Fermilab

Particle Physics Division

Mechanical Department Engineering Note

Number: MD-Eng-147 Date: August 1, 2008

Project: DECAM

Project Internal Reference: LN2 Testing at Lab A

Title: ASME Calculations for the 200 Liter 18 inch Flange

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Reviewer(s):

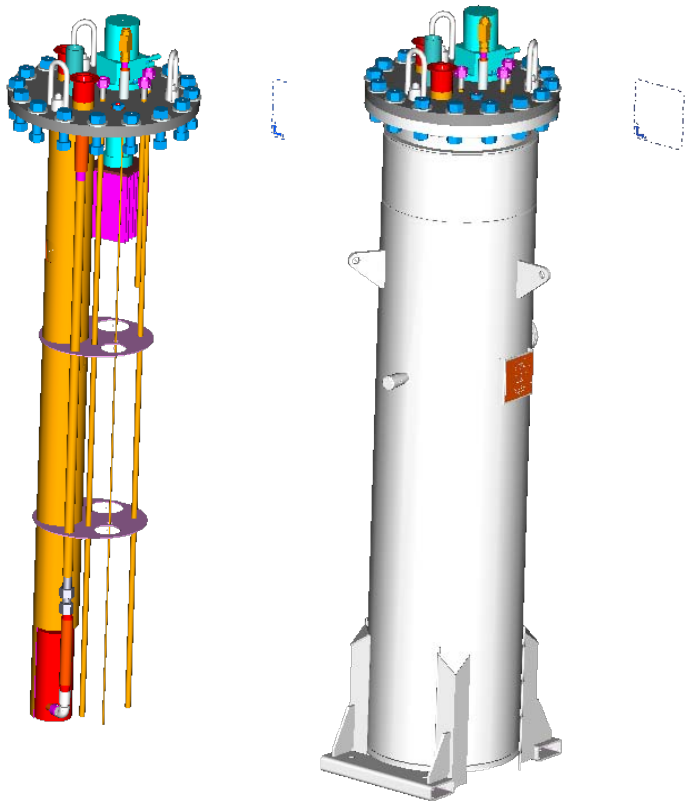
Key Words:

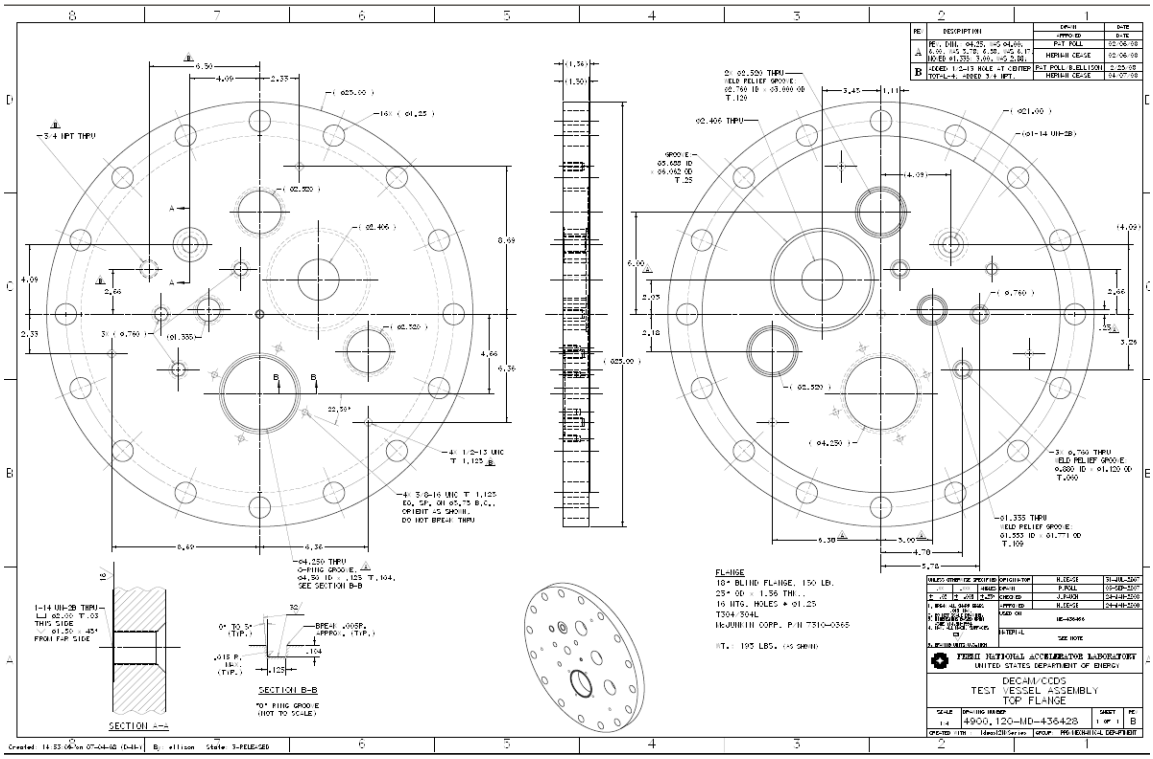
Abstract/Summary:

