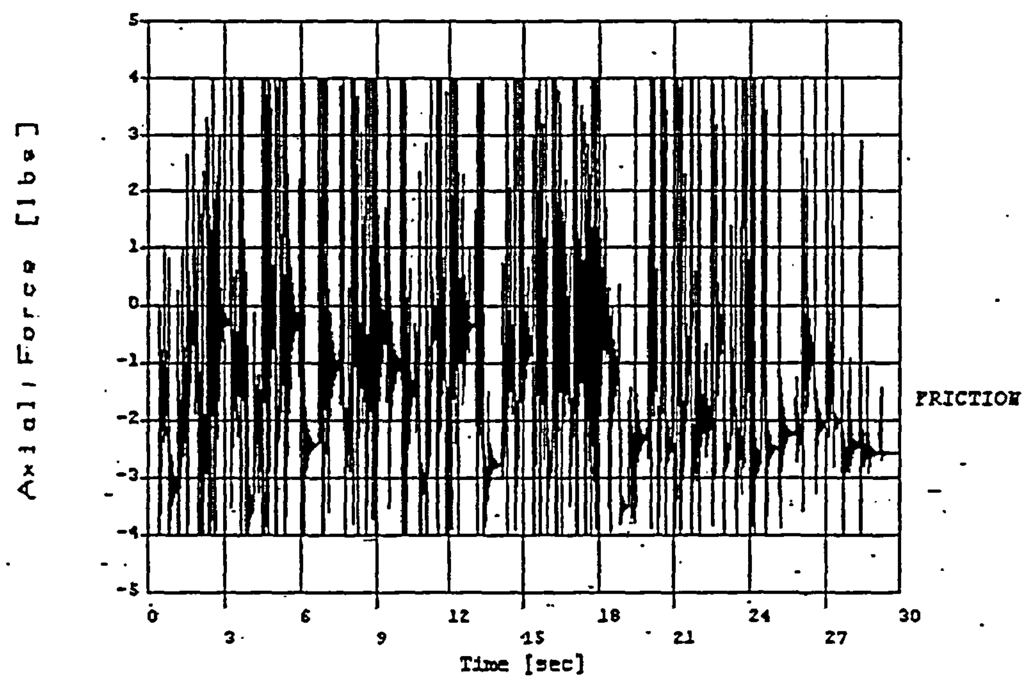


Figure 3.4 Force in friction element, N-S Response, Nominal Event. Whenever the force "hits" 4.0 or –4.0 lbs, some sliding occurs.

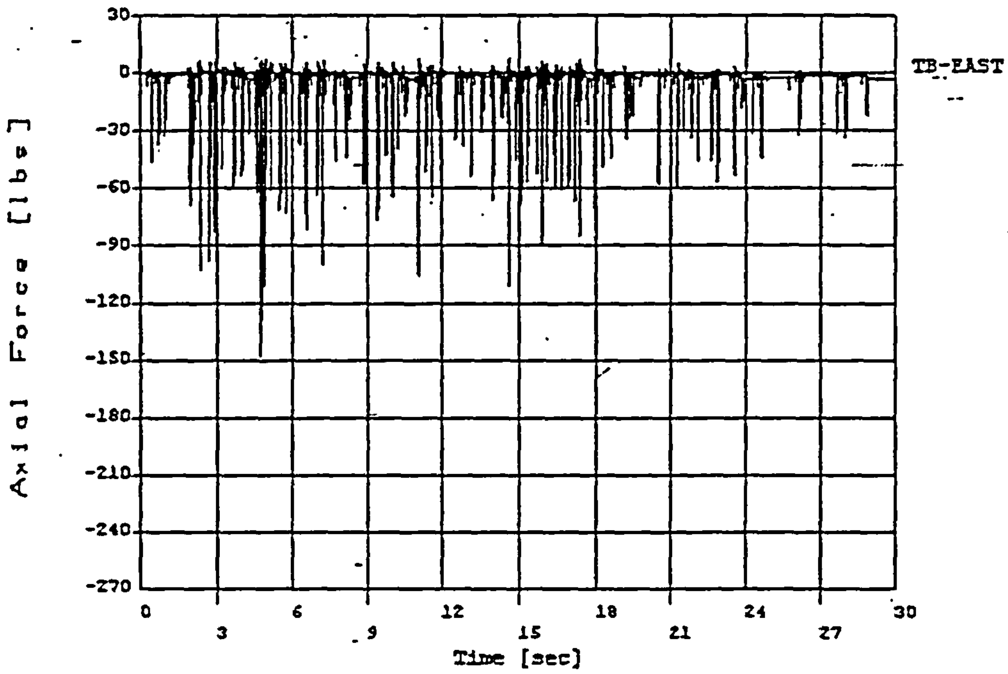


Figure 3.5 T-bar compression East end, E-W Response, Nominal Event.

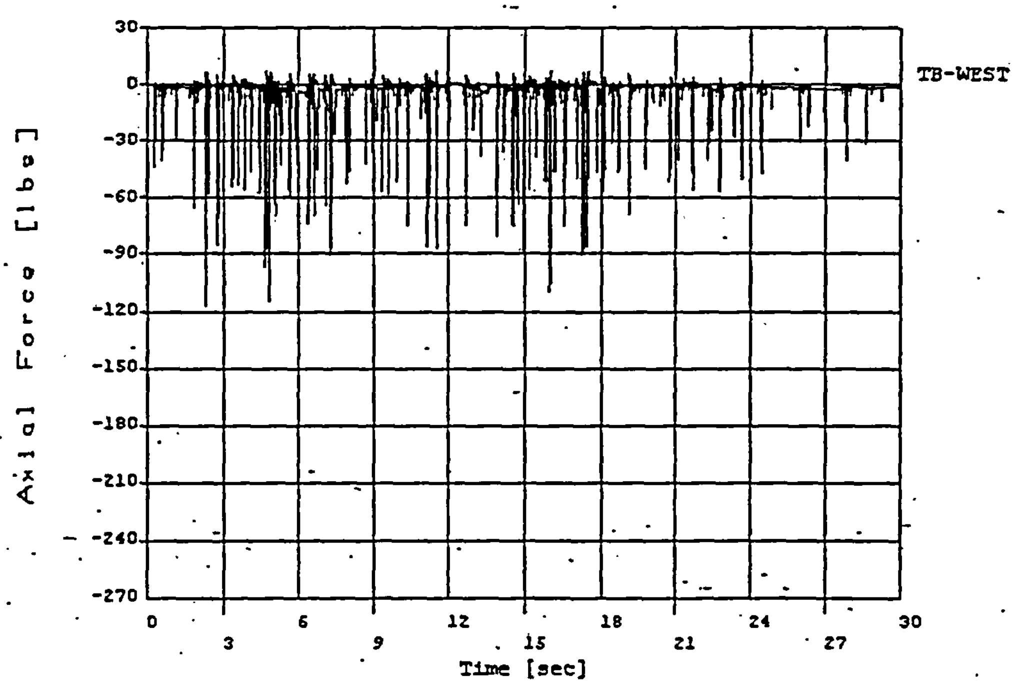


Figure 3.6 T-bar compression West end, E-W Response, Nominal Event.

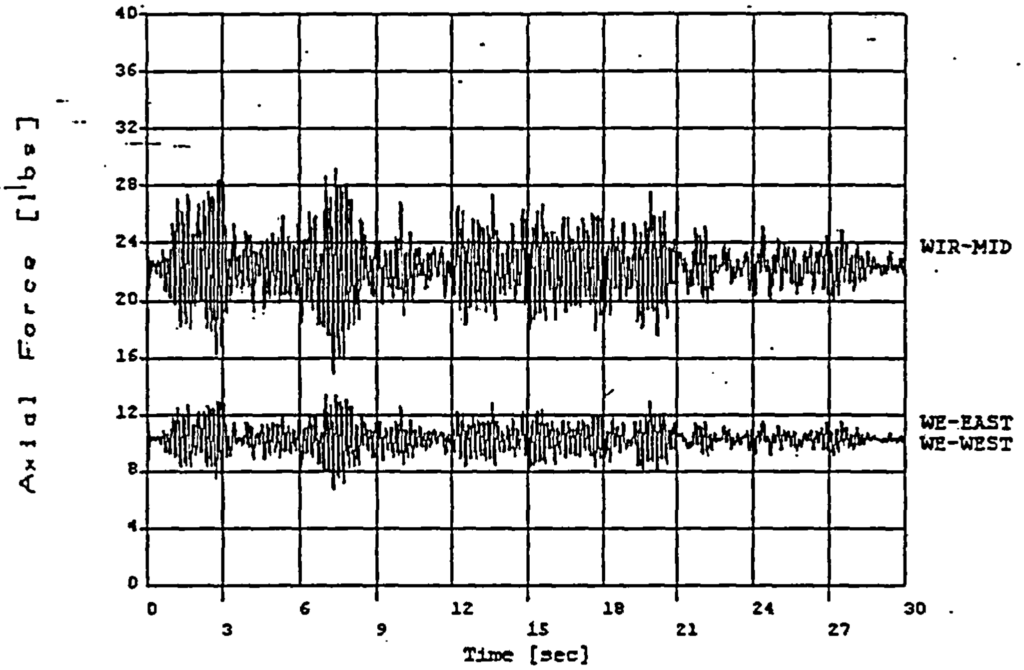


Figure 3.7 Wire Tension, E-W Response, Nominal Event. The lower level curve is for wires at end with lower tributary mass. The upper curve is for typical wire supporting airbar with triangular duct attached.

4. Qualification - Air Delivery Components

The air delivery components that are supported by the main control room suspended ceiling are:

- The airbars supporting the triangular duct and providing flow path from the duct to the control room below
- The triangular fiber board ducting
- The flex ducting supplying air from the Category I metal duct above to the triangular fiber board duct

The bases for seismic qualification of each of these components are provided in the following.

Air Bars

The air bars were explicitly modeled with actual cross section and material properties in the suspended ceiling model described in the previous sections. As discussed above, the only potentially significant loading to the airbars is in the form of compressive loads. Results from the time history analyses demonstrated that the ceiling grid as a whole (including the airbars) maintains integrity. A factor of safety well in excess of 1.3 was demonstrated. With the 3-D input motion based on 1.3 times the SSE response at the slab above the control room, the maximum axial-plus-bending stress of 4.16 ksi (see page B-78) is only 26% of the yield stress of 16 ksi. The air bars retain position, maintain integrity and thereby provide a sound support mechanism for the triangular ducting.

Triangular ducting

Figure 4.1 illustrates a cross section of the triangular duct and how it is attached to the airbar (Reference 5.1).

JOB NO.: 1116518 JOB: SQN MCR Suspended Ceiling & Air Delivery Components BY: NPD DATE 01/22/03

CALC NO.: R-002 SUBJECT: Seismic Qualification CHK: JKA DATE 01/22/03

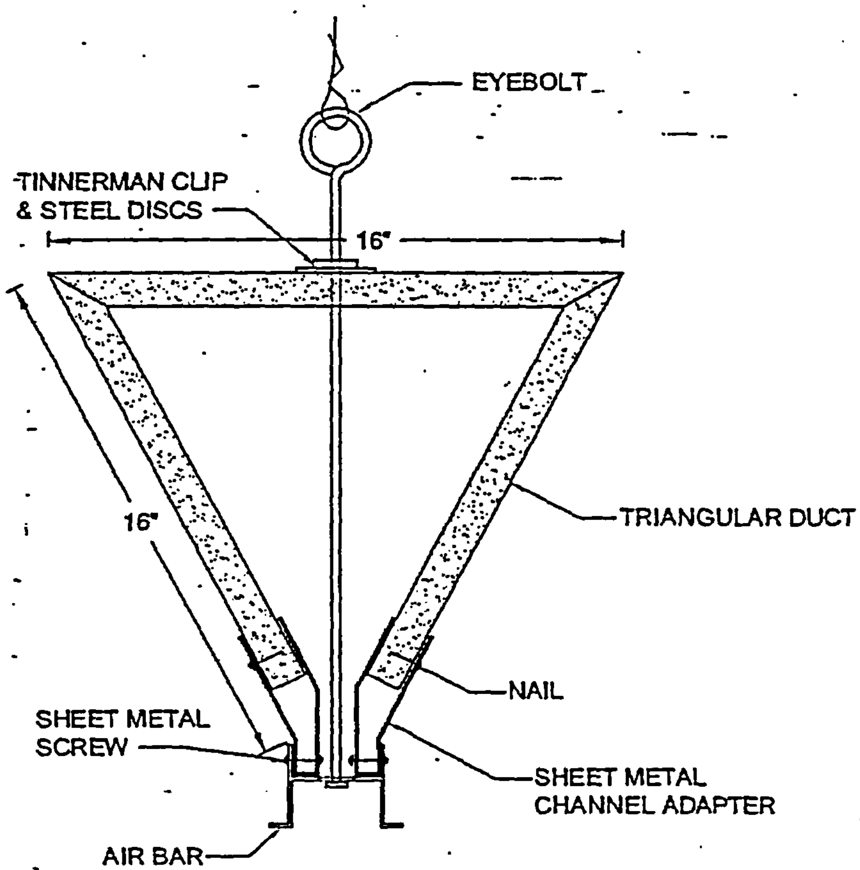


Figure 4.1. Schematic of triangular duct cross section, attachment to airbar illustrated

The bottom edges of the duct side panels mount to sheet metal channel adapter that is continuous over the length and secured to the airbars with sheet metal screws (Figure 4.1). Nails secure the duct side panels to the sheet metal adapter. Eyebolts at 4 foot centers run through holes in the duct top facet down to the airbar where they are secured with Modu-Flo channel hardware to the airbar. A wire hanger from the eye of the eyebolt connects the airbar to a unistrut above. The eyebolt shank provides lateral (N-S and E-W) support and the steel discs and Tinnerman clips secured on the shank provide vertical restraint for the duct. This arrangement provides for a continuous solid mounting of the duct to the airbar over the whole length of the triangular duct.

The seismic qualification of the triangular duct is based on: (a) The secure mounting mechanism described above, (b) Very light weight, 1.1 lb/ft, of the duct made of fiberboard, (c) The fiber board material not being subject to brittle failure modes, (d) Effective accelerations of less than 2 g, as further discussed in the following.

With a 4 foot section of the duct, weighing 4.4 lbs, subject to an effective lateral acceleration of 2 g, the duct attachment mechanism consisting of the continuous mounting to the airbar plus the lateral restraint by the eye bolt shank is subject to a total lateral force of 8.8 lbs. No deformation in the duct or the attachment mechanism is expected under such low applied force level.

Furthermore, as indicated by the sharp spikes of the airbar and T-bar axial force time histories, the higher amplitude acceleration, with peaks of the order of less than 2 g, is associated with impacts and thereby with high frequency. As demonstrated by earthquake experience data, tests and analytical research, high level acceleration associated with high frequency input is not "damaging", unless the component has brittle failure modes (Reference 5.6). Considering the nature of the fiberboard material response and the mounting configuration of the SQN MCR triangular duct, the response to be anticipated with increasing levels of seismic shaking (to levels well in excess of 2 g) involve (1) some longitudinal sliding of the triangular duct along sheet metal channel adapter, and (2) ovalizing of the holes in the top panel (at eye bolt shanks). Such behavior does not lead to sudden failure or loss of integrity, it is "ductile" in nature.

Refer to Att. #9 WBN RAI #13 RG 9/27/03

On the bases discussed above, the triangular duct will retain position with structural integrity and functional capability intact during the SQN SSE. Note that the position retention is based on the continuous (over the length) secure mounting on the sheet metal channel adapter and the additional lateral support from the eyebolt shanks. With this configuration, a connection between two adjacent sections (two duct section ends ship-lapped together) is not subject to relative displacements and the connection, with special reinforced tape wrapped over the connection area and the sheet metal adapter below the connection area, will maintain integrity and functional capability.

Refer to Att #9 WBN RAI #10 RG 9/27/03

Flex Duct

The 10 inch diameter flex duct sections with spiral wire/fabric construction routed from the Category I metal duct mounted independently to the reinforced concrete slab above are (1) light weight, (2) very flexible, and (3) securely attached to the above Category I metal duct and the triangular fiberboard duct with adjustable length metal bands. With the estimated accelerations of less than 1 g at the top attachment point (the zero period acceleration of the slab above is 0.38 g, and the metal duct and its anchorage are relatively rigid) and less than 2 g acceleration at the bottom attachment point (to the triangular duct), inertia forces on the flex duct are negligible. The relative displacement in the order of less than 1" between end points (the gaps at the suspended ceiling perimeter are less than 1/8" and the airbar/T-bar grid is relatively rigid in-plane) pose negligible demand for the flexible duct. The flex duct will maintain structural integrity and full functional capability under SQN SSE.

RG 9/27/03 Refer to Att #9 WBN RAI #14

Conclusion

The SQN suspended ceiling and air delivery components meet the applicable position retention, structural integrity and functionality criteria requirements when subjected to the SQN SSE, with minor modifications to their design as defined in Reference 5.13. This conclusion is predicated on the following conditions:

(1) The minor modifications (Reference 5.13) are installed at the north and south ends of the control room, and

(2) The ceiling and air delivery components are properly maintained to assure compliance with original design configuration with the minor modifications, in accordance with TVA-SQN design output documents.

5. References:

5.1 SQN Calculation SCG-2S90-088, "Control Room Suspended Ceiling, Light Fixture, and Air Distribution Duct I(L) Supports", Revision 3.

5.2 SQN drawing 1,2-46W402-3.

5.3 ANSYS Release 5.7.0, ANSYS, Inc., Southpointe, 275 Technology Drive, Canonsburg, PA 15317, www.ansys.com

5.4 Report No. CEB-80-20-C, "Dynamic Earthquake Analysis of the Auxiliary Control Building and Response Spectra for Attached Equipment", Revision 3.

5.5 Functionality Evaluation "Evaluation for Potential Buckling or Bending Failure of SQN Suspended Ceiling Support Grid", prepared by Jim Rochelle, October 3, 2002 (included as Appendix D to this calculation)

5.6 EPRI NP-5930 "A Criterion for Determining Exceedance of the Operating Basis Earthquake", July 1988.

5.7 TVA contract 72C4-75089 drawings 005-73-01B, 005-73-02A, and DET *11, 12, 12A, 17, and 33.

5.8 TVA contract 81X5-829726 drawing 629811 (3 heets).

5.9 "Critical Air Bar Dimensions", field notes by Roger Gish, December 21, 2002.

5.10 ABS Consulting Inc., "Quality Assurance Documentation for the RSPEC Computer Program", AA-QA-002, Doc-001, Revision 0, December 8, 1993.

5.11 ABS Consulting Inc., "Quality Assurance Documentation for the THICC Computer Program", AA-QA-011, Doc-001, Revision 0, April 7, 1997.

5.12 SQN-DC-V-41.0, Seismic Qualification of Category I(L) Fluid System Components and Electrical or Mechanical Equipment", Revision 1.

