Attachment 15 to
NRC-94-0050

HOPPER AND ASSOCIATES
ENGINEERS

DECO - USNRC DOCKET NO. 50-341

FERMI 2 CCHVAC DUCTING SYSTEMS

CONCERN ITEM NO. 19

EVALUATION CALCULATIONS

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May 1994

Revision 1, May 1994

CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 19 DATE: MAY 19, 94 PAGE: ii

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

PREPARED BY : M. Amir Khan 5/3/94

REVIEWED BY : M. E. Kr 5/10/94

REVISION 1 :-

PREPARED BY : M. Amir Khan MAY 19, 94

REVIEWED BY : M. E. Kr MAY 20 94

1.1 PROBLEM STATEMENT

ON MARCH 3, 1994, THE USNRC 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-09/89-696 AND HA-05/89-686, PERFORMED BY HOPPER AND ASSOCIATES. THIS PACKAGE IS PREPARED AS RESPONSE TO ONE OF THE COMMENTS POSED BY THE NRC REGARDING HA-09/89-696, NAMELY:

> 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.

STRUCTURAL INTEGRITY OF THE STIFFENERS WILL BE CHECKED IN THIS REPORT.

1.2 INVESTIGATION APPROACH

STIFFENER SIZES AND SPACINGS ARE AVAILABLE FROM THE DUCT CONSTRUCTION BROCHURE [1] FOR DUCTS OF DIFFERENT PANEL DIMENSIONS. BASED ON THESE SIZES, THE MAXIMUM ALLOWABLE INTERNAL PRESSURE WILL BE COMPUTED FOR STIFFENER SAFETY. REQUIREMENTS PER ANSI/ASME N509-1980 [3] WILL BE CHECKED. WELDS, BRAZINGS AND TIE RODS WILL ALSO BE EVALUATED.

1.3 RESULT SUMMARY

BOUNDING ANALYSES, ENCOMPASSING ALL POSSIBLE DUCT AND STIFFENER SIZES AND CONFIGURATIONS FOR THE 55 DUCTING SYSTEMS, SHOW THAT ALL STIFFENERS, WELDS, BRAZINGS AND TIE-RODS ARE STRUCTURALLY ADEQUATE. THE STIFFENERS MEET THE STRESS CRITERIA OF ANSI/ASME N509-80.

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TITLE: RESPONSE TO CONCERN 19 DATE: APRIL 26, '94 PAGE: 3

SUBJECT: 2.0 SYSTEM DESCRIPTION BY: MAK CK: HCF SHT: 1 OF 3

TABLE 2.1 BELOW LISTS THE 55 DUCTING SYSTEMS TO BE ANALYZED FOR STIFFENER INTEGRITY, AND IS TAKEN FROM [2]:

No.	DUCT SYSTEM
1	226B - 2A
2	- 2B
3	- 2C
4	- 2D
5	226B - 3A
6	- 3B
7	- 3C
8	- 3D
9	226B - 4A
10	- 4B
11	284B - 1
12	284B - 1 - 1A
13	- 1B
14	- 1C
15	284B - 1 - 2A
16	- 2B
17	- 2C
18	- 2D
19	- 2E
20	284B - 2A
21	- 2B
22	284B - 4A
23	- 4B
24	- 4C
25	284B - 5
26	2849 - 1
27	- 2
28	- 3

No.	DUCT SYSTEM
29	2849 - 4
30	- 5
31	- 6
32	- 7
33	- 8
34	- 9
35	- 10
36	2850 - 1
37	- 2
38	- 3
39	- 4
40	- 5
41	- 6
42	- 7
43	- 8
44	- 9
45	- 10
46	2853 - 1
47	- 2
48	- 3
49	2854 - 1
50	- 2
51	- 3
52	- 4
53	4126 - 1
54	4316 - 2
55	- 3

TABLE 2.1 LIST OF DUCTING SYSTEMS TO BE ANALYZED

THE STIFFENERS ARE MADE UP OF ANGLE SECTIONS VARYING IN SIZE FROM L $1\frac{1}{2}$ x $1\frac{1}{2}$ x $\frac{1}{8}$ TO L2x2x3/16

