DØ SOLENOID UPGRADE PROJECT

Pressure ratings for some Chimney and Control Dewar components

D-ZERO ENGINEERING NOTE # 3823.111-EN-341

May 25, 1993

Russ Rucinski

Pressure rating calculations were done for some of the chimney and control dewar components. This engineering note documents these calculations. The table below summarizes the components looked at, and what pressure rating are. The raw engineering calculations for each of the components follow.

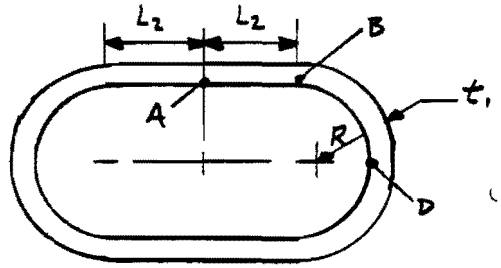
TABLE 1: Summary of ratings

Component	Internal pressure Rating	External pressure Rating	Code used Internal	Code used external
Chimney: Obround vacuum shell	52 psi	52 psi	ASME; Appendix 13	ASME; Appendix 13
Chimney: 8" sch. 10 vac. shell	445 psi	100 psi	ASME; UG-27	ASME; UG-28
Chimney: 10" sch. 10 vac. shell	398 psi	72 psi	ASME; UG-27	ASME; UG-28
LHe supply tubing	>1600 psi	n/a	ANSI B31.3	n/a
LHe return tubing	1387 psi	n/a	ANSI B31.3	n/a
LN2 tubing, aluminum	2087 psi	n/a	ANSI B31.3	n/a
LN2 tubing, stainless	>2100 psi	n/a	calc. not done	n/a
Control dewar 36" Ø vac. shell	102 psi	32 psi	ASME; UG-27	ASME; UG-28
Control dewar 12" Ø LHe vessel	365 psi	n/a	ASME; UG-27	n/a

~~REDO ASME STRESS CALCULATIONS FOR A TOTAL LENGTH OF 7" RATHER THAN THE PREVIOUS 6 3/4". (USING APPENDIX 13 CALCS).~~

-CALCULATE FOR THE INTERNAL & EXTERNAL PRESSURE.

DESIGN FOR 12 PSIG INTERNAL AND 30 PSID EXTERNAL.



$L_1 = 0$
$L_2 = 2.00''$
$R = 1.3125''$
$t_1 = 0.1875''$

INTERNAL PRESSURE:

13-7(c)

1.) MEMBRANE STRESS:

SHORT SIDE $(S_m)_C = (S_m)_D = \frac{P(R+L_2)}{t_1} = \frac{12psi\,(3.3125in)}{.1875in} = 212\ psi$

LONG-SIDED PLATE $(S_m)_A = (S_{m_B}) = \frac{P(L_1+R)}{t_1} = \frac{12psi\,(1.3125in)}{.1875in} = 84\ psi$

CORNER SECTIONS $(S_m)_{B-C} = \frac{P}{t_1}\left(\sqrt{L_2^2 - L_1^2} + R\right) = \frac{12psi}{.1875in}\left(\sqrt{2.0in^2 - 0in^2} + 1.3125in\right)$
$= 212\ psi$

2. BENDING STRESS:

SHORT SIDE: $(S_b)_D = \frac{C}{2I_1}\left[2M_A + P\left(L_2^2 + 2RL_2 - 2RL_1 - L_1^2\right)\right]$

$C = .09375$ $\qquad C_i = .09375,\ C_o = -.09375$

$I_1 = \frac{t^3}{12} = 5.493 \times 10^{-4}$

$M_A = PK_3$

$K_3 = -L_1^2(6\phi^2\alpha_3 - 3\pi\phi^2 + 6\phi^2 + \alpha_3^2 + 3\alpha_3^2 - 6\phi - 2 + 1.5\pi\phi\alpha_3^2$
$+ 6\phi\alpha_3)\cdot\left[3(2\alpha_3 + \pi\phi + 2)\right]^{-1}$

DETERMINE WHAT M_A IS: $M_A = PK_3 = P \cdot \lim_{L_1 \to 0} K^3$

$\lim_{L_1 \to 0} K_3 =$

$\lim_{L_1 \to 0} \left\{ -L_1^2\left(6\frac{R^2}{L_1^2}\cdot\frac{L_2}{L_1} - 3\pi\frac{R^2}{L_1^2} + 6\frac{R^2}{L_1^2} + \frac{L_2^3}{L_1^3} + 3\frac{L_2^2}{L_1^2} - 6\frac{R}{L_1} - 2\right.\right.$
$\left.\left. + 1.5\pi\frac{R}{L_1}\frac{L_2^2}{L_1^2} + 6\frac{L_2}{L_1}\frac{R}{L_1}\right)\cdot\left[3\left(2\frac{L_2}{L_1} + \pi\frac{R}{L_1} + 2\right)\right]^{-1}\right\} = L$

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OBROUND PRESSURE RATING	RUSS RUCINSI	5/25/93	

CALCULATE THE REQUIRED THICKNESS PER ASME SECTION VIII DIV. 1, APPENDIX 13 "VESSELS OF NON-CIRCULAR CROSS SECTION" 1992 EDITION USED.