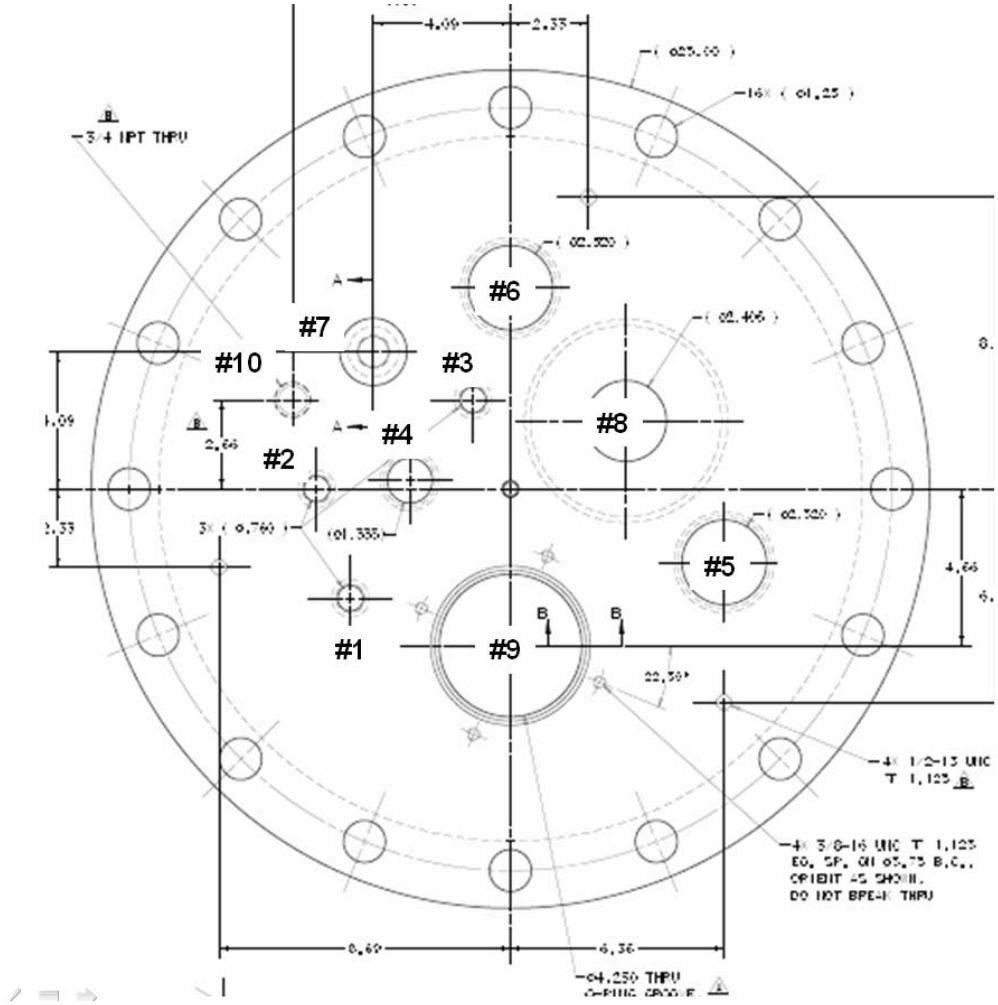
Applicable Codes:
ASME DIVISION I SECTION VIII,
ASME B16.5 Pipe Flanges and Flanged Fittings

Introduction:

An 18 inch class 150 flange assembly is used to cap the PHPK 200 L vessel. The PHPK vessel is ASME code stamped and has a MAWP of 150 psig. The flange is designed for a MAWP of 150 psig to match the vessel.




FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
DECAM/CCDS
TEST VESSEL ASSEMBLY
TOP FLANGE
4900.120-MD-436428
SECTION A-A
SECTION B-B
FL-HGE
10* BLIND FL-HGE, 150 LB.
25* OD x 1.56 THK.,
16 MTG. HOLES @ Ø1.25
T304/304L
DeJUNKIN CORP. P/N 7510-0365
WT.: 195 LBS. (45 GMIN)