RECTANGULAR DUCT - GALVANIZED OR STAINLESS STEEL

Duct Seam			Seam	Transverse Joint			Stiffener Between Joints		Remarks
Size Range Max. Side	Met. Ga.	Sec. lgth. Max.	Longitud-inal	Type	Angle Size	Tie Rods	Angle Size	Tie Rods	
0"-12"	18	60"	Brazed	Companion Angle	$1\frac{1}{2}$"x$1\frac{1}{2}$"x$\frac{1}{8}$"	No	See Note #1	No	
13"-30"	18	60"	Brazed	Companion Angle	$1\frac{1}{2}$"x$1\frac{1}{2}$"x$\frac{1}{4}$"	No	$1\frac{1}{2}$"x$1\frac{1}{2}$"x1/8" @2'-6"O.C.	No	
31"-36"	18	60"	Brazed	Companion Angle	$1\frac{1}{2}$"x$1\frac{1}{2}$"x$\frac{1}{2}$"	No	$1\frac{1}{2}$"x$1\frac{1}{2}$"x1/8" @2'-6"O.C.	No	
37"-48"	18	60"	Brazed	Companion Angle	$1\frac{1}{2}$"x$1\frac{1}{2}$"x 3/8"	Yes	$1\frac{1}{2}$"x$1\frac{1}{2}$"x1/8" @2'-6"O.C.	Yes	
49"-60"	18	48"	Brazed	Companion Angle	$1\frac{1}{2}$"x$1\frac{1}{2}$"x 3/8"	Yes	$1\frac{1}{2}$"x$1\frac{1}{2}$"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"	

TABLE 2.2 STIFFENER SIZES AND SPACINGS

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ANGLES

STIFFENER ~~ANGELS~~ ON ADJACENT PANELS ARE WELDED TOGETHER TO PROVIDE A MOMENT RESISTING CONNECTION [RECTANGULAR DUCTS]. A TYPICAL CONNECTION IS SHOWN BELOW:

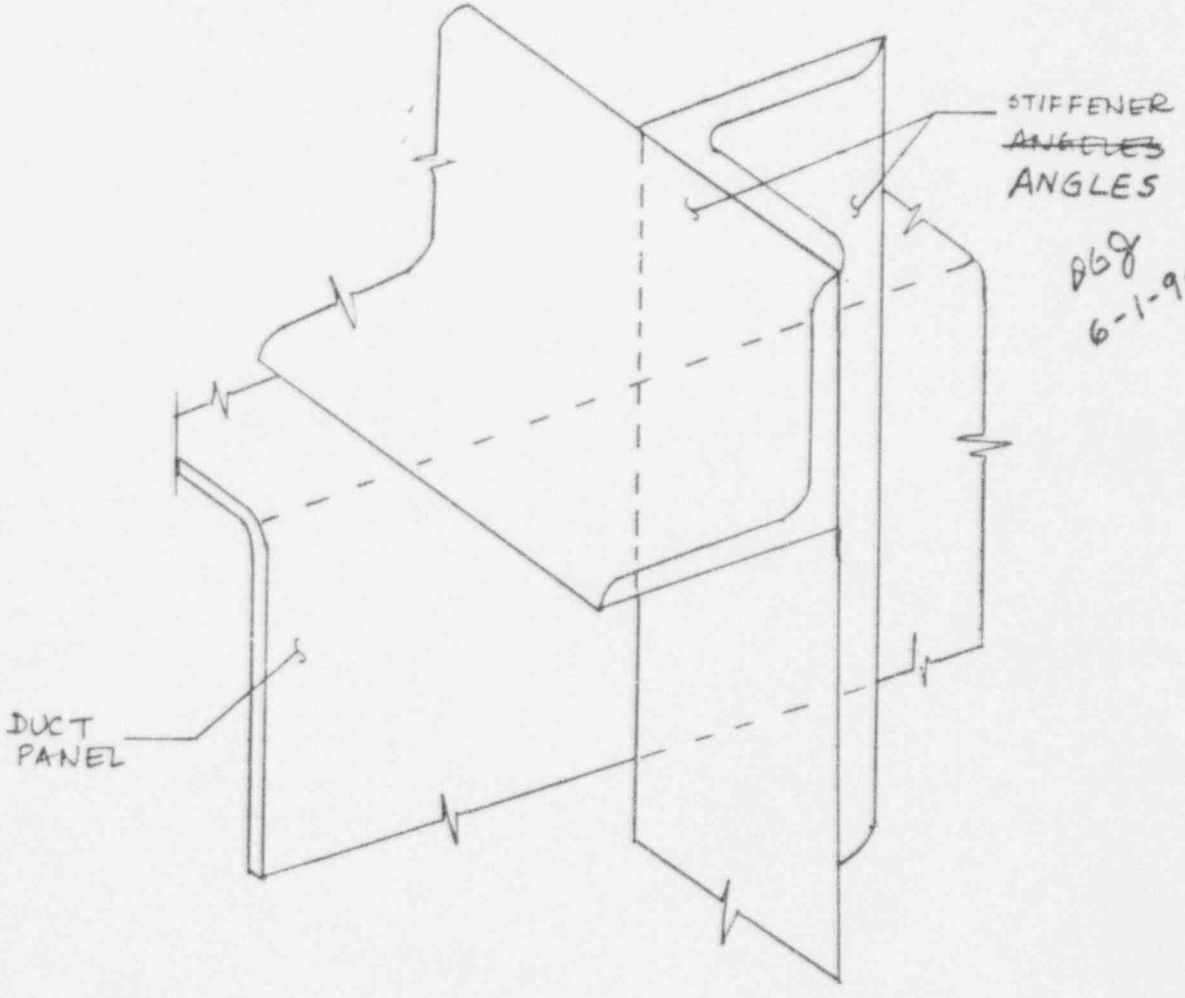

FIG. 2.1 TYPICAL STIFFENER CONNECTION FOR RECTANGULAR DUCTS (~~ANGELS~~ ANGLES LAPPED AND WELDED AT CORNERS)