ANALYZE OBROUND SHAPE, FIGURE 13-2(b) SKETCH 1
APPENDIX 13 ONLY COVERS INTERNAL PRESSURE, NOT EXTERNAL FOR AN OBROUND SHAPE. EXTERNAL PRESSURE DESIGN IS TO BE IN ACCORDANCE WITH U-2(g). {REF. 13-4(c) 2(e)}
{NOTE AN OBROUND SHAPE ALLOWS DIFFERENT THICKNESSES @ END}
→ CALCULATE FOR RECTANGULAR SHAPE FOR INTERNAL AND EXTERNAL PRESSURE. FIGURE 13-2(a), SKETCH 3.

DESIGN FOR 12 PSIG INTERNAL AND 30 PSID EXTERNAL PRESSURE. AFTER STRESSES WERE CALCULATED FOR THESE PRESSURES, THE MAWP'S WERE DETERMINED.

$L_1 = 0$
$L_2 = 2.00$ IN.
$R = 1.3125$ IN.
$t = 0.1875$ IN.
POINT C DOESN'T EXIST

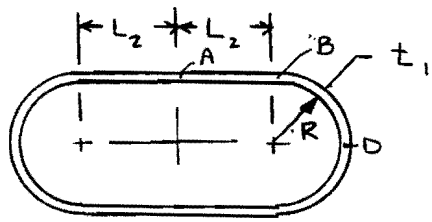

FIGURE 13-2(a) SK. 3 WITH VARIABLES

STABILITY CALCULATIONS ARE FOR A 3" x 6 3/4" OBROUND SHAPE. THE CALCULATIONS WERE NOT DONE FOR THE FINAL SELECTED 3" x 7" SHAPE.

THE CALCULATIONS STILL APPLY HOWEVER TO SHOW THAT $P_c > 10 \cdot P_{MAWP\ EXTERNAL}$.

3. TOTAL STRESS:

SHORT-SIDED PLATES: $(S_T)_D = (S_m)_D + (S_b)_D = 212\,psi + \pm 4984\,psi$

$= 5196\,psi$ TENSION INNER SURFACE

$= -4772\,psi$ COMPRESSION OUTER SURFACE

LONG-SIDED PLATES: $(S_T)_A = (S_m)_A + (S_b)_A = 84\,psi + \pm 4489\,psi$

$= 4573\,psi$ TENSION OUTER SURFACE

$= -4405\,psi$ COMPRESSION INNER SURFACE

$(S_T)_B = (S_m)_B + (S_b)_B = 84\,psi + \pm 393\,psi$

$= 477\,psi$ TENSION OUTER SURFACE

$= -309\,psi$ COMPRESSION INNER SURFACE

CORNER SECTION: $(S_T)_{B-C} = (S_m)_{B-C} + (S_b)_D = 212\,psi \pm 4984\,psi$

$= (S_T)_D$ $5196\,psi$ TENSION INNER SURFACE

$-4772\,psi$ COMPRESSION OUTER SURFACE

ALLOWABLES:

MEMBRANE STRESSES: 13-4 (b)

IN THE PLATES & PIPE, PTS. A, D THEY SHALL NOT EXCEED S AT PT. B; IN A WELD THEY SHALL NOT EXCEED S·E

COMBINATIONS = MEMBRANE & BENDING: 13-4 (b)

FOR PLATE SECTION THEY SHALL NOT EXCEED 1.5 × S·E

THE ALLOWABLE S, FOR 304 STN. STEEL & ALUM. APPEAR ON PAGE 2. ASSUME E = 0.60 AS OBTAINED FOR BUTT JOINT W/O BACKING STRIP, NO RADIOGRAPHIC EXAMINATION, TABLE UW-12

CONCLUSION - INTERNAL PRESSURE

THE CALCULATED STRESSES (MEMBRANE, & COMBINED MEMBRANE PLUS BENDING) ARE LESS THAN CODE ALLOWABLES FOR 304 STN. STEEL, 5083-0 ALUMINUM, & 6061-T6 ALUMINUM FOR INTERNAL PRESSURE LOADING EQUAL TO 12psig. THIS IS FOR $t_1 = 0.1875in$, $C_1 = 0$, $C_2 = 2.00in$, $R = 1.3125in$

$$= \lim_{L_1 \to 0} \left\{ -L_1^2 \left(\frac{6R^2L_2}{L_1^3} - \frac{3\pi R^2}{L_1^2} + \frac{6R^2}{L_1^2} + \frac{L_2^3}{L_1^3} + \frac{3L_2^2}{L_1^2} - \frac{6R}{L_1} - 2 + \frac{1.5\pi R L_2^2}{L_1^3} + \frac{6L_2R}{L_1^2} \right) \cdot \left[\frac{6L_2}{L_1} + \frac{3\pi R}{L_1} + 6 \right]^{-1} \right\}$$

$$= \lim_{L_1 \to 0} \left\{ -L_1^2 \left(\frac{6R^2L_2 + L_2^3 + 1.5\pi R L_2^2}{L_1^3} + \frac{-3\pi R^2 + 6R^2 + 3L_2^2 + 6L_2R}{L_1^2} + \frac{-6R}{L_1} - 2 \right) \cdot \left[\frac{6L_2 + 3\pi R + 6L_1}{L_1} \right]^{-1} \right\}$$

$$= \lim_{L_1 \to 0} \left\{ \frac{-L_1^3}{(6L_2 + 3\pi R + 6L_1)} \left(\frac{6R^2L_2 + L_2^3 + 1.5\pi R L_2^2 + L_1(-3\pi R^2 + 6R^2 + 3L_2^2 + 6L_2R)}{L_1^3} + \frac{-6RL_1^2 - 2L_1^3}{L_1^3} \right) \right\}$$

$$\boxed{= -\frac{(6R^2L_2 + L_2^3 + 1.5\pi R L_2^2)}{6L_2 + 3\pi R}}$$

FOR THIS CASE:

$$M_A = PK_3 = (12\text{psi}) \cdot \left[\frac{-(6(1.3125)^2 \cdot 2.00\text{in} + 2\text{in}^3 + 1.5\pi(1.3125)(2.0)^2)}{6(2.00) + 3\pi(1.3125)} \right]$$

$$= 12\text{psi} \left(\frac{-53.4119172}{24.3700211} \right) = -26.30 \text{ in-lb}$$

$$(S_b)_D = \frac{.09375}{2(5.493 \times 10^{-4})} \left[2(-26.30) + 12(2.0^2 + 2(1.3125)(2.0)) \right]$$

