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June 3, 1994
NRC-94-0050

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D. C. 20555

References: 1) Fermi 2
NRC Docket No. 50-341
NRC License No. NPF-43

2) NRC Letter dated March 3, 1994, Request for Additional Information

Subject: Detroit Edison Response to NRC Request for Additional Information - Control Center Heating, Ventilation and Air Conditioning (CCHVAC) System

Reference 2 requested that Detroit Edison provide additional information to address NRC staff concerns related to the seismic loading of the CCHVAC system during peak loading periods. The concerns were contained in Section 3.3 of the enclosure to Reference 2.

To effectively respond to these concerns, the concerns have been summarized as 19 separate statements. Each concern and its response are provided in Attachment 1. In addition, supporting documentation is attached for most of the concerns. In these cases, reference to the appropriate additional attachment to this letter is also provided.

If you have any questions, please contact Mr. Glen D. Ohlemacher at (313) 586-4275.

Sincerely,

DRGipson

Attachments

cc: T. G. Colburn
J. B. Martin (Attachment 1 only)
M. P. Phillips (Attachment 1 only)
K. R. Riemer (Attachment 1 only)

A001

NRC CONCERN 1: No reconciliation with the as-built geometries was apparently performed to verify that the analysis evaluated the as-built configurations

RESPONSE: Detroit Edison has walked down the duct systems evaluated in HA-05/89-686 to document the as-built configuration. Minor discrepancies, primarily with some hanger locations, were noted. The duct systems in HA-05/89-686 were re-evaluated by Hopper and Associates using the as-built configurations. This re-evaluation did not impact the results of the evaluation.

ENCLOSED SUPPORTING DOCUMENTATION: None

NRC CONCERN 2: Seismic analysis used full section properties rather than using "effective width" compressive flange as computed but not used. It thus appears that the internal moments and the deflections resulting from the seismic loading may have been underestimated.

RESPONSE: Full section properties were used for seismic analysis purposes appropriately to idealize the system dynamic characteristics. '... s results in a better stiffness representation than one would obtain using an "effective width" compressive flange for two reasons. First, those duct run lengths with effective reduced compression flanges are limited in extent and do not significantly influence the global dynamic characteristics of the systems. Second, although the "effective width" compression flange concept is useful and conservative for strength evaluation purposes, it greatly understates the compressive panel stiffness since plates actually continue to carry significant load after the traditional buckling limit is exceeded.

To verify the efficacy of the original idealization, iterative dynamic analyses were completed for systems 4316-1 and 4316-7, the two systems for which the concern is relevant. After convergence on the appropriate effective duct run geometry considering the localized nature of the unique compressive flange phenomena, the effect of this behavior was observed to have a negligible effect on the dynamic system characteristics and resulting system stresses. Response frequencies of systems 4316-1 and 4316-7 changed respectively 1.5% and 0.6%. Use of "effective width" section properties would significantly change the system dynamic response characteristics in an inappropriate manner. The supplementary calculations prepared validate the original assumption regarding the use of "full" section properties for dynamic analyses and "effective width" section properties for stress evaluation conservatism.

ENCLOSED SUPPORTING DOCUMENTATION: Attachment 2, Evaluation Calculations

NRC CONCERN 3: The section properties and the stresses were calculated based on the thickness of the galvanized sheet metal. These should be based on the thickness of the bare metal.

RESPONSE: The original assumption, that the effective sheet metal thickness is the galvanized material thickness, was made without due consideration of the need for significant analytical conservatisms. CCHVAC ducting systems have thus been reanalyzed using the bare metal thickness with satisfactory results as memorialized in the newly prepared detailed evaluation calculations.

Although the bare material is 8% thinner than the galvanized sheet metal, all reanalyzed system operational and operational plus Design Basis Earthquake (DBE) stresses remain below the respective allowable values. Furthermore, although it is not a licensing requirement, supplementary operational plus Site Specific Earthquake (SSE) stress analyses were also completed. In this extreme load evaluation situation, all stresses remain below yield levels and only one system (4316-1) is nominally stressed (5%) above the allowable level at one location. This singular overstress is not predicted if 4% rather than 2% damping is mobilized during the SSE - a reasonable expectation.

ENCLOSED SUPPORTING DOCUMENTATION: Attachment 3, Evaluation Calculations

NRC CONCERN 4:	In all analyses the beam bending stresses were based on one significant moment. It isn't clear that the highest longitudinal stresses were calculated, based on possible biaxial moment loading and axial loading.
RESPONSE:	The duct systems were re-evaluated for biaxial moments. The additional bending effect was demonstrated to be insignificant, as was assumed in the previous evaluation. Additionally, the re-evaluation also demonstrates axial loads were indeed included in the previous evaluation.
ENCLOSED SUPPORTING DOCUMENTATION:	Attachment 4, Evaluation Calculations

NRC CONCERN 5: There is no discussion of potential stress intensification or local deformation effects at "tee" type connections of equal or different size ducts, elbows, and "wye" fittings and rectangular-to-round transitions.

RESPONSE: Stresses at tee type connections, elbows, wye fittings, and rectangular-to-round transitions are secondary and peak stresses that may cause local yielding which is permitted for the SSE loading analyzed. Therefore, only primary stresses which may cause gross deformations or total collapse of the system were considered.

A corresponding philosophy is embraced by the ASME piping codes which require no secondary or peak stress check for the comparable earthquake loading. Furthermore, stress limits greater than yield are allowed for ASME secondary and peak stress checks when such checks are required under other loading conditions.

ENCLOSED SUPPORTING DOCUMENTATION: None

NRC CONCERN 6: The critical stresses and moments for plates in bending (representing the webs) did not consider the interaction with transverse compressive loading. These critical values may therefore be overestimated.

RESPONSE: The buckling assumptions were reviewed and compared to classical instability models. The literature review demonstrated instability plates under pure bending, and axial compression of panels is more critical than combined bending and transverse compression. In all cases of the previous analysis, instability due to axial loading occurs before or concurrent with instability due to bending, therefore, the previous analysis assumptions were conservative.

ENCLOSED SUPPORTING DOCUMENTATION: Attachment 5, Evaluation Calculations

NRC CONCERN 7:	The calculation of the edge membrane and bending stresses in panels did not include the seismic inertia loads acting on the panels.
RESPONSE:	Evaluation of the panel seismic inertia loads demonstrates a slight increase in the forces acting on the ducting system's panels. If the modal combination is performed using the SRSS method, the contribution of seismic inertia is 1.7% of that associated with design pressure. The seismic inertia loads acting on the panels were neglected in the previous analyses. However, the evaluated panel stress increases are insignificant and therefore validate the results of the original calculations.
ENCLOSED SUPPORTING DOCUMENTATION:	Attachment 6, Evaluation Calculations

NRC CONCERN 8: No discussion of the seismic qualification of the filter housings, and of the supports or the attachments to the building was presented.

RESPONSE: The filter housings are outside the scope of this evaluation. They were designed to the requirements of ORNL-NSIC-65. A seismic analysis was performed to demonstrate the stresses are within the allowables specified in the AISC specifications.

The supports were seismically qualified by Detroit Edison. The resultant stresses are within the AISC allowables. Hopper report HA-05/89-686 re-evaluated the duct systems for internal pressure effects which do not influence support loads.

Seismic analyses for supports are further disucssed under Concern 19.

ENCLOSED SUPPORTING DOCUMENTATION: None

NRC CONCERN 9: In evaluating the seismic spectra on which the dynamic analysis is based, it appears that the vertical spectra are plotted with incorrect horizontal coordinates. The correctness of the spectra values input in the dynamic analysis is therefore uncertain.

NRC CONCERN 10: The analysis states that there will be localized yielding under SSE loading but that the primary membrane stress will not exceed the allowable stress (0.9Sy). In view of the above, this assertion cannot be verified.

RESPONSE: The seismic spectra on which the dynamic analyses were based were directly taken from the Sargent and Lundy earthquake analysis. The vertical spectra used in the dynamic analyses are included as Figures 1 and 2.

The lower horizontal axes (abscissa) are annotated with periods in seconds and secondary upper horizontal axes show corresponding frequencies in cycles per second. Perhaps both abscissae were included to humor various engineers who have proclivities solely to embrace one unit tradition or the other.

Although Fermi has a Design Basis Earthquake (DBE) which represents the formal plant licensing basis, more conservative Site Specific Earthquake (SSE) spectra exist and have been used for supplementary seismic analyses. The DBE is also referred to as the Safe Shutdown Earthquake in Fermi 2 UFSAR Section 3.7. The relative amplitude of these spectra are seen in the following figures. For thoroughness, SSE analyses were completed for the ducting supplementary to the obligatory DBE analyses.

ENCLOSED SUPPORTING DOCUMENTATION: Attachment 7, Figures 1 and 2

NRC CONCERN 11: The structural integrity and air-tightness of the brazed joints in the longitudinal corner and middle seams was not evaluated. These are subject to direct longitudinal stresses due to beam bending, shear stresses due to beam torsion caused by seismic loading, and transverse edge bending and membrane stresses due to internal pressure and seismic loading. There is also a potential of fatigue failure due to repeated starts of the fans over the life of the plant which has not been evaluated.

RESPONSE: The longitudinal corner and middle seams of the CCHVAC and SGTS ducting are specific joint types, namely the "Pittsburg Lock" or the "ACME Lock." Plain seams such as the corner lap or the lap joint were not used. Therefore, Concern 11 will be addressed by Concern 13, which evaluates the "Pittsburg Lock" joint for the rectangular ducts and the "ACME Lock" joint for the circular ducts.

ENCLOSED SUPPORTING DOCUMENTATION: None

NRC CONCERN 12:	The structural integrity and air-tightness of the transverse joints was not evaluated.
RESPONSE:	An analysis of all components of the transverse joints was performed. The analysis demonstrated the transverse joint integrity by meeting the allowable strength requirements found in applicable codes. Additionally, the analysis considered air tightness and fatigue capability. Neither leakage nor fatigue is expected to be a concern in the analyzed systems.
ENCLOSED SUPPORTING DOCUMENTATION:	Attachment 8, Evaluation Calculations

NRC CONCERN 13: "Corner Lap" or "Pittsburg Lock" type corners and middle longitudinal "Acme Lock" type seams structural integrity was not evaluated. Therefore, the air tightness of the ducts cannot be assured.

RESPONSE: The structural integrity of the longitudinal "Pittsburg Lock" and "Acme Lock" seams was evaluated. The brazed joints are capable of withstanding operational and seismic loading without exceeding the applicable code allowable stresses. Additionally, the air tightness and fatigue life of longitudinal seams is not expected to be compromised.

ENCLOSED SUPPORTING DOCUMENTATION: Attachment 9, Evaluation Calculations

NRC CONCERN 14: The existing internal loads due to seismic loading were amplified by the product of the ratio of the SSE ZPA to the OBE ZPA and the ratio of the peak response acceleration to the ZPA, presumably of the SSE. The damping used for this calculation was not specified. However, there are two horizontal and one vertical component for each earthquake, and these are also dependent on the evaluation within the building. It is unclear how these directional components were actually applied in these calculations.

RESPONSE: The amplification factors used in the ductwork evaluation correspond to 2% damping response spectrum. Although amplification factors were calculated for three directions (two horizontal and one vertical) and two elevations (slab 3 elevation 641.5 ft. and slab 5 elevation 684.5 ft.), the three calculation amplification factors at each elevation were similar enough to chose a single value (slightly weighted average) to effectively envelope the evaluation. Additionally, system 2850-2 was analyzed independently by a detailed computer analysis and was not subject to the amplification ratios.

ENCLOSED SUPPORTING DOCUMENTATION: Attachment 10, Evaluation Calculations

NRC CONCERN 15: Details of the calculations to determine the maximum permissible internal pressure from the stresses under combined loads were not reported. Maximum permissible internal pressures are shown for two load combinations: DW and DW + SSE. An examination of the stated values indicates that for the rectangular ductwork the permissible internal pressure under combined DW + SSE loading is higher than under DW alone; in fact, in some sections it is considerably higher (in one case about 20 times larger). The basis for these results has not been presented. Since the details of these calculations are not shown, it is not possible to assess the quality or validity of these calculations, and the maximum allowable pressure results must therefore be considered as questionable.

RESPONSE: For the DW load combination, local instability is inadmissible and permissible internal pressures are restricted so as to comply with this analysis assumption. For the DW + SSE load combination, local panel instability is admissible and permissible internal pressure are correspondingly greater.

The calculational details in question were not summarized and reported by Hopper. In order to illustrate the techniques used, calculational details for two representative duct systems are attached. Both systems have a rectangular cross section. One system illustrates the procedure used to obtain the allowable pressure with no local instability, and the other system illustrates the procedure used to obtain the allowable pressure when local instability is present. If local instability is present, only membrane stresses are considered, and the allowable pressure loading increases.

ENCLOSED SUPPORTING DOCUMENTATION: Attachment 11, Evaluation Calculations

NRC CONCERN 16: For circular ducts the maximum allowable negative pressure is apparently total vacuum. The basis for this result was not presented, so it isn't clear if it was determined based on the interaction with simultaneous tensile and compressive axial loads, and if manufacturing imperfections were considered. These may have a significant effect on the allowable external pressure.

RESPONSE: The critical buckling strength of a thin tube under uniform lateral external pressure governs the design of a circular duct and establishes its required thickness. This buckling strength is enhanced (although minimally) when interaction with simultaneous compressive axial loads is considered. Thus, the calculations in HA-09/89-696 were restricted to evaluating the seismic effect on the elastic stability of a thin walled circular tube under uniform longitudinal compression or under a transverse bending moment. The mathematical equations used to determine these critical buckling strengths were derived based on extensive experimental data and implicitly include the effect of manufacturing imperfections.

Illustrative calculations of a bounding case circular duct system were prepared. It demonstrates that for the seismic loads under consideration, total vacuum pressure is needed to reach the critical buckling strength under uniform longitudinal compression. The uniform lateral buckling external pressure for the largest circular duct which was considered in the original design of the duct is 6.8 inches of water using a SMACNA recommended manufacturing imperfection strength reduction factor of 7.2. This conservative allowable pressure exceeds the bounding demand pressure of 6.0 inches of water.

ENCLOSED SUPPORTING DOCUMENTATION: Attachment 12, Evaluation Calculations

NRC CONCERN 17: The report also stated that some of the rectangular duct panels are loaded beyond their "bifurcation" point during SSE, and that this is structurally inconsequential since the redistributed stresses remain low. This statement is acceptable only if it is shown that the maximum redistributed stress remains below the allowable stress (0.9Sy) under the SSE loading conditions.

RESPONSE: The maximum redistributed stresses of all the rectangular ducts is presented and compared to the allowable stress (0.9Sy). With the exception of one non-essential 12 X 8 duct in system 2849-1, the maximum redistributed stress of all rectangular ducts is less than the allowable stress (0.9Sy) under the SSE loading conditions, provided the ducts are operating within the established permissible pressure.

ENCLOSED SUPPORTING DOCUMENTATION: Attachment 13, Evaluation Calculations

NRC CONCERN 18: The analysis of system 2850-2 indicated that this systems responded inelastically at one location, and it was thus concluded that a ductility factor of 2 was sufficient to achieve the required pressure load. The meaning of this is unclear since it implies that somewhere in the system the highest stress calculated on an elastic basis was about 2 Sy, considerable exceeding the maximum allowable stress.

RESPONSE: The HA-09/89-696 analysis conservatively predicted localized inelasticity at one ducting location. With the assumed ductility factor, localized strains exceed the elastic limit, however, corresponding stresses do not exceed the yield stress. The highest expected stress calculated on an elastic basis would be 1.3 Sy.

To quantify the conservatism of the original analysis, system 2850-2 was reanalyzed for the Site Specific Earthquake (SSE) using the actual pressure requirement and various damping valves. Literature review suggests damping values of 10%-15% for systems responding at or near yield. With damping value of 10%, all stresses in system 2850-2 were below 0.85 Sy. For a reasonable yet still conservative damping value of 7%, as recommended by Regulatory Guide 1.61, all stresses were below 0.95 Sy. Additionally, please recall the Fermi SSE is considerably more severe than the Design Basis Earthquake (DBE) which quantifies the licensing basis of the plant.

ENCLOSED SUPPORTING DOCUMENTATION: Attachment 14, Evaluation Calculations

NRC CONCERN 19: The analyses in this report address only the ductwork. No safety calculation of the supports, or calculated safety margins determined in such calculations have been reported. The design calculation report DC-5089 states that all hangers, stiffeners and supports meet the stress criteria of ANSI/ASME N509-80. No documentation has been provided to support this statement.

RESPONSE: An evaluation of the stiffeners was performed (Attachment 15). The bounding analyses encompassed all possible duct and stiffener sizes and configurations. The stiffeners, weldments, brazing, and tie rods were found to be structurally adequate. The stiffeners meet the stress criteria of ANSI/ASME N509-80, based on the maximum anticipated loading.

The hangers and supports were seismically qualified by Detroit Edison. All calculated stresses are within the AISC allowables. The AISC allowables are less than the allowables specified in ANSI/ASME N509-80. Due to the size of these seismic qualification calculations, a single representative calculation is attached (Attachment 16). The remaining calculations are available for review.

ENCLOSED SUPPORTING DOCUMENTATION: Attachment 15, Stiffener Evaluation Calculation
Attachment 16, Representative Qualification Calculation

Attachment 2 to
NRC-94-0050

HOPPER AND ASSOCIATES
ENGINEERS

DECO - USNRC DOCKET NO. 50-341

FERMI 2 CCHVAC DUCTING SYSTEMS

CONCERN ITEM NO. 2

EVALUATION CALCULATIONS

Prepared for: Detroit Edison Company
Nuclear Engineering Fermi 2
6400 North Dixie Highway
Newport, MI 48166

Prepared by: Hopper and Associates
300 Vista Del Mar
Redondo Beach, CA 90277

May, 1994

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 2 DATE: 27 APRIL 1994 PAGE: i

SUBJECT: TABLE OF CONTENTS BY: BJS CK: SHT: 1 OF 1

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PREPARED BY: Bill Schell 27 APRIL 1994

CHECKED BY: M. Amir Khan 5 MAY '94

1.1 PROBLEM STATEMENT

A QUESTION AROSE BY THE NRC [2] CONCERNING THE SECTION PROPERTIES OF BUCKLED MEMBERS USED IN THE COMPUTER ANALYSIS OF HA-05/89-686 [1]:

> Seismic analysis used full section properties rather than using "effective width" compressive flange as computed but not used. It thus appears that the internal moments and the deflections resulting from the seismic loading may have been underestimated.

THIS EVALUATION IS PREPARED AS A RESPONSE TO THIS CONCERN.

1.2 INVESTIGATION APPROACH

THE EFFECT OF THE POSTCRITICAL BEHAVIOR OF THIN WALLED PLATES ON THE "EFFECTIVE WIDTH" OF THE COMPRESSIVE FLANGE WILL BE INVESTIGATED. PLATES DIFFER FROM BEAMS IN THAT PLATES CONTINUE TO CARRY LOAD, SOMETIMES SEVERAL TIMES THE BUCKLING LOAD, BEFORE FAILING [3]. THIS

1.2 INVESTIGATION APPROACH (CONT.)

POSTBUCKLING CAPACITY WILL RESULT IN AN EFFECTIVE WIDTH OF THE COMPRESSIVE FLANGE AND THEREFORE A NEW MOMENT OF INERTIA OF THE BUCKLED SECTION CAN BE CALCULATED. THIS NEW MOMENT OF INERTIA WILL BE INPUT INTO THE COMPUTER MODEL [1] TO DETERMINE ITS EFFECT ON SYSTEM FREQUENCY.

1.3 RESULT SUMMARY

THE EFFECTIVE SECTION PROPERTIES ARE A FUNCTION OF LOADING BEYOND THE PROPORTIONAL LIMIT OR BUCKLING LOAD. USING THESE SECTIONS IN THE COMPUTER ANALYSIS RESULTED IN A 1.5% CHANGE (MAX) IN THE SYSTEM FREQUENCY. THEREFORE THE EFFECT OF LOCAL COMPRESSION FLANGE BUCKLING IS NEGLIGIBLE WITH REGARD TO THE OVERALL SYSTEM DYNAMICS.

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

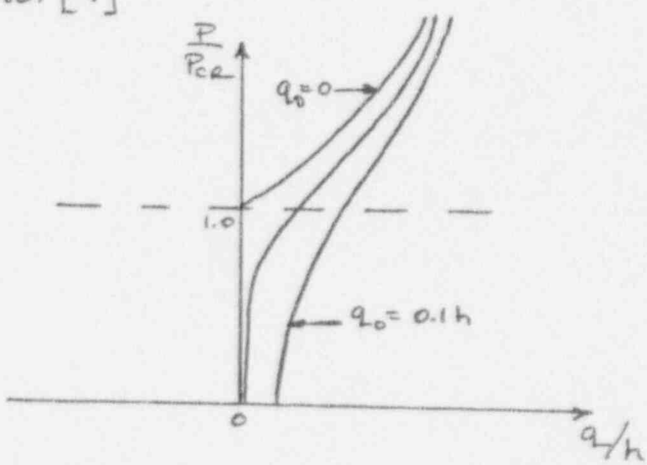
TITLE: RESPONSE TO CONCERN 2 DATE: 27 APRIL 1994 PAGE: 3

SUBJECT: 2.0 SYSTEM DESCRIPTION BY: RJS CK: MAK SHT: 1 OF 1

TWO DUCT SYSTEMS, 4316-1 AND 4316-7, WILL BE EVALUATED FOR LOCAL BUCKLING IN THIS ANALYSIS. SYSTEM 4316-1 IS A 14"x14" SQUARE DUCT LOCATED IN THE AUXILIARY BUILDING AT ELEVATION 690'-6". SYSTEM 4316-7 CONTAINS 16"x16" SQUARE DUCT AND IS LOCATED IN THE AUXILIARY BUILDING AT ELEVATION 690'-3". BOTH THE STIFFNESSES AND WEIGHTS ARE APPROPRIATELY MODELLED IN THE COMPUTER ANALYSIS. THE COMPUTER OUTPUT FOR THE EVALUATION IS FROM THE MODELS GENERATED IN HA-05/89-686 [1]

3.1 ASSUMPTIONS

1. THE BEHAVIOR OF PLATES IN COMPRESSION IS ELASTIC UNTIL THE ULTIMATE LOAD IS REACHED. BUCKLING DOES NOT CONSTITUTE PLASTIC OR UNRECOVERABLE DEFORMATIONS. UPON UNLOADING, THE ORIGINAL SHAPE OF THE DUCT IS MAINTAINED, UNLESS PLASTIC DEFORMATION OCCURS AT THE ULTIMATE COMPRESSIVE LOAD. THE LOAD-DEFORMATION CURVE FOR THE COMPRESSION FLANGE OF THE DUCT IS AS FOLLOWS: [4]



P/P_{CR} = LOAD DIVIDED BY CRITICAL LOAD

q/h = OUT OF PLANE DEFLECTION DIVIDED BY THICKNESS

q_o = INITIAL DEFLECTION (IMPERFECTION)

3.1 ASSUMPTIONS (CONT.)

2. DUCT MATERIAL IS LINEAR-ELASTIC IN THE RANGE OF LOADING CONSIDERED.
3. FROM COMPUTER OUTPUT, AXIAL FORCES ARE SMALL COMPARED TO BENDING MOMENTS AND THEREFORE ARE NEGLECTED.

3.2 SECTION PROPERTIES

THE PROPERTIES USED IN H&A REPORT HA-05/89-686 [1] ARE DUPLICATED HERE AND USED IN THIS EVALUATION FOR CONSISTENCY IN THE COMPARISON:

14"x14" SQUARE : $t = 0.0516''$
$A = 2.89\ in^2$
$I = 94.4\ in^4$

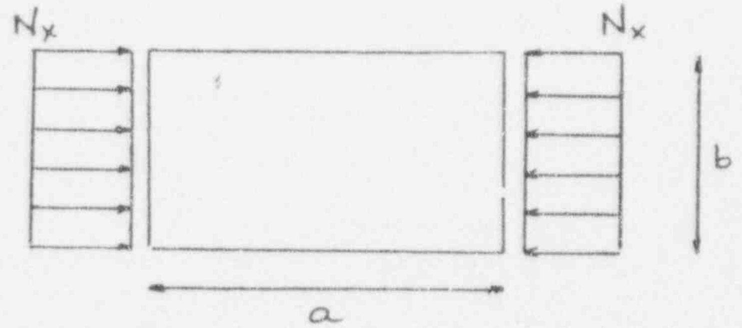
16"x16" SQUARE : $t = 0.0516''$
$A = 3.30\ in^2$
$I = 140.9\ in^4$

PANEL LENGTH = 29.5" (STIFFENER TO STIFFENER) $E = 29 \times 10^6$ psi
$\nu = 0.29$

3.3 DUCT PANEL BUCKLING

LIMITS ON PANEL BUCKLING WILL BE COMPUTED FOR COMPRESSION, SHEAR AND BENDING

3.3.A COMPRESSION



SIMPLY-SUPPORTED PLATE
N_x = COMPRESSIVE LOAD PER UNIT LENGTH

$$N_{CR} = \frac{\pi^2 D}{a^2}\left(m + \frac{1}{m}\left(\frac{a^2}{b^2}\right)\right)^2 \qquad (1)$$

REF 3, P. 352

$$D = \frac{Eh^3}{12(1-\nu^2)} = \frac{29\times10^6(0.0516)^3}{12(1-(.29)^2)} = 362.5$$

EQN (1) IS MINIMIZED WHEN $m = 2$

$$N_{CR,1} = \frac{\pi^2(362.5)}{(29.5)^2}\left(2 + \frac{1}{2}\left(\frac{29.5^2}{14^2}\right)\right)^2$$

$N_{CR,1}$ = 73.2 lb/in (FOR 14" □)

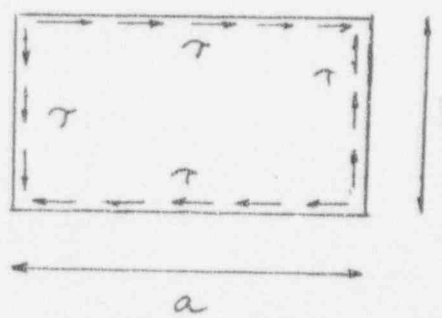
PRIMARY MODE HAS SHAPE OF 2 HALF SINE WAVES

3.3.A COMPRESSION (CONT.)

$$N_{CR,2} = \frac{\pi^2(362.5)}{(29.5)^2}\left(2 + \frac{1}{2}\left(\frac{29.5^2}{16^2}\right)\right)^2$$

$N_{CR,2} = 56.3$ lb/in (FOR 16" □)

3.3.B SHEAR



$$\tau_{CR} = K\frac{\pi^2 D}{b^2 h} \qquad (2)$$

REF 3, P. 382

K = FACTOR DETERMINED IN REF 3

$$\tau_{CR,1} = 6.5\frac{\pi^2(362.5)}{(14)^2(0.0516)} = 2299.4 \text{ psi (14" □)}$$

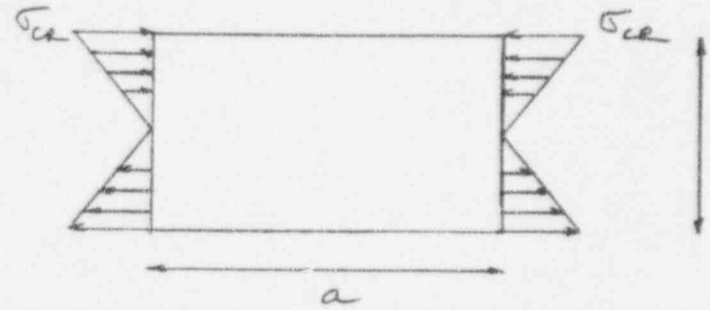
$$\tau_{CR,2} = 6.8\frac{\pi^2(362.5)}{(16)^2(0.0516)} = 1841.7 \text{ psi (16" □)}$$

K = 6.6 FOR a/b = 2

K = 6.1 FOR a/b = 2.5

K = 6.8 FOR a/b = 1.8

3.3.C BENDING



$$\sigma_{CR} = k\frac{\pi^2 D}{b^2 h}$$ (3) REF 3, P 377

$\alpha = 2.0$ (PURE BENDING)

$k = 24$ FROM FIG 9-20 P. 378

$$\sigma_{cr,1} = 24\frac{\pi^2(362.5)}{(14)^2(0.0516)} = 8490.1 \quad (14'' \square)$$

$$\sigma_{cr,2} = 24\frac{\pi^2(362.5)}{(16)^2(0.0516)} = 6500.2 \quad (16'' \square)$$

SUMMARY

	(PSI) $\sigma_{CR}(14'')$	$\sigma_{CR}(16'')$	(lb-IN) $M_{cr}(14'')$	$M_{cr}(16'')$
COMPRESSION	1418.6	1091.1	19130.8	19217.0
SHEAR	2334.8	1787.6	—	— (NOT CRITICAL)
BENDING	8490.1	6500.2	114,495	114,485

SUMMARY NOTES:

σ_{cr} = STRESS CAUSING PLATE TO BUCKLE

M_{cr} = CRITICAL MOMENT

WHERE $\sigma_{cr} = \dfrac{M_{cr}\,\bar{y}}{I_{DUCT}}$

M_{cr} IS THE MOMENT ON THE DUCT SECTION CAUSING THE PLATE TO BUCKLE UNDER σ_{CR}. THE PLATE COULD BE EITHER THE FLANGE OR THE WEB.

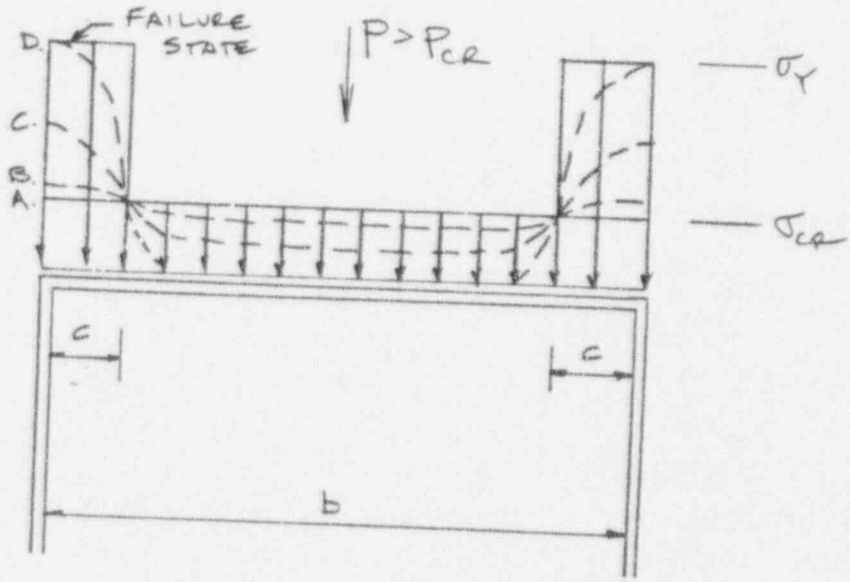
3.4 POST BUCKLING BEHAVIOR

FROM COMPUTER OUTPUT, SEVERAL DUCT ELEMENTS ARE SUBJECTED TO FORCES GREATER THAN THAT FORCE NECESSARY TO CAUSE BUCKLING IN THE COMPRESSION FLANGE OF THE DUCT. SINCE THE DUCT PANELS ARE ELASTIC UNTIL FAILURE OF THE COMPRESSION FLANGE, ONLY ONE FLANGE WILL BUCKLE AT A TIME UNDER THE CYCLIC LOAD.

AS THE LOAD IS INCREASED ABOVE THE CRITICAL LOAD, THE DISTRIBUTION OF N_x VARIES ACCORDING TO THE PICTURE ON PAGE 11. SINCE THE EDGE STRIPS ARE BUCKLED FOR $P > P_{cr}$, THE AVERAGE DISTRIBUTED FORCE, N_x, CARRIED OVER LENGTH C IS ESTIMATED AS THE CRITICAL VALUE OF A UNIFORM N_x FOR A SIMPLY SUPPORTED THIN-WALLED PLATE OF WIDTH, 2c, AND LENGTH, a [4]. SINCE DEFLECTIONS ARE SMALL NEAR THE DUCT CORNER, N_{cr} APPLIES, EVEN THOUGH THE OVERALL BEHAVIOR IS POSTCRITICAL. [4]

3.5 POST BUCKLING EVALUATION

AS DESCRIBED IN SECTION 3.1, PLATES CONTINUE TO CARRY SIGNIFICANT LOADS AFTER BUCKLING. STRESSES ARE REDISTRIBUTED FROM THE CENTER OF THE THE PLATE TO OUTER STRIPS ALONG THE CORNER OF THE DUCT.



STRESS DISTRIBUTION VARIES POST CRITICAL FROM A TO D. AT FAILURE, THE EFFECTIVE WIDTH, 2c, YIELDS:

$$P_U = 2ch\sigma_Y \qquad (3)$$

REF 3, p.419

3.5 POST BUCKLING EVALUATION (CONT.)

THE EFFECTIVE WIDTH, C, IS THE WIDTH RESULTING IN BUCKLING LOADS FOR $P > P_{CR}$.

$$\min |N_{CR}| = \frac{4\pi^2 D}{b^2}$$

N_{CR} = CRITICAL LOAD PER UNIT LENGTH = P_{CR}/b

D = FLEXURAL RIGIDITY

14"□ $\min |N_{CR}| = \frac{4\pi^2(362.5)}{14^2} = 73.0$ lb/in

16"□ $\min |N_{cr}| = \frac{4\pi^2(362.5)}{16^2} = 55.9$ lb/in

THESE VALUES CHECK WITH SECTION 3.3.A.

LET $|N_x| = P/2C$

$$\min |N_x| = \frac{4\pi^2 D}{(2c)^2} = \frac{\pi^2 D}{c^2}$$

OR $c^2 = \frac{\pi^2 D}{|N_x|}$ WHERE $|N_x| > |N_{cr}|$

$c^2 = \frac{\pi^2 D}{\beta |N_{CR}|}$ WHERE $\beta = |N_x| / |N_{CR}|$

(REF 4)

3.5 POST BUCKLING EVALUATION (CONT.)

$$C = \pi \sqrt{\frac{D}{\beta |N_{cr}|}}$$

$|N_{cr}|_{14''\square} = 73.0 \text{ lb/in}$

$D = 362.5$

$$C = \pi \sqrt{\frac{362.5}{\beta (73.0)}} = 7.0 \sqrt{\frac{1}{\beta}} = C$$

$$\beta = \frac{|N_x|}{|N_{cr}|} \qquad \left(16''\square : C = 8\sqrt{\frac{1}{\beta}}\right)$$

ASSUMING THAT THE ULTIMATE LOAD IS REACHED WHEN σ_{cr} BECOMES EQUAL TO THE YIELD STRESS ($\sigma_Y = 36$ ksi)

$$|N_{ULT}| = \sigma t = 1857.6 \text{ lb/in}$$

$$\beta = \frac{1857.6}{73.0} = 25.4$$

$C = 1.39$ (VERIFIED BY REF 3)

FIGURE 1 DESCRIBES THE EFFECTIVE WIDTH OF THE COMPRESSIVE FLANGE AS A FUNCTION OF LOAD.

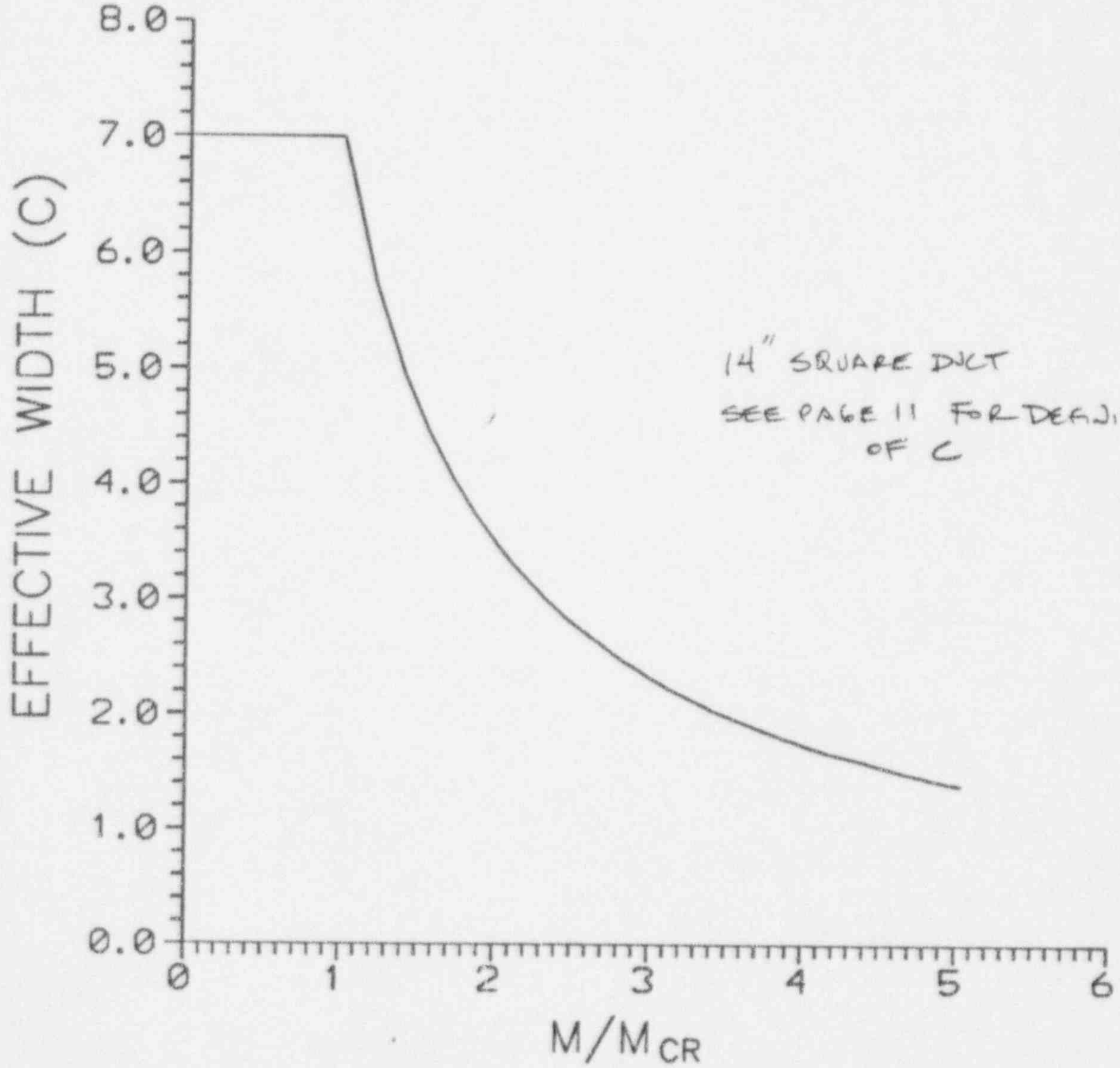


FIGURE 1 – EFFECTIVE WIDTH AS A FUNCTION OF LOADING

3.5 POST BUCKLING EVALUATION (CJT)

N_x NEEDS TO BE RELATED TO M_x (FROM COMPUTER OUTPUT)

TO FIND THE NEW MOMENT OF INERTIA:

$$\bar{\sigma} = \frac{M_x y}{I} \quad \text{(EQUIVALENT STRESS)}$$

IN REALITY, STRESS IS REDISTRIBUTED TO EFFECTIVE WIDTHS

$$\bar{\sigma} b t = \sigma (2c) t$$

$$\sigma = \bar{\sigma}\left(\frac{b}{2c}\right) = \left(\frac{b}{2c}\right) \frac{M_x y}{I}$$

$$\sigma_{cr} = \frac{M_{cr} y}{I}$$

$$\frac{\sigma}{\sigma_{cr}} = \frac{N_x}{N_{cr}} = \frac{M_x}{M_{cr}} \left(\frac{b}{2c}\right)$$

$$\left(\frac{2c}{b}\right) \beta = \frac{M_x}{M_{cr}}$$

SINCE $c = (b/2) \sqrt{\frac{1}{\beta}}$

$$\boxed{\frac{M_x}{M_{cr}} = \sqrt{\beta} = \sqrt{N_x / N_{cr}}}$$

3.5 POST BUCKLING EVALUATION (CONT.)

THE FOLLOWING PROCEDURE WAS USED FOR THE DETERMINATION OF THE SYSTEM FREQUENCY:

(1) OBTAIN $\frac{M_x}{M_{cr}}$ FROM HA-05/89-686 [1]

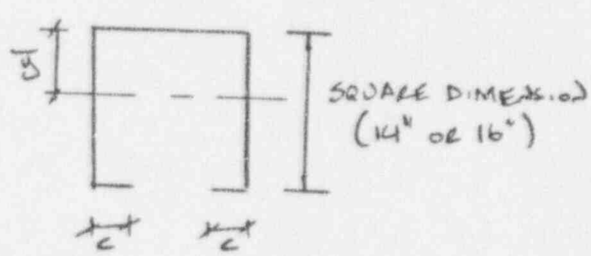
(2) CALCULATE $\beta = N_x/N_{cr}$

(3) DETERMINE EFFECTIVE WIDTH, C

(4) DETERMINE NEW MOMENT OF INERTIA

(5) INPUT NEW MOMENTS OF INERTIAS INTO THE COMPUTER MODEL (REPLACING BUCKLED ELEMENTS) AND RERUN MODEL OBTAINING NEW SYSTEM FREQUENCIES.

TABLES 1 AND 2 ILLUSTRATE THE CHANGE IN MOMENT OF INERTIA FOR THE 14" AND 16" SQUARE DUCT, RESPECTIVELY.