5.13 SQN DCN 21359.

ABS Consulting

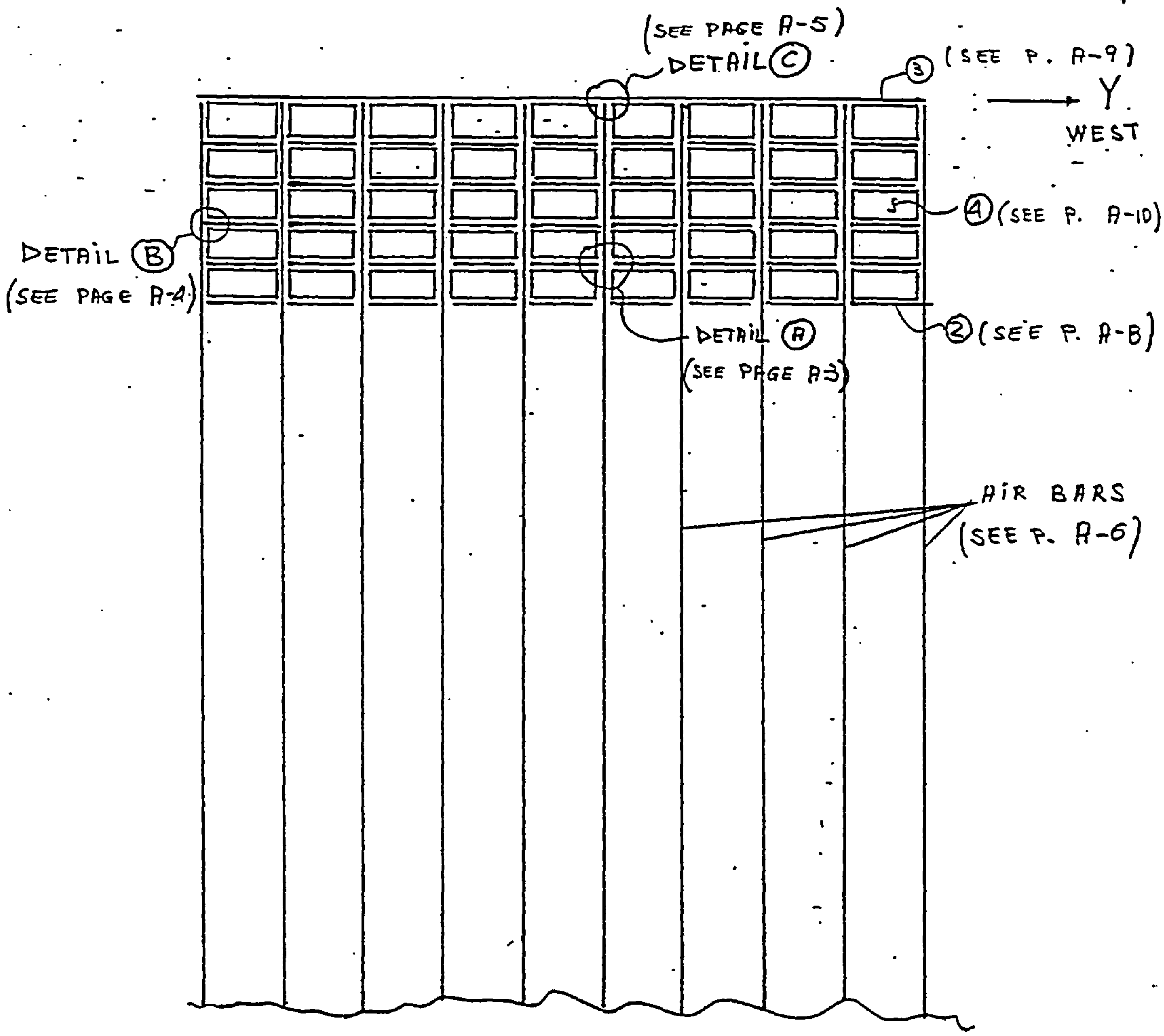
Appendix A: Property Details

(Total pages, including this cover: 28)

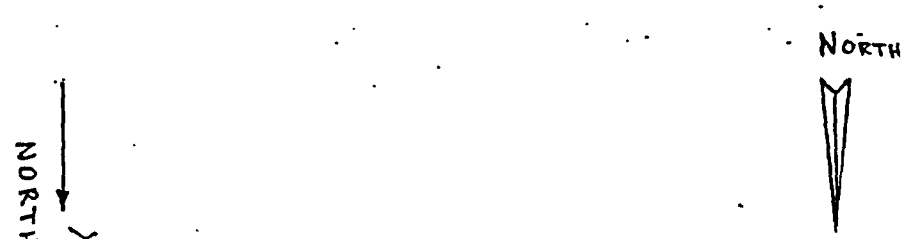
SHEET NO. A-2

JOB NO. 1116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/04/02

CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [initials] DATE 01/07/03

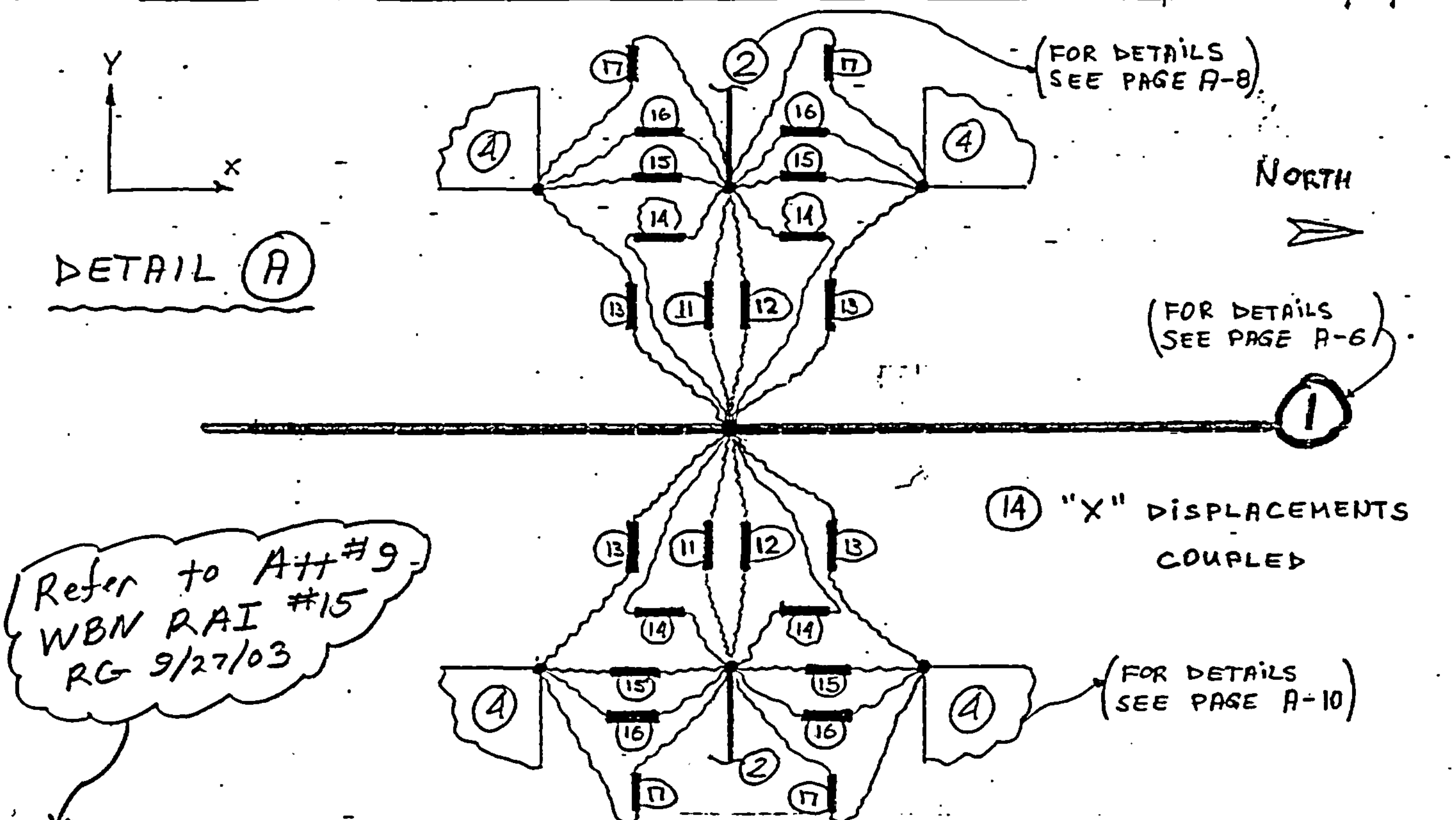


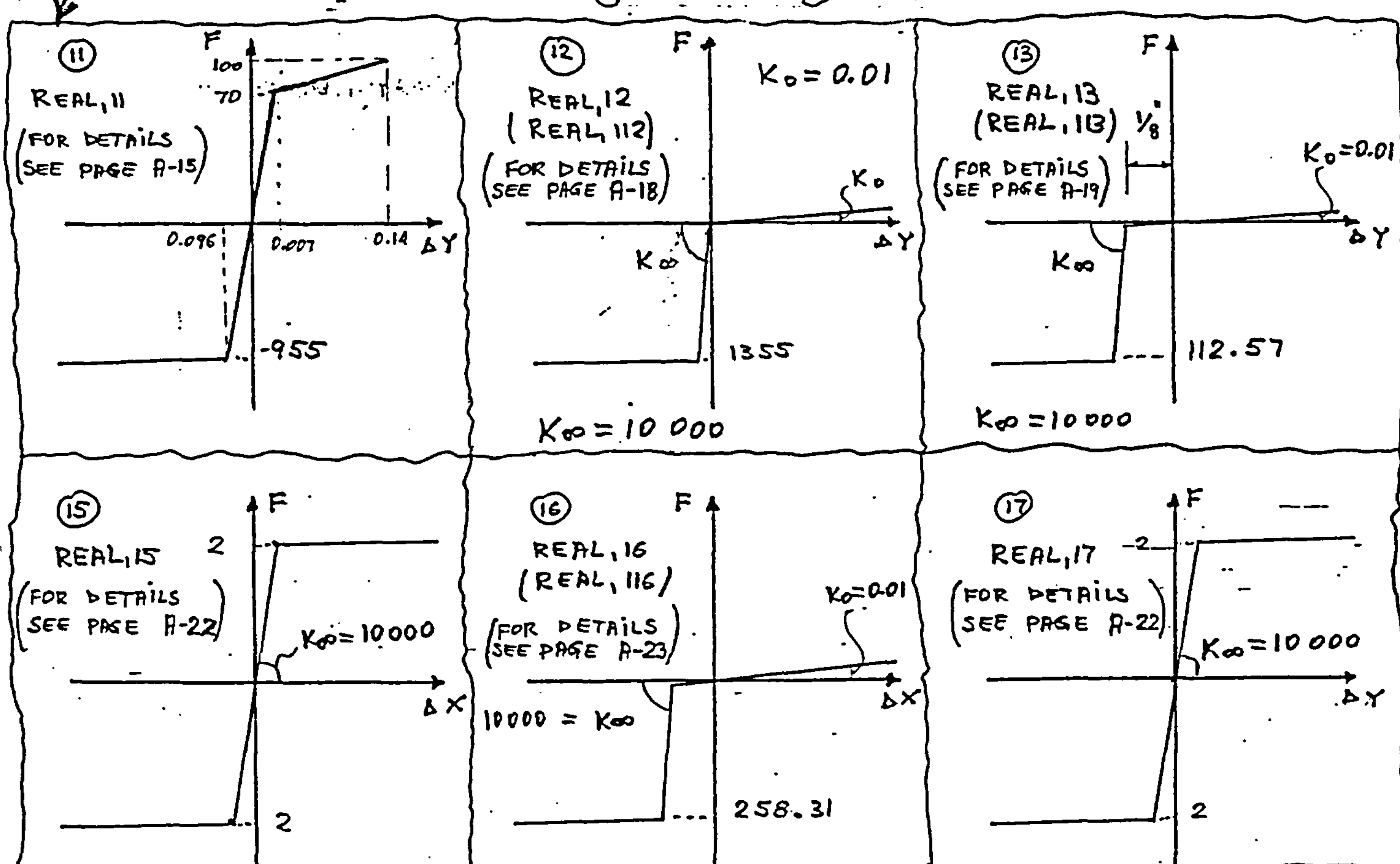
PLAN VIEW



SHEET NO. A-3

JOB NO. 1116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/04/02
CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [initials] DATE 01/07/03

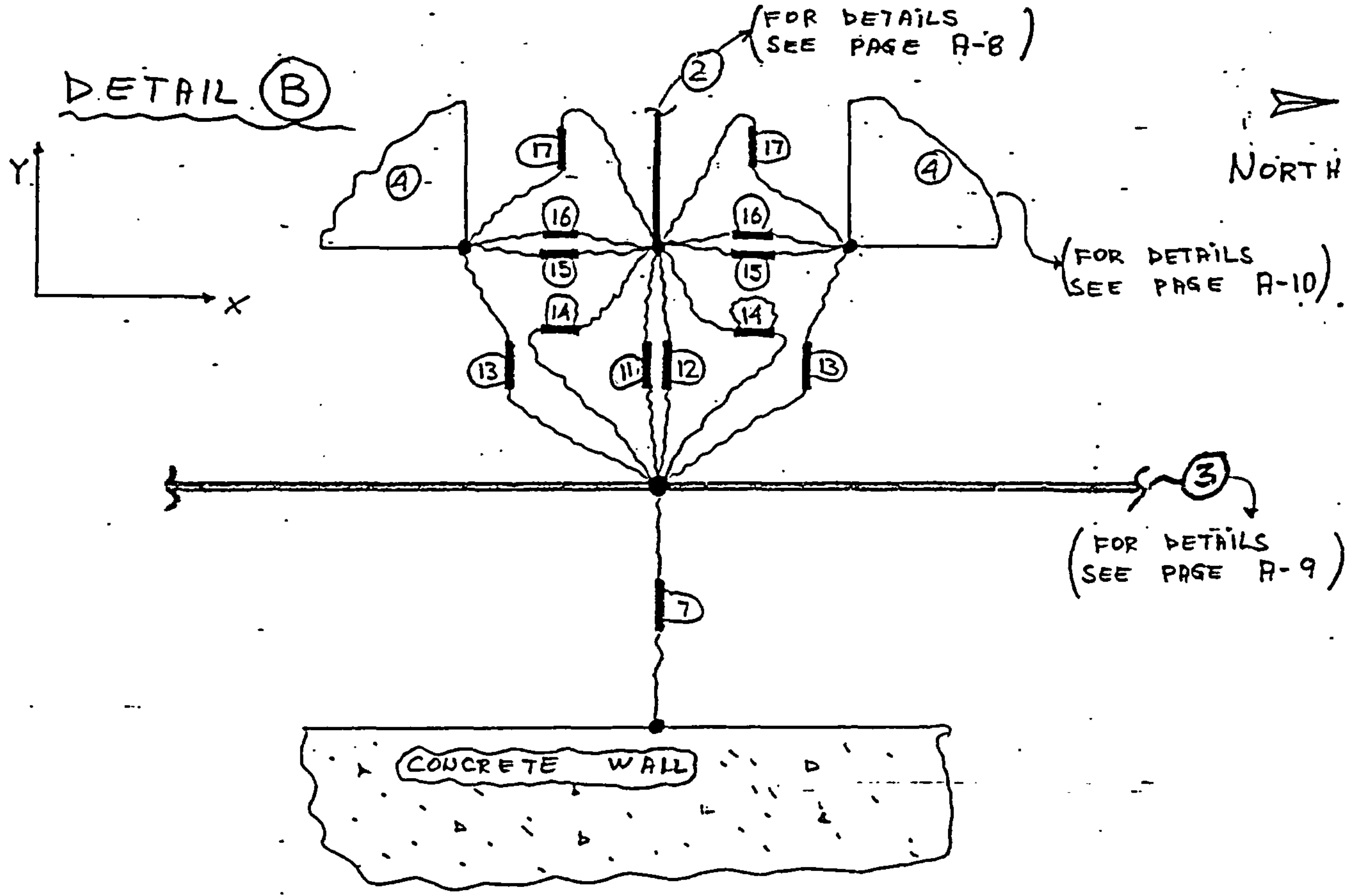




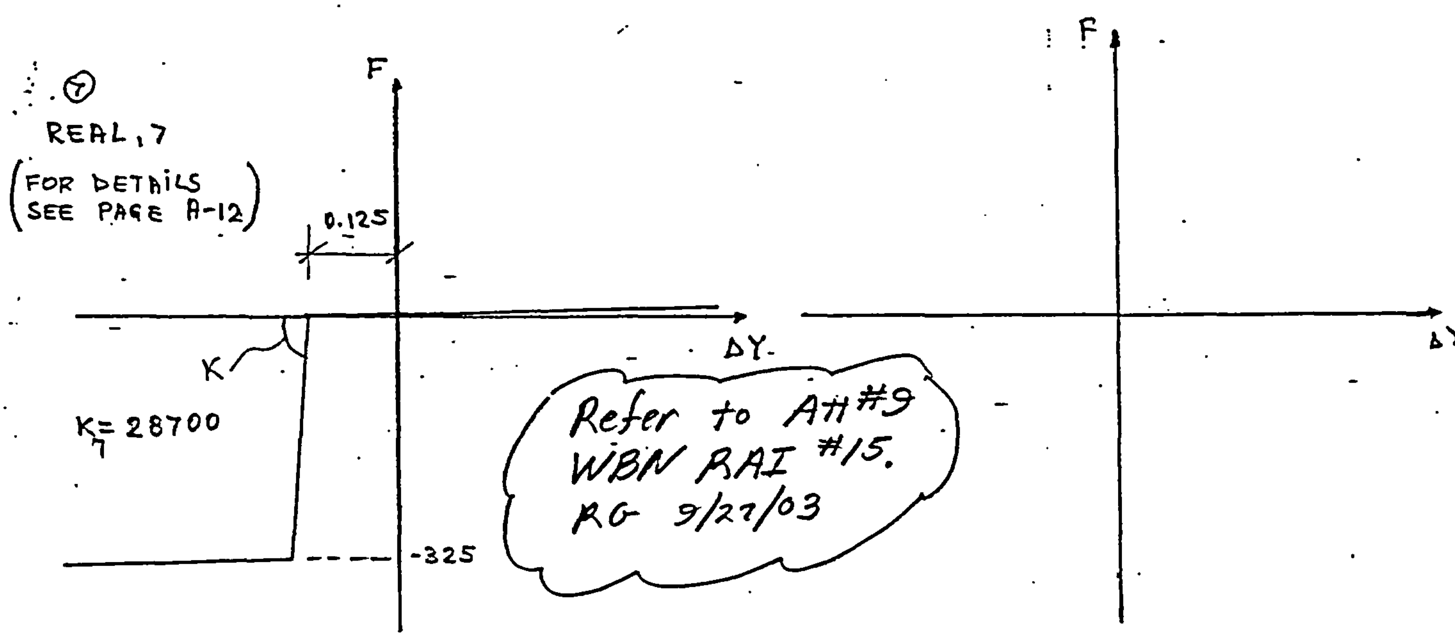
* ELEMENTS 11, 12, 13, 15, 16 & 17 – "COMBIN 39"

JOB NO. 1116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/04/02

CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [initials] DATE 01/07/03



FOR ELEMENT TYPE 11, 12, 13, 15, 16 & 17 SEE PAGE A-3



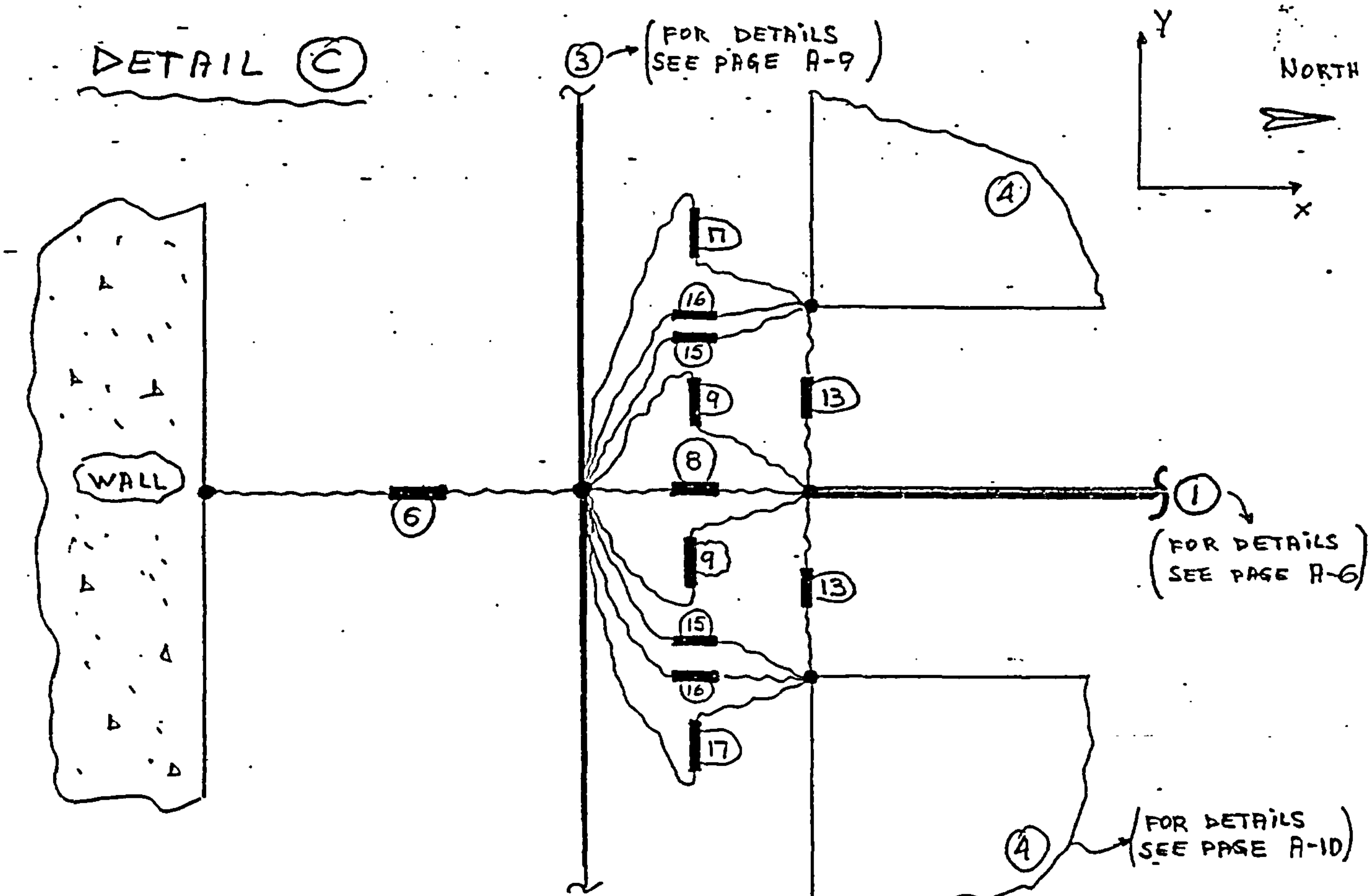
Refer to Att #9 WBN RAI #15. RG 9/27/03

SHEET NO. A-5

JOB NO. 116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/09/02

CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [initials] DATE 01/07/03

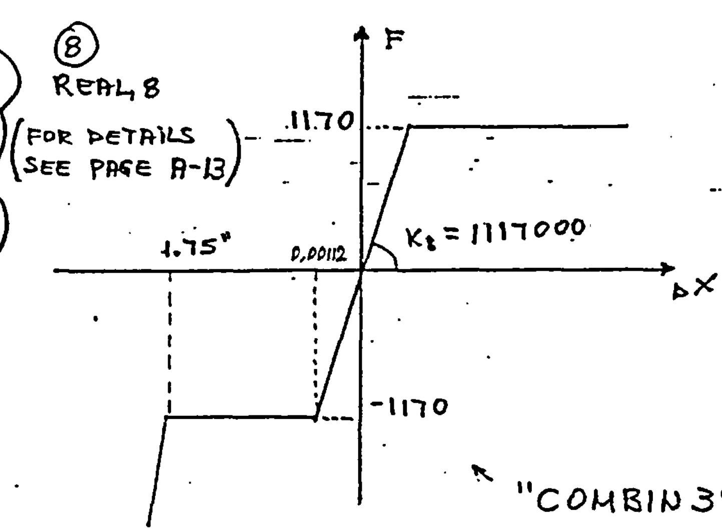
DETAIL (C)