$(S_b)_D = 4984$ TENSION ON INNER SURFACE

$(S_b)_D = -4984$ COMPRESSION ON OUTER SURFACE

LONG-SIDED PLATES:

$$(S_b)_A = \frac{M_A c}{I_1} = \frac{(-26.3\text{in-lb})(.09375\text{in})}{5.493 \times 10^{-4}} = -4489\text{psi}$$ COMPRESSION ON INNER SURFACE

$= 4489$ psi TENSION ON OUTER SURFACE.

$$(S_b)_B = \frac{c}{2I_1}(2M_A + PL_2^2) = \frac{.09375\text{in}}{2(5.493 \times 10^{-4})}(2(-26.30) + 12(2.0)^2)$$

$= -393$ psi COMPRESSION ON INNER SURFACE

$= 393$ psi TENSION ON OUTER SURFACE

CORNER SECTIONS: $(S_b)_{B\text{-}C\,max}$ OCCURS @ $\theta = \tan^{-1}(L_1/L_2) = 0°$

→ WHICH IS SAME AS PT. D.

CHECK AGAINST ALLOWABLES:

MEMBRANE STRESSES, O.K.

COMBINED STRESSES SHALL NOT EXCEED 1.5 · SE

FOR 304 STN. STEEL,

$1.5 \times SE = 1.5\,(15.04\,ksi)(.60) = 13.54\ ksi \rightarrow$ TOTAL STRESSES O.K.

~~FOR ALUMINUM,~~

~~1.5 x SE = 7.7 ksi | 5083-0~~

~~7.56 ksi | 6061-T6~~

~~TOTAL STRESSES COMBINED NOT O.K. FOR ALUMINUM.~~

⇒ THE STRESSES DUE TO EXTERNAL PRESSURE ARE ACCEPTABLE FOR 304 STN. STEEL, ~~BUT NOT FOR ALUMINUM.~~

NOTE: $S = 0.8\,(18.8\ ksi) = 15.04\ ksi$

FERMI FACTOR

TABLE UHA-23, PLATE 304 S.S.

R. RUCINSKI
5/25/93

EXTERNAL PRESSURE:

DESIGN FOR 30 PSID

-CHECK STRESSES DUE TO EXTERNAL PRESSURE

(1) STRESSES DUE TO EXTERNAL PRESSURE. SPECIFIC RULES FOR A SHAPE OF FIG. 13-2 (a) 3 ARE NOT GIVEN OTHER THAN THE DESIGN IS TO BE IN ACCORDANCE w/ U-2(g) {REF. 13-4(c) 2(a)}

FOLLOWING THE CODE METHOD (13-14) I WILL CALCULATE THE STRESSES USING THE EQUATIONS FOR INTERNAL PRESSURE BUT USING $P_{ex} = -30$ psig IN PLACE OF P.

{THE EQUATIONS WILL BE SHORTHAND VERSION, FOLLOWING THE CALCS. ON PGS. 1 THRU 4 SUBSTITUTING}

1.) MEMBRANE STRESSES:

$(S_m)_D = -530$ psi COMPRESSION

$(S_m)_A = (S_m)_B = -210$ psi COMPRESSION

$(S_m)_{B-C} = (S_m)_D = -530$ psi COMPRESSION

2.) BENDING STRESSES:

$M_A = 65.75$ in·lbs.

$(S_b)_D = -12{,}460$ psi COMPRESSION, INNER SURFACE
$12{,}460$ psi TENSION, OUTER SURFACE

$(S_b)_A = -11{,}223$ psi TENSION, INNER SURFACE
$11{,}223$ psi COMPRESSION, OUTER SURFACE

$(S_b)_B = -983$ psi TENSION, INNER SURFACE
983 psi COMPRESSION, OUTER SURFACE

3) TOTAL STRESSES:

$(S_T)_A = -11{,}433$ psi COMPRESSION OUTER SURFACE
$11{,}013$ psi TENSION INNER SURFACE

$(S_T)_B = -1193$ psi COMPRESSION OUTER SURFACE
773 psi TENSION INNER SURFACE

$(S_T)_D = -12{,}990$ psi COMPRESSION INNER SURFACE
$11{,}930$ psi TENSION OUTER SURFACE

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$$S_{crA} = \frac{\pi^2 E_z}{12(1-\nu^2)}\left(\frac{t_1}{H}\right)^2 K_A \qquad \frac{h}{H} = \frac{6.375}{2.625} = 2.43 \Rightarrow K_A = 5.8$$

(FROM FIG 13-14a)

$$S_{crA} = \frac{\pi^2(29\times10^6)}{12(1-(.303)^2)}\left(\frac{.1875}{2.625}\right)^2(5.8) = 777{,}161$$

$S_y = 15.04$ ksi

$S_{crA} > \frac{1}{2} S_y$ so: $S_{crA} = S_y - S_y^2/4S_{crA}$

NOTE: I AM NOT REAL COMFORTABLE WITH THIS EXPRESSION SINCE IT REDUCES TO $S_{crA} = \frac{1}{2}S_y$.