FINAL RESULT

THE CHART ON PAGE 21 SHOWS THE RESULTS FOR THE FIRST 5 MODES. (ALSO SEE APPENDIX A)

N/Ncr	c	Ay	A	$\bar{y}$	I1	I2	I(total)	M/Mcr
1.00	7.00	20.23	2.89	7.00	59.00	35.40	94.39	1.00
1.50	5.72	18.37	2.76	6.66	55.35	32.24	87.59	1.22
2.00	4.95	17.26	2.68	6.45	52.74	30.47	83.21	1.41
2.50	4.43	16.51	2.62	6.29	50.75	29.32	80.07	1.58
3.00	4.04	15.95	2.58	6.17	49.15	28.52	77.67	1.73
3.50	3.74	15.52	2.55	6.08	47.83	27.92	75.75	1.87
4.00	3.50	15.17	2.53	6.00	46.72	27.45	74.17	2.00
4.50	3.30	14.88	2.51	5.93	45.75	27.08	72.83	2.12
5.00	3.13	14.64	2.49	5.88	44.91	26.78	71.69	2.24
5.50	2.98	14.43	2.48	5.83	44.17	26.52	70.69	2.35
6.00	2.86	14.24	2.46	5.78	43.50	26.31	69.81	2.45
6.50	2.75	14.08	2.45	5.75	42.90	26.12	69.03	2.55
7.00	2.65	13.94	2.44	5.71	42.36	25.96	68.32	2.65
7.50	2.56	13.81	2.43	5.68	41.86	25.82	67.68	2.74
8.00	2.47	13.69	2.42	5.65	41.40	25.70	67.10	2.83
8.50	2.40	13.58	2.41	5.62	40.98	25.59	66.57	2.92
9.00	2.33	13.48	2.41	5.60	40.59	25.49	66.08	3.00
9.50	2.27	13.39	2.40	5.58	40.22	25.40	65.62	3.08
10.00	2.21	13.31	2.40	5.56	39.88	25.32	65.20	3.16
10.50	2.16	13.23	2.39	5.54	39.56	25.24	64.81	3.24
11.00	2.11	13.16	2.39	5.52	39.26	25.17	64.44	3.32
11.50	2.06	13.10	2.38	5.50	38.98	25.11	64.09	3.39
12.00	2.02	13.03	2.38	5.49	38.72	25.05	63.77	3.46
12.50	1.98	12.97	2.37	5.47	38.46	25.00	63.46	3.54
13.00	1.94	12.92	2.37	5.46	38.22	24.95	63.17	3.61
13.50	1.91	12.87	2.36	5.44	37.99	24.90	62.90	3.67
14.00	1.87	12.82	2.36	5.43	37.78	24.86	62.64	3.74
14.50	1.84	12.77	2.36	5.42	37.57	24.82	62.39	3.81
15.00	1.81	12.72	2.35	5.41	37.37	24.78	62.16	3.87
15.50	1.78	12.68	2.35	5.40	37.18	24.75	61.93	3.94
16.00	1.75	12.64	2.35	5.38	37.00	24.72	61.72	4.00
16.50	1.72	12.60	2.35	5.37	36.83	24.68	61.51	4.06
17.00	1.70	12.57	2.34	5.36	36.66	24.65	61.32	4.12
17.50	1.67	12.53	2.34	5.36	36.50	24.63	61.13	4.18
18.00	1.65	12.50	2.34	5.35	36.35	24.60	60.95	4.24
18.50	1.63	12.46	2.34	5.34	36.20	24.58	60.78	4.30
19.00	1.61	12.43	2.33	5.33	36.06	24.55	60.61	4.36
19.50	1.59	12.40	2.33	5.32	35.92	24.53	60.45	4.42
20.00	1.57	12.38	2.33	5.31	35.79	24.51	60.29	4.47
20.50	1.55	12.35	2.33	5.31	35.66	24.49	60.14	4.53
21.00	1.53	12.32	2.32	5.30	35.53	24.47	60.00	4.58
21.50	1.51	12.29	2.32	5.29	35.41	24.45	59.86	4.64
22.00	1.49	12.27	2.32	5.29	35.29	24.43	59.72	4.69
22.50	1.48	12.25	2.32	5.28	35.18	24.41	59.59	4.74
23.00	1.46	12.22	2.32	5.27	35.07	24.40	59.47	4.80
23.50	1.44	12.20	2.32	5.27	34.96	24.38	59.34	4.85
24.00	1.43	12.18	2.31	5.26	34.86	24.36	59.22	4.90

TABLE 1 - 14" SQUARE DUCT (4316-1)

24.50	1.41	12.16	2.31	5.26	34.76	24.35	59.11	4.95
25.00	1.40	12.14	2.31	5.25	34.66	24.34	59.00	5.00
25.40	1.39	12.12	2.31	5.25	34.58	24.32	58.91	5.04

TABLE 1 (CONT) - 14" SQUARE DUCT

N/Ncr	c	Ay	A	$\overline{y}$	I1	I2	I(total)	M/Mcr
1.00	8.00	26.42	3.30	8.00	88.06	52.84	140.90	1.00
1.50	6.53	24.00	3.15	7.62	82.62	48.12	130.74	1.22
2.00	5.66	22.55	3.06	7.37	78.73	45.48	124.20	1.41
2.50	5.06	21.56	3.00	7.19	75.75	43.77	119.52	1.58
3.00	4.62	20.84	2.95	7.05	73.37	42.57	115.93	1.73
3.50	4.28	20.27	2.92	6.95	71.40	41.67	113.07	1.87
4.00	4.00	19.81	2.89	6.86	69.73	40.98	110.71	2.00
4.50	3.77	19.44	2.87	6.78	68.30	40.42	108.72	2.12
5.00	3.58	19.12	2.85	6.72	67.04	39.97	107.01	2.24
5.50	3.41	18.84	2.83	6.66	65.93	39.59	105.52	2.35
6.00	3.27	18.60	2.81	6.61	64.94	39.27	104.21	2.45
6.50	3.14	18.39	2.80	6.57	64.04	38.99	103.04	2.55
7.00	3.02	18.20	2.79	6.53	63.23	38.75	101.98	2.65
7.50	2.92	18.03	2.78	6.49	62.49	38.54	101.03	2.74
8.00	2.83	17.88	2.77	6.46	61.80	38.36	100.16	2.83
8.50	2.74	17.74	2.76	6.43	61.17	38.19	99.36	2.92
9.00	2.67	17.61	2.75	6.40	60.59	38.04	98.63	3.00
9.50	2.60	17.50	2.74	6.37	60.04	37.91	97.95	3.08
10.00	2.53	17.39	2.74	6.35	59.54	37.79	97.32	3.16
10.50	2.47	17.29	2.73	6.33	59.06	37.68	96.74	3.24
11.00	2.41	17.19	2.73	6.31	58.61	37.58	96.19	3.32
11.50	2.36	17.10	2.72	6.29	58.19	37.48	95.67	3.39
12.00	2.31	17.02	2.72	6.27	57.79	37.40	95.19	3.46
12.50	2.26	16.95	2.71	6.25	57.41	37.32	94.73	3.54
13.00	2.22	16.87	2.71	6.24	57.06	37.24	94.30	3.61
13.50	2.18	16.80	2.70	6.22	56.72	37.18	93.89	3.67
14.00	2.14	16.74	2.70	6.21	56.39	37.11	93.50	3.74
14.50	2.10	16.68	2.69	6.19	56.08	37.05	93.13	3.81
15.00	2.07	16.62	2.69	6.18	55.79	37.00	92.78	3.87
15.50	2.03	16.56	2.69	6.17	55.51	36.94	92.45	3.94
16.00	2.00	16.51	2.68	6.15	55.24	36.89	92.13	4.00
16.50	1.97	16.46	2.68	6.14	54.98	36.85	91.82	4.06
17.00	1.94	16.41	2.68	6.13	54.73	36.80	91.53	4.12
17.50	1.91	16.37	2.67	6.12	54.49	36.76	91.25	4.18
18.00	1.89	16.32	2.67	6.11	54.26	36.72	90.98	4.24
18.50	1.86	16.28	2.67	6.10	54.04	36.68	90.72	4.30
19.00	1.84	16.24	2.67	6.09	53.82	36.65	90.47	4.36
19.50	1.81	16.20	2.66	6.08	53.62	36.61	90.23	4.42
20.00	1.79	16.16	2.66	6.07	53.42	36.58	90.00	4.47
20.50	1.77	16.13	2.66	6.06	53.22	36.55	89.78	4.53
21.00	1.75	16.09	2.66	6.06	53.04	36.52	89.56	4.58
21.50	1.73	16.06	2.65	6.05	52.86	36.49	89.35	4.64
22.00	1.71	16.03	2.65	6.04	52.68	36.47	89.15	4.69
22.50	1.69	15.99	2.65	6.03	52.51	36.44	88.95	4.74
23.00	1.67	15.96	2.65	6.03	52.35	36.42	88.77	4.80
23.50	1.65	15.93	2.65	6.02	52.19	36.39	88.58	4.85
24.00	1.63	15.91	2.65	6.01	52.03	36.37	88.40	4.90

TABLE 2 - 16" SQUARE DUCT (4316-7)

24.50	1.62	15.88	2.64	6.01	51.88	36.35	88.23	4.95
25.00	1.60	15.85	2.64	6.00	51.74	36.33	88.06	5.00
25.40	1.59	15.83	2.64	6.00	51.62	36.31	87.93	5.04

TABLE 2 (CONT.) - 16" SQUARE DUCT

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 2 DATE: 27 APRIL 1994 PAGE: 21

SUBJECT: 3.0 ANALYSIS BY: BS CK: MAK SHT: 18 OF 18

3.5 POST BUCKLING EVALUATION (CONT.)

	ORIGINAL [1]		MODIFIED [P. A1]	
SYSTEM	MODE	FREQUENCY	MODE	FREQUENCY
4316-1	1	10.98 Hz	1	10.81 Hz
	2	15.46	2	15.32
	3	15.65	3	15.56
	4	17.38	4	17.14
	5	21.31	5	21.16
4316-7	1	8.76 Hz	1	8.71 Hz
	2	9.68	2	9.58
	3	12.74	3	12.74
	4	20.37	4	20.30
	5	21.23	5	21.18

SYSTEM 4316-1 — 1.5% CHANGE (MODE 1)

SYSTEM 4316-7 — 0.6% CHANGE (MODE 1)

*FOR SYSTEM 4316-1 — S_A CHANGES FROM 1.39g TO 1.43g FOR THE PRIMARY SYSTEM FREQUENCY. (E-W DIRECTION)

FOR SYSTEM 4316-7 - S_A CHANGES FROM 1.92g TO 1.93g FOR THE PRIMARY SYSTEM FREQUENCY (E-W DIRECTION)

*VALUES OBTAINED FROM REF 1

BUCKLED DUCT PANELS CONTINUE TO CARRY LOAD, TYPICALLY SEVERAL TIMES THE BUCKLING LOAD, BEFORE FAILING. FOR THIS REASON, THE BUCKLED COMPRESSION SIDE OF THE DUCT SHOULD NOT BE ELIMINATED FROM THE MODEL UNTIL THE ULTIMATE LOAD IS REACHED. HOWEVER THE SECTION PROPERTIES DO CHANGE ACCORDING TO THE FACTORS DERIVED IN THIS EVALUATION. THIS RESULTS IN A MAXIMUM CHANGE OF 1.5% IN FREQUENCY AND APPROXIMATELY A 2% CHANGE IN ACCELERATIONS AT THE SYSTEM'S PRIMARY FREQUENCY. THEREFORE THE EFFECTS OF LOCAL BUCKLING ON THE OVERALL SYSTEM DYNAMICS ARE NEGLIGIBLE.

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 2 DATE: 27 APRIL 1994 PAGE: 23

SUBJECT: 5.0 REFERENCES BY: RJS CK: MAK SHT: 1 OF 1

1. DETROIT EDISON CO., HA-05/89-686, STRUCTURAL EVALUATION OF DUCTING SYSTEM 2848-3, 4316-1, 4316-6, AND 4316-7, PREPARED BY HOPPER AND ASSOCIATES, MAY 31, 1989.

2. FROM T.G. COLBURN OF THE U.S. NUCLEAR REGULATORY COMISSION TO D.R. GIPSON OF THE DETROIT EDISON CO., DOCKET NO. 50-341: FERMI 2 - CONTROL CENTER HEATING, VENTILATION, AND AIR CONDITIONING (CCHVAC) SYSTEM - REQUEST FOR ADDITIONAL INFORMATION, MARCH 3, 1994.

3. TIMOSHENKO, S.P. AND GERE, J.M., "THEORY OF ELASTIC STABILITY," SECOND EDITION, McGRAW HILL BOOK CO., NEW YORK, 1961.

4. BAŽANT, Z.P. AND CEDOLIN, L., "STABILITY OF STRUCTURES", OXFORD UNIVERSITY PRESS, 1991.

5. TIMOSHENKO, S., YOUNG, D.H AND WEAVER, W., "VIBRATION PROBLEMS IN ENGINEERING", FOURTH ED. JOHN WILEY & SONS, 1974.

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CALCULATION SHEET

TITLE: REPONSE TO CONCERN 2 DATE: 27APRIL1994 PAGE: A1

SUBJECT: APPENDIX A BY: BS CK: MAK SHT: 1 OF 1

SYSTEM FREQUENCIES CALCULATED USING NEW MOMENT OF INERTIAS:

TITLE = SSE FOR HVAC SYSTEM 4316-1

LOAD STEP =	1	ITERATION =	1	FREQ =	10.8106
LOAD STEP =	1	ITERATION =	2	FREQ =	15.3178
LOAD STEP =	1	ITERATION =	3	FREQ =	15.5617
LOAD STEP =	1	ITERATION =	4	FREQ =	17.1430
LOAD STEP =	1	ITERATION =	5	FREQ =	21.1566

TITLE = SSE FOR HVAC SYSTEM 4316-7

LOAD STEP =	1	ITERATION =	1	FREQ =	8.70859
LOAD STEP =	1	ITERATION =	2	FREQ =	9.57676
LOAD STEP =	1	ITERATION =	3	FREQ =	12.7380
LOAD STEP =	1	ITERATION =	4	FREQ =	20.3001
LOAD STEP =	1	ITERATION =	5	FREQ =	21.1809

Attachment 3 to
NRC-94-0050

HOPPER AND ASSOCIATES
ENGINEERS

DECO - USNRC DOCKET NO. 50-341

FERMI 2 CCHVAC DUCTING SYSTEMS

CONCERN ITEM NO. 3

EVALUATION CALCULATION

Prepared for: Detroit Edison Company
Nuclear Engineering Fermi 2
6400 North Dixie Highway
Newport, MI 48166

Prepared by: Hopper and Associates
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Redondo Beach, CA 90277

May, 1994

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: i

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: ii

SUBJECT: TABLE OF CONTENTS BY: HEK CK: MAK SHT: ii OF ii

PREPARED BY : H. E. K. MAY 4, 1994

REVIEWED BY : M. Amir Khan MAY 10, '94

:

1.0 INTRODUCTION.

1.1 PROBLEM STATEMENT

THE UNITED STATES NUCLEAR REGULATORY COMMISSION (USNRC) HAD MADE NUMEROUS COMMENTS [2] ON HOPPER AND ASSOCIATES' REPORT: HA-05/89-686 [1]. THE REPORT EVALUATED THE DESIGN INTEGRITY OF THE FOUR CCHVAC DUCTING SYSTEMS (2848-3, 4316-1, 4316-6, AND 4316-7) AT DECO - FERMI 2

THIS PACKAGE IS PREPARED IN RESPONSE TO ONE OF THE USNRC COMMENTS ON THE AFOREMENTIONED REPORT AS FOLLOWING: " THE SECTION PROPERTIES AND THE STRESSES WERE CALCULATED BASED ON THE THICKNESS OF THE GALVANIZED SHEET METAL. THESE SHOULD BE BASED ON THE THICKNESS OF THE BARE METAL." [2]

1.2 COMMENT RESPONSE APPROACH

THE HA-05/89-686 : "STRUCTURAL EVALUATION OF DUCTING SYSTEMS 2848-2, 4316-1, 4316-6, AND 4316-7" SHALL BE REVIEWED AND THE EFFECT OF BARE METAL THICKNESS ON STIFFNESS AND STRESS SHALL BE EVALUATED. THOSE DUCTING SYSTEMS DEEMED TO BE CRITICALLY AFFECTED SHALL BE RE-ANALYZED AND STRESSES SHALL BE RECALCULATED BASED ON THE THICKNESS OF BARE METAL. FIELD THICKNESS MEASUREMENTS SHALL BE CONDUCTED IF IT IS NECESSARY AND MEASUREMENT REQUIREMENTS SHALL BE ESTABLISHED.

1.3 RESPONSE SUMMARY

THE EFFECTS OF BARE METAL THICKNESS ARE INSIGNIFICANT FOR ALL THE CIRCULAR DUCTING SYSTEMS BECAUSE THE RESULTING STRESSES REMAIN WELL BELOW THE CODE ALLOWABLE UNDER OPERATIONAL AND OPERATIONAL PLUS SEISMIC (SSE, 7% DAMPING) LOADS.

STRESSES OF ALL SQUARE DUCTING SYSTEMS WERE CALCULATED BASED ON THE THICKNESS OF BARE METAL AND THE FOLLOWING CONCLUSIONS WERE WARRANTED:

(a) UNDER OPERATIONAL LOADING:

- SYSTEM 4316-1, (14" □ DUCT) REMAINS ELASTIC AND RESULTING STRESSES ARE LESS THAN 0.6 S_Y
- SYSTEM 4316-6, (16" □ DUCT) AND SYSTEM 4316-7 (16" □ DUCT) ARE ACCEPTABLE

(b) UNDER OPERATIONAL PLUS SEISMIC (SSE, 7% DAMPING):

- SYSTEM 4316-6, (16" □ DUCT) REMAINS ELASTIC AND RESULTING STRESSES ARE LESS THAN 0.9 S_Y
- LOCALIZED YIELDING AND BUCKLING OCCURS AT

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: 4

SUBJECT: 1.0 INTRODUCTION BY: HGK CK: MAK SHT: 4 OF 4

SOME LOCATIONS OF SYSTEM 4316-1, (14" SQ DUCT) AND 4316-7, (16" SQ. DUCT) THE PRIMARY STRESSES ARE LESS THAN 0.9 S_Y.

(c) UNDER OPERATIONAL PLUS SEISMIC (DBE) LOADINGS:

- SYSTEM 4316-1 (14" □ DUCT) YIELDS AND BUCKLES LOCALLY AT SOME LOCATIONS AND THE PRIMARY STRESSES ARE WITHIN 0.9 S_Y

NO FIELD MEASUREMENTS SHALL BE NECESSARY FOR ALL DUCTING SYSTEMS.

2.0 REVIEW OF THE EXISTING DUCTING ANALYSIS

A STRUCTURAL ANALYSIS WAS PERFORMED TO EVALUATE THE DESIGN INTEGRITY OF THE DUCTING SYSTEMS 2848-3, 4316-1, 4316-6, AND 4316-7. THIS ANALYSIS WAS DOCUMENTED IN HOPPER AND ASSOCIATES' REPORT HA-05/89-686 [1'].

THREE LOAD CONDITIONS WERE CONSIDERED FOR THE STRUCTURAL EVALUATION OF THE DUCTING SYSTEMS. THEY ARE : (1) INTERNAL PRESSURE

(2) EARTHQUAKE LOADING.

(3) SELF-WEIGHT

A STATIC ANALYSIS WAS PERFORMED TO DETERMINE THE STRESSES DUE TO THE SELF-WEIGHT OF THE DUCTING SYSTEMS. THEN, A DYNAMIC ANALYSIS WAS UNDERTAKEN TO CALCULATE THE STRESSES DUE TO EARTHQUAKE LOADING. THE STRESSES WERE CALCULATED FOR OPERATING BASIS EARTHQUAKE (OBE), THE DESIGN BASIC EARTHQUAKE (DBE), AND THE SITE SPECIFIC EARTHQUAKE (SSE).

LASTLY, A NEGATIVE 22" WATER PRESSURE WAS USED AS AN INTERNAL PRESSURE AND STRESSES WERE COMPUTED UNDER THIS CONDITION.

THE STRESSES FOR EACH OF THE ABOVE LOAD CASES WERE EVALUATED AND COMPARED TO THE REQUIREMENTS OF THE STANDARD ANSI/ASME N509-1980 [5] TABLE 2.0.1 SUMMARIZES THE CALCULATED STRESSES DUE TO OPERATIONAL LOAD AND OPERATIONAL PLUS SITE SPECIFIC EARTHQUAKE LOADS. THESE STRESSES WERE COMPARED TO THE ANSI/ASME ALLOWABLE VALUES AND THE FOLLOWING CONCLUSIONS WERE WARRANTED:

(a) ALL THE CIRCULAR AND SQUARE DUCTS REMAIN ELASTIC UNDER OPERATIONAL LOADS (SELF-WEIGHT PLUS INTERNAL 22" H_2O NEGATIVE PRESSURE) AND RESULTING STRESSES, LESS THAN 0.6 S_Y

(b) ALL THE CIRCULAR DUCTS REMAIN ELASTIC UNDER EARTHQUAKE (SSE) LOADING, RESULTING STRESSES ARE WELL WITHIN 0.9 S_Y.

(c) THE RIGID DUCT SYSTEM # 4316-6, 16" SQUARE DUCT

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: 7

SUBJECT: 2.0 REVIEW EXISTING DUCTING ANALYSIS BY: HEK CK: MAK SHT: 3 OF 4

DUCTING SYSTEM	DUCT SIZE	STRESSES DUE TO OPERATIONAL LOAD (PSI) PANEL	STIFFENER	ALLOWABLE STRESS 0.6Sy (PSI)	STRESSES DUE TO OPERATIONAL + SEISMIC(SSE) LOADS (PSI) PANEL	STIFFENER	ALLOWABLE STRESS 0.9Sy (PSI)
2848-3	18" CIR.	539	1124	21600	4809	-	32400
4316-1	14"SQ.	18880(FIXED)	5852	21600	43820(FIXED)	-	32400
		4434(S.S.)	-	21600	29370(S.S.)	-	32400
4316-6	16"SQ.	21460(FIXED)	7570	21600	22190(FIXED)	-	32400
		5042(S.S.)	-	21600	5775(S.S.)	-	32400
	17.5" C.R.	319	1093	21600	1206	-	32400
4316-7	16"SQ.	21050(FIXED)	7570	21600	43790(FIXED)	-	32400
		4632(S.S.)	-	21600	27370(S.S.)	-	32400
	18" CIR.	381	1124	21600	5824	-	32400

Sy = YIELD STRESS OF DUCT PANEL AND STIFFENER
SQ. = SQUARE DUCT
CIR. = CIRCULAR DUCT
FIXED = FIXED BOUNDARY CONDITION
S.S. = SIMPLE SUPPORTED BOUNDARY CONDITION
OPERATIONAL LOAD = SELF-WEIGHT + PRESSURE
OPERATIONAL + SEISMIC LOAD = SELF-WEIGHT + PRESSURE + SITE SPECIFIC EARTHQUAKE (SSE)

TABLE 2.0.1 SUMMARY OF STRESSES FOR DUCTING SYSTEMS 2848-3, 4316-1, 4316-6, AND 4316-7. [1]

REMAINS ELASTIC UNDER EARTHQUAKE (SSE) LOADS.

(d) LOCALIZED YIELDING AND BUCKLING OCCURS AT SOME LOCATIONS FOR THE SQUARE DUCTING SYSTEM NO. 4316-1 (14" SQUARE DUCT) AND 4316-7 (16" SQUARE DUCT). THE LOCALIZED CORNER YIELDING IS CAUSED BY FLEXURAL DEFORMATIONS. THE RESULTING PRIMARY MEMBRANE STRESSES ARE LESS THAN $0.9 S_Y$.

IT IS NOTED THAT THESE RESULTING STRESSES WERE COMPUTED BASED ON THE GALVANIZED THICKNESS OF NO. 18 GAGE SHEET METAL. THIS PROMPTED THE ACTION TO RE-EVALUATE THE DUCTING CAPABILITY AND THE EFFECT OF BARE METAL THICKNESS ON STIFFNESS AND STRESSES.

3.0 EVALUATION OF THE EFFECT OF BARE METAL THICKNESS

ACCORDING TO THE AISC MANUAL [6], THE FOLLOWINGS WERE ACQUIRED FOR A GAGE NO. 18 SHEET METAL :

(a) GALVANIZED SHEET GAGE THICKNESS = 0.0516"
(FOR HOT-DIPPED ZINC COATED SHEET)

(b) U.S. STANDARD GAGE THICKNESS = 0.0478"
(FOR UNCOATED SHEET)

THUS, % THICKNESS DIFFERENT $= \frac{(0.0516 - 0.0478)}{0.0478} \times 100\%$

$= 8\%$.

THE CALCULATED STRESSES, RESULTING FROM BOTH OPERATIONAL AND OPERATIONAL PLUS SEISMIC LOADS, TABULATED IN FIGURE 2.0.1 INDICATE THAT THERE ARE CONFORTABLE SAFETY MARGIN FOR ALL THE CIRCULAR DUCTS. HOWEVER, THE RESULTING STRESSES OF ALL SQUARE DUCTS ARE CLOSE TO THE ALLOWABLE STRESSES UNDER BOTH CONDITIONS. THEREFORE, AN INCREASED STRESSES DUE TO A 8% REDUCTION ON SHEET METAL THICKNESS WILL NOT COMPROMISE THE ALLOWABLE STRESS OF ANY

CIRCULAR DUCTS. BUT, THE INCREASED STRESSES MAY BE SIGNIFICANT TO THE 14" AND 16" SQUARE DUCT UNDER OPERATIONAL AND OPERATIONAL PLUS SEISMIC LOAD CONDITIONS.

THE NATURAL FREQUENCY OF AN INFINITELY LONG PLATE CAN BE APPROXIMATED BY IDEALIZING THE LONG PLATE AS A UNIFORM SINGLE-SPAN BEAM. BY APPLYING THE BEAM ANALOGY, THE NATURAL FREQUENCY CAN BE DETERMINED FROM THE FOLLOWING:

$$f_i = \frac{\lambda_i^2}{2\pi L^2}\left(\frac{EI}{m}\right)^{1/2} \qquad [7]$$

$$= \frac{1}{2\pi}\left(\frac{K}{m}\right)^{1/2}$$

WHERE E IS THE MODULUS OF ELASTICITY, m IS THE MASS, λ IS A DIMENSIONLESS PARAMETER WHICH IS A FUNCTION OF THE BOUNDARY CONDITION, I IS THE MOMENT OF INERTIA, L IS THE SPAN OF PLATE, AND K IS THE STIFFNESS CONSTANT. FROM THE ABOVE EQUATIONS, IT IS OBVIOUS THAT AN 8% REDUCTION IN SHEET METAL THICKNESS WILL MODERATELY CHANGE

THE MOMENT OF INERTIA I. THIS CHANGE IN I WILL RESULT IN A DIFFERENT STIFFNESS CONSTANT K, WHICH VARIES IN PROPORTION TO THE RATIO $(\frac{I_g}{I_b})^{1/2}$, WHERE I_g AND I_b ARE THE MOMENT OF INERTIA FOR GALVANIZED AND BARE SHEET METAL, RESPECTIVELY. THE SYSTEM FREQUENCY f_i WILL THEN BE AFFECTED AS K CHANGES. THUS, IT IS NECESSARY TO RE-CALCULATE THE FORCES AND MOMENTS DUE TO EARTHQUAKE FOR THOSE SQUARE DUCTING SYSTEMS WHICH DO NOT HAVE SUFFICIENT SAFETY MARGIN

IN SUMMARY, THE EFFECTS OF BARE METAL THICKNESS ARE INSIGNIFICANT TO ALL THE CIRCULAR DUCTING SYSTEMS BECAUSE THE STRESSES WILL REMAIN WELL BELOW THE ALLOWABLE UNDER OPERATIONAL AND OPERATIONAL PLUS SEISMIC LOADS. AS FOR THE SQUARE DUCTING SYSTEMS, STRESSES SHALL BE RE-CALCULATED BASED ON BARE METAL THICKNESS DURING OPERATIONAL LOADS. THE DYNAMIC ANALYSIS RE-EVALUATION CAN BE SIMPLIFIED BY REQUALIFYING THE HIGHEST STRESSED SQUARE DUCT SYSTEM.

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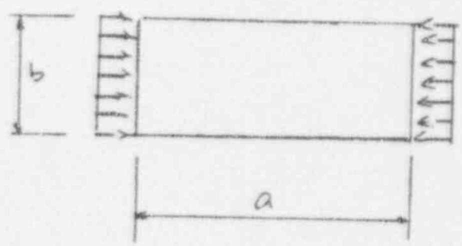
4.0 RE-DETERMINE DUCTING CAPABILITY

4.1 BUCKLING EVALUATION [3]

- COMPRESSIVE BUCKLING OF SIMPLY SUPPORTED PLATES (TIMOSHENKO, P 355)

$$\sigma_{CR} = \frac{K \pi^2 E}{12(1-\nu^2)} \left(\frac{h}{b}\right)^2$$

$K = 4$ CONSERVATIVE
$E = 29 \times 10^6$ PSI
$\nu = 0.29$
BARE METAL THICKNESS $h = 0.0478"$
$b = 14"$ OR $16"$



a = DISTANCE BETWEEN STIFFENERS

14" : $\sigma_{CR} = \frac{4(\pi^2) 29 \times 10^6}{12(1-0.29^2)} \left(\frac{0.0478"}{14"}\right)^2$

$= \underline{\underline{1214 \text{ PSI}}}$

$F_{CR} = 1214^{PSI} (0.0478" \times 14") = \underline{\underline{812 \text{ LB}}}$

16" : $\sigma_{CR} = \frac{4(\pi^2) 29 \times 10^6}{12(1-0.29^2)} \left(\frac{0.0478}{16"}\right)^2$

$= \underline{\underline{930 \text{ PSI}}}$

$F_{CR} = 930^{PSI} (0.0478" \times 16") = \underline{\underline{711 \text{ LB.}}}$

- ULTIMATE AND YIELDING STRENGTH

(TIMOSHENKO , P 418) :

$$P_{ULT} = \frac{\pi h^2}{\sqrt{3(1-\nu^2)}} \sqrt{E \, \sigma_{YP}}$$

BARE METAL THICKNESS : $h = 0.0478''$

$\nu = 0.29$

$E = 29 \times 10^6$ psi

$\sigma_{yp} = 36 \times 10^3$ psi

$$P_{ULT} = \frac{\pi (0.0478'')^2}{\sqrt{3(1-0.29^2)}} \sqrt{(29\times10^6)(36\times10^3)}$$

$= \underline{4423 \text{ LB}}$

14" :

$\sigma = 4423 \text{ LB} / (14'')(0.0478'')$

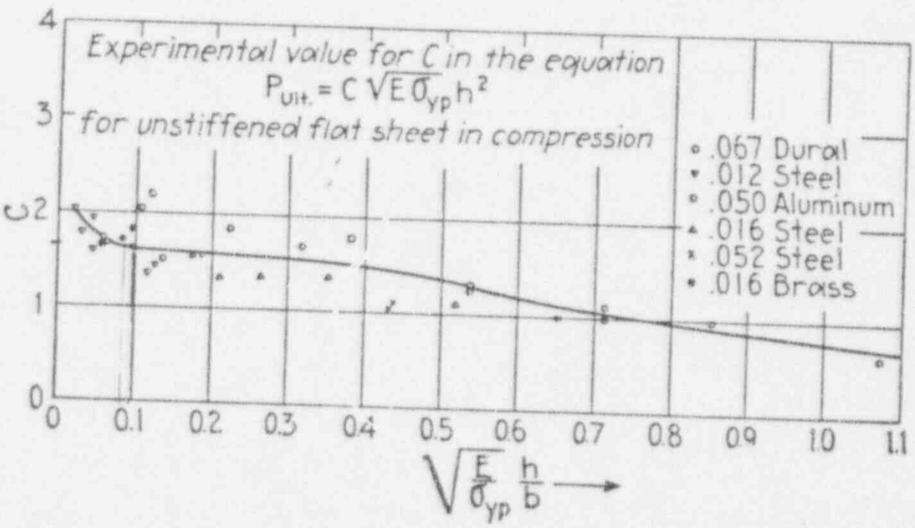
$= \underline{6612 \text{ psi}}$

16" :

$\sigma = 4423 \text{ LB} / (16'')(0.0478'')$

$= \underline{5786 \text{ psi}}$

USING EXPERIMENTAL VALUES TO FIND THE ULTIMATE LOAD, (TIMOSHENKO, P. 425):



16" : $\sqrt{\frac{E}{\sigma_{yp}}}\ \frac{h}{b} = \sqrt{\frac{29\times10^6 \text{ psi}}{36000 \text{ psi}}}\left(\frac{0.0478}{16}\right) \Rightarrow 0.085$

$C = 1.65$

14" : $\sqrt{\frac{29\times10^6 \text{ psi}}{36000 \text{ psi}}}\left(\frac{0.0478}{14}\right) \Rightarrow 0.097$

$C = 1.65$

$$P_{ULT.} = C\sqrt{E\,\sigma_{yp}}\,h^2$$

$$= 1.63\sqrt{29\times10^6\,\text{psi}\,(36000\,\text{psi})}\,(0.0478'')^2$$

$$= \underline{\underline{3852\ \text{LB.}}}$$

14":

$$\sigma = 3852^{LB}/(14'')(0.0478'') = 5756\ \text{psi}$$

16":

$$\sigma = 3852^{LB}/(16'')(0.0478'') = 5037\ \text{psi}$$

STRIP WIDTH:

14": $3852^{LB} = \{36000^{psi}(2C) + 1214^{psi}(14''-2C)\}\,0.0478''$

$C = 0.91''$

OR $4423^{LB} = \{36000^{psi}(2C) + 1214^{psi}(14''-2C)\}\,0.0478''$

$C = 1.09''$

16": $3852^{LB} = \{36000^{psi}(2C) + 930^{psi}(16''-2C)\}\,0.0478''$

$C = 0.94''$

OR $4423^{LB} = \{36000^{psi}(2C) + 930^{psi}(16''-2C)\}\,0.0478''$

$C = 1.10''$

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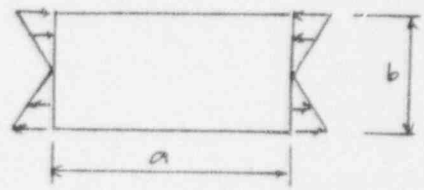
- BUCKLING OF SIMPLY SUPPORTED PLATE
  FOR BENDING AND COMPRESSION (TIMOSHENKO, P. 397)

$$\sigma_{CR} = K \frac{\pi^2 D}{b^2 h}$$



FROM FIGURE 9.20 : FOR PURE BENDING $\alpha = 2.0$

$$a/b : \frac{29.5''}{14''} = 2.11$$

$$\frac{29.5}{16''} = 1.84$$

OBTAIN K FACTOR : $K = 24$

FLEXURAL RIGIDITY OF PLATE : $D = \frac{Eh^3}{12(1-\nu^2)}$

$$= \frac{29\times10^6 \text{PSI} (0.0478)^3}{12(1-0.29^2)}$$

$$= 288.2$$

14" : $\sigma_{CR} = 24 \frac{\pi^2 (288.2)}{14^2 (0.0478)} = \underline{7278 \text{ PSI}}$

$$M_{CR} = \frac{\sigma_{CR} I}{c} = \frac{\sigma_{CR} h b^3}{12 (\frac{b}{2})} = \frac{\sigma_{CR} h b^2}{6} \Rightarrow \frac{7278^{\text{PSI}} (0.0478)(14)^2}{6}$$

$\Rightarrow \underline{11378 \text{ IN. LB}}$

16" : $\sigma_{CR} = \frac{24 \pi^2 (288.2)}{16^2 (0.0478)} = \underline{5579 \text{ PSI}}$

$$M_{CR} = \frac{5579 \text{PSI} (0.0478)(16)^2}{6} = \underline{11378 \text{ IN. LB}}$$

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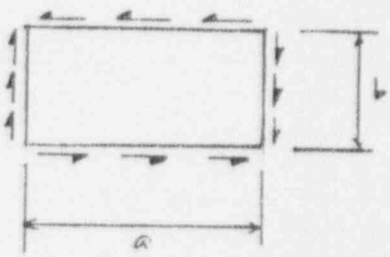
- BUCKLING OF RECTANGULAR PLATES UNDER SHEARING STRESS : (TIMOSHENKO , P. 379)

FOR AN INFINITELY LONG STRIP :



(1) SIMPLY SUPPORTED

$$\tau_{CR} = 5.35 \frac{\pi^2 D}{b^2 h}$$

(2) FIXED SUPPORTED

$$\tau_{CR} = 8.99 \frac{\pi^2 D}{b^2 h}$$

14" : $\tau_{CR} = 5.35 \frac{\pi^2 (288.2)}{(14)^2 (0.0478)} \Rightarrow$ 1624 PSI (S.S)

$M_{CR} = 14"(0.0478")(\frac{14"}{2})(4^{SIDES})\,1624^{PSI} =$ 30 420 LB.IN (S.S)

$\tau_{CR} = 8.99 \frac{\pi^2 (288.2)}{(14)^2 (0.0478)} \Rightarrow$ 2729 PSI (FIXED)

$M_{CR} = 14"(0.0478")(\frac{14"}{2})(4^{SIDES})(2729\,PSI) =$ 51 135 LB.IN (FIXED)

16" : $\tau_{CR} = 5.35 \frac{\pi^2 (288.2)}{(16)^2 (0.0478)} \Rightarrow$ 1244 PSI (S.S)

$M_{CR} = 16"(0.0478")(\frac{16"}{2})(4^{SIDES})(1244^{PSI}) =$ 30 445 $^{LB.IN}$ (S.S)

$\tau_{CR} = 8.99 \frac{\pi^2 (288.2)}{(16)^2 (0.0478)} \Rightarrow$ 2090 PSI (FIXED)

$M_{CR} = 16"(0.0478")(\frac{16"}{2})(4^{SIDES})(2090^{PSI}) =$ 51 150 $^{LB.IN}$ (FIXED).

4.2 PLATE MEMBRANCE & BENDING STRESSES [4]

FOR LARGE DEFLECTIONS OF A RECTANGULAR PLATE WITH AN ASPECT RATIO < 2/3, WE CAN USE THE INFINITELY LONG PLATE THEORY. (TIMOSHENKO, P. 427)

14" $\frac{14"}{29.5"} = .47 < \frac{2}{3}$

16" : $\frac{16"}{29.5"} = .54 < \frac{2}{3}$

∴ USE INFINITELY LONG PLATE THEORY, FIXED BOUNDARY CONDITION (TIMOSHENKO, P. 13)

MEMBRANE STRESS AT EDGE :

$$\sigma_1 = \frac{E u^2}{3(1 - \nu^2)} \left(\frac{h}{l} \right)^2$$

BENDING STRESS AT EDGE :

$$\sigma_2 = \frac{q}{2} \left(\frac{l}{h} \right)^2 \psi_1(u)$$

DEFLECTION AT CENTER :

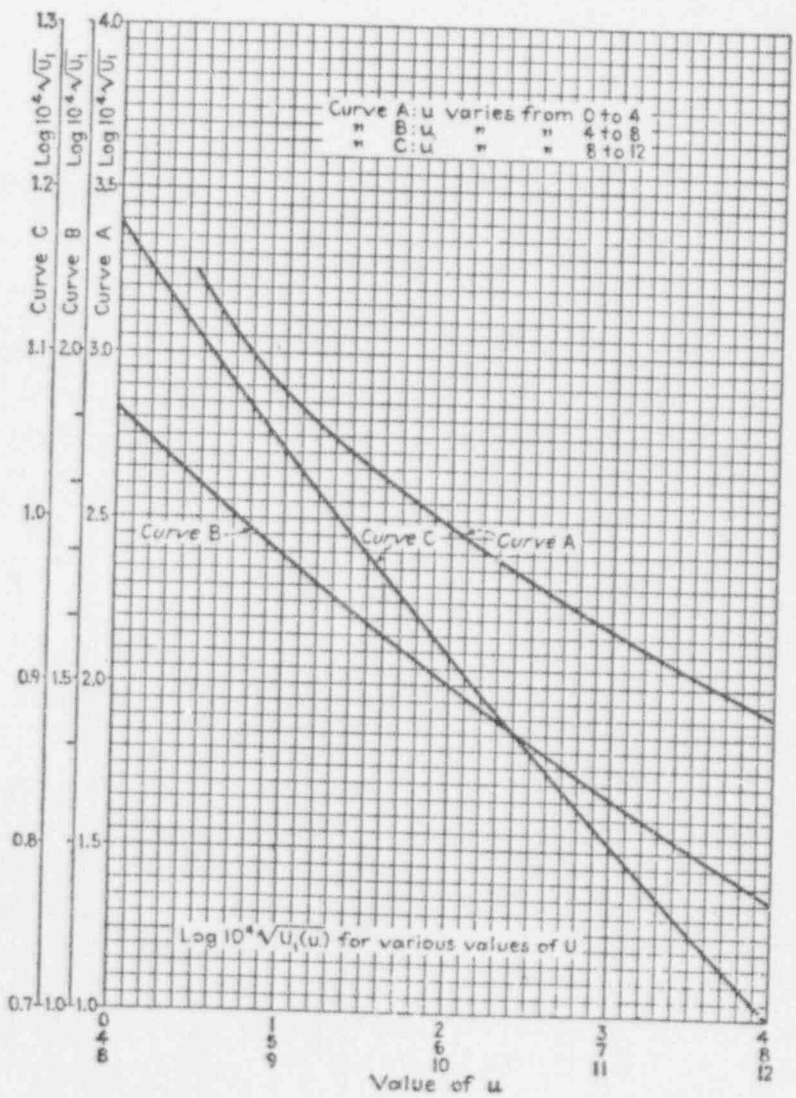
$$w_{max} = \frac{q l^4}{384 D} f_1(u) \qquad D = \frac{E h^3}{12(1 - \nu^2)}$$

WHERE:

$$f_1(u) = \frac{24}{u^4}\left(\frac{u^2}{2} + \frac{u}{\sinh u} - \frac{u}{\tanh u}\right)$$

$$\psi_1(u) = \frac{3(u - \tanh u)}{u^2 \tanh u}$$

AND u IS OBTAINED FROM



14" × 29.5" DUCT PANEL:

$$\sqrt{U_1} = \frac{E h^4}{(1-\nu^2) q \ell^4}$$

WHERE:
$$q = (0.284 \tfrac{LB}{IN^3})(0.0478") + (72")(62.4 \tfrac{LB}{FT^3})(\tfrac{1 FT}{12 IN})^3$$
$$= 0.808 \text{ PSI}$$
$$\ell = 14"$$

$$\sqrt{U_1} = \frac{(29\times10^6 \text{ PSI})(0.0478")^4}{(1-0.29^2)(0.808 \text{ PSI})(14")^4}$$
$$= 0.005325$$

$$\log_{10}\left[10^4\sqrt{U_1}\right] = 1.73$$

$$U = 4.85$$

$$f_1(u) = \frac{24}{(4.85)^4}\left(\frac{(4.85)^2}{2} + \frac{4.85}{\sinh 4.85} - \frac{4.85}{\tanh 4.85}\right)$$
$$= 0.303$$

$$\psi_1(u) = \frac{3(4.85 - \tanh 4.85)}{(4.85)^2 \tanh 4.85}$$

$$= 0.491$$

HENCE:

$$\sigma_1 = \frac{(29\times10^6 \text{ PSI})(4.85)^2}{3(1-0.29^2)}\left(\frac{0.0478"}{14"}\right)^2$$

$$= \underline{\underline{2894 \text{ PSI}}} \Rightarrow \sigma_m$$

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$$\sigma_2 = \frac{0.808 \text{ psi}}{2} \left(\frac{14 \text{ in}}{0.0478}\right)^2 (0.491)$$

$$= \underline{\underline{17016 \text{ psi}}} \Rightarrow \sigma_b$$

$$w_{MAX} = \frac{0.808^{\text{psi}} (14")^4}{384} (0.343) \frac{12(1 - 0.29^2)}{29 \times 10^6 (0.0478")^3}$$

$$= \underline{\underline{0.085"}}$$

16" × 29.5" DUCT PANEL :

$$\sqrt{u_1} = \frac{(29\times10^6 \text{ psi})(0.0478")^4}{(1-0.29^2)(0.808 \text{ psi})(16")^4} \Rightarrow 0.003122$$

$$\log_{10}\left[10^4\sqrt{u_1}\right] = 1.49$$

$$u = 6.0$$

$$f_1(u) = \frac{24}{(6.0)^4}\left(\frac{(6.0)^2}{2} + \frac{6.0}{\sinh 6.0} - \frac{6.0}{\tanh 6.0}\right)$$

$$= 0.222$$

$$\psi_1(u) = \frac{3(6 - \tanh 6)}{(6)^2 \tanh 6}$$

$$= 0.417$$

HENCE :

$$\sigma_1 = \frac{(29\times10^6 \text{ psi})(6.0)^2}{3(1-0.29^2)}\left(\frac{0.0478}{16"}\right)^2$$

$$= 3391 \text{ psi} \Rightarrow \sigma_m$$

$$\sigma_2 = \frac{0.808 \text{ psi}}{2}\left(\frac{16"}{0.0478}\right)^2(0.417)$$

$$= 18\,876 \text{ psi} \Rightarrow \sigma_b$$

$$W_{MAX} = \frac{0.808^{\text{psi}}(16")^4}{384}(0.222)\frac{12(1-0.29^2)}{29\times10^6(0.0478")^3}$$

$$= 0.106"$$

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SIMPLY SUPPORTED BOUNDARY CONDITION : [10]

AT THE CENTER OF THE LONG EDGE, ⊥ TO THE EDGE.

$$\sigma_1 = n_6 \sqrt[3]{p^2 E \left(\frac{a}{t}\right)^2}$$

$$= n_6 \sqrt[3]{(0.808 \text{ psi})^2 (29 \times 10^6) \left(\frac{29.5''}{0.0478''}\right)^2}$$

$$= n_6 \, 19320$$

AT THE CENTER OF THE LONG EDGE, // TO THE EDGE

$$\sigma_2 = n_7 \sqrt[3]{p^2 E \left(\frac{a}{t}\right)^2}$$

$$= n_7 \, 19320$$

14" × 29.5" PANEL :

FOR $\frac{a}{b} = \frac{29.5}{14} = 2.1$ OBTAIN $n_6 = .33$, $n_7 = .10$

$\sigma_1 = 6376$ psi

$\sigma_2 = 1932$ psi

16" × 29.5" PANEL :

FOR $\frac{a}{b} = \frac{29.5}{16} = 1.8$ OBTAIN $n_6 = .351$, $n_7 = .105$

$\sigma_1 = 6781$ psi

$\sigma_2 = 2029$ psi

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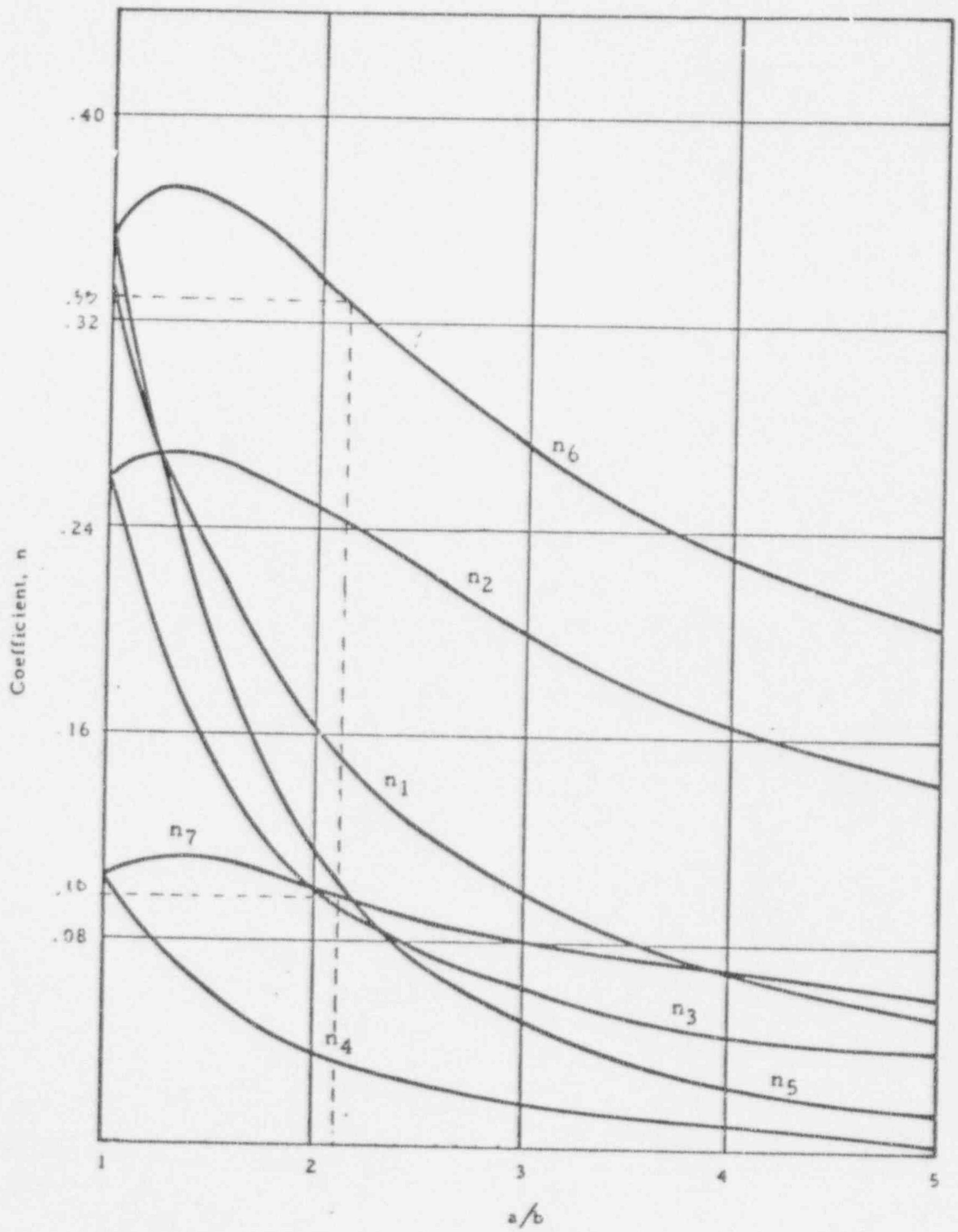
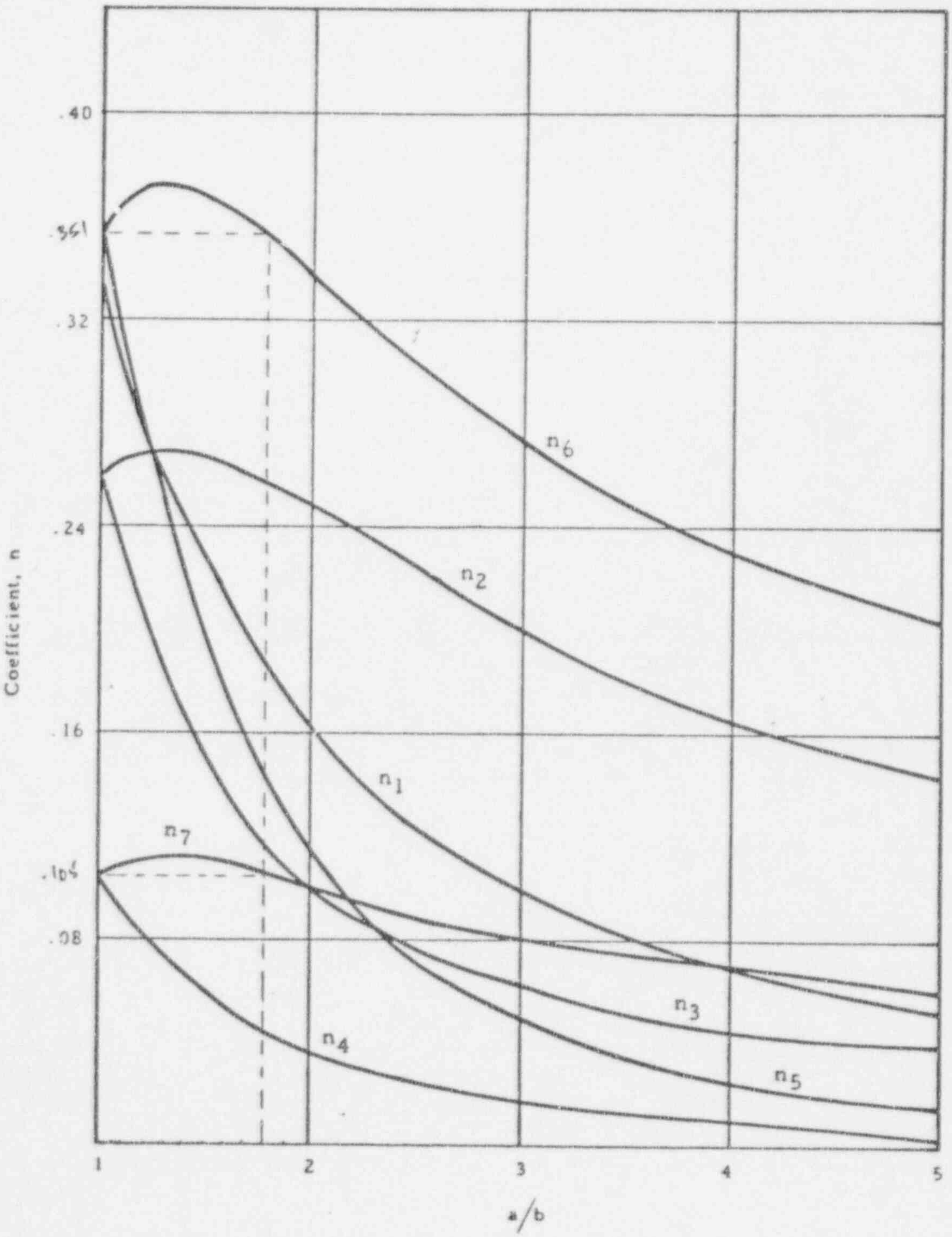
14" x 29.5" PANEL



16" × 29.5" PANEL



4.3 SYSTEM 4316-1, 14" □

PANEL STRESS

- FOR PRESSURE

σ_m = 2894 psi
σ_b = 17016 psi
} FIXED B.C. (FROM PAGE 20 AND 21)

σ_1 = 6376 psi
σ_2 = 1932 psi
} SIMPLY SUPPORTED B.C. (FROM PAGE 23)

- FOR SELF-WEIGHT : $\sigma = \pm \frac{M_z d}{2I} + \frac{f_x}{A}$

ASSUMING THAT FORCES AND MOMENTS DO NOT CHANGE DUE TO CHANGE IN THICKNESS.