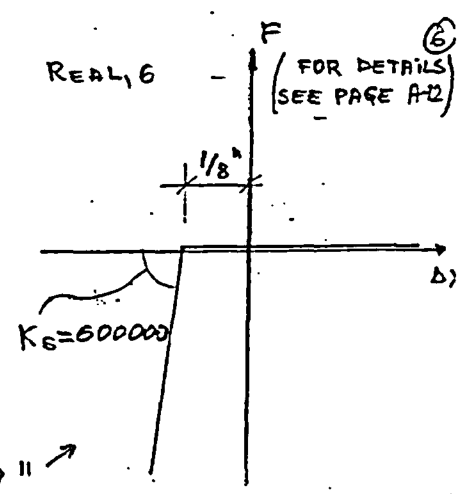


* (9) "Y" DISPLACEMENTS COUPLED

ELEMENTS 13, 15, 16 & 17 – SEE DETAIL (A)

Refer to Att #9, WBN RAI #15, RG 9/27/03





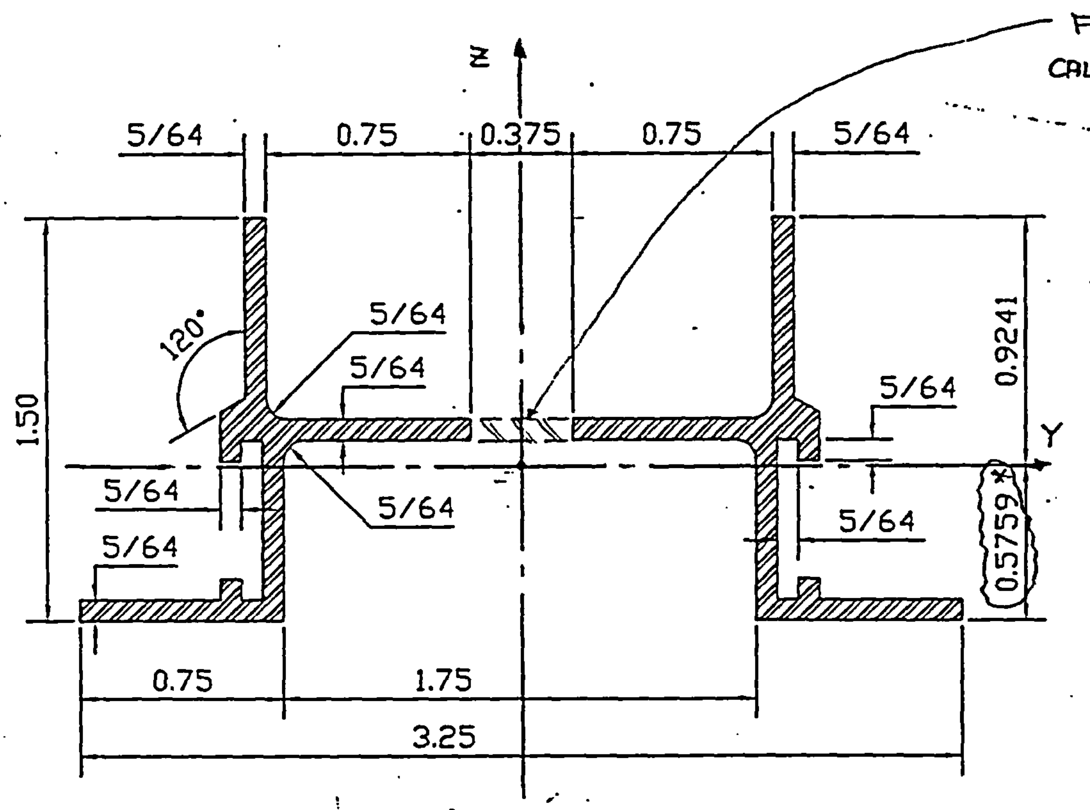
"COMBIN39"

SHEET NO. A-6

JOB NO. 1116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/23/02
CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D H DATE 01/07/03

① MAIN INTEGRATOR BAR (AIR BAR) (SEE PAGES A-2, A-3 & A-5)

* ASSUMED DIMENSION - SEE PAGES A 13 & E8 FROM CALC. SCQ - 2S90-88
* THICKNESS - 5/64" (FIELD MEASUREMENT)



AutoCAD INPUT

```
---------------- REGIONS ----------------
Area:                     0.5104
Perimeter:                12.7866
Bounding box:         X: -1.6250  --  1.6250
                      Y: 0.0000  --  1.5000
Centroid:             X: 0.0000
                      Y: 0.5759 *
Moments of inertia:   X: 0.2562
                      Y: 0.4915
Product of inertia:  XY: 0.0000
Radii of gyration:    X: 0.7085
                      Y: 0.9813
Principal moments and X-Y directions about centroid:
                      I: 0.0870 along [1.0000 0.0000]
                      J: 0.4915 along [0.0000 1.0000]
```

AutoCAD OUTPUT

ANSYS INPUT:

$A = 0.5104 \text{ in}^2$

$I_Y = 0.0870 \text{ in}^4$

$I_Z = 0.4915 \text{ in}^4$

** $A' = 0.5397$ FOR MASS CALCULATION

MATERIAL : ALUMINUM (E = 10700000 psi)

DENSITY → 165 PCF = $\frac{165}{12^3}$ = 0.0955 pci

$0.0955 \times 0.5397_{in^2} = 0.05154$ P/IN

WEIGHT OF FIBERGLASS DUCT: $3 \times \frac{16''}{12} \cdot \frac{1}{12}' \times 3.25$ PCF = 1.083
1.083 P/FT = 0.09028 P/IN

TOTAL WEIGHT (BAR + DUCT) = 0.05154+0.09028=0.14182 P/IN

$$\frac{0.14182 \text{ P/IN}}{0.5104 \text{ IN}^2} = 0.2779 \text{ P/IN}^3$$ FOR THE MODEL

USE:

PARAMETER IN THE MODEL ↓

A = 0.5104 IN^2 ("AREALG")

I_x = 0.0870 IN^4 ("IYYLG")

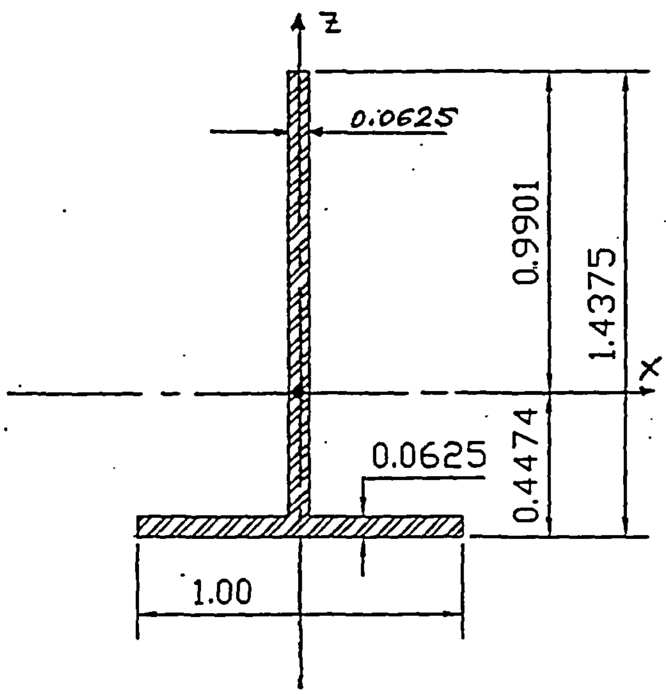
I_y = 0.4915 IN^4 ("IZZLG")

E = 10,700,000 P/IN^2 ("EMODLD")

DENSITY = 0.2336 ("DENSLG")

JOB NO. 111518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/18/02
CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [initials] DATE 01/07/03

② TEE BAR (REAL, 2) (SEE ALSO PAGES A-2, A-3 & A4)



AUTOCAD INPUT

```
----------------  REGIONS  ----------------

Area:                     0.1484
Perimeter:                4.8750
Bounding box:        X: -0.5000  --  0.5000
                     Y: -0.4474  --  0.9901
Centroid:            X: 0.0000
                     Y: 0.0000
Moments of inertia:  X: 0.0323
                     Y: 0.0052
Product of inertia: XY: 0.0000
Radii of gyration:   X: 0.4661
                     Y: 0.1878
Principal moments and X-Y directions about centroid:
                     I: 0.0052 along [0.0000 1.0000]
                     J: 0.0323 along [-1.0000 0.0000]
```

AUTOCAD OUTPUT

ANSYS INPUT:

$A = 0.1484$ in^2

$I_x = 0.0323$ in^4

$I_z = 0.0052$ in^4

JOB NO. 116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY VPD DATE 12/04/02
CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [initials] DATE 01/07/03

(3) PERIMETER BAR (MAIN BAR WITHOUT DUCT)
(SEE ALSO PAGES A-2, A-4 & A-5)

SAME SECTION PROPERTIES AS MAIN INTEGR. BAR

$A = 0.5104$ in² ("AREAED")

$I_x = 0.0870$ in⁴ ("IYYED")

$I_y = 0.4915$ in⁴ ("IZZED")

$E = 10\,700\,000$ psi ("EMODED")

$$\text{DENS.} = 0.0955 \times \frac{0.5397}{0.5104} = 0.1010$$

DENS. = 0.1010 ("DENSED")

REAL,3

(4) LUMINOUS CEILING: (REAL, 4)
(SEE ALSO PAGES A-2, A-3, A-4 & A-5)

WEIGHT: 0.9 PSF = 0.00625 LBS/IN^2

MATERIAL: E = 900 000 PSI ("EMODCP")

ASSUME THICKNESS 0.20 IN ("THICKCP")

$$\frac{0.00625 \text{ LBS/IN}^2}{0.20 \text{ IN}} = 0.03125 \text{ LBS/IN}^3$$

DENSITY = 0.03125 LBS/IN^3 ("DENSCP")

JOB NO. 1116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/04/02
CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [illegible] DATE 01/07/03

(5) WIRE ELEMENT

USE "LINK 10" – TENSION ONLY ELEMENT

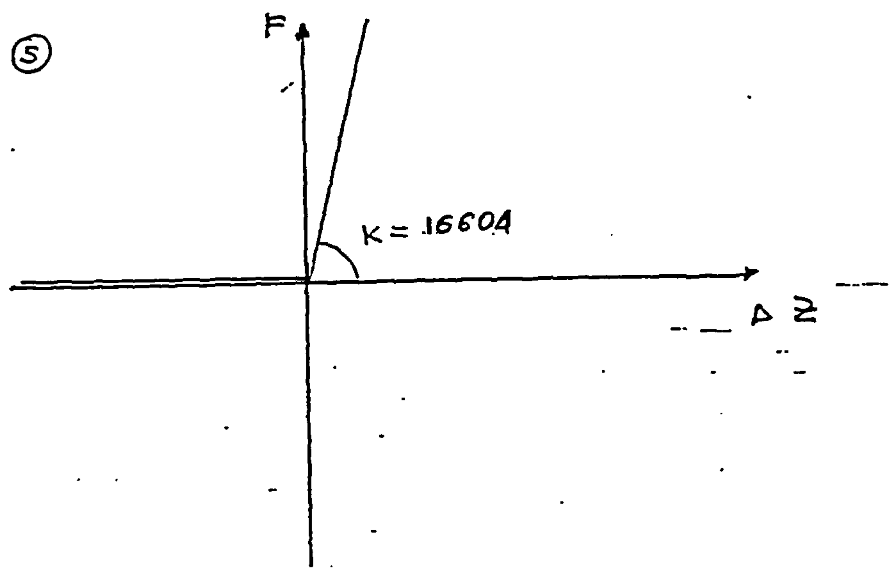
MATERIAL → STEEL – E = 29 000 000 psi

GAGE #8 WIRE → 0.162" φ , L = 36"

$$A = \frac{(0.162)^2 \times \pi}{4} = 0.02061 \text{ in}^2$$

$$K = \frac{AE}{L} = \frac{0.02061 \times 2.9 \times 10^7}{36} = 16604 \text{ LBS/in}$$

(5)



JOB NO. 1116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPB DATE 12/04/02
CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [illegible] DATE 01/07/03

(6) CONTACT ELEMENT → PERIMETER BAR – PLASTER PANEL

REAL, 6 = "X" (SEE ALSO PAGE A-5)

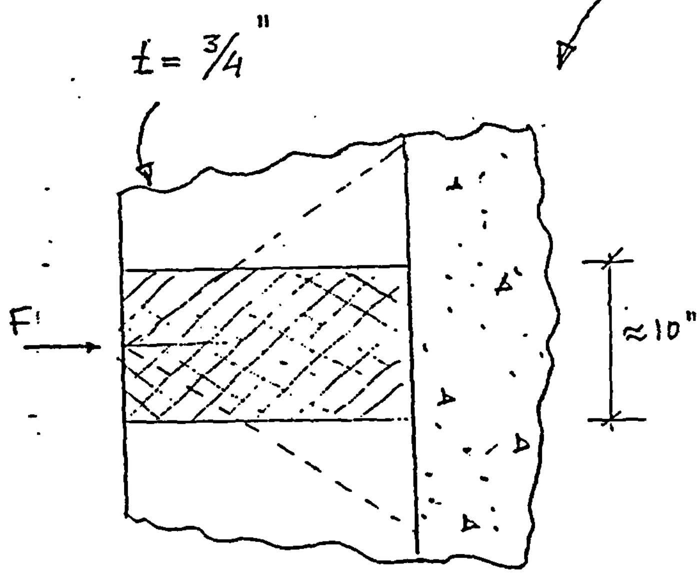
USE "COMBIN 39" ELEMENT

$E_{PL} = 57000\sqrt{1500}$

$E_{PL} = 2\,207\,600$ psi

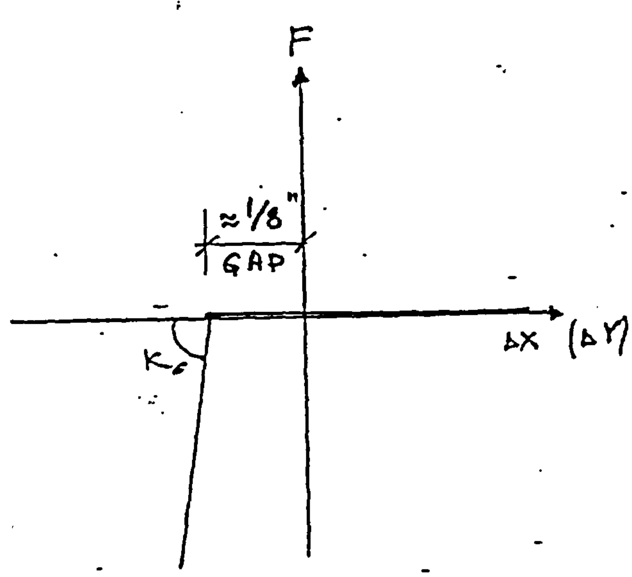
ASSUME $f'_c = 1500$ psi FOR THE PLASTER

PLASTER PANEL PLAN VIEW



$K = \frac{E \cdot A}{L} = \frac{2207600 \times 0.75 \times 10}{27"}$

$K_{6,7} = 613222$ P/in → SAY $K = 600000$

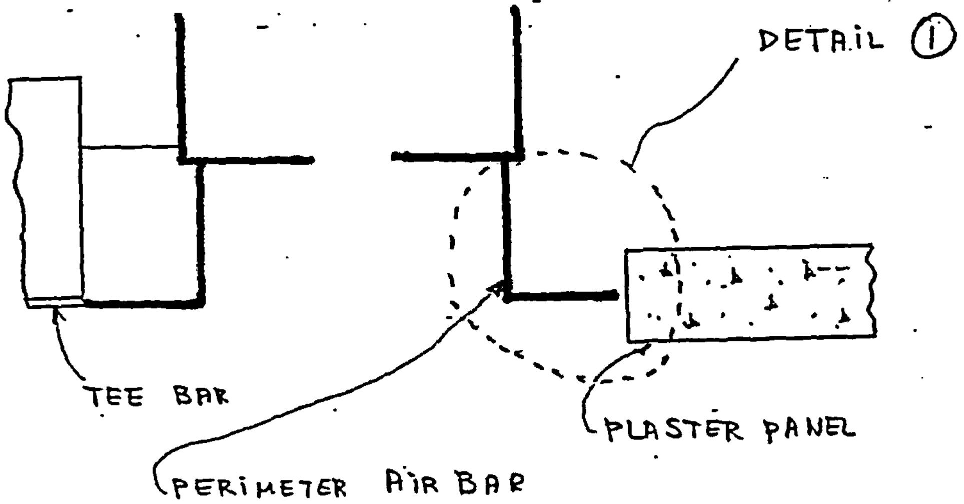


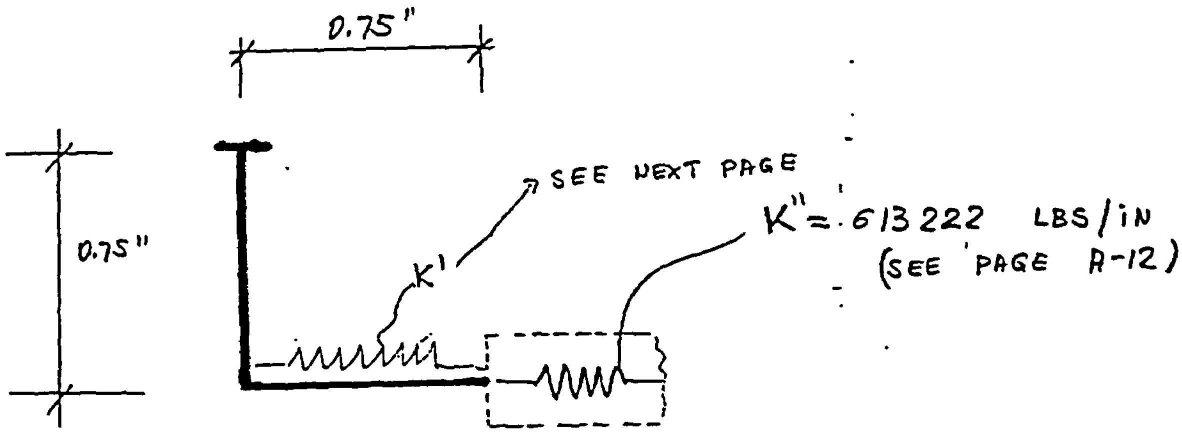
* FOR THE ANSYS-MODEL USE $K_6 = K_7 = 600000$