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SUBJECT: 3.0 ANALYSIS APPROACH BY: MAK CK: HCK SHT: 1 OF 2

3.1 ASSUMPTIONS AND REQUIREMENTS

1. THE STIFFENERS ARE SUBJECTED TO LOADING BY DEAD LOAD & INTERNAL PRESSURE ONLY, SEISMIC PANEL INERTIA IS NOT CONSIDERED SINCE THIS IS NOT THE GOVERNING LOAD CASE.
2. THE STIFFENERS ON ADJACENT PANELS ARE WELDED TOGETHER AT THE ENDS SUCH THAT THIS REPRESENTS A FIXED BOUNDARY.
3. NEGATIVE INTERNAL PRESSURE IS ASSUMED (MORE CONSERVATIVE FOR BUCKLING EVALUATION OF TIE-RODS)

3.2 CALCULATION METHOD

LOADING ON THE STIFFENERS IS DUE TO DEAD LOAD & INTERNAL PRESSURE IN THE DUCTS. WITH THE MAXIMUM ALLOWABLE STRESS ON THE STIFFENER AND ITS SECTIONAL PROPERTIES AVAILABLE, THE PERMISSIBLE LOADING ON THE STIFFENER MAY BE CALCULATED. THIS CAN THEN BE USED TO COMPUTE THE ALLOWABLE INTERNAL PRESSURE IN THE DUCT FOR STIFFENER SAFETY. THIS PRESSURE WILL THEN BE COMPARED TO THE UPPER-BOUND MAXIMUM PRESSURE POSSIBLE IN ANY DUCT (= 11.3" WATER COLUMN). MAXIMUM ALLOWABLE INTERNAL PRESSURE FOR WELD AND TIE-RODS INTEGRITY, WILL ALSO BE CALCULATED.

3.8 EVALUATION CONDITIONS AND CRITERIA

STIFFENERS ARE CHECKED AGAINST PROVISIONS IN ANSI/ASME N509-1980 [3]. THE ALLOWABLE STRESS IS $0.6\sigma_y$ FOR OPERATIONAL LOADING. DEFLECTIONS ARE LIMITED BY 1/8 IN. PER FT OF SPAN BUT NOT MORE THAN 3/4 IN.

4.1 DUCTING SYSTEM 2848-1-1B

36" x 7"

CHECK 36" PANEL STIFFENER

STIFFENER: $\angle 1\frac{1}{2}" \times 1\frac{1}{2}" \times \frac{1}{8}"$ @ 2'-6" O.C.

$\sigma_{ALLOW} = 0.6\sigma_y$ [3]

$= 21600$ PSI

ASSUME FULL PRESSURE ON PANEL GOES TO STIFFENER.

$q = pL = 29.5p$, WHERE p = INTERNAL PRESSURE + DUCT SELF WT. PRESSURE + STIFFENER SELF. WT. PRESS; L = SPACING B/W STIFFENERS

$s = 36"$

$$M_{MAX} = \frac{qs^2}{12} = \frac{29.5p(36)^2}{12} = 3186p$$

$$F = \frac{pLs}{2} = \frac{(29.5)(36)p}{2} = 531p$$

$$\sigma = \frac{M}{Z} + \frac{F}{A}, \quad Z = 0.072\ IN^3, \quad A = 0.359\ IN^2$$

$$\therefore 21600 = \frac{3186p}{0.072} + \frac{531p}{0.359} \quad \therefore p = 0.47\ psi$$

$= 13"$ W.C $>$ (11.8" W.C.*) OK.

CHECK DEFLECTION

$$\Delta = \frac{qs^4}{384EI} = \frac{(29.5)(0.47)(36)^4}{384(29E6)(0.078)} = 0.0268" \text{ (FIXED-FIXED)}$$

$< \frac{1}{8}"$ PER FOOT SPAN

O.K.

*NOTE: EQUIVALENT PRESSURE DUE TO DUCT + STIFFENER SELF-WEIGHT = (0.283)(0.0516)/0.03611 + (1.23/30x12)

$\therefore P_{TOTAL} = 11.3"$ INTERNAL PRESS. $+ 0.5"$ SELF. WT $= 11.8"$ W.C.

