Fermilab

Particle Physics Division

Mechanical Department Engineering Note

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Project: DECAM

Project Internal Reference: DES CTIO LN2 Vessel Flange

Title: ASME Calculations for the CTIO LN2 Vessel 10 inch Flange

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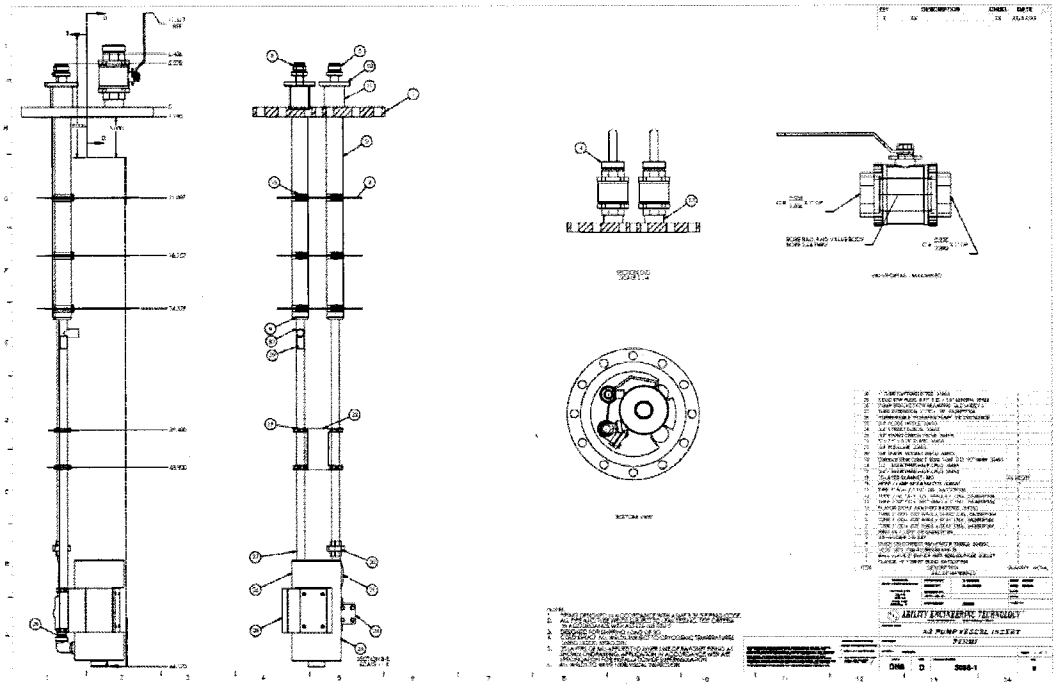
Key Words:

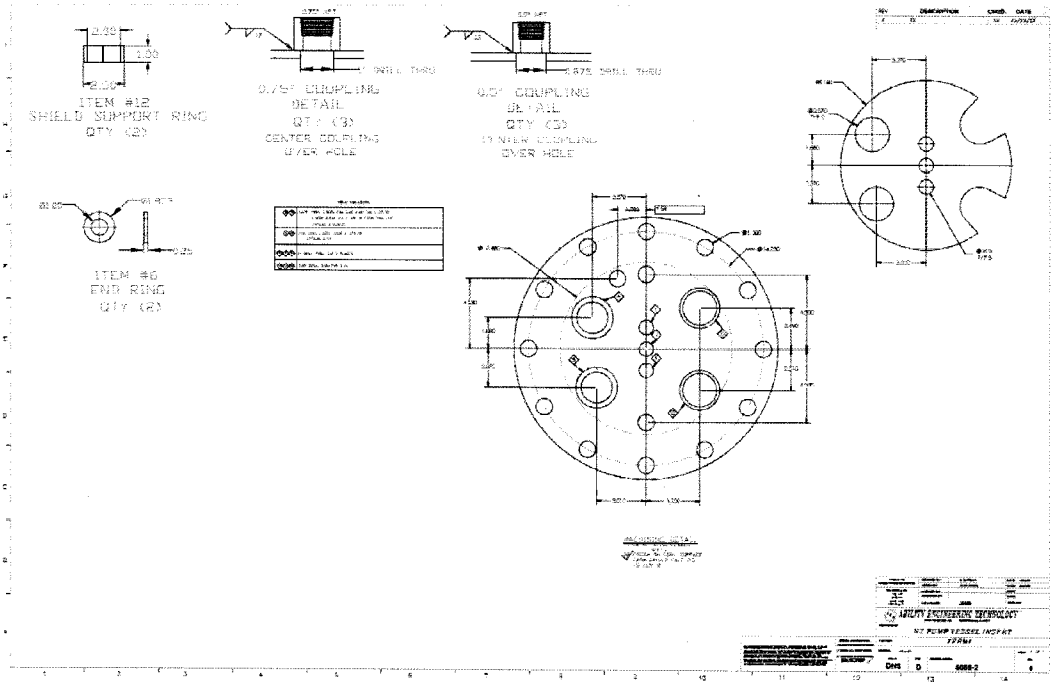
Abstract/Summary:

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

Introduction:

A 10 inch class 150 flange assembly is used to cap the CTIO 200 L vessel. The flange is provided by Ability Engineering PO#587133. The 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.