WHY NOT JUST SAY THIS? AND FURTHERMORE IT IS CONTRADICTORY TO SAY $S_{crA} = \frac{1}{2}S_y$ IS $S_{crA} > \frac{1}{2}S_y$.

$$S_{crA} = 15{,}040 - \frac{15040^2}{4(S_{crA})}$$

$$S_{crA}^2 = 15{,}040\, S_{crA} - 56{,}550{,}400$$

$$x^2 - 15{,}040\,x + 56{,}550{,}400 = 0$$

$$x = \frac{+15{,}040 \pm \sqrt{(15{,}040)^2 - 4(56{,}550{,}400)}}{2}$$

$$x = 7520 \pm 0 = 7520$$

$$S_{crA} = 7520 \text{ psi}$$

$$\frac{2.625}{6.375} = 0.41 \Rightarrow K_B = 12$$

$$S_{crB} = \frac{\pi^2(29\times10^6)}{12(1-0.303^2)}\left(\frac{.1875}{6.75}\right)^2(12)$$

$$= 243{,}173 \text{ psi}$$

$S_{crB} > \frac{1}{2}S_y \quad \therefore \quad S_{crB} = S_y - \frac{S_y^2}{4S_{crB}} \Rightarrow 7520$ psi

CHECK EQUATION:

$$\frac{2S_{mA}}{S_{crA}} + \frac{2S_{mB}}{S_{crB}} \overset{?}{\leq} 1.0$$

$$\frac{2(148.75)}{7520} + \frac{2(510)}{7520} \overset{?}{\leq} 1.0$$

$.175 \leq 1.0$ ✓ O.K. SHORT SIDE IS STABLE

SUBJECT: DØ SOLENOID CHIMNEY RECTANGLE THICKNESS

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~~CHECK AGAINST ALLOWABLES:~~

~~MEMBRANE STRESSES, O.K.~~

~~COMBINED STRESSES SHALL NOT EXCEED 1.5·SE~~

~~FOR 304 STN. STL.~~

~~$1.5 \times SE = 1.5(15.04\ ksi)(0.60) = 13.54\ ksi$ > TOTAL STRESSES O.K~~

~~FOR ALUMINUM~~

~~$1.5 \times SE = 7.2\ ksi$ |5083-0 < TOTAL COMBINED STRESSES NOT O.K. FOR ALUMINUM~~

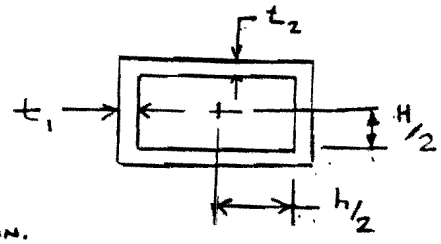
~~$7.56\ ksi$ |6061-T6~~

~~⇒ THE STRESSES DUE TO EXTERNAL PRESSURE ARE ACCEPTABLE FOR 304 STN. STL., BUT NOT FOR ALUMINUM~~

STABILITY:

THIS ANALYSIS IS NOT STRAIGHTFORWARD AND THEREFORE ENGINEERING JUDGEMENT COMES INTO PLAY.

ANALYZE AS A RECTANGLE IF SHAPE:
(PER SKETCH 13-2a(1))



$t_1 = t_2 = .1875$

$h/2 = 3.1875$ IN $h = 6.375$ IN.

$H/2 = 1.3125$ IN. $H = 2.625$ IN.

DO 'CODE' STABILITY ANALYSIS PER SECTION 13-14.

$$\frac{2S_{mA}}{S_{crA}} + \frac{2S_{mB}}{S_{crB}} \leq 1.0$$

SHORT SIDE PLATES: $S_{mA} = \dfrac{P_e h H}{2(t_1 H + t_2 h)} = \dfrac{30(6.375)(2.625)}{2(.1875)(2.625+6.375)}$

$= 148.75$

$S_{mB} = P_e h / 2t_1 = \dfrac{30(6.375)}{2(.1875)} = 510$

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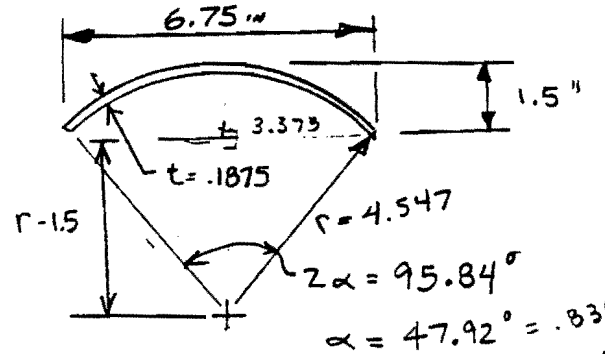
THIS AGREES (SORT OF) WITH TK SOLVER ROARK & YOUNG $q' = 1871$ psi

TRY ANOTHER CASE: THIN TUBE, UNIFORM LATERAL EXTERNAL PRESSURE
VERY LONG TUBE, FREE ENDS
ROARK & YOUNG CASE 19(a)

$$q' = \frac{1}{4}\frac{E}{1-\nu^2}\left(\frac{t}{r}\right)^3 = \frac{1}{4}\frac{(29\times10^6)}{1-.303^2}\left(\frac{.1875}{3.375}\right)^3 = \underline{1369 \text{ psi}}$$

USING TK SOLVER SETTING $q' = 30$ psi, $t = \underline{.0525}$".