FROM THE DUCT CONSTRUCTION SCHEDULE (TABLE 2.2) IT CAN BE SEEN THAT THE ABOVE WAS THE CRITICAL DUCT SYSTEM FOR ITS SIZE RANGE & CONFIGURATION (DUCT SIZES UPTO 36" HAVE L1½x1½x⅛ STIFFENERS @ 2'-6" WITH NO TIE-RODS). SINCE THIS IS FOUND TO BE OK, ALL PANEL STIFFENERS UPTO 36" ARE ALSO ADEQUATE.

CHECK WELDS ON 36"x7" DUCT.

ASSUME CONSERVATIVELY THAT NEGATIVE PRESSURE P EXISTS IN THE DUCT.

UNIFORM LOAD ON STIFFENER = 29.5p

THERE ARE 1" WELDS @ 8" CENTERS.

THEREFORE, NUMBER OF WELDS = 6

$\therefore$ LOAD ON EACH WELD = $\frac{29.5p(36")}{6} = 177p$

WELD CAPACITY IS BASED ON STRENGTH OF DUCT SHEET

$$R = \frac{F_u t L}{F.S} = \frac{(58000)(0.0478)(1)}{(2.5)} = 1109 \text{ LB} \quad \ldots\ldots [5]$$

$\therefore 177p = 1109 \Rightarrow p = 173.5"$ W.C. $\gg 11.8"$ W.C. O.K.

NOTE THAT THE STEEL GRADE USED (STIFFENER IS A575 & PANEL IS A527 STEEL) IS NOT COVERED BY SPECIFICATIONS OF [5]. HOWEVER, DUE TO LACK OF INFORMATION, STRENGTH REQUIREMENTS OF [5] IS USED. SINCE IT IS FOUND THAT THE ALLOWABLE PRESSURE IS >15 TIMES THE BOUNDING VALUE, SLIGHT CHANGES IN PROPERTIES AND F.S. WILL NOT ALTER THE OUTCOME IN ANY SIGNIFICANT WAY.

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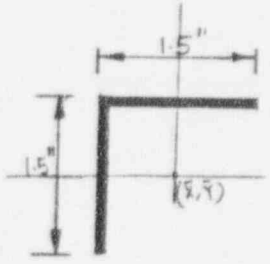

ASSUME WELD AS SHOWN

EACH LEG OF WELD $b = d = 1.5''$

$$\text{AREA} = \{1.5 - 0.125\}(0.088) + (1.5)(0.088) = 0.25\ \text{IN}^2$$

POLAR MOMENT OF INERTIA OF WELD

$$= \frac{(b+d)^4 - 6b^2d^2}{12(b+d)} \cdot t_e \qquad \text{REF [4]}$$

$$= \left[\frac{(3)^4 - (6)(1.5)^2(1.5)^2}{12(3)}\right](0.088) \qquad (\text{ASSUME } 1/8'' \text{ WELDS})$$

$$= 0.13\ \text{IN}^4$$

LET p BE THE ALLOWABLE PRESSURE FOR WELDED CONNECTION SAFETY. THEN,

$$\sigma = 21000 = \frac{Tc}{I_p} + \frac{E}{A}$$

$$\bar{X} = \bar{Y} = \frac{b^2 + ct}{2(b+d)} = \frac{1.5^2 + (1.375)(0.125)}{2(1.5+1.5)} = 0.6 \Rightarrow c = 1.5 - 0.6 = 0.9''$$

$$\therefore \quad 21000 = \frac{(29.5)\,p\,(36)^2(0.9)}{12(0.13)} + \frac{(29.5)(36)\,p}{2(0.25)}$$

$$\Rightarrow \quad p = 24.1'' \text{ W.C.} > (11.8'' \text{ W.C.}) \quad \underline{\text{O.K.}}$$

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4.2 DUCTING SYSTEM 2848-1-2C

29"x80"

CHECK 80" PANEL STIFFENER.

STIFFENER: L2"x2"x3/16" @ 2' O.C. WITH INTERNAL SUPPORT

FROM REF [6] p.9-12,

$M_{MAX} = \frac{wL^2}{12} \times \frac{1}{4}$ [SINCE EQUIVALENT PRESSURE DUE TO DUCT SELFWEIGHT IS VERY SMALL, IT WILL BE INCORPORATED INTO THE INTERNAL PRESSURE TERM]

$w = 24p$

$\therefore M_{MAX} = \frac{24pL^2}{12} \times \frac{1}{4} = \frac{(24)(80)^2}{12 \times 4} p = 3200p$

$\therefore \sigma = 21600 = \frac{3200p}{0.19}$

NOTE: FOR 2"x2"x3/16" STIFFENER

$\therefore p = 1.28 psi = 35.5" w.c. >> 11.9" w.c.$ O.K.