(SEE ALSO PAGES A-4 & A-5)

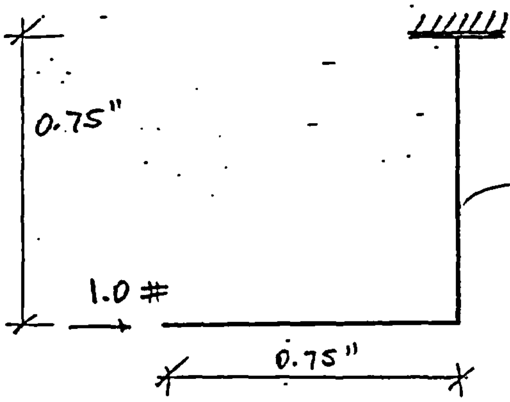
JOB NO. 116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/16/02
CALC. NO. R-002 SUBJECT SEISMIC QUALICATION CHK'D [initials] DATE 01/07/03

⑦ CONTACT ELEMENT → PERIMETER BAR – PLASTER PANEL
(SEE ALSO PAGE A-4)





DETAIL ①



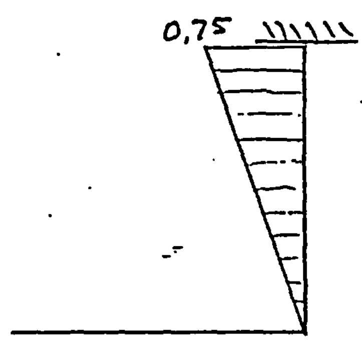
EFFECTIVE WIDTH ≈ 10"

10" × 5/64"

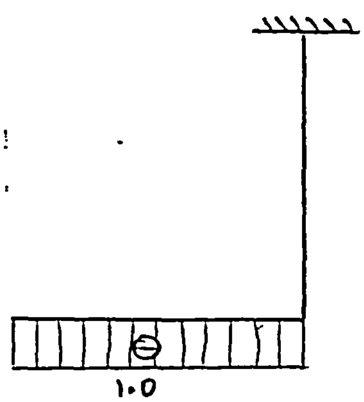
$$A = 5/64'' \times 10'' = 0.781 \text{ in}^2$$

$$I = \frac{10'' \times (5/64)^3}{12} = 0.000397 \text{ in}^4$$

$$Z = \frac{10 \times (5/64)^2}{4} = 0.01526 \text{ in}^3$$



$$\Delta_M = \frac{0.75^3/3}{10700000 \times 0.000397} = 0.000033104''$$



$$\Delta_N = \frac{1.0 \times 0.75}{10700000 \times 0.781} = 0.000000089''$$

$$\Delta = 0.000033104 + 0.000000089$$

$$\Delta = 0.000033193''$$

$$K' = \frac{1}{\Delta} = 30127 \Rightarrow$$

K' & K'' ARE IN SERIES

$$\frac{1}{K_7} = \frac{1}{K'} + \frac{1}{K''}$$

$$\frac{1}{K_7} = \frac{1}{30127} + \frac{1}{613222}$$

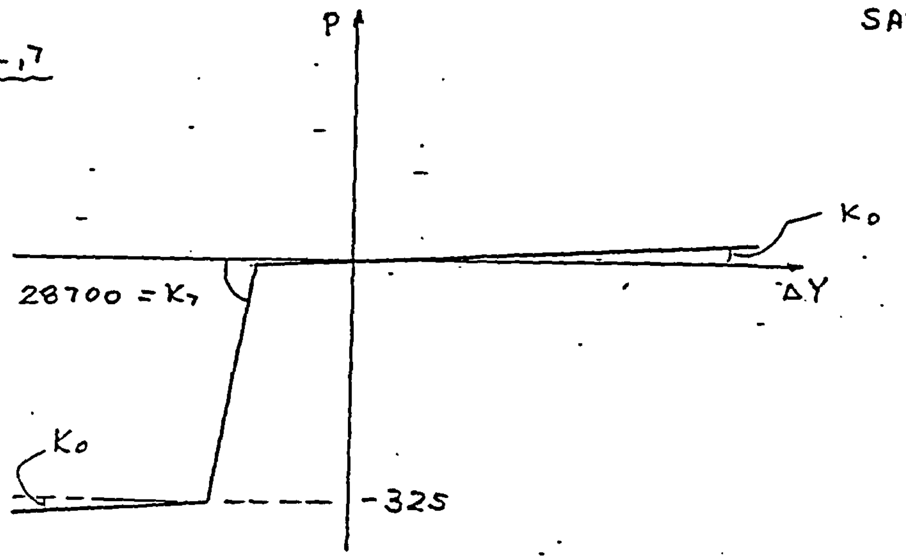
$K_7 = 28716$ → SAY $K_7 = 28700$ LBS/IN

$M_{YIELD} = F_Y \times Z = 16000 \times 0.01526 = 244.16$ LBS-IN

$P_{YIELD} = \frac{M_{YIELD}}{0.75''} = \frac{244.16}{0.75} = 325.55$

SAY $P_{YIELD} = 325$ LBS

REAL,7

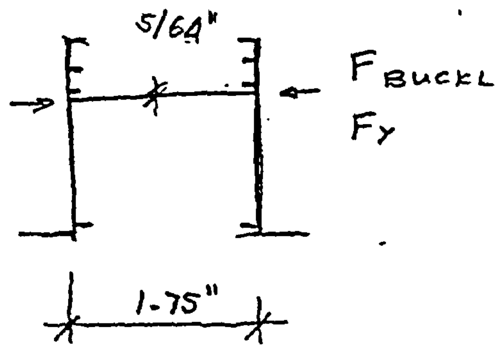


JOB NO. 1116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/04/02
CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [initials] DATE 01/07/03

(8) MAIN INT. BAR TO PERIMETER BAR CONNECTION

(SEE ALSO PAGE A-5)

REAL, 8 ($x = L_x$)
REAL, 108 ($x = 0.$)



$F_y = 16\,000$ psi (ALUMINUM)

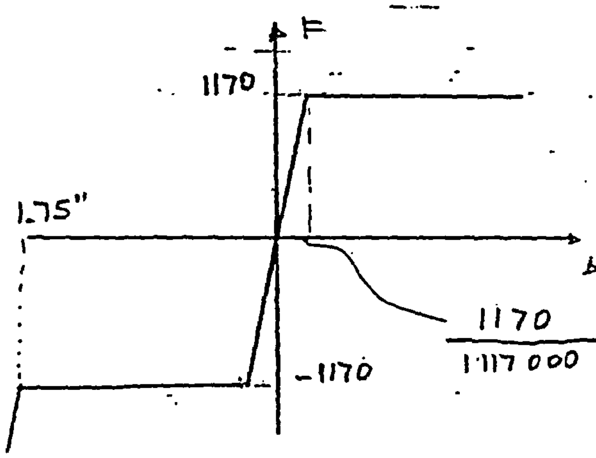
$A = 5/64 \times (3 \times 5/16) = 0.07324 \ in^2$ (YIELD AREA)

SEE NEXT PAGE FOR DETAILS

$$I = \left(\frac{(3 \times 5/16) \times (5/64)^3}{12} \times 0.375 + \frac{(3\ 15/16)(5/64)^3}{12} \times 1.375" \right) / 1.75" = 0.0001309$$

$F_{YIELD} = 0.07324 \times 16\,000 = 1172$ LBS $\Rightarrow$ (SAY 1170)

$$F_{BUCKL} = \frac{\pi^2 EI}{L^2} = \frac{3.14^2 \times 10700000 \times 0.0001309}{1.75^2} = 4514 > 1172$$

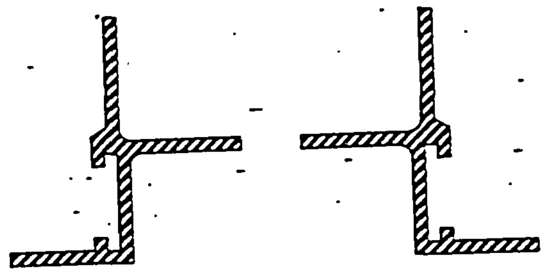


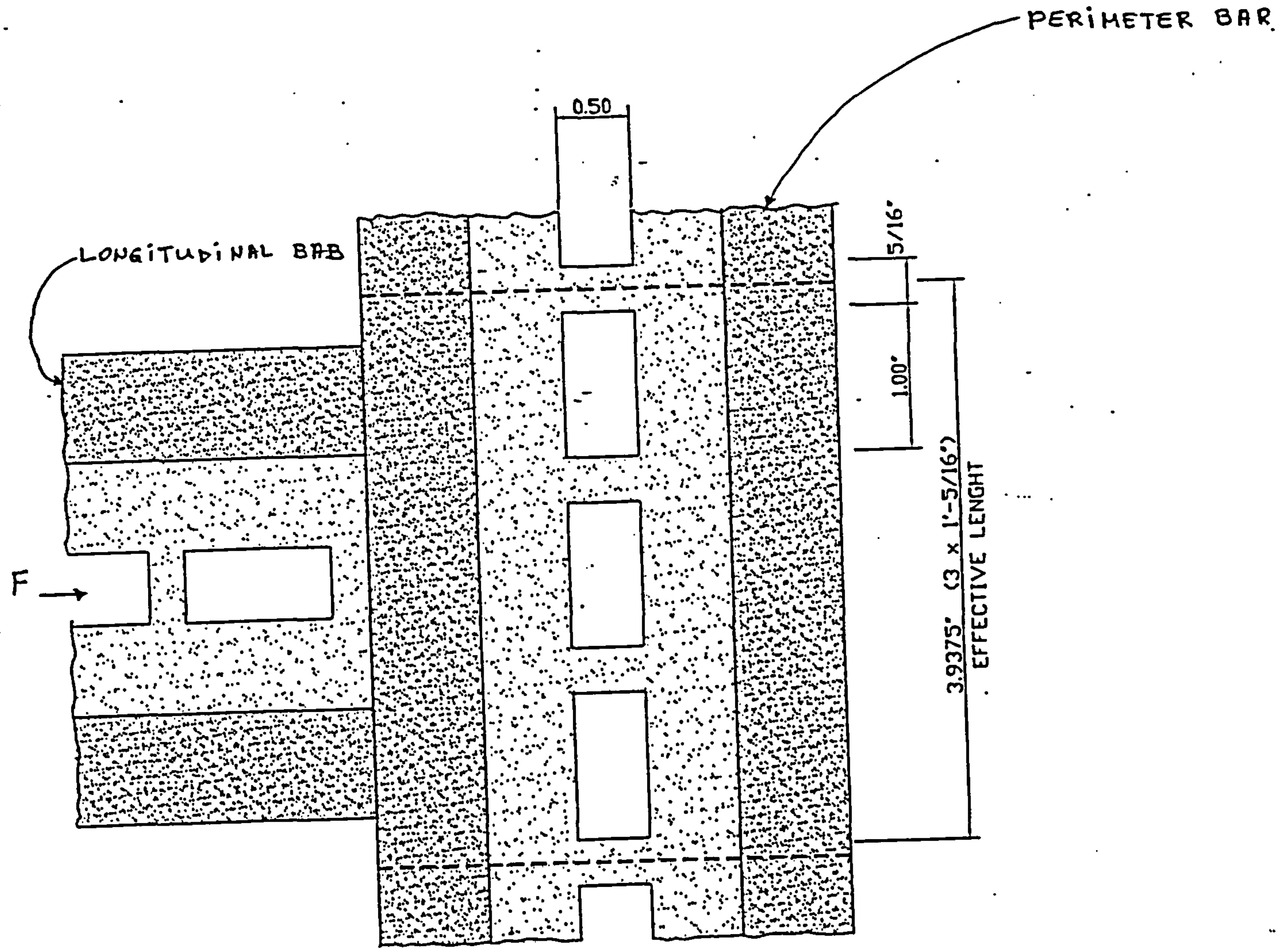
$\frac{1170}{1117\,000} = 0.00105"$

SEE NEXT PAGE FOR DETAILS

JOB NO. 111651B JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/23/02

CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [initials] DATE 01/07/03





$$(F = 1\ \text{LB}) \quad \Delta = \frac{1.0 \times 1.375}{10700000 \times (3.9375 \times 5/64)} + \frac{1.0 \times 0.375}{10700000 \times (15/16 \times 5/64)}$$

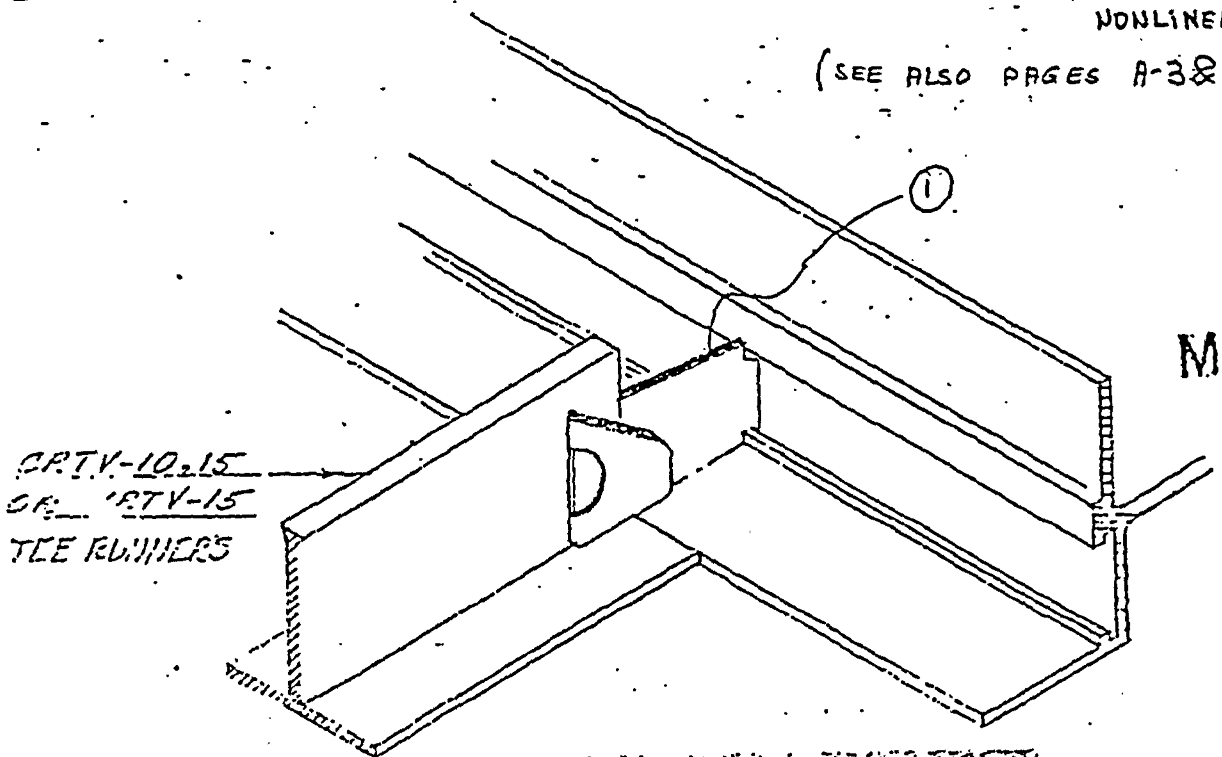
$$\Delta = 0.000\,000\,417 + 0.000\,000\,478 = 0.000\,000\,895$$

$$K_8 = \frac{1}{\Delta} = 1\,117\,318 \Rightarrow \text{SAY} \quad K_8 = 1\,117\,000$$

JOB NO. 1116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/02/02
CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D A DATE 01/07/03

(11) CONTACT ELEMENT - MAIN INT. BAR - TEE BAR NONLINEAR SPRING

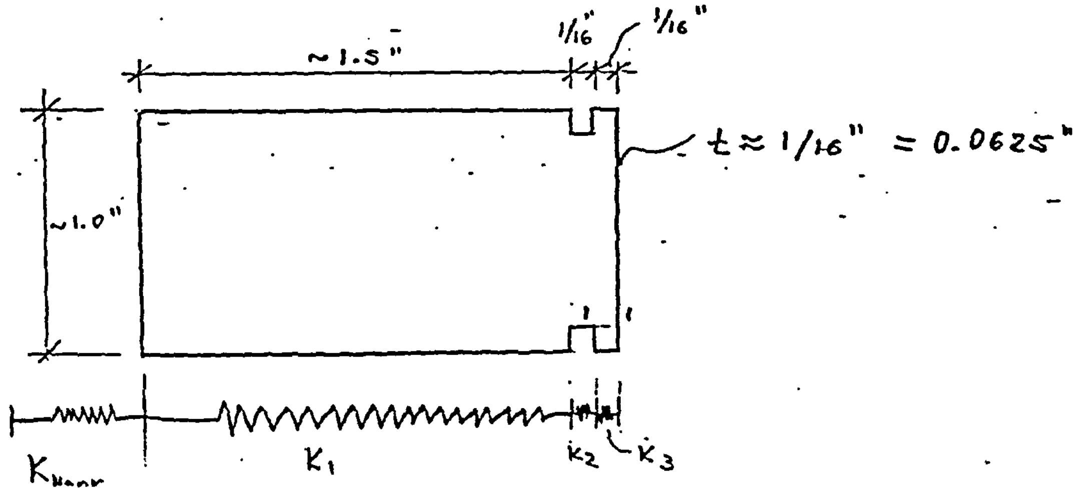
(SEE ALSO PAGES A-3 & A-4)



APPROVED

Date MAY 2 1972

CL-12 CLIP LOCKS TEE RUNNER TO A..DU-FLO EAR



$$\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \frac{1}{K_{HOOK}}$$

$$\Delta = \Delta_1 + \Delta_2 + \Delta_3 + \Delta^{*}_{HOOK}$$

$$\Delta = \frac{1}{10000} + \frac{1.0 \times 1.5''}{10700000 \times (0.0625 \times 1.0)} + \frac{1.0 \times 0.0625}{10700000 \times (0.0625 \times 0.875)} + \frac{1.0 \times 0.0625/2}{4115385 \times (0.0625 \times 0.0625 \times 2)}$$

$$G_{ALOW} = \frac{10700000}{2 \times (1 + 0.3)} \simeq 4115385$$

* BASED ON JUDGEMENT $K_{HOOK} = 10000$ (0.01" DISPL. ⇔ 100 LBS FORCE)

$$\Delta' = 0.00000224'' + 0.00000011'' + 0.00000194'' + 0.0001''$$ (0.0001" = Δ_{HOOK})

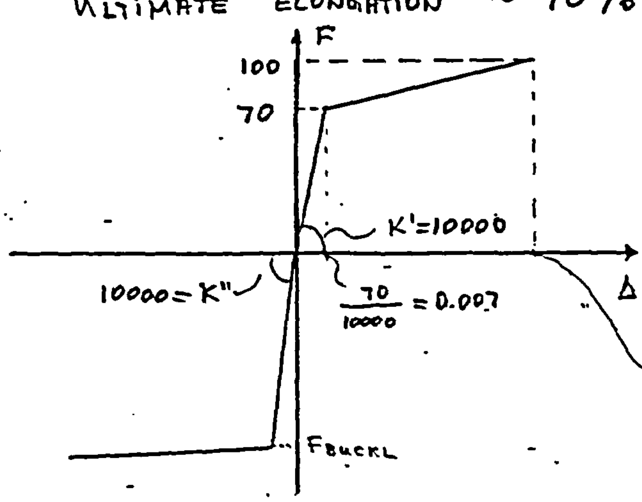
$$\Delta' = 0.00010429'' \Rightarrow K' = \frac{1}{\Delta'} = 9588.6 \Rightarrow \text{SAY } K' = 10000$$

$$\Delta'' = 0.0001'' + 0.00000224'' + 0.00000011'' + 0$$ ($\Delta_3 = 0$ → NO SHEAR)

$$\Delta'' = 0.00010235'' \Rightarrow K'' = \frac{1}{\Delta''} = 9770 \Rightarrow \text{SAY } K'' = 10000$$

SHEAR CAPACITY (6063 - T5)

YIELD STRES	9 000	psi
ULTIMATE STRES	13 000	psi
ULTIMATE ELONGATION	~ 10%	



≈ 20 × 0.007 = 0.140"

$$\Delta'' = 0.00000224 + 0.00000011$$
$$\Delta'' = 0.00000235$$
$$K'' = 425532$$
SAY $K'' = 425000$

