Attachment 12 to
NRC-94-0050

HOPPER AND ASSOCIATES
ENGINEERS

DECO - USNRC DOCKET NO. 50-341

FERMI 2 CCHVAC DUCTING SYSTEMS

CONCERN ITEM NO. 16

EVALUATION CALCULATIONS

Prepared for: Detroit Edison Company
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Revision 1, May 1994

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REVISION 1

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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-09/89-696 performed by Hopper & Associates.

This package is prepared in order to respond to one of the comments posed by the NRC regarding HA 09/89-696. Namely,

> 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.

1.2 INVESTIGATION APPROACH

The 55 ducting systems analyzed by HA-09/89-696 will be reviewed, and the worst case circular duct size will be selected. The analysis approach used in analyzing the ducts will be presented. Imperfection limits and effects on circular ducts will be considered and included as a part of the analysis approach. A detailed calculation for a bounding circular duct will be performed in order to demonstrate the procedure used in determining the allowable pressure in HA-09/89-696. The effects of imperfections will be evaluated. In addition it shall be shown that the critical buckling strength of a thin tube under uniform lateral external pressure is enhanced (minimally) when interaction with simultanious compressive axial loads is considered. Thus the calculations in HA-09/89-696 considered only the seismic effect on the elastic stability of a thin walled circular tube.

SYSTEM DESCRIPTION

A worst case bounding system is selected to be,

2849-10 (DUCT SIZE 48¼" ø)

Geometrical properties of the duct are summarized below

[Ref 6]

SYSTEM	LOCATION	GAGE	THICKNESS*	
			GALVANIZED	BASE METAL
2849-10 (48¼" O.D)	SLAB 5	18	.0516"	.0478"

* Galvanized thickness was used in HA-09/89-696. To show that results will not be effected, bare metal thickness is used throughout this package.

The allowable design pressure in this system is -6" H_2O. [Ref 10]

3.1 LOAD CONDITIONS

1. DEAD LOAD + PRESSURE
2. DEAD LOAD + PRESSURE + SEISMIC

3.2 EXISTING ANALYSIS

An analysis of the ducting systems was performed by Fluor-Pioneer [Ref 1]. The results of these analyses are documented in form of design reports. All th structural evaluation work in HA-09/89-696 is based upon data contained in these design reports. The assumptions made by Fluor-Pioneer are summarized in HA-09/89-696.

3.3 LOAD FACTORS

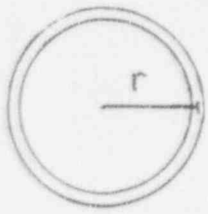
As discussed previously, the following load factors are used to magnify the Fluor-Pioneer Loads

SLAB 3: L.F. = 22

SLAB 5: L.F. = 20

3.4 DUCT CAPABILITY EVALUATION

3.4.1 DUCT PROPERTIES



$$I_{xx} = I_{yy} = \pi r^3 t$$

$$r = \frac{48\frac{1}{4}"}{2} = 24.125"$$

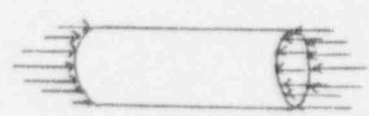
$$t = 0.0478" \quad (18\text{ gage})$$

$$I_{xx} = \pi (24.125)^3 (0.0478) = 2108 \text{ in}^4$$

3.4.2 BUCKLING STRESS [Ref 2, Pg 471]

The axial compressive buckling stress for a cylinder is given by Timoshenko,

$$\sigma_{cr} = E \frac{0.6\frac{h}{a} - 10^{-7}\frac{a}{h}}{1 + .004\frac{E}{\sigma_y}}$$



where,

$E = 29 \times 10^6$ psi

a = radius of duct

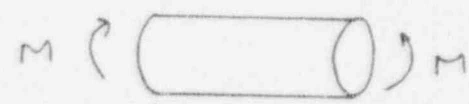
$h = .0478"$

$\sigma_y = 36{,}000$ psi

Solving,

$\sigma_{cr} = 7{,}818$ psi ← axial

Cylindrical bending buckling stress is determined from Figure 3.4.2.1 [Ref 3, Pg 8.40]



$\frac{L}{r} = \frac{60}{24.125} = 2.5$

$\frac{r}{t} = \frac{24.125}{.0478} = 505$

$\frac{\sigma_{cr}}{E} = .21 \times 10^{-3}$

$\sigma_{cr} = .21 \times 10^{-3} \times (29 \times 10^{6}\ \text{psi})$

$= 6090$ psi ← bending

It should be noted that the above critical values are based on experimental results, and thus implicitely include the effects of imperfections. For example, the theoretical solution for an axially compressed cylinder is

$\sigma_{cr} = \frac{E t}{r\sqrt{3(1-\nu^2)}}$ [Ref 2, Pg 467] which for our case corresponds to,

$$\sigma_{cr} = \frac{(29 \times 10^6)(.0478)}{24.125\,(3(1-.29^2))^{1/2}} = 34,663 \text{ psi}$$

Therefore the ratio between the theoretical value and the value used in the analysis is

$$\frac{34,663}{7,818} = 4.43$$

[Ref 3]

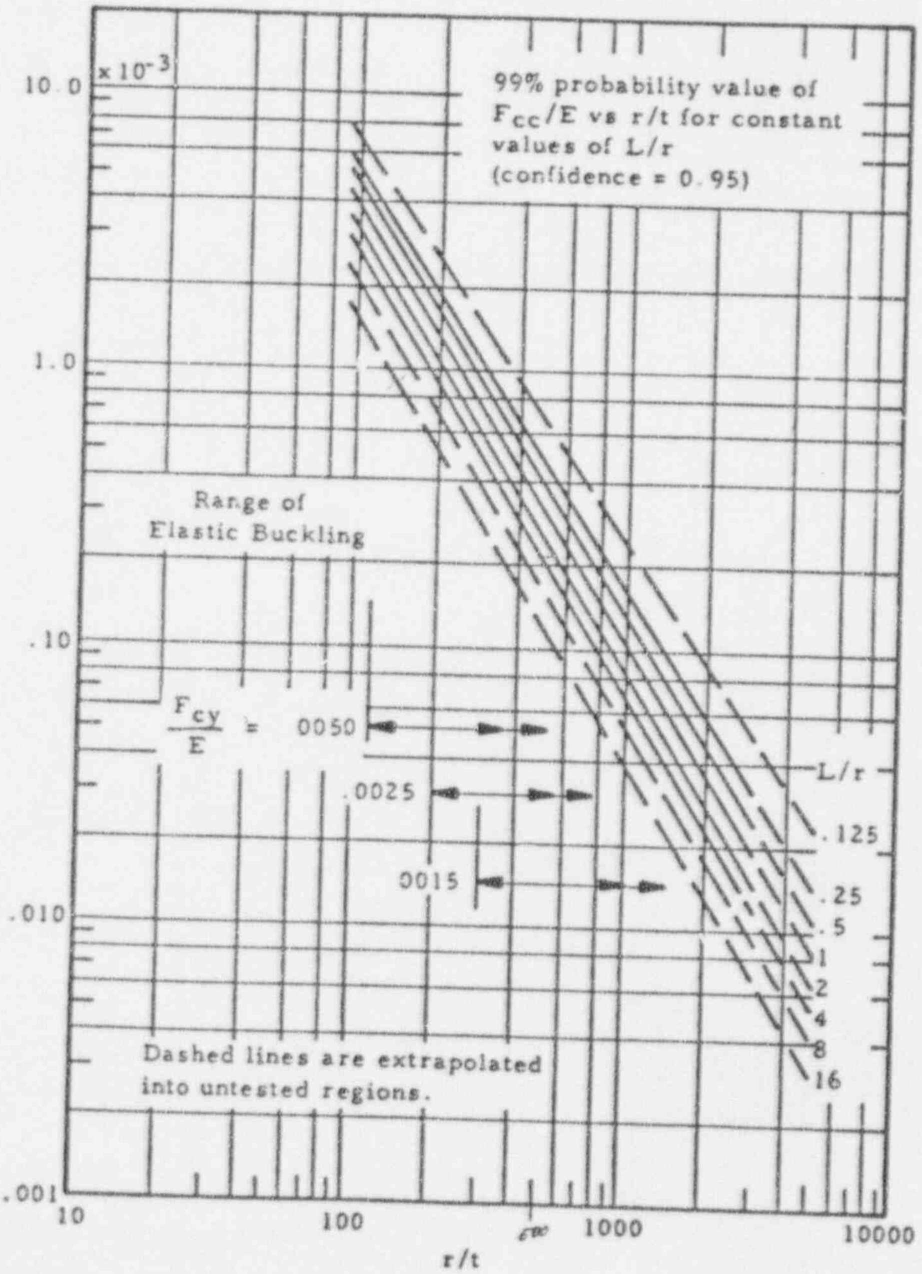


FIGURE 3.4.2.1. CIRCULAR CYLINDER IN PURE BENDING.

3.5 PRESSURE CAPABILITY PROCEDURE

Circular duct dimensions are based upon the diameter of the duct and the stiffner spacing. The allowable pressure is controlled by the longitudinal critical buckling stress.

The stresses arising from Dead-Weight and Seismic loading are conservatively subtracted from the critical pure bending stress. The remaining stress is allowed to be taken up by internal pressure.