FROM THE DUCT CONSTRUCTION SCHEDULE (TABLE 2.2) IT CAN BE SEEN THAT FOR DUCT SIZES 61" TO 96", THE STIFFENERS ARE OF THE SAME SIZE AND CONFIGURATION (i.e., L2"x2"x3/16" @ 2' O.C. WITH TIE-RODS). FOR THIS SIZE RANGE, THE ABOVE WAS THE STIFFENER WITH THE WORST CASE IMPOSED LOADING. SINCE THIS WAS FOUND ADEQUATE, ALL PANEL STIFFENERS FROM 61" TO 80" ARE ALSO O.K.

CHECK WELDS ON 29" × 80" DUCT:

UNIFORM LOAD ON STIFFENER = 24p

THERE ARE 1" BRAZED FILLET WELDS @ 8" CENTERS.

SINCE WIDTH OF PANEL = 80",

∴ NUMBER OF WELDS = 11

∴ LOAD ON EACH WELD (BRAZING)

$$= \frac{(24")\,p\,(80")}{11} = 174.5p$$

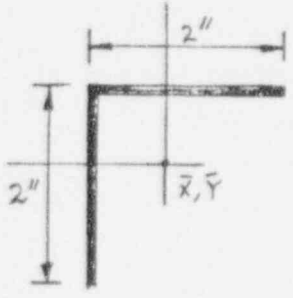
STRENGTH OF BRAZING IS BASED ON CAPACITY OF DUCT SHEET [5, 8]:

$$R = \frac{F_u L t}{F.S.} = \frac{(58000)(0.0478)(1)}{(2.5)} = 1109 \text{ LB}$$

$$\therefore 174.5p = 1109 \Rightarrow p = 6.35 \text{ psi} = 176" \text{W.C.} \gg 11.9" \text{W.C}$$

O.K.

CHECK STIFFENER-TO-STIFFENER MOMENT RESISTING WELD CONNECTIONS FOR L 2" x 2" x 3/16"



$$\text{AREA} = (2 - 0.125)(0.088) + (2)(0.088)$$

$$= 0.341 \text{ IN}^2$$

POLAR MOMENT OF INERTIA OF WELD

$$= \left[\frac{(b+d)^4 - 6b^2d^2}{12(b+d)}\right] \cdot t \qquad \text{REF [4]}$$

$$= \frac{(4)^4 - (6)(2)^2(2)^2}{12(4)} \cdot (0.088) \qquad (\text{ASSUME } \tfrac{1}{8}\text{" WELD})$$

$$= 0.30 \text{ IN}^4$$

LET p BE THE ALLOWABLE INTERNAL PRESSURE FOR WELDED CONNECTION SAFETY. THEN,

$$\sigma = 21000 = \frac{Ic}{I_p} + \frac{F}{A}$$

NOW, $\bar{x} = \bar{y} = \frac{b^2 + ct}{2(b+d)} = \frac{2^2 + (1.875)(0.125)}{2(4)} = 0.53" \therefore c = 1.47"$

$$\therefore 21000 = \frac{(24)p(80)^2(1.47)}{12(4)(0.30)} + \frac{(24)p(80)}{2(0.34)}$$

$\therefore p = 1.13 \text{ psi} = 31.4" \text{ W.C.} >> (11.9" \text{ W.C.})$ O.K.

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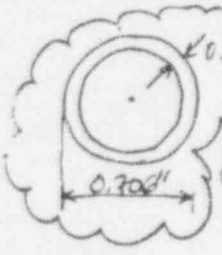
NEXT, THE SAFETY OF THE TIE-ROD NEEDS TO BE CHECKED. FROM [6], p. 9-13:

COMPRESSIVE FORCE ON TIE ROD,

$$F = SLW_{cr}$$
$$= (24")(80")(0.5p)$$
$$= 960p$$

NOW, THE TIE-RODS ARE ½" NOMINAL DIA THIN WALLED CONDUIT PIPE (O.D. = 0.706", I.D = 0.622", 0.3LB/FT)



AREA = $\frac{\pi}{4}(0.706^2 - 0.622^2)$
= 0.088 SQIN.

RADIUS OF GYRATION = $r = \frac{\sqrt{d_o^2 + d_i^2}}{4}$
= 0.24"

L = 29". LET K = 1.0

∴ SLENDERNESS RATIO = $\frac{KL}{r} = \frac{29}{0.24} = 121$

NOW, $C_c = \left(\frac{2\pi^2 E}{F_y}\right)^{1/2} = \sqrt{\frac{2\pi^2 (29E6)}{36}} = 126$

FROM [7] TABLE C-36 p. 3-16,

ALLOWABLE STRESS = 10140 PSI

∴ $960p = (10140)(0.088) \Rightarrow p = 0.93 psi = 25.7" W.C > 11.9" W.C$

CHECK DEFLECTION:

$$\Delta = \frac{(24)(0.93)(40)^4}{(384)(29E6)(0.272)} = 0.02" < \tfrac{1}{8}" \text{ PER FOOT SPAN O.K}$$