MAXIMUM MOMENTS / FORCES FOR SELF-WT. AT ELEMENT #19

$F_x = 0.$ $M_z = -2795$ IN. LBS [1, P. 91]

WHERE $I = \frac{bd^3 - b_1 d_1^3}{12} \Rightarrow \frac{14(14)^3 - [14 - 2(0.0478)](14 - 2(0.0478))^3}{12}$

$\Rightarrow 86.6\ \text{IN}^4$

$\sigma = \frac{(2795\ \text{IN.}^{\#})(14")}{2(86.6\ \text{IN}^4)} + 0$

$= 226$ psi

COMBINED STRESSES DUE TO PRESSURE + SELF-WEIGHT:

$\sigma = (2894 + 17016)^{psi} + 226^{psi}$

$= 20136$ psi (FIXED)

$\sigma = (6376 - 1932)^{psi} + 226^{psi}$

$= 4670$ psi (SIMPLY SUPPORTED)

AS A PERCENTAGE IN YIELD:

FIXED: $\frac{\sigma}{\sigma_{yp}} * 100\% \Rightarrow \frac{20136^{psi}}{36000\ psi} * 100\%$

$\Rightarrow 55.9\% < .60\ \sigma_{yp}$

OPERATIONAL ALLOWABLE

O.K

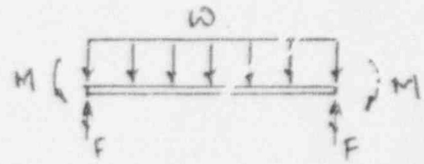
SIMPLY SUPPORTED: $\frac{4670^{psi}}{36000\ psi} * 100\%$

$\Rightarrow 13.0\% < .60\ \sigma_{yp}$

O.K

STIFFENERS : $1\frac{1}{2}" \times 1\frac{1}{2}" \times \frac{1}{8}"$ ANGLE.

ASSUME ALL PRESSURE IN PANEL RESISTED BY STIFFENERS.



$$W = 0.808 \text{ PSI} (29.6")$$
$$= 23.9 \text{ LB/IN}$$

$$M = \frac{W l^2}{12} \Rightarrow \frac{(23.9 \text{ LB/IN})(14")^2}{12}$$
$$\Rightarrow 390.4 \text{ IN LB}$$

$$F = \frac{W l}{2} \Rightarrow \frac{(23.9 \text{ LB/IN})(14")}{2} = 167.3 \text{ LB}$$

$$\sigma = \frac{Mc}{I} + \frac{F}{A}$$

WHERE $I = 0.078 \text{ IN}^4$, $c = 1.08"$, $A = 0.375 \text{ IN}^2$.

$$= \frac{(390.4 \text{ IN-LB})(1.08")}{0.078 \text{ IN}^4} + \frac{167.3 \text{ LB}}{0.375 \text{ IN}^2}$$

$$= 5852 \text{ PSI}$$

AS A PERCENT OF YIELD:

$$\frac{5852 \text{ PSI}}{36000 \text{ PSI}} \times 100\% = 16.3\% < 0.60\,\sigma_{yp}$$

OPERATIONAL ALLOWABLE

O.K.

BUCKLING DETERMINATION, OPERATIONAL LOADS [1, PAGE 96]

BENDING : LARGEST MOMENT AT ELEMENT 19

M_z = 2795 IN.LBS < 11378 IN.LBS (SEE PAGE 16)
O.K.

TORSION : LARGEST MOMENT AT ELEMENT 30

M_x = 4342 IN.LBS < 30440 IN.LBS (SEE PAGE 17)
O.K.

AXIAL : LARGEST FORCE AT ELEMENT 19

F_x = 199.6 LBS < 812 LBS (SEE PAGE 12).

∴ NO BUCKLING DUE TO OPERATIONAL LOAD

- SEISMIC LOADING (SSE)

TABLE 2.0.1 INDICATES THAT THE STRESS (FOR SIMPLY SUPPORTED CASE) OF SYSTEM #4316-1, 14" SQ. DUCT DUE TO OPERATIONAL PLUS SEISMIC (SSE), WHICH IS 29370 PSI, IS THE CLOSEST TO THE $0.9S_y$ ALLOWABLE (32400 PSI). THUS, A DYNAMIC ANALYSIS WAS RE-PERFORMED FOR THE SYSTEM BY USING THE ORIGINAL ANALYTICAL COMPUTER MODEL [1] EXCEPT THE FOLLOWINGS:

(a) THE SECTION PROPERTIES OF THE 14" SQ. DUCT SYSTEM WERE CALCULATED BASED ON THE BARE METAL THICKNESS. (AREA OF BARE METAL WAS USED).

(b) THE SYSTEM MASS DENSITY WAS INCREASED FROM 0.0012 TO 0.00125 $\frac{LB \cdot SEC^2}{IN}$ TO COMPENSATE THE SYSTEM WEIGHT LOSS DUE TO AREA REDUCTION. THEORETICALLY, SYSTEM WEIGHT SHALL REMAIN UNCHANGED.

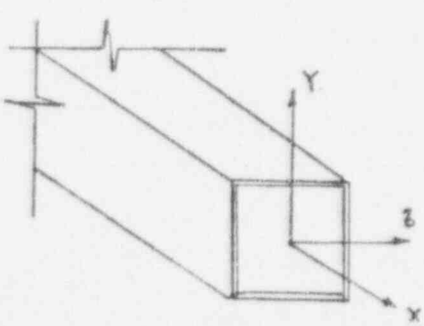
(c) 7% DAMPING SITE SPECIFIC EARTHQUAKE RESPONSE SPECTRA WERE USED. [8, 9].

IN ADDITION, THE MODIFIED COMPUTER MODEL WAS RE-ANALYZED WITH 2% DAMPING SITE SPECIFIC EARTHQUAKE RESPONSE SPECTRA, AND 1% DAMPING DESIGN BASIC EARTHQUAKE RESPONSE SPECTRA. THE RESULTS OF THESE ANALYSES ARE SUMMARIZED IN TABLE 4.3.1

DUCT SYSTEM : 4316-1 , 14' SQ. DUCT.

CRITICAL LOCATION : ELEMENT 21
NODE 22

FORCES AND MOMENTS (F) (M)	SSE 7% DAMPING	SSE 2% DAMPING	DBE 1% DAMPING
F_x (LBS)	1082.1	1221.8	791.0
F_Y (LBS)	0	0	0
F_z (LBS)	1558.2	1759.4	1132.7
M_x (IN. LBS)	0	0	0
M_Y (IN. LBS)	52531.3	59298.6	38158.0
M_z (IN. LBS)	0	0	0



NOTE:
COMPUTER OUTPUTS ARE PROVIDED IN APPENDIX A.

TABLE 4.3.1 SUMMARY OF RESULTS.

PANEL STRESSES DUE TO SEISMIC LOADINGS:

$$\sigma = \frac{M_y \ell}{2I} + \frac{F_x}{A}$$

$I = 86.6 \text{ in}^4$ $\ell = 14"$

$A = (0.0478")(14")(4) = 2.68 \text{ in}^2$

- SSE LOADING (7% DAMPING)

$$\sigma = \frac{(52\,531.3^{\text{IN-LBS}})(14")}{2(86.6 \text{ in}^4)} + \frac{1092.1^{\text{LBS}}}{2.68 \text{ in}^2} \Rightarrow 4650^{\text{PSI}} > 1214^{\text{PSI}}$$

BUCKLING OCCURS

FOR PANEL STRESSES, ASSUMING STRIP WIDTH: C = 1.0 (SEE PAGE 18)

$$4650^{\text{PSI}}(14")(0.0478") = \{\sigma\, 2(1.0) + 1214^{\text{PSI}}(14" - 2(1.0))\}(0.0478)$$

$$\sigma = \underline{25\,266 \text{ PSI}}$$

- SSE LOADING (2% DAMPING)

$$\sigma = \frac{(59\,298.6^{\text{IN-LBS}})(14")}{2(86.6 \text{ in}^4)} + \frac{1321.8^{\text{LBS}}}{2.68 \text{ in}^2} \Rightarrow 5249.1^{\text{PSI}} > 1214^{\text{PSI}}$$

BUCKLING OCCURS

FOR PANEL STRESSES, ASSUMING STRIP WIDTH: C = 1.0 (SEE PAGE 18)

$$5249.1^{\text{PSI}}(14")(0.0478") = \{\sigma\, 2(1.0) + 1214^{\text{PSI}}(14" - 2(1.0))\}(0.0478)$$

$$\sigma = \underline{29\,460 \text{ PSI}}$$

- DBE LOADING (1% DAMPING)

$$\sigma = \frac{(38158.0^{\text{IN.LBS}})(14'')}{2\ (86.6\ \text{IN}^4)} + \frac{791.0^{\text{LB}}}{2.68\ \text{IN}^2} \Rightarrow 3380^{\text{PSI}} > 1214^{\text{PSI}}$$

BUCKLING OCCURS

FOR PANEL STRESSES, ASSUMING STRIP WIDTH: C=1.0 (SEE PAGE 15)

$$3380^{\text{PSI}}(14'')(0.0478'') = \left\{\sigma\, 2(1.0) + 1214^{\text{PSI}}(14'' - 2(1.0))\right\}(0.0478'')$$

$$\sigma = \underline{16376\ \text{PSI}}$$

BUCKLING DETERMINATION, SEISMIC LOAD:

BENDING: LARGEST MOMENT @ ELEMENT 21

SSE (7% DAMPING): M_Y = 52551.3 IN.LBS
SSE (2% DAMPING): M_Y = 59298.6 IN.LBS
DBE (1% DAMPING): M_Y = 38158.0 IN.LBS
} > 11378 IN.LBS

TORSION: LARGEST MOMENT @ ELEMENT 36

SSE (7% DAMPING): M_x = 5194.8 IN.LBS
SSE (2% DAMPING): M_x = 4747.0 IN.LBS
DBE (1% DAMPING): M_x = 4313.4 IN.LBS
} < 30430 IN.LBS

AXIAL: LARGEST FORCE @ ELEMENT 21

SSE (7% DAMPING): F_x = 1082.1 LBS
SSE (2% DAMPING): F_x = 1221.8 LBS
} > 812 LBS
DBE (1% DAMPING): F_x = 791.0 LBS < 812 LBS

∴ BUCKLING OCCURS DUE TO BENDING & AXIAL LOADINGS (SSE)

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: 34

SUBJECT: 4.0 RE-DETERMINE DUCTING CAPABILITY BY: HEK CK: MAK SHT: 23 OF 36

COMBINED OPERATING PLUS SEISMIC LOADINGS:

PANEL STRESSES:

(1) OPERATING + SSE (7% DAMPING):

σ = 20 136 PSI + 25 266 PSI ⇒ 45 402 PSI > 0.9 S_y PSI (FIXED)

σ = 4670 PSI + 25 266 PSI ⇒ 29 936 PSI < 0.9 S_y = 32 400 PSI (S.S.)

(2) OPERATING + SSE (2% DAMPING):

σ = 20 136 PSI + 29 460 PSI ⇒ 49 596 PSI > 0.9 S_y PSI (FIXED)

σ = 4670 PSI + 29 460 PSI ⇒ 34 130 PSI > 0.9 S_y = 32 400 PSI (S.S.)

(3) OPERATING + DBE 1% (DAMPING):

σ = 20 136 PSI + 16 376 PSI ⇒ 36 512 PSI > 0.9 S_y (FIXED)

σ = 4670 PSI + 16 376 PSI ⇒ 21 046 PSI < 0.9 S_y (S.S.)

∴ A PLASTIC HINGE WILL FORM AT THE DUCT CORNER DURING MAXIMUM DUCT PRESSURE PLUS SSE (7% DAMPING), OR MAXIMUM DUCT PRESSURE PLUS DBE (1% DAMPING). AT OTHER AREA, STRESSES ARE LESS THAN 0.9 S_y ALLOWABLE.

AS A PERCENTAGE OF YIELD:

(1): $\frac{29\,936 \text{ PSI}}{36\,000 \text{ PSI}} \times 100\% = 83.2\%$ ← ∴ SYSTEM # 4416.1 IS ADEQUATE

(3): $\frac{21\,046 \text{ PSI}}{36\,000 \text{ PSI}} \times 100\% = 58.5\%$

4.4 SYSTEM 4316-6, 16" □

PANEL STRESS

- FOR PRESSURE

$\sigma_m = 3391$ psi
$\sigma_b = 18876$ psi
} FIXED B.C (SEE PAGE 22)

$\sigma_1 = 6781$ psi
$\sigma_2 = 2029$ psi
} SIMPLY SUPPORTED B.C (SEE PAGE 23)

- FOR SELF-WEIGHT

$$\sigma = \pm \frac{M_z l}{2I} + \frac{F_x}{A}$$

MAX. MOMENTS/FORCES FOR SELF-WEIGHT AT : [1, P. 164]

	F_x	M_z
ELEMENT 23	NIL	-9211 IN.LBS

WHERE

$$I = \frac{bd^3 - b_1 d_1^3}{12} \Rightarrow \frac{16(16)^3 - \{16 - 2(0.0478)\}\{16 - 2(0.0478)\}^3}{12}$$

$$\Rightarrow 129.4 \text{ IN}^4$$

$$\sigma = \frac{(9211 \text{ IN.LBS})(16")}{2(129.4 \text{ IN}^4)} + 0 \Rightarrow 569.5 \text{ PSI}$$

COMBINED STRESSES DUE TO PRESSURE + SELF-WEIGHT

$\sigma = (3391 + 18876)^{psi} + 569.5^{psi}$

$= 22837$ psi (FIXED).

$\sigma = (6781 - 2029)^{psi} + 569.5^{psi}$

$= 5322$ psi (SIMPLY SUPPORTED).

AS A PERCENT IN YIELD:

SIMPLY SUPPORTED : $\frac{5322 \text{ psi}}{36000 \text{ psi}} * 100\%$

$\Rightarrow 14.8\%$ < $.60\,\sigma_{YP}$ OPERATIONAL ALLOWABLE

O.K

FIXED : $\frac{22837^{psi}}{36000 \text{ psi}} * 100\%$

$= 63.4\%$ > $.60\,\sigma_{YP}$

N.G

IN CONSERVATIVELY ASSUMED FIXED BOUNDARY CONDITION, A 3.4 % OVERSTRESSED WAS ENCOUNTERED UNDER OPERATIONAL LOAD

STIFFENER : $1\frac{1}{2}" \times 1\frac{1}{2}" \times \frac{1}{8}"$

$$M = \frac{wl^2}{12} \Rightarrow \frac{23.9 \text{ LB/IN} (16^{\text{IN}})^2}{12} \Rightarrow 509.9 \text{ IN.LBS}$$

$$F = \frac{wl}{2} \Rightarrow \frac{(23.9 \text{ IN.LBS})(16")}{2} \Rightarrow 191.2 \text{ IN.LBS}$$

$$\sigma = \frac{Mc}{I} + \frac{F}{A} \Rightarrow \frac{(509.9 \text{ IN.LB})(1.08")}{0.078 \text{ IN}^4} + \frac{191.2 \text{ LBS}}{0.375 \text{ IN}^2}$$

$$\Rightarrow 7570 \text{ PSI}$$

AS A PERCENTAGE OF YIELD :

$$\frac{7570 \text{ PSI}}{36000 \text{ PSI}} * 100\% = 21.0\% \quad < 0.60\,\sigma_{YP}$$

ALLOWABLE O.K.

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: 38

SUBJECT: 4.0 RE-DETERMINE DUCTING CAPABILITY BY: HKF CK: MAK SHT: 27 OF 36

BUCKLING DETERMINATION, OPERATIONAL LOAD [1, PAGE 108]

BENDING, LARGEST MOMENT AT ELEMENT 23:

M_z = 9211 IN. LBS. < 11 378 IN. LBS
(SEE PAGE 16)

TORSION: LARGEST MOMENT AT ELEMENT 6:

M_x = 1256 IN. LBS < 20 448 IN. LBS
(SEE PAGE 17)

AXIAL: LARGEST FORCE AT ELEMENT 23

F_x = 575.7 LBS < 711 LBS
(SEE PAGE 17)

∴ NO BUCKLING DUE TO OPERATIONAL LOADS

SEISMIC LOADING (SSE).

THE FORCES AND MOMENTS OBTAINED FROM THE ORIGINAL DYNAMIC ANALYSIS [1] WERE ADOPTED TO RECALCULATE THE STRESSES BASED ON THE BARE METAL THICKNESS. THE ORIGINAL DYNAMIC ANALYTICAL MODEL WAS DEVELOPED BY CONSERVATIVELY USING THE SITE SPECIFIC EARTHQUAKE SPECTRA WITH A 2% CRITICAL DAMPING. THE UTILIZATION OF THE SITE SPECIFIC EARTHQUAKE SPECTRA (7% CRITICAL DAMPING) WOULD PRODUCE SMALLER SYSTEM REACTIONS. THEREFORE, THESE ORIGINAL FORCES AND MOMENTS WERE USED FOR CONSERVATISM.

PANEL STRESSES :

$$\sigma_Y = \frac{M_Y d}{2I} + \frac{F_x}{A} \qquad \left.\begin{aligned} M_Y &= 9881.3 \text{ IN-LBS} \\ F_x &= 567.9 \text{ LBS} \end{aligned}\right\} [1, \text{PAGE } 109]$$

BARE METAL $I_B = 129.4 \text{ IN}^4$

$$\therefore \sigma = \frac{(9881.3^{\text{IN-LBS}})(16")}{2(129.4)^{\text{IN}^4}} + \frac{567.9^{\text{LBS}}}{(16")(0.0478")(4)}$$

$$= 610.9 \text{ PSI} + 185.6 \text{ PSI} \Rightarrow 796.5^{\text{PSI}} < 930^{\text{PSI}}$$

NO BUCKLING DUE TO SSE

$$\text{STRESS AS \% OF YIELD} \Rightarrow \frac{796.5 \text{ PSI}}{36000 \text{ PSI}} \times 100\% = 2.2\%$$

BUCKLING DETERMINATION, SEISMIC LOAD.

BENDING : LARGEST MOMENT AT ELEMENT 23

M_y = 5814 IN. LBS < 11378 IN. LBS

TORSION ; LARGEST MOMENT AT ELEMENT 1

M_x = 2278 IN. LBS < 30445 IN. LBS

AXIAL : LARGEST FORCE AT ELEMENT 11

F_x = 480 LBS (1.044) < 711 LBS

∴ NO BUCKLING FOR SEISMIC LOADS.

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: 41

SUBJECT: 4.0 RE-DETERMINE DUCTING CAPABILITY BY: HEK CK: MAK SHT: 30 OF 36

COMBINED OPERATING PLUS SEISMIC

PANEL STRESSES

σ = 22837 psi + 797 psi

= 23634 psi < $0.9S_y$ = 32400 psi (FIXED)

σ = 5322 psi + 797 psi

= 6119 psi < $0.9S_y$ (SIMPLY SUPPORTED)

AS A PERCENTAGE OF YIELD:

FIXED: $\frac{23634}{36000}$ * 100% = 65.8%

SIMPLY SUPPORTED: $\frac{6119}{36000}$ * 100% = 17.0%

4.3 SYSTEM 4316-7, 16" □

PANEL STRESS.

- FOR PRESSURE

σ_m = 3391 PSI
σ_b = 18 876 PSI
} FIXED B.C.

σ_1 = 6781 PSI
σ_2 = 2029 PSI
} SIMPLY SUPPORTED B.C.

- FOR SELF-WEIGHT

$$\sigma = \pm \frac{M_z \ell}{2I} + \frac{F_x}{A}$$

MAX MOMENTS/FORCES FOR SELF-WEIGHT AT : [1, P.120]

	F_x	M_z
ELEMENT	NIL	1994 IN. LBS.

$$\sigma = \frac{(1994 \text{ IN.LBS.})(16")}{2\ (129.4 \text{ IN}^4)} + 0$$

$$= 123.3 \text{ PSI}$$

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: 43

SUBJECT: 4.0 RE-DETERMINE DUCTING CAPABILITY BY: HEK CK: MAK SHT: 32 OF 36

COMBINED STRESSES DUE TO PRESSURE + SELF-WEIGHT

$\sigma = (3391 + 18876)^{psi} + 123.3^{psi}$

$= 22390 \text{ psi}$

$\sigma = (6781 - 2029)^{psi} + 123.3^{psi}$

$= 4875 \text{ psi}$

AS A PERCENT IN YIELD:

SIMPLY SUPPORTED : $\frac{4875 \text{ psi}}{36000 \text{ psi}} * 100\%$

$\Rightarrow 13.5\% < 0.60\,\sigma_Y$ OPERATIONAL ALLOWABLE.

FIXED : $\frac{22390 \text{ psi}}{36000 \text{ psi}} * 100\%$

$= 62.2\% > 0.60\,\sigma_Y$

AGAIN, THE CONSERVATIVELY ASSUMED FIXED BOUNDARY CONDITION AT THE JOINTS RESULTED IN A 2.2% OVERSTRESS UNDER OPERATIONAL LOAD.

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: 44

SUBJECT: 4.0 RE-DETERMINE DUCTING CAPABILITY BY: HEF CK: MBK SHT: 33 OF 36

BUCKLING DETERMINATION, OPERATING LOADS

BENDING, LARGEST MOMENT AT ELEMENT 42

M_z = 1994 IN.LBS < 11378 IN LBS

TORSION, LARGEST MOMENT AT ELEMENT 59

M_x = 1787 IN.LBS < 30448 IN.LBS

AXIAL, LARGEST FORCE AT ELEMENT 42

F_x = 124.6 LBS < 711 LBS

∴ NO BUCKLING DUE TO OPERATIONAL LOADS

SEISMIC LOADING, SSE

- PANEL STRESSES [1, PAGE 125]

$$\sigma = \frac{M_y f}{2I} + \frac{F_x}{A}$$

USING ORIGINAL REACTIONS : (SEE PAGE 39)

M_y = 61543 IN-LBS

F_x = 796.5 LBS

$$\therefore \quad \sigma = \frac{(61543^{\text{IN-LBS}})(16")}{2\,(129.4\text{ IN}^4)} + \frac{796.5\text{ LBS}}{16"(0.0478")(4)}$$

$$= 3804.8 + 260 = 4065 \text{ PSI}$$

BUCKLING STRESS = 930 PSI < 4065 PSI

∴ PANEL BUCKLES

BUCKLING YIELD STRESS = 5037 PSI > 4065 PSI

∴ PANEL DOES NOT YIELD DUE TO BUCKLING ONLY

YIELD STRIP WIDTH

$$(36000^{\text{PSI}})(2c) + (930^{\text{PSI}})(16" - 2c) = 5037^{\text{PSI}}(16")$$

$$72000\,c + 14880 - 1860c = 80592$$

$$c = 0.94" \quad (\text{SAY } c = 1.0)$$

SEE PAGE 15

HENCE COMPRESSIVE STRESS :

$$\sigma\, 2(1.0) + (930^{\text{PSI}})(16" - 2(1.0)) = (4065^{\text{PSI}})(16")$$

$$\sigma = 26010 \text{ PSI}$$

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: 46

SUBJECT: 4.0 RE-DETERMINE DUCTING CAPABILITY BY: HEK CK: [illegible] SHT: 35 OF 36

BUCKLING DETERMINATION, SEISMIC LOADS [1, PAGE 126]

BENDING, LARGEST MOMENT AT ELEMENT 43

$M_y = 61543$ IN.LBS > 11378 IN.LBS

TORSION, LARGEST MOMENT

$M_x = 8608$ IN.LBS < 30430 IN.LBS

AXIAL, LARGEST FORCE

$F_x = 4041$ LBS > 812 LBS

∴ BUCKLING OCCURS DUE TO BENDING AND AXIAL LOADS.

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: 47

SUBJECT: 4.0 RE-DETERMINE DUCTING CAPABILITY BY: HGK CK: MAK SHT: 36 OF 36

COMBINED OPERATING PLUS SEISMIC

PANEL STRESSES

σ = (22390 + 26010) PSI

= 48400 PSI > 36000 PSI (FIXED)

σ = (4875 + 26010) PSI

= 30885 PSI < $0.9 S_y$ = 32400 PSI (SIMPLY SUPPORTED)

5.0 RESULTS SUMMARY AND DISCUSSIONS.

THE RE-CALCULATED STRESSES OF ALL THE SQUARE DUCTING SYSTEMS BASED ON THE BARE METAL THICKNESS ARE SUMMARIZED AND PRESENTED IN TABLE 5.0.1. THE RESULTS INDICATE THAT:

(a) DURING OPERATIONAL LOADING, DUCTING SYSTEM 4316-1, (14" SQ. DUCT) REMAINS ELASTIC AND RESULTING STRESSES ARE WELL WITHIN 0.6 S_Y. HOWEVER, DUCTING SYSTEMS 4316-6 (16" SQ DUCT) AND 4316-7 (16" SQ DUCT) COULD BE SLIGHTLY OVERSTRESSED BY 3.4 % AND 2.2 %, RESPECTIVELY. THESE OVERSTRESSES ARE POSSIBLE IF AND ONLY IF THE FULLY FIXITY AT THE EDGES OF THE DUCT PANEL IS ASSUMED.

(b) SYSTEM 4316-6, (16" SQ DUCT) REMAINS ELASTIC UNDER OPERATIONAL PLUS SEISMIC (SSE, 7% DAMPING) LOADS, RESULTING STRESSES ARE LESS THAN 0.9 S_Y. LOCALIZED YIELDING AND BUCKLING OCCURS AT SOME LOCATIONS FOR THE SQUARE DUCTING SYSTEM NO. 4316-1, (14" SQ. DUCT)

AND 4316-7 (16" SQUARE DUCT). THE RESULTING PRIMARY STRESSES ARE LESS THAN $0.9S_Y$.

LOADINGS	DUCTING SYSTEM 4316-1, 14" SQ. (PSI)	DUCTING SYSTEM 4316-6, 16" SQ (PSI)	DUCTING SYSTEM 4316-7, 16" SQ (PSI)
OPERATIONAL (DEAD LOAD + PRESSURE)	20136 (FIXED) 4670 (S.S.)	22837 (FIXED) 5322 (S.S.)	22390 (FIXED) 4875 (S.S.)
ALLOWABLE ($0.6S_Y$)	21600	21600	21600
OPERATIONAL + SSE WITH 7% DAMPING	45402 (FIXED) 29938 (S.S.)	23634 (FIXED) 6119 (S.S.)	48400 (FIXED) 30885 (S.S.)
OPERATIONAL + SSE WITH 2% DAMPING	49596 (FIXED) 34130 (S.S.)	-	-
OPERATIONAL + DBE WITH 1% DAMPING	36512 (FIXED) 21046 (S.S.)	-	-
ALLOWABLE ($0.9S_Y$)	32400	32400	32400

TABLE 5.0.1 SUMMARY OF STRESSES (PSI) BASED ON THE BARE METAL THICKNESS

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CALCULATION SHEET

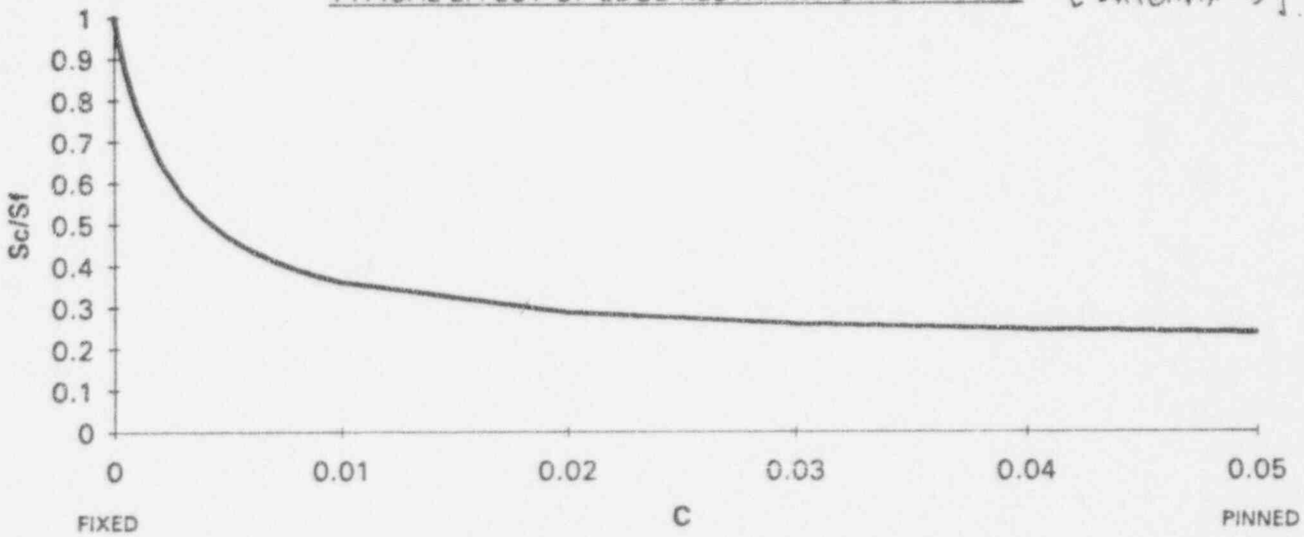
TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: 50

SUBJECT: 5.0 RESULTS SUMMARY AND DISCUSSIONS BY: HCK CK: MAK SHT: 3 OF 6

ALTHOUGH THE DUCTING SYSTEM # 4316-6 AND # 4316-7 CAN BE POSSIBLY OVERSTRESSED BY A FEW PERCENT, THIS POSSIBILITY DEPENDS UPON THE RIGIDITY OF RESTRAINT AT THE EDGES OF DUCT PANEL. IT SHOULD BE NOTED THE ANALYSIS PERFORMED WAS BASED UPON THE ASSUMPTION THAT THE DUCT PANEL EDGES ARE FULLY FIXED, THE TYPICAL AS BUILT "PITTSBURGH LOCK" JOINTS ARE LIKELY NOT PERFECTLY RESTRAINED.

FROM THE THEORY OF PLATES AND SHELLS [4, PAGE 17], THE TYPICAL EFFECT OF EDGE RESTRAINT ON STRESSES CURVE WAS GENERATED AND ILLUSTRATED IN FIGURE 5.0.1. FOR AN UNIFORMLY LOADED RECTANGULAR PLATE WITH ELASTICALLY BUILT-IN EDGES, THE SLOPE OF THE DEFLECTION CURVE AT THE END OF THE STRIP PANEL IS PROPORTIONAL TO THE MOMENT AND DEPENDS ON THE EDGE RIGIDITY RESTRAINT FACTOR. IF THE RESTRAINT IS VERY RIGID, THE EDGE REGIDITY RETRAINT FACTOR BECOMES SMALL AND THE EDGE CONDITIONS APPROACH FULLY FIXED. IF THE RESTRAINT

TYPICAL EFFECT OF EDGE RESTRAINT ON STRESSES [APPENDIX 8]



Sc = Combined Membrane and Bending Stresses
Sf = Combined Stress at Fully Fixed Boudary
C = Edge Rigidity Restraint Factor

FIGURE 5.0.1

IS VERY FLEXIBLE, THE EDGE RIGIDITY RESTRAINT FACTOR BECOMES LARGE AND THE CONDITIONS AT THE EDGES APPROACH THOSE OF SIMPLE SUPPORTED EDGES. THE CURVE DEPICTS THAT A SLIGHT IMPERFECT FIXITY CONDITION AT THE EDGES WILL SIGNIFICANT REDUCING THE STRESSES. SINCE THE AS BUILT DUCT EDGE CONDITIONS ARE BETWEEN THE SIMPLY SUPPORTED EDGES AND THE ABSOLUTELY FIXED EDGES, A 2 TO 4 PERCENT OVERSTRESSED AT THE ABSOLUTELY FIXED CONDITIONS IN THE ANALYSIS CAN BE IGNORED. THUS, ONE CAN SAY THAT THE DUCTING SYSTEMS 4316-6 (16" SQ DUCT) AND 4316-7 (16" SQ. DUCT) ARE ACCEPTABLE UNDER THE OPERATIONAL LOADS.

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: 43

SUBJECT: 6.0 CONCLUSIONS BY: HEK CK: MAL SHT: 1 OF 2

6.0 CONCLUSIONS.

IN RESPONSE TO THE USNRC COMMENT, THE HA-05/89-686 STRUCTURAL EVALUATION REPORT [1] WAS REVIEWED. THE EFFECT OF BARE METAL THICKNESS ON STIFFNESS AND STRESS WAS EVALUATED. THOSE DUCTING SYSTEMS DEEMED TO BE SEVERELY AFFECTED WERE REANALYZED AND STRESSES WERE RE-CALCULATED BASED ON THE THICKNESS OF BARE METAL.

THE EFFECTS OF BARE METAL THICKNESS ARE INSIGNIFICANT TO ALL THE CIRCULAR DUCTING SYSTEMS BECAUSE THE RESULTING STRESSES WILL REMAIN WELL BELOW THE CODE ALLOWABLE UNDER OPERATIONAL AND OPERATIONAL PLUS SEISMIC LOADS. STRESSES OF ALL SQUARE DUCTING SYSTEMS WERE CALCULATED BASED ON THE THICKNESS OF BARE METAL AND THE FOLLOWING CONCLUSIONS WERE REACHED:

(A) DURING OPERATIONAL LOADING (DEAD WT. + INTERNAL PRESSURE), SYSTEM 4316-1, (14" SQ DUCT) REMAINS ELASTIC AND

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO.3 DATE: APRIL '94 PAGE: 54

SUBJECT: 6.0 CONCLUSIONS BY: HEK CK: MAK SHT: 2 OF 2

RESULTING STRESSES ARE LESS THAN 0.6 S_Y. DUCTING SYSTEM 4316-6, (16" SQ. DUCT) AND 4316-7, (16" SQ. DUCT) COULD BE SLIGHTLY OVERSTRESSED BY 3.4% AND 2.2% IF THE EDGES OF DUCT PANEL ARE FULLY FIXED AS ANALYZED. SINCE THE AS BUILT EDGE RIGIDITY OF RESTRAINTS ARE BETWEEN THE SIMPLY SUPPORTED AND THE ABSOLUTELY FIXED CONDITIONS, BOTH SYSTEMS ARE ACCEPTABLE.

(b) SYSTEM 4316-6, (16" SQ. DUCT) REMAINS ELASTIC UNDER OPERATIONAL PLUS SEISMIC (SSE, 7% DAMPING) LOADS, RESULTING STRESSES ARE LESS THAN 0.9 S_Y. LOCALIZED YIELDING AND BUCKLING OCCURS AT SOME LOCATIONS OF SYSTEM 4316-1, (14" SQ. DUCT) AND 4316-7, (16" SQ DUCT), THE RESULTING PRIMARY STRESSES ARE LESS THAN 0.9 S_Y

(c) UNDER OPERATIONAL PLUS SEISMIC (DBE) LOADINGS, SYSTEM 4316-1 (14" □ DUCT) YIELDS AND BUCKLES AT SOME LOCATIONS. THE PRIMARY STRESSES ARE WITHIN 0.9 S_Y

7.0 REFERENCES

[1] DETROIT EDISON COMPANY. HA-05/89-686: STRUCTURAL EVALUATION OF DUCTING SYSTEM 2848-3, 4316-1, 4316-6, AND 4316-7, PREPARED BY HOPPER AND ASSOCIATES, MAY 31, 1989

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HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: 56

SUBJECT: 7.0 REFERENCES. BY: HEK CK: MAK SHT: 2 OF 2

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HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A1

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A1 OF A72

APPENDIX A

COMPUTER ANALYSIS FOR

SYSTEM 4316-1, 14" SQ. DUCT

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A2

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: [illegible] SHT: A2 OF A72

```
/PREP7
/OUT,OUTN2S2,SSE
/TITLE,SSE FOR HVAC SYSTEM 4316-1
C****
C****RE-ANALYZE SYSTEM 4316-1 BASED ON BARE SHEET METAL THICKNESS
C****USE SITE SPECIFIC EARTHQUAKE WITH 7% DAMPING
C****DATE: 4-25-94
C****
KAN,2
KAY,2,90
ET,1,4
,2,14,,1
,3,14,,3
,4,21,,,2
EX,1,29.E6
NUXY,1,0.29
DENS.1,0.00125
N,1,196.,,-26.
,2,196.,,4.
,3,196.,,42.
,4,196.,,84.
,5,196.,,90.
,6,196.,,114.
,7,196.,,151.
,8,182.,,151.
,9,124.,,151.
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,11,65.,,151.
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,13,6.0,,151.
,14,2.,,151.
,15,-12.,,151.
,16,-84.,,151.
,17,-94.,,151.
,18,-118.,,151.
,19,-169.,,151.
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,24,-230.,,217.
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,33,-230.,-37.,539.
,34,-230.,-37.,565.
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,36,-204.,-65.,565.
,37,-204.,-84.,565.
,38,-30.,,133.
,39,-48.,,115.
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,42,-118.,,115.
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HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 2 DATE: APRIL '94 PAGE: A3

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A3 OF A72

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,55,182.,-2.5,173.5
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,63,-129.,-2.5,173.5
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,67,-204.,-2.5,217.
,68,-204.,-2.5,248.
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,81,-204.,-84.,341.5
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,120,-193.,,139.
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,126,-242.,,313.
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C****MATREIAL PROPERTIES FOR GALVANIZED SHEET METAL:
C****R,1,2.89,94.4,94.4,14.,14.
C****RMORE,,141.6
C****R,2,3.92,235.9,235.9,19.,19.
C****RMORE,,353.9
C****R,3,2.06,34.4,34.4,10.,10.
C****RMORE,,51.6
R,1,2.68,86.6,86.6,14.0,14.0
RMORE,,131.2
R,2,3.63,216.9,216.9,19.0,19.0
RMORE,,327.9
R,3,1.91,31.4,31.4,10.0,10.0
RMORE,,47.8
R,4,.071
,5,.056
,6,.113
,7,.106
,8,.128
,9,.015
,10,.117
,11,.097
,12,.174
,13,.077
,14,.23
,15,.153
,16,.04
,17,.3
,18,.217
,19,.181
,20,.2
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,22,.258
,23,.171
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,34,740.
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EGEN,30,1,-1
E,73,78
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,79,80
,80,81
TYPE,4
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REAL,9
E,36
REAL,10
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,68
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REAL,12
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REAL,32
E,28,128

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E,10,110
REAL,27
E,14,114
REAL,28
E,41,141
REAL,29
E,20,120
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E,82,182
REAL,35
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,110,ALL,,,130,10
,108,ALL,,,128,20
,126,ALL,,,141,15
,182,ALL,,,192,10
,194,ALL
,282,ALL
,294,ALL
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,50,UY,,,70,20,ROTX,ROTZ
,64,UY,,,67,3,ROTX,ROTZ
,92,UY,,,94,2,ROTX,ROTZ
,82,ROTY,,,94,12
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,37,ALL
,77,ALL,,,81,4
CP,1,UZ,8,55,85
,2,UZ,10,57,88
,3,UX,4,50
,4,UZ,14,59
,5,UZ,17,41,61
,6,UZ,20,64
,7,UZ,24,67
,8,UZ,26,70
TOTAL,90,1
MLIST
ITER,1,1,1
PRDISP,-1
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HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: 1.8

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A8 OF A72

```
PRNF,-1
PRRF,-1
PRSTR,-1
SVTYPE,2
SED,1.0,0.0,0.0    *E-W DIRECTION
FREQ,.91,1.25,2.0,3.03,3.33,3.85,4.55,5.71,6.06
FREQ,6.67,7.14,13.3,20.0,23.3,50.0,500.0
SV,0.07,54.1,77.3,119.8,224.1,347.8,579.6,850.1,850.1,850.1
SV,0.07,792.1,695.5,309.1,282.1,231.8,208.7,208.7
C****SPECTRUM ACCELERATION (IN/SEC) WITH 2% DAMPING
C****SV,0.02,73.3,88.8,166.0,347.0,618.0,1040.0,1540.0,1540.0,1270.0
C****SV,0.02,1270.0,888.0,328.0,328.0,212.0,208.0,208.0
LWRITE
SED,0.0,1.0,0.0    *VERTICAL DIRECTION
FREQ
FREQ,1.0,1.7,3.3,5.0,5.6,6.7,10.0,11.1,15.2
FREQ,18.2,25.0,33.3,50.0,500.0
SV,0.07,92.7,92.7,111.3,185.5,214.5,214.5,695.5,1197.8,1197.8
SV,0.07,726.4,440.5,289.8,193.2,193.2
C****SPECTRUM ACCELERATION (IN/SEC) WITH 2% DAMPING
C****SV,0.02,92.6,92.6,173.7,308.8,347.4,347.4,1351.0,2123.0,2123.0
C****SV,0.02,1080.8,521.1,308.8,208.4,208.4
LWRITE
SED,0.0,0.0,1.0    *N-S DIRECTION
FREQ
FREQ,.91,1.14,1.33,1.54,2.22,3.33,3.85,4.55,5.56
FREQ,5.71,5.88,6.06,9.09,13.3,16.7,20.0,33.3,500.0
SV,0.07,50.2,69.6,73.4,96.6,183.5,444.4,618.2,811.4,811.4
SV,0.07,772.8,734.2,734.2,357.4,241.5,231.8,202.9,185.5,185.5
C****SPECTRUM ACCELERATION (IN/SEC) WITH 2% DAMPING
C****SV,0.02,77.2,88.8,124.0,124.0,262.0,502.0,1160.0,1580.0,1580.0
C****SV,0.02,1350.0,1310.0,1040.0,425.0,270.0,270.0,212.0,185.0,185.0
LWRITE
AFWRITE
FINISH
/OUT,OUTN2S2,ANS
/INP,27
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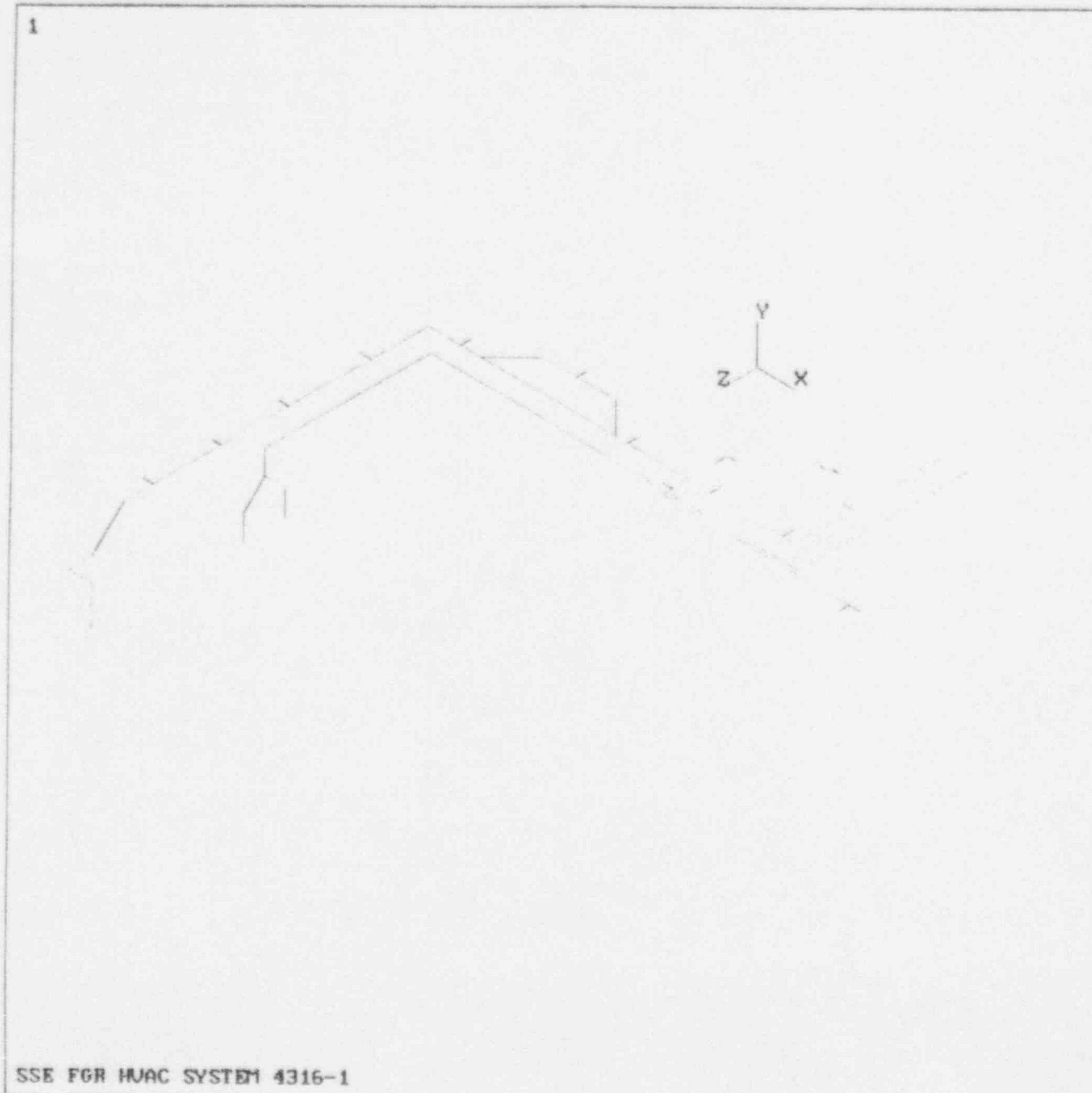
HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: Response to Concern No. 3 DATE: April '94 PAGE: A9