3.6 Applied Loads [Ref 1]

From Fluor-Pioneer Output

Deadweight,

$M_x = 0$ ft# (Torsion)

$M_y = 0$ ft#

$M_z = 336$ ft#

Seismic, including Load Factor multiplier,

$M_x = 0\,(20) = 0$ ft# (Torsion)

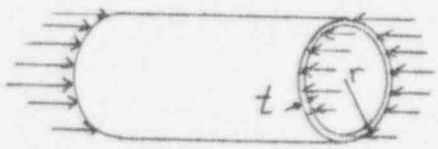
$M_y = 65.5\,(20) = 1310$ ft#

$M_z = 60.5\,(20) = 1210$ ft#

3.7 EFFECT OF IMPERFECTION EVALUATION

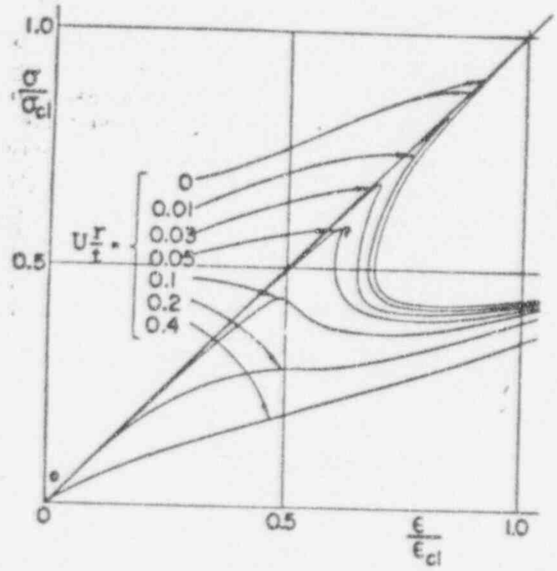
In the case of thin cylindrical shells there always exist some initial deflections and other imperfections. The effect of these imperfections is to reduce the critical buckling strength of the circular ducts. Imperfections play a role for both axial compression and and external pressure.

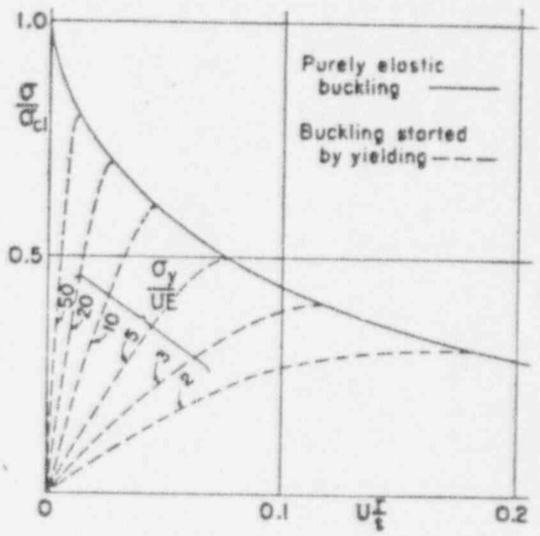
AXIAL COMPRESSION



From [Ref 7, Pg 73], the reduction in strength depends on an "unevenness" factor U. A reasonable range for factor U is given at .0002 to .001. The value of U necessary to explain most of the experimental cylinder strengths is around .0002.

From [Ref 7],





For our case,

$r = \frac{48.25}{2}$ inch $= 24.125''$

$t = .0478$ inch

Take $U = .001$ the lower bound value,

$$U\frac{r}{t} = \frac{.001\ (24.125)}{.0478} = .505$$

From the above curves, the values asymptote to, $\frac{\sigma}{\sigma_{cl}} \approx .3$

σ_{cl} = Critical stress for perfect shape and elasticity

σ = average axial stress

The 0.3, can be viewed as a correction factor. The imperfection safety factor is

$$S.F._1 = \frac{1}{0.3} = \underline{3.3}$$

From [Ref 8, Pg 48], the lower bound equation for the correction factor is given as

$$C = 1 - 0.9\left(1 - e^{-\frac{1}{16}\sqrt{\frac{r}{t}}}\right)$$

$$\frac{r}{t} = \frac{24.125}{.0478} = 505$$

$$C = .32$$

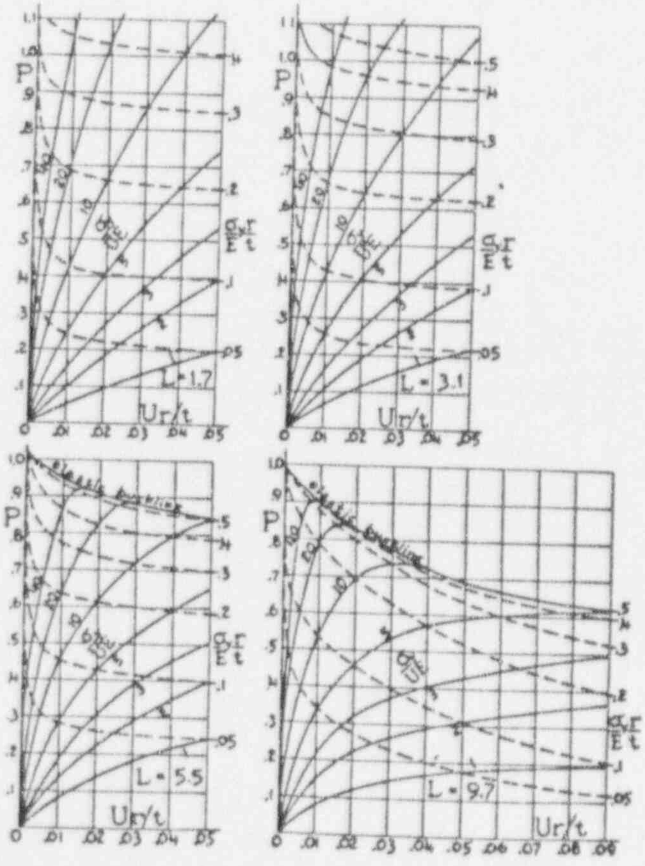
or,

$$S.F._2 = \frac{1}{.32} = \underline{3.13}$$

EXTERNAL PRESSURE

Using the same method as in the case of axially compressed cylindrical shells it was shown that imperfections do not produce so great a reduction in critical pressure as was found for the case of axial compression. [Ref 2, Pg 482]

From [Ref 9, Pg 568-575], as for axially compressed cylinders, the reduction in critical pressure depends on an "unevenness" factor U. a reasonable range of U is given as .0001 to .0005. The following curves are also published,



where

$$L = \frac{\ell}{\sqrt{rt}}$$

σ_y = 36,000 psi

E = 29×10^6 psi

r = 24.125 inch, radius of duct
t = .0478 inch.

$$P = \frac{r^{3/2}\ell}{t^{5/2}}\frac{p}{E} = \frac{p}{p_{cr}}$$

ℓ = 60", distance between stiffners or length of cylinder

U = .0005, lower bound factor

Now,

$$\frac{Ur}{t} = \frac{.0005\,(24.125)}{.0478} = 0.25$$

$$\frac{\sigma_y}{UE} = \frac{36{,}000}{(.0005)(29 \times 10^6)} = 2.5$$

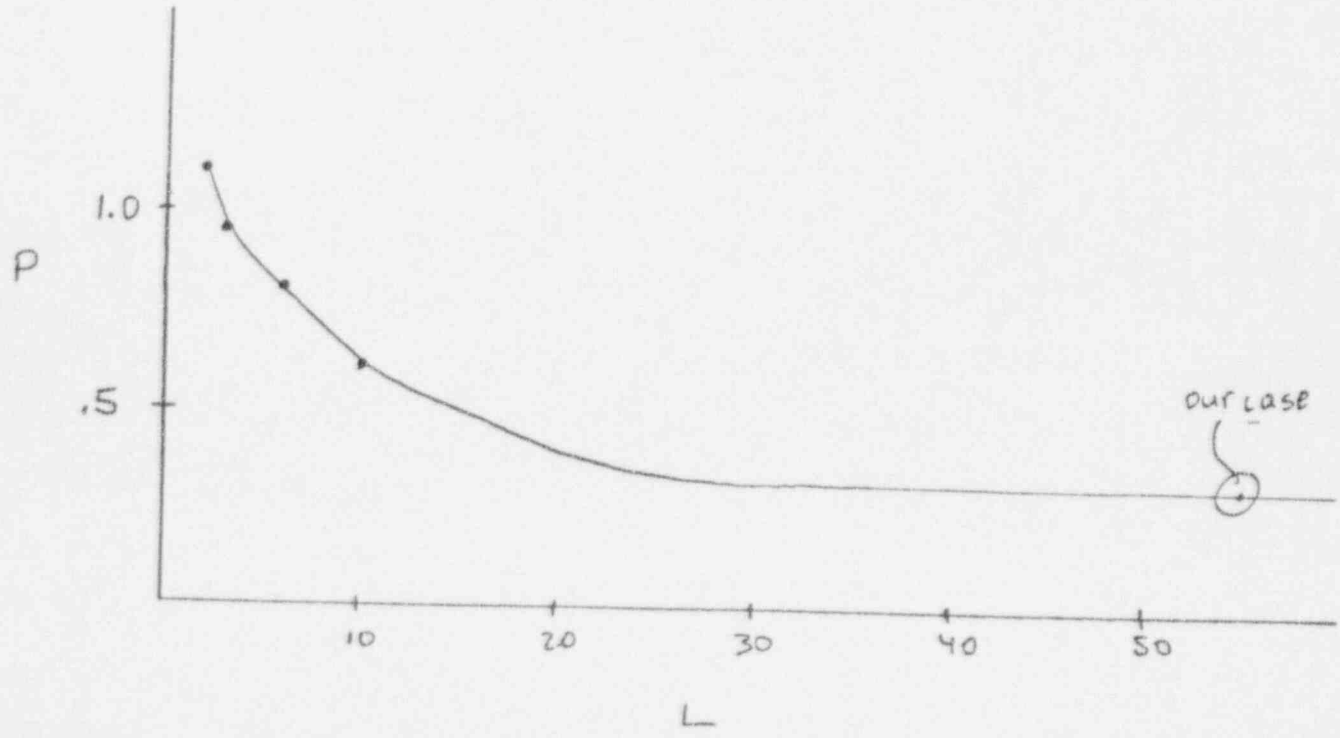
$$\frac{\sigma_y r}{E t} = \frac{(36{,}000)(24.125)}{(29 \times 10^6)(.0478")} = 0.63$$

$$L = \frac{60"}{\sqrt{(.0478)(24.125)}} = 55.8$$

From the calculated dimensionless factors and the the four charts, the P versus L relation is determined.

