Fermilab

Particle Physics Division

Mechanical Department Engineering Note

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Project: Solid Xenon

Project Internal Reference: Solid Xenon, Top Flange

Title: ASME Calculations for the Solid Xenon, ASME 12 inch Class 150 flange

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Key Words:

Abstract/Summary:

Applicable Codes:
ASME DIVISION I SECTION VIII,
ASME B16.5 Pipe Flanges and Flanged Fittings

Introduction:

A 12 inch class 150 flange assembly is used to cap the Solid Xenon vessel. The flange is designed for a MAWP of 75 psig to match the relief valve on the outer vacuum vessel. This is the maximum relief pressure in the system. The top flange assembly drawing, 486129, is shown in Figure 1. The top flange weldment, 486123 is shown in Figure 2. The machining print for the top flange, drawing 486111 is shown in Figure 3.

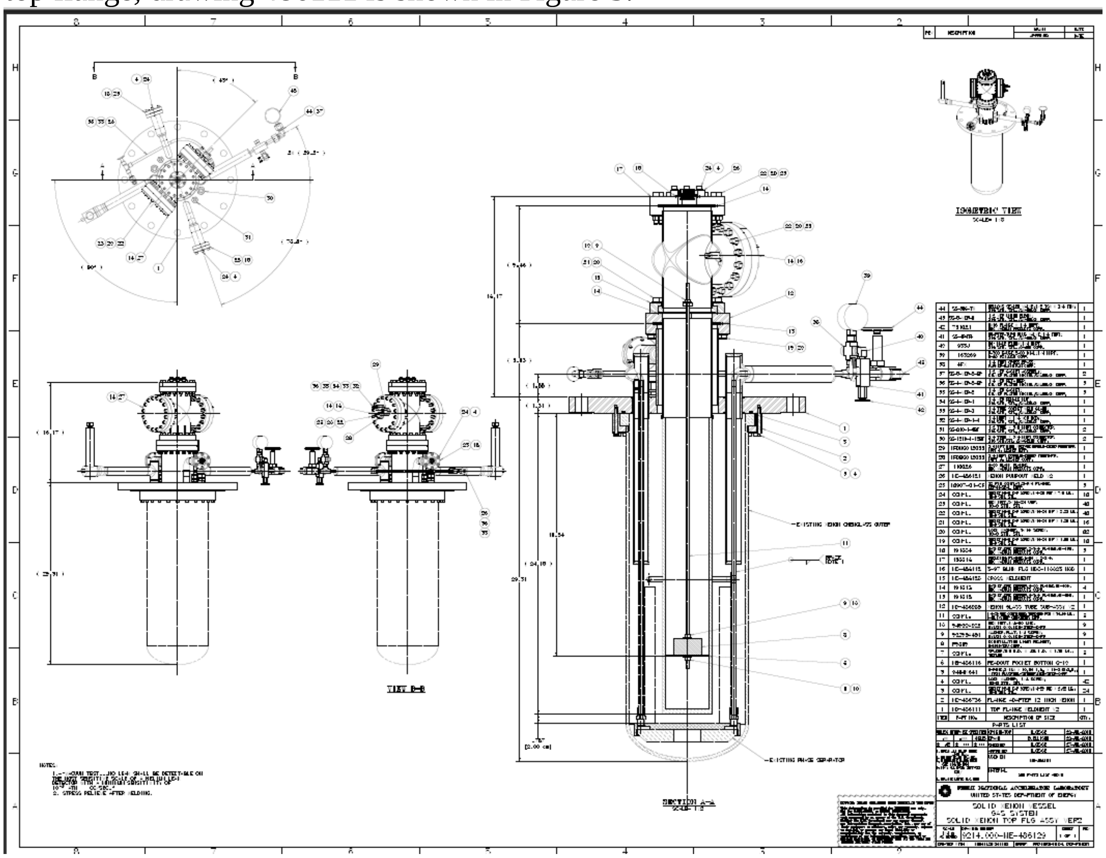

Figure 1. Drawing 486129, Solid Xenon top flange assembly

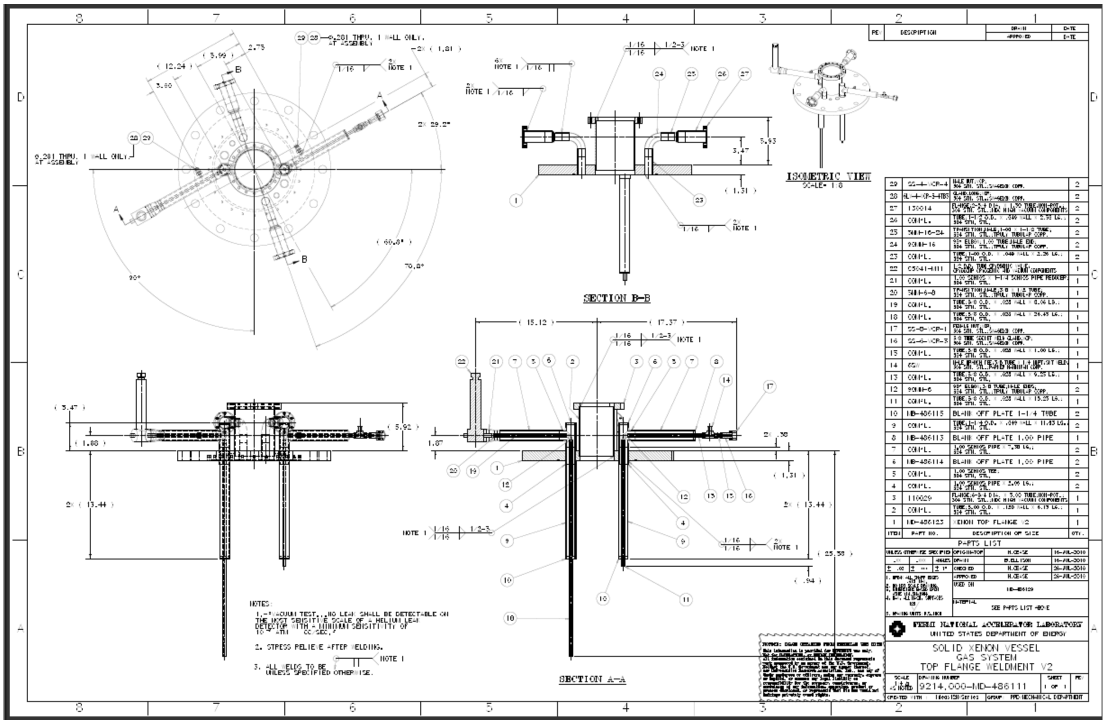

Figure 2. Drawing 486123, Solid Xenon top flange weldment

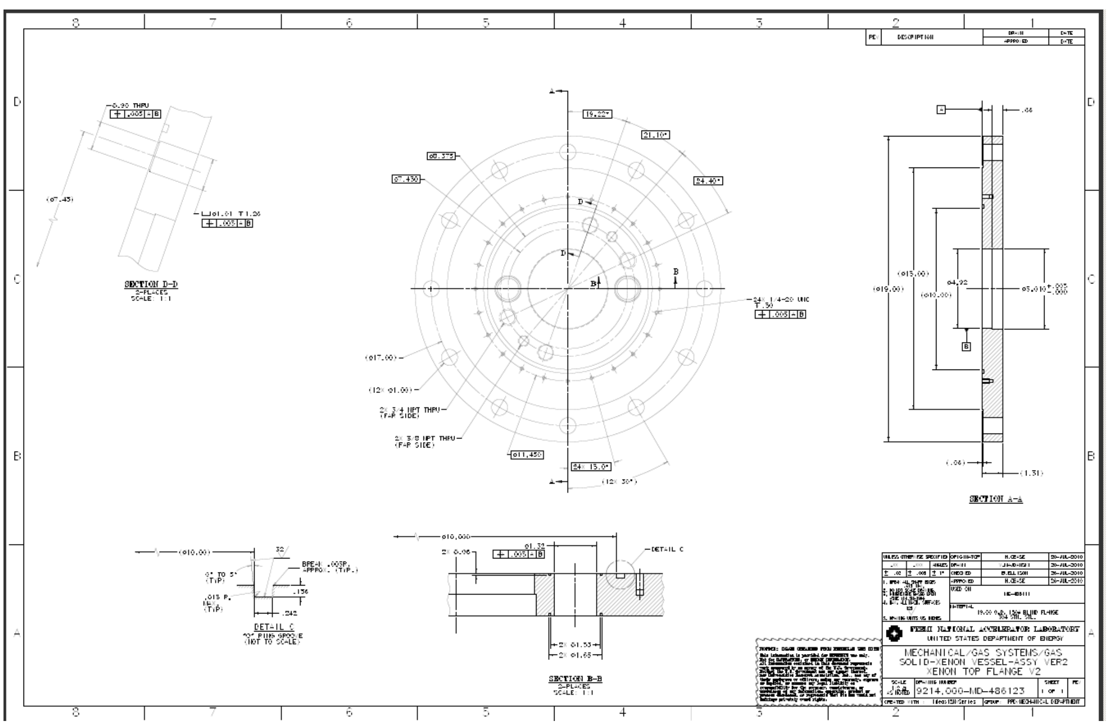

Figure 3. Drawing 486123, Solid Xenon top flange