Hole Values and Designations:

#A 1.87 inch Thru, 2.5" tube, 0.065" wall, Supply
#B 1.87 inch Thru, 2.5" tube, 0.065" wall, Return
#C 2.06 inch Thru, 2.5" pipe, 0.120" wall, Cryocooler stinger 1
#D 2.06 inch Thru, 2.5" pipe, 0.120" wall, Cryocooler stinger 2
#E 1.00 inch Thru, ¾"FNPT coupling class 3000, not used
#F 1.315 inch Thru, ¾"FNPT coupling class 3000, Electronic power 7 Wires
#G 1.00 inch Thru, ¾"FNPT coupling class 3000, Electronic signals 12+ wires
#I 0.875 inch Thru, ½ "FNPT coupling class 3000, Full trycock /fill
#J 0.875 inch Thru, ½ "FNPT coupling class 3000, LN2 Liquid Level
#K 0.875 inch Thru, ½ "FNPT coupling class 3000, Drain

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 = 10 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 = The greater of W_{m1} or W_{m2}, 43,600 lbs total bolt load
Hg = 1.127 inch, gasket moment arm, center of gasket reaction to center of bolt hole
P = 150 psig, internal design pressure

t = 0.930 inch, required thickness

t = 1.253 for a 10 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 = The greater of W_{m1} or W_{m2}

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

b_o = basic gasket seating width = (outer radius – inner radius) / 2
b_o = (12.75 inch/2 – 10.48 inch/2)/2 = 0.567 inch
b = 0.377 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 = 16 inch – 2 * 0.377 inch = 15.247 inches
M = 2.9 gasket factor for a stiff group 1a gasket.
Appendix 2, Table 2-5.1

W_{m1} = 0.785* (15.25 inch)^2*150 psi
+ (2*0.377 inch*3.14*15.247 inch * 2.9* 150 psi)
= 43,600 lbs

W_{m2} = Bolt load to seat the gasket
= 3.14 *b*G*y
=3.14*0.377*15.247*2400
=43,269 lbs

Use W= W_{m1} =43,600 lbs

Load on each bolt

Load = W / # of bolts

= 43,600 lbs/ 12 bolts

= 3,630 lbs per bolt

Bolt Stress

Stress = Load / area of 7/8 inch bolt

= 3,630 lbs/ 0.462 $inch^2$

= 7,860 psi

Required torque

Torque = kDF

K = 0.2 steel fastener

D = 0.875 inch bolt diameter

F = 3,630 lb clamping load

Torque = 0.2 * 0.875 inch * 3,630 lbs = 635 in.lbs

= 53 foot lbs.

Note: A Belleville washer will be used to maintain the preload on the gasket.

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

All openings in the flange meet UG-36(c)(3) and do not require any additional reinforcement. However UG-39 calculations are provided.

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.

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 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	1.875	0.065	0.035	0.862
B	1.875	0.065	0.035	0.862
C	2.060	0.154	0	0.947
D	2.060	0.154	0	0.947
E	1.000	0.133	0	0.460
F	1.000	0.133	0	0.460
G	1.000	0.133	0	0.460
I	0.875	0.109	0	0.402
J	0.875	0.109	0	0.402
K	0.875	0.109	0	0.402

Table 2. Available Hole Reinforcement Area

hole #	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 ($inch^2$)	Area Available UG-37.1 A43 ($inch^2$)	Total Area Available UG-37.1 A1(b)+A2+A3+A41+A43 area ($inch^2$)
A	0.849	0.006	0.021	0.004	0.001	0.882
B	0.849	0.006	0.021	0.004	0.001	0.882
C	0.906	0.000	0.119	0.024	0.000	1.049
D	0.906	0.000	0.119	0.024	0.000	1.049
E	0.893	0.000	0.088	0.018	0.000	0.999
F	0.893	0.000	0.088	0.018	0.000	0.999
G	0.893	0.000	0.088	0.018	0.000	0.999
I	0.877	0.000	0.059	0.012	0.000	0.949
J	0.877	0.000	0.059	0.012	0.000	0.949
K	0.877	0.000	0.059	0.012	0.000	0.949

Annulus outer diameter assumes thickness of reinforcement is

$$T_{reinforcement} = t_{flange} - t_{required} = 1.25 - 0.93 = 0.32 \text{ inch}$$

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.

For each opening, the available area of reinforcement exceeds the required area. Holes F and J 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-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. Note that additional requirements apply for holes E, F, I, and J.

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	4.26	3.75	
C to D	5.00	4.12	
A to C	6.55	3.935	
B to D	6.26	3.935	
A to E	5.35	2.924	
E to F	1.56	2.05	1.281
I to J	1.31	1.75	1.094

UG-27 Thickness of Shells Under Internal Pressure
The nozzles attached to the 10 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)
A	-3.27	1.88	1.875	0.065	1.87	150	0.025	0.012
B	-3.01	-2.37	1.875	0.065	1.87	150	0.025	0.012
C	3.25	2.49	2.06	0.154	2.157	150	0.029	0.014
D	3.25	-2.51	2.06	0.154	2.157	150	0.029	0.014

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 and satisfies the requirement for reinforcement around the openings. All Nozzle wall thicknesses exceed the required wall thickness. A nut torque on the flange should not exceed 50 ft.lbs to prevent overstressing the flange. If the gasket does not seat with this low nut torque, use a softer gasket.