L	P
1.7	~1.1
3.1	~.95
5.5	~.8
9.7	~.6

Plotting L vs P



It appears that P approximately asymptotes to 0.3. But the validity of this is questionable because the factors used in this package are off the charts.

A more useful and generic bound is found from [Ref 8, Pg.49], where the correction factor is reported as

$C = .75$, for all values of R/t

Thus, the safety factor is

$$S.F._3 = \frac{1}{.75} = \underline{1.33}$$

The "Industrial Duct Construction Standards" published by SMACNA [Ref 5, Pg 7.8], accounts for various imperfections such as, lack of roundness, by a bounding safety factor obtained from,

$$S.F. = \frac{(52 + D)}{14}, \quad D = 48.125''$$

$$S.F. = 7.15$$

although the SMACNA safety factor is significantely larger than other references, it will be used in this package as a bounding value for all types of loading.

4.1 ANALYSIS OF 48 1/4" ϕ DUCT

DW + Pressure

$M_x = 0$ ft# $M_y = 0$ ft# $M_z = 336$ ft#

$$\sigma_{DW} = \frac{(M_x + M_z)(12)(D)}{2(I)}$$

$$= \frac{(336)(12)(48\tfrac{1}{4})}{2(2108)}$$

$$= 46 \text{ psi} \ll \sigma_{cr} = 6090 \text{ psi}$$

∴ no buckling

Now,

$$\sigma_{cr} - \sigma_{DW} = \frac{pr}{2t}$$

$$p = \frac{(6090 - 46) \times 2 \times (.0478)}{(24.125)}$$

$$p = 24.0 \text{ psi}$$

To account for various imperfections such as, lack of roundness, a bounding safety factor as discussed in Section 3.7 of this package, is used. Where,

S.F. = 7.15

$$P_{all} = \frac{\left(\frac{6090}{7.15} - 46\right) \times 2 \times (.0478)}{(24.125)}$$

P_{all} = 3.2 psi

Without explicitely accounting for imperfections, the allowable pressure is total vacuum,

p = 14.7 psi or 407" H_2O

With imperfections,

p = 3.2 psi or 88" H_2O

DW + Seismic + Pressure

$M_x = 0\ ft\#$ $M_y = 1310\ ft\#$ $M_z = 1210\ ft\#$

$$\sigma_s = \frac{(1310+1210)(12)(48\tfrac{1}{4}")}{2(2108)}$$

$= 345$ psi

$= 345$ psi $< 6{,}090$ psi

∴ no buckling

Now,

$$\sigma_{cr} - \sigma_{DW} - \sigma_s = \frac{pr}{2t}$$

$$6090 - 46 - 345 = \frac{p(24.125)}{2(.0478)}$$

$p = 22.6$ psi use 14.7 psi or 407" H_2O

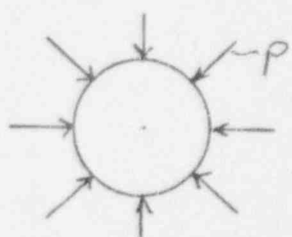
Dividing by the safety factor

$$p_{all} = \frac{\left(\frac{6090}{7.5} - 46 - 345\right) \times 2 \times (.0478)}{(24.125)}$$

$p_{all} = 1.83$ psi or 50" H_2O

The results indicate that for the given DW and Seismic loading the system is capable of withstanding an allowable pressure of 1.83 psi. It does not however mean that buckling will not occur. If buckling of the duct due to internal pressure is taken as the limiting criteria, then the critical allowable pressure will be,

$$P_{cr} = .807 \frac{Et^2}{Lr}\left[\left(\frac{1}{1-\nu^2}\right)^3 \frac{t^2}{r^2}\right]^{1/4}$$ [Ref 4, TAB. 35, 19b]



L = 60", distance between stiffners [Ref 6]

t = .0478"

ν = .29

r = 24.125"

$$P_{cr} = .807 \frac{(29\times10^6)(.0478)^2}{(60)(24.126)}\left[\left(\frac{1}{1-.29^2}\right)^3\left(\frac{.0478}{24.125}\right)^2\right]^{1/4}$$

$P_{cr} = 1.76$ psi or 48.7" H_2O

By including the safety factor we get

$$P_{cr} = \frac{1.76}{7.15}$$

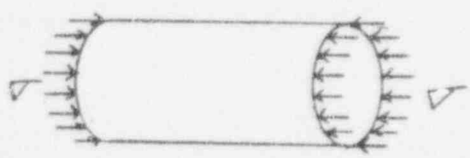
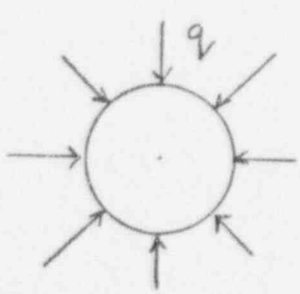
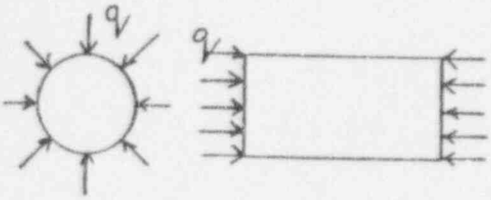
$P_{cr} = .246$ psi or 6.8" H_2O > 6" H_2O

In fact, for any circular duct, the transverse, pressure induced, critical buckling stress is going to be the controlling failure mode, not the longitudinal, seismic induced, stresses.

For an allowable pressure of 11.3" H_2O, at 18 gage the maximum duct size is 37" diameter

4.2 TRANSVERSE AND LONGITUDINAL PRESSURE INTERACTION

[Ref 4, Pg 690] presents a solution for a thin tube under longitudinal and transverse pressure, the effect of each force component and their interaction is summarized below.

	THEORY	FOR 48 1/4" ϕ
	$\sigma_{cr} = \frac{Et}{r\sqrt{3(1-\nu^2)}}$	34,663 psi
	$q_{cr} = \frac{.862E}{\left(\frac{l}{r}\right)\left(\frac{r}{t}\right)^{2.5}}$	1.76 psi
	$q_{cr} = \frac{.92E}{\left(\frac{l}{r}\right)\left(\frac{r}{t}\right)^{2.5}}$	1.88 psi

From the summary table it is clear that the critical condition is the tube under transverse pressure alone. And in fact, longitudinal pressure enhances minimally the tube capability.

CONCLUSIONS

In response to a comment posed by the NRC in Docket No. 50-341, a more detailed procedure for calculating allowable pressure, as published in HA-09/89-696, is presented. This is achieved by selecting a representative round ducting system and performing a detailed calculation to determine the allowable pressure.

It was found that the inclusion of a bounding imperfection factor reduces the allowable pressure dramatically. also , the longitudinal stresses introduced by seismic loading, are never the controlling capacity parameter. Thus the design system pressure, will remain as the ultimate allowable pressure.

HOPPER AND ASSOCIATES
ENGINEERS

HA-05/94-0812
Revision 1

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 16 DATE: APR 94 PAGE: 28

SUBJECT: 6.0 REFERENCES BY: A.R. CK: LLV SHT: 1 OF 2

REFERENCES

1. Fluor-Pioneer, Inc. Design Reports on Microfilm Rolls "AA" Through "AH", Project 10-4221, Client: Robert Irsay (Microfilm Rolls are on file with DECo.)

2. Timoshenko & Gere. "Theory of Elastic Stability", 2nd Edition, McGraw-Hill, 1961.

3. Maddux, Vorst, Giessler & Moritz. "Stress Analysis Manual", Technical Report AFFDL-TR-69-42, Wreight-Patterson AFB, Ohio, 1970.

4. Young. "Roark's Formulas for Stress and Strain", 6th Edition, McGraw-Hill, 1989.

5. SMACNA, "Round Industrial Duct Construction Standards", SMACNA, 1977.

6. R I Co, "Duct Construction Brochure Enrico Fermi Atomic P.P #2 3071-104-Type I", (Edison File 89-686)

7. Donnell & Wan, "Effect of Imperfections on Buckling of Thin Cylinders and Columns Under Axial Compression", Journal of Applied Mechanics, Vol. 17 No. 1, 1950.

8. Popov & Medwadowski, "Concrete Shell Buckling", ACI Publication SP-67, ACI 1981.

9. Donnell, "Effect of Imperfections on Buckling of Thin Cylinders Under External Pressure", Journal of Applied Mechanics, Vol. 23 No. 4, 1956.