SUBJECT: Appendix A - Analysis of System 4316-1 BY: HCF CK: [illegible] SHT: A9 OF A72



ANSYS-PC 4.4A1
APR 28 1994
10:59:43
PLOT NO. 1
POST1 ELEMENTS
TYPE NUM

XV =1
YV =1
ZV =1
DIST=446.856
XF =37
YF =-34.5
ZF =269.5

```
C****
C****POST-PROCESSING FILE FOR SYSTEM 4316-1
C****
STRESS,I1,4,19
STRESS,I3,4,20
STRESS,J1,4,21
STRESS,J3,4,22
LCLIM,3
LCASE,1
SET,1,1
LCASE,2
SET,1,2
LCSRSS,3,1,2
LCASE,2
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LCASE,2
SET,1,4
LCSRSS,3,2,3
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LCASE,3
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ERSEL,REAL,1
NELEM
PRDISP
PREFOR
PRSTRS,I1,I3,J1,J3
EALL
ESEL,TYPE,1
ERSEL,REAL,2
NELEM
PRDISP
PREFOR
PRSTRS,I1,I3,J1,J3
EALL
ESEL,TYPE,1
ERSEL,REAL,3
NELEM
PRDISP
PREFOR
PRSTRS,I1,I3, I1,J3
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HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A12

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A12 OF A72

***** EIGENVALUE (NATURAL FREQUENCY) SOLUTION *****

MODE	FREQUENCY (CYCLES/TIME)
1	10.7695426
2	15.1177832
3	15.3198123
4	17.0026697
5	20.9726790
6	33.2040876
7	38.4820832
8	42.7501592
9	46.3968674
10	49.8360342
11	57.4085106
12	62.5323514
13	67.4258425
14	73.5391224
15	77.7194027
16	94.4166889
17	96.8474360
18	100.193515
19	103.959923
20	109.827858
21	117.908533
22	125.812873
23	129.000925
24	131.653735
25	131.653765
26	141.530581
27	148.659846
28	156.759910
29	159.374828
30	165.305014
31	174.021746
32	177.438660
33	179.906185
34	180.402718
35	184.503323
36	190.152778
37	192.409454
38	196.087267
39	196.963765
40	205.927181
41	209.731960
42	210.643335
43	220.306140
44	232.944272
45	233.656787
46	240.790530
47	246.065899
48	256.029051
49	262.407669
50	271.648106
51	273.355190
52	284.101987
53	290.099916
54	301.867852

HOPPER AND ASSOCIATES
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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A13

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEC CK: MAK SHT: A13 OF A22

55	306.761172
56	309.646233
57	311.770890
58	323.230341
59	333.279760
60	334.280432
61	339.994843
62	343.111751
63	359.850875
64	362.807178
65	368.421677
66	368.749603
67	383.813871
68	384.443363
69	386.430062
70	399.224644
71	403.377980
72	408.013764
73	419.355707
74	419.907105
75	423.997270
76	438.531399
77	440.938242
78	444.542627
79	446.685301
80	447.364878
81	473.197421
82	496.514332
83	502.596206
84	520.995600
85	529.055039
86	556.358411
87	569.244922
88	594.840871
89	613.332875
90	658.328138

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A14

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A14 OF A72

PRINT NODAL DISPLACEMENTS

***** POST1 NODAL DISPLACEMENT LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	2.73E-03	4.65E-17	5.08E-04	2.34E-18	1.75E-04	0.00E+00
3	1.27E-02	9.07E-17	1.15E-03	1.24E-18	3.43E-04	0.00E+00
4	3.01E-02	0.00E+00	1.86E-03	0.00E+00	5.11E-04	0.00E+00
5	3.31E-02	0.00E+00	1.96E-03	0.00E+00	5.35E-04	0.00E+00
6	4.61E-02	0.00E+00	2.36E-03	0.00E+00	5.78E-04	0.00E+00
7	6.59E-02	0.00E+00	2.99E-03	0.00E+00	4.88E-04	0.00E+00
8	6.59E-02	0.00E+00	8.87E-03	0.00E+00	3.90E-04	0.00E+00
9	6.60E-02	9.91E-18	1.93E-02	0.00E+00	1.21E-04	3.15E-19
10	6.61E-02	0.00E+00	2.03E-02	0.00E+00	1.23E-04	0.00E+00
11	6.60E-02	1.92E-17	2.19E-02	0.00E+00	9.79E-05	4.16E-19
12	6.60E-02	1.68E-17	2.29E-02	0.00E+00	6.65E-05	4.69E-19
13	6.60E-02	3.22E-19	2.28E-02	0.00E+00	4.84E-05	1.57E-19
14	6.60E-02	0.00E+00	2.26E-02	0.00E+00	5.38E-05	0.00E+00
15	6.59E-02	7.56E-18	2.17E-02	2.06E-18	7.98E-05	8.43E-19
16	6.55E-02	1.21E-18	1.39E-02	2.51E-19	1.35E-04	2.27E-19
17	6.54E-02	0.00E+00	1.26E-02	0.00E+00	1.34E-04	0.00E+00
18	6.52E-02	1.17E-17	9.62E-03	2.02E-19	1.26E-04	4.69E-19
19	6.48E-02	4.58E-18	4.16E-03	6.31E-19	1.01E-04	2.92E-19
20	6.46E-02	0.00E+00	2.76E-03	0.00E+00	5.02E-05	0.00E+00
21	6.42E-02	2.21E-18	1.74E-03	1.26E-20	1.96E-04	1.32E-19
22	6.40E-02	3.56E-18	3.22E-03	1.73E-20	3.74E-04	1.33E-19
23	5.76E-02	3.21E-18	3.01E-03	4.28E-20	6.09E-04	1.07E-19
24	1.54E-02	0.00E+00	2.21E-03	0.00E+00	7.89E-04	0.00E+00
25	1.76E-02	4.63E-21	2.08E-03	0.00E+00	4.66E-04	0.00E+00
26	3.47E-02	0.00E+00	1.95E-03	0.00E+00	2.81E-04	0.00E+00
27	4.27E-02	2.22E-17	1.99E-03	0.00E+00	1.74E-04	0.00E+00
28	4.50E-02	0.00E+00	2.05E-03	0.00E+00	1.10E-04	0.00E+00
29	4.16E-02	2.24E-17	2.09E-03	0.00E+00	1.85E-04	0.00E+00
30	3.30E-02	0.00E+00	2.14E-03	0.00E+00	2.84E-04	0.00E+00
31	2.31E-02	5.59E-04	2.16E-03	1.96E-05	3.23E-04	9.01E-05
32	1.54E-02	8.74E-04	2.07E-03	1.36E-05	3.07E-04	1.21E-04
33	7.92E-03	1.15E-03	1.95E-03	1.63E-05	2.59E-04	1.17E-04
34	2.33E-03	1.51E-03	1.96E-03	1.31E-05	1.76E-04	6.74E-05
35	2.26E-03	1.22E-04	2.75E-03	7.03E-05	1.05E-04	6.34E-05
36	5.20E-04	4.95E-05	6.65E-04	6.23E-05	4.24E-05	4.93E-05
37	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
38	6.70E-02	7.37E-17	2.01E-02	3.20E-18	1.01E-04	7.07E-20
39	6.81E-02	1.03E-16	1.82E-02	2.67E-18	1.20E-04	2.47E-18
40	6.81E-02	8.33E-18	1.38E-02	5.80E-19	1.30E-04	1.57E-18
41	6.81E-02	0.00E+00	1.26E-02	0.00E+00	1.27E-04	0.00E+00
42	6.81E-02	1.12E-17	9.80E-03	4.81E-19	1.22E-04	7.53E-19
43	6.64E-02	1.53E-17	5.99E-03	9.09E-19	1.23E-04	1.63E-19
44	6.80E-02	2.24E-17	8.07E-03	7.81E-19	1.24E-04	6.64E-19
45	6.81E-02	1.51E-17	9.23E-03	5.81E-19	1.22E-04	7.71E-19

MAXIMUMS

	UX	UY	UZ	ROTX	ROTY	ROTZ
NODE	41	34	12	35	24	32
VALUE	6.81E-02	1.51E-03	2.29E-02	7.03E-05	7.89E-04	1.21E-04

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A 15

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HCK CK: MAK SHT: A15 OF A72

PRINT NODAL FORCES PER ELEMENT

***** POST1 ELEMENT NODE FORCE LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z FORCES ARE IN GLOBAL COORDINATES

ELEM	NODE	FX	FY	FZ	MX	MY	MZ
1	1	194.72443	1.27E-11	1314.9881	3.87E-10	16573.625	0.00E+00
	2	194.72443	1.27E-11	1314.9881	5.17E-12	13008.98	0.00E+00
2	2	191.07662	1.27E-11	1314.9881	5.17E-12	13008.98	0.00E+00
	3	191.07662	1.27E-11	1314.9881	4.78E-10	11566.692	0.00E+00
3	3	179.93974	2.63E-11	1314.9881	4.78E-10	11566.692	0.00E+00
	4	179.93974	2.63E-11	1314.9881	6.27E-10	14740.023	0.00E+00
4	4	489.69984	0.00E+00	1304.7183	0.00E+00	14740.023	0.00E+00
	5	489.69984	0.00E+00	1304.7183	0.00E+00	11892.555	0.00E+00
5	5	489.69984	0.00E+00	1304.7183	0.00E+00	11892.555	0.00E+00
	6	489.69984	0.00E+00	1304.7183	0.00E+00	3278.9449	0.00E+00
6	6	462.55143	0.00E+00	1304.7183	0.00E+00	3278.9449	0.00E+00
	7	462.55143	0.00E+00	1304.7183	0.00E+00	17694.059	0.00E+00
7	7	462.55143	0.00E+00	1304.7183	0.00E+00	17694.059	0.00E+00
	8	462.55143	0.00E+00	1304.7183	0.00E+00	26242.589	0.00E+00
8	8	320.89886	2.94E-12	333.40459	0.00E+00	26242.589	7.17E-11
	9	320.89886	2.94E-12	333.40459	0.00E+00	7324.1068	9.90E-11
9	9	320.89886	9.96E-12	348.31831	0.00E+00	7324.1068	9.90E-11
	10	320.89886	9.96E-12	348.31831	0.00E+00	2908.3084	1.60E-10
10	10	262.58076	1.04E-11	114.25403	0.00E+00	2908.3084	2.03E-10
	11	262.58076	1.04E-11	114.25403	0.00E+00	3833.4589	1.39E-10
11	11	262.58076	3.90E-12	68.133366	0.00E+00	3833.4589	1.39E-10
	12	262.58076	3.90E-12	68.133366	0.00E+00	4577.2402	4.58E-11
12	12	262.58076	3.90E-12	68.133366	0.00E+00	4577.2402	4.58E-11
	13	262.58076	3.90E-12	68.133366	0.00E+00	6297.627	9.06E-11
13	13	262.58076	3.90E-12	68.133366	0.00E+00	6297.627	9.06E-11
	14	262.58076	3.90E-12	68.133366	0.00E+00	6520.9241	1.06E-10

ELEM =		FX	FY	FZ	MX	MY	MZ
ELEM =	14	FX	FY	FZ	MX	MY	MZ
14		344.40386	1.82E-11	100.13486	2.17E-10	6520.9241	2.79E-10
15		344.40386	1.82E-11	100.13486	2.17E-10	6363.6171	2.39E-11
ELEM =	15	FX	FY	FZ	MX	MY	MZ
15		464.33077	2.30E-12	51.228575	3.71E-11	3813.9474	1.20E-10
16		464.33077	2.30E-12	51.228575	3.71E-11	1374.8641	4.56E-11
ELEM =	16	FX	FY	FZ	MX	MY	MZ
16		652.32198	2.30E-12	238.32457	3.71E-11	1374.8641	4.56E-11
17		652.32198	2.30E-12	238.32457	3.71E-11	2240.8764	6.86E-11
ELEM =	17	FX	FY	FZ	MX	MY	MZ
17		652.32198	1.34E-11	58.12386	1.24E-11	2240.8764	2.09E-10
18		652.32198	1.34E-11	58.12386	1.24E-11	1285.9171	1.12E-10
ELEM =	18	FX	FY	FZ	MX	MY	MZ
18		652.32198	3.08E-12	31.325881	1.24E-11	1285.9171	1.12E-10
19		652.32198	3.08E-12	31.325881	1.24E-11	2066.2284	5.02E-11
ELEM =	19	FX	FY	FZ	MX	MY	MZ
19		892.94015	2.70E-12	114.29334	3.88E-11	6025.1058	1.86E-11
20		892.94015	2.70E-12	114.29334	3.88E-11	6258.7639	6.01E-11
ELEM =	20	FX	FY	FZ	MX	MY	MZ
20		1082.113	6.50E-13	1558.2111	6.90E-13	6258.7639	2.11E-11
21		1082.113	6.50E-13	1558.2111	6.90E-13	36996.475	3.52E-12
ELEM =	21	FX	FY	FZ	MX	MY	MZ
21		1082.113	6.50E-13	1558.2111	6.90E-13	36996.475	3.52E-12
22		1082.113	6.50E-13	1558.2111	6.90E-13	52531.318	2.98E-12
ELEM =	22	FX	FY	FZ	MX	MY	MZ
22		1082.113	6.50E-13	1558.2111	6.90E-13	52531.318	2.98E-12
23		1082.113	6.50E-13	1558.2111	9.14E-12	38584.381	2.98E-12
ELEM =	23	FX	FY	FZ	MX	MY	MZ
23		1154.3887	4.21E-13	1558.0981	9.14E-12	38584.381	2.98E-12
24		1154.3887	4.21E-13	1558.0981	1.32E-11	23823.309	2.98E-12
ELEM =	24	FX	FY	FZ	MX	MY	MZ
24		176.48461	1.26E-15	257.73685	3.03E-14	23823.309	0.00E+00
25		176.48461	1.26E-15	257.73685	3.03E-14	16772.706	0.00E+00
ELEM =	25	FX	FY	FZ	MX	MY	MZ
25		162.8962	1.26E-15	257.73685	3.03E-14	16772.706	0.00E+00
26		162.8962	1.26E-15	257.73685	3.03E-14	10173.612	0.00E+00
ELEM =	26	FX	FY	FZ	MX	MY	MZ
26		136.87145	1.13E-11	331.06802	2.20E-10	10173.612	0.00E+00
27		136.87145	1.13E-11	331.06802	2.20E-10	10436.349	0.00E+00
ELEM =	27	FX	FY	FZ	MX	MY	MZ
27		99.421347	1.13E-11	331.06802	2.20E-10	10436.349	0.00E+00
28		99.421347	1.13E-11	331.06802	2.20E-10	10470.45	0.00E+00
ELEM =	28	FX	FY	FZ	MX	MY	MZ
28		60.292202	1.14E-11	313.98542	2.22E-10	10470.45	0.00E+00
29		60.292202	1.14E-11	313.98542	2.22E-10	10053.508	0.00E+00

ELEM = 29	FX	FY	FZ	MX	MY	MZ
29	113.61969	1.14E-11	313.98542	2.22E-10	10053.508	0.00E+00
30	113.61969	1.14E-11	313.98542	2.22E-10	6371.7842	0.00E+00

ELEM = 30	FX	FY	FZ	MX	MY	MZ
30	137.46603	210.11411	307.00207	4849.5389	6371.7842	4028.2552
31	137.46603	210.11411	307.00207	2229.7557	2910.0138	4028.2552

ELEM = 31	FX	FY	FZ	MX	MY	MZ
31	189.06723	207.08726	307.00207	2229.7557	2910.0138	4028.2552
32	189.06723	207.08726	307.00207	460.09895	2920.8744	768.68419

ELEM = 32	FX	FY	FZ	MX	MY	MZ
32	189.06723	207.08726	307.00207	460.09895	2920.8744	768.68419
33	189.06723	207.08726	307.00207	1637.9286	5750.0657	3069.7447

ELEM = 33	FX	FY	FZ	MX	MY	MZ
33	217.08554	204.05618	312.47325	1637.9286	5750.0657	3069.7447
34	217.08554	204.05618	312.47325	3808.8797	11032.289	3069.7447

ELEM = 34	FX	FY	FZ	MX	MY	MZ
34	217.08554	202.46157	312.47325	3808.8797	11032.289	3069.7447
35	217.08554	202.46157	312.47325	3808.8797	3290.5528	2254.8464

ELEM = 35	FX	FY	FZ	MX	MY	MZ
35	227.74243	202.46157	320.55527	3808.8797	3290.5528	2254.8464
36	227.74243	202.46157	320.55527	5194.8049	3290.5528	4386.6617

ELEM = 36	FX	FY	FZ	MX	MY	MZ
36	227.74243	202.46157	320.55527	5194.8049	3290.5528	4386.6617
37	227.74243	202.46157	320.55527	11278.933	3290.5528	8669.9031

ELEM = 37	FX	FY	FZ	MX	MY	MZ
15	203.47229	2.05E-11	79.116081	2.54E-10	3227.5365	1.44E-10
38	203.47229	2.05E-11	79.116081	1.25E-10	2411.9641	2.26E-10

ELEM = 38	FX	FY	FZ	MX	MY	MZ
38	141.95373	4.49E-12	79.116081	1.25E-10	2411.9641	2.26E-10
39	141.95373	4.49E-12	79.116081	8.55E-11	2455.3951	1.98E-10

ELEM = 39	FX	FY	FZ	MX	MY	MZ
39	141.95373	1.44E-11	97.008202	8.55E-11	2455.3951	1.98E-10
40	141.95373	1.44E-11	97.008202	8.55E-11	1322.2619	3.22E-10

ELEM = 40	FX	FY	FZ	MX	MY	MZ
40	141.95373	1.44E-11	97.008202	8.55E-11	1322.2619	3.22E-10
41	141.95373	1.44E-11	97.008202	8.55E-11	2210.9265	4.67E-10

ELEM = 41	FX	FY	FZ	MX	MY	MZ
41	188.15563	4.80E-12	74.3184	2.95E-11	2210.9265	1.36E-10
42	188.15563	4.80E-12	74.3184	2.95E-11	1745.5827	2.12E-11

ELEM = 42	FX	FY	FZ	MX	MY	MZ
42	188.15563	4.80E-12	75.817176	2.95E-11	1745.5827	2.12E-11
45	188.15563	4.80E-12	75.817176	2.95E-11	1884.2289	3.58E-12

ELEM = 43	FX	FY	FZ	MX	MY	MZ
45	188.15563	4.80E-12	75.817176	2.95E-11	1884.2289	3.58E-12

44	188.15563	4.80E-12	75.817176	2.95E-11	2327.8904	5.10E-11

ELEM = 44	FX	FY	FZ	MX	MY	MZ
44	188.15563	1.43E-12	75.817176	2.95E-11	2327.8904	5.10E-11
43	188.15563	1.43E-12	75.817176	1.89E-11	1227.4369	4.11E-11

ELEM = 45	FX	FY	FZ	MX	MY	MZ
43	289.92659	3.55E-12	75.817176	1.89E-11	1227.4369	4.11E-11
19	289.92659	3.55E-12	75.817176	5.12E-11	4400.0203	3.26E-11

PRINT ELEMENT STRESS ITEMS PER ELEMENT

***** POST1 ELEMENT STRESS LISTING *****

CALCULATED LOAD CASE = 3

ELEM	I1	I3	J1	J3
1	976.75854	1765.4687	672.78511	1496.7689
2	672.78511	1496.7689	648.63212	1345.0113
3	648.63212	1345.0113	1069.0898	1475.7013
4	1068.3881	1473.6698	858.7739	1258.8443
5	858.7739	1258.8443	580.26574	527.07013
6	580.26574	527.07013	1366.7089	1642.3375
7	1497.0451	1381.8762	2208.4941	2044.829
8	2146.5848	2102.3898	616.9066	590.82242
9	616.9066	590.82242	289.74983	235.04748
10	247.06943	262.07586	362.59652	282.40814
11	362.59652	282.40814	407.57709	356.17092
12	407.57709	356.17092	527.87416	508.72782
13	527.87416	508.72782	544.26139	527.86188
14	525.84242	558.72901	500.78344	558.04917
15	339.09477	367.60394	115.42498	267.23455
16	174.23111	335.90921	244.70057	352.46397
17	244.70057	352.46397	243.72018	284.07622
18	243.72018	284.07622	220.72921	354.34186
19	356.8942	754.33801	343.30724	784.88594
20	342.21682	849.01879	2634.9389	3356.9436
21	2634.9389	3356.9436	3889.315	4610.7908
22	3718.1563	4786.5973	2587.6496	3665.2929
23	2588.2879	3664.8288	1519.2463	2405.061
24	1852.1405	2001.1235	1275.466	1438.0063
25	1275.466	1438.0063	738.25543	908.8382
26	753.44872	902.96522	743.73349	949.02673
27	743.73349	949.02673	740.04547	956.78653
28	739.84245	955.33896	710.09597	918.68442
29	710.09597	918.68442	428.89452	611.58388
30	791.45308	988.57411	296.78496	498.73637
31	396.2407	618.87224	165.46543	315.33875
32	165.46543	315.33875	503.79166	758.42882
33	487.03388	702.79576	1089.1628	1306.8926
34	1067.9439	1212.6127	369.69314	513.87615
35	416.88526	558.44791	667.31401	804.31267
36	667.31401	804.31267	1490.6591	1629.2033
37	298.66954	239.68772	227.57375	186.44371
38	213.43747	192.92463	206.19108	207.42008
39	204.36013	206.47327	119.94554	118.6214
40	119.94554	118.6214	185.87692	186.91475
41	181.2357	202.20765	122.65462	186.09466
42	122.65462	186.09466	141.22559	190.54401

43	141.22559	190.54401	173.2957	225.03361
44	177.59894	220.6825	117.82555	123.42331
45	131.83957	140.32117	312.50726	415.58555

MINIMUMS				
ELEMENT	40	40	15	39
VALUE	119.94554	118.6214	115.42498	118.6214

MAXIMUMS				
ELEMENT	22	22	21	21
VALUE	3718.1563	4786.5973	3889.315	4610.7908

178 ELEMENTS (OF 178 DEFINED) SELECTED BY EALL COMMAND.

ESEL FOR LABEL = TYPE FROM 1 TO 1 BY 1

91 ELEMENTS (OF 178 DEFINED) SELECTED BY ESEL COMMAND.

ERSE FOR LABEL = REAL FROM 2 TO 2 BY 1

34 ELEMENTS (OF 178 DEFINED) SELECTED BY ERSE COMMAND.

35 NODES (OF 108 DEFINED) SELECTED FROM 34 SELECTED ELEMENTS BY NELE COMMAND.

PRINT NODAL DISPLACEMENTS

***** POST1 NODAL DISPLACEMENT LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
47	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
48	1.15E-03	4.15E-18	5.44E-04	2.27E-19	9.08E-05	0.00E+00
49	7.15E-03	8.71E-18	1.21E-03	6.15E-20	2.80E-04	0.00E+00
50	3.01E-02	0.00E+00	2.14E-03	0.00E+00	7.17E-04	0.00E+00
51	4.98E-02	2.05E-18	2.61E-03	1.30E-19	8.98E-04	7.55E-20
52	9.33E-02	8.41E-18	3.58E-03	1.16E-19	7.26E-04	2.33E-19
53	0.10304458	1.01E-17	3.88E-03	9.81E-20	5.26E-04	2.81E-19
54	0.10331206	5.46E-18	2.78E-03	6.06E-20	3.33E-04	3.13E-19
55	0.10367451	0.00E+00	8.87E-03	0.00E+00	1.94E-04	0.00E+00
56	0.10419648	3.67E-17	1.48E-02	0.00E+00	1.57E-04	3.82E-19
57	0.10474654	0.00E+00	2.03E-02	0.00E+00	1.22E-04	0.00E+00
58	0.10514765	7.26E-18	2.28E-02	0.00E+00	9.25E-05	1.33E-19
59	0.1056627	0.00E+00	2.26E-02	0.00E+00	7.14E-05	0.00E+00
60	0.10585692	0.00E+00	2.08E-02	0.00E+00	9.93E-05	0.00E+00
61	0.10623035	0.00E+00	1.26E-02	0.00E+00	1.13E-04	0.00E+00
62	0.10628151	3.90E-18	1.18E-02	0.00E+00	1.05E-04	7.05E-19
63	0.10631008	2.46E-17	1.04E-02	0.00E+00	9.07E-05	4.78E-19
64	0.10638326	0.00E+00	2.76E-03	0.00E+00	2.55E-04	0.00E+00
65	0.10639585	0.00E+00	1.99E-03	0.00E+00	3.10E-04	0.00E+00
66	0.10117017	0.00E+00	2.06E-03	0.00E+00	3.77E-04	0.00E+00
67	0.89113308	0.00000000	2.21E-03	0.00E+00	4.90E-04	0.00E+00
68	0.72562235	0.10632051	2.13E-03	2.69E-24	5.79E-04	0.00E+00
69	0.36856709	0.39033507	1.97E-03	1.25E-24	6.01E-04	0.00E+00
70	0.33292042	0.00000000	1.95E-03	0.00E+00	5.92E-04	0.00E+00
71	1.34E-02	5.82E-05	1.71E-03	5.45E-06	4.70E-04	7.92E-05
72	6.88E-03	1.51E-04	1.61E-03	2.31E-05	3.87E-04	1.12E-04
73	3.55E-03	8.79E-05	8.02E-04	2.09E-05	9.95E-05	1.15E-04

74	1.53E-03	1.75E-04	5.33E-04	1.07E-05	6.89E-05	6.57E-05
75	3.52E-04	2.11E-04	3.14E-04	1.26E-05	5.02E-05	2.88E-05
76	8.19E-05	1.07E-04	1.14E-04	1.29E-05	2.55E-05	1.14E-05
77	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
78	2.89E-03	4.88E-05	5.35E-04	1.39E-05	4.26E-05	1.22E-04
79	1.81E-03	1.44E-04	3.08E-04	1.41E-05	1.47E-05	1.02E-04
80	5.44E-04	7.34E-05	1.05E-04	1.23E-05	7.46E-06	6.73E-05
81	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MAXIMUMS						
NODE	65	75	58	72	51	78
VALUE	0.10639585	2.11E-04	2.28E-02	2.31E-05	8.98E-04	1.22E-04

PRINT NODAL FORCES PER ELEMENT

***** POST1 ELEMENT NODE FORCE LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z FORCES ARE IN GLOBAL COORDINATES

ELEM = 58	FX	FY	FZ	MX	MY	MZ
47	559.5858	3.36E-12	2046.6733	9.80E-11	15147.239	0.00E+00
48	559.5858	3.36E-12	2046.6733	3.85E-12	26930.174	0.00E+00

ELEM = 59	FX	FY	FZ	MX	MY	MZ
48	559.5858	3.36E-12	2046.6733	3.85E-12	26930.174	0.00E+00
49	559.5858	3.36E-12	2046.6733	1.11E-10	44579.847	0.00E+00

ELEM = 60	FX	FY	FZ	MX	MY	MZ
49	569.83593	4.94E-12	2046.6733	1.11E-10	44579.847	0.00E+00
50	569.83593	4.94E-12	2046.6733	1.27E-10	71343.876	0.00E+00

ELEM = 61	FX	FY	FZ	MX	MY	MZ
50	1967.3837	2.77E-12	2046.6733	6.67E-11	71343.876	1.16E-11
51	1967.3837	2.77E-12	2046.6733	7.98E-12	24364.836	1.16E-11

ELEM = 62	FX	FY	FZ	MX	MY	MZ
51	1828.4683	2.22E-13	2047.623	7.98E-12	24364.836	1.16E-11
52	1828.4683	2.22E-13	2047.623	6.13E-12	67455.019	1.16E-11

ELEM = 63	FX	FY	FZ	MX	MY	MZ
52	1828.4683	2.22E-13	2047.623	6.13E-12	67455.019	1.16E-11
53	1828.4683	2.22E-13	2047.623	8.93E-12	95765.271	1.16E-11

ELEM = 64	FX	FY	FZ	MX	MY	MZ
53	1828.4683	2.22E-13	2047.623	8.93E-12	95765.271	1.16E-11
54	1828.4683	2.22E-13	2047.623	8.93E-12	64344.199	1.45E-11

ELEM = 65	FX	FY	FZ	MX	MY	MZ
54	1537.6357	7.46E-12	2047.623	8.93E-12	64344.199	1.45E-11
55	1537.6357	7.46E-12	2047.623	8.93E-12	16466.147	1.72E-10

ELEM = 66	FX	FY	FZ	MX	MY	MZ
55	1537.6357	4.82E-11	204.94418	0.00E+00	16466.147	9.35E-10
56	1537.6357	4.82E-11	204.94418	0.00E+00	12382.72	8.02E-10

ELEM = 67	FX	FY	FZ	MX	MY	MZ

56	1217.6024	3.13E-11	165.33171	0.00E+00	12382.72	8.02E-10
57	1217.6024	3.13E-11	165.33171	0.00E+00	10077.933	7.01E-10
ELEM = 68	FX	FY	FZ	MX	MY	MZ
57	1217.6024	8.70E-12	197.61806	0.00E+00	10077.933	1.76E-10
58	1217.6024	8.70E-12	197.61806	0.00E+00	11516.987	1.28E-10
ELEM = 69	FX	FY	FZ	MX	MY	MZ
58	901.29006	3.76E-12	141.23038	0.00E+00	11516.987	1.28E-10
59	901.29006	3.76E-12	141.23038	0.00E+00	14632.63	1.01E-10
ELEM = 70	FX	FY	FZ	MX	MY	MZ
59	901.29006	0.00E+00	157.06806	0.00E+00	14632.63	0.00E+00
60	901.29006	0.00E+00	157.06806	0.00E+00	12023.263	0.00E+00
ELEM = 71	FX	FY	FZ	MX	MY	MZ
60	556.338	0.00E+00	262.51349	0.00E+00	12023.263	0.00E+00
61	556.338	0.00E+00	262.51349	0.00E+00	10535.049	0.00E+00
ELEM = 72	FX	FY	FZ	MX	MY	MZ
61	556.338	2.86E-11	508.79306	0.00E+00	10535.049	5.87E-10
62	556.338	2.86E-11	508.79306	0.00E+00	6128.8704	3.00E-10
ELEM = 73	FX	FY	FZ	MX	MY	MZ
62	184.67661	2.86E-11	508.79306	0.00E+00	6128.8704	3.00E-10
63	184.67661	2.86E-11	508.79306	0.00E+00	8972.9661	4.15E-10
ELEM = 74	FX	FY	FZ	MX	MY	MZ
63	184.67661	1.15E-11	466.40101	0.00E+00	8972.9661	4.15E-10
64	184.67661	1.15E-11	466.40101	0.00E+00	38142.008	3.21E-10
ELEM = 75	FX	FY	FZ	MX	MY	MZ
64	184.67661	0.00E+00	1053.6714	0.00E+00	38142.008	0.00E+00
65	184.67661	0.00E+00	1053.6714	0.00E+00	27684.378	0.00E+00
ELEM = 76	FX	FY	FZ	MX	MY	MZ
65	184.67661	0.00E+00	1053.6714	0.00E+00	27684.378	0.00E+00
66	184.67661	0.00E+00	1053.6714	0.00E+00	29231.956	0.00E+00
ELEM = 77	FX	FY	FZ	MX	MY	MZ
66	256.62078	0.00E+00	1053.6714	0.00E+00	29231.956	0.00E+00
67	256.62078	0.00E+00	1053.6714	0.00E+00	23191.69	0.00E+00
ELEM = 78	FX	FY	FZ	MX	MY	MZ
67	290.68558	1.64E-16	349.09879	3.08E-15	23191.69	0.00E+00
68	290.68558	1.64E-16	349.09879	1.99E-15	15009.736	0.00E+00
ELEM = 79	FX	FY	FZ	MX	MY	MZ
68	401.10345	5.33E-17	349.09879	1.99E-15	15009.736	0.00E+00
69	401.10345	5.33E-17	349.09879	1.15E-15	11187.769	0.00E+00
ELEM = 80	FX	FY	FZ	MX	MY	MZ
69	401.10345	5.33E-17	349.09879	1.15E-15	11187.769	0.00E+00
70	401.10345	5.33E-17	349.09879	1.47E-15	13331.49	0.00E+00
ELEM = 81	FX	FY	FZ	MX	MY	MZ
70	529.55074	236.88376	675.4107	3456.4625	13331.49	7890.0265
71	529.55074	236.88376	675.4107	5308.2366	29994.341	7890.0265
ELEM = 82	FX	FY	FZ	MX	MY	MZ
71	529.55074	236.88376	675.4107	5308.2366	29994.341	7890.0265

	FX	FY	FZ	MX	MY	MZ
72	529.55074	236.88376	675.4107	8979.9349	37819.128	7890.0265

ELEM = 83	FX	FY	FZ	MX	MY	MZ
72	529.55074	236.88376	675.4107	8979.9349	37819.128	7890.0265
73	529.55074	236.88376	675.4107	9931.5648	37819.128	6937.3941

ELEM = 84	FX	FY	FZ	MX	MY	MZ
73	373.88678	752.3119	379.56345	6025.0304	15084.734	19155.965
74	373.88678	752.3119	379.56345	1552.049	10643.9	14836.56

ELEM = 85	FX	FY	FZ	MX	MY	MZ
74	373.88678	752.3119	379.56345	1552.049	10643.9	14836.56
75	373.88678	752.3119	379.56345	2920.9324	6268.6441	10656.262

ELEM = 86	FX	FY	FZ	MX	MY	MZ
75	373.88678	752.3119	379.56345	2920.9324	6268.6441	10656.262
76	373.88678	752.3119	379.56345	2582.7377	6268.6441	6204.9632

ELEM = 87	FX	FY	FZ	MX	MY	MZ
76	373.88678	752.3119	379.56345	2582.7377	6268.6441	6204.9632
77	373.88678	752.3119	379.56345	8276.1895	6268.6441	4766.2132

ELEM = 88	FX	FY	FZ	MX	MY	MZ
73	880.00007	515.42814	295.84725	3906.5344	22798.464	12485.985
78	880.00007	515.42814	295.84725	1271.5637	12249.596	2626.5933

ELEM = 89	FX	FY	FZ	MX	MY	MZ
78	880.00007	515.42814	295.84725	1271.5637	12249.596	2626.5933
79	880.00007	515.42814	295.84725	1363.407	1833.7111	8995.8541

ELEM = 90	FX	FY	FZ	MX	MY	MZ
79	880.00007	515.42814	295.84725	1363.407	1833.7111	8995.8541
80	880.00007	515.42814	295.84725	2926.3782	1833.7111	21631.856

ELEM = 91	FX	FY	FZ	MX	MY	MZ
80	880.00007	515.42814	295.84725	2926.3782	1833.7111	21631.856
81	880.00007	515.42814	295.84725	7364.0869	1833.7111	34798.941

PRINT ELEMENT STRESS ITEMS PER ELEMENT

***** POST1 ELEMENT STRESS LISTING *****

CALCULATED LOAD CASE = 3

ELEM	I1	I3	J1	J3
58	1151.4031	436.29075	1723.9707	667.9993
59	1722.9707	667.9993	2497.1571	1422.9955
60	2497.1571	1422.9955	3659.2913	2602.6899
61	3659.2913	2602.6899	1597.7125	600.62046
62	1598.4164	599.23731	3494.4976	2425.3972
63	3494.4976	2425.3972	4733.5511	3662.8161
64	4680.463	3713.0932	3305.332	2338.1297
65	3227.0734	2414.4314	1083.6063	474.25378
66	1083.6063	474.25378	940.21555	251.28031
67	855.40171	285.65642	734.35248	274.63343
68	734.35248	274.63343	754.54229	405.70108
69	682.48665	407.93516	742.7557	626.97706
70	742.7557	626.97706	601.48199	562.26667
71	562.7139	533.81672	598.146	339.15247

72	598.146	339.15247	392.08492	193.30191
73	295.77022	248.62579	424.86368	365.48066
74	424.86368	365.48066	1701.8407	1640.3043
75	1701.8407	1640.3043	1243.4411	1183.0361
76	1474.7925	966.45811	1544.8346	1029.7992
77	1544.8346	1029.7992	1278.5731	772.8835
78	931.50771	1101.9884	571.52616	745.81121
79	571.52616	745.81121	403.51948	579.56442

ELEM	I1	I3	J1	J3
80	403.51948	579.56442	495.12391	674.71599
81	587.09296	860.16146	1367.8377	1572.1545
82	1367.8377	1572.1545	1826.3387	2044.7885
83	657.92126	744.5123	659.2112	745.38011
84	1126.2361	1383.3535	727.46489	980.24786
85	727.46489	980.24786	510.66117	785.55121
86	462.30405	726.04152	275.52357	543.3824
87	275.52357	543.3824	442.23953	699.23378
88	1304.6096	1123.2348	579.62259	410.9574
89	579.62259	410.9574	414.37592	212.59876
90	548.36056	364.54088	1140.6847	962.42123
91	1140.6847	962.42123	1862.9824	1684.8077

MINIMUMS				
ELEMENT	87	73	86	72
VALUE	275.52357	248.62579	275.52357	193.30191

MAXIMUMS				
ELEMENT	64	64	63	63
VALUE	4680.463	3713.0932	4733.5511	3662.8161

178 ELEMENTS (OF 178 DEFINED) SELECTED BY EALL COMMAND.

ESEL FOR LABEL = TYPE FROM 1 TO 1 BY 1

91 ELEMENTS (OF 178 DEFINED) SELECTED BY ESEL COMMAND.

ERSE FOR LABEL = REAL FROM 3 TO 3 BY 1

12 ELEMENTS (OF 178 DEFINED) SELECTED BY ERSE COMMAND.

13 NODES (OF 108 DEFINED) SELECTED FROM 12 SELECTED ELEMENTS BY NELE COMMAND.

PRINT NODAL DISPLACEMENTS

***** POST1 NODAL DISPLACEMENT LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
82	3.34E-02	0.00E+00	1.96E-03	0.00E+00	0.00E+00	0.00E+00
83	3.34E-02	1.20E-04	2.21E-03	0.00E+00	3.89E-05	7.89E-06
84	3.34E-02	2.82E-04	3.05E-03	0.00E+00	6.67E-05	2.84E-06
85	3.32E-02	0.00E+00	8.87E-03	0.00E+00	1.51E-04	0.00E+00
86	3.32E-02	1.87E-18	9.61E-03	0.00E+00	1.61E-04	5.92E-19
87	3.30E-02	3.70E-17	1.56E-02	0.00E+00	1.58E-04	3.19E-18
88	3.28E-02	0.00E+00	2.03E-02	0.00E+00	2.54E-04	0.00E+00
89	3.28E-02	0.00E+00	2.11E-02	0.00E+00	2.95E-04	0.00E+00
90	3.28E-02	0.00E+00	2.18E-02	0.00E+00	3.29E-04	0.00E+00

91	3.07E-02	0.00E+00	2.18E-02	0.00E+00	3.67E-04	0.00E+00
92	2.89E-02	0.00E+00	2.19E-02	0.00E+00	3.92E-04	0.00E+00
93	1.99E-02	0.00E+00	2.19E-02	0.00E+00	4.11E-04	0.00E+00
94	9.27E-03	0.00E+00	2.20E-02	0.00E+00	0.00E+00	0.00E+00

MAXIMUMS

NODE	82	84	94	0	93	83
VALUE	0.33435486E-01	0.28205206E-03	0.21952519E-01	0.00000000E+00	0.41128482E-03	0.78929072E-

PRINT NODAL FORCES PER ELEMENT

***** POST1 ELEMENT NODE FORCE LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z FORCES ARE IN GLOBAL COORDINATES

ELEM	FX	FY	FZ	MX	MY	MZ
ELEM = 46	FX	FY	FZ	MX	MY	MZ
82	91.069416	19.737391	34.364753	0.00E+00	1774.2245	536.31875
83	91.069416	19.737391	34.364753	0.00E+00	1246.9846	62.62136
ELEM = 47	FX	FY	FZ	MX	MY	MZ
83	91.069416	19.737391	34.364753	0.00E+00	1246.9846	62.62136
84	91.069416	19.737391	34.364753	0.00E+00	1158.5959	430.81342
ELEM = 48	FX	FY	FZ	MX	MY	MZ
84	91.069416	10.832989	29.785915	0.00E+00	1158.5959	430.81342
85	91.069416	10.832989	29.785915	0.00E+00	2382.0336	359.99478
ELEM = 49	FX	FY	FZ	MX	MY	MZ
85	280.10922	4.68E-12	122.67909	0.00E+00	2382.0336	1.04E-10
86	280.10922	4.68E-12	122.67909	0.00E+00	1753.6462	7.57E-11
ELEM = 50	FX	FY	FZ	MX	MY	MZ
86	280.10922	4.68E-12	122.67909	0.00E+00	1753.6462	7.57E-11
87	280.10922	4.68E-12	122.67909	0.00E+00	3783.9667	1.16E-10
ELEM = 51	FX	FY	FZ	MX	MY	MZ
87	280.10922	6.70E-12	111.74601	0.00E+00	3783.9667	1.16E-10
88	280.10922	6.70E-12	111.74601	0.00E+00	7845.5819	1.32E-10
ELEM = 52	FX	FY	FZ	MX	MY	MZ
88	280.10922	0.00E+00	125.1007	0.00E+00	7845.5819	0.00E+00
89	280.10922	0.00E+00	125.1007	0.00E+00	7837.5296	0.00E+00
ELEM = 53	FX	FY	FZ	MX	MY	MZ
89	280.10922	0.00E+00	125.1007	0.00E+00	7837.5296	0.00E+00
90	280.10922	0.00E+00	125.1007	0.00E+00	7885.5813	0.00E+00
ELEM = 54	FX	FY	FZ	MX	MY	MZ
90	280.10922	0.00E+00	125.1007	0.00E+00	7885.5813	0.00E+00
91	280.10922	0.00E+00	125.1007	0.00E+00	6276.9759	0.00E+00
ELEM = 55	FX	FY	FZ	MX	MY	MZ
91	280.10922	0.00E+00	125.1007	0.00E+00	6276.9759	0.00E+00
92	280.10922	0.00E+00	125.1007	0.00E+00	4973.0091	0.00E+00
ELEM = 56	FX	FY	FZ	MX	MY	MZ
92	310.63301	0.00E+00	125.1007	0.00E+00	4973.0091	0.00E+00
93	310.63301	0.00E+00	125.1007	0.00E+00	2821.8533	0.00E+00

ELEM = 57	FX	FY	FZ	MX	MY	MZ
93	314.40328	0.00E+00	125.1007	0.00E+00	2821.8533	0.00E+00
94	314.40328	0.00E+00	125.1007	0.00E+00	15435.342	0.00E+00

PRINT ELEMENT STRESS ITEMS PER ELEMENT

***** POST1 ELEMENT STRESS LISTING *****

CALCULATED LOAD CASE = 3

ELEM	I1	I3	J1	J3
46	311.97898	287.16198	210.39511	198.38953
47	210.39511	198.38953	206.68671	199.61095
48	206.68671	199.61095	406.82349	365.41456
49	468.45369	333.63165	355.00723	270.07038
50	355.00723	270.07038	739.33283	471.71669
51	739.33283	471.71669	1380.3357	1122.1281
52	1380.3357	1122.1281	1374.6252	1126.2769
53	1374.6252	1126.2769	1378.0127	1139.0738
54	1228.0877	1285.9914	970.72083	1031.676
55	970.72083	1031.676	761.66635	826.19217
56	761.66635	826.19217	430.70746	476.32272
57	430.70746	476.32272	2439.8189	2477.4958

MINIMUMS

ELEMENT	48	47	47	46
VALUE	206.68671	198.38953	206.68671	198.38953

MAXIMUMS

ELEMENT	52	54	57	57
VALUE	1380.3357	1285.9914	2439.8189	2477.4958

***** END OF INPUT ENCOUNTERED ON FILE38. FILE38 REWOUND

***** INPUT FILE SWITCHED FROM FILE38 TO FILE 5

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A26

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A26 OF A72

```
/PREP7
/OUT,OUTN1S2,SSE
/TITLE,SSE FOR HVAC SYSTEM 4316-1
C****
C****RE-ANALYZE SYSTEM 4316-1 BASED ON BARE SHEET METAL THICKNESS
C****USE SITE SPECIFIC EARTHQUAKE WITH 2% DAMPING
C****DATE: 4-25-94
C****
KAN,2
KAY,2,90
ET,1,4
,2,14,,1
,3,14,,3
,4,21,,,2
EX,1,29.E6
NUXY,1,0.29
DENS,1,0.00125
C****DENSITY IS INCREASED FROM 0.0012 TO 0.00125.
C****THIS IS TO RECOVER THE WT. LOSS DUE TO AREA REDUCTION
C****BECAUSE SYSTEM WT. REMAINS THE SAME.
N,1,196.,,-26.
,2,196.,,4.
,3,196.,,42.
,4,196.,,84.
,5,196.,,90.
,6,196.,,114.
,7,196.,,151.
,8,182.,,151.
,9,124.,,151.
,10,98.,,151.
,11,65.,,151.
,12,41.,,151.
,13,6.0,,151.
,14,2.,,151.
,15,-12.,,151.
,16,-84.,,151.
,17,-94.,,151.
,18,-118.,,151.
,19,-169.,,151.
,20,-193.,,151.
,21,-220.,,151.
,22,-230.,,151.
,23,-230.,,164.
,24,-230.,,217.
,25,-230.,,265.
,26,-230.,,313.
,27,-230.,,352.
,28,-230.,,391.
,29,-230.,,430.
,30,-230.,,469.
,31,-230.,,502.
,32,-230.,-18.5,520.5
,33,-230.,-37.,539.
,34,-230.,-37.,565.
,35,-204.,-37.,565.
,36,-204.,-65.,565.
,37,-204.,-84.,565.
,38,-30.,,133.
,39,-48.,,115.
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HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A27

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316.1 BY: HEK CK: MAK SHT: A27 OF A77

,40,-84.,,115.
,41,-94.,,115.
,42,-118.,,115.
,43,-151.,,133.
,44,-133.,,115.
,45,-123.,,115.
,47,222.5,-2.5,-26.
,48,222.5,-2.5,2.
,49,222.5,-2.5,36.
,50,222.5,-2.5,84.
,51,222.5,-2.5,108.
,52,222.5,-2.5,158.
,53,222.5,-2.5,173.5
,54,207.,-2.5,173.5
,55,182.,-2.5,173.5
,56,146.,-2.5,173.5
,57,98.,-2.5,173.5
,58,63.0,-2.5,173.5
,59,2.,-2.5,173.5
,60,-21.,-2.5,173.5
,61,-94.,-2.5,173.5
,62,-104.,-2.5,173.5
,63,-129.,-2.5,173.5
,64,-193.,-2.5,173.5
,65,-204.,-2.5,173.5
,66,-204.,-2.5,189.
,67,-204.,-2.5,217.
,68,-204.,-2.5,248.
,69,-204.,-2.5,307.
,70,-204.,-2.5,313.
,71,-204.,-2.5,350.
,72,-204.,-2.5,365.5
,73,-204.,-30.5,365.5
,74,-204.,-42.5,377.5
,75,-204.,-54.5,389.5
,76,-204.,-69.,389.5
,77,-204.,-84.,389.5
,78,-204.,-42.5,353.5
,79,-204.,-54.5,341.5
,80,-204.,-69.,341.5
,81,-204.,-84.,341.5
,82,304.,15.,195.
,83,280.,15.,195.
,84,255.,15.,195.
,85,182.,15.,195.
,86,176.,15.,195.
,87,135.,15.,195.
,88,98.,15.,195.
,89,92.,15.,195.
,90,87.,15.,195.
,91,87.,15.,189.
,92,87.,15.,184.
,93,87.,15.,162.
,94,87.,15.,120.
,104,184.,,84.
,108,182.,,139.
,110,98.,,139.
,114,2.,,139.
,141,-94.,,103.