4.3 DUCTING SYSTEM 4126-1

48" x 48"

STIFFENER: L 1½" x 1½" x ⅛" @ 2'-6" O.C. WITH TIE-ROD

FROM REF [6] p. 9-12

$$M_{MAX} = \frac{wL^2}{12} \times \frac{1}{4}$$

$w = 29.5p$

$$\therefore M_{MAX} = \frac{29.5pL^2}{12} \times \frac{1}{4} = \frac{(29.5)(48)^2}{48}p = 1416p$$

$$\therefore \sigma = 21600 = \frac{1416p}{0.072}$$

OR, $p = 1.1\,psi = 30"\,W.C. > (11.8"\,W.C.)$ O.K.

FROM THE DUCT CONSTRUCTION SCHEDULE (TABLE 2.2) IT CAN BE SEEN THAT THE ABOVE WAS THE CRITICAL DUCT SYSTEM FOR ITS SIZE RANGE AND CONFIGURATION (DUCT SIZES 37" TO 48" HAVE L 1½ x 1½ x ⅛ STIFFENERS @ 2'-6" O.C. WITH TIE-RODS). SINCE THIS IS FOUND TO BE ADEQUATE, ALL PANEL STIFFENERS FROM 37" TO 48" WILL ALSO BE OK.

CHECK BRAZINGS BETWEEN STIFFENERS AND DUCT SHEETS:

UNIFORM LOAD ON STIFFENER = 29.5 p

THERE ARE 1" BRAZED FILLET WELDS @ 8" CENTERS.

SINCE WIDTH OF PANEL = 48"

∴ NUMBER OF WELDS = 7

∴ LOAD ON EACH WELD

$$= \frac{(29.5)\,p\,(48)}{7} = 202.3\,p$$

CAPACITY OF THE WELD IS BASED ON STRENGTH OF DUCT SHEET [5,8]:

$$R = \frac{F_u L t}{F.S.} = \frac{(58000)(0.0478)(1)}{(2.5)} = 1109 \text{ LB}$$

∴ $202p = 1109 \Rightarrow p = 5.5 \text{ psi} = 152" \text{ W.C.} >> 11.8" \text{ W.C.}$

O.K.

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CHECK STIFFENER-TO-STIFFENER MOMENT RESISTING WELD CONNECTION FOR L $1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{8}$

USING PROPERTIES EVALUATED PREVIOUSLY FOR CONNECTION WELD,

$A = 0.25\ in^2$

$I_p = 0.13\ in^4$

$c = 0.9''$

$$\sigma = \frac{Tc}{I_p} + \frac{F}{A}$$

$$\therefore 21000 = \frac{(29.5)p(48)^2(0.9)}{12(4)(0.13)} + \frac{29.5p(48)}{2(0.25)}$$

$$\Rightarrow p = 1.66\ psi = 46.03''\ W.C. >> (11.8''\ W.C.)\ \underline{O.K.}$$

CHECK ADEQUACY OF TIE-RODS:

COMPRESSIVE FORCE ON TIE-ROD, (FROM [6])

$F = SLW_{cr}$

$= (29.5)(48)(0.5p)$

$= 708p$

PROPERTIES OF TIE-ROD ($\frac{1}{2}$" ϕ PIPE)

$r = 0.24"$

$A = 0.088$ SQ. IN

$L = 48"$, $K = 1.0$

SLENDERNESS, $\frac{KL}{r} = \frac{48}{0.26} = 200 > C_c = 126$

FROM [7] TABLE C-36 p. 3-16

ALLOWABLE STRESS = 3.73 KSI

$\therefore 708p = (3730)(0.088)$

OR $p = 0.46$ PSI $= 12.8"$ W.C. $> 11.8"$ W.C. O.K.

CHECK DEFLECTION

SINCE THERE ARE TIE-RODS, $\therefore L' = 24"$

$\therefore \Delta = \frac{(29.5)(0.46)(24)^4}{(384)(29E6)(0.078)} = 0.005" < \frac{1}{8}"$ PER FOOT SPAN

4.4 DUCTING SYSTEM 2849-3

60" x 26" - CHECK 60" WIDE PANEL

STIFFENER: L 1½" x 1½" x ⅛" @ 2' O.C WITH TIE-ROD

FROM REF [6], p. 9-12

$$M_{MAX} = \frac{wL^2}{12} \times \frac{1}{4}$$

$w = 24p$

$$\therefore M_{MAX} = \frac{24pL^2}{12} \times \frac{1}{4} = \frac{(24)(60)^2(p)}{48} = 1800p$$

$$\therefore \sigma = 21600 = \frac{1800p}{0.072}$$

OR, $p = 0.864$ psi $= 23.9$" W.C. $>$ 11.8" W.C. O.K.