10. FAX from Dave Jax at DECo on MAY 24, 1994

Attachment 13 to
NRC-94-0050

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DECO - USNRC DOCKET NO. 50-341

FERMI 2 CCHVAC DUCTING SYSTEMS

CONCERN ITEM NO. 17

EVALUATION CALCULATIONS

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ENGINEERS

CALCULATION SHEET

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PREPARED BY : H. E. Ker APRIL 12, 1994

CHECKED BY : M. Amir Khan April 20, 1994

1.0 PROBLEM STATEMENT

THE UNITED STATES NUCLEAR REGULATORY COMMISSION (USNRC) HAD IDENTIFIED NUMEROUS CONCERNS ON THE FERMI 2 - CCHVAC SYSTEM OF DETROIT EDISON COMPANY [4]. ONE OF THESE CONCERNS IS REGARDING THE SS DUCTS SYSTEM EVALUATED IN HOPPER AND ASSOCIATES REPORT HA-09/89-696 . [2]

THIS PACKAGE IS PREPARED IN RESPONSE TO ONE OF THE USNRC COMMENTS ON THE AFORESAID REPORT AS FOLLOWING: "THE REPORT 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 ($0.9 S_Y$) UNDER THE SSE LOADING CONDITIONS."

2.0 COMMENT RESPONSE APPROACH

THE DOCUMENTED STRUCTURAL EVALUATION OF CCHVAC DUCTING SYSTEM [2] SHALL BE REVIEWED. STRESSES OF ALL THE RECTANGULAR DUCTS DUE TO VARIOUS LOADINGS WILL BE SUMMARIZED. THE MAXIMUM REDISTRIBUTED STRESS UNDER SITE SPECIFIC EARTHQUAKE CONDITIONS (SSE) FOR EACH SYSTEMS SHALL THEN BE COMPARED TO THE ALLOWABLE STRESS.

3.0 RESPONSE SUMMARY

WITH AN EXCEPTION OF A NON-ESSENTIAL DUCTING SYSTEM NO. 2849-1 (DUCT 12x8), THE MAXIMUM REDISTRIBUTED STRESS IS LESS THAN THE 0.9 S_Y ALLOWABLE UNDER SSE CONDITIONS. THIS IS TRUE FOR ALL THE RECTANGULAR DUCTS IF THESE DUCTINGS ARE OPERATING WITHIN THE ESTABLISHED PERMISSIBLE PRESSURE.

4.0 DUCTING EVALUATION PROCEDURE.

AN ANALYSIS FOR EACH OF THE 55 DUCTING SYSTEMS WAS PERFORMED BY FLUOR PIONEER, INC. AND RESULTS WERE DOCUMENTED IN THE ORIGINAL DESIGN REPORTS [1]. STRUCTURAL EVALUATION OF DUCTING SYSTEMS COMPLETED BY HOPPER AND ASSOCIATES [2] WAS BASED UPON ANALYSIS RESULTS CONTAINED IN THE ORIGINAL DESIGN PACKAGE. TWO LOADING CONDITIONS WERE CONSIDERED IN THE EVALUATION :

(a) SELF - WEIGHT PLUS PRESSURE

(b) SELF - WEIGHT PLUS SEISMIC PLUS PRESSURE

ALL THE DUCT LOADS DUE TO SELF-WEIGHT AND EARTHQUAKE WERE TAKEN FROM THE FLUOR PIONEER'S REPORT. THE SEISMIC LOADS WERE MODIFIED AS FOLLOWING :

(a) FOR A RIGID DUCTING SYSTEM, A SEISMIC FACTOR

$$S = \frac{\text{ZERO PERIOD ACCELERATION OF SITE SPECIFIC EARTHQUAKE(SSE)}}{\text{ZERO PERIOD ACCELERATION OF OPERATING BASIS EARTHQUAKE(OBE)}}$$

WAS APPLIED.

(b) FOR SOME DUCTING SYSTEMS, IT WAS CONCLUDED THAT A RIGID RESPONSE MIGHT NOT BE CONSERVATIVE IN ALL CASES. THUS, IT WAS ASSUMED THAT SOME OF THE RIGIDLY CLASSIFIED DUCTING SYSTEMS WILL RESPOND AT THE WORST RESONANT FREQUENCY. A DYNAMIC CORRECTION FACTOR D WAS ESTABLISHED TO TAKE ANY FREQUENCY SHIFTS OF THE DUCTING SYSTEMS INTO ACCOUNT. THE FACTOR D IS DEFINED AS:

$$D = \frac{\text{PEAK RESPONSE ACCELERATION (SSE)}}{\text{ZERO PERIOD ACCELERATION (SSE)}}$$

WITH THE COMPUTATION OF THE FACTORS S AND D, THE NEW SEISMIC LOADS CAN BE CALCULATED AS:

NEW LOADS = (ORIGINAL LOADS)(S)(D)

OR

= (ORIGINAL LOADS)(S)

DEPENDING UPON THE LOCATION OF THE DUCTWORK AND THE DIRECTION OF SEISMIC EXCITATION.

THEN, DUCT STRESSES WERE CALCULATED FROM THE DUCT DEAD LOAD PLUS THE MODIFIED SEISMIC LOAD AND COMPARED TO THE CRITICAL BUCKLING STRESS OF THE DUCT. IF NO BUCKLING OCCURED, THE MEMBRANE AND BENDING STRESSES IN THE DUCT WERE COMPARED DIRECTLY TO THE STRESS REQUIREMENTS OF ANSI/ASME N509-1980, PARAGRAPH 5.10.3.3:

(a) ALLOWABLE STRESS DURING NORMAL PLANT OPERATION = 0.6 OF YIELD STRESS

(b) ALLOWABLE STRESS FOR SELF-WEIGHT PLUS SEISMIC LOADS PLUS PRESSURE = 0.9 OF YIELD STRESS.

ONCE THE ALLOWABLE STRESSES AND THE OPERATIONAL STRESSES DUE TO SELF-WEIGHT AND SEISMIC LOADS WERE ESTABLISHED, THE MAXIMUM PERMISSIBLE INTERNAL PRESSURE CAN BE DETERMINED. IF BUCKLING OCCURED, THE YIELD WILL TAKE PLACE LOCALLY AT THE CORNERS OF DUCT AND STRESS WILL BE REDISTRIBUTED. THE LOAD CARRYING CAPACITY WILL THEN BE PERFORMED BY MEMBRANE ACTION ALONE THE RESULTING PRIMARY MEMBRANE STRESSES ARE LESS THAN 0.9 S_y.

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

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SUBJECT: STRESSES SUMMARY OF RECT. DUCTS BY: HKK CK: MAK SHT: 1 OF 8

5.0 STRESSES SUMMARY OF RECTANGULAR DUCTS

STRESSES OF ALL THE RECTANGULAR DUCTS DUE TO DEAD LOAD, EARTHQUAKE, AND PRESSURE ARE SUMMARIZED AND PRESENTED IN TABLE 5.0.1

THE MAXIMUM REDISTRIBUTED STRESS FOR EACH DUCTING SYSTEMS IS OBTAINED AS FOLLOWING :

(a) SUMMATION OF STRESSES DUE TO DUCT DEAD WEIGHT PLUS EARTHQUAKE AND STRESSES DUE TO PRESSURE :

$\Rightarrow (S_{dw} + S_{eq}) + (S_b + S_m)$

OR

(b) SUMMATION OF STRESS ON POST BUCKLING EFFECTIVE AREA AND STRESSES DUE TO PRESSURE :

$\Rightarrow S_{max} + (S_b + S_m)$

THE TABULATED MAXIMUM REDISTRIBUTED STRESS OF ALL RECTANGULAR DUCTING SYSTEMS IS COMPARED TO THE 0.9 OF YIELD STRESS. THE RESULTS

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CALCULATION SHEET

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SHOW THAT WITH AN EXCEPTION OF A NON-ESSENTIAL DUCTING SYSTEM (SYSTEM NO. 2849-1 , DUCT 12x8), MAXIMUM REDISTRIBUTED STRESS OF ALL RECTANGULAR DUCTINGS IS ± 0.02% DIFFERENT FROM THE $0.9 S_y$. THUS, IT IS CONCLUDED THAT THESE STRESSES ARE EQUAL. THE MAXIMUM REDISTRIBUTED STRESS IS LESS THAN THE $0.9 S_y$ ALLOWABLE UNDER SSE CONDITIONS IF IT IS OPERATING WITHIN THE PERMISSIBLE PRESSURE.