JOB NO. 1116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/03/02
CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [initials] DATE 01/07/03

ULTIMATE CAPACITY FOR SHEAR (SECTION 1-1)

$2 \times (0.0625 \times 0.0625) \times 13000 = 101.6$ LBS (SAY 100 LBS)

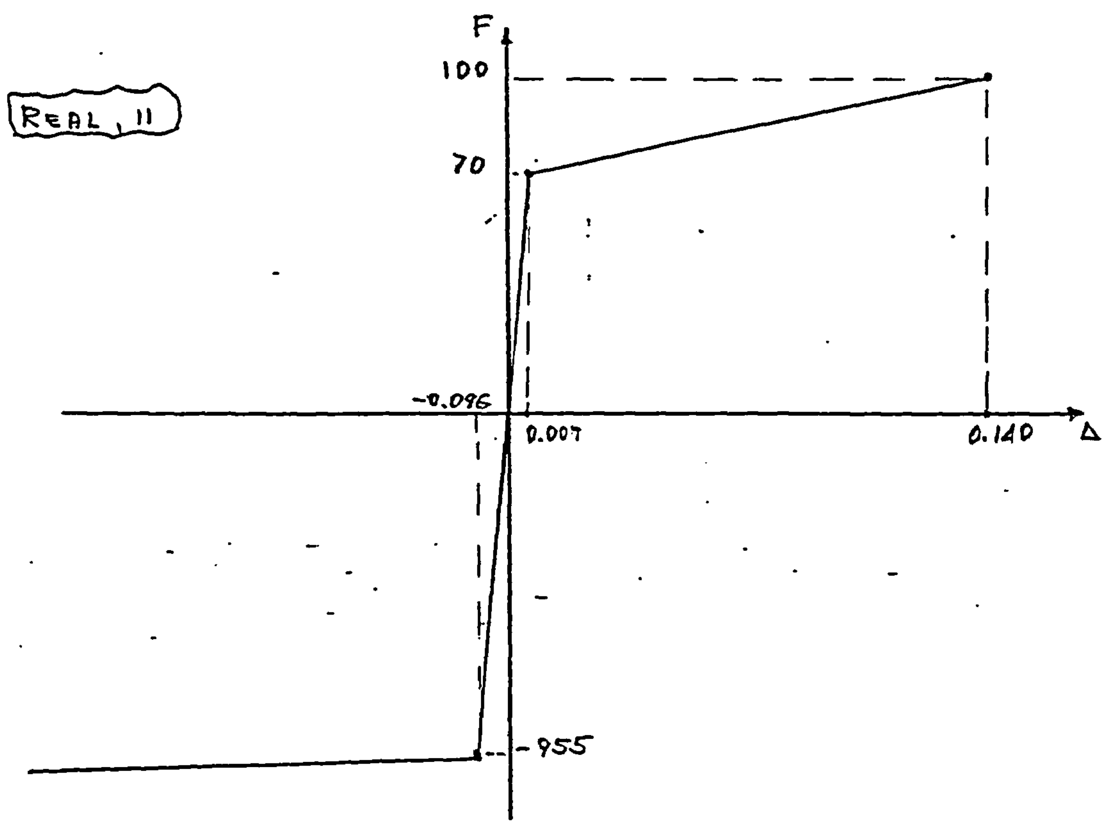
YIELD

$2 \times (0.0625 \times 0.0625) \times 9000 = 70.3$ LBS (SAY 70 LBS)

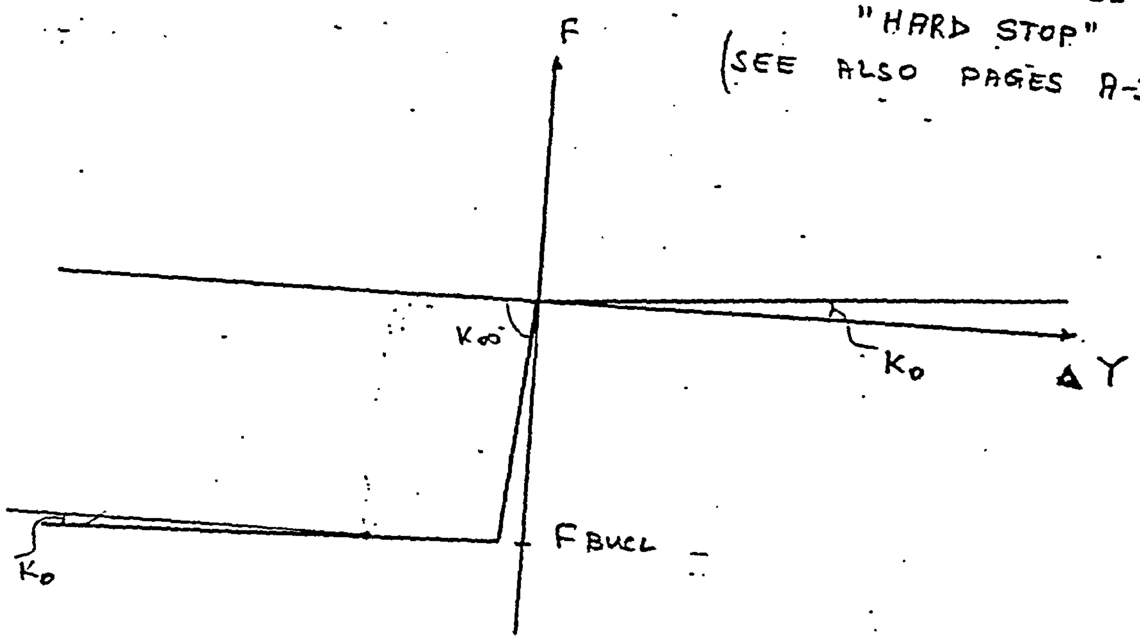
BUCKLING FORCE FOR THE CLIP ELEMENT

$$F_{BUCL} = \frac{\pi^2 E I}{L^2} = \frac{\pi^2 \times 10700000 \times \left[1.0 \times (1/16)^3 / 12\right]}{1.5^2} = 954.9 \approx 955 \#$$

$$\frac{955}{10000} = 0.096''$$



⑫ CONTACT ELEMENT – MAIN INT. BAR – TEE BAR
"HARD STOP"
(SEE ALSO PAGES A-3 & A-4)



$$F_{BUCL} = \frac{\pi^2 EI}{L^2} = \frac{\pi^2 \times 10.7E6 \times 0.0323}{50.25^2} = 1351 \text{ LBS}$$

$I = 0.0323$ in^4

$L = 50.25$ in

$F_{BUCKL} \doteq$ 1351 LBS

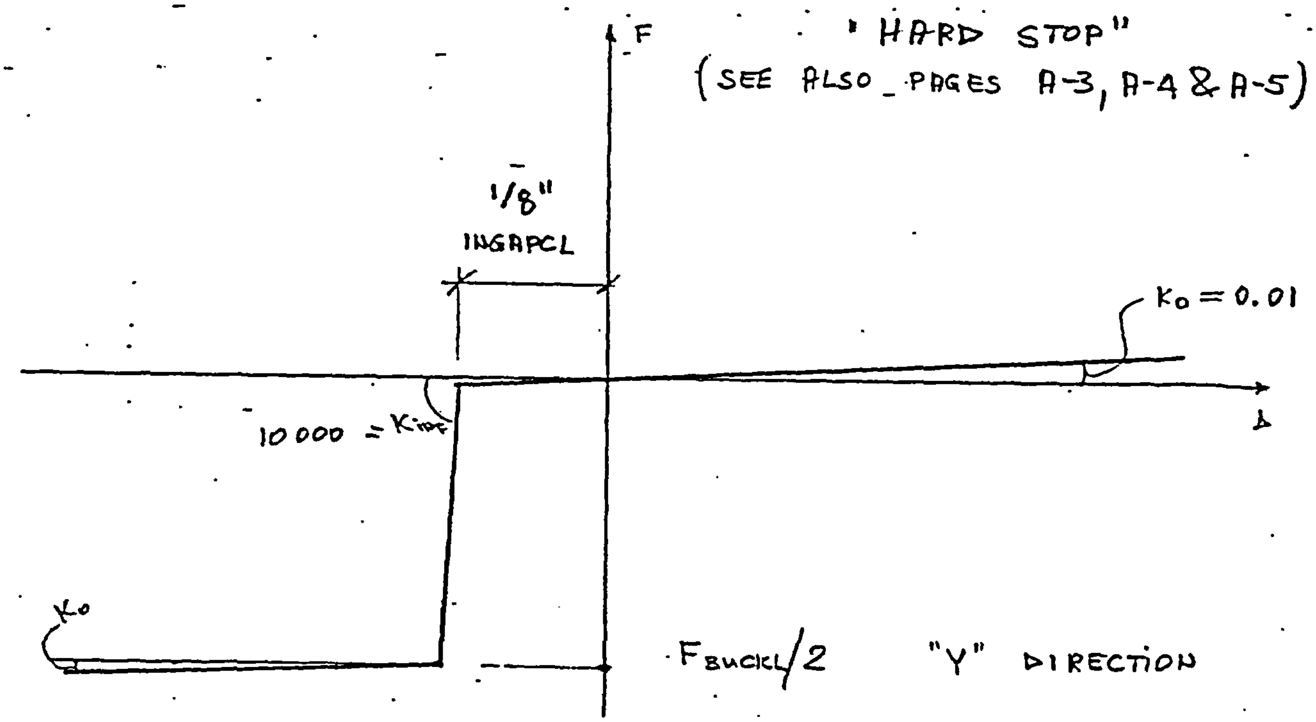
REAL, 12 – "HARD STOP IN COMPRESSION"
REAL, 112 – "HARD STOP IN TENSION"

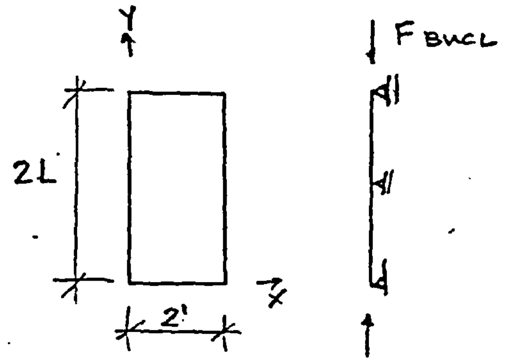
SHEET NO. A-22

JOB NO. 1116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/05/02
CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [initials] DATE 01/07/03

(13) CONTACT ELEMENT – MAIN INT. BAR – CEILING "HARD STOP"

(SEE ALSO PAGES A-3, A-4 & A-5)





$$F_{BUCL} = \frac{\pi^2 EI}{L}$$

$2L = 50.25" \Rightarrow L = 25.125"$

$$I = \frac{24 \times 0.2^3}{12} = 0.016 \text{ IN}^4$$

$$F_{BUCKL} = \frac{\pi^2 \times 900000 \times 0.016}{25.125^2} = 225.14 \#$$

$F_{BUCKL}/2 = 112.57 \#$ (112.57 FOR THE ANSYS MODEL)

REAL, 13 – "HARD STOP IN COMPRESSION"
REAL, 113 – "HARD STOP IN TENSION"

(14) ASSUME RIGID CONNECTION: FOR LONGITUDINAL DISPLACEMENTS

* SEE ALSO PAGES A-3 & A-4

JOB NO. 1116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/06/02

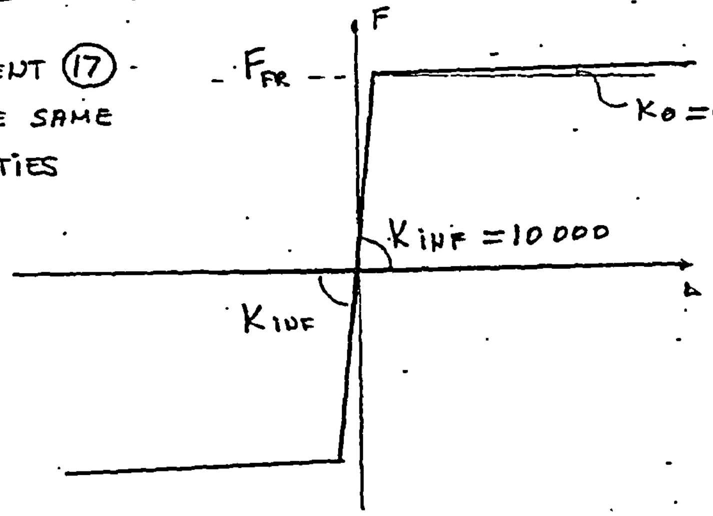
CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [illegible] DATE 01/07/03

(15) CONTACT ELEMENT TEE BAR – CEILING

(SEE ALSO A-3, A-4 & A-5)

NONLINEAR SPRING

* ELEMENT (17) HAS THE SAME PROPERTIES



WEIGHT OF 1 CEILING PANEL $2' \times 4' \times 0.9$ PSF $= 7.2$ LBS

$\frac{7.2}{4} = 1.8$ LBS / CORNER

TENSION IN NYLON BOLTS ≈ 8.2 LBS

FRICTION COEFFICIENT → ASSUME $\mu = 0.2$

$F_{FR} = (1.8 + 8.2) \times 0.2 = 2$ LBS ('FRICT_CT')

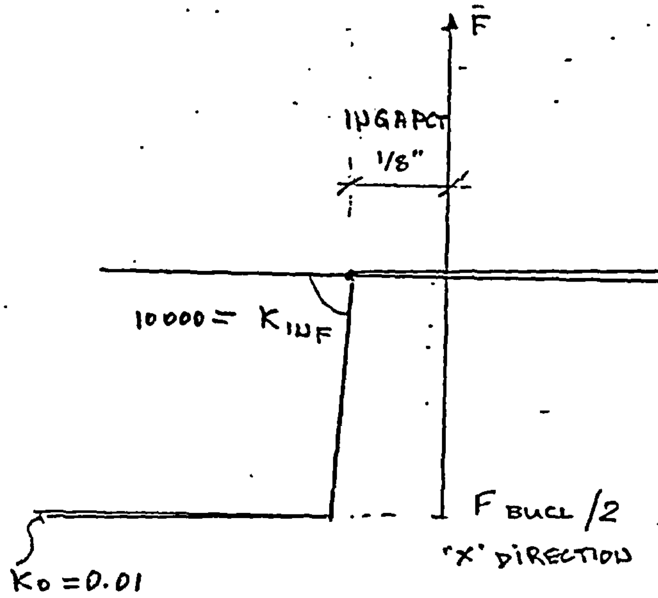
$K_o = 0.01$ ("KO") "ZERO" SLOPE

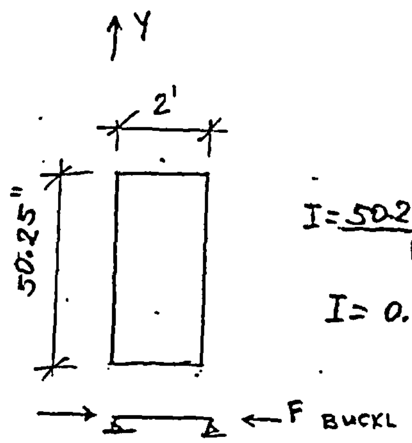
$K_{INF} = 0.9999$ ("KINFIN") "≈90°" SLOPE

(REAL, 15 & REAL, 17)

(16) CONTACT ELEMENT → TEE-BAR-CEILING "HARD STOP"

(SEE ALSO PAGES A-3, A-4 & A-5)





$I = \frac{50.25 \times 0.2^3}{12} =$

$I = 0.0335\ in^4$

$F_{BUCKL} = \frac{\pi^2 EI}{L^2}$

$E = 900\,000$ PSI $L = 24"$

$F_{BUCKL} = \frac{\pi^2 \times 900000 \times 0.0335}{24^2} = 516.62$ LBS

$F_{BUCKL}/2 = 258.31$ #   (258.31 # FOR ANSYS MODEL)

REAL, 16 - "HARD STOP IN COMPRESSION"

REAL, 116 - "HARD STOP IN TENSION"

JOB NO. 1116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/06/02
CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [initials] DATE 01/07/03

LOAD PER WIRE (ANSYS MODEL)

- CEILING : 2 × 23.70" × 48" × 0.20" × 0.03125 = 14.220 LBS
- AIR BAR : 48.0" × 0.5104 in² × 0.2779 pci = 6.808 LBS
- TEE BAR : 2 × 48" × 0.1484 in² × 0.0955 pci = 1.361 LBS

Σ = 22.389 LBS

TOTAL DEAD LOAD @ SUPPORT POINT W/ DUCT → 22.39 #
(22.39 # FROM THE MODEL)

- CEILING : = 14.220 #
- AIR BAR (NO DUCT) : 48.0" × 0.5104 × 0.1010 = 2.474 #
- TEE BAR : = 1.361 #

Σ = 18.055 LBS

TOTAL DEAD LOAD @ SUPORT WITHOUT DUCT → 18.06 LBS
(18.06 # FROM THE MODEL)

JOB NO. 1116518 JOB MCR CEILING AND AIR DELIVERY COMPONENTS BY NPD DATE 12/06/02
CALC. NO. R-002 SUBJECT SEISMIC QUALIFICATION CHK'D [initials] DATE 01/07/03

TOTAL MASS (ANSYS MODEL)

– CEILING : 9 × 73 × 23.70 × 48" × 0.20" × 0.03125 = 4671.30 LBS

$$\frac{4671.3}{386.4} = 12.089 \quad \frac{LBS}{g} \quad (\text{ELEM. TYPE } ④)$$

– AIR BAR (W/ DUCT) : 5 × 73 × 24" × 0.5104 in² × 0.2779 = 1242.52 LBS

$$\frac{1242.52}{386.4} = 3.216 \quad \frac{LBS}{g} \quad (\text{ELEM. TYPE } ①)$$

– AIR BAR (NO DUCT) : 5 × 73 × 24" × 0.5104 × 0.1010 = 451.58 LBS

$$\frac{451.58}{386.4} = 1.169 \quad \frac{LBS}{g} \quad (\text{ELEM. TYPE } ③)$$

– PERIMETER BAR : 2 × 9 × 50.25" × 0.5104 × 0.1010 = 46.63 LBS

$$\frac{46.63}{386.4} = 0.121 \quad \frac{LBS}{g} \quad (\text{ELEM. TYPE } ③)$$

– TEE BAR : 72 × 9 × 48" × 0.1484 × 0.0955 = 440.81 LBS

$$\frac{440.81}{386.4} = 1.141 \quad \frac{LBS}{g} \quad (\text{ELEM. TYPE } ②)$$

TOTAL MASS : (3.216) + (1.141) + (1.169 + 0.121) + (12.089) = 17.736
EL. ① EL. ② EL. ③ EL. ④

ELEM. TYPE (1)

$M_1 = 3.216$ (3.216 FROM ANSYS)

ELEM. TYPE (2)

$M_2 = 1.141$ (1.141 FROM ANSYS)

ELEM TYPE (3)

$M_3 = 1.169 + 0.121 = 1.290$ (1.290 FROM ANSYS)

ELEM TYPE (4)

$M_4 = 12.089$ (12.089 FROM ANSYS)

$$\frac{\text{MASS OF CEILING}}{\text{TOTAL MASS}} = \frac{12.089}{17.736} = 0.682 \approx 68\%$$

Appendix B: Computer File Prints

(Total pages, including this cover: 90)

APPENDIX B: FILE PRINTOUTS

"MODEL DEVELOPMENT"

"INPUT MOTIONS"

"EAST - WEST" MODEL

"NORTH - SOUTH" MODEL

File — *See Page*

Time History Input files:

Postprocessing Input files:

File — *See Page*

Postprocessing Output files::

File — *See Page*

Appendix E: ANSYS QA Verification

(Total pages, including this cover: 2)

All computer runs from which results were extracted for use in the evaluations documented in the previous sections were performed on TVA's ANSYS Release 5.7 installation on the EVEREST server which has been verified and maintained in accordance with TVA's quality assurance program.

The error reports related to ANSYS Release 5.7 on file at TVA Scientific Engineering Server (TVASES) were reviewed to determine applicability to the analyses performed as part of this evaluation. The error reports are listed in Table E-1. None of the listed error reports have any bearing to the analyses performed; they do not apply to the element types or features used in the analyses.