TRY ANOTHER CASE CURVED PANEL UNDER UNIFORM RADIAL PRESSUR.
CASE 21(a) - FREE EDGES, CASE 21b - EDGES CLAMPED



$$(r-1.5)^2 + 3.375^2 = r^2 \quad \text{PYTHAGOREAN THEOREM}$$

$$r^2 - 3r + 2.25 + 11.39 = r^2$$

$$r = 4.547 \text{ IN.}$$

$$\alpha = 47.92^\circ = .836 \text{ RADIANS}$$

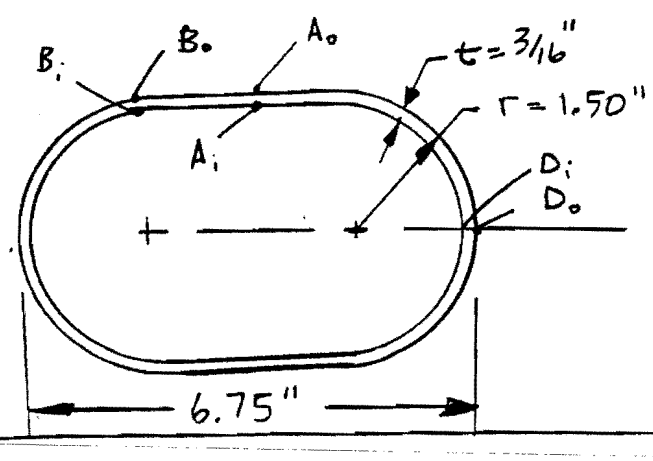
SIMPLY SUPPORTED:

$$q' = \frac{Et^3\left(\frac{\pi}{\alpha^2}-1\right)}{12r^3(1-\nu^2)} = \frac{29\times10^6(.1875)^3\left(\frac{\pi}{.836^2}-1\right)}{12(4.547)^3(1-.303^2)}$$

$$q' = 652 \text{ psi}$$

CONCLUSION ON STABILITY

BASED ON THE RESULTS OF THE STABILITY CASES I DID DO, I FEEL THAT THE SHAPE ON PAGE 4 IS STABLE AGAINST BUCKLING.



SUBJECT: DØ SOLENOID CHIMNEY RECTANGLE THICKNESS

NAME: RUSS RUCINSKI

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LONG SIDE PLATES: $S_{mA} = \frac{P_e h H}{2(t_1 H + t_2 h)} = 148.75$ psi

$$S_{mB} = \frac{P_e H}{2 t_2} = \frac{30(2.625)}{2(.1875)} = 210 \text{ psi}$$

$$S_{crA} = \frac{\pi^2 (29\times10^6)}{12(1-.303^2)}\left(\frac{.1875}{6.375}\right)^2 5.8 = 131{,}768 \text{ psi}$$

$S_{crA} > \frac{1}{2} S_y$ so $S_{crA} = 7520$

$S_{crB} = 7520$

CHECK EQUATION:

$$\frac{2(148.75)}{7520} + \frac{2(210)}{7520} \overset{?}{\leq} 1.0 \qquad \text{YES} \qquad \text{LONG SIDE O.K.}$$

$$.0954 \leq 1.0$$

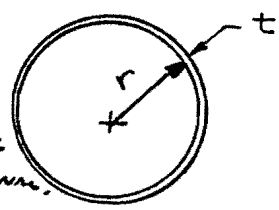
END PLATES NOT APPLICABLE.

TRY NON-CODE STABILITY ANALYSIS: CIRCULAR SHAPES TO BE CONSIDERED.

CONSIDER,

REF. ROARK & YOUNG TABLE 35, CASE 2a

ENDS HELD CIRCULAR, EXTERNAL PRESSURE, LATERAL & LONGITUDINAL, THIN TUBE.



l - LENGTH SAY 60 IN.

$t = .1875$ IN.

$r = 3.375$ IN. {WILL ENVELOPE ACTUAL SHAPE}

CHECK

$$60 < \left(\frac{l}{r}\right)^2\left(\frac{r}{t}\right) \overset{?}{<} 2.5\left(\frac{r}{t}\right)^2$$

$$60 \overset{?}{<} 316 \cdot 18 \overset{?}{<} 2.5 \cdot (18)^2$$

$$60 \overset{?}{<} 5688 \overset{?}{<} 810 \leftarrow \text{NOT SATISFIED}$$

$$q' = \frac{Et/r}{1+\frac{1}{2}\left(\frac{\pi r}{nl}\right)^2}\left\{\frac{1}{n^2\left[1+\left(\frac{nl}{\pi r}\right)^2\right]^2} + \frac{n^2 t^2}{12 r^2(1-\nu^2)}\left[1+\left(\frac{\pi r}{nl}\right)^2\right]^2\right\}$$

n - # LOBES FORMED BY TUBE

SAY $n=1$

$$q' = \frac{29\times10^6(.1875)/3.375}{1+\frac{1}{2}\left(\frac{\pi(3.375)}{60}\right)^2}\left\{\frac{1}{\left[1+\left(\frac{60}{\pi(3.375)}\right)^2\right]^2} + \frac{(.1875)^2}{12(3.375)^2(1-.303^2)}\left[1+\left(\frac{\pi(3.375)}{60}\right)\right.\right.$$

$$q' = 1{,}586{,}342\left\{9.17023\times10^{-4} + 3.01166\times10^{-4}\right\} = 1932 \text{ psi}$$

- EXTERNAL PRESSURE

PER APPENDIX 13 OF ASME CODE, THE STRESSES FOR EXTERNAL PRESSURE ARE CALCULATED THE SAME AS THEY ARE FOR INTERNAL PRESSURE, WITH A SIGN CHANGE ON P. THEREFORE SINCE SCALING WORKED FOR INTERNAL PRESSURE, IT WILL BE SUITABLE FOR EXTERNAL PRESSURE.