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SYSTEM NO.	RECTANGULAR DUCT SIZE	Smax OR Sdw + Seq (PSI)	Sb + Sm (PSI)	SUMMATION OF [Smax OR Sdw + Seq] AND Sb + Sm (PSI)	0.9Sy (PSI)	REMARK
2848-1	14X14	25250	7150	32400	32400	
2848-1-1A	16X20	9236	23160	32396	32400	
	24X20	1648	30750	32398	32400	
	32X20	295	32100	32395	32400	SEE NOTE 2
	20X16	9236	23160	32396	32400	
	16X43	13230	19170	32400	32400	
	16X66	4831	27570	32401	32400	
2848-1-1B	12X7	3224	29180	32404	32400	
	18X7	620	31780	32400	32400	SEE NOTE 2
	24X7	10380	22020	32400	32400	
	36X7	11060	21340	32400	32400	
	48X7	1348	31050	32398	32400	
	7X24	13470	18930	32400	32400	
	8X57	7827	24573	32400	32400	SEE NOTE 1
	8X66	26730	5673	32403	32400	
	8X36	6659	25740	32399	32400	
2848-1-1C	16X9	8663	23740	32403	32400	
	24X9	5021	27380	32401	32400	
	32X9	1717	30680	32397	32400	
	8X41	1972	30430	32402	32400	
	8X66	24010	8391	32401	32400	
2848-1-2A	32X40	11530	20870	32400	32400	
	48X40	3389	29010	32399	32400	
	64X40	210	32190	32400	32400	SEE NOTE 2
	32X32	769	31630	32399	32400	
	24X49	4110	28290	32400	32400	
	24X66	224	32180	32404	32400	SEE NOTE 2
	24X32	669	31730	32399	32400	
2848-1-2B	21X40	15250	17150	32400	32400	
	21X51	6254	26150	32404	32400	
	21X80	7780	24620	32400	32400	

TABLE 5.0.1 SUMMARY OF STRESSES FOR ALL RECTANGULAR DUCTING SYSTEMS OF FERMI 2 - CCHVAC SYSTEM

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SUBJECT: STRESSES SUMMARY OF REQ. DUCTS BY: HEK CK: MAK SHT: 4 OF 8

2848-1-2B (CONT'D)	21X53	3629		28770	32399	32400	
	16X66	8422		23980	32402	32400	
2848-1-2C	29X40	12430		19970	32400	32400	
	29X55	8941		23460	32401	32400	
	29X80	2056		30340	32396	32400	
	29X40	13880		18520	32400	32400	
	24X40		170	32230	32400	32400	SEE NOTE 2
	24X66	2774		29630	32404	32400	
	24X55	10200		22200	32400	32400	
2848-1-2D	16X66	11930		20470	32400	32400	
	16X44	13870		18530	32400	32400	
	16X20	1983		30420	32403	32400	
	20X10	5492		26910	32402	32400	
2848-1-2E	20X10		452	31950	32402	32400	SEE NOTE 2
	16X10		186	32210	32396	32400	SEE NOTE 2
	16X66		132	32270	32402	32400	SEE NOTE 2
2848-2A	51.5X51.5	8051		24350	32401	32400	
	78X34	15120		17280	32400	32400	
2848-2B	74X36	29920		2477	32397	32400	
	51X38	15450		16950	32400	32400	
2848-5	10X10	19180		13220	32400	32400	
2849-1	20X16		199	32200	32399	32400	SEE NOTE 2
	18X12		0	32400	32400	32400	SEE NOTE 2
	16X16	24040		8357	32397	32400	
	12X10	13070		19330	32400	32400	
	12X8	78210		0	78210	32400	SEE NOTE 3
	10X8	14490		17900	32390	32400	
	10X6	3064		29340	32404	32400	
	16X12	13340		19060	32400	32400	
2849-2	19X19	27680		4720	32400	32400	
2849-3	60X26	7088		25312	32400	32400	
	38X34	8689		23711	32400	32400	

TABLE 5.0.1 (CONT'D)

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2849-3 (CONT'D)	78X34	22490	9910	32400	32400	
	32X30	21550	10850	32400	32400	
	50X20	14580	17820	32400	32400	
	22X12	16340	16060	32400	32400	
2849-4	12X6	1490	30910	32400	32400	SEE NOTE 2
2849-5	74X30	19610	12790	32400	32400	
	124X48	296	32100	32396	32400	SEE NOTE 2
2849-6	10X10	1062	31338	32400	32400	SEE NOTE 2
2849-9	74X30	4963	27440	32403	32400	
	124X76	1593	30810	32403	32400	
	72X30	22140	10260	32400	32400	
	52X44	7388	25010	32398	32400	
2850-1	24X18	394	32006	32400	32400	SEE NOTE 2
	24X14	18310	14090	32400	32400	
	24X8	1886	30514	32400	32400	
	34X20	27290	5110	32400	32400	
	28X14	21820	10580	32400	32400	
	20X18	977	31423	32400	32400	
	20X14	14050	18350	32400	32400	
	16X14	13270	19130	32400	32400	
	14X10	630	31770	32400	32400	SEE NOTE 2
	14X8	25320	7080	32400	32400	
	12X12	1271	31129	32400	32400	SEE NOTE 2
	10X8	1025	31375	32400	32400	SEE NOTE 2
2850-2	40X32	9348	23050	32398	32400	
	40X26	11050	21350	32400	32400	
	34X26	10420	21980	32400	32400	
	34X20	7775	24620	32395	32400	
	26X10	10300	22100	32400	32400	
	16X10	4278	28120	32398	32400	
	14X10	5242	27160	32402	32400	
	14X8	2762	29640	32402	32400	
	10X8	1367	31030	32397	32400	SEE NOTE 2
	10X6	741	31660	32401	32400	SEE NOTE 2
	26X16	8636	23760	32396	32400	

TABLE 5.0.1 (CONT'D)

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2850-2 (CONT'D)	16X14	6882	25520	32402	32400	
	14X14	1467	30930	32397	32400	SEE NOTE 2
	8X8	2626	29770	32396	32400	SEE NOTE 2
2850-3	60X26	3250	29150	32400	32400	
	40X40	8589	23811	32400	32400	
2850-4	20X16	17670	14730	32400	32400	
	16X12	25380	7018	32398	32400	
	16X9	22060	10340	32400	32400	
	12X12	16430	15970	32400	32400	
	12X10	21090	11310	32400	32400	
	10X8	11810	20590	32400	32400	
	8X8	2624	29780	32404	32400	SEE NOTE 2
2850-5	16X9	8396	24000	32396	32400	SEE NOTE 1
	14X6	4557	27840	32397	32400	SEE NOTE 1
	12X6	22720	9677	32397	32400	
	10X6	4299	28100	32399	32400	
2850-6	14X6	13330	19070	32400	32400	SEE NOTE 1
	12X7	8109	24290	32399	32400	SEE NOTE 1
	12X6	9409	22990	32399	32400	SEE NOTE 1
	10X6	810	31590	32400	32400	SEE NOTE 2
2850-7	36X30	20040	12360	32400	32400	
	40X20	17660	14740	32400	32400	
2850-8	12X6	19270	13130	32400	32400	SEE NOTE 1
2850-9	40X20	28300	4100	32400	32400	
	40X21	25040	7360	32400	32400	
	10X6	1517	30883	32400	32400	SEE NOTE 2
2850-10	10X6	27160	5240	32400	32400	
2853-1	40X20	14760	17640	32400	32400	
	32X20	15810	16590	32400	32400	
	26X20	1630	30770	32400	32400	
	20X20	702	31700	32402	32400	SEE NOTE 2
	20X12	9201	23200	32401	32400	
	24X18	4154	28250	32404	32400	

TABLE 5.0.1 (CONT'D)

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2853-2	36X30	12330	20070	32400	32400	
	32X30	4440	27960	32400	32400	
2853-3	40X40	5279	27120	32399	32400	
	38X38	8250	24150	32400	32400	
	38X32	4980	27420	32400	32400	
	38X28	8484	23920	32404	32400	
	38X20	7014	25390	32404	32400	
	32X20	2583	29820	32403	32400	
	22X20	2801	29600	32401	32400	
	20X12	2768	29630	32398	32400	
2854-1	36X30	3882	28520	32402	32400	
	36X10	19450	12950	32400	32400	
	34X22	2248	30150	32398	32400	
	32X20	9239	23160	32399	32400	
	26X20	13090	19310	32400	32400	
	24X16	23520	8880	32400	32400	
	20X10	29110	3291	32401	32400	
	20X6	10990	21410	32400	32400	
2854-2	36X10	13750	18650	32400	32400	
	34X22	20190	12210	32400	32400	
	34X20	3468	28932	32400	32400	SEE NOTE 1
	30X24	3383	29020	32403	32400	
	30X12	5317	27080	32397	32400	SEE NOTE 1
	26X20	16940	15460	32400	32400	
	20X12	16300	16100	32400	32400	
	20X9	4659	27740	32399	32400	SEE NOTE 1
2854-3	38X28	1735	30670	32405	32400	
	38X30	1696	30700	32396	32400	
	36X30	1432	30970	32402	32400	
	36X18	20390	12010	32400	32400	
	48X14	22070	10330	32400	32400	
	36X12	22820	9583	32403	32400	
	28X16	14640	17770	32410	32400	
2854-4	36X12	11590	20810	32400	32400	
	24X20	2112	30290	32402	32400	SEE NOTE 1
	24X16	2865	29540	32405	32400	SEE NOTE 1
	24X8	5905	26500	32405	32400	

TABLE 5.0.1 (CONT'D)

4126-1	48X48	3860	28540	32400	32400	
4316-2	19X19	22900	9500	32400	32400	
4316-3	10X10	891	31500	32391	32400	SEE NOTE 2

Sdw = Stress due to Duct Self-Weight
Seq = Stress due to Earthquake
Sb = Bending Stress in Duct Panel
Sm = Membrane Stress in Duct Panel
Smax = Stress on Post Buckling Effective Area
Sy = Yield Stress of Duct

NOTE: (1) Stresses determined based on SSE ZPA/OBE ZPA multiplication factor only. This is acce[illegible] or a rigid system.
(2) No Buckling.
(3) Non-Essential Duct.

