Muon Design Note #1

TITLE: Repair Patch for the Chicago Cyclotron Magnet Upper Coil Vacuum Shell

AUTHOR: Roman Dachniwskyj RD

DATE: March 11, 1985

OBJECTIVE: To describe the design, installation and adequacy of the proposed repair patch for the Chicago Cyclotron Magnet upper coil vacuum shell.

PRESSURE RATING INTERNAL AND EXTERNAL OF THE PRESENT SHELL

The ASME Code Section VIII, Div. 1, Paragraph UG-27 does not specifically address the question of end conditions when determining the internal MAWP of a cylinder, therefore it will be assumed that the Code equations were determined by using the worst possible end conditions. The MAWP internal for the upper coil vacuum shell

$= (SEt)/(R + 0.6\ t) = 70.5$ psi, where

$S = (18.8 \times 10^3)\ (0.8) = 15 \times 10^3$ psi
$E = 0.60$
$t = 0.125$
$R = 15.875$.

Using the above argument regarding end conditions the external MAWP will be calculated using Paragraph UG-28. In this calculation the difficult parameter to determine is the length of the cylinder. The length of the cylinder varies from 47 inches to 64 inches, as you move from the inside of the coil to the outside of the coil respectively. For the worst case or lowest external MAWP, the length of the cylinder will be taken to be 64 inches, diameter to be 32 inches and the thickness to be 1/8 inch, therefore the external MAWP = 10.9 psid. To increase the external MAWP above 15 psid, radial ribs were welded onto the vacuum shell. The radial ribs act as stiffening rings, thereby reducing length of the cylinder to 36 inches. The external MAWP of a cylinder with the above length and the same diameter and thickness as before is 21.3 psid.

DYE PENETRANT TEST

The area occupied by and surrounding the dent was inspected for cracks and pin holes using dye penetrant supplied by Magnaflux. No cracks or pin holes were found in the vacuum shell or in the adjacent welds.

REPAIR PATCH DESIGN

The mechanically simplest repair is just placing a patch right over the damaged area. The purpose of the patch would be to prevent the damaged area from being loaded with an external pressure, thereby preventing any further buckling of the vacuum shell. To ensure that there can never be a differential pressure across the damaged area an opening (passage) must be provided between the present vacuum shell and the volume produced by the addition of the patch. This passage is produced by moving the upper coil vacuum vent over to the east and south and leaving the present opening for the vacuum vent pipe uncovered. To ensure that there are no trapped pockets and/or virtual leaks, 1/16 inch shims ~ 1/2 inch in width will be welded around the perimeter of the patch, see Fig. 1. Before welding the patch on, a dye will be sprayed or painted onto the damaged area and the patch placed over the dyed area, this procedure will indicate if more shims are necessary to prevent the occurance of any trapped pockets of air.

The actual patch will extend at least four inches beyond the damaged area on all sides except for the west side where the patch will butt up against a radial rib. Since the external pressure rating per Code, for the vacuum shell is above 15 psid, there is no need for additional ribbing. See Fig. 2 for the actual dimensions and location of the patch. The patch itself will be 1/4 inch thick by ~ 18 inches long by 22 inches wide, radius 16 inches and has a 8.625 inch opening. A complete shell of this thickness, length, radius and without the opening has an external MAWP of 113 psid. Paragraph UG-37 requires that the reinforcement required for the above opening to be equal to $1/2 \times d_1 \times t_r \times F$, which with $F = 1.0$, $t_r = 0.125$ in and $d_1 = 8.625$ is equal to 0.54 in^2.

There is a column just to the west of the vent opening whose area of reinforcement overlaps the area of reinforcement of the 8.625 inch vacuum vent, therefore the requirements of paragraph UG-42 must be satisfied. The diameter of the column opening is 12.75 inches. First it must be determined if 50% of the total required reinforcement lies between the centers of the two openings.

The total required reinforcement = $1/2\ (d_1 + d_2) \cdot F \cdot t_r = 1.34\ in^2$, where

d_1 = 8.625 in. vent diameter

d_2 = 12.75 in. column diameter

F = 1.0

t_r = 0.125.