THE HIGHEST STRESS FOR 30 psi EXTERNAL PRESSURE WAS:

$(S_T)_D = -12{,}990$ psi COMPRESSION AT THE INNER SURFACE

$$P_a = 30 \text{ psi} \times \frac{22{,}600}{12{,}990} = \underline{52 \text{ psi}}$$ ← MAX. ALLOWABLE EXTERNAL PRESSURE

STABILITY STILL IS O.K. PER 10/27/92 CALCS BY ME.

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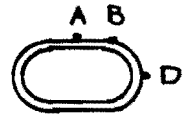
SUBJECT: OBROUND PRESSURE RATING. {REF. 3/31/93 RAR CALCS, 11/18/92 G.GORDON CALCS. et al.}		NAME: RUSS RUCINSKI	DATE: 4/26/93	REVISION DATE

THERE ARE TWO ALLOWABLES FOR THE SHAPE:
FOR THE COMBINED STRESSES, MEMBRANE PLUS BENDING.



AT PT. A & D $S_a = 1.5SE = 22.6$ KSI

AT PT. B $S_a = 1.5SE = 13.54$ KSI

- INTERNAL PRESSURE

LARGEST STRESS @ 12 PSIG WAS 5196 psi TENSION ON INNER SURFACE AT POINT D. (DUE TO BENDING)

STRESS AT POINT B IS VERY LOW

ESTIMATED $P_a = 12 \text{ psi} \times \frac{22600}{5196} = 52 \text{ psi}$

$$(S_m)_{B-C} = \frac{P}{t_1}\left(\sqrt{L_2^2 - L_1^2} + R\right) = \frac{52 \text{ psi}}{.1875}\left(\sqrt{2^2+0^2} + 1.3125_{IN}\right) = 919 \text{ psi}$$

$$(S_b)_D = \frac{c}{2I_1}\left[2M_A + P\left(L_2^2 + 2RL_2 - 2RL_1 - L_1^2\right)\right]$$

$$M_A = P \cdot K_3 = 52 \text{ psi}\left[-2.19\right] = -114 \text{ in-lb}$$

$$(S_b)_D = 85.33\left[2(-114 \text{ in-lb}) + 52(9.25)\right]$$

$= 21{,}588$ TENSION ON INNER SURFACE
$-21{,}588$ COMPRESSION ON OUTER SURFACE

COMBINED STRESS

$$(S_T)_D = (S_m)_{B-C} + (S_b)_D = 919 \pm 21{,}588$$

$= 22{,}508$ psi TENSION ON INNER SURFACE
$-20{,}669$ psi COMPRESSION, OUTER SURFACE

THE COMBINED STRESS IS VERY CLOSE TO THE ALLOWABLE.

$\therefore$ THE MAXIMUM ALLOWABLE WORKING INTERNAL PRESSURE IS 52 psi

546707

St	Input	Name	Output	Unit	Comment
					D0 chimney vacuum jacket
					Mat'l: Welded pipe
					304 Stn. Stl. Sa=16.0 ksi
					For Fermi S=Sa*0.8
		Pc	110.3582	psid	Collapse Pressure
	.148	t		in	Thickness of Shell
		D	8.624	in	Outside Diameter of Shell
	4.164	R		in	Inside Radius of Shell
	220	L		in	Distance Between Stiffening Rings
		P	445.44771	psid	Internal Pressure
	28000000	E		psi	Modulus of Elasticity
	12800	S		psi	Maximum Allowable Stress per CODE
	1	Ej		---	Joint Efficiency
		C1	'UG27c1	---	Applicable Code Paragraph (int. pres.)
		t1	.148	in	Thickness per UG-27 c1
		t2	.07195404	in	Thickness per UG-27 c2

FERMILAB ENGINEERING NOTE	SECTION RD / DØ	PROJECT DØ SOLENOID UPGRADE	SERIAL-CATEGORY 3823.111	PAGE
SUBJECT: 8" PIPE PRESSURE RATING		NAME: RUSS RUCINSKI	DATE: 4/26/93	REVISION DATE

PICK 8" SCH.10 PIPE, 304 STN. STL. {USE TUBE SALES INFORMATION}

$D_o = 8.625''$ $t_{WALL} = .148''$ W304A-312 OR W304LA-312

WELDED PIPE

INTERNAL PRESSURE, UG-27 (1986 EDITION OF ASME CODE)

$$P = \frac{SEt}{R + 0.6t}$$

SE = 16.0 KSI

TABLE UHA-23, WELDED PIPE UNS # S30400. PER NOTE 4, THE MAXIMUM ALLOWABLE STRESS INCLUDES A JOINT EFFICIENCY OF 0.85. SEE UG-31a (1986 EDITION ONLY)

FERMI IN-HOUSE FACTOR

$$P = \frac{(0.8)(16{,}000\ psi)(.148\ in.)}{(4.1645\ in.) + (0.6)(.148\ in.)} = \boxed{445\ psi}$$

EXTERNAL PRESSURE, UG-28

$D_o/t = 58.3 > 10$ USE FIG. 5-UHA-28.1 PER TABLE UHA-23.