TABLE 5.0.1 (CONT'D)

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CALCULATION SHEET

TITLE: DECO - USNRC DOCKET NO. 50-341 DATE: APRIL '94 PAGE: 15

SUBJECT: CONCLUSIONS BY: HEF CK: MAK SHT: 1 OF 1

6.0 CONCLUSIONS

IN RESPONSE TO THE USNRC COMMENT, THE MAXIMUM REDISTRIBUTED STRESS OF ALL THE RECTANGULAR DUCTS WAS SUMMARIZED AND COMPARED TO THE ALLOWABLE STRESS ($0.9\ S_y$) UNDER THE SSE LOADING CONDITIONS.

WITH AN EXCEPTION OF THE SYSTEM 2049-1: 12×8 DUCT, A NON-ESSENTIAL SYSTEM, THE MAXIMUM REDISTRIBUTED STRESS OF ALL RECTANGULAR DUCTS IS LESS THAN $0.9(S_Y)$ ALLOWABLE STRESS UNDER SSE CONDITIONS IF THESE DUCTINGS ARE OPERATING WITHIN THE ESTABLISHED PERMISSIBLE PRESSURE.

7.0 REFERENCES

[1] FLUOR PIONEER, INC, DESIGN REPORTS ON MICROFILM ROLLS "AA" THROUGH "AH", PROJECT 10-4221, CLIENT: ROBERT IRSAT. MICRO FILM ROLLS ARE ON FILE WITH DECO

[2] HOPPER AND ASSOCIATES, STRUCTURAL EVALUATION OF CCHVAC AND SGTS DUCTING SYSTEMS CALCULATIONS: HA-09/89-696, FOR DETROIT EDITION COMPANY, SEPTEMBER 29, 1989.

[3] ANSI/ASME N509-1980: NUCLEAR POWER PLANT AIR CLEANING UNITS AND COMPONENTS, ASME, NEW YORK, NEW YORK. 10017 (1980)

[4] FROM THE U.S. NUCLEAR REGULATORY COMMISSION TO DETROIT EDISON COMPANY: DOCKET NO. 50-341, FERMI 2 - CONTROL CENTER HEATING, VENTILATION AND AIR CONDITIONING (CCHVAC) SYSTEM - REQUEST FOR ADDITIONAL INFORMATION, MARCH 3, 1994

Attachment 14 to
NRC-94-0050

HOPPER AND ASSOCIATES
ENGINEERS

DECO - USNRC DOCKET NO. 50-341

FERMI 2 CCHVAC DUCTING SYSTEMS

CONCERN ITEM NO. 18

EVALUATION CALCULATIONS

Prepared for: Detroit Edison Company
Nuclear Engineering Fermi 2
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April, 1994

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 18 DATE: APR 94 PAGE: i

SUBJECT: TABLE OF CONTENTS BY: A.R. CK: SHT: i OF i

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PREPARED BY: Alex Raizman 4-19-94

CHECKED BY: M. Amir Khan APRIL 21, 94

HOPPER AND ASSOCIATES
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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 18 DATE: APR '94 PAGE: 1

SUBJECT: 1.0 INTRODUCTION BY: A.R. CK: MAK 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-09/89-696, performed by Hopper & Associates.

This package is prepared in order to respond to one of the comments posed by the NRC regarding HA-09/89-696. Namely,

> Likewise, the analysis of system 2850-2 indicated that this system 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 2Sy, considerably exceeding the maximum allowable stress.

1.2 INVESTIGATION APPROACH

The actual pressure that system 2850-Z is subjected to will be determined. The procedure used in evaluating system 2850-Z by HA-09/89-696 will be summarized. Using the actual design pressure, the stresses developed in the ducting will be evaluated.

2.1 ACTUAL SYSTEM PRESSURE

Duct system 2850-2 is a supply duct for the main control room. Per [Ref 1] the design pressure for this system is 6" Water Column (Positive).

In the calculation report HA-09/89-696, the bounding pressure was selected to be 11.3" Water Column (Negative). For system 2850-2, the report found the lowest allowable pressure to be 11.6" W.C.

2.2 ANALYSIS PROCEDURE

A computer run of system 2850-2 was performed by Hopper & Associates using the computer Code ANSYS [Ref 2]. Stresses were determined for the following loading conditions,

1. Dead Weight
2. Seismic, using Site Specific Earthquake (SSE) response spectra, with ductility of 2 and damping of 10%.
3. Seismic, SSE response spectra, with ductility of 1 (elastic) and damping of 10%.
4. Seismic, SSE response spectra, with ductility of 1 (elastic) and damping of 2%.

The resulting stresses are summarized in Table 2.2.1. Loading conditions 1 and 2 were used in HA-09/89-696.

The rigorous procedure used in obtaining the results presented in this package is discussed in "Response to Concern 15" [Ref 8], which provides detailed calculations and procedures for two rectangular duct sizes.

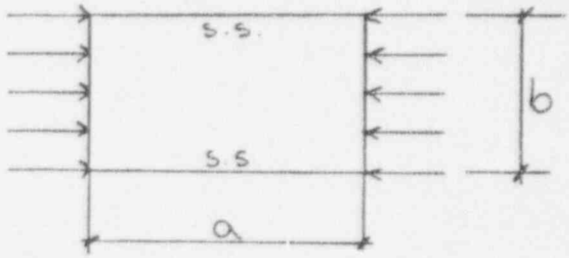
DUCT (in x in)	STRESSES			
	DW (PSI)	SEISMIC μ=2 DAMP=10%	SEISMIC μ=1 DAMP=10%	SEISMIC μ=1 DAMP=2%
40x32	85	774 psi	827 psi	955 psi
40x26	115	869	931	1095
34x26	87	1034	1116	1318
34x20	101	792	838	951
26x16	81	1256	1618	2299
26x10	171	1354	2163	4063
16x14	126	2019	2396	3433
16x10	108	1560	2615	5240
14x14	235	1232	1852	3226
14x10	162	2054	3365	6034
14x8	239	1458	1742	2853
10x8	272	1095	1469	1899
10x6	132	609	971	1805
8x8	312	2314	2469	2819

TABLE 2.2.1 SYSTEM 2850-2, RESULT STRESSES

2.3 BUCKLING STRESS [Ref 3, Pg 355]

Plate elastic compressive buckling stress.

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



where,

$E = 29 \times 10^6$ psi

$\nu = .29$

$h = .0516$ inch, 18 gage

$K = \left(\frac{a}{b} + \frac{b}{a}\right)^2$, but $K = 4$ for $(b/a < 1)$

b (in)	a (in)	t (in)	b/a	k	S critical (psi)
40	30	0.0516	1.33	4.34	188
34	30	0.0516	1.13	4.06	244
26	30	0.0516	0.87	4.00	410
16	60	0.0516	0.27	4.00	1083
14	60	0.0516	0.23	4.00	1415
10	60	0.0516	0.17	4.00	2773
8	60	0.0516	0.13	4.00	4334

2.4 DAMPING EVALUATION

A damping value of 2% was used throughout the analyses performed in HA-09/89-696. However, for system 2850-2, the 2% damping value appeared to be too conservative. A review of the available literature produced a more reasonable value.

Referring to the ducting as a bolted steel assembly, Regulatory Guide 1.61 recommends a damping value of 7% for a Safe Shutdown Earthquake.

Other references like, [Ref 4, Pg. 862] and [Ref 5, Pg 1-4-22], list the recommended damping value at 10-15%, at or just below yield point.

[Ref 6, Pg 11-2-1] discusses that 7% damping is adequate as shown through tests performed on ducting systems.

From [Ref 7, Pg 4-32], which specifically addresses HVAC ducting, the conservatively estimated damping is reported at 7% of critical.

From above, it is evident that use of 10% damping is not unreasonable, and that 7% would yield appropriate yet still conservative results.

3.1 REANALYSIS FOR ACTUAL PRESSURE

As mentioned earlier, the design pressure for system 2850-2 is 6" W.C. Using this pressure and the various loading conditions, the total stresses acting on the ducts are determined. These are shown in Tables 3.1.1 through 3.1.3.

Exceedance of the allowable stress of $.9\sigma_y$ occures for only the 26"x10" duct size, under the 2% damping SSE loading. The duct is shown to be stressed to $1.3\sigma_y$, which suggests that there will be yielding at the corners.

As was shown in Section 2.4, the use of 2% damping is very conservative for an SSE type loading. For a more reasonable yet still conservative analysis a value of 7% damping can be used.

b (in)	d (in)	Scritical (psi)	Sdw (psi)	Seq (psi)	Sdw + Seq or Smax (psi)	Sb + Sm (psi)	S combined (psi)	%S yield	NOTES
40	32	188	85	774	9348	13650	22998	64	< 90% S yield O.K.
40	26	188	115	869	11055	13650	24705	69	< 90% S yield O.K.
34	26	244	87	1034	10421	13650	24071	67	< 90% S yield O.K.
34	20	244	101	792	7775	13650	21425	60	< 90% S yield O.K.
26	16	410	81	1256	8636	12240	20876	58	< 90% S yield O.K.
26	10	410	171	1354	10304	12240	22544	63	< 90% S yield O.K.
16	14	1083	126	2019	6882	8040	14922	41	< 90% S yield O.K.
16	10	1083	108	1560	4278	8040	12318	34	< 90% S yield O.K.
14	14	1415	235	1232	1663	6920	8583	24	< 90% S yield O.K.
14	10	1415	162	2054	5242	6920	12162	34	< 90% S yield O.K.
14	8	1415	239	1458	2762	6920	9682	27	< 90% S yield O.K.
10	8	2773	272	1095	1367	4090	5457	15	< 90% S yield O.K.
10	6	2773	132	609	741	4090	4831	13	< 90% S yield O.K.
8	8	4334	312	2314	2626	2640	5266	15	< 90% S yield O.K.