The total available reinforcement between the centers of the two openings equals

(1) The area provided by the column reinforcement ring

= $(W)(t) = (2.5)(0.250) = 0.625\ in^2$, where

t = thickness of ring and W = width of reinforcing ring

plus

(2) The area available from the patch beyond that necessary for the external pressure

= (1.0)(0.250 - 0.125) = 0.125 in^2

The requirements of Paragraph UG-42 A-2 are met because the ratio of the available area of reinforcement between the openings to the total required area of reinforcement equals 0.750/1.34 = 0.56 or 56%. To meet the requirements of Paragraph UG-37 there must be 0.54 - 0.125 = 0.415 in^2 of reinforcement available on the east side of the 8.625 inch opening and 0.80 - 0.564 = 0.236 in^2 available on the west side of the column opening. The 8.625 inch vent opening has (0.125)(4) = 0.5 in^2 of available reinforcement area on its east side and 12.75 inch column opening has (2.5)(0.25) = 0.625 in^2 available reinforcement area on its west side therefore the requirements of Paragraph UG-37 are met.

The patch will be welded with a 1/4 inch extended fillet and 3/4 inch diameter plug welds on its north, south and east side and with a butt weld on the west side as shown in Fig. 1. The weld design and size of how the vent pipe is welded into the patch is shown in Fig. 1.

By using the 3 to 1 slope weld detail for attaching the patch to the vacuum jacket, one can assume that a complete cylinder is being fabricated by using a piece of 1/8 inch thick material welded to 1/4 inch thick material. This fabrication method will produce a cylinder which is out of round by 0.188 (thickness of original vacuum shell plus the 1/16 shim) inch. The allowable out of roundness per code for a 32 inch diameter cylinder is 0.225 inch, which is greater than 0.188 inch, therefore the cylinder can be code ratable for a MAWP of 15 psi external per Paragraph UG-80.

The dented area can also be analyzed as a half circle cut out of the shell with a diameter of approximately 14 inches. The required area of reinforcement for a MAWP of 15 psi external = 1/2 x t_r x d x F = (1/2)(0.125)(14)(1) = 0.875 in^2. Due to the stiffness of the radial rib which forms the west edge of the half circle, it is safe to say that the shell west of the rib does not feel any effects due to the half circle, see Fig. 2. This requires that reinforcement for the dented area only be added to the shell which is east of the radial rib. For adequate reinforcement per Code the patch must extend 3.5 inches beyond the dented area. The actual patch extends a minimum of 4.0 inches beyond the patch. Therefore the dented area is adequately reinforced and the shell is Code ratable for MAWP of 15 psi external per paragraph UG-37.

CONCLUSION

The repair patch described in this note is more than sufficient as shown by using the rules of the ASME Pressure and Boiler Code Section VIII, Division 1 to prevent buckling of the damaged area when the upper coil vacuum jacket is subjected to an external pressure of 15 psi.

Appendix A

OBJECTIVE: Sample calculation showing the method used to determine external MAWP for cylinders.

Parameters

D_o = 32 in

t = 0.125 in

L = 36.0 in

$D_o/t = \frac{32}{0.125} = 256$ $\qquad$ $L/D_o = 36/32 = 1.125$

From Fig. 5-UGO-28.0

Factor A = 0.0003

From Fig. 5-UHA-28.1

Factor B = 4200

$$P = \frac{4}{3}\ \frac{B}{D_o/t} = \frac{(4)(4100)}{(3)(256)} = 21.3 \text{ psi}$$

Appendix B

OBJECTIVE: To determine if the existing rib that is between the column and the vacuum vent pipe meets the stiffening ring requirements per the Code, Paragraph UG-29.

Parameters

D_o = 32 in

H = 10.750 in height of rib

W = 1.0 in thickness of rib

t = 0.125 in thickness of vacuum shell

P = 14.7 psid external

Calculation:

$$I_s = \frac{[D_o^2 L_s (t + A_s/L_s) A]}{14}$$

$$A_s = (H)(W) = (0.750)(1.0) = 0.75 \text{ in}^2$$

$$L_s = \frac{36}{2} + \frac{28}{2} = 32 \text{ in}$$

$$\text{Factor B} = \frac{3}{4} \left(\frac{P D_o}{t + A_s/L_s} \right)$$

$$= 2{,}377$$

From Fig. 5-UHA-28.1

Factor A = 0.00017

$\therefore I_s = 0.059 \text{ in}^4$ = required moment of inertia of the stiffening ring

$$I = \frac{1}{12} Wh^3 = \frac{1}{12} (1.0)(0.75)^3 = 0.035 \text{ in}^4$$ = available moment of inertia of the stiffening ring

The required moment of inertia $I_s = 0.059$ in^4 is greater than the actual moment of inertia $I = 0.035$ in^4. For the rib to meet Code, its height would have to be increased by 0.140 in, it base (width) increased by 0.70 in or the maximum allowable external pressure per Code reduced to 8.7 psid.