$L \approx 220$ in {MAX. SPAN BETWEEN ELBOWS} {$E = 28.0 \times 10^6$ psi}

$L/D_o \approx 25.5$

"A" = 0.00033 PER FIG. 5-UGO-28.0

"B" = 4500 PER FIG. 5-UHA-28.1

P_a = ALLOWABLE EXTERNAL WORKING PRESSURE

$$P_a = \frac{4B}{3(D_o/t)} = \frac{4(4500)}{3(58.3)} = 102.9\ psi = \boxed{100\ psi}$$

THE EXTERNAL PRESSURE CASE DOES NOT INCLUDE ANY FERMI FACTOR - FERMI REQUIRES DESIGN FOR 30 PSID

546707

R. RUCINSKI 5/18/93
REV. 5/25/93

St	Input	Name	Output	Unit	Comment
					D0 chimney, 10" vacuum jacket
					Mat'l: Welded pipe, Sa=16.0 ksi
					304 Stn. Stl. Sa=16.0 ksi
					Mat'l: Plate, Sa=18.8 ksi
					For Fermi S=Sa*0.8
		Pc	104.10955	psid	Collapse Pressure
	.165	t		in	Thickness of Shell
	10.75	D		in	Outside Diameter of Shell
		R	5.21	in	Inside Radius of Shell
	220	L		in	Distance Between Stiffening Rings
		P	397.81503	psid	Internal Pressure
	28000000	E		psi	Modulus of Elasticity
	12800	S		psi	Maximum Allowable Stress per CODE
	1	Ej		---	Joint Efficiency
		C1	'UG27c1	---	Applicable Code Paragraph (int. pres.)
		t1	.165	in	Thickness per UG-27 c1
		t2	.08046144	in	Thickness per UG-27 c2

EXTERNAL PRESSURE, UG-28

$D_o/t = 10.75/.165 = 65.1 > 10$

$L \approx 220$ IN.

$L/D_o \approx 220/10.75 = 20.5$

USE FIG. 5-UGO-28.0 TO GET "A" $A = .00025$

USE FIG 5-UHA-28.1 TO GET "B" $B = 3500$

$$P_a = \frac{4B}{3(D_o/t)} = \frac{4(3500)}{3(65.1)} = \boxed{72 \text{ psi}}$$

S Rule

```
  "Cylindrical Vessel under external pressure
  "per CGA 341
  Pc=2.6*E*(t/D)^2.5/((L/D)-0.45*sqrt(t/D))

  "Cylindrical Vessel under internal Pressure
  "per ASME BPV VIII div.1 UG-27
  if P<0.385*S*Ej then Cl='UG27cl
* if and (P<1.25*S*Ej,P>0.385*S*Ej) then Cl='UG27c2
  t1=P*R/(S*Ej-0.6*P)
  t2=P*R/(2*S*Ej+0.4*P)
  if Cl='UG27cl then t=t1
* if Cl='UG27c2 then t=t2
  D=2*(R+t)
```

St	Input	Name	Output	Unit	Comment
					LHe supply tubing-bounding case
					R. Rucinski 5/25/93
		P	1600	psig	Internal pressure (external 0 psig)
	1.25	D		in	Outside diameter
	8	S		ksi	Basic allowable stress
	1	E		---	Quality factor
	.4	Y		---	Table 304.1.1 coefficient (typ. 0.4)
		d	1.0185185	in	internal diameter for t3d
		t3a	.11574074	in	Thickness from equation 3a
		t3b	.125	in	Thickness from equation 3b
		t3c	.11468964	in	Thickness from equation 3c (Lamé Equat
		t3d	.11574074	in	Thickness from equation 3d
	.125	t		in	max of equations 3a, 3b, 3c, & 3d
		Check	'Valid	Answers	Check validity of equations

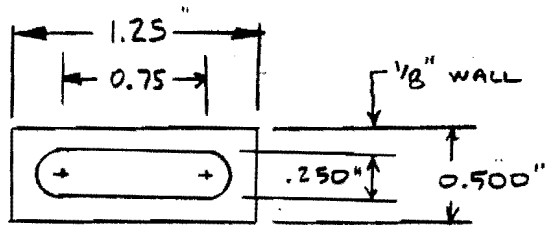
FERMILAB ENGINEERING NOTE	SECTION RD/DØ	PROJECT DØ SOLENOID UPGRADE	SERIAL-CATEGORY 3823.111	PAGE 1
SUBJECT LHe SUPPLY AND RETURN LINES		NAME RUSS RUCINSKI		
		DATE 4-12-93	REVISION DATE	

DETERMINE PRESSURE RATING & SIZE OF TUBES.

- LHe RETURN: 3/4" O.D. x 0.065" WALL, 6061-T6 ALUM.

→ PER LLNL GUIDE, MAWP = 1720 PSI FOR THIS TUBE.

- LHe SUPPLY: NEEDS TO BE RECTANGULAR
  WILL HAVE TO BE A SPECIALLY EXTRUDED SHAPE TO PRESSURE APPLICATION STANDARDS.
  PARTICULARLY; ASTM-B-210 AND ASTM-B-241