Sdw = Stress due to duct Dead Weight
Seq = Stress due to Earthquake
Sm + Sb = Membrane and Bending Stresses on panel due to pressure. See [Ref. 8] for detailed procedure.
Smax = Stress on post buckling effective area. See [Ref. 8] for detailed procedure.
Scomb. = Summation of Sdw + Seq + (Sm + Sb) or
Smax + (Sm + Sb)

TABLE 3.1.1 SYSTEM 2850-2, STRESSES FOR DUCTILITY = 2 AND DAMPING OF 10%

b (in)	d (in)	Scritical (psi)	Sdw (psi)	Seq (psi)	Sdw + Seq or Smax (psi)	Sb + Sm (psi)	S combined (psi)	%S yield	NOTES
40	32	188	85	827	10072	13650	23722	66	< 90% S yield O.K.
40	26	188	115	931	11901	13650	25551	71	< 90% S yield O.K.
34	26	244	87	1116	11372	13650	25022	70	< 90% S yield O.K.
34	20	244	101	838	8309	13650	21959	61	< 90% S yield O.K.
26	16	410	81	1618	11848	12240	24088	67	< 90% S yield O.K.
26	10	410	171	2163	17483	12240	29723	83	< 90% S yield O.K.
16	14	1083	126	2396	8941	8040	16981	47	< 90% S yield O.K.
16	10	1083	108	2615	10039	8040	18079	50	< 90% S yield O.K.
14	14	1415	235	1852	4626	6920	11546	32	< 90% S yield O.K.
14	10	1415	162	3365	11506	6920	18426	51	< 90% S yield O.K.
14	8	1415	239	1742	4119	6920	11039	31	< 90% S yield O.K.
10	8	2773	272	1469	1741	4090	5831	16	< 90% S yield O.K.
10	6	2773	132	971	1103	4090	5193	14	< 90% S yield O.K.
8	8	4334	312	2469	2781	2640	5421	15	< 90% S yield O.K.

Sdw = Stress due to duct Dead Weight
Seq = Stress due to Earthquake
Sm + Sb = Membrane and Bending Stresses on panel due to pressure. See [Ref. 8] for detailed procedure.
Smax = Stress on post buckling effective area. See [Ref. 8] for detailed procedure.
Scomb. = Summation of Sdw + Seq + (Sm + Sb) or
Smax + (Sm + Sb)

TABLE 3.1.2 SYSTEM 2850-2, STRESSES FOR DUCTILITY = 1 AND DAMPING OF 10%

b (in)	d (in)	Scritical (psi)	Sdw (psi)	Seq (psi)	Sdw + Seq or Smax (psi)	Sb + Sm (psi)	S combined (psi)	%S yield	NOTES
40	32	188	85	955	11819	13650	25469	71	< 90% S yield O.K.
40	26	188	115	1095	14140	13650	27790	77	< 90% S yield O.K.
34	26	244	87	1318	13716	13650	27366	76	< 90% S yield O.K.
34	20	244	101	951	9620	13650	23270	65	< 90% S yield O.K.
26	16	410	81	2299	17891	12240	30131	84	< 90% S yield O.K.
26	10	410	171	4063	34343	12240	46583	129	Exceeds Allowable
16	14	1083	126	3433	14604	8040	22644	63	< 90% S yield O.K.
16	10	1083	108	5240	24373	8040	32413	90	< 90% S yield O.K.
14	14	1415	235	3226	11191	6920	18111	50	< 90% S yield O.K.
14	10	1415	162	6034	24259	6920	31179	87	< 90% S yield O.K.
14	8	1415	239	2853	9428	6920	16348	45	< 90% S yield O.K.
10	8	2773	272	1899	2171	4090	6261	17	< 90% S yield O.K.
10	6	2773	132	1805	1937	4090	6027	17	< 90% S yield O.K.
8	8	4334	312	2819	3131	2640	5771	16	< 90% S yield O.K.

Sdw = Stress due to duct Dead Weight
Seq = Stress due to Earthquake
Sm + Sb = Membrane and Bending Stresses on panel due to pressure. See [Ref. 8] for detailed procedure.
Smax = Stress on post buckling effective area. See [Ref. 8] for detailed procedure.
Scomb. = Summation of Sdw + Seq + (Sm + Sb) or
Smax + (Sm + Sb)

TABLE 3.1.3 SYSTEM 2850-2, STRESSES FOR DUCTILITY = 1 AND DAMPING OF 2%

The stresses corresponding to 7% damping are determined by appropriately scaling the results obtained from 2% and 10% damping computer runs. The first mode natural frequency of system 2850-2 was determined to be 5.7 Hz. From the response spectra in Figures 3.1.1 and 3.1.2, the acceleration factors corresponding to that frequency are as follows,

	2%	7%	10%
E-W	4.0g	2.2g	1.8g
N-S	3.5g	2.0g	1.6g

For 26"x10",

E-W

$$S_{EQ\,7\%} = \left(\frac{2.2}{4.0}\right)(4063\text{ psi}) = 2235\text{ psi}$$

or

$$S_{EQ\,7\%} = \left(\frac{2.2}{1.8}\right)(2163\text{ psi}) = 2644\text{ psi}$$

averaged, $\bar{S}_{EQ\,7\%} = \frac{2644+2235}{2} = 2440\text{ psi}$

N-S

$S_{EQ7\%} = \left(\frac{2.0}{3.5}\right)(4063\ psi) = 2322\ psi$

or

$S_{EQ7\%} = \left(\frac{2.0}{1.6}\right)(2163\ psi) = 2704\ psi$

averaged, $\bar{S}_{EQ7\%} = \frac{2704 + 2322}{2} = 2513\ psi$

Use larger of the two values, i.e

$S_{EQ7\%} = \underline{2513\ psi}$

S_{max}, the stress on the post buckled effective area is calculated from

$$S_{max}(N) + S_{cr}(b - N) = (S_{EQ} + S_{DW})(b)$$

where,

b = 26", largest duct dimension

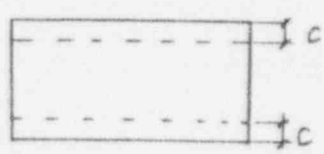
S_{cr} = 410 psi, panel buckling stress

S_{DW} = 171 psi, Dead Weight stress

S_{EQ} = 2513 psi, Seismic stress @ 7% damping

N = 2c + 2h

$c = \frac{\pi h}{\sqrt{12(1-\nu^2)}}\sqrt{\frac{E}{\sigma_{YP}}}$ [Ref 3, Pg 418]



$h = .0516$ inch, duct thickness

$\nu = .29$

$E = 29 \times 10^6$ psi

$\sigma_{yp} = 36{,}000$ psi, yield stress of steel

$$C = \frac{\pi(.0516)}{\sqrt{12(1-(.29)^2)}} \sqrt{\frac{29 \times 10^6}{36{,}000}} = 1.388 \text{ inch}$$