FROM THE DUCT CONSTRUCTION SCHEDULE (TABLE 2.2) IT CAN BE SEEN THAT THE ABOVE WAS THE CRITICAL DUCT SYSTEM FOR ITS SIZE RANGE AND CONFIGURATION (DUCT SIZES 49" TO 60" HAVE L 1½" x 1½" x ⅛" STIFFENERS @ 2' WITH TIE-RODS). SINCE THIS IS FOUND TO BE OK, ALL PANEL STIFFENERS FROM 49" TO 60" WILL ALSO BE ADEQUATE.

CHECK BRAZINGS BETWEEN STIFFENERS AND DUCT SHEETS:

UNIFORM LOAD ON STIFFENER = 24 P.

1" BRAZED FILLET WELDS @ 8" CENTERS.

WIDTH OF PANEL = 60"

∴ NUMBER OF WELDS = 8

LOAD PER WELD = $\frac{(24)(P)(60)}{8} = 180P$

CAPACITY OF BRAZING IS BASED ON STRENGTH OF DUCT SHEET METAL [5,8]:

$$R = \frac{F_u L t}{F.S.} = \frac{(58000)(0.0478)(1)}{(2.5)} = 1109 \text{ LB}$$

$\therefore 180P = 1109 \Rightarrow P = 6.16 \text{ psi}$

$= 170.6" \text{ W.C.} > 11.8" \text{ W.C.}$

O.K.

CHECK DEFLECTION

$L' = 60"/2 = 30"$

$\Delta = \frac{(24)(0.864)(30)^4}{(384)(29E6)(0.078)} = 0.02" < \frac{1}{8}"$ PER FOOT SPAN. O.K.

CHECK STIFFENER-TO-STIFFENER MOMENT RESISTING WELD CONNECTION:

PROPERTIES OF WELD (EVALUATED PREVIOUSLY)

$A = 0.25\,IN^2$

$I_p = 0.13\,IN^4$

$c = 0.9''$

$$\sigma = \frac{Tc}{I_p} + \frac{F}{A}$$

$$\therefore 21000 = \frac{(24)p(60)^2(0.9)}{12(4)(0.13)} + \frac{(24)p(60)}{2(0.25)}$$

$\therefore p = 1.37\,PSI = 37.9''\,W.C. > 11.8''\,W.C.$ O.K.

CHECK ADEQUACY OF TIE RODS:

COMPRESSIVE FORCE, $F = SLW_{cr}$

$= (24)(60)(0.5p)$

$= 720p$

PROPERTIES OF TIE-ROD:

$r = 0.24''$

$A = 0.058\ SQ.IN$

$L = 26''$, $K = 1.0$

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SLENDERNESS RATIO, $\frac{KL}{r} = 108$

FROM [7], TABLE C-36 p. 3-16

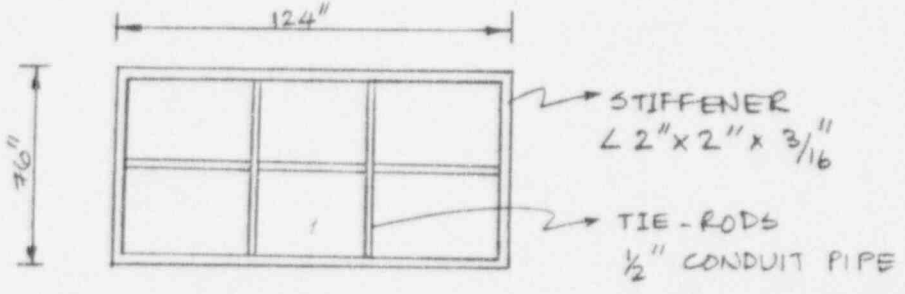
ALLOWABLE STRESS = 11.94 KSI

$\therefore 720p = (11940)(0.088)$

OR, $p = 1.46$ PSI $= 40.4$" W.C $>>$ 11.8" W.C. O.K.

4.5 DUCTING SYSTEM 2849-9

124" x 76"



ASSUME STIFFENERS ARE SPACED 2' O.C.

THIS SYSTEM HAS TWO INTERNAL SUPPORTS (i.e., TIE RODS FOR THE 124" WIDE PANEL). FROM [6]

$$M_{MAX} = (0.11)\frac{wL^2}{12} \quad \text{(TWO TIE-RODS)}$$

$$w = 24p$$

$$\therefore M_{MAX} = \frac{(0.11)(24p)(124)^2}{12} = 3382.7p$$

$$\therefore \sigma = 21600 = \frac{3382.7p}{0.19}$$

$$\therefore p = 1.2 \text{ psi} = 33.6" \text{ W.C.} > 11.9" \text{ W.C.} \quad \underline{\text{O.K.}}$$

CHECK BRAZING OF STIFFENER TO DUCT SHEET:

UNIFORM LOAD ON STIFFENER = 24p

1" BRAZED FILLET WELDS @ 8" CENTERS

WIDTH OF PANEL = 124"

∴ NUMBER OF WELDS = 16

$$\therefore \text{LOAD ON EACH WELD} = \frac{24p(124)}{16} = 186p$$

STRENGTH OF BRAZING IS BASED ON STRENGTH OF DUCT PANEL SHEET [5,8]:

$$R = \frac{F_u L t}{F.S.} = \frac{(58000)(0.0478)(1)}{(2.5)} = 1109 \text{ LB}$$

$$\therefore 186p = 1109 \Rightarrow p = 6.0 \text{ psi} = 166\text{"W.C.} >> 11.9\text{"W.C.}$$ O.K.