Table E-1. ANSYS Release 5.7 Class 3 Error Reports

1999-23 R2	2000-33 R1	2001-01	2001-02	2001-03	2001-07
2001-08	2001-10	2001-11	2001-13	2001-14	2001-15
2001-18	2001-19	2002-01	2002-02	2002-09	2002-10
2002-13	2002-20	2002-21	2002-22	2002-23	2002-25
2002-27	2002-28	2002-32	2002-33	2002-35	

Subject: Review of The WBN RAI (As The RAI Relates to SQN)

REFERENCES

Attachment 9

Review of WBN RAI

(As The RAI Relates to SQN)

Note: The WBN RAI contained 15 requests.

Request 1 concerns the QA Program. This Attachment does not address request 1. Enclosure 6 of the SQN Licensing Amendment addresses request 1.

Requests 2 - 5 concern the Licensing Amendment. This Attachment does not address requests 2 -5. The SQN Licensing Amendment addresses requests 2 - 5.

Requests 6 and 7 concern the ABS Consulting Report. This Attachment addresses requests 6 and 7.

Request 8 concerns a response spectra confirmation unique to WBN. This attachment does not address request 8.

Request 9 concerns the ABS Consulting Report. This attachment addresses request 9.

Request 10 concerns tape related degradation and air leakage observed at WBN. This attachment addresses attachment 10.

Request 11 - 15 concerns the ABS Consulting Report. This attachment addresses requests 11 - 15.

Note: On the following pages, strike-through indicates a deletion and underline indicates an addition.

ENCLOSURE 1

TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT (WBN)
UNIT 1
DOCKET NUMBER 50-390

PROPOSED LICENSE AMENDMENT REQUEST WBN-TS-03-05

Subject: Watts Bar Nuclear Plant (WBN) – License Amendment to Revise the Updated Final Safety Analysis Report and the Technical Specification Bases for the Seismic Qualification of the Main Control Room Air Delivery Components and Suspended Ceiling - Request for Additional Information.

NRC Request - Item 1: WBN RAI 1 addressed in SQN Licensing Submittal as Enclosure 6.

The last sentence of the evaluation results provided on Page E1-6 of Enclosure 1 states that, "since the flexible and triangular ducting was not designed, procured, and installed in accordance with an Appendix B QA program, alternate acceptable limited QA requirements for the ducting are being established. However, this QA classification change decreases the qualification/safety classification for the duct work and results in the above criteria being met." Discuss and compare key elements of WBN's "alternate acceptable limited QA requirements" with those of 10 CFR 50, Appendix B QA program and elaborate on your rationale for concluding that the alternate, limited QA requirements are acceptable.

TVA Response: WBN RAI 1 addressed in SQN Licensing Submittal as Enclosure 6.

The eighteen 10 CFR 50 Appendix B Program criteria are listed in Table 1 below. The proposed Alternate QA Requirements and Appendix B QA Requirements and associated TVA implementing processes, procedures, and general engineering specifications are compared for each criterion. Then, for the WBN suspended ceiling and air delivery components application, anticipated differences in the resulting documentation are identified and evaluated criterion by criterion. (Note that some of the Appendix B QA Record documentation would typically be provided by a vendor under contract to TVA.)

The Appendix B QA requirements used in this comparison are per the current NRC-approved TVA Nuclear Quality Assurance Plan (NQAP) for safety-related items.

The Alternate QA requirements used in this comparison are per the current TVA NQAP for quality-related seismic Category I(L) pressure boundary and position retention items. Those standard, "Augmented" QA requirements for quality-related items are provided in Appendix E to Nuclear Engineering Department Procedure (NEDP) 4, "Q-List and Unique Component Identifier (UNID) Control." Pressure boundary and position retention requirements are applied to the air delivery components. Position retention requirements are applied to the remainder of the suspended ceiling. These same QA Requirements have been applied extensively for seismic Category I(L)A [Pressure Boundary] and I(L)B [Position Retention] for other commodities throughout the plant.

The Alternate QA requirements are proposed for this application because:

1. It is not possible to back-fit all Appendix B QA Requirements to the existing suspended ceiling and air delivery components,
2. Application of the Alternate QA requirements is reasonable and practical for the existing items, and,
3. The Alternate QA requirements support seismic qualification of the application with margins that are adequate to ensure proper function.

Pending NRC approval of this license amendment request, no modifications will be required for seismic qualification of the original design. However, design documentation will be appropriately revised to reflect the approved changes. Also, future design changes, modifications, and maintenance will be performed using the Alternate QA Requirements.

The Alternate QA program requirements outlined in NEDP-4 and as described below are applicable to TVA processes and are not invoked on suppliers. The following tabulated comparison is applicable to future modification and maintenance activities affecting the Main Control Room air delivery components and suspended ceiling. Although the specific Alternate QA Program requirements are not invoked on the suppliers, in the future, the flexible and triangular duct in the Main Control Room (MCR) will be procured to Underwriters Laboratories (UL) 181, "Standard for Factory-Made Air Ducts and Air Connectors" requirements.

Alternate QA requirements for the original installation were less stringent than the current requirements. However, the existing suspended ceiling and air delivery component installation were determined acceptable for seismic qualification based on existing design documentation, field examination, and structural analysis (refer to the key activities comparison after the table).

Table 1

Comparison of Proposed Alternate QA Requirements and Appendix B QA Requirements
Page 1 of 12

10 CFR 50 Appendix B Criterion	10 CFR 50 Appendix B QA Requirements	Alternate QA Requirements	Comparison
1. Organization	TVA Nuclear Organization and responsibilities would be per TVA's NQAP Section 4.	TVA Nuclear (TVAN) Organization and responsibilities are per TVA's NQAP Section 4 and NEDP-4 Appendix E, Element 1.	There would be no difference in TVA Nuclear Organization.
2. Quality Assurance Program	Quality Assurance (QA) Program activities would be per Section 5 of TVA's NQAP for safety-related items.	NEDP-4 Appendix E is a graded approach and TVA's NQAP Section 5.2 allows a graded approach	There would be no difference in the Quality Assurance Program plan, but the specific plan requirements for Alternate QA would be limited and focused relative to Appendix B. The Alternate QA requirements permit a graded approach in which the application and verification of QA requirements is limited and focused to the application and its importance to safety. For this application, the Alternate QA focus is on assuring structural integrity and flow delivery during a design basis seismic event, concurrent with normal operation. Sufficient documentation is produced for that purpose. However, the Alternate QA approach results in a lesser quantity of documentation than required for full Appendix B compliance. The differences are primarily in Material and QC Inspection documentation.

Table 1
Page 2 of 12

10 CFR 50 Appendix B Criterion	10 CFR 50 Appendix B QA Requirements	Alternate QA Requirements	Comparison
3. Design Control	Design Control activities would be per TVA's NQAP Section 7 for safety-related items. The implementing TVAN process for the Appendix B requirements is Standard Programs and Processes (SPP) 9.3, "Plant Modification and Engineering Change Control."	Applicable Design Control requirements are specified in NEDP-4 Appendix E, Element 3 for seismic Category I(L) Pressure Boundary and Position Retention items (Q10). The implementing TVAN process for the Alternate QA requirements is SPP-9.3.	There would be no difference in the TVA Design Control process and the specific process requirements for Alternate QA and Appendix B would be very similar. For this application, modification (DCN) and Engineering Document Change (EDC) packages for the Alternate (quality related) change and the Appendix B (safety related) change would be very similar. Both would require adequate design input and output to support the change. Drawings and supporting calculations for seismic qualification would be nearly identical. Alternate QA design input and output documentation for this application will assure that suspended ceiling and air delivery component qualification is maintained and that any future design changes are also seismically qualified accordingly. There would be no significant difference in the TVA Design Control documentation for this application.
4. Procurement Document Control	Procurement Document Control activities would be per TVA's NQAP Section 8.1 for safety-related items. The implementing TVAN process for the Appendix B QA requirements is SPP-4.1, "Procurement of	Applicable Procurement Document Control requirements are specified in NEDP-4 Appendix E, Element 4 for seismic Category I(L) Pressure Boundary and Position Retention items (Q10).	There would be no difference in the general Procurement Document Control process, but the specific process requirements for Alternate QA and Appendix B materials would be different. Specific Alternate QA requirements are not invoked on the suppliers. However, compliance with applicable UL-181 requirements will be required for future MCR flexible and triangular duct procurements.

Table 1
Page 3 of 12

10 CFR 50 Appendix B Criterion	10 CFR 50 Appendix B QA Requirements	Alternate QA Requirements	Comparison
4. Procurement Document Control (continued)	Materials, Labor and Services."	The implementing TVAN process for the Alternate QA requirements is SPP-4.1.	For this application, reasonable assurance of the critical characteristics for existing materials was obtained based on existing drawing and calculation documentation plus field examination. Per the Alternate QA approach new non-pressure boundary components of the suspended ceiling (for modification or maintenance) would be procured commercial grade, but such components would be specified as good as or better than the components they are replacing. For this application, there would be no significant difference in the quality requirements for procured services (that is, the contractor, ABS Consulting Inc, was fully qualified to perform the services). The overall quality of seismic qualification documentation would be equivalent. The difference in Procurement Document Control documentation is acceptable for this application because compensating factors (refer to the comparison of key activities following this table) are present in the Alternate QA approach.
5. Instructions, Procedures, and Drawings	Instructions, Procedures, and Drawings activities would be per TVA's NQAP Sections 6.1 and 7 for safety-related items.	Applicable Instructions, Procedures, and Drawings requirements are specified in NEDP-4 Appendix E, Element 5 for	There would be no difference in the TVAN Instructions, Procedures, and Drawings processes, and the specific process requirements for Alternate QA and Appendix B would be very similar. The implementing department procedure for "Seismic/Structural Qualification"

Table 1
Page 4 of 12

10 CFR 50 Appendix B Criterion	10 CFR 50 Appendix B QA Requirements	Alternate QA Requirements	Comparison
5. Instructions, Procedures, and Drawings (continued)	The implementing TVAN processes for the Appendix B QA requirements are SPP-2.1, "Administration of Standard Programs and Processes and Standard Department Procedures," SPP-2.2, "Administration of Site Technical Procedures," and SPP-2.3, "Document Control."	seismic Category I(L) Pressure Boundary and Position Retention items (Q10). The Implementing TVAN processes for the Alternate QA requirements are SPP-2.1, SPP-2.2, and SPP-2.3.	is NEDP-9. It addresses both Seismic Category I [Appendix B] and I(L) [Alternate QA] applications. There would be no significant differences in the Seismic/Structural Qualification requirements for this application. There would be no significant differences in Instructions, Procedures, and Drawings documentation for this application.
6. Document Control	Document Control activities would be activities would be per TVA's NQAP Section 6.2 for safety-related items. The implementing TVAN processes for the Appendix B QA requirements would be SPP-2.1 and SPP-2.3.	Applicable Document Control requirements are specified in NEDP-4 Appendix E, Element 6 for seismic Category I(L) Pressure Boundary and Position Retention items (Q10). The implementing TVAN processes for the Alternate QA requirements are SPP-2.1 and SPP-2.3.	There would be no difference in the TVAN Document Control processes, and the specific requirements for Alternate QA and Appendix B would be very similar. For this application, the QA Record documents would be maintained in a very similar manner for the Alternate QA and the Appendix B approaches. The extent of QA Record documents would be more for the Appendix B QA approach. However, the extent of QA Record documentation is sufficient using the Alternate QA approach.

Table 1
Page 5 of 12

10 CFR 50 Appendix B Criterion	10 CFR 50 Appendix B QA Requirements	Alternate QA Requirements	Comparison
7. Control of Purchased Material, Equipment and Services	Control of Purchased Material, Equipment and Services activities would be per TVA's NQAP Section 8.2 for safety-related items. The implementing TVAN processes for the Appendix B requirements are SPP-4.1 and SPP-4.2, "Material Receipt and Inspection."	Applicable Control of Purchased Material, Equipment and Services requirements are specified in NEDP-4 Appendix E, Element 7 for seismic Category I(L) Pressure Boundary and Position Retention items (Q10). The implementing TVAN processes for the Alternate QA requirements are SPP-4.1 and SPP-4.2.	There would be no difference in the Control of Purchased Material, Equipment and Services processes, but the specific process requirements for Alternate QA and Appendix B materials would be different. Refer to Criterion 4 above, Procurement Document Control, for comparison of the procured materials (new and existing) and services for this application, by the Alternate and the Appendix B approaches. For this application, new flexible and triangular ducting materials (for modification or maintenance) would be subject to similar receipt control and inspection requirements when using both Alternate QA and Appendix B approaches. In each case critical characteristics for acceptance would be utilized to assure that the item received is as specified. Reasonable assurance of critical material properties would be obtained in both cases and the appropriate overall quality of seismic qualification documentation would be applied. The difference in Control of Purchased Material, Equipment and Services documentation is acceptable for this application because compensating factors (refer to the comparison of key activities following this table) are present in the Alternate QA approach.

Table 1
Page 6 of 12

10 CFR 50 Appendix B Criterion	10 CFR 50 Appendix B QA Requirements	Alternate QA Requirements	Comparison
8. Identification and Control of Materials, Parts, and Components	Identification and Control of Materials, Parts, and Components activities would be per TVA's NQAP Section 8.3 for safety-related items. The implementing TVAN process for the Appendix B QA requirements is SPP-4.4, "Material Issue, Control, and Return".	Applicable Identification and Control of Materials, Parts, and Components requirements are specified in NEDP-4 Appendix E, Element 8 for seismic Category I(L) Pressure Boundary and Position Retention items (Q10). The implementing process for the Alternate QA requirements is SPP-4.4.	There would be no difference in the TVA Identification and Control of Materials, Parts, and Components processes, but the specific process requirements for Alternate QA and Appendix B materials would be different. For this application, new materials (for modification and maintenance) would be subject to the SPP-4.4 requirements in both cases. The flexible and triangular duct in the Main Control Room shall be procured to the UL -181 requirements. Also Modification and Maintenance activities would be performed in accordance with SPP-6.0, "Modification and Maintenance" in both cases." For the existing installation, reasonable assurance of adequate identification and control of existing materials and components was obtained from design documentation and field observation. The difference in Identification and Control of Materials, Parts, and Components documentation is acceptable for this application, because compensating factors (refer to the comparison of key activities following this table) are present in the Alternate QA approach.
9. Control of Special Processes	Control of Special Processes activities would be per TVA's NQAP Section 9.3 for safety-related items. The implementing TVAN General	Applicable Control of Special Processes requirements are specified in NEDP-4 Appendix E, Element 9 for seismic Category I(L) Pressure Boundary and Position	There would be no difference in the TVA Control of Special Processes general specifications but the specific process requirements for Alternate QA and Appendix B installation would be different. For future applications, the G-95 modification and maintenance

Table 1
Page 7 of 12

10 CFR 50 Appendix B Criterion	10 CFR 50 Appendix B QA Requirements	Alternate QA Requirements	Comparison
9. Control of Special Processes (continued)	Engineering Specification for the Appendix B QA requirements is G-95, "Installation Modification and Maintenance of HVAC Duct."	Retention items (Q10). The implementing TVAN General Engineering Specification for the Alternate QA requirements is G-95.	requirements will invoke the guidelines in North American Insulation Manufacturers Association (NAIMA) standard for fibrous glass duct construction. G-95 also includes construction requirements for metal ducting used for Appendix B and Alternate QA requirements. G-95 was first issued in 1990 and therefore was not applied to the original installation. The Alternate QA requirements prior to 1990 were less stringent. Special Processes used for the existing suspended ceiling and air delivery component installation were determined acceptable for seismic qualification based on existing design documentation, field examination, and structural analysis. QA Records of the original installation Special Processes activities were not located. The difference in Control of Special Processes documentation is acceptable for this application, because compensating factors (refer to the comparison of key activities following this table) are present in the Alternate QA approach.
10. Inspection	Inspection activities would be per TVA's NQAP Section 9.1 for safety-related items. The implementing TVAN procedures for the Appendix B QA requirements are Nuclear Assurance Department	Applicable Inspection requirements are specified in NEDP-4 Appendix E, Element 10 for seismic Category I(L) Pressure Boundary and Position Retention items (Q10).	Appendix B and Alternate QA program procedures require inspection and verification. However, the specific procedure requirements for Alternate QA and Appendix B installations would be different in some aspects. Line Verification and Graded QC Inspection for Alternate QA (quality related) installations at TVA Nuclear plants provide assurance that the installed and maintained configuration

Table 1
Page 8 of 12

10 CFR 50 Appendix B Criterion	10 CFR 50 Appendix B QA Requirements	Alternate QA Requirements	Comparison
10. Inspection (continued)	Procedure (NADP) 1, "Conduct of Quality Assessment and Inspection" and NADP-5, "Grading of Quality Assurance Records."	The implementing TVAN procedures for the Alternate QA requirements are NADP-1 and NADP-5.	is in compliance with applicable design output drawings and G-Spec requirements. In this case QC Inspection is only performed when specified on design output drawings or associated G-Specs. By comparison, both Line Verification and QC Inspections would be performed for Appendix B (safety-related) installations. For the current installation, Line Verification has been performed for maintenance repairs and that practice will continue for any future repairs and modifications. Inspection/Verification of the existing installation was determined acceptable for seismic qualification based on existing design documentation, field examination, and structural analysis. The difference in Inspection and Verification documentation is acceptable for this application because compensating factors (refer to the comparison of key activities following this table) are present in the Alternate QA approach.
11. Test Control	Test Control activities would be per TVA's NQAP Section 9.4 for safety-related items. The implementing TVAN G-Spec for the Appendix B QA requirements is G-37,	Applicable Test Control requirements are specified in NEDP-4 Appendix E, Element 11 for seismic Category I(L) Pressure Boundary and Position Retention items (Q10).	Both the Appendix B and Alternate QA programs require test control; however, the Appendix B warrants additional testing over that required for Alternate QA. In addition, the rigor of acceptance criteria and level of documentation of testing is greater for the Appendix B QA than that required for Augmented QA. However, the

Table 1
Page 9 of 12

10 CFR 50 Appendix B Criterion	10 CFR 50 Appendix B QA Requirements	Alternate QA Requirements	Comparison
11. Test Control (continued)	"Testing and Balancing of HVAC Systems During Installation, Modification, and Maintenance."	The implementing TVAN G-Spec for Alternate QA requirements is G-37.	testing control required for this application is adequate to ensure the equipment will perform as designed.
12. Control of Measuring and Test Equipment	Control of Measuring and Test Equipment activities would be per TVA's NQAP Section 9.5 for safety-related items. The implementing TVAN G-Specs for the Appendix B QA requirements are G-37 and G-95.	Applicable Control of Measuring and Test Equipment requirements are specified in NEDP-4 Appendix E, Element 12 for seismic Category I(L) Pressure Boundary and Position Retention items (Q10). The implementing TVAN G-Specs for the Alternate QA requirements are G-37 and G-95.	There is no significant difference in the Control of TVA Measuring and Test Equipment general specifications, and the specific specification requirements for Alternate QA and Appendix B would be very similar. HVAC system flow tests would accurately measure flow in accordance with the applicable testing requirements in either case.
13. Handling, Storage and Shipping	Handling, Storage and Shipping would be per TVA's NQAP Section 9.6 for safety-related items. The implementing TVAN process for the Appendix B QA requirements is SPP-4.3, "Material Storage and Handling."	Applicable Handling, Storage and Shipping requirements are specified in NEDP-4 Appendix E, Element 13 for seismic Category I(L) Pressure Boundary and Position Retention items (Q10). The implementing TVAN process for the Alternate QA requirements is SPP-4.3.	There is no difference in the process for Handling, Storage and Shipping for Appendix B and Alternate QA materials for this application. New triangular or flexible duct material (for modification or maintenance) would be handled, stored and shipped in the same manner for both Appendix B and Alternate QA requirements.

Table 1
Page 10 of 12

10 CFR 50 Appendix B Criterion	10 CFR 50 Appendix B QA Requirements	Alternate QA Requirements	Comparison
14. Inspection, Test, and Operating Status	Inspection, Test, and Operating Status activities would be per TVA's NQAP Section 9.7 for safety-related items. The implementing TVAN process for the Appendix B QA requirements is SPP-10.1, "System Status Control."	Applicable Inspection, Test, and Operating Status requirements are specified in NEDP-4 Appendix E, Element 14 for seismic Category I(L) Pressure Boundary and Position Retention items (Q10). The implementing TVAN process for the Alternate QA requirements is SPP-10.1.	There would be no difference in the TVA Inspection, Test, and Operating Status processes for Alternate QA and Appendix B QA programs. There would be no significant difference in Inspection, Test, and Operating Status documentation for this application.
15. Nonconforming Materials, Parts, and Components	Nonconforming Materials, Parts, and Components activities would be per TVA's NQAP Section 10.2.1 for safety-related items. The implementing TVAN process for the Appendix B QA requirements is SPP-3.1, "Corrective Action Program."	Applicable Nonconforming Materials, Parts, and Components requirements are specified in NEDP-4 Appendix E, Element 15 for seismic Category I(L) Pressure Boundary and Position Retention items (Q10). The implementing TVAN process for the Alternate QA requirements is SPP-3.1.	There would be no difference in the TVA Nonconforming Materials, Parts, and Components process, and the specific process requirements for Alternate QA and Appendix B would be very similar. The possibility of an unacceptable material for the existing application is very remote considering the field examination, repair, document review, and seismic qualification activities. There would be no significant difference in Nonconforming Materials, Parts, and Components documentation for this application.