$$N = (1.388)(2) + 2(.0516) = 2.88 \text{ inch}$$

So,

$$S_{max} = \frac{(2513 + 171)26 - 410(26 - 2.88)}{2.88}$$

$$= 20939 \text{ psi}$$

as before,

$$S_m + S_b = 12{,}240 \text{psi}$$

$$S_{comb} = S_{max} + S_m + S_b = 20939 + 12{,}240 \text{ psi}$$

$$= 33180 \text{ psi}$$

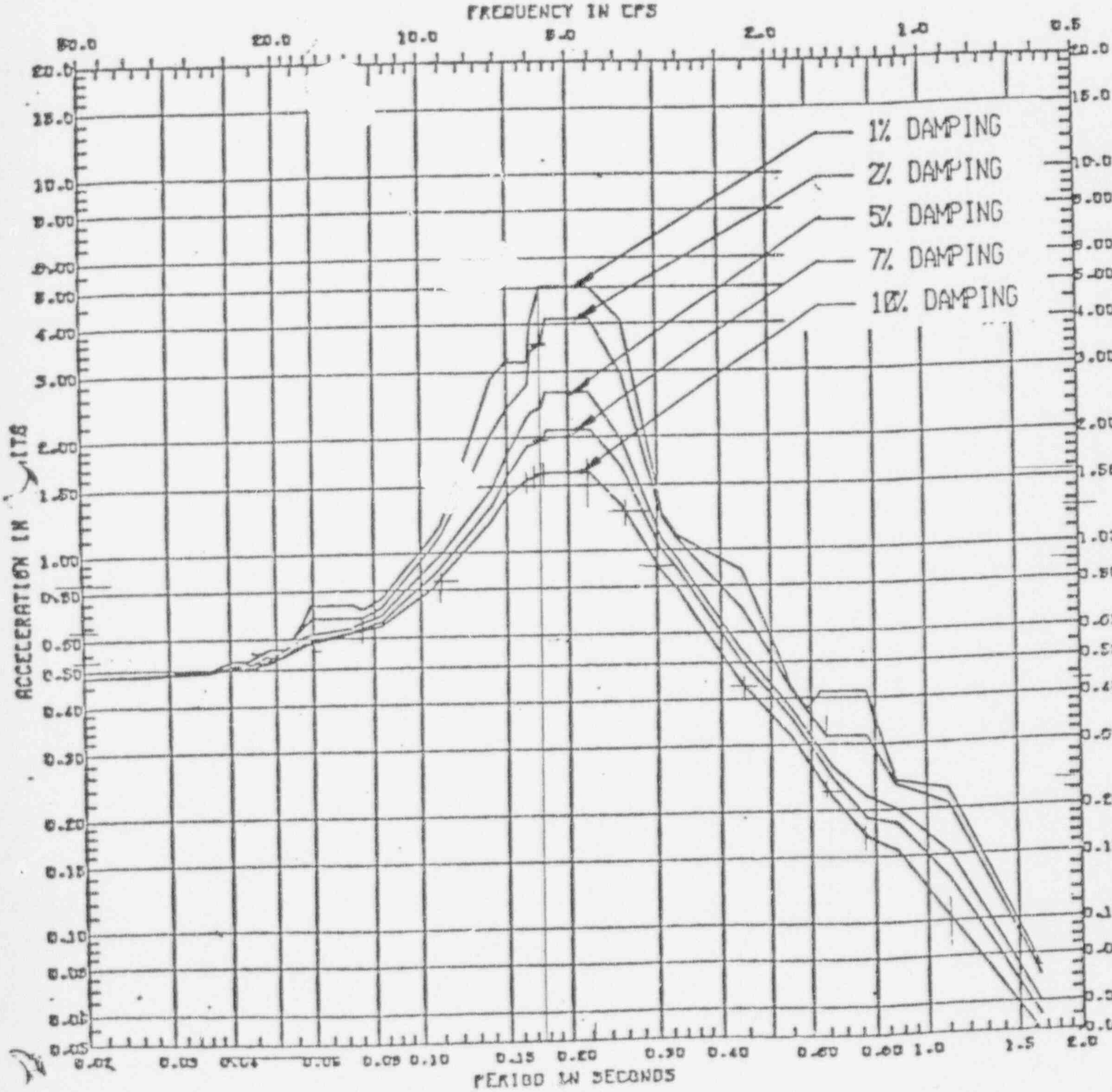
$$\% S_y = \frac{33180}{36000} \times 100 = 92\%$$

ENRICO FERMI
UNIT 2

PREPARED BY: A. Krolikowski 10/20/81
A. KROLIKOWSKI DATE

SYSTEM ENGR: [signature] 4/14/81
Y. ANAND DATE

SITE SPECIFIC EARTHQUAKE 5% SITE DAMPING



REACTOR AUXILLARY BUILDING: RESPONSE SPECTRUM

FIGURE NO. 3.1.1

SPECTRUM	NODE	ELEV	DIRECT	LOCATION	
SES-B-37	5	684-6	NS	REA-AUX BLDG	SLAB 5

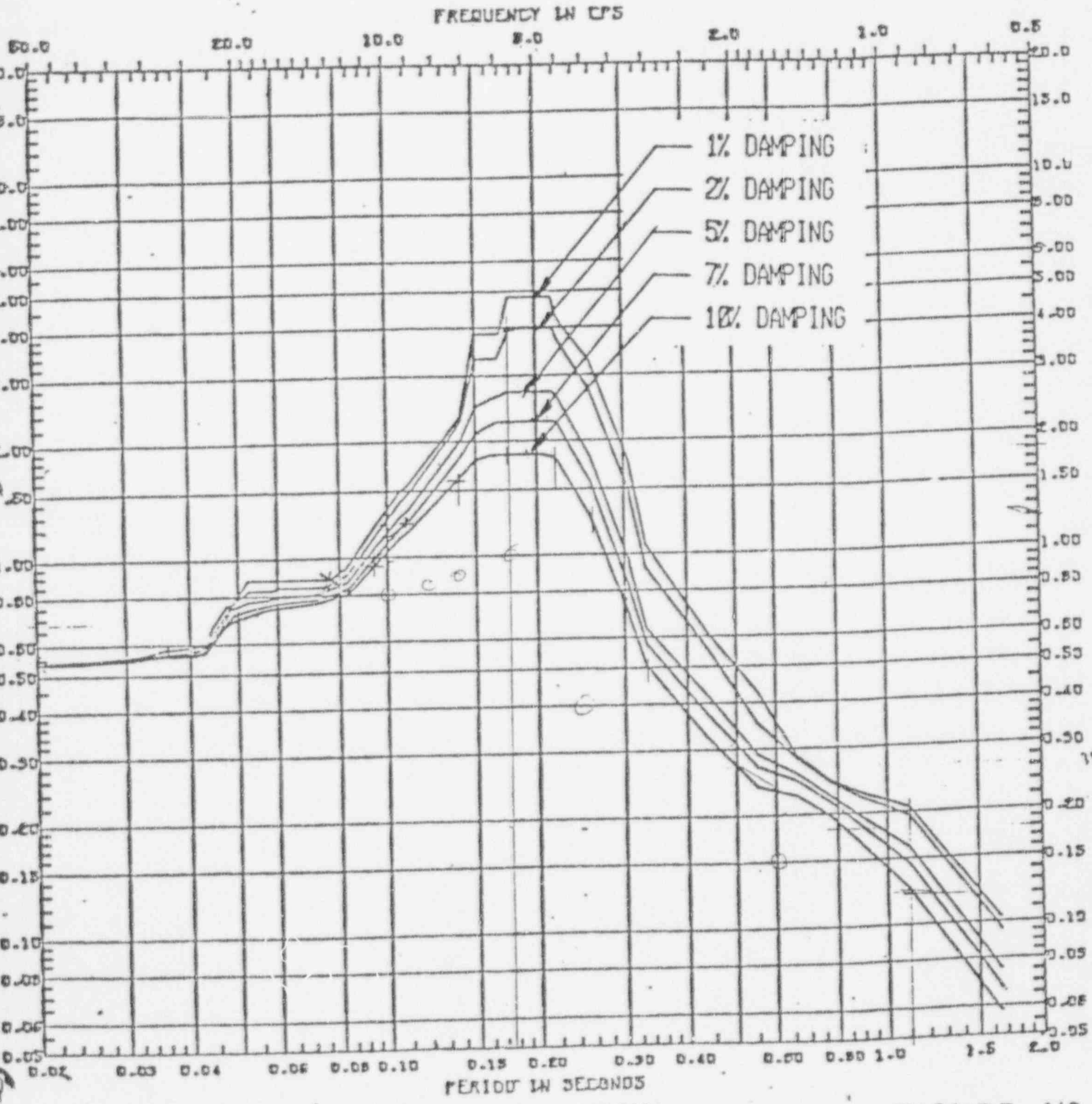
ENRICO FERMI UNIT 2

PREPARED BY: A. KROLIKOWSKI DATE

SYSTEM ENGR: Y. ANAND DATE 4/6/81

SITE SPECIFIC EARTHQUAKE 5% SITE DAMPING

9 of 9



REACTOR AUXILLARY BUILDING: RESPONSE SPECTRUM

FIGURE NO. 3.1.2

SPECTRUM	NODE	ELEV	DIRECT	LOCATION	
SES-B-38	5	684-6	EW	REA-AUX BLDG	SLAB 5

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TITLE: RESPONSE TO CONCERN 18	DATE: APR 94 PAGE: 19
SUBJECT: 4.0 CONCLUSIONS	BY: A.R CK: MAK SHT: 1 OF 1

CONCLUSIONS

In response to a concern posed by the NRC in Docket No. 50-341, ducting system 2850-2 was reanalyzed for actual design pressure of 6" W.C. (Positive).

It is shown that for a very conservative case of 2% damping, only the 26"x10" duct size exceeds the allowable stress value of $.9\sigma_y$. For more reasonable, yet still conservative value of damping of 7%, all the duct sizes are at or below the allowable stress.

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ENGINEERS

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 1B DATE: APR '94 PAGE: 20
SUBJECT: 5.0 REFERENCES BY: A.R. CK: MAK SHT: 1 OF 2

REFERENCES

1. Telecopy transmission from Dave Jax, DECo Fermi 2, to Hopper & Associates, April 12, 1994.
2. Swanson Analysis Systems, Inc. ANSYS-PC/LINEAR 4.3A4; 12-1-88.
3. Timoshenko & Gere. "Theory of Elastic Stability", 2nd Edition, McGraw-Hill, 1961.
4. Newmark & Hall, "Procedures and Criteria for Earthquake Resistant Design" from "Selected Papers by Nathan M. Newmark, Civil Engineering Classics", ASCE, 1976.
5. Hall, Newmark, Kennedy & Stevenson, "Seismic Resistance of Existing Facilities", from "Civil Engineering and Nuclear Power, Vol 6: Design and Analysis of Nuclear Facilities for Earthquake", 2nd Conference On, ASCE, Tennessee, 1980

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 18 DATE: APR 94 PAGE: 21

SUBJECT: REFERENCES BY: A.R CK: NMK SHT: 2 OF 2

6. Neely & Warrix, "A Procedure for Seismically Qualifying HVAC Ducts Used in Nuclear Power Plants" from "ibid, vol 1" 2nd Conference on, ASCE, Tennessee, 1980.

7. Jack R. Benjamin & Associates et al. "A Methodology for Assesment of Nuclear Power Plant Seismic Margin, Revision 1", NP-6041-SL, Project 2722-23, EPRI, 1991.

8. Hopper & Associates, "DECo - USNRC Docket NO. 50-341 Fermi-2 CCHVAC Ducting Systems Concern Item 15", April, 1994.