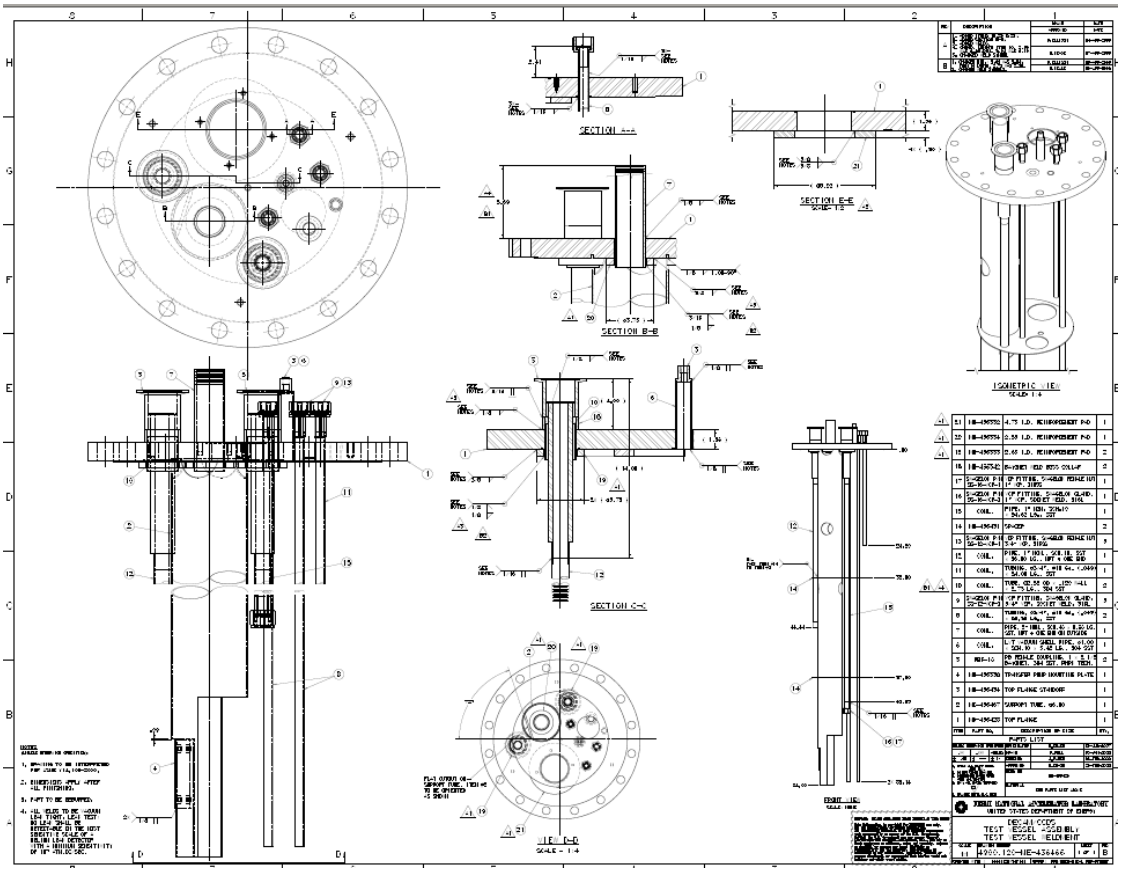


Hole Values and Designations:

#1 0.76 inch, ¾” ID tube, 0.049” wall, Fill Port (from bottom)
#2 0.76 inch, ¾” ID tube, 0.049” wall, Drain Port (from bottom)
#3 0.76 inch, ¾” ID tube, 0.049” wall, Full Trycock (top liquid level)
#4 1.335 inch, 1inch pipe, sch10, 0.109” wall, (Liquid level transmitter)
#5 2.52 inch, PHPK bayonet, rated 150 psig (Supply, from pump)
#6 2.52 inch, PHPK bayonet, rated 150 psig (Return)
#7 1.25 inch, threaded. (Electric connector feed thru)
#8 2.406 inch, 2 inch pipe, sch40, Relief and regulator valve
#9 4.25 inch, Al-300 Cryocooler, flange rated for 150 psig
#10 1.05 inch, ¾ NPT Electric connector feed thru

Reinforcing pads are needed on Holes #5, #6, #8 and #9. Dimensions and thickness are listed:
#5 2.52 inch, ID = 2.52 inch, OD = 3.75 inch, thickness = ½ inch
#6 2.52 inch, ID = 2.52 inch, OD = 3.75 inch, thickness = ½ inch
#8 2.406 inch, ID = 2.41 inch, OD = 3.75 inch, thickness = ½ inch
#9 4.25 inch, ID = 4.75 inch, OD = 8.0 inch, thickness = ½ inch

Weldment Drawing #436466



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 = 18 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 = 69,400 lbs, total bolt load
Hg = 1.295 inch, gasket moment arm, center of gasket reaction to
center of bolt hole
P = 150 psig, internal design pressure

t = 1.23 inch, required thickness

t = 1.56 for a 18 inch class 150 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 = (21 inch/2 – 18.18 inch/2)/2 = 0.705 inch
b = 0.42 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 = 21 inch – 2 * 0.42 inch = 20.16 inches
M = 2.7 gasket factor for a stiff group 1a gasket.
Appendix 2, Table 2-5.1