Table 1
Page 11 of 12

10 CFR 50 Appendix B Criterion	10 CFR 50 Appendix B QA Requirements	Alternate QA Requirements	Comparison
16. Corrective Action	Corrective Action activities would be per TVA's NQAP Section 10 for safety-related items. The implementing TVAN process for the Appendix B QA requirements is SPP-3.1.	Applicable Corrective Action requirements are specified in NEDP-4 Appendix E, Element 16 for seismic Category I(L) Pressure Boundary and Position Retention items (Q10). The implementing TVAN process for the Alternate QA requirements is SPP-3.1.	There would be no difference in the TVA Corrective Action process and documentation for the Alternate QA and the Appendix B QA programs. There would be no significant difference in Corrective Action documentation for this application.
17. Quality Assurance Records	Quality Assurance Records activities would be per TVA's NQAP Section 6.3 for safety-related items. The implementing TVAN process for the Appendix B QA requirements is SPP-2.4, "Records Management."	Applicable Quality Assurance Records requirements are specified in NEDP-4 Appendix E, Element 17 for seismic Category I(L) Pressure Boundary and Position Retention items (Q10). The implementing TVAN process for the Alternate QA requirements is SPP-2.4.	For this application, the Alternate QA focus is on assuring structural integrity and flow delivery during a design basis seismic event, concurrent with normal operation. Sufficient QA Record documentation is produced for that purpose. However, the Alternate QA approach results in a lesser quantity of QA Record documentation than required for full Appendix B compliance. The differences are primarily in Material and QC Inspection documentation. The difference in QA Records documentation is acceptable for this application, because compensating factors (refer to the comparison of key activities following this table) are present in the Alternate QA approach.

Table 1
Page 12 of 12

10 CFR 50 Appendix B Criterion	10 CFR 50 Appendix B QA Requirements	Alternate QA Requirements	Comparison
18. Audits	Audits activities would be per TVA's NQAP Section 12 for safety-related items. The implementing TVAN procedures for the Appendix B QA requirements are NADP-1, "Conduct of Quality Assessment and Inspections" and NADP-2, "Audits."	Applicable Audits requirements are specified in NEDP-4 Appendix E, Element 18 for seismic Category I(L) Pressure Boundary and Position Retention items (Q10). The implementing TVAN procedures for Alternate QA requirements are NADP-1 and NADP-2.	There would be no difference in the TVA internal Audits procedures, and the specific internal TVA process requirements for Alternate QA and Appendix B would be very similar. There would be no significant difference in the TVA Audit documentation for this application.

TVA Response (NRC Request - Item 1 continued)

a. The Key Alternate QA Activities for seismic qualification of the WBN suspended ceiling and air delivery components were:

   i. Visually inspect the existing suspended ceiling and air delivery components for damage, material deterioration, or deviation from the original design. Based on that inspection, make any needed repairs or replacements. Replace any degraded tape.

   ii. Establish appropriate member and material properties for use in seismic qualification analysis, based on existing documentation (drawings, calculations, and contract documents) plus supplementary field inspection data, as needed.

   For example, the material specification for the aluminum grid members was obtained from original contract documentation. Section properties for the grid members were obtained from existing calculations and verified by field examination. Dimensions of the triangular ducts were verified by field examination. The overall configuration was obtained from existing drawings and verified by field examination. Needed repairs were identified by field examination.

   iii. Seismically qualify the suspended ceiling and air delivery components for WBN design basis loading conditions. Demonstrate that the suspended ceiling remains structurally stable with appropriate margin and that functionality of the air delivery components is maintained during and after the design basis seismic event. Determine whether modifications to the original design are needed.

   iv. Issue design output requiring periodic inspections, maintenance, and testing to ensure that the air delivery components remain as seismically qualified and that duct flow remains within acceptable limits. Also upgrade design output drawings to ensure configuration control is maintained.

b. The Key Appendix B QA Activities for equipment assemblies of this type would typically be:

   i. Procure the suspended ceiling and air delivery components from a vendor. Contractually, assign seismic qualification responsibilities to the vendor. Ensure that material properties used in qualification by analysis are conservative and reliable. (Documented material property justification would be a vendor responsibility.) Require qualification in accordance with NRC approved criteria for WBN.

ii. Review and approve the seismic qualification report, design output drawings, and vendor manuals to be used for installation and configuration control.

iii. Install the assembly and perform QC verification of the installation.

iv. Maintain configuration control and perform any required modifications in accordance with approved design and modification procedures.

c. Comparison of Key Activities and End Products:

The Alternate QA and the Appendix B QA activities produce similar end products:

i. Seismically qualified installation,
ii. Design output drawings,
iii. Maintenance and test requirements, and
iv. Seismic qualification reports.

The main differences in the Alternate QA and Appendix B QA activities would be in the timing and responsibilities for the end products. The supporting QA documentation would be more extensive for the Appendix B activities, as indicated in the preceding table. Material property and QC inspection documentation would be more rigorous and detailed for the Appendix B installation. For example, QC inspection results for the Appendix B installation would be extensive and readily retrievable. Also material properties would be readily available in vendor contract documentation as QA Records.

However the actual factors of safety against structural or pressure boundary failure for the Alternate QA (Seismic Category I(L)) activities would be at least equal to the factors of safety ensured by Appendix B (Seismic Category I) activities, as indicated by the responses to Requests 8, 13, and 14. In each case seismic qualification would be by analysis, test, or a combination of analysis and test.

Based on this comparison, the Alternate QA activities outlined herein are adequate to ensure safe function in the areas important to seismic qualification.

NRC Request - Item 2: WBN RAI 2 addressed in SQN Licensing Submittal, Enclosure 1 Sections 3.0 and 4.0.

The first paragraph of Page E1-7 refers to the use of a transient dynamic finite element analysis of the air delivery components that are non-conservative in some aspects relative to linear elastic analysis methods. Discuss key aspects of the above noted analytical non-conservatism and explain how the overall effect of the non-conservative seismic response results are adequately accounted for in WBN's seismic qualification of safety related ducting for the CB HVAC system.

TVA Response: WBN RAI 2 addressed in SQN Licensing Submittal, Enclosure 1 Section 3.0 and 4.0.

The following response is in two parts:

a. Clarification of Intent:

Referring to the words in the first sentence of the Request:
"... a transient dynamic finite element analysis of the air delivery components that are non-conservative in some aspects relative to linear elastic analysis methods."

What was intended, is more accurately expressed by the following revised words:
"... a transient dynamic finite element analysis of the air delivery components that is generally more realistic and reduces conservatism in some aspects relative to linear elastic analysis methods."

b. Discussion:

The non-linear Time History (T-H) analysis (i.e. transient dynamic finite element analysis) provides more realistic results (closer to actual response) than would be obtained from linear elastic response spectra analysis of the suspended ceiling and air delivery components using the linear elastic analysis criteria. For example, the linear elastic analysis criteria would require assumption of: 1) low structural damping, and 2) no gaps, impact loads, internal friction or other non-linear effects. For the suspended ceiling, where the luminous panels represent a large portion of the overall mass (in the order of 70 percent of the total suspended mass) and undergo sliding against friction within the ceiling grid, use of standard linear elastic analysis methodology would result in significantly conservative prediction of the response.

Since shake table testing of the entire assembly would be impossible due to the size and complexity of the assembly, non-linear time history analysis was chosen as the best (i.e. most accurate) available alternative.

The key factor in seismic qualification of the air delivery components is a demonstration that the aluminum air bars remain structurally stable and provide continuous support for the triangular ducts. That fact is demonstrated directly in the ANSYS model results, as described on Sheet 26 of Report 1116518-R-001 (included in Enclosure 2 of TVA's March 12, 2003, license amendment request).

Qualification of the attached triangular duct and flexible duct is then justified as described on Pages 26 through 29 of Report 1116518-R-001.

A level of assurance of the validity of the ANSYS results for the nonlinear time history analyses of the WBN ceiling structure is provided by the various verification problems in the ANSYS Verification Manual that include one or more of the particular features present in the WBN model. These include the following:

- Nonlinear time history analysis
- Nonlinear spring elements
- Coulomb friction
- Gap/Impact condition
- Geometric nonlinearity and/or buckling condition

Of the total of 249 verification problems included in the ANSYS Version 5.7, Verification Manual, nine sample problems, with at least one of these features employed in each, are identified in Table 2 below. A copy of the detailed description of each of the problems, cut from the ANSYS Version 5.7 Verification Manual, is provided in Enclosure 2 of this submittal. For each problem, the description provides (a) reference to a, "standard" text that details the "exact" analytical solution for the problem and (b) comparison of this exact result to the solution obtained with ANSYS.

Table 2
Verification Problems Included in the ANSYS Version 5.7, Verification Manual

Verification Problem	NonLinear T-H Analysis	NonLinear Spring	Coulomb Friction	Gap/ Impact	Geom. NL and/or Buckling
VM9 Large Lateral Deflection of Unequal Stiffness Springs	X	X			
VM21 Tie Rod with Lateral Loading					X
VM31 Cable Supporting Hanging Loads					X
VM73 Free Vibration with Coulomb Damping	X		X		
VM79 Transient Response of a Bilinear Spring Assembly	X	X		X	
VM83 Impact of a Block on a Spring Scale	X			X	
VM85 Transient Displacement in a Suddenly Stopped Moving Bar	X			X	
VM136 Large Deflection of a Buckled Bar					X
VM156 Natural Frequency of a Nonlinear Spring-Mass System	X	X			

NRC Request - Item 3: WBN RAI 3 addressed in SQN Licensing Submittal, Enclosure 1 Section 3.0

With respect to the first paragraph of Page E1-7, you stated that NRC has not approved the application of the time history analysis methodology for qualification of the air delivery components, however, the methodology has been approved for other WBN applications. Is the time history analysis methodology currently used for qualification of the air delivery components identical to the one previously approved by the NRC? As applicable, discuss and justify any elements of the current methodology that are different from those of the one previously approved by the NRC.

TVA Response: WBN RAI 3 addressed in SQN Licensing Submittal, Enclosure 1 Section 3.0.

Non-linear finite element T-H analysis for seismic qualification of the suspended ceiling and air delivery components applies the same basic structural analysis methods as used for seismic qualification of the seismic Category I WBN ice condensers and fuel racks.

Ice condenser analyses, described in WBN Updated Final Safety Analysis Report (UFSAR) Section 6.7.17, were performed by Westinghouse using their Proprietary software. Those analyses include consideration of gaps, sliding, impact loads, and increased effective damping. Fuel rack analyses were performed by Holtec using their proprietary software. Those analyses are briefly described in UFSAR Section 9.1.2.3.

The suspended ceiling and air delivery component analyses were performed by ABS Consulting (formerly EQE Incorporated) using ANSYS software. The analysis runs were made on TVA's QA verified ANSYS installation. ABS reviewed the error reports (issued by ANSYS Inc. as part of the QA program) applicable to this ANSYS installation and determined that none of the errors have any impact on the element types or features used in the analysis (reference Appendix E of Report 1116518-R-001).

In summary, the same basic analytical methods were used for previously approved and current analyses. The current analyses are not identical to previously approved analyses, but they were performed by an industry expert using QA verified software. Consequently, the quality and accuracy of the current analysis results is expected to be equivalent to previously approved non-linear time history seismic analyses for safety-related seismic Category I equipment assemblies at WBN.

NRC Request - Item 4: WBN RAI 4 addressed in SQN Licensing Submittal, Enclosure 1 Section 4.0.

The second paragraph of Page E1-8 refers to the use of a transient dynamic finite element analysis of the air delivery components using ANSYS general purpose finite element software (Reference 3). Discuss key assumptions and limitations of the ANSYS program used that are applicable to the full model shown on Figure 2-2 and how the assumptions and the limitations are properly integrated into WBN's formulation of the 3-D MCR suspended ceiling finite element model.

TVA Response: WBN RAI 4 addressed in SQN Licensing Submittal, Enclosure 1 Section 4.0.

The features of the WBN suspended ceiling and air delivery components model include, in addition to modeling aspects customarily included in the, "conventional" linear structural models, nonlinear element types to represent gaps and sliding, with friction, "across" the gaps, and geometric nonlinearity effects. The nonlinear gap/sliding element types and the associated modeling assumptions that are described on Pages A-3 through A-5 of Appendix A of the WBN license amendment submittal are, "standard" implementations of gap/sliding modeling in general purpose nonlinear finite element software. The properties, gap widths and friction coefficient values, assigned to these elements are based on information provided on design/vendor drawings for the WBN installation and on observations in the field. For example, the general configuration was observed to be consistent with the design output drawings and the gap around the outer periphery of the suspended ceiling was observed to vary from zero to approximately 1/8-inch. There are no additional assumptions/limitations to the ones described on Pages A-3 through A-5 of Appendix A of the WBN license amendment submittal. Modeling was done in a manner consistent with the ANSYS user's manuals. The proper function of the selected elements is covered by the ANSYS program QA. The treatment of geometric nonlinearity effects is consistent with the standard formulations developed for nonlinear finite element applications.

ANSYS is a general-purpose finite element software, with modeling and solver capabilities that are more extensive than those implemented in several other finite element codes often used for civil/structural analyses. ANSYS Inc. supports a 10 CFR 50 Appendix B compliant QA verification program (including verification problems and error notices). The WBN control room suspended ceiling analyses were performed using TVA's ANSYS installation that has been verified to this 10 CFR 50 Appendix B compliant QA verification package. The non-linear time history analyses were run by ABS Consulting on a TVA computer server, using TVA's QA verified ANSYS version 5.7 software. In addition, ABS reviewed the ANSYS version 5.7 software error reports and determined that none of them could have any impact on the analysis. Their review of the error reports is documented in Report 1116518-R-001 Appendix E (provided in Enclosure 3 of this submittal). ANSYS has been widely used in nuclear, aero-space, maritime, oil and gas, and electronics industries to solve linear and nonlinear structural stress and dynamics problems (as well as problems involving heat transfer, fluid flow and electro-magnetism). Such wide use of the software over the last several decades provides a level of additional assurance of the quality and verification of the software.

This analysis was well within the capability of the ANSYS program and the knowledge level of the analysts.

NRC Request - Item 5: WBN RAI 5 addressed in SQN Licensing Submittal, Enclosure 1 Section 4.0.

The last two sentences of Page E1-9 state, "The flexible and triangular duct capacities were based on analysis for potential failure modes, industry precedents, and the analytical determination that the ceiling grid work remains stable. Other suspended ceiling components, including luminous panels, were shown to remain in their position during and after the SSE." Discuss the specific potential failure mode analyses performed, applicable test-based component capacity data and key applicable industry precedents considered in confirming the seismic resistant capacities for the flexible and triangular ducting. Also, discuss WBN's basis for asserting that suspended ceiling components were shown to retain their position and physical configuration as well as maintain ducting pressure boundary during and after the SSE. The staff is particularly interested in WBN's discussion of available observed or experimentally obtained HVAC components seismic response data (including round flexible and triangular ducting) that offer reasonable basis for the above assertion. The substance of this RAI also applies to the italicized sentences of Notes 2 and 4 of Page E1-10 proposed for revising UFSAR tables 3.2-2a and 3.2-6, respectively.

TVA Response: WBN RAI 5 addressed in SQN Licensing Submittal, Enclosure 1 Section 4.0.

The suspended ceiling grid-work, support wires, and luminous panels are explicitly modeled and their response determined from the ANSYS T-H analysis. Effective masses of the triangular and flexible ducts are also attached to the air bars which are main structural members in the grid-work. The ANSYS output is the basis for asserting that the grid-work remains stable and the luminous panels remain in place. Most importantly, deformations in the air bars and the T-bars are negligible as they were demonstrated not to buckle, and at the ceiling perimeter displacements are limited to 1/8-inch, the approximate gap width along the perimeter. For very light items such as both the triangular and flexible round duct, both theory and seismic experience data support that deformation demand tends to be the important determinant of seismic performance, inertial loading being typically insignificant. This is supported by seismic experience data for various types of HVAC ducting as documented in Electric Power Research Institute (EPRI) Report No. 1007896, "Seismic Evaluation Guidelines for HVAC Duct and Damper System," April 2003.

The database includes information on HVAC duct performance at thirty eight sites, in fifteen earthquakes varying in magnitude from 5.5 to 8.1 with peak ground accelerations ranging from 0.25 g to 0.85 g, at the investigated sites. Collectively, these sites contained thousands of HVAC duct spans. In general, duct systems exhibited good seismic behavior, with few instances of damage or failure. Where damage or failure occurred, it could be attributed to a particular inadequate design or construction aspect, or to seismic spatial interaction. The design aspects demonstrated by the experience data as causing vulnerability to seismic damage are as follows:

a. Inadequate connection detail either between two adjacent duct sections or at a point where a grille/diffuser connects to duct, e.g., a lap joint either with small number of rivets or relying on friction only.

b. Inadequate range of free displacement in the bellows connecting duct to equipment in an installation where either or both are on flexible supports and therefore subject to significant differential displacement. (In some cases, equipment such as air handling units or fans have been mounted on inadequately designed vibration isolators with the result that the equipment dislodged and the bellows tore.)

c. Inadequate supports.

d. The end of a long flexibly supported duct run not attached to the last support.

With the absence of any of these features in the triangular duct and the flexible round ducting in the WBN Control Room ceiling installation, the earthquake experience data clearly supports the capability of this ducting to withstand the WBN SSE without loss of structural integrity.
The triangular duct is continuously supported by the air bars and is also supported by support rods on 4-foot centers. Thus it has redundant support load paths and is primarily loaded by self-weight seismic inertial loads. Those loads are small due to the light weight of the ducting material and well within the structural capacity of the triangular duct material. Additional justification for qualification of the triangular ducts is provided on Sheets 26 through 28 of report 116518-R-001 (included in Enclosure 2 of TVA's March 12, 2003, license amendment request).

The flexible ducts in this application are similar to flexible hoses and ducts which have been seismically tested in numerous applications and as part of equipment assemblies. Seismic testing and earthquake performance experience indicate that flexible hoses and ducts which are properly designed for their pressure and flow delivery loads do not fail due to seismic inertial loads. Failure may occur due to excessive relative end movements. In the current application, the flexible ducts have been properly designed for their flow delivery function and the relative end movements have been shown to be small and well within the end movement capabilities of the ducts. The flexible ducts have been visually examined to verify that the ducts are properly installed and not degraded. Additional justification for qualification of the flexible ducts is provided on Sheets 28 and 29 of Report 116518-R-001 (included in Enclosure 2 of TVA's March 12, 2003, license amendment request). Refer to the responses for Item 13 and 14 for additional information on seismic qualification of the triangular and flexible ducts, respectively.

NRC Request - Item 6: Request and response apply to SQN with no changes.

The first paragraph on Sheet 3 of Enclosure 3 states that both the suspended ceiling and the air delivery components have been classified as Seismic Class I(L) with special requirements on position retention, structural integrity and maintaining flow delivery function. Explain both the analytical as well as component performance/test based considerations that form the basis for defining the special requirements attributable to a Category I(L) component. Also, indicate key differences from a structural performance/integrity perspective between a Seismic Category I component and one categorized as Seismic Category I(L).

TVA Response: Request and response apply to SQN with no changes.

Functionality of the air delivery components is assured by the structural integrity of the air delivery components. Structural integrity is assured for the design bases SSE as described above. From a structural integrity/performance perspective there is no significant difference between air delivery components classified as Seismic Category I(L) with special requirements for structural integrity and flow delivery and air delivery components classified as Seismic Category I. Both perform exactly the same function.

The credible mechanisms for reducing, cutting off, or restricting flow from the metal supply ducting to the MCR airspace are fully addressed by the seismic qualification analysis and supported by the Alternate QA Requirements. Refer to the response for Item 1 for additional information.

NRC Request - Item 7: Request and response apply to SQN with minor editorial changes, as marked.