Conclusion:

It is difficult to change (remove) the present rib and replace it with a larger one. It is possible through welding to increase the height of the rib by adding additional material to the top of the rib. This is not necessary because the Compressed Gas Association pamphlet-341, paragraph 1f(3) states that outer vacuum shells and rings for insulated tank trucks that carry liquified gases can be designed for 7.5 psid in accordance with the ASME Code formulas, therefore it is reasonable to say the rib is of satisfactory size.

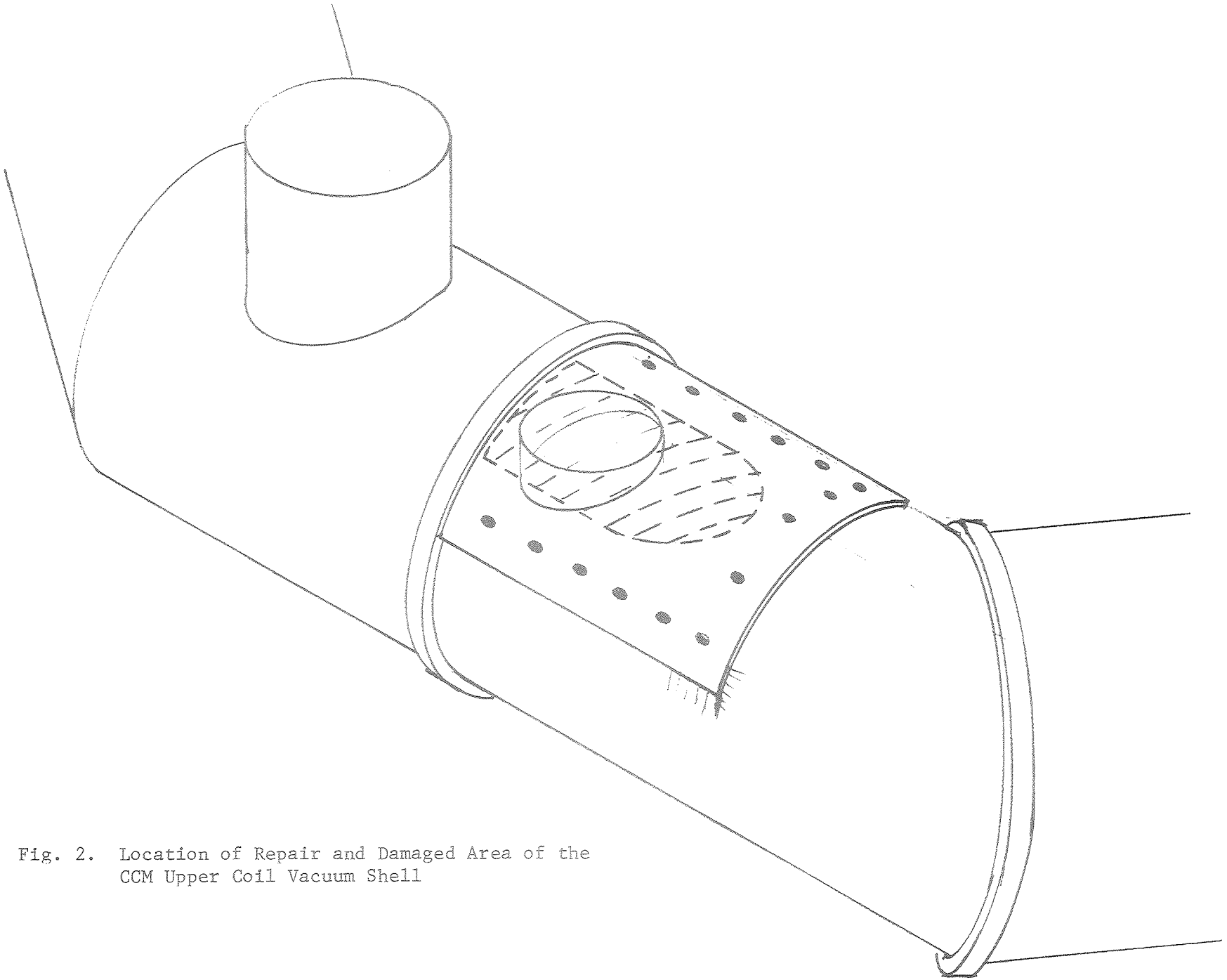
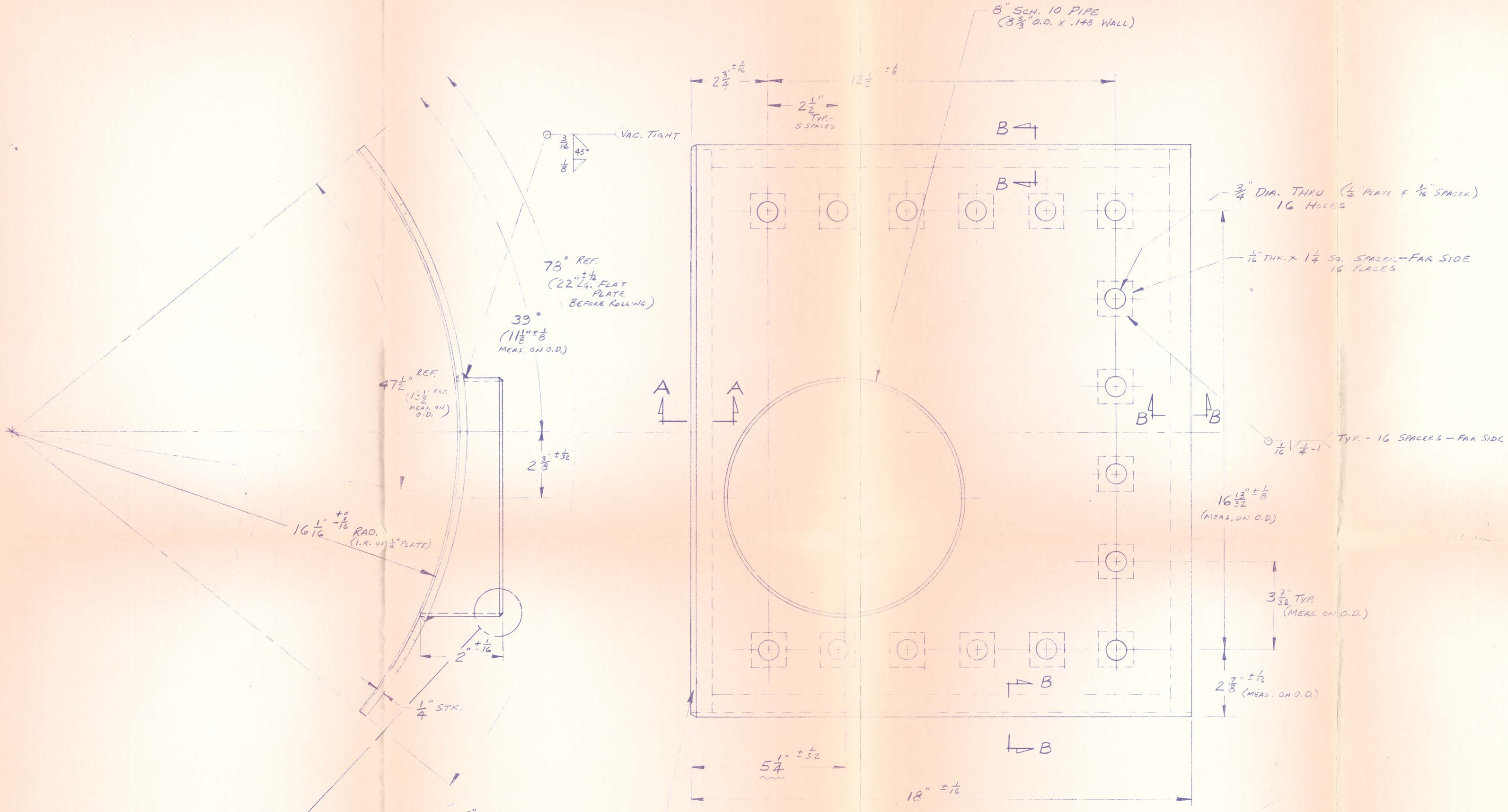
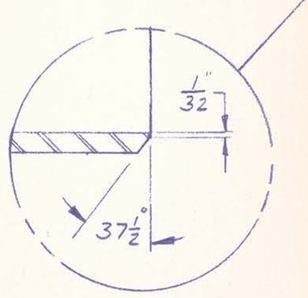