FLOW PATH HAS 1/4" x 0.75" SLOT CROSS-SECTION

$r_H = A/P$ = HYDRAULIC RADIUS

$$A = \frac{\pi(.25\,in)^2}{4} + (0.75\,in.)(.25\,in.) = 0.2366\,in^2$$

$$P = \pi(.25\,in.) + 2(.75\,in.) = 2.2854\,in.$$

$$r_H = \frac{0.2366\,in}{2.2854\,in} = 0.1035\,in.$$

$D_H = 4 \times r_H =$ <u>0.414 IN HYDRAULIC DIAMETER</u>

TRY TO "BOUND" TUBE TO GET MAWP

MAWP FOR THIS SHAPE WOULD BE > 1.25" O.D. x 1/8" WALL

$$P = \frac{2SEt}{D_o - 2yt} \approx \frac{2SEt}{D_o} \qquad \text{USE } SE = \frac{P \cdot D_o}{2t} = \frac{1720\,psi\,(.75\,in)}{2\,(.065)}$$

$$= 9923\,psi$$

$$P = \frac{2(9923\,psi)(.125\,in)}{1.25\,in.}$$

$P = 1985$ psi → MAWP OF THIS SHAPE > 1985 psi

546707

St	Input	Name	Output	Unit	Comment
					LHe return tubing
					R. Rucinski 5/25/93
		P	1386.6667	psig	Internal pressure (external 0 psig)
	.75	D		in	Outside diameter
	8	S		ksi	Basic allowable stress
	1	E		---	Quality factor
	.4	Y		---	Table 304.1.1 coefficient (typ. 0.4)
		d	.62842893	in	internal diameter for t3d
		t3a	.06078554	in	Thickness from equation 3a
		t3b	.065	in	Thickness from equation 3b
		t3c	.06023548	in	Thickness from equation 3c (Lamé Equat
		t3d	.06078554	in	Thickness from equation 3d
	.065	t		in	max of equations 3a, 3b, 3c, & 3d
		Check	'Valid	Answers	Check validity of equations

ALLOWABLE

S = 8 KSI FROM TABLE A-1, 6061-T6 WELDED SEAMLESS TUBES.

S Rule

```
  "from ANSI/ASME B31.3-1984
  "section 304.1  Pressure design of straight metallic pipe
  "program checked by hand calculations:  no errors present  B.S. 22-Apr-93
* t3a=P*D/2/(S*E+P*Y)
* t3b=P*D/2/S/E
* t3c=D/2*(1-sqrt((S*E-P)/(S*E+P)))  "Lamé Equation
* t3d=P*d/2/(S*E-P*(1-Y))
* d=D-2*t3d
* t=max(t3a,t3b,t3c,t3d)
* if or (t>D/6,P/S/E>0.385) then Check='Invalid else Check='Valid
```

R. RUCINSKI 5/4/93

St	Input	Name	Output	Unit	Comment
					D0 control dewar vacuum jacket
					Mat'l: Welded pipe, Sa=16.0 ksi
					304 Stn. Stl. Sa=16.0 ksi
					Mat'l: Plate, Sa=18.8 ksi
					For Fermi S=Sa*0.8
		Pc	87.095166	psid	Collapse Pressure
	.1874	t		in	Thickness of Shell
	36	D		in	Outside Diameter of Shell
		R	17.8126	in	Inside Radius of Shell
	60	L		in	Distance Between Stiffening Rings
		P	102.20465	psid	Internal Pressure
	28000000	E		psi	Modulus of Elasticity
	15040	S		psi	Maximum Allowable Stress per CODE
	.65	Ej		---	Joint Efficiency
		C1	'UG27c1	---	Applicable Code Paragraph (int. pres.)
		t1	.1874	in	Thickness per UG-27 c1
		t2	.09291795	in	Thickness per UG-27 c2

EXTERNAL PRESSURE, UG-28

$D_o/t = 36/.1874 = 192$

$L = 48\,IN + \frac{2}{3}(6\,IN) = 52\,IN.$

HEAD DEPTH

$L/D_o = 52/36 = 1.44$

USE FIG 5-UGO-28.0 → GET "A". A = .00033

USE FIG 5-UHA-28.1 (304 S S PLATE) "B" = 4500

$$P_a = \frac{4B}{3(D_o/t)} = \frac{4(4500)}{3(192)} = \underline{31.25\ psi}$$

St	Input	Name	Output	Unit	Comment
					LN2 tubing, alum. 6061-T6
					R. Rucinski 5/25/93
		P	2080	psig	Internal pressure (external 0 psig)
	.5	D		in	Outside diameter
	8	S		ksi	Basic allowable stress
	1	E		---	Quality factor
	.4	Y		---	Table 304.1.1 coefficient (typ. 0.4)
		d	.38224638	in	internal diameter for t3d
		t3a	.05887681	in	Thickness from equation 3a
		t3b	.065	in	Thickness from equation 3b
		t3c	.05841099	in	Thickness from equation 3c (Lamé Equat
		t3d	.05887681	in	Thickness from equation 3d
	.065	t		in	max of equations 3a, 3b, 3c, & 3d
		Check	'Valid	Answers	Check validity of equations

R. Rucinski 5/4/93

St	Input	Name	Output	Unit	Comment
					D0 control dewar reservoir
					Mat'l: Welded pipe, Sa=16.0 ksi
					304 Stn. Stl. Sa=16.0 ksi
					Mat'l: Plate, Sa=18.8 ksi
					For Fermi S=Sa*0.8
		Pc	749.7368	psid	Collapse Pressure
	.18	t		in	Thickness of Shell
	12.75	D		in	Outside Diameter of Shell
		R	6.195	in	Inside Radius of Shell
	30	L		in	Distance Between Stiffening Rings
		P	365.54022	psid	Internal Pressure
	28000000	E		psi	Modulus of Elasticity
	12800	S		psi	Maximum Allowable Stress per CODE
	1	Ej		---	Joint Efficiency
		Cl	'UG27cl	---	Applicable Code Paragraph (int. pres.)
		tl	.18	in	Thickness per UG-27 cl
		t2	.08795551	in	Thickness per UG-27 c2