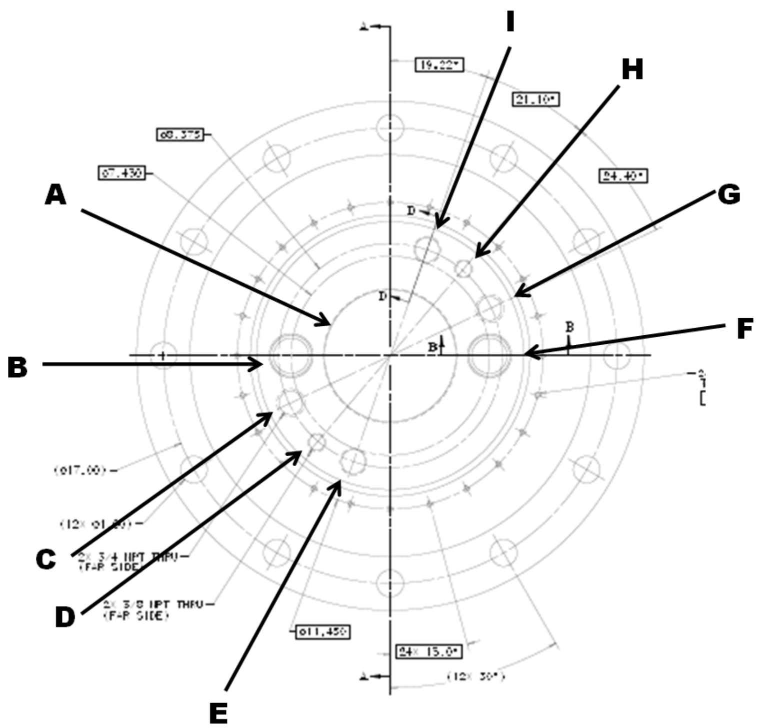

Figure 4. Top Flange Opening Designations.

Top Flange opening designations and diameters:

#A 5.0 inch diameter thru, Access for Xenon inner vessel
#B 1.32 inch diameter, 1 inch sch 10 nozzle,
#C 0.921 inch diameter,
#D 0.578 inch diameter,
#E 0.90 inch diameter, 1 inch , 0.049 tube nozzle
#F 1.32 inch diameter, 1 inch sch 10 nozzle,
#G 0.921 inch diameter,
#H 0.578 inch diameter,
#I 0.90 inch diameter, 1 inch , 0.049 tube nozzle

Nozzles attached to the openings are not considered here for the flange reinforcement.