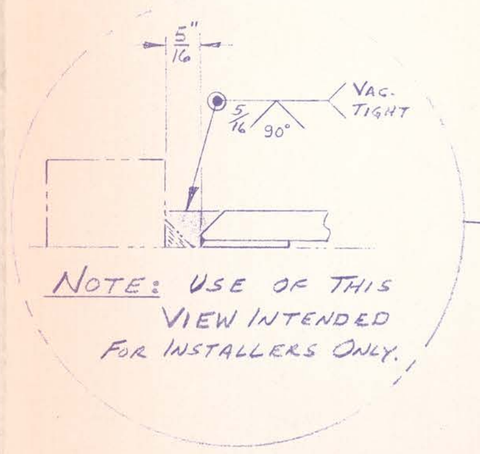
Fig. 2. Location of Repair and Damaged Area of the CCM Upper Coil Vacuum Shell

REV.	DESCRIPTION	DRAWN	DATE
		APPD.	DATE

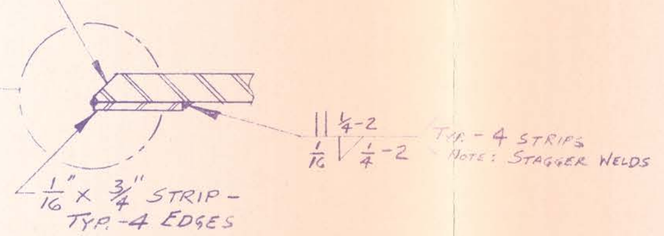




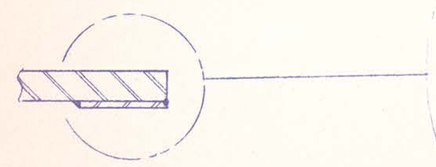
WELD PREP
FULL SIZE



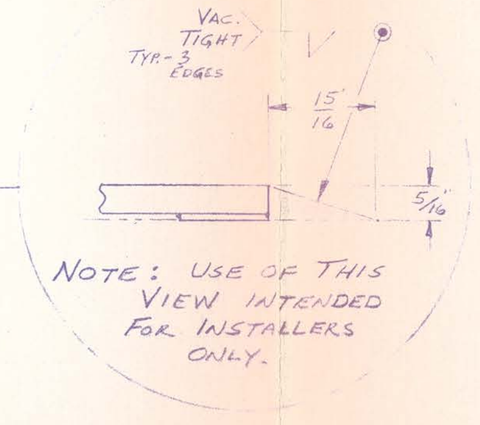
NOTE: USE OF THIS VIEW INTENDED FOR INSTALLERS ONLY.



SECTION A-A
FULL SIZE



SECTION B-B (TYP-3 EDGES)
FULL SIZE



NOTE: USE OF THIS VIEW INTENDED FOR INSTALLERS ONLY.

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
		PARTS LIST	

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	R. DACHNOWSKYJ	3-5-85
FRACTIONS	DECIMALS	ANGLES	DRAWN	E. KRAFT	3-5-85
± 1/64	± ~~~~	± 1/2°	CHECKED		
1. BREAK ALL SHARP EDGES 1/64 MAX.			APPROVED		
2. DO NOT SCALE DWG.			USED ON		
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's.			MATERIAL- 304 STN. STL.		
√ MAX. ALL MACHINED SURFACES					

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

CRYOGENICS DEPT.
C.C.M. UPPER VACUUM SHELL
REPAIR PATCH

SCALE	FILMED	DRAWING NUMBER	REV.
1/2" = 1"		2753.700-MD-156995	

BRUNING-40-107