CHECK STIFFENER-TO-STIFFENER MOMENT RESISTING WELD CONNECTION:

FROM PREVIOUS ANALYSIS, PROPERTIES OF WELD -

$A = 0.341 \text{ IN}^2$

$I_p = 0.30 \text{ IN}^4$

$c = 1.47"$

$$\sigma = 21000 = \frac{Tc}{I_p} + \frac{F}{A}$$

$$\therefore 21000 = \frac{(24)p(124)^2(1.47)(0.11)}{12(0.30)} + \frac{24p(124)}{2(0.34)}$$

$$\therefore p = 1.00 \text{ psi} = 27.8\text{" W.C.} > 11.9\text{" W.C.}$$ O.K.

CHECK COMPRESSION ON TIE-RODS:

FROM [6],

$$F = 0.7 SL W_{cr} = (0.7)(24)(124)(0.5p)$$

$$= 1041.6p$$

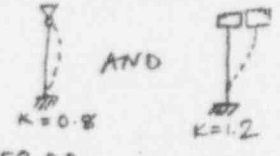
PROPERTIES OF TIE-ROD:

$A = 0.088$ SQ.IN

$r = 0.24$"

$L = 38$", $K = 1.0$

NOTE: K=1.0 USED AS AN AVERAGE OF TWO CASES:



SLENDERNESS RATIO, $\frac{KL}{r} = 158.33$

FROM [7], EQUATION (E2-2) p. 5-42

$$F_a = \frac{12\pi^2 E}{23\left(\frac{KL}{r}\right)^2} = \frac{(12)(\pi)^2(29\times10^6)}{(23)(158.33)^2} = 5.96 \text{ KSI}$$

$\therefore 1041.6p = (5960)(0.088) \Rightarrow p = 0.50 \text{ psi} = 13.9\text{" W.C.} > 11.9\text{" W.C.}$

O.K.

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CHECK TIE-ROD SPANNING 124". SINCE THIS HAS INTERMEDIATE SUPPORTS, FOLLOWING THE SAME AVERAGING, USE $K=1.0$ AND $L' = L/3 = 41.33"$

$$F = SLW_{cr} = (24)(76)(0.5p)$$

$$= 912p$$

USING $K=1.0$ AND $L' = L/3 = 124"/3 = 41.3"$,

$$\frac{KL}{r} = 172.2$$

$$\therefore Fa = \frac{12\pi^2 E}{23\left(\frac{KL}{r}\right)^2} = 5035 \text{ psi}$$

$\therefore 912p = (5035)(0.088)$, or $p = 0.49$ psi

$= 13.45"$ W.C. $> 11.9"$ W.C. O.K.

CHECK DEFLECTION OF 124" STIFFENER

$L' = L/3 = 124/3 = 41.33"$

$$\therefore \Delta = \frac{(24)(0.49)(41.33)^4}{(384)(29E6)(0.272)} = 0.01" < 1/8"$$ PER FOOT SPAN O.K.

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CALCULATION SHEET

TITLE: RESPONSE TO CONCERN 19 DATE: MAY 03, '94 PAGE: 27

SUBJECT: 5.0 CONCLUSIONS BY: MAK CK: MEF SHT: 1 OF 1

CRITICAL STIFFENERS FOR THE 55 CCHVAC DUCTING SYSTEMS HAVE BEEN EVALUATED. BOUNDING ANALYSES, TO ENCOMPASS ALL POSSIBLE DUCT AND STIFFENER SIZES AND CONFIGURATIONS, WERE DONE TO EVALUATE THE STRUCTURAL INTEGRITY OF THE STIFFENERS. THE WELDS, BRAZINGS AND THE INTERNAL SUPPORTS (TIE-RODS) WERE ALSO EVALUATED. BASED ON THE FACT THAT 11.3" W.C. IS THE MAXIMUM POSSIBLE INTERNAL PRESSURE FOR ANY DUCT, IT WAS FOUND THAT ALL STIFFENERS, WELDS, BRAZINGS AND TIE-RODS ARE ADEQUATE. THE STIFFENERS WERE FOUND TO MEET THE STRESS CRITERIA OF ANSI/ASME N509-80.

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