Required Flange Thickness with a 0.8 multiplier on allowable stress:
UG-34 case J, Flat Head Cover, bolted using a raised face flange.

$$t = d\sqrt{CP/SE + 1.9Whg/SEd^3}$$

t = minimum head thickness
d = 12.438 inches, inside flange diameter
C = 0.3 flange attachment factor
S = 0.8 *20,000 psi SS 304 Plate, Maximum allowable stress in tension
Spec. no SA-182, Section II, Part D, Table 1A.
0.8 multiplier for Fermi in house Flange construction.
E = 1, welded joint efficiency
W_{m2} = 50,300 lbs, total bolt load
Hg = 1.4 inch, gasket moment arm, center of gasket reaction to center of bolt hole
P = 75 psig, internal design pressure

t = 0.844 inch, required thickness

t = 1.313 for a 12 inch class 150 raised face flange,

Flange thickness satisfies requirement with a 0.8 multiplier on stress

Appendix 2-5(e) Flange Design Bolt Load W

The bolt loads used in the design of the flange shall be the values obtained from from $W = W_{m1}$

$W_{m1} = 0.785*G^2*P+(2b*3.14*GmP)$

b_o = basic gasket seating width = (outer radius – inner radius) / 2
b_o = (12.438 inch/2 – 15 inch/2)/2 = 0.641 inch
b = 0.40 inch, effective gasket seating width = $0.5*(b_o)^{½}$ when b_o > ¼
G = Diameter of gasket load reaction, gasket O.D. -2*b
G = 19 inch – 2 * 0.40 inch = 18.20 inches
M = 2.7 gasket factor for a stiff group 1a gasket.
Appendix 2, Table 2-5.1

W_{m1} = 0.785* (18.2 inch)^2*75 psi
+ (2*0.4 inch*3.14*18.2 inch * 2.7* 75 psi)
= 28,800 lbs

W_{m2} = Bolt load to seat the gasket
= 3.14 *b*G*y
=3.14*0.4*18.2*2200
=50,300 lbs

Use the greater of Wm1 and Wm2,
W_{m2}= 50,300 lbs

Load on each bolt

Load = W_{m2} / # of bolts

= 50,300 lbs/ 12 bolts

= 4,200 lbs per bolt

Bolt Stress

Stress = Load / area of 7/8 inch bolt

= 4,200 lbs/ 0.462 $inch^2$

= 9,100 psi

Required torque

Torque = kDF

K = 0.2 steel fastener

D = 0.875 inch bolt diameter

F = 4,200 lb clamping load

Torque = 0.2 * 0.875 inch * 4200 lbs = 735 in.lbs

= 61 foot lbs.

Note: Bolts are ASTM A193, Grade 8B CL 1, Stainless Steel bolts.
Reference: ASME B16.5 Table 1B Listing of Bolting Specifications.
Gasket material is Durabla 8500, 150# ring gasket, Gasket Factor m=2.7

Reinforcement Requirements for Openings in Flat Heads UG-39

UG-36(c)(3) Openings in vessels not subject to rapid fluctuations in pressure do not require reinforcement other than that inherent in the construction under the following conditions:

> 2-3⁄8 in. (60 mm) diameter — in vessel shells or heads over a required minimum thickness of 3⁄8 in.

Even though all but one of the openings in the top flange are smaller than 2-3/8 inch diameter, all openings will be analyzed for reinforcement.

UG-39(b)(2) Multiple openings none of which have diameters exceeding one-half the head diameter and no pair having an average diameter greater than one quarter the head diameter may be reinforced individually as required by

$$A = 0.5dt$$

Where

d = diameter of the opening
t = 0.844 inches, minimum required thickness of the flange
A= cross sectional area of the reinforcement
when the spacing between any pair of adjacent openings is equal to or greater than twice the average diameter of the pair.

Table 1. Required Hole Reinforcement Area

hole #	Finished Diameter d (inch)	Outward Nozzle Wall inch	Inner Nozzle Wall Inch	Required Reinforcement Cross sectional UG-39(b)(2) area ($inch^2$)
A	5.000	0	0	2.110
B	1.320	0	0	0.557
C	0.921	0	0	0.389
D	0.578	0	0	0.244
E	0.900	0	0	0.389
F	1.320	0	0	0.380
G	0.921	0	0	0.389
H	0.578	0	0	0.244
I	0.900	0	0	0.389