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A 28

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HCK CK: NGK SHT: A28 OF A72

```
,120,-193.,,139.
,124,-242.,,217.
,126,-242.,,313.
,128,-242.,,391.
,130,-242.,,469.
,182,304.,15.,207.
,192,75.,15.,184.
,194,87.,15.,132.
,282,316.,15.,195.
,294,99.,15.,120.
C****MATREIAL PROPERTIES FOR GALVANIZED SHEET METAL:
C****R,1,2.89,94.4,94.4,14.,14.
C****RMORE,,141.6
C****R,2,3.92,235.9,235.9,19.,19.
C****RMORE,,353.9
C****R,3,2.06,34.4,34.4,10.,10.
C****RMORE,,51.6
R,1,2.68,86.6,86.6,14.0,14.0
RMORE,,131.2
R,2,3.63,216.9,216.9,19.0,19.0
RMORE,,327.9
R,3,1.91,31.4,31.4,10.0,10.0
RMORE,,47.8
R,4,.071
,5,.056
,6,.113
,7,.106
,8,.128
,9,.015
,10,.117
,11,.097
,12,.174
,13,.077
,14,.23
,15,.153
,16,.04
,17,.3
,18,.217
,19,.181
,20,.2
,21,.166
,22,.258
,23,.171
,24,91550.
,25,57735.
,26,31455.
,27,957.
,28,73800.
,29,35000.
,30,86088.
,31,4880.
,32,2000.
,33,3150.
,34,740.
,35,470.
,36,32260.
,37,37040.
E,1,2
EGEN,36,1,-1
```

```
E,15,38
,38,39
,39,40
,40,41
,41,42
,42,45
,45,44
,44,43
,43,19
REAL,3
E,82,83
EGEN,12,1,-1
REAL,2
E,47,48
EGEN,30,1,-1
E,73,78
,78,79
,79,80
,80,81
TYPE,4
REAL,4
E,2
,3
,9
,11
,13
,18
,21
,23
,27
REAL,5
E,5
,15
,45
REAL,6
E,7
,19
,31
,33
,35
,38
,43
REAL,7
E,16
,40
REAL,8
E,25
;29
REAL,9
E,36
REAL,10
E,48
,58
REAL,11
E,49
,54
,62
,63
,66
```

,68
,71
REAL,12
E,51
,56
,60
REAL,13
E,52
,69
REAL,14
E,73
REAL,15
E,75
,76
,79
,80
REAL,16
E,84
,86
,87
,89
,91
,93
REAL,17
E,4
,50
REAL,18
E,8
,55
,85
,94
REAL,19
E,10
,20
,57
,64
REAL,20
E,28
,30
,14
,59
,82
REAL,21
E,17
,41
,61
,92
REAL,22
E,24
,67
REAL,23
E,26
,70
TYPE,2
REAL,24
E,4,104
REAL,30
E,24,124
REAL,31

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A31

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A31 OF A72

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E,26,126
REAL,32
E,28,128
,30,130
REAL,33
E,92,192
REAL,34
E,82,282
REAL,37
E,94,294
TYPE,3
REAL,25
E,8,108
REAL,26
E,10,110
REAL,27
E,14,114
REAL,28
E,41,141
REAL,29
E,20,120
REAL,36
E,82,182
REAL,35
E,94,194
WSTART,1
,47
,82
WAVES
D,104,ALL,,,124,10
,110,ALL,,,130,10
,108,ALL,,,128,20
,126,ALL,,,141,15
,182,ALL,,,192,10
,194,ALL
,282,ALL
,294,ALL
,24,UY,,,30,2,ROTX,ROTZ
,55,UY,,,61,2,ROTX,ROTZ
,82,UY,,,88,3,ROTX,ROTZ
,8,UY,,,20,6,ROTX,ROTZ
,4,UY,,,10,6,ROTX,ROTZ
,17,UY,,,41,24,ROTX,ROTZ
,50,UY,,,70,20,ROTX,ROTZ
,64,UY,,,67,3,ROTX,ROTZ
,92,UY,,,94,2,ROTX,ROTZ
,82,ROTY,,,94,12
,1,ALL,,,47,46
,37,ALL
,77,ALL,,,81,4
CP,1,UZ,8,55,85
,2,UZ,10,57,88
,3,UX,4,50
,4,UZ,14,59
,5,UZ,17,41,61
,6,UZ,20,64
,7,UZ,24,67
,8,UZ,26,70
TOTAL,90,1
```

```
MLIST
ITER,1,1,1
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1
SVTYPE,2
SED,1.0,0.0,0.0     *E-W DIRECTION
FREQ,.91,1.25,2.0,3.03,3.33,3.85,4.55,5.71,6.06
FREQ,6.67,7.14,13.3,20.0,23.3,50.0,500.0
SV,0.02,73.3,88.8,166.0,347.0,618.0,1040.0,1540.0,1540.0,1270.0
SV,0.02,1270.0,888.0,328.0,328.0,212.0,208.0,208.0
LWRITE
SED,0.0,1.0,0.0     *VERTICAL DIRECTION
FREQ
FREQ,1.0,1.7,3.3,5.0,5.6,6.7,10.0,11.1,15.2
FREQ,18.2,25.0,33.3,50.0,500.0
SV,0.02,92.6,92.6,173.7,308.8,347.4,347.4,1351.0,2123.0,2123.0
SV,0.02,1080.8,521.1,308.8,208.4,208.4
LWRITE
SED,0.0,0.0,1.0     *N-S DIRECTION
FREQ
FREQ,.91,1.14,1.33,1.54,2.22,3.33,3.85,4.55,5.56
FREQ,5.71,5.88,6.06,9.09,13.3,16.7,20.0,33.3,500.0
SV,0.02,77.2,88.8,124.0,124.0,262.0,502.0,1160.0,1580.0,1580.0
SV,0.02,1350.0,1310.0,1040.0,425.0,270.0,270.0,212.0,185.0,185.0
LWRITE
AFWRITE
FINISH
/OUT,OUTN1S2,ANS
/INP,27
FINI
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HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A33

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 43161 BY: HEK CK: MAK SHT: A33 OF A72

```
C****
C****POST-PROCESSING FILE FOR SYSTEM 4316-1
C****
STRESS,I1,4,19
STRESS,I3,4,20
STRESS,J1,4,21
STRESS,J3,4,22
LCLIM,3
LCASE,1
SET,1,1
LCASE,2
SET,1,2
LCSRSS,3,1,2
LCASE,2
SET,1,3
LCSRSS,3,2,3
LCASE,2
SET,1,4
LCSRSS,3,2,3
LCASE,2
SET,1,5
LCSRSS,3,2,3
LCASE,2
SET,1,6
LCSRSS,3,2,3
LCASE,2
SET,1,7
LCSRSS,3,2,3
LCASE,2
SET,1,8
LCSRSS,3,2,3
LCASE,2
SET,1,9
LCSRSS,3,2,3
LCASE,2
SET,1,10
LCSRSS,3,2,3
LCASE,2
SET,1,11
LCSRSS,3,2,3
LCASE,2
SET,1,12
LCSRSS,3,2,3
LCASE,2
SET,1,13
LCSRSS,3,2,3
LCASE,2
SET,2,18
LCSRSS,3,2,3
LCASE,2
SET,2,24
LCSRSS,3,2,3
LCASE,2
SET,2,25
LCSRSS,3,2,3
LCASE,2
SET,3,1
LCSRSS,3,2,3
LCASE,2
SET,3,2
LCSRSS,3,2,3
```

```
LCASE,2
SET,3,3
LCSRSS,3,2,3
LCASE,2
SET,3,4
LCSRSS,3,2,3
LCASE,2
SET,3,5
LCSRSS,3,2,3
LCASE,2
SET,3,6
LCSRSS,3,2,3
LCASE,2
SET,3,7
LCSRSS,3,2,3
LCASE,2
SET,3,8
LCSRSS,3,2,3
LCASE,2
SET,3,9
LCSRSS,3,2,3
LCASE,2
SET,3,10
LCSRSS,3,2,3
LCASE,2
SET,3,11
LCSRSS,3,2,3
LCASE,2
SET,3,12
LCSRSS,3,2,3
LCASE,2
SET,3,13
LCSRSS,3,2,3
LCASE,2
SET,3,19
LCSRSS,3,2,3
LCASE,2
SET,3,20
LCSRSS,3,2,3
LCASE,3
ESEL,TYPE,1
ERSEL,REAL,,1
NELEM
PRDISP
PREFOR
PRSTRS,I1,I3,J1,J3
EALL
ESEL,TYPE,1
ERSEL,REAL,2
NELEM
PRDISP
PREFOR
PRSTRS,I1,I3,J1,J3
EALL
ESEL,TYPE,1
ERSEL,REAL,3
NELEM
PRDISP
PREFOR
PRSTRS,I1,I3,J1,J3
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HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A35

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEE CK: MAK SHT: A35 OF A72

***** EIGENVALUE (NATURAL FREQUENCY) SOLUTION *****

MODE	FREQUENCY (CYCLES/TIME)
1	10.7695426
2	15.1177832
3	15.3198123
4	17.0026897
5	20.9726790
6	33.2040876
7	38.4820832
8	42.7501592
9	46.3968674
10	49.8360342
11	57.4085106
12	62.5323514
13	67.4258425
14	73.5391224
15	77.7194027
16	94.4166889
17	96.8474360
18	100.193515
19	103.959923
20	109.827858
21	117.908533
22	125.812873
23	129.000925
24	131.653735
25	131.653765
26	141.530581
27	148.659846
28	156.759910
29	159.374828
30	165.305014
31	174.021746
32	177.438660
33	179.906185
34	180.402718
35	184.503323
36	190.152778
37	192.409454
38	196.087267
39	196.963765
40	205.927181
41	209.731960
42	210.643335
43	220.306140
44	232.944272
45	233.656787
46	240.790530
47	246.065899
48	256.029051
49	262.407669
50	271.648106
51	273.355190
52	284.101987
53	290.099916
54	301.867852

55	306.761172
56	309.646233
57	311.770890
58	323.230341
59	333.279760
60	334.280432
61	339.994843
62	343.111751
63	359.850875
64	362.807178
65	368.421677
66	368.749603
67	383.813871
68	384.443363
69	386.430062
70	399.224644
71	403.377980
72	408.013764
73	419.355707
74	419.907105
75	423.997270
76	438.531399
77	440.938242
78	444.542627
79	446.685301
80	447.364878
81	473.197421
82	496.514332
83	502.596206
84	520.995600
85	529.055039
86	556.358411
87	569.244922
88	594.840871
89	613.332875
90	658.328138

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CALCULATION SHEET

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SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEE CK: MAK SHT: A37 OF A72

PRINT NODAL DISPLACEMENTS

***** POST1 NODAL DISPLACEMENT LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	3.08E-03	5.25E-17	5.68E-04	2.64E-18	1.97E-04	0.00E+00
3	1.43E-02	1.02E-16	1.29E-03	1.40E-18	3.88E-04	0.00E+00
4	3.40E-02	0.00E+00	2.08E-03	0.00E+00	5.77E-04	0.00E+00
5	3.74E-02	0.00E+00	2.19E-03	0.00E+00	6.03E-04	0.00E+00
6	5.21E-02	0.00E+00	2.64E-03	0.00E+00	6.51E-04	0.00E+00
7	7.44E-02	0.00E+00	3.34E-03	0.00E+00	5.51E-04	0.00E+00
8	7.44E-02	0.00E+00	9.98E-03	0.00E+00	4.39E-04	0.00E+00
9	7.45E-02	1.04E-17	2.16E-02	0.00E+00	1.27E-04	3.32E-19
10	7.46E-02	0.00E+00	2.25E-02	0.00E+00	1.29E-04	0.00E+00
11	7.46E-02	2.07E-17	2.40E-02	0.00E+00	1.02E-04	4.47E-19
12	7.45E-02	1.81E-17	2.49E-02	0.00E+00	6.90E-05	5.03E-19
13	7.45E-02	3.46E-19	2.47E-02	0.00E+00	5.21E-05	1.68E-19
14	7.45E-02	0.00E+00	2.45E-02	0.00E+00	5.81E-05	0.00E+00
15	7.44E-02	8.53E-18	2.36E-02	2.33E-18	8.64E-05	9.51E-19
16	7.40E-02	1.37E-18	1.52E-02	2.84E-19	1.45E-04	2.56E-19
17	7.39E-02	0.00E+00	1.38E-02	0.00E+00	1.45E-04	0.00E+00
18	7.37E-02	1.27E-17	1.06E-02	2.20E-19	1.36E-04	5.06E-19
19	7.32E-02	4.86E-18	4.56E-03	6.89E-19	1.11E-04	3.11E-19
20	7.29E-02	0.00E+00	3.00E-03	0.00E+00	5.39E-05	0.00E+00
21	7.25E-02	2.41E-18	1.78E-03	1.38E-20	2.22E-04	1.44E-19
22	7.23E-02	3.88E-18	3.54E-03	1.89E-20	4.22E-04	1.45E-19
23	6.50E-02	3.51E-18	3.29E-03	4.66E-20	6.88E-04	1.17E-19
24	1.74E-02	0.00E+00	2.36E-03	0.00E+00	8.91E-04	0.00E+00
25	1.97E-02	4.64E-21	2.21E-03	0.00E+00	5.24E-04	0.00E+00
26	3.90E-02	0.00E+00	2.06E-03	0.00E+00	3.14E-04	0.00E+00
27	4.79E-02	2.51E-17	2.10E-03	0.00E+00	1.94E-04	0.00E+00
28	5.05E-02	0.00E+00	2.16E-03	0.00E+00	1.22E-04	0.00E+00
29	4.66E-02	2.49E-17	2.20E-03	0.00E+00	2.07E-04	0.00E+00
30	3.69E-02	0.00E+00	2.25E-03	0.00E+00	3.18E-04	0.00E+00
31	2.58E-02	6.15E-04	2.29E-03	2.14E-05	3.61E-04	9.99E-05
32	1.72E-02	9.56E-04	2.17E-03	1.45E-05	3.44E-04	1.35E-04
33	8.83E-03	1.26E-03	2.03E-03	1.78E-05	2.89E-04	1.29E-04
34	2.56E-03	1.65E-03	2.05E-03	1.40E-05	1.96E-04	7.40E-05
35	2.48E-03	1.36E-04	3.05E-03	7.77E-05	1.16E-04	6.94E-05
36	5.72E-04	5.52E-05	7.36E-04	6.90E-05	4.71E-05	5.42E-05
37	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
38	7.56E-02	8.32E-17	2.19E-02	3.62E-18	1.09E-04	7.79E-20
39	7.69E-02	1.17E-16	1.98E-02	3.01E-18	1.29E-04	2.79E-18
40	7.69E-02	9.41E-[illegible]	1.51E-02	6.54E-19	1.39E-04	1.77E-18
41	7.69E-02	0.00E [illegible]	1.38E-02	0.00E+00	1.36E-04	0.00E+00
42	7.69E-02	1.22[illegible]	1.08E-02	5.26E-19	1.31E-04	8.17E-19
43	7.50E-02	1.64[illegible]	6.59E-03	9.94E-19	1.35E-04	1.78E-19
44	7.68E-02	2.43E-[illegible]	8.88E-03	8.54E-19	1.35E-04	7.20E-19
45	7.69E-02	1.63E-17	1.01E-02	6.35E-19	1.32E-04	8.36E-19

MAXIMUMS

	UX	UY	UZ	ROTX	ROTY	ROTZ
NODE	41	34	12	35	24	32
VALUE	7.69E-02	1.65E-03	2.49E-02	7.77E-05	8.91E-04	1.35E-04

PRINT NODAL FORCES PER ELEMENT

***** POST1 ELEMENT NODE FORCE LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z FORCES ARE IN GLOBAL COORDINATES

ELEM	FX	FY	FZ	MX	MY	MZ
ELEM = 1	FX	FY	FZ	MX	MY	MZ
1	216.26947	1.43E-11	1470.4765	4.36E-10	18669.612	0.00E+00
2	216.26947	1.43E-11	1470.4765	5.83E-12	14695.943	0.00E+00
ELEM = 2	FX	FY	FZ	MX	MY	MZ
2	212.47046	1.43E-11	1470.4765	5.83E-12	14695.943	0.00E+00
3	212.47046	1.43E-11	1470.4765	5.39E-10	13009.673	0.00E+00
ELEM = 3	FX	FY	FZ	MX	MY	MZ
3	200.43854	2.97E-11	1470.4765	5.39E-10	13009.673	0.00E+00
4	200.43854	2.97E-11	1470.4765	7.06E-10	16441.327	0.00E+00
ELEM = 4	FX	FY	FZ	MX	MY	MZ
4	542.86155	0.00E+00	1459.7692	0.00E+00	16441.327	0.00E+00
5	542.86155	0.00E+00	1459.7692	0.00E+00	13274.374	0.00E+00
ELEM = 5	FX	FY	FZ	MX	MY	MZ
5	542.86155	0.00E+00	1459.7692	0.00E+00	13274.374	0.00E+00
6	542.86155	0.00E+00	1459.7692	0.00E+00	3458.1881	0.00E+00
ELEM = 6	FX	FY	FZ	MX	MY	MZ
6	512.24782	0.00E+00	1459.7692	0.00E+00	3458.1881	0.00E+00
7	512.24782	0.00E+00	1459.7692	0.00E+00	19428.849	0.00E+00
ELEM = 7	FX	FY	FZ	MX	MY	MZ
7	512.24782	0.00E+00	1459.7692	0.00E+00	19428.849	0.00E+00
8	512.24782	0.00E+00	1459.7692	0.00E+00	29582.303	0.00E+00
ELEM = 8	FX	FY	FZ	MX	MY	MZ
8	352.43354	3.10E-12	375.13139	0.00E+00	29582.303	7.55E-11
9	352.43354	3.10E-12	375.13139	0.00E+00	8208.6364	1.04E-10
ELEM = 9	FX	FY	FZ	MX	MY	MZ
9	352.43354	1.05E-11	392.76688	0.00E+00	8208.6364	1.04E-10
10	352.43354	1.05E-11	392.76688	0.00E+00	3117.3662	1.68E-10
ELEM = 10	FX	FY	FZ	MX	MY	MZ
10	288.11055	1.11E-11	121.69309	0.00E+00	3117.3662	2.18E-10
11	288.11055	1.11E-11	121.69309	0.00E+00	4013.1757	1.50E-10
ELEM = 11	FX	FY	FZ	MX	MY	MZ
11	288.11055	4.19E-12	71.909942	0.00E+00	4013.1757	1.50E-10
12	288.11055	4.19E-12	71.909942	0.00E+00	4812.2074	4.92E-11
ELEM = 12	FX	FY	FZ	MX	MY	MZ
12	288.11055	4.19E-12	71.909942	0.00E+00	4812.2074	4.92E-11
13	288.11055	4.19E-12	71.909942	0.00E+00	6642.2402	9.73E-11
ELEM = 13	FX	FY	FZ	MX	MY	MZ
13	288.11055	4.19E-12	71.909942	0.00E+00	6642.2402	9.73E-11
14	288.11055	4.19E-12	71.909942	0.00E+00	6879.0767	1.14E-10

ELEM =	FX	FY	FZ	MX	MY	MZ
ELEM = 14	FX	FY	FZ	MX	MY	MZ
14	384.85052	2.06E-11	104.0153	2.45E-10	6879.0767	3.15E-10
15	384.85052	2.06E-11	104.0153	2.45E-10	6722.6243	2.70E-11
ELEM = 15	FX	FY	FZ	MX	MY	MZ
15	520.24651	2.60E-12	53.781901	4.19E-11	3989.8653	1.36E-10
16	520.24651	2.60E-12	53.781901	4.19E-11	1492.738	5.14E-11
ELEM = 16	FX	FY	FZ	MX	MY	MZ
16	734.08112	2.60E-12	248.25302	4.19E-11	1492.738	5.14E-11
17	734.08112	2.60E-12	248.25302	4.19E-11	2369.755	7.74E-11
ELEM = 17	FX	FY	FZ	MX	MY	MZ
17	734.08112	1.45E-11	60.431891	1.35E-11	2369.755	2.26E-10
18	734.08112	1.45E-11	60.431891	1.35E-11	1340.8424	1.22E-10
ELEM = 18	FX	FY	FZ	MX	MY	MZ
18	734.08112	3.37E-12	34.390647	1.35E-11	1340.8424	1.22E-10
19	734.08112	3.37E-12	34.390647	1.35E-11	2195.6623	5.50E-11
ELEM = 19	FX	FY	FZ	MX	MY	MZ
19	1008.5289	2.84E-12	115.46763	4.23E-11	6651.3493	2.03E-11
20	1008.5289	2.84E-12	115.46763	4.23E-11	6915.1245	6.35E-11
ELEM = 20	FX	FY	FZ	MX	MY	MZ
20	1221.7687	7.09E-13	1759.5122	7.53E-13	6915.1245	2.30E-11
21	1221.7687	7.09E-13	1759.5122	7.53E-13	41749.265	3.84E-12
ELEM = 21	FX	FY	FZ	MX	MY	MZ
21	1221.7687	7.09E-13	1759.5122	7.53E-13	41749.265	3.84E-12
22	1221.7687	7.09E-13	1759.5122	7.53E-13	59298.594	3.25E-12
ELEM = 22	FX	FY	FZ	MX	MY	MZ
22	1221.7687	7.09E-13	1759.5122	7.53E-13	59298.594	3.25E-12
23	1221.7687	7.09E-13	1759.5122	9.97E-12	43547.128	3.25E-12
ELEM = 23	FX	FY	FZ	MX	MY	MZ
23	1303.1371	4.59E-13	1759.307	9.97E-12	43547.128	3.25E-12
24	1303.1371	4.59E-13	1759.307	1.44E-11	26862.53	3.25E-12
ELEM = 24	FX	FY	FZ	MX	MY	MZ
24	196.64162	1.26E-15	285.35197	3.03E-14	26862.53	0.00E+00
25	196.64162	1.26E-15	285.35197	3.03E-14	18916.666	0.00E+00
ELEM = 25	FX	FY	FZ	MX	MY	MZ
25	183.13476	1.26E-15	285.35197	3.03E-14	18916.666	0.00E+00
26	183.13476	1.26E-15	285.35197	3.03E-14	11441.728	0.00E+00
ELEM = 26	FX	FY	FZ	MX	MY	MZ
26	152.05863	1.27E-11	366.21207	2.48E-10	11441.728	0.00E+00
27	152.05863	1.27E-11	366.21207	2.48E-10	11701.922	0.00E+00
ELEM = 27	FX	FY	FZ	MX	MY	MZ
27	110.24742	1.27E-11	366.21207	2.48E-10	11701.922	0.00E+00
28	110.24742	1.27E-11	366.21207	2.48E-10	11691.156	0.00E+00

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A40

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A40 OF A72

ELEM =	FX	FY	FZ	MX	MY	MZ
ELEM = 28	FX	FY	FZ	MX	MY	MZ
28	65.956082	1.26E-11	350.19352	2.46E-10	11691.156	0.00E+00
29	65.956082	1.26E-11	350.19352	2.46E-10	11206.712	0.00E+00
ELEM = 29	FX	FY	FZ	MX	MY	MZ
29	126.26272	1.26E-11	350.19352	2.46E-10	11206.712	0.00E+00
30	126.26272	1.26E-11	350.19352	2.46E-10	7068.6497	0.00E+00
ELEM = 30	FX	FY	FZ	MX	MY	MZ
30	153.00979	233.58208	342.77448	5365.2565	7068.6497	4466.3313
31	153.00979	233.58208	342.77448	2491.219	3174.0507	4466.3313
ELEM = 31	FX	FY	FZ	MX	MY	MZ
31	210.33849	230.73054	342.77448	2491.219	3174.0507	4466.3313
32	210.33849	230.73054	342.77448	493.4279	3247.161	829.43407
ELEM = 32	FX	FY	FZ	MX	MY	MZ
32	210.33849	230.73054	342.77448	493.4279	3247.161	829.43407
33	210.33849	230.73054	342.77448	1816.6386	6426.3017	3422.2287
ELEM = 33	FX	FY	FZ	MX	MY	MZ
33	240.71881	227.46673	347.04897	1816.6386	6426.3017	3422.2287
34	240.71881	227.46673	347.04897	4224.8286	12311.538	3422.2287
ELEM = 34	FX	FY	FZ	MX	MY	MZ
34	240.71881	225.64649	347.04897	4224.8286	12311.538	3422.2287
35	240.71881	225.64649	347.04897	4224.8286	3653.9366	2502.0851
ELEM = 35	FX	FY	FZ	MX	MY	MZ
35	251.09157	225.64649	355.10311	4224.8286	3653.9366	2502.0851
36	251.09157	225.64649	355.10311	5746.977	3653.9366	4809.3565
ELEM = 36	FX	FY	FZ	MX	MY	MZ
36	251.09157	225.64649	355.10311	5746.977	3653.9366	4809.3565
37	251.09157	225.64649	355.10311	12487.321	3653.9366	9532.9958
ELEM = 37	FX	FY	FZ	MX	MY	MZ
15	218.62277	2.32E-11	81.0056	2.87E-10	3475.5744	1.63E-10
38	218.62277	2.32E-11	81.0056	1.39E-10	2514.7319	2.54E-10
ELEM = 38	FX	FY	FZ	MX	MY	MZ
38	144.47383	4.92E-12	81.0056	1.39E-10	2514.7319	2.54E-10
39	144.47383	4.92E-12	81.0056	9.64E-11	2565.6545	2.23E-10
ELEM = 39	FX	FY	FZ	MX	MY	MZ
39	144.47383	1.63E-11	101.14546	9.64E-11	2565.6545	2.23E-10
40	144.47383	1.63E-11	101.14546	9.64E-11	1369.9135	3.64E-10
ELEM = 40	FX	FY	FZ	MX	MY	MZ
40	144.47383	1.63E-11	101.14546	9.64E-11	1369.9135	3.64E-10
41	144.47383	1.63E-11	101.14546	9.64E-11	2296.8345	5.27E-10
ELEM = 41	FX	FY	FZ	MX	MY	MZ
41	202.74522	5.22E-12	78.61377	3.23E-11	2296.8345	1.48E-10
42	202.74522	5.22E-12	78.61377	3.23E-11	1913.8749	2.29E-11
ELEM = 42	FX	FY	FZ	MX	MY	MZ
42	202.74522	5.22E-12	78.408714	3.23E-11	1913.8749	2.29E-11
45	202.74522	5.22E-12	78.408714	3.23E-11	2074.7761	3.89E-12

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: April '94 PAGE: A41

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316 BY: HZK CK: MAK SHT: A41 OF A72

ELEM = 43	FX	FY	FZ	MX	MY	MZ
45	202.74522	5.22E-12	78.408714	3.23E-11	2074.7761	3.89E-12
44	202.74522	5.22E-12	78.408714	3.23E-11	2551.557	5.54E-11

ELEM = 44	FX	FY	FZ	MX	MY	MZ
44	202.74522	1.55E-12	78.408714	3.23E-11	2551.557	5.54E-11
43	202.74522	1.55E-12	78.408714	2.00E-11	1274.9148	4.39E-11

ELEM = 45	FX	FY	FZ	MX	MY	MZ
43	321.18598	3.86E-12	78.408714	2.00E-11	1274.9148	4.39E-11
19	321.18598	3.86E-12	78.408714	5.59E-11	4903.2254	3.57E-11

PRINT ELEMENT STRESS ITEMS PER ELEMENT

***** POST1 ELEMENT STRESS LISTING *****

CALCULATED LOAD CASE = 3

ELEM	I1	I3	J1	J3
1	1092.1432	1990.9912	754.03677	1689.8884
2	754.03677	1689.8884	715.30626	1517.2778
3	715.30626	1517.2778	1178.5825	1656.9269
4	1178.0757	1654.6493	946.29127	1414.3926
5	946.29127	1414.3926	632.005	591.79247
6	632.005	591.79247	1478.3224	1827.7402
7	1640.6685	1521.1742	2487.7704	2306.4132
8	2418.1388	2371.2166	690.51954	662.02412
9	690.51954	662.02412	312.2458	253.13764
10	262.64358	284.81835	381.60865	296.55963
11	381.60865	296.55963	428.02992	377.50706
12	428.02992	377.50706	553.77415	541.27176
13	553.77415	541.27176	570.98388	561.66246
14	550.68886	596.95674	523.26133	598.33553
15	359.02513	393.05003	123.0936	298.88504
16	192.10656	377.18314	266.99424	390.06627
17	266.99424	390.06627	269.57655	317.61014
18	269.57655	317.61014	241.07854	393.61489
19	386.58228	843.73681	370.27448	878.06394
20	370.16164	950.53218	2972.9065	3788.6724
21	2972.9065	3788.6724	4389.9709	5205.1066
22	4196.6583	5403.6518	2919.9375	4137.209
23	2920.7082	4136.6406	1710.6239	2713.8609
24	2088.1433	2256.4868	1438.4178	1621.6292
25	1438.4178	1621.6292	829.98734	1022.0047
26	846.07103	1015.9759	833.39631	1064.0413
27	833.39631	1064.0413	825.2182	1068.8578
28	825.31982	1067.2834	790.54314	1024.8583
29	790.54314	1024.8583	474.00794	679.99282
30	876.2324	1097.5482	325.60776	554.48775
31	435.06268	686.44006	179.12894	350.90183
32	179.12894	350.90183	562.183	846.97731
33	543.86139	784.77329	1213.9837	1456.6595
34	1191.3174	1353.0818	409.77868	571.38057
35	462.32209	620.61256	736.15873	889.99604
36	736.15873	889.99604	1648.155	1803.5534
37	323.62789	254.86381	238.01614	194.48941
38	222.07421	200.85957	215.82726	215.54755
39	213.94053	214.61381	124.9064	121.38261

40	124.9064	121.38261	193.95632	192.69068
41	188.97721	211.35373	131.80884	204.78662
42	131.80884	204.78662	151.65498	211.41973
43	151.65498	211.41973	186.96968	248.11958
44	191.73888	242.90103	124.08982	128.5751
45	141.22164	148.82686	348.40656	462.19932

MINIMUMS				
ELEMENT	40	40	15	39
VALUE	124.9064	121.38261	123.0936	121.38261

MAXIMUMS				
ELEMENT	22	22	21	21
VALUE	4196.6583	5403.6518	4389.9709	5205.1066

178 ELEMENTS (OF 178 DEFINED) SELECTED BY EALL COMMAND.

ESEL FOR LABEL = TYPE FROM 1 TO 1 BY 1

91 ELEMENTS (OF 178 DEFINED) SELECTED BY ESEL COMMAND.

ERSE FOR LABEL = REAL FROM 2 TO 2 BY 1

34 ELEMENTS (OF 178 DEFINED) SELECTED BY ERSE COMMAND.

35 NODES (OF 108 DEFINED) SELECTED FROM 34 SELECTED ELEMENTS BY NELE COMMAND.

PRINT NODAL DISPLACEMENTS

***** POST1 NODAL DISPLACEMENT LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
47	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
48	1.29E-03	4.66E-18	6.14E-04	2.54E-19	1.02E-04	0.00E+00
49	8.07E-03	9.77E-18	1.36E-03	6.89E-20	3.16E-04	0.00E+00
50	3.40E-02	0.00E+00	2.41E-03	0.00E+00	8.10E-04	0.00E+00
51	5.62E-02	2.25E-18	2.94E-03	1.42E-19	1.01E-03	8.26E-20
52	0.10539611	9.21E-18	4.04E-03	1.27E-19	8.20E-04	2.55E-19
53	0.1164374	1.10E-17	4.38E-03	1.07E-19	5.94E-04	3.08E-19
54	0.11673957	5.98E-18	3.13E-03	6.63E-20	3.76E-04	3.43E-19
55	0.11714903	0.00E+00	9.98E-03	0.00E+00	2.17E-04	0.00E+00
56	0.1177387	4.15E-17	1.66E-02	0.00E+00	1.71E-04	4.32E-19
57	0.11836011	0.00E+00	2.25E-02	0.00E+00	1.29E-04	0.00E+00
58	0.11881325	7.95E-18	2.50E-02	0.00E+00	9.65E-05	1.45E-19
59	0.11939512	0.00E+00	2.45E-02	0.00E+00	7.90E-05	0.00E+00
60	0.11961453	0.00E+00	2.26E-02	0.00E+00	1.08E-04	0.00E+00
61	0.12003643	0.00E+00	1.38E-02	0.00E+00	1.18E-04	0.00E+00
62	0.12009423	4.40E-18	1.30E-02	0.00E+00	1.10E-04	7.95E-19
63	0.12012651	2.78E-17	1.15E-02	0.00E+00	9.54E-05	5.39E-19
64	0.1202092	0.00E+00	3.00E-03	0.00E+00	2.87E-04	0.00E+00
65	0.12022342	0.00E+00	2.08E-03	0.00E+00	3.49E-04	0.00E+00
66	0.11431775	0.00E+00	2.17E-03	0.00E+00	4.25E-04	0.00E+00

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A 43

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEF CK: MAK SHT: A43 OF A72

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
67	0.10068819	0.00E+00	2.36E-03	0.00E+00	5.53E-04	0.00E+00
68	0.81972627	0.10603208	2.26E-03	2.68E-24	6.54E-04	0.00E+00
69	0.41589777	0.38927616	2.08E-03	1.25E-24	6.79E-04	0.00E+00
70	0.37558566	0.00000000	2.06E-03	0.00E+00	6.68E-04	0.00E+00
71	1.51E-02	6.16E-05	1.81E-03	5.76E-06	5.31E-04	8.83E-05
72	7.67E-03	1.60E-04	1.71E-03	2.44E-05	4.37E-04	1.25E-04
73	3.96E-03	9.31E-05	8.49E-04	2.22E-05	1.12E-04	1.28E-04
74	1.68E-03	1.85E-04	5.64E-04	1.13E-05	7.77E-05	7.26E-05
75	3.67E-04	2.23E-04	3.33E-04	1.33E-05	5.65E-05	3.10E-05
76	8.25E-05	1.13E-04	1.21E-04	1.37E-05	2.87E-05	1.16E-05
77	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
78	3.24E-03	5.17E-05	5.66E-04	1.48E-05	4.82E-05	1.37E-04
79	2.03E-03	1.53E-04	3.26E-04	1.49E-05	1.65E-05	1.15E-04
80	6.11E-04	7.77E-05	1.11E-04	1.30E-05	8.37E-06	7.56E-05
81	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

MAXIMUMS

	UX	UY	UZ	ROTX	ROTY	ROTZ
NODE	65	75	58	72	51	78
VALUE	0.12022342	2.23E-04	2.50E-02	2.44E-05	1.01E-03	1.37E-04

PRINT NODAL FORCES PER ELEMENT

***** POST1 ELEMENT NODE FORCE LISTING *****

CALCULATED LOAD CASE= 3

THE FOLLOWING X,Y,Z FORCES ARE IN GLOBAL COORDINATES

ELEM= 58	FX	FY	FZ	MX	MY	MZ
47	629.56469	3.77E-12	2309.6973	1.10E-10	16879.184	0.00E+00
48	629.56469	3.77E-12	2309.6973	4.32E-12	30407.428	0.00E+00

ELEM= 59	FX	FY	FZ	MX	MY	MZ
48	629.56469	3.77E-12	2309.6973	4.32E-12	30407.428	0.00E+00
49	629.56469	3.77E-12	2309.6973	1.24E-10	50367.703	0.00E+00

ELEM= 60	FX	FY	FZ	MX	MY	MZ
49	641.91086	5.54E-12	2309.6973	1.24E-10	50367.703	0.00E+00
50	641.91086	5.54E-12	2309.6973	1.42E-10	80551.632	0.00E+00

ELEM= 61	FX	FY	FZ	MX	MY	MZ
50	2222.1859	3.04E-12	2309.6973	7.32E-11	80551.632	1.27E-11
51	2222.1859	3.04E-12	2309.6973	8.98E-12	27446.831	1.27E-11

ELEM= 62	FX	FY	FZ	MX	MY	MZ
51	2065.0846	2.46E-13	2311.0231	8.98E-12	27446.831	1.27E-11
52	2065.0846	2.46E-13	2311.0231	6.72E-12	76189.194	1.27E-11

ELEM= 63	FX	FY	FZ	MX	MY	MZ
52	2065.0846	2.46E-13	2311.0231	6.72E-12	76189.194	1.27E-11
53	2065.0846	2.46E-13	2311.0231	9.78E-12	108168.19	1.27E-11

ELEM= 64	FX	FY	FZ	MX	MY	MZ
53	2065.0846	2.46E-13	2311.0231	9.78E-12	108168.19	1.27E-11
54	2065.0846	2.46E-13	2311.0231	9.78E-12	72658.084	1.58E-11

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A44

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HRK CK: MKK SHT: A44 OF A72

ELEM = 65	FX	FY	FZ	MX	MY	MZ
54	1736.4185	8.16E-12	2311.0231	9.78E-12	72658.084	1.58E-11
55	1736.4185	8.16E-12	2311.0231	9.78E-12	18168.012	1.88E-10

ELEM = 66	FX	FY	FZ	MX	MY	MZ
55	1736.4185	5.45E-11	214.62364	0.00E+00	18168.012	1.06E-09
56	1736.4185	5.45E-11	214.62364	0.00E+00	13837.604	9.05E-10

ELEM = 67	FX	FY	FZ	MX	MY	MZ
56	1374.6217	3.54E-11	176.55714	0.00E+00	13837.604	9.05E-10
57	1374.6217	3.54E-11	176.55714	0.00E+00	10981.939	7.92E-10

ELEM = 68	FX	FY	FZ	MX	MY	MZ
57	1374.6217	9.52E-12	205.35757	0.00E+00	10981.939	1.93E-10
58	1374.6217	9.52E-12	205.35757	0.00E+00	12443.691	1.41E-10

ELEM = 69	FX	FY	FZ	MX	MY	MZ
58	1016.6993	4.12E-12	146.06903	0.00E+00	12443.691	1.41E-10
59	1016.6993	4.12E-12	146.06903	0.00E+00	15378.435	1.11E-10

ELEM = 70	FX	FY	FZ	MX	MY	MZ
59	1016.6993	0.00E+00	172.17721	0.00E+00	15378.435	0.00E+00
60	1016.6993	0.00E+00	172.17721	0.00E+00	12547.927	0.00E+00

ELEM = 71	FX	FY	FZ	MX	MY	MZ
60	625.39598	0.00E+00	281.62736	0.00E+00	12547.927	0.00E+00
61	625.39598	0.00E+00	281.62736	0.00E+00	11767.573	0.00E+00

ELEM = 72	FX	FY	FZ	MX	MY	MZ
61	625.39598	3.23E-11	573.62576	0.00E+00	11767.573	6.62E-10
62	625.39598	3.23E-11	573.62576	0.00E+00	6711.8478	3.39E-10

ELEM = 73	FX	FY	FZ	MX	MY	MZ
62	195.90735	3.23E-11	573.62576	0.00E+00	6711.8478	3.39E-10
63	195.90735	3.23E-11	573.62576	0.00E+00	9969.8264	4.68E-10

ELEM = 74	FX	FY	FZ	MX	MY	MZ
63	195.90735	1.30E-11	526.41769	0.00E+00	9969.8264	4.68E-10
64	195.90735	1.30E-11	526.41769	0.00E+00	43003.53	3.62E-10

ELEM = 75	FX	FY	FZ	MX	MY	MZ
64	195.90735	0.00E+00	1187.2699	0.00E+00	43003.53	0.00E+00
65	195.90735	0.00E+00	1187.2699	0.00E+00	31116.58	0.00E+00

ELEM = 76	FX	FY	FZ	MX	MY	MZ
65	195.90735	0.00E+00	1187.2699	0.00E+00	31116.58	0.00E+00
66	195.90735	0.00E+00	1187.2699	0.00E+00	32948.457	0.00E+00

ELEM = 77	FX	FY	FZ	MX	MY	MZ
66	279.69183	0.00E+00	1187.2699	0.00E+00	32948.457	0.00E+00
67	279.69183	0.00E+00	1187.2699	0.00E+00	26155.169	0.00E+00

ELEM = 78	FX	FY	FZ	MX	MY	MZ
67	325.47805	1.63E-16	386.50286	3.08E-15	26155.169	0.00E+00
68	325.47805	1.63E-16	386.50286	1.99E-15	16811.997	0.00E+00

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A45

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEE CK: MAK SHT: A45 OF A72

ELEM =	FX	FY	FZ	MX	MY	MZ
79						
68	452.36641	5.31E-17	386.50286	1.99E-15	16811.997	0.00E+00
69	452.36641	5.31E-17	386.50286	1.15E-15	12203.618	0.00E+00
80						
69	452.36641	5.31E-17	386.50286	1.15E-15	12203.618	0.00E+00
70	452.36641	5.31E-17	386.50286	1.47E-15	14667.582	0.00E+00
81						
70	590.58757	250.6938	714.78632	3657.9701	14667.582	8799.4431
71	590.58757	250.6938	714.78632	5617.7004	33890.789	8799.4431
82						
71	590.58757	250.6938	714.78632	5617.7004	33890.789	8799.4431
72	590.58757	250.6938	714.78632	9503.4542	42701.935	8799.4431
83						
72	590.58757	250.6938	714.78632	9503.4542	42701.935	8799.4431
73	590.58757	250.6938	714.78632	10510.563	42701.935	7737.0088
84						
73	421.91177	796.17077	401.69154	6376.2823	17044.265	21605.378
74	421.91177	796.17077	401.69154	1642.5316	12021.977	16691.26
85						
74	421.91177	796.17077	401.69154	1642.5316	12021.977	16691.26
75	421.91177	796.17077	401.69154	3091.2192	7058.0178	11902.549
86						
75	421.91177	796.17077	401.69154	3091.2192	7058.0178	11902.549
76	421.91177	796.17077	401.69154	2733.3082	7058.0178	6679.5827
87						
76	421.91177	796.17077	401.69154	2733.3082	7058.0178	6679.5827
77	421.91177	796.17077	401.69154	8758.6813	7058.0178	4794.3204
88						
73	991.52639	545.47697	313.09478	4134.2806	25714.614	14108.016
78	991.52639	545.47697	313.09478	1345.6943	13826.228	2843.3456
89						
78	991.52639	545.47697	313.09478	1345.6943	13826.228	2843.3456
79	991.52639	545.47697	313.09478	1442.8919	2056.1255	10013.641
90						
79	991.52639	545.47697	313.09478	1442.8919	2056.1255	10013.641
80	991.52639	545.47697	313.09478	3096.9824	2056.1255	24278.239
91						
80	991.52639	545.47697	313.09478	3096.9824	2056.1255	24278.239
81	991.52639	545.47697	313.09478	7793.4042	2056.1255	39121.516

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A46

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A46 OF A72

PRINT ELEMENT STRESS ITEMS PER ELEMENT

***** POST1 ELEMENT STRESS LISTING *****

CALCULATED LOAD CASE = 3

ELEM	I1	I3	J1	J3
58	1296.7009	470.5046	1947.4484	751.40511
59	1947.4484	751.40511	2821.3711	1607.147
60	2821.3711	1607.147	4132.9243	2936.5516
61	4132.9243	2936.5516	1803.6529	668.45999
62	1804.443	667.0215	3947.6369	2738.2589
63	3947.6369	2738.2589	5347.2278	4136.2512
64	5287.0981	4193.4065	3733.1125	2639.2914
65	3644.6579	2725.5859	1212.1671	504.67662
66	1212.1671	504.67662	1058.5325	267.9545
67	962.15769	309.361	818.76033	281.33938
68	818.76033	281.33938	836.31714	425.99551
69	752.91627	429.07502	796.00596	656.22605
70	796.00596	656.22605	639.94915	592.83051
71	592.6881	558.72703	671.26586	374.24182
72	671.26586	374.24182	436.55131	204.0262
73	325.23839	269.97131	472.49687	404.88317
74	472.49687	404.88317	1918.9168	1849.0027
75	1918.9168	1849.0027	1398.0716	1328.9378
76	1660.0844	1083.0171	1742.0854	1159.4038
77	1742.0854	1159.4038	1442.791	870.03813
78	1050.6289	1242.3821	640.32776	834.90841
79	640.32776	834.90841	437.43739	634.59888
80	437.43739	634.59888	543.0699	743.75336
81	645.83851	933.52859	1544.2393	1768.7146
82	1544.2393	1768.7146	2056.5387	2292.5577
83	717.61051	807.17411	716.60751	805.44821
84	1269.2454	1547.165	820.01742	1095.6493
85	820.01742	1095.6493	572.30174	864.66839
86	516.49834	795.52768	299.82843	577.68101
87	299.82843	577.68101	465.03232	723.49678
88	1464.3409	1266.8882	649.03029	462.31836
89	649.03029	462.31836	446.88201	234.93583
90	601.78213	406.96351	1270.0689	1079.4544
91	1270.0689	1079.4544	2076.9924	1886.8995

MINIMUMS

ELEMENT	87	73	86	72
VALUE	299.82843	269.97131	299.82843	204.0262

MAXIMUMS

ELEMENT	64	64	63	63
VALUE	5287.0981	4193.4065	5347.2278	4136.2512

178 ELEMENTS (OF 178 DEFINED) SELECTED BY EALL COMMAND.

ESEL FOR LABEL = TYPE FROM 1 TO 1 BY 1

91 ELEMENTS (OF 178 DEFINED) SELECTED BY ESEL COMMAND.

ERSE FOR LABEL = REAL FROM 3 TO 3 BY 1

12 ELEMENTS (OF 178 DEFINED) SELECTED BY ERSE COMMAND.

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A47

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HGK CK: MAK SHT: A47 OF A72

13 NODES (OF 108 DEFINED) SELECTED FROM 12 SELECTED ELEMENTS BY NELE COMMAND.

PRINT NODAL DISPLACEMENTS

***** POST1 NODAL DISPLACEMENT LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
82	3.67E-02	0.00E+00	2.00E-03	0.00E+00	0.00E+00	0.00E+00
83	3.67E-02	1.29E-04	2.30E-03	0.00E+00	4.37E-05	8.51E-06
84	3.66E-02	3.04E-04	3.31E-03	0.00E+00	7.51E-05	3.06E-06
85	3.65E-02	0.00E+00	9.98E-03	0.00E+00	1.65E-04	0.00E+00
86	3.64E-02	2.11E-18	1.08E-02	0.00E+00	1.76E-04	6.67E-19
87	3.62E-02	4.17E-17	1.73E-02	0.00E+00	1.71E-04	3.60E-19
88	3.60E-02	0.00E+00	2.25E-02	0.00E+00	2.78E-04	0.00E+00
89	3.60E-02	0.00E+00	2.34E-02	0.00E+00	3.23E-04	0.00E+00
90	3.60E-02	0.00E+00	2.42E-02	0.00E+00	3.62E-04	0.00E+00
91	3.37E-02	0.00E+00	2.42E-02	0.00E+00	4.04E-04	0.00E+00
92	3.17E-02	0.00E+00	2.42E-02	0.00E+00	4.31E-04	0.00E+00
93	2.18E-02	0.00E+00	2.42E-02	0.00E+00	4.51E-04	0.00E+00
94	1.01E-02	0.00E+00	2.43E-02	0.00E+00	0.00E+00	0.00E+00

MAXIMUMS						
NODE	82	84	94	0	93	83
VALUE	3.67E-02	3.04E-04	2.43E-02	0.00E+00	4.51E-04	8.51E-06

PRINT NODAL FORCES PER ELEMENT

***** POST1 ELEMENT NODE FORCE LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z FORCES ARE IN GLOBAL COORDINATES

ELEM = 46	FX	FY	FZ	MX	MY	MZ
82	99.701062	21.29023	36.758819	0.00E+00	1979.9643	578.5136
83	99.701062	21.29023	36.758819	0.00E+00	1403.5346	67.548092

ELEM = 47	FX	FY	FZ	MX	MY	MZ
83	99.701062	21.29023	36.758819	0.00E+00	1403.5346	67.548092
84	99.701062	21.29023	36.758819	0.00E+00	1262.3504	464.70765

ELEM = 48	FX	FY	FZ	MX	MY	MZ
84	99.701062	11.685274	31.848594	0.00E+00	1262.3504	464.70765
85	99.701062	11.685274	31.848594	0.00E+00	2547.6206	388.31735

ELEM = 49	FX	FY	FZ	MX	MY	MZ
85	306.99284	5.28E-12	133.70524	0.00E+00	2547.6206	1.17E-10
86	306.99284	5.28E-12	133.70524	0.00E+00	1859.3944	8.54E-11

ELEM = 50	FX	FY	FZ	MX	MY	MZ
86	306.99284	5.28E-12	133.70524	0.00E+00	1859.3944	8.54E-11
87	306.99284	5.28E-12	133.70524	0.00E+00	4144.9785	1.31E-10

ELEM = 51	FX	FY	FZ	MX	MY	MZ
87	306.99284	7.56E-12	121.93856	0.00E+00	4144.9785	1.31E-10
88	306.99284	7.56E-12	121.93856	0.00E+00	8585.1278	1.49E-10

ELEM = 52	FX	FY	FZ	MX	MY	MZ
88	306.99284	0.00E+00	129.56199	0.00E+00	8585.1278	0.00E+00
89	306.99284	0.00E+00	129.56199	0.00E+00	8565.307	0.00E+00

ELEM = 53	FX	FY	FZ	MX	MY	MZ
89	306.99284	0.00E+00	129.56199	0.00E+00	8565.307	0.00E+00
90	306.99284	0.00E+00	129.56199	0.00E+00	8602.584	0.00E+00

ELEM = 54	FX	FY	FZ	MX	MY	MZ
90	306.99284	0.00E+00	129.56199	0.00E+00	8602.584	0.00E+00
91	306.99284	0.00E+00	129.56199	0.00E+00	6836.2517	0.00E+00

ELEM = 55	FX	FY	FZ	MX	MY	MZ
91	306.99284	0.00E+00	129.56199	0.00E+00	6836.2517	0.00E+00
92	306.99284	0.00E+00	129.56199	0.00E+00	5403.0266	0.00E+00

ELEM = 56	FX	FY	FZ	MX	MY	MZ
92	340.20387	0.00E+00	129.56199	0.00E+00	5403.0266	0.00E+00
93	340.20387	0.00E+00	129.56199	0.00E+00	3086.1205	0.00E+00

ELEM = 57	FX	FY	FZ	MX	MY	MZ
93	344.17875	0.00E+00	129.56199	0.00E+00	3086.1205	0.00E+00
94	344.17875	0.00E+00	129.56199	0.00E+00	16928.908	0.00E+00

PRINT ELEMENT STRESS ITEMS PER ELEMENT

***** POST1 ELEMENT STRESS LISTING *****

CALCULATED LOAD CASE = 3

ELEM	I1	I3	J1	J3
46	346.70996	319.7032	235.97817	223.42838
47	235.97817	223.42838	225.25615	217.00381
48	225.25615	217.00381	436.97264	389.21583
49	506.51011	352.49813	382.54184	284.00442
50	382.54184	284.00442	810.40529	515.93222
51	810.40529	515.93222	1511.4992	1226.6769
52	1511.4992	1226.6769	1503.7644	1229.1542
53	1503.7644	1229.1542	1505.2862	1240.4413
54	1340.7746	1401.5847	1058.373	1122.0699
55	1058.373	1122.0699	828.84399	895.90196
56	828.84399	895.90196	472.56883	518.52637
57	472.56883	518.52637	2676.357	2716.5718

MINIMUMS

ELEMENT	48	48	47	47
VALUE	225.25615	217.00381	225.25615	217.00381

MAXIMUMS

ELEMENT	52	54	57	57
VALUE	1511.4992	1401.5847	2676.357	2716.5718

***** END OF INPUT ENCOUNTERED ON FILE38. FILE38 REWOUND

***** INPUT FILE SWITCHED FROM FILE38 TO FILE 5

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A 49

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A49 OF A72

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/PREP7
/OUT,OUTN1D2,DBE
/TITLE,DBE FOR HVAC SYSTEM 4316-1
C****
C****RE-ANALYZE SYSTEM 4316-1 BASED ON BARE SHEET METAL THICKNESS
C****USE DESIGN BASIC EARTHQUAKE WITH 1% DAMPING
C****DATE: 4-25-94
C****
KAN,2
KAY,2,90
ET,1,4
,2,14,,1
,3,14,,3
,4,21,,,2
EX,1,29.E6
NUXY,1,0.29
DENS,1,0.00125
N,1,196.,,-26.
,2,196.,,4.
,3,196.,,42.
,4,196.,,84.
,5,196.,,90.
,6,196.,,114.
,7,196.,,151.
,8,182.,,151.
,9,124.,,151.
,10,98.,,151.
,11,65.,,151.
,12,41.,,151.
,13,6.0,,151.
,14,2.,,151.
,15,-12.,,151.
,16,-84.,,151.
,17,-94.,,151.
,18,-118.,,151.
,19,-169.,,151.
,20,-193.,,151.
,21,-220.,,151.
,22,-230.,,151.
,23,-230.,,164.
,24,-230.,,217.
,25,-230.,,265.
,26,-230.,,313.
,27,-230.,,352.
,28,-230.,,391.
,29,-230.,,430.
,30,-230.,,469.
,31,-230.,,502.
,32,-230.,-18.5,520.5
,33,-230.,-37.,539.
,34,-230.,-37.,565.
,35,-204.,-37.,565.
,36,-204.,-65.,565.
,37,-204.,-84.,565.
,38,-30.,,133.
,39,-48.,,115.
,40,-84.,,115.
,41,-94.,,115.
,42,-118.,,115.
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HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A50

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A50 OF A72

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,43,-151.,,133.
,44,-133.,,115.
,45,-123.,,115.
,47,222.5,-2.5,-26.
,48,222.5,-2.5,2.
,49,222.5,-2.5,36.
,50,222.5,-2.5,84.
,51,222.5,-2.5,108.
,52,222.5,-2.5,158.
,53,222.5,-2.5,173.5
,54,207.,-2.5,173.5
,55,182.,-2.5,173.5
,56,146.,-2.5,173.5
,57,98.,-2.5,173.5
,58,63.0,-2.5,173.5
,59,2.,-2.5,173.5
,60,-21.,-2.5,173.5
,61,-94.,-2.5,173.5
,62,-104.,-2.5,173.5
,63,-129.,-2.5,173.5
,64,-193.,-2.5,173.5
,65,-204.,-2.5,173.5
,66,-204.,-2.5,189.
,67,-204.,-2.5,217.
,68,-204.,-2.5,248.
,69,-204.,-2.5,307.
,70,-204.,-2.5,313.
,71,-204.,-2.5,350.
,72,-204.,-2.5,365.5
,73,-204.,-30.5,365.5
,74,-204.,-42.5,377.5
,75,-204.,-54.5,389.5
,76,-204.,-69.,389.5
,77,-204.,-84.,389.5
,78,-204.,-42.5,353.5
,79,-204.,-54.5,341.5
,80,-204.,-69.,341.5
,81,-204.,-84.,341.5
,82,304.,15.,195.
,83,280.,15.,195.
,84,255.,15.,195.
,85,182.,15.,195.
,86,176.,15.,195.
,87,135.,15.,195.
,88,98.,15.,195.
,89,92.,15.,195.
,90,87.,15.,195.
,91,87.,15.,189.
,92,87.,15.,184.
,93,87.,15.,162.
,94,87.,15.,120.
,104,184.,,84.
,108,182.,,139.
,110,98.,,139.
,114,2.,,139.
,141,-94.,,103.
,120,-193.,,139.
,124,-242.,,217.
,126,-242.,,313.
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HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A51

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HCE CK: [illegible] SHT: A51 OF A72