W_{m1} = 0.785* $(20.16 \text{ inch})^2$*150 psi
+ (2*0.42 inch*3.14*20.16 inch * 2.7* 150 psi)
= 69,400 lbs

Load on each bolt
Load = Wml / # of bolts
= 69,400 lbs/ 16 bolts
= 4,336 lbs per bolt

Bolt Stress
Stress = Load / area of 1 1/8 inch bolt
= 4336 lbs/ 0.763 inch^2
= 5,680 psi

Required torque
Torque = kDF
K = 0.2 steel fastener
D = 1.125 inch bolt diameter
F = 4,336 lb clamping load
Torque = 0.2 * 1.125 inch * 4336 lbs = 975 in.lbs
= 81 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-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 = 1.23 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

hole #	Hole Diameter d (inch)	Required Reinforcement Cross sectional UG-39(b)(2) area ($inch^2$)	Reinforcement Area available UG-37.1 A1 area ($inch^2$)	Reinforcement Area available UG-37.1 A5 t_e = 0.5 inch area ($inch^2$)	Total Area Available UG-37.1 A1+A5 area ($inch^2$)
1	0.662	0.408	1.025 A1(b)	0.000	1.025
2	0.662	0.408	1.025 A1(b)	0.000	1.025
3	0.662	0.408	1.025 A1(b)	0.000	1.025
4	1.117	0.688	1.025 A1(b)	0.000	1.025
5	2.28	1.404	1.025 A1(b)	0.615	1.640
6	2.28	1.404	1.025 A1(b)	0.615	1.640
7	1.25	0.770	1.025 A1(b)	0.000	1.025
8	2.098	1.292	1.025 A1(b)	0.672	1.697
9	4.25	2.617	1.396 A1(a)	1.625	3.021
10	1.05	0.646	1.025 A1(b)	0.000	1.025

Annulus outer diameter assumes thickness of reinforcement is

$$T_{reinforcement} = t_{flange} - t_{required} = 1.56 - 1.23 = 0.33 \text{ inch}$$

The total area available is taken from UG-37.1 A1, area available in the shell and A5, area available in the reinforcement pad. The area available in the nozzle wall and welds is not included in the calculation and is considered to be conservative.

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.
UG-39 (b)(2) The spacing between any pair of adjacent openings is equal to or greater than twice the average diameter of the pair.

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

Pairs	Distance Between Pairs (inch)	2x ave diameter d (inch)
9to4	5.75	5.585
9to1	4.98	4.912
9to8	7.53	6.656
9to5	6.85	2.52
6to8	9.67	4.926
5to8	5.13	4.926
4to1	3.94	2.095
4to3	3.06	2.095
4to2	2.79	2.095
4to8	6.69	3.741
3to8	4.60	3.166
3to6	5.57	3.28
7to10	2.80	2.3

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UG-27 Thickness of Shells Under Internal Pressure

The nozzles attached to the 18 inch flange are shells under internal pressure. The minimum wall thickness required in the nozzles is calculated.

Circumferential Stress

Trequired = P R / (S E – 0.6 P)

Where,

P = 150 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

Trequired = P R / (2*S E + 0.4 P)

Where,

P = 150 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.

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

Table 3, Wall Thickness Required in Nozzles

Nozzle Hole #	X_coord (inch)	Y_coord (inch)	opening diameter (inch)	nozzle wall (inch)	Inner Diam (inch)	MAWP Nozzle (psi)	Stress Nozzle Wall UG-27 Internal Pressure	
							Circ. t_min (inch)	Long. t_min (inch)
1	4.78	-3.26	0.76	0.049	0.662	150	0.009	0.004
2	5.78	0	0.76	0.049	0.662	150	0.009	0.004
3	1.11	2.66	0.76	0.049	0.662	150	0.009	0.004
4	3	0.25	1.335	0.109	1.117	150	0.015	0.007
5	-6.38	-2.18	2.52	0.12	2.28	150	0.031	0.015
6	6	0	2.52	0.12	2.28	150	0.031	0.015
7	4.09	4.09	1.25	0	1.25		N/A	N/A
8	-3.45	2.03	2.406	0.154	2.098	150	0.028	0.014
9	0	-4.66	4.25	0	4.25		N/A	N/A
10	6.5	2.66	1.05	0	1.05		N/A	N/A

Summary

A standard class 150 flange thickness exceeds the required thickness for an allowable working pressure of 150 psig. The extra flange thickness is used as reinforcement around the openings in the flange. Additional flange thickness is added in a reinforcing pad for the 4 largest openings. The flange thickness with the additional reinforcing pads satisfies the requirement for reinforcement around the openings. All Nozzle wall thicknesses exceed the required wall thickness.