Table 2. Available Hole Reinforcement Area

hole #	Area Available UG-37.1 A1(a) ($inch^2$)	Area Available UG-37.1 A1(b) ($inch^2$)	Area Available UG-37.1 A2 ($inch^2$)	Area Available UG-37.1 A3 ($inch^2$)	Area Available UG-37.1 A41 ($inch^2$)	Total Area Available UG-37.1 A1(a)+A1(b)+A2+A3+A41 area ($inch^2$)
A	2.343		0.000	0.000	0.000	2.343
B		1.230	0.000	0.000	0.000	1.230
C		1.230	0.000	0.000	0.000	1.230
D		1.230	0.000	0.000	0.000	1.230
E		1.230	0.000	0.000	0.000	1.230
F		1.230	0.000	0.000	0.000	1.230
G		1.230	0.000	0.000	0.000	1.230
H		1.230	0.000	0.000	0.000	1.230
I		1.230	0.000	0.000	0.000	1.230

Annulus outer diameter assumes thickness of reinforcement is

$$T_{reinforcement} = t_{flange} - t_{required} = 1.313 - 0.844 = 0.47 \text{ inch}$$

The total area available is taken from UG-37.1 A1, area available in the shell and A2, area in the outer nozzle wall, A3 area in the inner nozzle wall, A41 area in the outer weld.

UG-40 Limits of Reinforcement
UG40(b)(1)The limits of reinforcement shall be at a distance on each side of the axis of the opening, within a diameter of the finished opening.

The outer radius of the reinforcement annulus is smaller than the hole diameter for each opening.
The required reinforcement in table 2 is taken using the requirements of UG-39 (b)(2) and considering the spacing between holes.

Table 3 lists the distances between pairs, and 2x the average diameter, and 1.25x the average diameter.

Pairs	Distance Between Pairs (inch)	2x ave diameter d (inch)	1.25X ave diameter d (inch)
A to B	3.72	6.320	3.950
A to C	4.19	5.921	3.701
A to D	4.19	5.578	3.486
A to E	4.19	5.900	3.688
B to C	1.79	2.241	1.401
C to D	1.77	1.499	
D to E	1.54	1.478	

For each opening, the available area of reinforcement exceeds the required area. Holes B thru I, have more than twice the available area of reinforcement per UG-39 for holes closer than 2x but greater than 1.25 times the average diameter.

UG-27 Thickness of Shells Under Internal Pressure
The nozzles attached to the 12 inch flange are shells under internal pressure. The minimum wall thickness required in the nozzles is calculated.

Circumferential Stress
$T_{required} = P R / (S E – 0.6 P)$
Where,

P = 75 psi MAWP
R = inside radius of the nozzle
S = 0.8 *14,200 psi
SS 304 and 316 Tube, seamless pipe and weld pipe,
Maximum allowable stress in tension, Section II, Part D, Table 1A.
0.8 multiplier for Fermi in house Flange construction.
E = 0.5 Joint Efficiency, Conservative.

Longitudinal Stress
$T_{required} = P R / (2*S E + 0.4 P)$
Where,

P = 75 psi relief valve setting on vacuum vessel
R = inside radius of the nozzle
S = 0.8 *14,200 psi
SS 304 and 316 Tube, seamless pipe and weld pipe,
Maximum allowable stress in tension, Section II, Part D, Table 1A.
0.8 multiplier for Fermi in house Flange construction.
E = 0.5 Joint Efficiency, Conservative.

The wall thickness required for the nozzles is listed in Table 3.

Table 3, Wall Thickness Required in Nozzles

							UG-27, Required Nozzle Wall with Internal Pressure	
Nozzle Hole #	X_coord (inch)	Y_coord (inch)	opening diameter (inch)	nozzle wall (inch)	Inner Diam (inch)	MAWP Nozzle (psi)	Circ. t_min (inch)	Long. t_min (inch)
B	-3.715	0	1.320	0.109	1.782	75	0.012	0.006
E	-1.375	-3.954	0.900	0.049	1.902	75	0.013	0.006
F	0	3.715	1.320	0.109	2.157	75	0.014	0.007
I	1.375	3.954	0.900	0.049	2.157	75	0.014	0.007

Summary

A standard class 150 flange thickness exceeds the required thickness for an allowable working pressure of 75 psig. The extra flange thickness is used as reinforcement around the openings in the flange and satisfies the requirement for reinforcement around the openings. All Nozzle wall thicknesses exceed the required wall thickness.