Third paragraph on Sheet 3 of Enclosure 3 states that during the level of seismic response implied by the ~~WBN~~ SQN SSE, with a peak ground acceleration of 0.18 g, the response of the ceiling structure will involve significant nonlinear behavior resulting in significant damping in excess of the level, e.g., 5% or 7%, typically used in structural design. Discuss the basis for your statement and, as available, provide a quantitative or an earthquake-experience based justification for this ~~WBN's~~ SQN's assertion.

TVA Response: Request and response apply to SQN with minor editorial changes, as marked.

This statement expresses an expectation, considering the construction of the suspended ceiling and air delivery components. Regulatory Guide 1.61, Damping Values for Seismic Design of Nuclear Power Plants," specifies a damping of 7 percent of critical for bolted steel structures subject to SSE. However, the SQN FSAR restricts this damping value to 5 percent of critical. On this basis, ~~7~~ 5 percent damping should be used for a structure consisting of just the air-bars and the intersecting T-bars bolted together, i.e., the grid without the luminous panels that (a) account for roughly 70 percent of the total suspended mass and (b) are subject to sliding against friction within the grid panels. The ~~WBN~~ SQN ceiling is constructed such that significant non-linear behavior and associated increased damping is expected. That expectation is borne out by the actual analysis results. The damping used in modeling the linear elastic portion of the seismic response prediction is actually ~~significantly~~ less than ~~7~~ 5 percent of critical as shown by the figure on Sheet 11 of report 1116518-R-00~~1~~2. This is rationale to preclude, "double counting" the energy dissipation in the system.

Raleigh proportional damping (refer to Item 11 response) simulates the effective damping which would occur in the suspended ceiling grid-work in the absence of gaps and sliding of the ceiling panels with associated friction (directly simulated in the model). The grid-work members (airbars and T-bars) are attached to each other by mechanical connections. No friction is directly simulated in the mechanical connections between grid-work members.

NRC Request - Item 8: RAI 8 is unique to WBN. RAI 8 does not apply to SQN.

Last paragraph on Sheet 3 of Enclosure 3 indicates that the WBN SSE Set B (Evaluation) time histories were used as the input motion in the time history analysis of the CR HVAC components. Also discussed in this paragraph are methods used to account for uncertainties involved in dynamic modeling, shifting in the response spectrum peak frequency, and an indirect way of incorporating a design safety factor of 1.3. Confirm that the above SSE Set B (Evaluation) time histories were previously reviewed and accepted by the NRC staff as part of the WBN's current licensing basis (CLB) for seismic analysis and design. Also, discuss briefly WBN's basis for selecting time histories applicable to elevation 771', node 310 (North-East corner) as input motions for the transient finite element seismic analysis of CR suspended ceiling.

TVA Response: RAI 8 is unique to WBN. RAI 8 does not apply to SQN.

The Set B input and response spectra were developed by TVA-WBN before startup in response to an Outstanding Issue in the Safety Evaluation Report (SER). They are implemented by TVA-WBN in accordance with UFSAR Sections 3.7, 3.7.1, 3.7.2, and 3.7.3. The associated NRC Safety Evaluations are documented in NUREG-0847 Supplements 6, 7, 8, 9, 11, and 12. Supplement 6 is the primary SER directly related to Set B. The suspended ceiling and air delivery component analysis has been performed in accordance with proposed new UFSAR Section 3.7.3.18.

The seismic analysis of the Auxiliary-Control Building is documented in TVA-WBN Report CEB-80-27 R4. Node 310 of the Auxiliary-Control Building Set B model is at the extreme south-west corner of the building (column line N) at Elevation 771.5. It was chosen because it captures the torsional response of the building due to East-West input for the MCR which is located in the south end of the building. The MCR floor is at Elevation 757 and the suspended ceiling is at Elevation 765. Thus, node point 310 is above and outside (relative to building center of rigidity) the MCR suspended ceiling location. Therefore conservative input motion for analysis of the existing suspended ceiling and air delivery components is provided by use of the Set B time history at node 310. The amplitude of that time history input was multiplied by 1.3 to ensure an adequate safety factor.

By comparison, seismic SSE testing per WBN UFSAR Section 3.7.3.16 ensures a safety factor of 1.1 against structural failure or loss of function. Analysis of seismic Category I and I(L) equipment assemblies for SSE conditions per Section 3.7.3.16 assures a safety factor of about 1.2 to 1.4 against structural failure due to elastic buckling or plastic deformation. Analysis of seismic Category I and I(L) duct supports for SSE conditions per UFSAR Section 3.7.3.17 ensures a safety factor of about 1.1 to 1.3 against structural failure due to elastic buckling or plastic deformation. Actual safety factors against structural failure for most of the seismic Category I and I(L) equipment and supports at WBN are substantially more than these minimum ensured values. The actual safety factor against structural failure of the WBN suspended ceiling is also substantially more than 1.3, based on ABS Report 1116518-R-001.

NRC Request - Item 9: Request and response apply to SQN with minor editorial changes, as marked.

Referring to the second paragraph on Sheet 4 of Enclosure 3, briefly summarize the scope and results of a hand calculation method performed earlier as part of the ceiling grid functionality evaluation, and compare key results of the hand calculation to those results obtained from the transient finite element non-linear dynamic analysis for the ~~WBN~~ SQN CB ceiling structure.

TVA Response: Request and response apply to SQN with minor editorial changes, as marked.

The hand calculation addressed the as-found condition on ~~September 30, 2002~~, relative to the potential for instability of the suspended ceiling air bars, due to impact of the suspended ceiling with the border structure attached to the MCR walls. If the air bars were to buckle or distort significantly the attached triangular ducts could also be damaged, causing potential loss of function. Earthquake experience indicated this as the critical failure mode. The hand calculation utilized the equivalent static analysis method and analytical assumptions based on experience insights and engineering judgments. For example, the peak of the ~~7~~ 5 percent damped response spectra and a 1.0 multimode factor were used for buckling instability evaluation. This hand calculation Functionality Evaluation is included in Appendix D of Report 1116518-R-00~~1~~2. Conclusions from the hand calculation were:

a. Buckling of the suspended ceiling grid work will not occur.
b. The safety factor against structural failure of an air bar is greater than ~~1.5~~ 1.3 and probably as high as ~~2.0~~ 1.8.
c. A safety factor of at least ~~2.1~~ 1.8 is present against structural failure of the T-bars.
d. Functionality of the flow diffusers (triangular ducts) and flexible ducts is assured.
e. The panels (vinyl light diffusers and aluminum louvers) will ~~retain their installed positions~~ not fall.

Some key results from the hand calculation and the non-linear time history analysis are compared at the bottom of Page ~~18~~ 17 and top of Page ~~19~~ 18 of Report 1116518-R-00~~1~~2. Those results and a few others are listed in Table 3 below. The comparison indicates the hand calculation results are conservative relative to the non-linear time history seismic qualification analysis.

Table 3
Key Results from the Hand Calculation and the Non-linear Time History Analysis

	Air Bar Compressive Force(2) (LB)	T-Bar Compressive Force (LB)	Typical Wire Min. Tensile Force(2) (LB)
Hand Calc(1)	~~4213~~ 1777	~~393~~ 269	~~3.7~~ 0.5
T-H Analysis	~~1254~~ 810	~~284~~ 183	~~9.4~~ 10.9

(1) Hand calculation results have been multiplied by 1.3 for direct comparison to T-H analysis results.

(2) Air bar compressive force and typical support wire minimum loads are indicators of the potential for air bar buckling. Typical support wire deadweight load is 24 pounds. Lower compressive force in an air bar and higher wire force, indicates less potential for air bar buckling.

A safety factor greater than 2 against structural failure of an air bar is predicted based on the T-H analysis results (reference Sheet ~~36~~ 23 of Report 1116518-R-00~~1~~2).

NRC Request - Item 10: Request and response apply to SQN with minor editorial changes, as marked.

The last part of the fourth paragraph on Sheet ~~28~~ 25 of Enclosure 3 states that, "With this configuration, a connection between two adjacent sections is not subject to relative displacements and the connection, with special reinforced tape wrapped over the connection area, will maintain integrity and functional capability." Given the facts that prior reinforced tape related degradation and air leakage of the ducting were observed at WBN and the lack of long term functionality/integrity testing data for the ducting, elaborate on ~~WBN's~~ SQN's basis for drawing the above conclusion.

TVA Response: Request and response apply to SQN with minor editorial changes, as marked.

Previously existing degraded and/or damaged tape has been replaced with new reinforced tape of the type recommended by the vendor. In addition, ~~WBN~~ SQN has issued design output documents in ~~Engineering Documentation Change (EDC) E-51362-A and System Description N3-30CB-4002~~ Design Change Notice (DCN) D-21359-A and Drawing 46W402-3 requiring periodic inspections (at 36 month intervals) of the flexible and triangular ducting to ensure that they remain in good condition and that any degraded or damaged tape is promptly replaced before the degradation or damage becomes significant.

The installed reinforced tape has adequate adhesion, tension, and shear properties to withstand the small seismic inertial forces between sections of the triangular duct without structural damage or loss of functionality.

NRC Request - Item 11:

Request and response apply to SQN with minor editorial changes, as marked.

The first paragraph on Sheet 11 of Enclosure 3 states that Raleigh proportional damping with mass and stiffness proportional coefficients of 0.2 and 0.001, respectively, was used in the transient dynamic analysis. Discuss your rationale for selecting these proportional damping coefficients. Are these coefficients derived from applicable vendor model testing results or pertinent data based on past earthquake experience? Also, discuss pertinent ANSYS code verification data that support the use of the above proportional damping coefficients.

TVA Response:

Request and response apply to SQN with minor editorial changes, as marked.

Raleigh proportional damping is a commonly used method to represent damping in structural systems. The method involves representation of a viscous damping matrix D as a linear combination of the mass and stiffness matrices (M and K) as follows:

$$D = \alpha M + \beta K$$

As derived in the theory of dynamics of multi-degree of freedom systems (see e.g., R. W. Clough and J. Penzien, "Dynamics of Structures,' McGraw-Hill, Chapter 19-3), damping coefficient in each of the modes ξ_k can be expressed in terms of the proportionality coefficients α and β, and the modal natural angular frequency, ω_k, as:

$$\xi_k = \frac{1}{2}(\frac{\alpha}{\omega_k} + \beta\omega_k)$$

The figure on the referenced Sheet 11 of Enclosure 3 of TVA's ~~March 12, 2003~~, license amendment request illustrates this dependency of the modal damping ξ_k as a function of the modal angular frequency ω_k (for α = 0.2 and β = 0.001).

As is stated on the referenced Sheet 11:

> "At the frequency of ideal pendulum with wire length of 24" of 0.64 Hz, the above results in less than 3 percent damping, and the damping remaining below 5 percent up to about 16 Hz. Use of linear elastic damping of ~~7~~ 5 percent would be consistent with the ~~WBN~~ SQN UFSAR requirements for linear elastic analysis of the suspended ceiling."

The 7 5 percent damping of WBN SQN UFSAR is consistent with conservative relative to guidelines in Regulatory Guide 1.61 which specifies a damping of 7 percent of critical for bolted steel structures. Damping criteria guidelines, such as the damping of 7 percent of critical for bolted steel structures, are based on information accumulated from experience and tests on various, "generic" categories of structures/construction. They are typically not based on vendor test information. On this basis, if the ceiling consisted just of the grid members, i.e., the air-bars and the intersecting T-bars, linear analysis of this structure could be performed using 7 5 percent damping.

In nonlinear analysis such as conducted for the WBN SQN suspended ceiling, damping (energy dissipation) is incorporated in the model not only through the Raleigh proportional damping, but also through inclusion of energy dissipating friction elements at the luminous panel grid interface. To avoid unrealistically over-damping the system, the Raleigh proportional damping is specified lower than the 7 5 percent guideline FSAR value intended for use in linear analysis.

The Raleigh proportional damping method is a product of the classical structural dynamics theory and has been implemented in various structural analysis/dynamics software. The Raleigh damping is implemented in ANSYS as part of the commonly used Newmark- β time stepping algorithm (as in some other codes with structural dynamics capabilities). Verification of these aspects of the ANSYS code are covered by the overall QA of the software.

NRC Request - Item 12:

Request and response apply to SQN with minor editorial changes, as marked.

The first paragraph on Sheet 12 of Enclosure 3 states that there is very little cross coupling between the North-South and East-West responses. Discuss WBN's SQN's quantitative basis for asserting that only minimal cross coupling effects exist for the Main Control Room ceiling system. Also, indicate how your sub-modeling approach in the proposed analysis affect the results when compared with a rigorous 3-D seismic response analysis. Discuss WBN's SQN's specific method used to combine the seismic responses due to each of the three component earthquake time history motions.

TVA Response:

Request and response apply to SQN with minor editorial changes, as marked.

Category I and I(L) equipment and fluid system components at WBN SQN are seismically qualified by analysis or test by 2D Methodology (Larger of North-South + Vertical and East-West + Vertical) and IEEE 344-1975 as described in UFSAR Section 3.7.3.6.3. The suspended ceiling and air delivery components constitute a non-NSSS equipment assembly and the analysis results presented in Report 1116518-R-0012 comply with the 2D Methodology described in UFSAR Section 3.7.3.6.3 SQN Equipment Seismic Design Criteria.

In addition, the suspended ceiling configuration precludes significant cross-coupling in the North-South and East-West directions because the main structural members T-bars and air bars are in the North-South East-West and East-West North-South directions, respectively.

Both the North-South and East-West strip models are subjected to the same vertical time history input. Examination of the results on Page ~~18~~17 of Report 1116518-R-00~~1~~2 indicates that the calculated minimum wire forces for the North-South and East-West strip models are nearly the same, indicating that the vertical response is dominated by vertical input and that there is very little cross-coupling between North-South or East-West, as expected.

Finally, the structural margins determined from the T-H analysis are large (e.g., air bar and T-bar safety factors greater than 2) so that any small level of unaccounted for cross-coupling in the suspended ceiling will be readily accommodated. ~~Also note that the input motion is conservative as described in the response to Item 8.~~

NRC Request - Item 13: Request and response apply to SQN with minor editorial changes, as marked.

Referring to the ~~third~~ second paragraph on Sheet ~~28~~25 of Enclosure 3, you stated that no sudden failure or loss of integrity of the ~~WBN~~ SQN MCR triangular duct is expected and the duct seismic response should be ductile in nature. Provide a duct-material property test based rationalization, including applicable vendor tested stress-strain curve or material constitutive law for the triangular duct to support your assertion of ductile, no sudden failure or loss of integrity.

TVA Response: Request and response apply to SQN with minor editorial changes, as marked.

The triangular ducts are made of fibrous glass material. Fibrous glass ducts of this type are subjected to UL-181 tests including structural integrity tests for local puncture, static bending load, pressure capacity, impact, and leakage. The static load, puncture, and impact tests clearly indicate that the material is quite flexible and ductile (not brittle). The pressure load test ensures that the duct is structurally capable of 2.5 times the rated operating pressure. The leakage test also indicates that the duct is durable since it is performed after the static load, impact and pressure tests.

There is reasonable assurance that the ~~WBN~~ SQN triangular and flexible ducts comply with UL-181 requirements. Field inspection of the ~~WBN~~SQN material indicates that it is identical to the UL-181 Listed material. Also, since the UL-181 standard has been available since 1961, it is reasonable to assume that the ~~WBN~~SQN material conforms to UL-181 requirements. However documentation is not available that unequivocally establishes that fact.

If purchased to UL-181 requirements today, the triangular duct material would be very similar to the installed material at ~~WBN~~SQN. That new material would be procured to comply with applicable UL-181 Class 1 requirements. It would probably be purchased from one of the member companies of the NAIMA air handling committee

(Certainteed Corporation, Knauf Fiberglass, Owens Corning, or Schuller International). ~~A copy of NAIMA Publication AH100 9/96 is provided in Enclosure 4 of this submittal. It discusses the required UL-181 testing for fibrous glass HVAC duct systems, including the structural integrity tests. It also describes the required UL-181A tests for connecting tape between sections of the fibrous glass ducting, similar to the tape used between triangular duct sections at WBN.~~ Since the triangular ducting material is quite flexible (low effective modulus of elasticity), the triangular ducts will readily conform to the very small deformation of the supporting air bars indicated by the analyses, with negligible internal forces developing due to these deformations, or inertia, without any structural damage to the triangular duct or the reinforced tape between triangular duct sections. This behavior and performance is further supported by seismic experience data (refer to response to request 5).

NRC Request - Item 14:

Request and response apply to SQN with minor editorial changes, as marked.

The ~~first~~ last paragraph on Sheet ~~29~~ 25 of Enclosure 3 discusses your judgment based conclusion regarding the structural integrity and full functional capability of the 10 inch diameter duct sections with spiral wire/fabric construction under ~~WBN~~ SQN SSE. As applicable, provide pertinent vendor tests based-data to support the above conclusion. If no vendor test data are available, provide a simplified, response spectrum method based seismic response analysis of the 10 inch diameter flexible ducts, considering the duct mass and flexibility, relative displacements of the duct supports and the transient time histories corresponding to the ~~WBN~~ SQN SSE at the duct supports in order to justify the above qualitative conclusion.

TVA Response:

Request and response apply to SQN with minor editorial changes, as marked.

As indicated in the response to Item 5 above there is extensive seismic testing with similar flexible hoses and ducts and extensive seismic experience data for various different types of ducts, including flexible round ducting. This information consistently demonstrates that the critical seismic failure mode for flexible ducting is structural damage in cases where the amplitude of relative end movements exceed the deformation capacity provided by the geometric configuration of the duct run or when the end connections are inferior. Given the flexibility and the very light weight of this type of ducting, inertial loading does not pose a challenge for structural integrity.

The end connections for the ~~WBN~~ SQN flexible ducts are adjustable metal clamps which provide structurally sound attachments to the metal and triangular ducts. Thus failure due to inferior end connections is not credible for this application.

For this application, the relative end movements due to design basis SSE loading are less than 1-inch (Reference Report 11165180R-00~~1~~2 Sheet ~~29~~25). The 10-inch diameter flexible ducts vary in length from 3 to 8 feet. Flexible ducts of this type are capable of bending 180 degrees over a mandrel whose diameter is equal to the inside diameter of the flexible duct without any structural damage (Reference UL-181, Section 7). Thus the bend radius to the centerline of a 10 inch flexible duct can be as small as 10 inches without structural damage. The seismic relative end movement demand for this application is obviously much less than the end movement capacity of the flexible ducts. Hence the conclusion in Report 11165180R-00~~1~~2 (Sheet ~~29~~25) is that, "The relative displacement in the order of less than 1" between the end points ---- pose negligible demand for the flexible duct."

NRC Request - Item 15: Request and response apply to SQN with minor editorial changes, as marked.

Referring to the various stress-strain curves presented on Sheets A-3 through A-5 of Appendix A, provide a discussion of the basis, including available material test data, for your quantitative definitions of various deformable/flexible elements representing the transient finite element dynamic analysis model. Also discuss both upper and lower bound results of the key grid member responses under the ~~WBN~~ SQN SSE and the sensitivities of the members' seismic response with respect to the quantitative parameters selected for the stress-strain curves representing various model elements.

TVA Response: Request and response apply to SQN with minor editorial changes, as marked.

The steps in the evaluation of the ~~WBN~~ SQN suspended ceiling response were as follows:

i. Perform a nonlinear time history analysis of the ceiling using a model that is representative of the actual configuration, after repairs and minor modifications.

ii. Recognizing uncertainties in the modeling parameters, rerun the analysis varying the parameters considered most significant in establishing the ceiling response envelope as follows:

- Address uncertainty in the frequency characteristics of the input motion by shifting the input motion response peaks by +/- ~~15~~ 10 percent (consistent with ~~WBN~~ SQN UFSAR ~~and US NRC Regulatory Guide 1.122 guidelines~~)

- Address uncertainty/variability in the clearance (gap) around the perimeter of the ceiling grid by running the following cases:

  (a) no gap, and

  (b) 1/8-inch gap

iii. Review the results for reasonableness, safety margins indicated and in comparison with the results from the hand calculation Functionality Evaluation to determine whether additional analyses were required to establish seismic qualification of the suspended ceiling and air delivery components.

Since the results from these nonlinear time history analyses (1) indicated large safety margins, and (2) supported the conclusions from the simplified but more conservative hand calculation evaluations, it was concluded that the completed analyses in Report 1116518-R-0012 establish that the WBN SQN suspended ceiling and air delivery components seismic capacity exceeds the WBN SQN design basis seismic demand with margins exceeding those required for seismic qualification of Category I and I(L) equipment assemblies.