```
,128,-242.,,391.
,130,-242.,,469.
,182,304.,15.,207.
,192,75.,15.,184.
,194,87.,15.,132.
,282,316.,15.,195.
,[illegible],99.,15.,120.
C****MATERIAL PROPERTIES FOR GALVANIZED SHEET METAL:
C****R,1,2.89,94.4,94.4,14.,14.
C****RMORE,,141.6
C****R,2,3.92,235.9,235.9,19.,19.
C****RMORE,,353.9
C****R,3,2.06,34.4,34.4,10.,10.
C****RMORE,,51.6
R,1,2.68,86.6,86.6,14.0,14.0
RMORE,,131.2
R,2,3.63,216.9,216.9,19.0,19.0
RMORE,,327.9
R,3,1.91,31.4,31.4,10.0,10.0
RMORE,,47.8
R,4,.071
,5,.056
,6,.113
,7,.106
,8,.128
,9,.015
,10,.117
,11,.097
,12,.174
,13,.077
,14,.23
,15,.153
,16,.04
,17,.3
,18,.217
,19,.181
,20,.2
,21,.166
,22,.258
,23,.171
,24,91550.
,25,57735.
,26,31455.
,27,957.
,28,73800.
,29,35000.
,30,86088.
,31,4880.
,32,2000.
,33,3150.
,34,740.
,35,470.
,36,32260.
,37,37040.
E,1,2
EGEN,36,1,-1
E,15,38
,38,39
,39,40
```

```
,40,41
,41,42
,42,45
,45,44
,44,43
,43,19
REAL,3
E,82,83
EGEN,12,1,-1
REAL,2
E,47,48
EGEN,30,1,-1
E,73,78
,78,79
,79,80
,80,81
TYPE,4
REAL,4
E,2
,3
,9
,11
,13
,18
,21
,23
,27
REAL,5
E,5
,15
,45
REAL,6
E,7
,19
,31
,33
,35
,38
,43
REAL,7
E,16
,40
REAL,8
E,25
,29
REAL,9
E,36
REAL,10
E,48
,58
REAL,11
E,49
,54
,62
,63
,66
,68
,71
REAL,12
```

```
E,51
,56
,60
REAL,13
E,52
,69
REAL,14
E,73
REAL,15
E,75
,76
,79
,80
REAL,16
E,84
,86
,87
,89
,91
,93
REAL,17
E,4
,50
REAL,18
E,8
,55
,85
,94
REAL,19
E,10
,20
,57
,64
REAL,20
E,28
,30
,14
,59
,82
REAL,21
E,17
,41
,61
,92
REAL,22
E,24
,67
REAL,23
E,26
,70
TYPE,2
REAL,24
E,4,104
REAL,30
E,24,124
REAL,31
E,26,126
REAL,32
E,28,128
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HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A54

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEE CK: MAK SHT: A54 OF A72

```
,30,130
REAL,33
E,92,192
REAL,34
E,82,282
REAL,37
E,94,294
TYPE,3
REAL,25
E,8,108
REAL,26
E,10,110
REAL,27
E,14,114
REAL,28
E,41,141
REAL,29
E,20,120
REAL,36
E,82,182
REAL,35
E,94,194
WSTART,1
,47
,82
WAVES
D,104,ALL,,,124,10
,110,ALL,,,130,10
,108,ALL,,,128,20
,126,ALL,,,141,15
,182,ALL,,,192,10
,194,ALL
,282,ALL
,294,ALL
,24,UY,,,30,2,ROTX,ROTZ
,55,UY,,,61,2,ROTX,ROTZ
,82,UY,,,88,3,ROTX,ROTZ
,8,UY,,,20,6,ROTX,ROTZ
,4,UY,,,10,6,ROTX,ROTZ
,17,UY,,,41,24,ROTX,ROTZ
,50,UY,,,70,20,ROTX,ROTZ
,64,UY,,,67,3,ROTX,ROTZ
,92,UY,,,94,2,ROTX,ROTZ
,82,ROTY,,,94,12
,1,ALL,,,47,46
,37,ALL
,77,ALL,,,81,4
CP,1,UZ,8,55,85
,2,UZ,10,57,88
,3,UX,4,50
,4,UZ,14,59
,5,UZ,17,41,61
,6,UZ,20,64
,7,UZ,24,67
,8,UZ,26,70
TOTAL,90,1
MLIST
ITER,1,1,1
PRDISP,-1
```

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A56

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A55 OF A72

```
PRNF,-1
PRRF,-1
PRSTR,-1
SVTYPE,2
SED,1.0,0.0,0.0    *E-W DIRECTION
FREQ,1.0,1.25,1.7,2.5,3.3,3.8,4.4,5.9,6.7
FREQ,7.5,8.7,10.0,11.1,16.7,20.0,25.0,500.0
SV,0.01,77.2,104.2,166.0,270.2,463.2,675.5,1351.0,1351.0,733.4
SV,0.01,540.4,386.0,289.5,289.5,289.5,185.3,142.8,142.8
LWRITE
SED,0.0,1.0,0.0    *VERTICAL DIRECTION
FREQ
FREQ,1.67,2.5,3.3,4.0,5.0,5.5,6.67,8.3,9.1
FREQ,10.0,10.5,10.9,14.7,16.7,20.0,25.0,50.0,500.0
SV,0.01,40.5,61.8,84.9,108.1,146.7,169.8,169.8,366.7,501.8
SV,0.01,772.0,1042.2,1389.6,1389.6,849.2,463.2,270.2,100.4,100.4
LWRITE
SED,0.0,0.0,1.0    *N-S DIRECTION
FREQ
FREQ,1.0,1.4,2.0,2.5,3.3,4.3,5.5,6.7,7.7
FREQ,9.1,10.0,11.1,16.1,20.0,33.0,50.0,500.0
SV,0.01,77.2,115.8,204.6,281.8,463.2,1659.8,1659.8,579.0,405.3
SV,0.01,289.5,270.2,254.8,254.8,154.4,123.5,119.7,119.7
LWRITE
AFWRITE
FINISH
/OUT,OUTN1D2,ANS
/INP,27
```

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A56

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A56 OF A72

```
C****
C****POST-PROCESSING FILE SYSTEM 4316-1 (DBE)
C****
STRESS,I1,4,19
STRESS,I3,4,20
STRESS,J1,4,21
STRESS,J3,4,22
LCLIM,3
LCASE,1
SET,1,1
LCASE,2
SET,1,2
LCSRSS,3,1,2
LCASE,2
SET,1,3
LCSRSS,3,2,3
LCASE,2
SET,1,4
LCSRSS,3,2,3
LCASE,2
SET,1,5
LCSRSS,3,2,3
LCASE,2
SET,1,6
LCSRSS,3,2,3
LCASE,2
SET,1,7
LCSRSS,3,2,3
LCASE,2
SET,1,8
LCSRSS,3,2,3
LCASE,2
SET,1,9
LCSRSS,3,2,3
LCASE,2
SET,1,10
LCSRSS,3,2,3
LCASE,2
SET,1,11
LCSRSS,3,2,3
LCASE,2
SET,1,12
LCSRSS,3,2,3
LCASE,2
SET,1,13
LCSRSS,3,2,3
LCASE,2
SET,2,18
LCSRSS,3,2,3
LCASE,2
SET,2,24
LCSRSS,3,2,3
LCASE,2
SET,2,25
LCSRSS,3,2,3
LCASE,2
SET,3,1
LCSRSS,3,2,3
LCASE,2
```

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A57

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 436-1 BY: HEK CK: MAK SHT: A57 OF A72

```
SET,3,2
LCSRSS,3,2,3
LCASE,2
SET,3,3
LCSRSS,3,2,3
LCASE,2
SET,3,4
LCSRSS,3,2,3
LCASE,2
SET,3,5
LCSRSS,3,2,3
LCASE,2
SET,3,6
LCSRSS,3,2,3
LCASE,2
SET,3,7
LCSRSS,3,2,3
LCASE,2
SET,3,8
LCSRSS,3,2,3
LCASE,2
SET,3,9
LCSRSS,3,2,3
LCASE,2
SET,3,10
LCSRSS,3,2,3
LCASE,2
SET,3,11
LCSRSS,3,2,3
LCASE,2
SET,3,12
LCSRSS,3,2,3
LCASE,2
SET,3,13
LCSRSS,3,2,3
LCASE,2
SET,3,19
LCSRSS,3,2,3
LCASE,2
SET,3,20
LCSRSS,3,2,3
LCASE,3
ESEL,TYPE,1
ERSEL,REAL,1
NELEM
PRDISP
PREFOR
PRSTRS,I1,I3,J1,J3
EALL
ESEL,TYPE,1
ERSEL,REAL,2
NELEM
PRDISP
PREFOR
PRSTRS,I1,I3,J1,J3
EALL
ESEL,TYPE,1
ERSEL,REAL,3
NELEM
```

PRDISP
PREFOR
PRSTRS,I1,I3,J1,J3

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A59

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A59 OF A72

***** EIGENVALUE (NATURAL FREQUENCY) SOLUTION *****

MODE	FREQUENCY (CYCLES/TIME)
1	10.7695426
2	15.1177832
3	15.3198123
4	17.0026697
5	20.9726790
6	33.2040876
7	38.4820832
8	42.7501592
9	46.3968674
10	49.8360342
11	57.4085106
12	62.5323514
13	67.4258425
14	73.5391224
15	77.7194027
16	94.4166889
17	96.8474360
18	100.193515
19	103.959923
20	109.827858
21	117.908533
22	125.812873
23	129.000925
24	131.653735
25	131.653765
26	141.530581
27	148.659846
28	156.759910
29	159.374828
30	165.305014
31	174.021746
32	177.438660
33	179.906185
34	180.402718
35	184.503323
36	190.152778
37	192.409454
38	196.087267
39	196.963765
40	205.927181
41	209.731960
42	210.643335
43	220.306140
44	232.944272
45	233.656787
46	240.790530
47	246.065899
48	256.029051
49	262.407669
50	271.648106
51	273.355190
52	284.101987
53	290.099916
54	301.867852

55	306.761172
56	309.646233
57	311.770890
58	323.230341
59	333.279760
60	334.280432
61	339.994843
62	343.111751
63	359.850875
64	362.807178
65	368.421677
66	368.749603
67	383.813871
68	384.443363
69	386.430062
70	399.224644
71	403.377980
72	408.013764
73	419.355707
74	419.907105
75	423.997270
76	438.531399
77	440.938242
78	444.542627
79	446.685301
80	447.364978
81	473.197421
82	496.514332
83	502.596206
84	520.995600
85	529.055039
86	556.358411
87	569.244922
88	594.840871
89	613.332875
90	658.328138

PRINT NODAL DISPLACEMENTS

***** POST1 NODAL DISPLACEMENT LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	2.01E-03	3.37E-17	3.76E-04	1.70E-18	1.27E-04	0.00E+00
3	9.12E-03	6.56E-17	8.51E-04	8.96E-19	2.45E-04	0.00E+00
4	2.15E-02	0.00E+00	1.38E-03	0.00E+00	3.75E-04	0.00E+00
5	2.36E-02	0.00E+00	1.45E-03	0.00E+00	3.96E-04	0.00E+00
6	3.31E-02	0.00E+00	1.75E-03	0.00E+00	4.35E-04	0.00E+00
7	4.77E-02	0.00E+00	2.21E-03	0.00E+00	3.59E-04	0.00E+00
8	4.77E-02	0.00E+00	6.34E-03	0.00E+00	2.84E-04	0.00E+00
9	4.78E-02	7.33E-18	1.40E-02	0.00E+00	9.04E-05	2.33E-19
10	4.79E-02	0.00E+00	1.48E-02	0.00E+00	9.10E-05	0.00E+00
11	4.78E-02	1.53E-17	1.60E-02	0.00E+00	7.15E-05	3.32E-19
12	4.78E-02	1.34E-17	1.67E-02	0.00E+00	4.73E-05	3.74E-19
13	4.78E-02	2.57E-19	1.67E-02	0.00E+00	3.44E-05	1.25E-19
14	4.78E-02	0.00E+00	1.66E-02	0.00E+00	3.88E-05	0.00E+00
15	4.78E-02	5.55E-18	1.59E-02	1.49E-18	5.90E-05	6.18E-19
16	4.75E-02	8.90E-19	1.01E-02	1.82E-19	1.00E-04	1.67E-19
17	4.75E-02	0.00E+00	9.14E-03	0.00E+00	9.91E-05	0.00E+00
18	4.73E-02	1.05E-17	6.95E-03	1.92E-19	9.24E-05	4.14E-19
19	4.70E-02	3.63E-18	2.96E-03	6.00E-19	7.41E-05	2.39E-19
20	4.68E-02	0.00E+00	1.96E-03	0.00E+00	3.70E-05	0.00E+00
21	4.66E-02	2.09E-18	1.26E-03	1.19E-20	1.41E-04	1.25E-19
22	4.65E-02	3.36E-18	2.33E-03	1.64E-20	2.70E-04	1.26E-19
23	4.18E-02	3.04E-18	2.18E-03	4.04E-20	4.41E-04	1.01E-19
24	1.15E-02	0.00E+00	1.60E-03	0.00E+00	5.73E-04	0.00E+00
25	1.43E-02	2.99E-21	1.51E-03	0.00E+00	3.58E-04	0.00E+00
26	2.83E-02	0.00E+00	1.43E-03	0.00E+00	2.45E-04	0.00E+00
27	3.57E-02	1.61E-17	1.48E-03	0.00E+00	1.64E-04	0.00E+00
28	3.86E-02	0.00E+00	1.55E-03	0.00E+00	8.66E-05	0.00E+00
29	3.64E-02	1.99E-17	1.61E-03	0.00E+00	1.42E-04	0.00E+00
30	2.93E-02	0.00E+00	1.67E-03	0.00E+00	2.38E-04	0.00E+00
31	2.08E-02	4.94E-04	1.72E-03	1.73E-05	2.80E-04	8.26E-05
32	1.39E-02	7.76E-04	1.62E-03	1.09E-05	2.72E-04	1.11E-04
33	7.21E-03	1.03E-03	1.50E-03	1.45E-05	2.32E-04	1.06E-04
34	2.10E-03	1.36E-03	1.54E-03	9.58E-06	1.60E-04	6.14E-05
35	2.04E-03	1.06E-04	2.29E-03	5.80E-05	9.56E-05	5.72E-05
36	4.68E-04	4.28E-05	5.56E-04	5.21E-05	3.86E-05	4.44E-05
37	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
38	4.85E-02	5.33E-17	1.47E-02	2.30E-18	7.50E-05	6.01E-20
39	4.94E-02	7.44E-17	1.33E-02	1.92E-18	8.91E-05	1.78E-18
40	4.94E-02	5.99E-18	1.00E-02	4.17E-19	9.62E-05	1.13E-18
41	4.94E-02	0.00E+00	9.14E-03	0.00E+00	9.34E-05	0.00E+00
42	4.94E-02	1.03E-17	7.08E-03	4.60E-19	8.93E-05	6.90E-19
43	4.82E-02	1.31E-17	4.29E-03	8.67E-19	9.05E-05	1.57E-19
44	4.93E-02	2.05E-17	5.81E-03	7.47E-19	9.07E-05	6.07E-19
45	4.94E-02	1.38E-17	6.66E-03	5.55E-19	8.95E-05	7.07E-19

MAXIMUMS

	UX	UY	UZ	ROTX	ROTY	ROTZ
NODE	41	34	12	35	24	32
VALUE	4.94E-02	1.36E-03	1.67E-02	5.80E-05	5.73E-04	1.11E-04

PRINT NODAL FORCES PER ELEMENT

***** POST1 ELEMENT NODE FORCE LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z FORCES ARE IN GLOBAL COORDINATES

ELEM	NODE	FX	FY	FZ	MX	MY	MZ
1	1	177.6496	9.21E-12	972.97794	2.80E-10	12474.129	0.00E+00
	2	177.6496	9.21E-12	972.97794	3.74E-12	9295.6462	0.00E+00
2	2	174.98792	9.21E-12	972.97794	3.74E-12	9295.6462	0.00E+00
	3	174.98792	9.21E-12	972.97794	3.46E-10	8950.4645	0.00E+00
3	3	167.17893	1.90E-11	972.97794	3.46E-10	8950.4645	0.00E+00
	4	167.17893	1.90E-11	972.97794	4.53E-10	13200.662	0.00E+00
4	4	425.0251	0.00E+00	965.319	0.00E+00	13200.662	0.00E+00
	5	425.0251	0.00E+00	965.319	0.00E+00	10707.853	0.00E+00
5	5	425.0251	0.00E+00	965.319	0.00E+00	10707.853	0.00E+00
	6	425.0251	0.00E+00	965.319	0.00E+00	2515.159	0.00E+00
6	6	405.3462	0.00E+00	965.319	0.00E+00	2515.159	0.00E+00
	7	405.3462	0.00E+00	965.319	0.00E+00	14966.779	0.00E+00
7	7	405.3462	0.00E+00	965.319	0.00E+00	14966.779	0.00E+00
	8	405.3462	0.00E+00	965.319	0.00E+00	19211.523	0.00E+00
8	8	293.37556	2.18E-12	245.53362	0.00E+00	19211.523	5.30E-11
	9	293.37556	2.18E-12	245.53362	0.00E+00	5258.4406	7.32E-11
9	9	293.37556	7.37E-12	256.6755	0.00E+00	5258.4406	7.32E-11
	10	293.37556	7.37E-12	256.6755	0.00E+00	2228.714	1.18E-10
10	10	228.5476	8.27E-12	85.115031	0.00E+00	2228.714	1.62E-10
	11	228.5476	8.27E-12	85.115031	0.00E+00	2862.7668	1.11E-10
11	11	228.5476	3.11E-12	49.924635	0.00E+00	2862.7668	1.11E-10
	12	228.5476	3.11E-12	49.924635	0.00E+00	3408.9152	3.66E-11
12	12	228.5476	3.11E-12	49.924635	0.00E+00	3408.9152	3.66E-11
	13	228.5476	3.11E-12	49.924635	0.00E+00	4665.0655	7.23E-11

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A63

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 436-1 BY: HEK CK: MAK SHT: A63 OF A72

ELEM = 13	FX	FY	FZ	MX	MY	MZ
13	228.5476	3.11E-12	49.924635	0.00E+00	4665.0655	7.23E-11
14	228.5476	3.11E-12	49.924635	0.00E+00	4828.122	8.47E-11
ELEM = 14	FX	FY	FZ	MX	MY	MZ
14	256.8026	1.34E-11	70.203577	1.57E-10	4828.122	2.05E-10
15	256.8026	1.34E-11	70.203577	1.57E-10	4658.3189	1.73E-11
ELEM = 15	FX	FY	FZ	MX	MY	MZ
15	331.69172	1.69E-12	37.778619	2.68E-11	2800.8364	8.82E-11
16	331.69172	1.69E-12	37.778619	2.68E-11	955.78651	3.34E-11
ELEM = 16	FX	FY	FZ	MX	MY	MZ
16	466.70158	1.69E-12	173.00155	2.68E-11	955.78651	3.34E-11
17	466.70158	1.69E-12	173.00155	2.68E-11	1645.827	5.03E-11
ELEM = 17	FX	FY	FZ	MX	MY	MZ
17	466.70158	1.22E-11	41.187573	1.18E-11	1645.827	1.90E-10
18	466.70158	1.22E-11	41.187573	1.18E-11	929.91706	1.04E-10
ELEM = 18	FX	FY	FZ	MX	MY	MZ
18	466.70158	2.92E-12	22.271312	1.18E-11	929.91706	1.04E-10
19	466.70158	2.92E-12	22.271312	1.18E-11	1507.8809	4.84E-11
ELEM = 19	FX	FY	FZ	MX	MY	MZ
19	648.74396	2.04E-12	78.332428	3.68E-11	4521.4986	1.76E-11
20	648.74396	2.04E-12	78.332428	3.68E-11	4596.1608	4.63E-11
ELEM = 20	FX	FY	FZ	MX	MY	MZ
20	791.04433	6.14E-13	1132.6703	6.53E-13	4596.1608	1.99E-11
21	791.04433	6.14E-13	1132.6703	6.53E-13	26866.811	3.33E-12
ELEM = 21	FX	FY	FZ	MX	MY	MZ
21	791.04433	6.14E-13	1132.6703	6.53E-13	26866.811	3.33E-12
22	791.04433	6.14E-13	1132.6703	6.53E-13	38157.999	2.81E-12
ELEM = 22	FX	FY	FZ	MX	MY	MZ
22	791.04433	6.14E-13	1132.6703	6.53E-13	38157.999	2.81E-12
23	791.04433	6.14E-13	1132.6703	8.64E-12	28024.612	2.81E-12
ELEM = 23	FX	FY	FZ	MX	MY	MZ
23	846.33494	3.98E-13	1133.084	8.64E-12	28024.612	2.81E-12
24	846.33494	3.98E-13	1133.084	1.25E-11	18286.917	2.81E-12
ELEM = 24	FX	FY	FZ	MX	MY	MZ
24	149.72352	8.14E-16	181.3334	1.95E-14	18286.917	0.00E+00
25	149.72352	8.14E-16	181.3334	1.95E-14	12355.687	0.00E+00
ELEM = 25	FX	FY	FZ	MX	MY	MZ
25	131.53815	8.14E-16	181.3334	1.95E-14	12355.687	0.00E+00
26	131.53815	8.14E-16	181.3334	1.95E-14	7380.4672	0.00E+00
ELEM = 26	FX	FY	FZ	MX	MY	MZ
26	126.54918	8.18E-12	282.31184	1.60E-10	7380.4672	0.00E+00
27	126.54918	8.18E-12	282.31184	1.60E-10	8371.9273	0.00E+00
ELEM = 27	FX	FY	FZ	MX	MY	MZ
27	82.604001	8.18E-12	282.31184	1.60E-10	8371.9273	0.00E+00
28	82.604001	8.18E-12	282.31184	1.60E-10	9199.0733	0.00E+00

ELEM =	FX	FY	FZ	MX	MY	MZ
ELEM = 28	FX	FY	FZ	MX	MY	MZ
28	44.036136	1.01E-11	271.17205	1.97E-10	9199.0733	0.00E+00
29	44.036136	1.01E-11	271.17205	1.97E-10	9177.6427	0.00E+00
ELEM = 29	FX	FY	FZ	MX	MY	MZ
29	94.407091	1.01E-11	271.17205	1.97E-10	9177.6427	0.00E+00
30	94.407091	1.01E-11	271.17205	1.97E-10	5942.5418	0.00E+00
ELEM = 30	FX	FY	FZ	MX	MY	MZ
30	122.46022	181.54334	264.02481	4251.4107	5942.5418	3690.8626
31	122.46022	181.54334	264.02481	1828.9303	2498.9382	3690.8626
ELEM = 31	FX	FY	FZ	MX	MY	MZ
31	171.17729	179.78652	264.02481	1828.9303	2498.9382	3690.8626
32	171.17729	179.78652	264.02481	325.87613	2154.5876	655.95647
ELEM = 32	FX	FY	FZ	MX	MY	MZ
32	171.17729	179.78652	264.02481	325.87613	2154.5876	655.95647
33	171.17729	179.78652	264.02481	1384.3651	4805.9124	2700.9408
ELEM = 33	FX	FY	FZ	MX	MY	MZ
33	196.08295	176.85768	265.0039	1384.3651	4805.9124	2700.9408
34	196.08295	176.85768	265.0039	3285.5131	9682.4731	2700.9408
ELEM = 34	FX	FY	FZ	MX	MY	MZ
34	196.08295	175.11	265.0039	3285.5131	9682.4731	2700.9408
35	196.08295	175.11	265.0039	3285.5131	2999.75	1885.5928
ELEM = 35	FX	FY	FZ	MX	MY	MZ
35	203.24552	175.11	270.68727	3285.5131	2999.75	1885.5928
36	203.24552	175.11	270.68727	4312.403	2999.75	3958.1083
ELEM = 36	FX	FY	FZ	MX	MY	MZ
36	203.24552	175.11	270.68727	4312.403	2999.75	3958.1083
37	203.24552	175.11	270.68727	9451.07	2999.75	7795.7433
ELEM = 37	FX	FY	FZ	MX	MY	MZ
15	148.15549	1.51E-11	53.537382	1.84E-10	2369.01	1.05E-10
38	148.15549	1.51E-11	53.537382	9.68E-11	1758.2709	1.66E-10
ELEM = 38	FX	FY	FZ	MX	MY	MZ
38	96.520912	3.90E-12	53.537382	9.68E-11	1758.2709	1.66E-10
39	96.520912	3.90E-12	53.537382	6.14E-11	1814.9621	1.42E-10
ELEM = 39	FX	FY	FZ	MX	MY	MZ
39	96.520912	1.04E-11	71.018925	6.14E-11	1814.9621	1.42E-10
40	96.520912	1.04E-11	71.018925	6.14E-11	948.00949	2.32E-10
ELEM = 40	FX	FY	FZ	MX	MY	MZ
40	96.520912	1.04E-11	71.018925	6.14E-11	948.00949	2.32E-10
41	96.520912	1.04E-11	71.018925	6.14E-11	1597.9484	3.35E-10
ELEM = 41	FX	FY	FZ	MX	MY	MZ
41	137.49955	4.42E-12	54.70529	2.82E-11	1597.9484	1.25E-10
42	137.49955	4.42E-12	54.70529	2.82E-11	1269.7585	1.92E-11
ELEM = 42	FX	FY	FZ	MX	MY	MZ

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A 65

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEF CK: MAK SHT: A65 OF A72

42	137.49955	4.42E-12	53.852385	2.82E-11	1269.7585	1.92E-11
45	137.49955	4.42E-12	53.852385	2.82E-11	1380.2224	3.35E-12

ELEM = 43	FX	FY	FZ	MX	MY	MZ
45	137.49955	4.42E-12	53.852385	2.82E-11	1380.2224	3.35E-12
44	137.49955	4.42E-12	53.852385	2.82E-11	1710.4035	4.72E-11

ELEM = 44	FX	FY	FZ	MX	MY	MZ
44	137.49955	1.32E-12	53.852385	2.82E-11	1710.4035	4.72E-11
43	137.49955	1.32E-12	53.852385	1.48E-11	890.2608	3.40E-11

ELEM = 45	FX	FY	FZ	MX	MY	MZ
43	218.89612	3.26E-12	53.852385	1.48E-11	890.2608	3.40E-11
19	218.89612	3.26E-12	53.852385	4.86E-11	3328.427	3.14E-11

PRINT ELEMENT STRESS ITEMS PER ELEMENT

***** POST1 ELEMENT STRESS LISTING *****

CALCULATED LOAD CASE = 3

ELEM	I1	I3	J1	J3
1	769.4838	1305.6994	494.48547	1071.5602
2	494.48547	1071.5602	544.01872	1007.2235
3	544.01872	1007.2235	994.18993	1245.9121
4	993.9788	1244.4208	804.26237	1054.0058
5	804.26237	1054.0058	425.11758	401.7697
6	425.11758	401.7697	1175.1587	1343.7427
7	1248.0327	1189.6764	1613.1067	1505.5236
8	1570.7816	1542.5868	443.47329	434.31362
9	443.47329	434.31362	233.20559	185.71476
10	201.20287	197.40952	278.18824	210.35585
11	278.18824	210.35585	306.54765	269.12134
12	306.54765	269.12134	389.0771	384.12031
13	389.0771	384.12031	400.59056	398.35163
14	389.17559	414.14713	367.26703	408.70655
15	249.29157	266.4572	81.618645	189.5038
16	125.11799	238.60865	178.92726	253.04652
17	178.92726	253.04652	175.25924	203.06488
18	175.25924	203.06488	163.13179	252.4889
19	301.26647	541.83293	279.1655	561.5217
20	286.11464	606.98405	1934.6833	2421.4981
21	1934.6833	2421.4981	2845.98	3331.8548
22	2725.5451	3457.6383	1902.4675	2645.893
23	1903.1428	2645.4566	1245.794	1781.9658
24	1431.0802	1526.7821	944.76294	1054.2736
25	944.76294	1054.2736	538.52306	656.46718
26	543.86744	661.9678	590.28338	767.88291
27	590.28338	767.88291	650.72467	839.37792
28	651.55495	837.70946	651.84744	834.40376
29	651.84744	834.40376	399.16872	567.98006
30	727.52786	901.29193	250.82662	427.79147
31	360.81038	561.88101	127.53463	239.01487
32	127.53463	239.01487	429.65556	647.38406
33	408.73368	590.80932	955.8612	1139.4471
34	935.03692	1067.6485	324.88902	457.40465
35	356.10006	477.83284	586.24411	705.66303
36	586.24411	705.66303	1303.1527	1423.4088

37	217.02744	177.69277	165.26869	135.73104
38	154.37734	140.27259	153.1934	150.62412
39	152.04177	150.07586	85.074384	84.264688
40	85.074384	84.264688	134.29844	133.88436
41	134.80996	143.03056	93.281231	132.78415
42	93.281231	132.78415	107.19835	136.62623
43	107.19835	136.62623	132.60103	160.966
44	135.16152	157.88278	86.839608	88.219933
45	98.366389	101.22378	250.6273	302.85544

MINIMUMS				
ELEMENT	40	40	15	39
VALUE	85.074384	84.264688	81.618645	84.264688

MAXIMUMS				
ELEMENT	22	22	21	21
VALUE	2725.5451	3457.6383	2845.98	3331.8548

178 ELEMENTS (OF 178 DEFINED) SELECTED BY EALL COMMAND.

ESEL FOR LABEL = TYPE FROM 1 TO 1 BY 1

91 ELEMENTS (OF 178 DEFINED) SELECTED BY ESEL COMMAND.

ERSE FOR LABEL = REAL FROM 2 TO 2 BY 1

34 ELEMENTS (OF 178 DEFINED) SELECTED BY ERSE COMMAND.

35 NODES (OF 108 DEFINED) SELECTED FROM 34 SELECTED ELEMENTS BY NELE COMMAND.

PRINT NODAL DISPLACEMENTS

***** POST1 NODAL DISPLACEMENT LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
47	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
48	8.46E-04	3.55E-18	3.94E-04	1.94E-19	6.59E-05	0.00E+00
49	5.13E-03	7.45E-18	8.72E-04	5.26E-20	2.00E-04	0.00E+00
50	2.15E-02	0.00E+00	1.55E-03	0.00E+00	5.12E-04	0.00E+00
51	3.55E-02	1.99E-18	1.89E-03	1.25E-19	6.43E-04	7.27E-20
52	6.66E-02	8.10E-18	2.59E-03	1.12E-19	5.19E-04	2.24E-19
53	7.36E-02	9.69E-18	2.81E-03	9.45E-20	3.76E-04	2.71E-19
54	7.38E-02	5.26E-18	2.00E-03	5.83E-20	2.37E-04	3.02E-19
55	7.40E-02	0.00E+00	6.34E-03	0.00E+00	1.40E-04	0.00E+00
56	7.44E-02	2.64E-17	1.06E-02	0.00E+00	1.16E-04	2.75E-19
57	7.48E-02	0.00E+00	1.48E-02	0.00E+00	9.11E-05	0.00E+00
58	7.51E-02	6.94E-18	1.66E-02	0.00E+00	6.75E-05	1.27E-19
59	7.55E-02	0.00E+00	1.66E-02	0.00E+00	5.12E-05	0.00E+00
60	7.56E-02	0.00E+00	1.52E-02	0.00E+00	7.28E-05	0.00E+00
61	7.59E-02	0.00E+00	9.14E-03	0.00E+00	8.39E-05	0.00E+00
62	7.59E-02	2.88E-18	8.55E-03	0.00E+00	7.81E-05	5.21E-19
63	7.59E-02	1.82E-17	7.44E-03	0.00E+00	6.76E-05	3.53E-19
64	7.60E-02	0.00E+00	1.96E-03	0.00E+00	1.82E-04	0.00E+00
65	7.60E-02	0.00E+00	1.43E-03	0.00E+00	2.21E-04	0.00E+00
66	7.23E-02	0.00E+00	1.49E-03	0.00E+00	2.69E-04	0.00E+00

67	6.37E-02	0.00E+00	1.60E-03	0.00E+00	3.49E-04	0.00E+00
68	5.19E-02	7.14E-23	1.54E-03	1.81E-24	4.13E-04	0.00E+00
69	2.64E-02	2.62E-24	1.44E-03	8.40E-25	4.30E-04	0.00E+00
70	2.38E-02	0.00E+00	1.43E-03	0.00E+00	4.23E-04	0.00E+00
71	9.59E-03	4.26E-05	1.25E-03	3.98E-06	3.36E-04	5.64E-05
72	4.90E-03	1.10E-04	1.18E-03	1.69E-05	2.77E-04	8.00E-05
73	2.53E-03	6.43E-05	5.86E-04	1.53E-05	7.12E-05	8.15E-05
74	1.08E-03	1.28E-04	3.90E-04	7.83E-06	4.93E-05	4.66E-05
75	2.42E-04	1.54E-04	2.30E-04	9.18E-06	3.59E-05	2.01E-05
76	5.50E-05	7.84E-05	8.34E-05	9.47E-06	1.82E-05	7.71E-06
77	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
78	2.06E-03	3.57E-05	3.91E-04	1.02E-05	3.05E-05	8.74E-05
79	1.29E-03	1.06E-04	2.25E-04	1.03E-05	1.04E-05	7.32E-05
80	3.89E-04	5.37E-05	7.69E-05	8.97E-06	5.29E-06	4.81E-05
81	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

MAXIMUMS

NODE	65	75	58	72	51	78
VALUE	7.60E-02	1.54E-04	1.66E-02	1.69E-05	6.43E-04	8.74E-05

PRINT NODAL FORCES PER ELEMENT

***** POST1 ELEMENT NODE FORCE LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z FORCES ARE IN GLOBAL COORDINATES

ELEM = 58	FX	FY	FZ	MX	MY	MZ
47	417.35816	2.88E-12	1480.9435	8.38E-11	11724.716	0.00E+00
48	417.35816	2.88E-12	1480.9435	3.29E-12	19223.368	0.00E+00

ELEM = 59	FX	FY	FZ	MX	MY	MZ
48	417.35816	2.88E-12	1480.9435	3.29E-12	19223.368	0.00E+00
49	417.35816	2.88E-12	1480.9435	9.45E-11	31914.32	0.00E+00

ELEM = 60	FX	FY	FZ	MX	MY	MZ
49	423.93909	4.22E-12	1480.9435	9.45E-11	31914.32	0.00E+00
50	423.93909	4.22E-12	1480.9435	1.08E-10	51613.178	0.00E+00

ELEM = 61	FX	FY	FZ	MX	MY	MZ
50	1419.8466	2.70E-12	1480.9435	6.47E-11	51613.178	1.12E-11
51	1419.8466	2.70E-12	1480.9435	8.12E-12	17715.132	1.12E-11

ELEM = 62	FX	FY	FZ	MX	MY	MZ
51	1320.4059	2.19E-13	1481.2607	8.12E-12	17715.132	1.12E-11
52	1320.4059	2.19E-13	1481.2607	5.92E-12	48607.362	1.12E-11

ELEM = 63	FX	FY	FZ	MX	MY	MZ
52	1320.4059	2.19E-13	1481.2607	5.92E-12	48607.362	1.12E-11
53	1320.4059	2.19E-13	1481.2607	8.60E-12	69049.828	1.12E-11

ELEM = 64	FX	FY	FZ	MX	MY	MZ
53	1320.4059	2.19E-13	1481.2607	8.60E-12	69049.828	1.12E-11
54	1320.4059	2.19E-13	1481.2607	8.60E-12	46345.891	1.39E-11

ELEM = 65	FX	FY	FZ	MX	MY	MZ
54	1110.9828	7.18E-12	1481.2607	8.60E-12	46345.891	1.39E-11

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A68

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 431L-1 BY: HEK CK: MAK SHT: A68 OF A72

55	1110.9828	7.18E-12	1481.2607	8.60E-12	11991.516	1.66E-10
ELEM = 66	FX	FY	FZ	MX	MY	MZ
55	1110.9828	3.47E-11	152.21507	0.00E+00	11991.516	6.73E-10
56	1110.9828	3.47E-11	152.21507	0.00E+00	8823.4363	5.77E-10
ELEM = 67	FX	FY	FZ	MX	MY	MZ
56	880.33371	2.25E-11	124.74982	0.00E+00	8823.4363	5.77E-10
57	880.33371	2.25E-11	124.74982	0.00E+00	7206.6577	5.05E-10
ELEM = 68	FX	FY	FZ	MX	MY	MZ
57	880.33371	8.31E-12	142.35838	0.00E+00	7206.6577	1.68E-10
58	880.33371	8.31E-12	142.35838	0.00E+00	8501.4925	1.23E-10
ELEM = 69	FX	FY	FZ	MX	MY	MZ
58	652.13835	3.59E-12	97.714121	0.00E+00	8501.4925	1.23E-10
59	652.13835	3.59E-12	97.714121	0.00E+00	10748.105	9.65E-11
ELEM = 70	FX	FY	FZ	MX	MY	MZ
59	652.13835	0.00E+00	114.19307	0.00E+00	10748.105	0.00E+00
60	652.13835	0.00E+00	114.19307	0.00E+00	8798.011	0.00E+00
ELEM = 71	FX	FY	FZ	MX	MY	MZ
60	402.7717	0.00E+00	191.76234	0.00E+00	8798.011	0.00E+00
61	402.7717	0.00E+00	191.76234	0.00E+00	7566.8544	0.00E+00
ELEM = 72	FX	FY	FZ	MX	MY	MZ
61	402.7717	2.11E-11	362.04579	0.00E+00	7566.8544	4.33E-10
62	402.7717	2.11E-11	362.04579	0.00E+00	4456.5996	2.22E-10
ELEM = 73	FX	FY	FZ	MX	MY	MZ
62	130.12361	2.11E-11	362.04579	0.00E+00	4456.5996	2.22E-10
63	130.12361	2.11E-11	362.04579	0.00E+00	6408.1022	3.06E-10
ELEM = 74	FX	FY	FZ	MX	MY	MZ
63	130.12361	8.48E-12	332.09237	0.00E+00	6408.1022	3.06E-10
64	130.12361	8.48E-12	332.09237	0.00E+00	27155.432	2.37E-10
ELEM = 75	FX	FY	FZ	MX	MY	MZ
64	130.12361	0.00E+00	777.4641	0.00E+00	27155.432	0.00E+00
65	130.12361	0.00E+00	777.4641	0.00E+00	19803.773	0.00E+00
ELEM = 76	FX	FY	FZ	MX	MY	MZ
65	130.12361	0.00E+00	777.4641	0.00E+00	19803.773	0.00E+00
66	130.12361	0.00E+00	777.4641	0.00E+00	20991.2	0.00E+00
ELEM = 77	FX	FY	FZ	MX	MY	MZ
66	178.39239	0.00E+00	777.4641	0.00E+00	20991.2	0.00E+00
67	178.39239	0.00E+00	777.4641	0.00E+00	16725.334	0.00E+00
ELEM = 78	FX	FY	FZ	MX	MY	MZ
67	206.4746	1.10E-16	245.61204	2.07E-15	16725.334	0.00E+00
68	206.4746	1.10E-16	245.61204	1.34E-15	10855.167	0.00E+00
ELEM = 79	FX	FY	FZ	MX	MY	MZ
68	287.22652	3.58E-17	245.61204	1.34E-15	10855.167	0.00E+00
69	287.22652	3.58E-17	245.61204	7.73E-16	7730.5686	0.00E+00
ELEM = 80	FX	FY	FZ	MX	MY	MZ

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: A 69

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEK CK: MAK SHT: A69 OF A72

69	287.22652	3.58E-17	245.61204	7.7[illegible]E-16	7790.5686	0.00E+00
70	287.22652	3.58E-17	245.61204	9.88E-16	9330.4115	0.00E+00
ELEM = 81	FX	FY	FZ	MX	MY	MZ
70	377.13104	173.17668	493.76701	2526.8879	9330.4115	5619.0535
71	377.13104	173.17668	493.76701	3880.6494	21445.066	5619.0535
ELEM = 82	FX	FY	FZ	MX	MY	MZ
71	377.13104	173.17668	493.76701	3880.6494	21445.066	5619.0535
72	377.13104	173.17668	493.76701	6564.888	27052.099	5619.0535
ELEM = 83	FX	FY	FZ	MX	MY	MZ
72	377.13104	173.17668	493.76701	6564.888	27052.099	5619.0535
73	377.13104	173.17668	493.76701	7260.5882	27052.099	4940.6157
ELEM = 84	FX	FY	FZ	MX	MY	MZ
73	266.73066	549.98654	277.48437	4404.6699	10785.386	13701.149
74	266.73066	549.98654	277.48437	1134.6438	7613.1455	10604.375
ELEM = 85	FX	FY	FZ	MX	MY	MZ
74	266.73066	549.98654	277.48437	1134.6438	7613.1455	10604.375
75	266.73066	549.98654	277.48437	2135.3823	4481.6576	7594.3346
ELEM = 86	FX	FY	FZ	MX	MY	MZ
75	266.73066	549.98654	277.48437	2135.3823	4481.6576	7594.3346
76	266.73066	549.98654	277.48437	1888.141	4481.6576	4338.2431
ELEM = 87	FX	FY	FZ	MX	MY	MZ
76	266.73066	549.98654	277.48437	1888.141	4481.6576	4338.2431
77	266.73066	549.98654	277.48437	6050.4065	4481.6576	3179.4312
ELEM = 88	FX	FY	FZ	MX	MY	MZ
73	629.26996	376.80986	216.28264	2855.9183	16306.525	8926.9981
78	629.26996	376.80986	216.28264	929.59174	8762.2044	1819.3786
ELEM = 89	FX	FY	FZ	MX	MY	MZ
78	629.26996	376.80986	216.28264	929.59174	8762.2044	1819.3786
79	629.26996	376.80986	216.28264	996.73483	1300.817	6400.8918
ELEM = 90	FX	FY	FZ	MX	MY	MZ
79	629.26996	376.80986	216.28264	996.73483	1300.817	6400.8918
80	629.26996	376.80986	216.28264	2139.3635	1300.817	15447.795
ELEM = 91	FX	FY	FZ	MX	MY	MZ
80	629.26996	376.80986	216.28264	2139.3635	1300.817	15447.795
81	629.26996	376.80986	216.28264	5383.6031	1300.817	24866.337

PRINT ELEMENT STRESS ITEMS PER ELEMENT

***** POST1 ELEMENT STRESS LISTING *****

ELEM	I1	I3	J1	J3
58	846.83085	378.40399	1229.8246	488.08089
59	1229.8246	488.08089	1783.8026	1028.9342
60	1783.8026	1028.9342	2635.4149	1899.5109
61	2635.4149	1899.5109	1148.926	465.73617

62	1149.3865	464.75196	2509.5667	1760.6774
63	2509.5667	1760.6774	3403.5241	2653.6733
64	3367.2021	2686.9139	2374.8827	1692.7995
65	2319.3851	1746.0829	781.34228	358.53701
66	781.34228	358.53701	670.15771	192.16641
67	609.32569	212.24816	527.31584	197.05035
68	527.31584	197.05035	549.97098	304.07106
69	498.59697	305.36889	543.38195	460.98661
70	543.38195	460.98661	439.52905	410.29764
71	411.30526	390.42357	429.07671	245.34664
72	429.07671	245.34664	283.51653	142.97845
73	214.65489	180.81779	303.22113	261.1061
74	303.22113	261.1061	1211.5186	1167.923
75	1211.5186	1167.923	889.61291	846.09273
76	1051.6002	700.42485	1104.3052	750.21459
77	1104.3052	750.21459	915.79212	571.25789
78	674.26357	792.33306	417.05534	536.02008
79	417.05534	536.02008	280.63497	404.05574
ELEM	I1	I3	J1	J3
80	280.63497	404.05574	346.42048	472.39734
81	423.02702	595.82838	991.86118	1120.3833
82	991.86118	1120.3833	1324.4249	1458.4155
83	482.28111	529.02371	484.47583	530.14933
84	824.93602	982.07782	534.32758	693.49562
85	534.32758	693.49562	386.57751	550.15173
86	351.7926	507.00331	223.468	371.61486
87	223.468	371.61486	345.08224	473.49862
88	928.44479	815.08049	410.4139	302.87283
89	410.4139	302.87283	286.07271	170.18775
90	383.33026	272.86508	808.07981	698.46809
91	808.07981	698.46809	1326.0122	1217.7541

MINIMUMS				
ELEMENT	73	73	86	72
VALUE	214.65489	180.81779	223.468	142.97845

MAXIMUMS				
ELEMENT	64	64	63	63
VALUE	3367.2021	2686.9139	3403.5241	2653.6733

178 ELEMENTS (OF 178 DEFINED) SELECTED BY EALL COMMAND.

ESEL FOR LABEL = TYPE FROM 1 TO 1 BY 1

91 ELEMENTS (OF 178 DEFINED) SELECTED BY ESEL COMMAND.

ERSE FOR LABEL = REAL FROM 3 TO 3 BY 1

12 ELEMENTS (OF 178 DEFINED) SELECTED BY ERSE COMMAND.

13 NODES (OF 108 DEFINED) SELECTED FROM 12 SELECTED ELEMENTS BY NELE COMMAND.

PRINT NODAL DISPLACEMENTS

***** POST1 NODAL DISPLACEMENT LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
82	3.23E-02	0.00E+00	1.38E-03	0.00E+00	0.00E+00	0.00E+00
83	3.22E-02	6.22E-05	1.60E-03	0.00E+00	2.88E-05	4.10E-06
84	3.22E-02	1.47E-04	2.26E-03	0.00E+00	4.80E-05	1.48E-06
85	3.21E-02	0.00E+00	6.34E-03	0.00E+00	1.17E-04	0.00E+00
86	3.21E-02	1.35E-18	6.89E-03	0.00E+00	1.26E-04	4.28E-19
87	3.19E-02	2.68E-17	1.14E-02	0.00E+00	1.16E-04	2.31E-19
88	3.17E-02	0.00E+00	1.48E-02	0.00E+00	2.34E-04	0.00E+00
89	3.17E-02	0.00E+00	1.54E-02	0.00E+00	2.77E-04	0.00E+00
90	3.16E-02	0.00E+00	1.60E-02	0.00E+00	3.13E-04	0.00E+00
91	2.97E-02	0.00E+00	1.60E-02	0.00E+00	3.52E-04	0.00E+00
92	2.79E-02	0.00E+00	1.60E-02	0.00E+00	3.77E-04	0.00E+00
93	1.91E-02	0.00E+00	1.61E-02	0.00E+00	3.97E-04	0.00E+00
94	8.85E-03	0.00E+00	1.61E-02	0.00E+00	0.00E+00	0.00E+00

MAXIMUMS

	UX	UY	UZ	ROTX	ROTY	ROTZ
NODE	82	84	94	0	93	83
VALUE	3.23E-02	1.47E-04	1.61E-02	0.00E+00	3.97E-04	4.10E-06

PRINT NODAL FORCES PER ELEMENT

***** POST1 ELEMENT NODE FORCE LISTING *****

CALCULATED LOAD CASE = 3

THE FOLLOWING X,Y,Z FORCES ARE IN GLOBAL COORDINATES

ELEM = 46	FX	FY	FZ	MX	MY	MZ
82	87.37065	10.256905	27.687408	0.00E+00	1343.8151	278.70809
83	87.37065	10.256905	27.687408	0.00E+00	898.57572	32.542363

ELEM = 47	FX	FY	FZ	MX	MY	MZ
83	87.37065	10.256905	27.687408	0.00E+00	898.57572	32.542363
84	87.37065	10.256905	27.687408	0.00E+00	840.54364	223.88027

ELEM = 48	FX	FY	FZ	MX	MY	MZ
84	87.37065	5.6295657	24.156541	0.00E+00	840.54364	223.88027
85	87.37065	5.6295657	24.156541	0.00E+00	2016.6323	187.07803

ELEM = 49	FX	FY	FZ	MX	MY	MZ
85	269.83352	3.39E-12	114.97032	0.00E+00	2016.6323	7.52E-11
86	269.83352	3.39E-12	114.97032	0.00E+00	1411.2799	5.48E-11

ELEM = 50	FX	FY	FZ	MX	MY	MZ
86	269.83352	3.39E-12	114.97032	0.00E+00	1411.2799	5.48E-11
87	269.83352	3.39E-12	114.97032	0.00E+00	3644.6289	8.41E-11

ELEM = 51	FX	FY	FZ	MX	MY	MZ
87	269.83352	4.85E-12	105.52725	0.00E+00	3644.6289	8.41E-11
88	269.83352	4.85E-12	105.52725	0.00E+00	7509.8802	9.55E-11

ELEM = 52	FX	FY	FZ	MX	MY	MZ
88	269.83352	0.00E+00	89.840966	0.00E+00	7509.8802	0.00E+00
89	269.83352	0.00E+00	89.840966	0.00E+00	7444.8233	0.00E+00

ELEM = 53	FX	FY	FZ	MX	MY	MZ
89	269.83352	0.00E+00	89.840966	0.00E+00	7444.8233	0.00E+00
90	269.83352	0.00E+00	89.840966	0.00E+00	7420.1459	0.00E+00

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN No. 3 DATE: APRIL '94 PAGE: A72

SUBJECT: APPENDIX A - ANALYSIS OF SYSTEM 4316-1 BY: HEE CK: MAK SHT: A72 OF A72

ELEM = 54	FX	FY	FZ	MX	MY	MZ
90	269.83352	0.00E+00	89.840966	0.00E+00	7420.1459	0.00E+00
91	269.83352	0.00E+00	89.840966	0.00E+00	5843.2696	0.00E+00

ELEM = 55	FX	FY	FZ	MX	MY	MZ
91	269.83352	0.00E+00	89.840966	0.00E+00	5843.2696	0.00E+00
92	269.83352	0.00E+00	89.840966	0.00E+00	4551.8552	0.00E+00

ELEM = 56	FX	FY	FZ	MX	MY	MZ
92	298.42002	0.00E+00	89.840966	0.00E+00	4551.8552	0.00E+00
93	298.42002	0.00E+00	89.840966	0.00E+00	2565.2189	0.00E+00

ELEM = 57	FX	FY	FZ	MX	MY	MZ
93	301.37929	0.00E+00	89.840966	0.00E+00	2565.2189	0.00E+00
94	301.37929	0.00E+00	89.840966	0.00E+00	14888.044	0.00E+00

PRINT ELEMENT STRESS ITEMS PER ELEMENT

***** POST1 ELEMENT STRESS LISTING *****

CALCULATED LOAD CASE = 3

ELEM	I1	I3	J1	J3
46	240.82248	204.89778	158.85807	141.26525
47	158.85807	141.26525	153.50682	138.3287
48	153.50682	138.3287	351.21522	298.14337
49	423.19775	258.9522	315.61313	203.24549
50	315.61313	203.24549	715.15087	449.55491
51	715.15087	449.55491	1326.8804	1067.4153
52	1326.8804	1067.4153	1313.7922	1060.4712
53	1313.7922	1060.4712	1307.1968	1059.8505
54	1159.5731	1204.9669	907.66749	955.02093
55	907.66749	955.02093	701.02924	750.80251
56	701.02924	750.80251	391.67733	429.78649
57	391.67733	429.78649	2354.3101	2387.9194
MINIMUMS				
ELEMENT	48	48	47	47
VALUE	153.50682	138.3287	153.50682	138.3287
MAXIMUMS				
ELEMENT	52	54	57	57
VALUE	1326.8804	1204.9669	2354.3101	2387.9194

***** END OF INPUT ENCOUNTERED ON FILE38. FILE38 REWOUND

***** INPUT FILE SWITCHED FROM FILE38 TO FILE 5

APPENDIX B

DISCUSSIONS OF THE TYPICAL EFFECT

OF EDGE RESTRAINT ON STRESSES

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

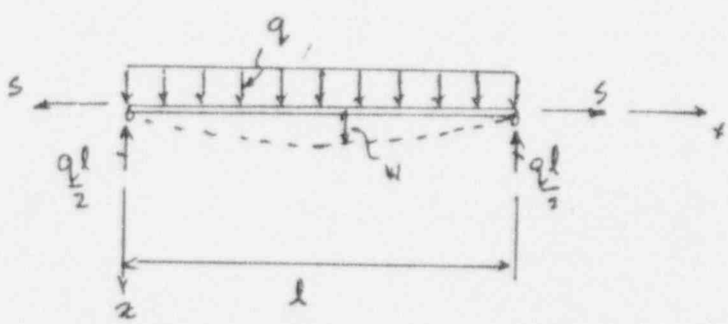
TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: B2

SUBJECT: APPENDIX B - EDGE RESTRAINT ON STRESSES PLOT BY: HGK CK: MHC SHT: B2 OF B7

REFER TO "THEORY OF PLATES AND SHELLS" BY S. TIMOSHENKO AND S. WOINOWSKY-KRIEGER, 2 ND EDITION, 1959. (CYLINDRICAL BENDING OF LONG RECTANGULAR PLATES)

CONSIDER THE FOLLOWING TWO CONDITIONS:

(A) CYLINDRICAL BENDING OF UNIFORMLY LOADED RECTANGULAR PLATES WITH SIMPLY SUPPORTED EDGES.



q = UNIFORM LOAD
u, v, w = COMPONENT OF DISPLACEMENT
S = AXIAL TENSION FORCE
h = THICKNESS
ν = POISSON RATIO

ASSUME THAT A UNIFORMLY LOADED LONG RECTANGULAR PLATE WITH LONGITUDINAL EDGES WHICH ARE FREE TO ROTATE BUT CANNOT MOVE TOWARD EACH OTHER DURING BENDING.

THEN,

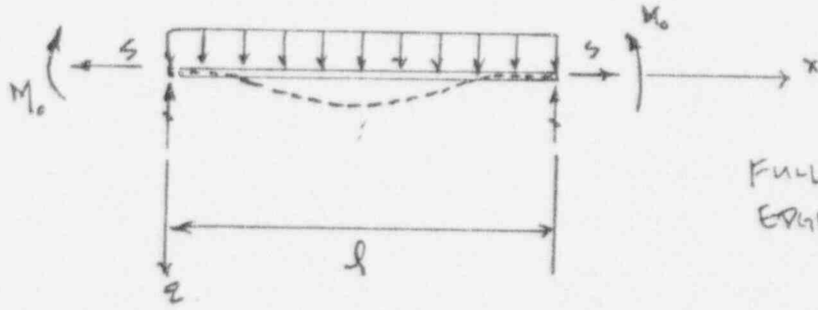
- DIRECT TENSILE STRESS: $\sigma_1 = \frac{E u^2}{3(1-\nu^2)}\left(\frac{h}{l}\right)^2$
- BENDING STRESS: $\sigma_2 = \frac{3}{4} q \left(\frac{l}{h}\right)^2 \psi_0$ [PAGE 11]

WHERE: $\psi_0 = \frac{1 - \operatorname{sech} u}{\frac{u^2}{2}}$

MAXIMUM STRESS IN THE PLATE: $S_c = \sigma_1 + \sigma_2$

- MAX. MOMENT: $M_{max.} = \frac{q l^2}{8} \psi_0(u)$

B) CYLINDERICAL BENDING OF UNIFORMLY LOADED RECTANGULAR PLATES WITH BUILT-IN EDGES.



FULL FIXED EDGES CONDITION

ASSUME THAT THE LONGITUDINAL EDGES ARE FIXED WITH NO ROTATION.

THEN,

- DIRECT TENSILE STRESS : $\sigma_1 = \frac{E u^2}{3(1-\nu^2)} \left(\frac{h}{\ell}\right)^2$

- BENDING STRESS : $\sigma_2 = \frac{q}{2} \left(\frac{\ell}{h}\right)^2 \psi_1(u)$ [PAGE 14]

  WHERE:

$$\psi_1(u) = \frac{3(u - \tanh u)}{u^2 \tanh u}$$

MAXIMUM STRESS IN THE PLATE : $S_c = \sigma_1 + \sigma_2$

- BENDING MOMENT AT EDGES : $M_0 = -\frac{q\ell^2}{12} \psi_1(u)$ [PAGE 13]

FOR AN UNIFORMLY LOADED RECTANGULAR PLATE, ASSUME THAT WHEN BENDING OCCURS, THE LONGITUDINAL EDGES OF THE PLATE ROTATE THROUGH AN ANGLE PROPORTIONAL TO THE BENDING MOMENT AT THE EDGES. THIS ASSUMPTION IS VALID FOR THE UNIFORMLY LOAD RECTANGULAR PLATE WITH ELASTICALLY BUILT-IN EDGES. UNLIKE THE CONDITION OF FULLY FIXED EDGES, THE SLOPE OF THE DEFLECTION CURVE AT THE ENDS OF THE STRIP IS NO LONGER ZERO BUT IS PROPORTIONAL TO THE MOMENT, AND DEPENDS ON THE RIGIDITY OF RESTRAINT FACTOR ALONG THE EDGES. UNDER THESE CONDITIONS, THE END MOMENTS WILL BE SMALLER THAN THOSE WITH ABSOLUTELY BUILT-IN EDGES. THE BENDING MOMENT:

$$M_0 = -\gamma \frac{q l^2}{12} \psi_1(u)$$

WHERE:

$$\gamma = \frac{\tanh u}{\frac{2\beta}{l} D u + \tanh u}$$

β = RIGIDITY OF RESTRAINT FACTOR

γ = NUMERICAL FACTOR SMALLER THAN UNITY

$$D = \frac{E h^3}{12(1-\nu^2)} \qquad S = \frac{4u^2 D}{l^2}$$

THE DEFLECTION CURVE FOR THE UNIFORMLY LOADED RECTANGULAR PLATE WITH ELASTICALLY BUILT-IN EDGES CAN BE REPRESENTED IN THE FOLLOWING FORM:

$$w = \frac{q l^4}{16 u^4 D} \frac{\tanh u - \gamma(\tanh u - u)}{\tanh u} \left\{ \frac{\cosh\left[u\left(1 - \frac{2x}{l}\right)\right]}{\cosh u} - 1 \right\} + \frac{q l^2}{8 u^2 D} x (l - x)$$

FOR $\gamma = 1$, THIS EXPRESSION IS FOR DEFLECTION OF A PLATE WITH ABSOLUTELY BUILT-IN EDGES

FOR $\gamma = 0$, THIS EXPRESSION BECOMES AN EXPRESSION FOR A PLATE WITH SIMPLY SUPPORTED EDGES.

IN CALCULATING THE TENSILE PARAMETER u:

$$\frac{S(1 - \nu^2) l}{h E} = \frac{1}{2} \int_0^l \left(\frac{dw}{dx}\right)^2 dx$$

SUBSTITUTING THE w EXPRESSION AND PERFORMIN THE INTEGRATION, OBTAIN

$$\frac{E^2 h^8}{(1 - \nu^2)^2 q^2 l^8} = (1 - \gamma) U_0 + \gamma U_1 - \gamma (1 - \gamma) U_2$$

WHERE:
$$U_0 = \frac{135}{16} \frac{\tanh u}{u^9} + \frac{27}{16} \frac{\tanh^2 u}{u^8} - \frac{135}{16 u^8} + \frac{9}{8 u^6}$$

$$U_1 = -\frac{81}{16 u^7 \tanh u} - \frac{27}{16 u^6 \sinh^2 u} + \frac{27}{4 u^8} + \frac{9}{8 u^6}$$

$$U_2 = \frac{27}{16} \frac{(u - \tanh u)^2}{u^4 \tanh^2 u} \left(u \tanh^2 u - u + \tanh u \right)$$

THE ABOVE EQUATION CAN BE SOLVED BY THE TRIAL AND ERROR METHOD AS FOLLOWINGS:

(1) CALCULATE THE LEFT-HAND SIDE OF THE EQUATION AND, USING THE CORRESPONDING FIGURES DETERMINE THE VALUES OF THE PARAMETER u FOR SIMPLY SUPPORTED EDGES AND FOR ABSOLUTELY BUILT-IN EDGES. NATURALLY u FOR ELASTICALLY BUILT-IN EDGES MUST HAVE A VALUE INTERMEDIATE BETWEEN THESE TWO.

(2) BY USING VALUE OF u, CALCULATE U_0, U_1, AND U_2 AND SOLVE THE RIGHT-HAND SIDE OF THE EQUATION.

(3) IF THE VALUE IS DIFFERENT FROM THE VALUE OF THE LEFT-HAND SIDE, REPEAT (1) AND (2).

(4) TWO SUCH TRIAL CALCULATIONS WILL BE SUFFICIENT TO DETERMINE BY INTERPOLATION THE VALUE OF u

(5) ONCE u IS DETERMINED, THE BENDING MOMENT M_0 AND THE MAX. BENDING STRESS CAN BE FOUND.

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN NO. 3 DATE: APRIL '94 PAGE: B7

SUBJECT: APPENDIX B - EDGE RESTRAINT ON STRESSES PLOT BY: HGF CK: MAK SHT: B7 OF B7

THE EFFECT OF EDGE RESTRAINT ON STRESSES PLOT (IN FIGURE 5.0.1) WAS GENERATED FOR AN UNIFORMLY LOAD RECTANGULAR PLATE WITH VARIOUS DEGREE OF RIGIDITY OF THE CONSTRAINTS AT THE EDGES. THE MAXIMUM STRESS WILL OCCUR AT THE ENDS OR AT THE MIDDLE, DEPENDING ON THE EDGE FIXITY CONDITIONS.

Attachment 4 to
NRC-94-0050

HOPPER AND ASSOCIATES
ENGINEERS

DECO - USNRC DOCKET NO. 50-341

FERMI 2 CCHVAC DUCTING SYSTEMS

CONCERN ITEM NO. 4

EVALUATION CALCULATIONS

Prepared for: Detroit Edison Company
Nuclear Engineering Fermi 2
6400 North Dixie Highway
Newport, MI 48166

Prepared by: Hopper and Associates
300 Vista Del Mar
Redondo Beach, CA 90277

April, 1994

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 4 DATE: APRIL 20, 1994 PAGE: i

SUBJECT: TABLE OF CONTENTS BY: NAK CK: A.R SHT: 1 OF 1

TABLE OF CONTENTS

PREPARED BY : M. Amir Khan APRIL 21, 94

REVIEWED BY : Alex Reizman April 21, 1994

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 4 DATE: APRIL 19, 94 PAGE: 1

SUBJECT: 1.0 INTRODUCTION BY: MAK CK: A.R SHT: 1 OF 2

1.1 PROBLEM STATEMENT

ON MARCH 3, 1994, THE U.S.N.R.C SUBMITTED DOCKET NO. 50-341 TO DETROIT EDISON COMPANY. THIS DOCKET CONSISTS OF A REQUEST FOR ADDITIONAL INFORMATION ON FERMI 2 CCHVAC SYSTEM DESIGN AND OPERATION. IN PARTICULAR, THERE ARE SEVERAL CONCERNS REGARDING THE STRUCTURAL INTEGRITY CALCULATIONS, HA-05/89-686 AND HA-09/89-676, PERFORMED BY HOPPER AND ASSOCIATES.

THIS PACKAGE IS PREPARED AS RESPONSE TO ONE OF THE COMMENTS POSED BY THE NRC REGARDING HA-05/89-686, NAMELY:

> In all analyses the beam bending stresses were based on one significant moment. It isn't clear that the highest longitudinal stresses were calculated, based on possible biaxial moment loading and axial loading.

1.2 INVESTIGATION APPROACH

FROM THE COMPUTER ANALYSIS RESULTS DOCUMENTED IN [1], BIAXIAL BENDING EFFECTS WILL BE EVALUATED. THE EXTENT TO WHICH THE HIGHEST LONGITUDINAL STRESSES (AS REPORTED IN HA-05/89-686) ARE AFFECTED BY CONSIDERING BIAXIAL MOMENT LOADING WILL BE EVALUATED. ALSO, IT WILL BE SHOWN THAT AXIAL LOADING EFFECTS WERE INDEED INCLUDED IN THE ANALYSIS DONE IN [1].

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ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 4 DATE: APRIL 19, 1994 PAGE: 3

SUBJECT: 2.0 ANALYSIS APPROACH BY: MAK CK: A.R. SHT: 1 OF 1

IN THE EXISTING ANALYSIS [1], MAXIMUM LONGITUDINAL STRESSES WERE EVALUATED BASED ON THE MAXIMUM FORCES AND MOMENTS OBTAINED IN EACH OF THE FOUR DUCTING SYSTEMS. FOR THE SEISMIC LOADING CASE, THE SSE ANALYSIS PRODUCED THE WORST CASE EFFECT. LONGITUDINAL STRESSES WERE THEN CALCULATED BASED ON THE GREATER BENDING MOMENT ABOUT THE TWO FLEXURAL AXES AND THE AXIAL FORCE (OBTAINED BY AN SRSS OF FORCES AND MOMENTS DUE TO EARTHQUAKES IN 3 DIRECTIONS) IN THIS REPORT, THE EFFECT OF THE BENDING MOMENT ABOUT THE OTHER FLEXURAL AXIS WILL BE ADDED TO THE MAXIMUM LONGITUDINAL STRESSES FOR SSE LOADING COMPUTED IN [1].

3.1 DUCTING SYSTEM 2848-3

THIS IS A ROUND DUCTING SYSTEM. AS A VERY CONSERVATIVE ESTIMATE, THE MAXIMUM STRESSES AT THE EXTREME FIBER WOULD BE SUMMED UP FOR BOTH THE MOMENTS (EVEN THOUGH THEY ACT ABOUT TWO ORTHOGONAL AXES).

FROM REF[1], PAGES 26 & 85,

$F_{AXIAL} = 662.9$ LB, $M_1 = 47930$ LB-IN, $M_2 = 369.2$ LB-IN
(SSE LOADING)

$$\sigma = \frac{M_1 d}{2I} + \frac{F_{AXIAL}}{A} + \frac{M_2 d}{2I}$$

[NOTE: AXIAL LOADING WAS INCLUDED IN [1]]

$$= \frac{(47930)(18)}{(2)(106.7)} + \frac{662.9}{2.918} + \frac{(369.2)(18)}{(2)(106.7)}$$

$$= 4301 \text{ psi}$$

$$\% \sigma_{yp} = \frac{4301}{36000} \times 100 = 11.9\%$$ (SAME AS REPORTED IN [1])

HENCE, M_2 HAS INSIGNIFICANT EFFECT ON THE HIGHEST LONGITUDINAL STRESSES.

3.2 DUCTING SYSTEM 4316-1

THIS IS A 14" x 14" SQUARE DUCTING SYSTEM.

FROM REF [1], PAGES 37 & 97,

$F_{AXIAL} = 990.6$ LB, $M_1 = 57502$ LB-IN, $M_2 = 152.4$ LB-IN

(SSE LOADING)

$$\sigma = \frac{M_1 d}{2I} + \frac{F_{AXIAL}}{A} + \frac{M_2 d}{2I}$$

$$= \frac{(57502)(14)}{2(94.4)} + \frac{990.6}{2.89} + \frac{(152.4)(14)}{2(94.4)}$$

(NOTE: AXIAL LOADING WAS INCLUDED IN [1])

$= 4618$ psi ∴ BUCKLING OCCURS

MAXIMUM PANEL STRESS ASSUMING MINIMUM STRIP WIDTH $C = 0.95"$

$$(4618)(14)(0.0516) = [\sigma 2(0.95) + (1415)(14 - 2(0.95))](0.0576)$$

OR, $\sigma = 25016$ psi

AS PERCENTAGE OF YIELD STRENGTH

$$\frac{\sigma}{\sigma_{yp}} \times 100\% = 69.5\%$$ (THIS WAS 69.3% IN [1])

HENCE, THE EFFECT OF M_2 IS INSIGNIFICANT.

3.3 DUCTING SYSTEM 4316-6

THIS SYSTEM CONSISTS OF 16"x16" SQUARE DUCTS AND 17.5" Ø ROUND DUCTS.

16"x16" SQUARE DUCTS

FROM REF [1], PAGES 48 & 109,

$F_{AXIAL} = 567.9$ LB, $M_1 = 9881.3$ LB-IN, $M_2 = 120.2$ LB-IN

(SSE LOADING)

$$\sigma = \frac{M_1 d}{2I} + \frac{F_{AXIAL}}{A} + \frac{M_2 d}{2I}$$

$$= \frac{(9881.3)(16)}{(2)(141)} + \frac{567.9}{3.3} + \frac{(120.2)(16)}{(2)(141)}$$ (NOTE: AXIAL LOADING WAS INCLUDED IN [1])

$= 739.6$ psi < 1083 psi ∴ NO BUCKLING

$$\therefore \frac{\sigma}{\sigma_{yp}}\% = \frac{739.6}{36000} \times 100 = 2.05\%$$ (THIS WAS 2.04% IN [1])

HENCE, THE EFFECT OF M_2 IS INSIGNIFICANT.

17.5" Ø ROUND DUCTS

FROM PAGE 49 OF REF [1], $M_2 = 0$. HENCE, WORST CASE EFFECT DOES NOT HAVE BIAXIAL BENDING.

3.4 DUCTING SYSTEM 4316-7

THIS SYSTEM CONSISTS OF 16" x 16" SQUARE DUCTS AND 18" ∅ ROUND DUCTS.

18" ∅ ROUND DUCTS

FROM REF [1], PAGES 61 & 134,

F_{AXIAL} = 1298 LB, M_1 = 65643 LB-IN, M_2 = 235.2 LB-IN

$$\sigma = \frac{M_1 d}{2I} + \frac{F_{AXIAL}}{A} + \frac{M_2 d}{2I}$$

$$= \frac{(65643)(18)}{(2)(118.2)} + \frac{1298}{2.92} + \frac{(235.2)(18)}{(2)(118.2)}$$ (NOTE: AXIAL LOADING WAS INCLUDED IN [1])

$$= 5461 \text{ psi}$$

AS A PERCENTAGE OF YIELD,

$$\frac{\sigma}{\sigma_{YP}} \times 100\% = 15.2\%$$ (THIS WAS 15.1% IN [1])

HENCE, THE EFFECT OF M_2 IS INSIGNIFICANT.

16" x 16" SQUARE DUCTS

FROM PAGE 60 OF REF [1], $M_2 = 0$. HENCE, WORST CASE EFFECT DOES NOT EXPERIENCE BIAXIAL BENDING.

3.5 SELF WEIGHT ANALYSIS

ANALYSES PRESENTED IN THE PRECEDING SECTIONS CONSIDERED BI-AXIAL MOMENT ARISING OUT OF SSE LOADING ONLY. NO COMPUTATIONS WERE PRESENTED FOR SELF-WEIGHT LOADING. THIS IS BECAUSE THE DUCTS LIE ESSENTIALLY IN A SINGLE PLANE, THUS MOMENTS EXIST CHIEFLY ABOUT ONE AXIS ONLY.

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 4 DATE: APRIL 21, 94 PAGE: 9

SUBJECT: 4.0 CONCLUSIONS BY: MAK CK: A.R. SHT: 1 OF 1

CONCLUSIONS

THE EFFECT OF BIAXIAL MOMENTS WAS EVALUATED. IT WAS FOUND THAT THE MOMENTS NOT CONSIDERED IN THE CALCULATIONS DONE IN [1] ARE INDEED NEGLIGIBLE AND PRODUCE VIRTUALLY NO EFFECT ON THE OVERALL STRESSES.

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 14 DATE: APRIL 19,1994 PAGE: 10

SUBJECT: 5.0 REFERENCES BY: MAK CK: A.R. SHT: 1 OF 1

1. HOPPER AND ASSOCIATES REPORT HA-05/89-686 "STRUCTURAL EVALUATION OF DUCTING SYSTEMS 2848-3, 4316-1, 4316-6, AND 4316-7", MAY 31, 1989.

Attachment 5 to
NRC-94-0050

HOPPER AND ASSOCIATES
ENGINEERS

DECO - USNRC DOCKET NO. 50-341

FERMI 2 CCHVAC DUCTING SYSTEMS

CONCERN ITEM NO. 6

EVALUATION CALCULATIONS

Prepared for: Detroit Edison Company
Nuclear Engineering Fermi 2
6400 North Dixie Highway
Newport, MI 48166

Prepared by: Hopper and Associates
300 Vista Del Mar
Redondo Beach, CA 90277

April, 1994

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 6 DATE: APRIL 21, 94 PAGE: i

SUBJECT: TABLE OF CONTENTS BY: MAK CK: G.R. SHT: 1 OF 1

TABLE OF CONTENTS

PREPARED BY: M. Amir Khan APRIL 21, 94

REVIEWED BY: Alex Reizman April 25, 1994

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 6 DATE: APRIL 20, 94 PAGE: 1

SUBJECT: 1.0 INTRODUCTION BY: MAK CK: O.R. SHT: 1 OF 2

1.1 PROBLEM STATEMENT

ON MARCH 3, 1994, THE U.S.N.R.C SUBMITTED DOCKET NO. 50-341 TO DETROIT EDISON CO. THIS DOCKET CONSISTS OF A REQUEST FOR ADDITIONAL INFORMATION ON FERMI 2 CCHVAC SYSTEM DESIGN AND OPERATION. IN PARTICULAR, THERE ARE SEVERAL CONCERNS REGARDING THE STRUCTURAL INTEGRITY CALCULATIONS, HA-05/89-686 AND HA-09/89-696, PERFORMED BY HOPPER AND ASSOCIATES. THIS PACKAGE IS PREPARED AS RESPONSE TO ONE OF THE COMMENTS POSED BY THE NRC REGARDING HA-05/89-686, NAMELY:

> The critical stresses and moments for plates in bending (representing the webs) did not consider the interaction with transverse compressive loading. These critical values may therefore be overestimated.

1.2 INVESTIGATION APPROACH

CRITICAL BUCKLING STRESSES CALCULATED IN HA-05/89-686 [1] WILL BE REVIEWED. PANEL BUCKLING CRITERIA ESTABLISHED AND USED IN [1] WILL ALSO BE REVIEWED AND DOCUMENTED. WHETHER OR NOT BUCKLING EVALUATION USED CONSERVATIVE CRITICAL STRESSES WILL BE INVESTIGATED.

AVAILABLE LITERATURE WILL BE REVIEWED TO EVALUATE THE CRITICAL STRESSES FOR PLATES UNDER COMBINED BENDING AND TRANSVERSE COMPRESSION. THESE STRESSES WOULD THEN BE CHECKED AGAINST THE ASSUMPTIONS UNDER WHICH BUCKLING ANALYSIS WAS DONE IN [1]. BASED ON THESE FINDINGS, IT WILL BE DETERMINED WHETHER BUCKLING ANALYSIS DONE IN [1] WAS CONSERVATIVE OR NOT.

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 6 DATE: APRIL 21, '94 PAGE: 4

SUBJECT: 3.0 ANALYSIS BY: MAK CK: A.R. SHT: 1 OF 8

3.1 EXISTING ANALYSIS

THE BUCKLING ANALYSIS CARRIED OUT IN [1] WAS DONE WITH ONE BASIC ASSUMPTION: BUCKLING OF A PANEL DUE TO COMPRESSION (AXIAL) IS MORE CRITICAL THAN BUCKLING DUE TO BENDING MOMENT (PURE BENDING OF PANELS REPRESENTING THE WEBS). IF IT WAS FOUND THAT AXIAL COMPRESSION OF PANELS (REPRESENTING FLANGES) WAS LARGE ENOUGH TO CAUSE BUCKLING, THE WEB PANELS WERE CONSERVATIVELY ASSUMED TO BE INEFFECTIVE IN CARRYING ANY LOAD. MAXIMUM PANEL STRESSES WERE THEN EVALUATED BASED ON THIS ASSUMPTION. THIS ASSUMPTION WAS BASED ON THE FACT THAT CRITICAL BUCKLING STRESS FOR PANELS UNDER PURE COMPRESSION IS 1/6 OF THE CRITICAL STRESS FOR PANELS UNDER PURE BENDING (SEE PAGES 62 & 66 OF [1]).

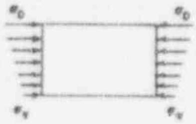
HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 6 DATE: APRIL 26, '94 PAGE: 5

SUBJECT: ANALYSIS BY: MAK CK: A.R. SHT: 2 OF 8

3. Rectangular plate under linearly varying stress on edges b (bending or bending combined with tension or compression)



3a. All edges simply supported

$$\sigma'_c = K\frac{E}{1-\nu^2}\left(\frac{t}{b}\right)^2$$

Here K depends on $\frac{a}{b}$ and on $\alpha = \frac{\sigma_o}{\sigma_o - \sigma_v}$ and may be found from the following table

	$\frac{a}{b}$ = 0.4	0.5	0.6	0.667	0.75	0.8	0.9	1.0	1.5
α = 0.5	K = 23.9	21.1	19.8	19.7	19.8	20.1	21.1	21.1	19.8
0.75	15.4		10.6		9.5	9.2		9.1	9.5
1.00	12.4		8.0		6.9	6.7		6.4	6.9
1.25	10.95		6.8		5.8	5.7		5.4	5.8
1.50	8.9		5.3		5.0	4.9		4.8	5.0
∞ (pure compression)	6.92		4.23			3.45		3.29	3.57

(Refs. 1, 6)

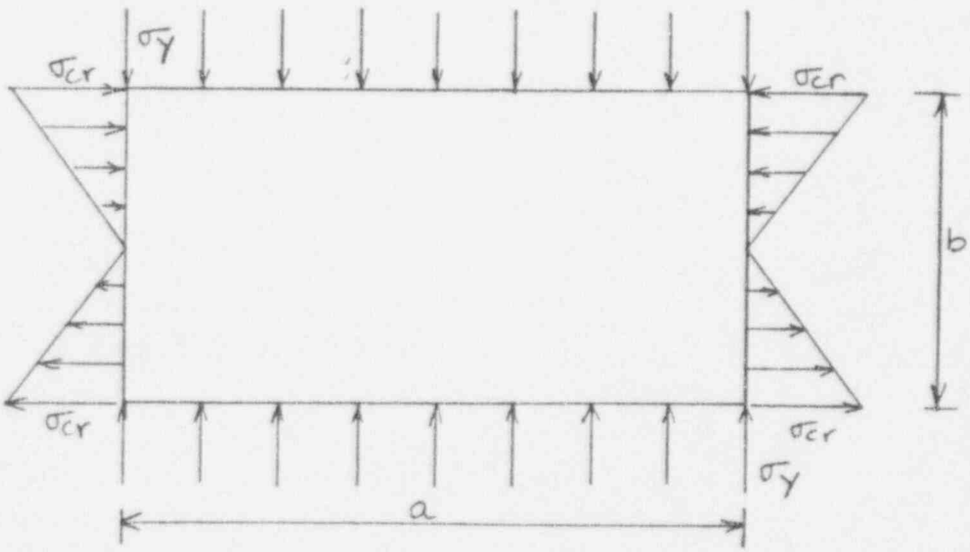
THE ABOVE TABLE, TAKEN FROM [4], ALSO DEMONSTRATES THE FACT THAT BUCKLING OF PLATES UNDER PURE COMPRESSION IS MORE CRITICAL THAN UNDER PURE BENDING. (FOR $\alpha = 0.5$ (PURE BENDING), K = 19.8, WHEREAS FOR $\alpha \to \infty$ (PURE COMPRESSION), K = 3.57 FOR THE CASE WHERE $a/b = 1.5$).

3.2 BUCKLING OF PLATE UNDER BENDING AND TRANSVERSE COMPRESSION

CRITICAL PANEL STRESSES WERE EVALUATED IN [1] FOR THE CASE OF PURE BENDING; TRANSVERSE COMPRESSION WAS IGNORED. IF THE EFFECT OF TRANSVERSE COMPRESSION IS INCLUDED, THIS CRITICAL STRESS WOULD BE REDUCED. HOWEVER, IF THIS REDUCED CRITICAL STRESS IS STILL GREATER THAN THE ONE CALCULATED FOR AXIAL COMPRESSION, THE STRESSES EVALUATED IN [1] WOULD STILL BE CONSERVATIVE (BY VIRTUE OF THE DISCUSSION PRESENTED IN THE PREVIOUS SECTION). LET US INVESTIGATE IF CONSERVATISM WAS EVER COMPROMISED IN THE ANALYSIS.

WE START OFF BY ANALYZING THE BUCKLING OF PLATES UNDER COMBINED BENDING AND TRANSVERSE COMPRESSION.

THE CLOSEST CASE WHICH HAS A CLASSICAL SOLUTION WAS FOUND IN [2], P.379:



FOR $\frac{\sigma_y}{4\pi^2 D/b^2 h} = 0.33$ AND $a = b$ (or $\frac{a}{b} = 1$)

THE REDUCTION IN σ_{cr} FROM THE CASE OF PURE BENDING IS 25%.

FOR OUR CASE,

$b = 14''$ & $16''$, $a = 29.5''$, $h = 0.0516''$

$$D = \frac{Eh^3}{12(1-\nu^2)} = \frac{29 \times 10^6 \times (0.0516)^3}{12(1-0.29^2)} = 362.5$$

ALSO,

FOR 14"x14" PANEL, $\frac{a}{b} = 2.1$

FOR 16"x16" PANEL, $\frac{a}{b} = 1.8$

INTERNAL NEGATIVE PRESSURE = 22" OF W.C.

= 0.795 psi

$$\sigma_{y_{14''}} = \frac{\left(\frac{14''}{2}\right)(0.795\text{psi})}{0.0516''} = 107.8 \text{ psi}$$

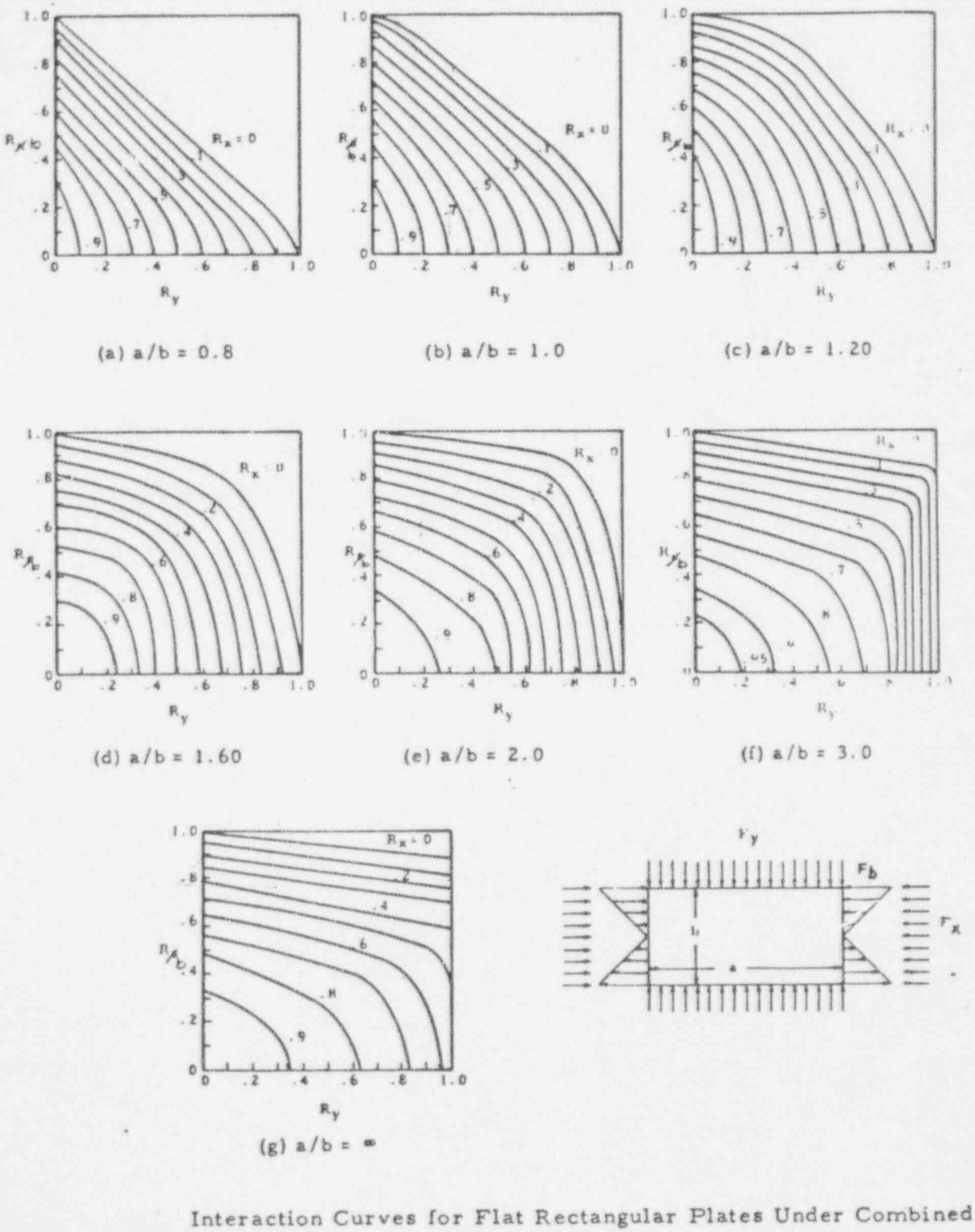
$$\therefore \frac{\sigma_y}{4\pi^2 D/b^2 h} = \frac{(107.8)(14)^2(0.0516)}{(4)(\pi)^2(362.5)}$$

= 0.08 (NOTE: FOR 16"x16" DUCT, THIS IS 0.09)

FOR RATIOS $\frac{a}{b} = 1$ AND $\frac{\sigma_y}{4\pi^2 D/b^2 h} = \frac{1}{3}$, REDUCTION IN σ_{cr} (PURE BENDING) = 25%. HOWEVER, THESE RATIOS ARE DIFFERENT FOR OUR CASE.

WE THEREFORE TURN TO REF [3] WHICH GIVES INTERACTION CURVES FOR PLATES UNDER COMBINED LOADING. FIGURE 3.2.1 ON THE NEXT PAGE SHOWS THE APPLICABLE CURVES.

9
6/8



Interaction Curves for Flat Rectangular Plates Under Combined Biaxial-Compression and Longitudinal-Bending Loadings

FIG. 3.2.1 [FROM[3]]

USE $\frac{a}{b} \simeq 1.6$ AND $R_y = \frac{\sigma_y}{4\pi^2 D/b^2 h} = 0.08$, $R_x = 0$

FROM FIG. 3.2.1, CURVE (e),

$$R_b = 0.95$$

HENCE, ONLY 5% REDUCTION IN σ_{cr} FROM THE CASE OF PURE BENDING.

TO CONFIRM THAT THESE CURVES DO INDEED CHECK AGAINST THEORY IN [2], WE WILL SOLVE THE PROBLEM WITH $\frac{a}{b} = 1$ AND $R_Y = \frac{\sigma_Y}{4\pi^2 D/b^2 h} = \frac{1}{3}$ (FROM [2]) USING THE CURVES HERE.

FROM FIG. 3.2.1 CURVE (b),

$$R_b = 0.80$$

OR, 20% REDUCTION IN σ_{cr} FROM THE CASE OF PURE BENDING. THIS MATCHES WELL WITH THE 25% GIVEN IN [2].

IT THEREFORE FOLLOWS THAT THE ANALYSIS DONE IN [1] WAS INDEED CONSERVATIVE, SINCE ONLY 5% REDUCTION IN σ_{cr} IS OBTAINED DUE

TO THE INCLUSION OF TRANSVERSE COMPRESSION. (NOTE: TO RENDER THE STRESS EVALUATIONS IN [1] UNCONSERVATIVE, THE REDUCTION SHOULD HAVE BEEN $(1-\frac{1}{6})\times 100$ = 83.33%, RATHER THAN THE 5% FOUND HERE).

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 6	DATE: APRIL 21, 94	PAGE: 12	
SUBJECT: 4.0 CONCLUSIONS	BY: MAK	CK: A.R.	SHT: 1 OF 1

CONCLUSIONS

THE EFFECT OF TRANSVERSE COMPRESSION ON PANELS (REPRESENTING THE WEB) IN BENDING HAS BEEN INVESTIGATED. IT WAS FOUND THAT THE ASSUMPTIONS UNDER WHICH ANALYSES IN [1] WERE CARRIED OUT WERE INDEED CONSERVATIVE, SINCE IT WAS ESTABLISHED THAT AXIAL COMPRESSION OF THE PANELS IS MORE CRITICAL THAN BENDING COMBINED WITH TRANSVERSE COMPRESSION. IN ALL CASES OF ANALYSIS IN [1], BUCKLING DUE TO AXIAL LOADING OCCURS BEFORE, OR CONCURRENT WITH, BUCKLING DUE TO BENDING.

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 6 DATE: APRIL 21, 1994 PAGE: 13

SUBJECT: 5.0 REFERENCES BY: MAK CK: a.R. SHT: 1 OF 1

REFERENCES

1. HOPPER AND ASSOCIATES REPORT "STRUCTURAL EVALUATION OF DUCTING SYSTEMS 2848-3, 4316-1, 4316-6, AND 4316-7" NO. HA-05/89-686, MAY 31, 1989.

2. TIMOSHENKO, S.P., AND GERE, J.M.; "THEORY OF ELASTIC STABILITY", SECOND EDITION, McGRAW-HILL BOOK CO., 1961.

3. MADDUX, G.E., VORST, L.A., GIESSLER, F.J., AND MORITZ, T.; "STRESS ANALYSIS MANUAL", AIR FORCE FLIGHT DYNAMICS LABORATORY, WRIGHT-PATTERSON AFB, OHIO; OCT '86.

4. YOUNG, W.C.; "ROARKS FORMULAS FOR STRESS AND STRAIN", McGRAW-HILL BOOK CO, 6TH ED.

Attachment 6 to
NRC-94-0050

HOPPER AND ASSOCIATES
ENGINEERS

DECO - USNRC DOCKET NO. 50-341

FERMI 2 CCHVAC DUCTING SYSTEMS

CONCERN ITEM NO. 7

EVALUATION CALCULATIONS

Prepared for: Detroit Edison Company
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6400 North Dixie Highway
Newport, MI 48166

Prepared by: Hopper and Associates
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April, 1994

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 7 DATE: APRIL '94 PAGE: i

SUBJECT: TABLE OF CONTENTS BY: LLV CK: A.R SHT: 1 OF 1

TABLE OF CONTENTS PG

PREPARED BY: LAURA L VENDEMIA 4/26/94 (SECTIONS 1.0 – 4.1, 5.0 – 6.0)
[signature]

CHECKED BY: Alex Reizman 5-5-94

PREPARED BY: M. Amir Khan (SECTION 4.2)

CHECKED BY: Alex Reizman 5-5-94

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 7 DATE: APRIL '94 PAGE: 1

SUBJECT: 1.0 INTRODUCTION BY: LLV CK: A.R SHT: 1 OF 2

1.0 INTRODUCTION

1.1 PROBLEM STATEMENT

ON MARCH 3, 1994, THE USNRC SUBMITTED DOCKET NO. 50-341 TO DETROIT EDISON COMPANY. THE ~~[illegible]~~ DOCKET CONSISTS OF REQUESTS FOR ADDITIONAL INFORMATION ON FERMI 2 CCHVAC SYSTEM AND DESIGN AND OPERATION.

DGJ 5-27-94

THIS PACKAGE IS PREPARED TO RESPOND TO CONCERN NO. 7:

The calculation of the edge membrane and bending stresses in panels did not include the seismic inertia loads acting on the panels.

1.2 INVESTIGATION APROACH

THE MAXIMUM PANEL SIZE WILL BE CONSIDERED, TO QUANTIFY THE INDIVIDUAL PANEL FREQUENCY. THE PANEL FREQUENCY WILL BE COMPARED TO THE SYSTEM FREQUENCY, AND THE ACTUAL ACCELERATIONS WILL BE EVALUATED FROM RESPONSE SPECTRA. THE INERTIAL FORCE WILL BE COMPARED TO THE DESIGN PRESSURE TO EVALUATE INERTIA EFFECTS.

1.3 RESULT SUMMARY

THE PANEL SEISMIC INERTIA IS EQUAL TO 3.1% OF THE DESIGN PRESSURE IN THE LATERAL DIRECTIONS USING THE ABSOLUTE SUMMATION METHOD FOR COMBINING MODAL ACCELERATIONS. IF THE SRSS METHOD FOR COMBINING MODAL ACCELERATIONS IS USED TO EVALUATE THE ACCELERATION, THE SEISMIC INERTIA FORCE EFFECT IS ONLY 1.7% OF DESIGN PRESSURE. ALTHOUGH SEISMIC INERTIA EFFECT WAS NOT CONSIDERED IN THE PREVIOUS ANALYSES, ITS EFFECT IS NOT SIGNIFICANT

2.0 SYSTEM DESCRIPTION

A TABLE REPRESENTING THE RECTANGULAR DUCT AT FERMI-2 IS SHOWN BELOW [1]

TYPE I DUCTWORK

RECTANGULAR DUCT - GALVANIZED OR STAINLESS STEEL

Duct Seam			Seam	Transverse Joint			Stiffener Between Joints		Remark
Size Range Max. Side	Met. Ga.	Sec. lgth. Max.	Longitudinal	Type	Angle Size	Tie Rods	Angle Size	Tie Rods	
0"-12"	18	60"	Brazed	Companion Angle	1½"x1½"x¼"	No	See Note #1	No	
* 13"-30"	18	60"	Brazed	Companion Angle	1½"x1½"x¼"	No	1½"x1½"x1/8" @2'-6"O.C.	No	
31"-36"	18	60"	Brazed	Companion Angle	1½"x1½"x¼"	No	1½"x1½"x1/8" @2'-6"O.C.	No	
37"-48"	18	60"	Brazed	Companion Angle	1½"x1½"x 3/8"	Yes	1½"x1½"x1/8" @2'-6"O.C.	Yes	
49"-60"	18	48"	Brazed	Companion Angle	1½"x1½"x 3/8"	Yes	1½"x1½"x1/8" @2'O.C.	Yes	
61"-90"	16	48"	Brazed	Companion Angle	2"x2"x 3/16"	Yes	2"x2"x3/16" @2'O.C.	Yes	
91"-96"	14	48"	Brazed	Companion Angle	2"x2"x 3/16"	Yes	2"x2"x3/16" @2'O.C.	Yes	
97"-Up	14	48"	Brazed	Companion Angle	2"x2"x 3/8"	Yes @48"	2"x2"x3/16"	Yes @48"	

Notes: 1. Transverse Joints are at intervals such that stiffening between joints is not required.

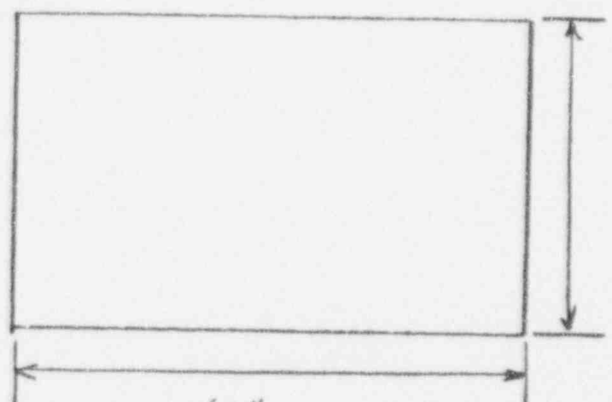
2. All round fittings to be two gauges heavier than duct (18 ga. duct = 14 ga. fittings) (16 ga. duct 12 ga fittings) (14 ga. duct 10 ga. fittings).

TABLE 2.1 DUCT SIZES

THE LARGEST DUCT SIZE IS 16" SQ (DUCTING SYSTEMS 4316-6, 4316-7)

FOR SIZE RANGE 13"-30", MAX SECTIONAL LENGTH IS 60" AND 18 GA.

THE MATERIAL FOR 16 GA AND LIGHTER IS ASTM A-527 [3]



[2] 18 GA = STANDARD 0.0478" t

GALVANIZED 0.0516" t

FIGURE 2.1 MAXIMUM PANEL SIZE

3.0 ANALYSIS APPROACH

3.1 ASSUMPTIONS

1) ASSUME MAXIMUM PANEL SIZE OF 60" x 16" x 0.0516" (GALVANIZED)

2) ASSUME RESPONSE SPECTRA FROM PREVIOUS CCHVAC EVALUATION HA 05789-686

3) ASSUME PANEL IS A PLATE

4) ASSUME VENDOR SPEC OF MAXIMUM PANEL (60") IS GREATER THAN FERMI SUPPORT LENGTH (CONSERVATIVE)

5) ASSUME 2% SPECTRA DAMPING, SAME AS PREVIOUS CCHVAC CALCULATIONS.

3.2 CALCULATION METHOD

TWO CASES OF PANEL FIXIVITY WILL BE CONSIDERED,

A) SIMPLY SUPPORTED SS/SS

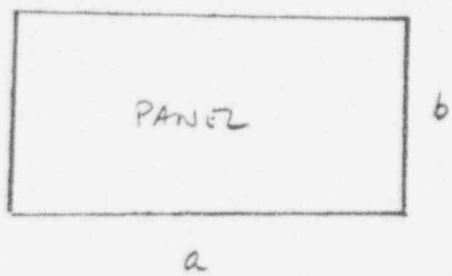
B) FIXED F/F

THE TRUE PANEL FIXIVITY WILL BE IN BETWEEN.

THE PANEL NATURAL FREQUENCY f_{11} WILL BE CALCULATED FROM FORMULAS FOR NATURAL FREQUENCIES AND MODE SHAPES [4]. THE INDIVIDUAL PANEL FREQUENCY WILL BE COMPARED TO THE SYSTEM FREQUENCY. IF THE PANEL FREQUENCY IS RIGID AS COMPARED TO THE SYSTEM FREQUENCY, THEN THE PANEL INERTIA EFFECTS WILL BE EVALUATED BASED ON ACTUAL ACCELERATIONS OF SPECIFIC NODES FROM THE PREVIOUS RESPONSE SPECTRUM [HA 05/89-686]. THE MAXIMUM ACCELERATION WILL BE USED TO EVALUATE THE INERTIA EFFECTS OF THE PANEL COMPARED TO THE DESIGN PRESSURE LOAD.

4.0 ANALYSIS

4.1 PANEL FREQUENCY DETERMINATION



$a = 60"$ b $16"$

$h = 0.0516"$

$\nu = 0.29$

$E = 29 \times 10^6$ psi

$\gamma = \rho h = 0.284 lb/in^3 (0.0516")/386.4$
= mass per unit area

[4] TABLE 11-4.16 SIMPLY SUPPORTED:

$= 3.79 \times 10^{-5}$

$$\lambda_{ij}^2 = \pi^2 \left[i^2 + j^2 \left(\frac{a}{b}\right)^2 \right] \quad \text{for } i = 1,\ j = 1$$

$$\lambda_{11}^2 = \pi^2 \left[1 + (3.75)^2 \right]$$

$$= 148.66$$

$$f_{ij} = \frac{\lambda_{ij}^2}{2\pi a^2} \left[\frac{E h^3}{12 \gamma (1 - \nu^2)} \right]^{1/2}$$

$$f_{11} = \frac{148.66}{2\pi (60)^2} \left[\frac{29 \times 10^6 (0.0516)^3}{12 (3.79 \times 10^{-5}) [1 - 0.29^2]} \right]^{1/2}$$

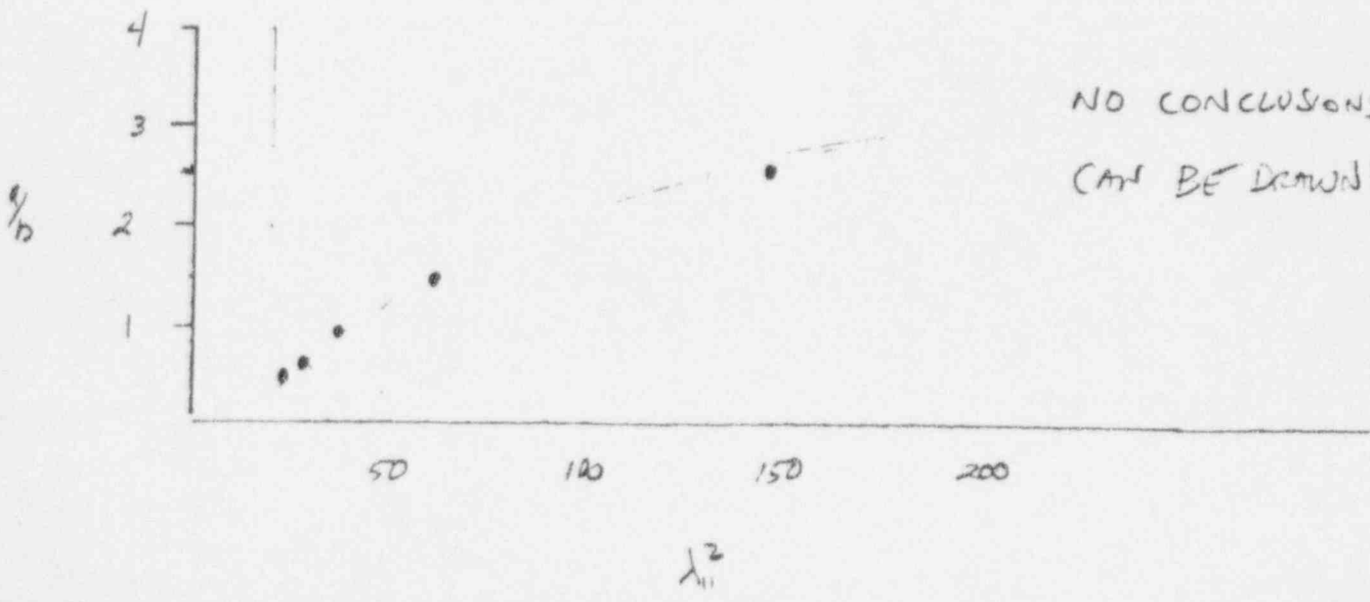
$$= (6.57 \times 10^{-3})(3103)$$

$= 20.39$ Hz SIMPLY SUPPORTED

FOR FIXED-FIXED, THE RATIO $a/b = 3.75$ IS NOT GIVEN TO EXACTLY FIND λ^2. THEREFORE IT WILL BE EXTRAPOLATED

TABLE 11-4.21 [4]

a/b	λ_{11}^2
0.4	23.65
0.66	27.01
1.0	35.99
1.5	60.77
2.5	147.80
3.75	?



NO CONCLUSIONS CAN BE DRAWN!

EQUATION 11-21 AND TABLE 11-5 [4] PROVIDE AN APPROXIMATE SOLUTION FOR PLATES

$$f_{ij} = \frac{\pi}{2}\left[\frac{G_1^4}{a^4} + \frac{G_2^4}{b^4} - \frac{2J_1J_2 + 2\nu(H_1H_2 - J_1J_2)}{a^2b^2}\right]^{1/2}\left[\frac{Eh^3}{12\gamma(1-\nu^2)}\right]^{1/2}$$

LET $i=j=1$ TABLE 11-5 [4]

BOUNDARY	G_1	G_2	J_1	J_2	H_1	H_2
SS/SS	1	1	1	1	1	1
F/F	1.506	1.506	1.248	1.248	1.248	1.248

	G_1^4/a^4	G_2^4/b^4	$2J_1J_2/a^2b^2$	$2\nu(H_1H_2-J_1J_2)/a^2b^2$	$\left[\frac{Eh^3}{12\gamma(1-\nu^2)}\right]^{1/2}$
SS/SS	7.72×10^{-8}	1.53×10^{-5}	2.17×10^{-6}	0	3103
F/F	3.97×10^{-7}	7.85×10^{-5}	3.38×10^{-6}	0	

TO CHECK THE APPROXIMATE EQUATION FOR S/S WITH THE PREVIOUS EXACT SOLUTION

$$f_{ss} = 20.43\ Hz$$

$$f_n = \frac{\pi}{2}\left[7.72\times10^{-8} + 1.53\times10^{-5} + 2.17\times10^{-6} + 0\right]^{1/2}(3103)$$

$$= \frac{\pi}{2}\left(1.65\times10^{-5}\right)^{1/2}(3103)$$

$$= \underline{\underline{20.46\ Hz}} \quad \text{SIMPLY SUPPORTED}$$

$$\text{ERROR} = \left|\frac{20.43-20.46}{20.43}\right|(100) = 0.15\%\ \text{ERROR USING APPROXIMATION}$$

SOLVE FOR FIXED-FIXED f_n

$$f_n = \frac{\pi}{2}\left[3.97\times10^{-7} + 7.85\times10^{-5} + 3.38\times10^{-6}\right]^{1/2}(3109)$$

$$= \frac{\pi}{2}\left[8.23\times10^{-5}\right]^{1/2}(3109)$$

$$= \underline{\underline{44.30\ Hz}} \quad \text{FIXED-FIXED}$$

THE SYSTEM FREQUENCIES ARE AROUND 10 Hz (HA 5189-686). THEREFORE THE PANEL IS RIGID COMPARED TO THE SYSTEM, SO THE ACTUAL SYSTEM ACCELERATIONS WILL BE USED TO EVALUATE PANEL INERTIA EFFECTS.

4.2 CRITICAL ACCELERATION DETERMINATION

AS WAS DEMONSTRATED IN THE PREVIOUS SECTION, THE INDIVIDUAL PANELS CONSTITUTE A HIGH FREQUENCY SYSTEM. WHEN WE COMPARE THIS FREQUENCY WITH THE NATURAL FREQUENCIES OF DUCTING SYSTEMS 4316-1 AND 4316-7, WE SEE THAT THE OVERALL SYSTEMS HAVE NATURAL FREQUENCIES MUCH LOWER THAN THE INDIVIDUAL PANELS. HENCE IT IS REASONABLE TO EVALUATE PANEL INERTIA EFFECTS BASED ON THE ACTUAL ACCELERATIONS OF THE POINTS (NODES) OF INTEREST (THESE ACCELERATIONS CAN BE EVALUATED FROM THE RESPONSE SPECTRUM ANALYSES CARRIED OUT IN HA-05/89-686 [6]). THE NODES OF INTEREST ARE THOSE WHERE MAXIMUM STRESSES WERE FOUND TO OCCUR IN THE PREVIOUS ANALYSES.

THE METHODOLOGY USED IS AS FOLLOWS:
FROM THE RESPONSE SPECTRUM ANALYSIS DONE ON THE COMPUTER USING ANSYS [5], THE

ACTUAL DISPLACEMENTS, FOR EACH LOAD CASE (i.e, E-W, N-S & VERTICAL SSE'S) FOR EACH MODE OF SYSTEM VIBRATION ARE AVAILABLE AT THE NODE OF INTEREST. USING SUFFICIENT NUMBER OF MODES TO ENSURE >90% MASS PARTICIPATION, THE FOLLOWING FORMULATION CAN BE APPLIED:

$$A_{Xi} = (2\pi f_i)^2 \left[U_{X1i}^2 + U_{X2i}^2 + U_{X3i}^2 \right]^{1/2}$$

$$A_{Yi} = (2\pi f_i)^2 \left[U_{Y1i}^2 + U_{Y2i}^2 + U_{Y3i}^2 \right]^{1/2}$$

$$A_{Zi} = (2\pi f_i)^2 \left[U_{Z1i}^2 + U_{Z2i}^2 + U_{Z3i}^2 \right]^{1/2}$$

AND,

$$A_X = \sum_{i=1}^{N} A_{Xi}$$ (UPPER-BOUND MAXIMUM ACCEL.).

$$A_Y = \sum_{i=1}^{N} A_{Yi}$$ (N SHOULD BE SUFFICIENT TO ENSURE >90% MASS PARTICIPATION)

$$A_Z = \sum_{i=1}^{N} A_{Zi}$$

WHERE,

A_{Xi}, A_{Yi}, A_{Zi} = ACCELERATIONS IN THE GLOBAL X, Y & Z DIRECTIONS FOR i^{th} MODE.

$U_{X1i}, U_{X2i}, U_{X3i}$ = DISPLACEMENTS IN THE GLOBAL X-DIRECTION FOR THE THREE LOAD CASES FOR MODE i. (SIMILAR FOR Y & Z).

BASED ON THIS, THE ACCELERATIONS FOR THE NODES OF INTEREST WERE EVALUATED FOR SYSTEMS 4316-1 & 4316-7, WHICH COMPRISE OF THE 14"X14" AND 16"X16" DUCTS RESPECTIVELY. NOTE THAT ONLY THE SIGNIFICANT MODES AND SIGNIFICANT LOADINGS ARE USED IN THE EVALUATION. ALSO, THE ACCELERATIONS COMPUTED HERE ARE CONSERVATIVE, UPPER-BOUND ESTIMATES BASED ON ABSOLUTE ALGEBRAIC SUMMATION OF INDIVIDUAL MODES.

RESULTS OF THE ANALYSES ARE PRESENTED IN TABLES 4.2.1 AND 4.2.2. IT CAN BE SEEN THAT THE WORST PANEL ACCELERATION FOR 4316-1 OCCURS LATERALLY AND EQUALS 1.74g (UPPER-BOUND). VERTICAL ACCELERATIONS WERE FOUND TO BE MUCH LOWER.
(NOTE: VERY MINOR DIFFERENCES IN NATURAL FREQUENCIES CAN BE SEEN BETWEEN THOSE IN TABLES 4.2.1 & 4.2.2 AND THE CORRESPONDING

	E-W DIRECTION				N-S DIRECTION			
FREQ, Hz	E-W EQ., in	N-S EQ., in	SRSS,in	ACCEL, g	E-W EQ., in	N-S EQ., in	SRSS, in	ACCEL, g
10.95	0.069	0.0055	0.069218856	0.847909803	0.0028	0.00022	0.00280863	0.034404853
15.437	0.0017	0.0024	0.002941088	0.071602941	0.000017	0.000024	0.00002941	0.000716029
15.636	0.0094	0.000055	0.009400161	0.234792172	0.0003	0.0000017	0.000300005	0.007493359
17.351	0.011	0.0023	0.011237882	0.345645178	0.00091	0.00018	0.000927631	0.028531293
21.275	0.0018	0.0038	0.004204759	0.194436265	0.000077	0.00016	0.000177564	0.008210909
34.24	0.000015	0.000033	3.62491E-05	0.004341724	0.000085	0.00019	0.000208147	0.024930661
39.306	0.000008	0.000032	3.29848E-05	0.0052063	0.00008	0.00032	0.000329848	0.052062995
41.965	0.00003	0.00006	6.7082E-05	0.012069179	0.00042	0.0009	0.000993177	0.17868907
48.211	0.000025	0.0001	0.000103078	0.02447675	0.00026	0.001	0.001033247	0.245354238
51.245	0	0.000006	0.000006	0.001609723	0	0.00003	0.00003	0.008048617
60.662	0.00000006	0.00000001	6.08276E-08	2.28682E-05	0.00005	0.00001	5.09902E-05	0.01916978

ACCEL, g'S = 1.742112902

ACCEL, g'S = 0.607611805

TABLE 4.2.1 **DUCTING SYSTEM 4316-1: MAXIMUM ACCELERATION OF NODE 22 (SSE)**

	E-W DIRECTION					N-S DIRECTION				
FREQ,Hz	E-W EQ., in	VERT. EQ., IN	N-S EQ., in	SRSS, in	ACCEL, g	E-W EQ., in	VERT. EQ., in	N-S EQ., in	SRSS, in	ACCEL, g
8.7587	0.00749	0.0000525	0.000755	0.00752814	0.05900162	0.0168	0.000118	0.00169	0.0168852	0.13233738
9.6804	0.00241	0.000014	0.000152	0.00241483	0.02311905	0.00291	0.000017	0.000184	0.00291586	0.02791582
12.744	0.000102	0.0000285	0.0000609	0.00012217	0.00202706	0.00491	0.00117	0.00251	0.00563712	0.09353317
20.376	0.0003	0.000057	0.00187	0.00189477	0.08036947	0.00195	0.00037	0.0121	0.0122617	0.52009864
21.226	0.000175	0.000026	0.000139	0.00022499	0.01035626	0.000811	0.000119	0.000647	0.00104427	0.04806671
25.591	0.00739	0.000014	0.00189	0.00762787	0.51035783	0.00059	0.00000112	0.00015	0.00060877	0.04073099
36.116	0	0.0000196	0.000159	0.0001602	0.02134854	0	0.000007	0.0000569	5.7329E-05	0.0076396
42.59	0.00038	0.00000844	0.0000336	0.00038158	0.07071202	0.000137	0.00000303	0.0000121	0.00013757	0.02549327
49.274	0	0	0.000171	0.000171	0.04241591	0	0	0.0000464	0.0000464	0.01150935
63.743	0.000013	0	0.00000456	1.3777E-05	0.00571877	5.55E-07	0	1.94E-07	5.8793E-07	0.00024405
75.022	0	0	0.0000372	0.0000372	0.02139032	0	0	0.0000728	0.0000728	0.04186062
87.544	0	0	0.00000478	0.00000478	0.00374264	0	0	0.00000106	0.00000106	0.00082996
100.57	0	2.37E-07	0.00000216	2.173E-06	0.00224536	0	0.0000003	0.00000276	2.7763E-06	0.00286876

ACCEL, g'S= 0.85280485

ACCEL, g'S= 0.95312831

TABLE 4.2.2 **DUCTING SYSTEM 4316-7: MAXIMUM ACCELERATION OF NODE 715 (SSE)**

VALUES REPORTED IN [6]. THIS DIFFERENCE, ON AN AVERAGE ABOUT 1%, MAY POSSIBLY BE ATTRIBUTED TO USING A DIFFERENT VERSION OF THE COMPUTER PROGRAM; SEE REF [5] HERE VS. REF [8] IN HA-05/89-686).

PRESSURE EFFECT ON THE PANEL (INERTIAL):

$$P_{INERTIAL} = \gamma_{STEEL} \cdot t \cdot A$$

$$= (0.28)(0.0576)(1.74g)$$

$$= 0.025 \text{ LB/IN}^2$$

PRESSURE USED IN THE ANALYSIS WAS 0.795 LB/IN²

$$\%P = \frac{0.025}{0.795}(100) = 3.1\%$$

IF, HOWEVER, THE SRSS METHOD IS USED (INSTEAD OF ABSOLUTE SUMMATION) TO EVALUATE THE ACCELERATION, THE SEISMIC INERTIA PRESSURE EFFECT AS A PERCENTAGE OF DESIGN PRESSURE IS ONLY 1.7%.

IT THEREFORE FOLLOWS THAT ALTHOUGH SEISMIC INERTIA EFFECT WAS NOT CONSIDERED IN THE PREVIOUS ANALYSES, ITS EFFECT IS NONETHELESS NOT SIGNIFICANT.

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 7	DATE: APRIL '94	PAGE: 17	
SUBJECT: 5.0 CONCLUSION	BY: LLV	CK: A.R.	SHT: 1 OF 1

CONCLUSION

THE SEISMIC INERTIA EQUIVALENT PRESSURE LOAD OF THE DUCT PANEL IS LESS THAN 3.1% OF THE DESIGN PRESSURE IN THE LATERAL DIRECTION USING ABSOLUTE SUMMATION TO EVALUATE THE ACCELERATIONS AND 1.7% OF THE DESIGN PRESSURE LOAD USING THE SRSS METHOD.

THESE PERCENTAGES ARE CONSIDERED NEGLIGIBLE, SINCE CONSERVATISM WAS USED TO FULLY ENVELOPE THE DUCT SYSTEMS. ALTHOUGH SEISMIC INERTIA EFFECTS OF THE INDIVIDUAL PANELS WAS NOT PREVIOUSLY CONSIDERED, ITS EFFECT IS DEMONSTRATED TO BE NEGLIGIBLE.

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 7 DATE: APRIL 94 PAGE: 18

SUBJECT: 6.0 REFERENCES BY: LLV CK: A.R. SHT: 1 OF 1

6.0 REFERENCES

1) DUCT CONSTRUCTION BROCHURE, ENRICO FERMI ATOMIC P.P. UNIT #2 3071-104-TYPE 1, THE ROBERT IRSAY COMPANY, PAGE DB-3, REV 1, 11/24/76.

2) MANUAL OF STEEL CONSTRUCTION, AISC, CHICAGO, 9TH ED, 6-2, 1989.

3) DUCT CONST. BROCHURE, 3071-104-QA LEVEL 1, PAGE DB-2, REV 4, 7/21/77.

4) BLEVINS, R.D, FORMULAS FOR NATURAL FREQUENCY AND MODE SHAPE, KRIEGER PUB. CO., FL, 1993.

5) SWANSON ANALYSIS SYSTEMS, INC; ANSYS COMPUTER PROGRAM REV. 4.4A.

6) HOPPER AND ASSOCIATES REPORT "STRUCTURAL EVALUATION OF DUCTING SYSTEMS 2848-3, 4316-1, 4316-6, AND 4316-7," HA-05/89-686, MAY 31, 1989.

Attachment 7 to
NRC-94-0050

HOPPER AND ASSOCIATES
ENGINEERS

SARGENT & LUNDY
ENGINEERS

CLIENT DETROIT EDISON CO.
PROJECT ENRICO FERMI JOB NO. 3988
DESIGN BY SGM DATE April 5, 1972
CHECKED BY HHS DATE 4/18/72 SHEET ___ OF ___

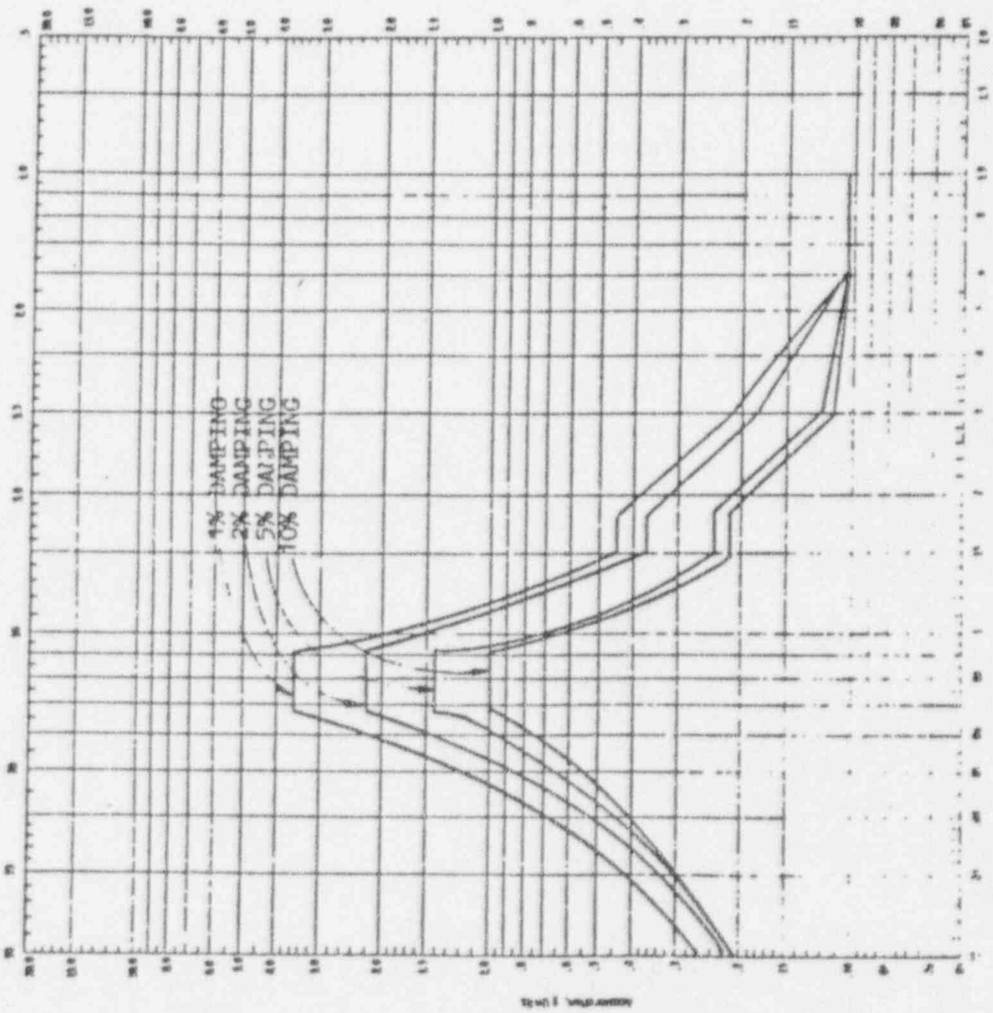


FIGURE C–19
VERTICAL RESPONSE SPECTRA
DESIGN BASIS EARTHQUAKE AUXILIARY BUILDING
SLAB EL. 643'–6" & 677'–6"

Design Basis Earthquake Vertical Direction

Figure 1

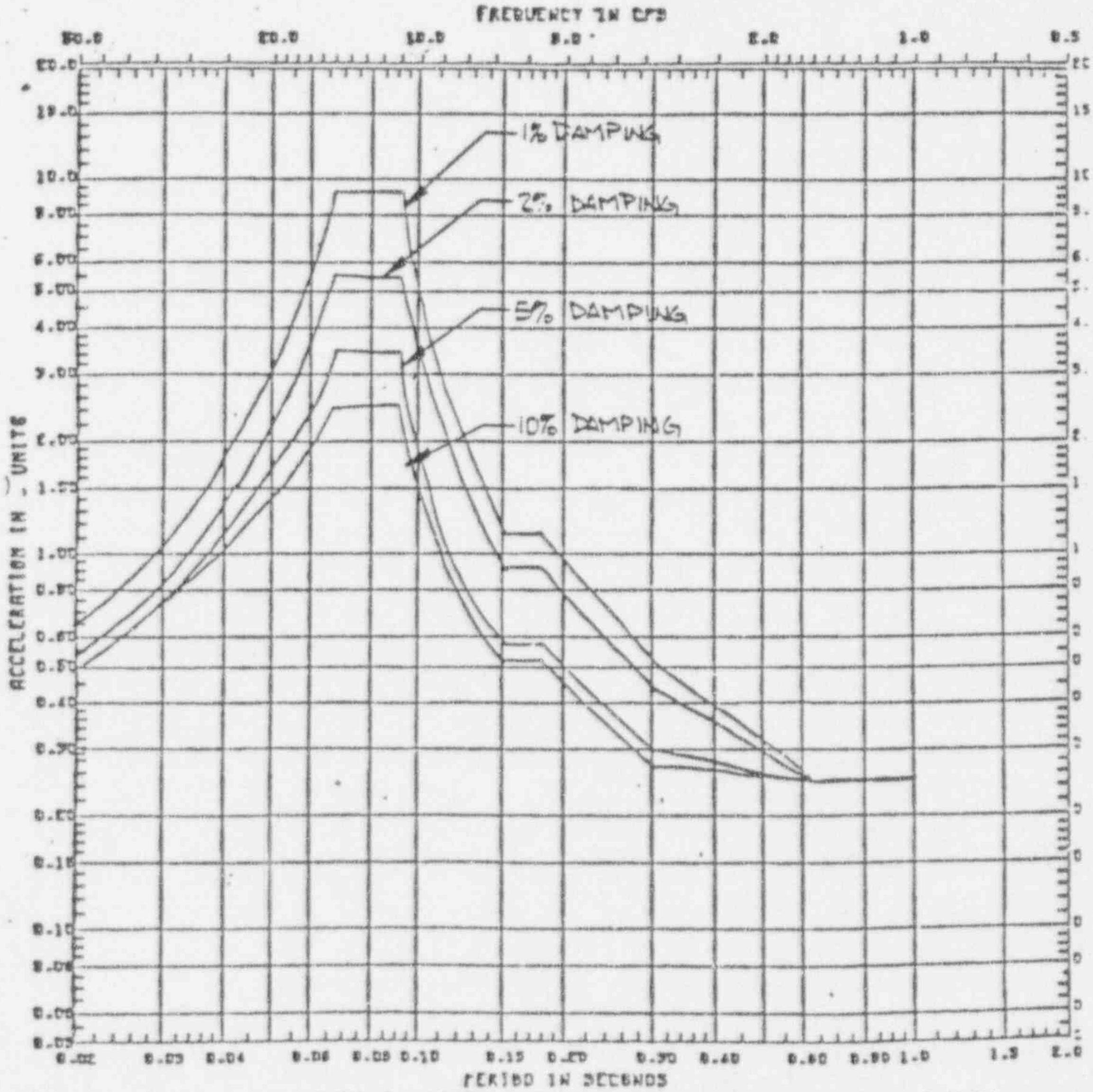
HOPPER AND ASSOCIATES
ENGINEERS

ENRICO FERMI UNIT 2

PREPARED BY: A. Krolikowski 10/21/81
A. KROLIKOWSKI DATE

SYSTEM ENGR: Y. Anand 11/4/81
Y. ANAND DATE

SITE SPECIFIC EARTHQUAKE 5% SITE DAMPING



REACTOR-AUXILLIARY BUILDING:RESPONSE SPECTRUM

SPECTRUM	NODE	ELEV	DIRECT	LOCATION
SES-C-19		643-6	VERT	AUXILLIARY BUILDING SLAB

FIGURE NO. SE5-C-19

Site Specific Earthquake Vertical Direction

Figure 2