OBJECTIVE

To evaluate the following components of 3-60B cask:

1. Cask tie-down lugs/brackets for installation of the impact limiters.
2. Impact limiter tie-down attachment.
3. Cask drain port assembly.

INTRODUCTION

3-60 Cask is detailed per Reference 1. To evaluate the cask tie-down lug/bracket and the impact limiter tie-down attachment, the maximum applied loading per Table 4 of Reference 2 is utilized. The maximum attachment force is 56,890 lbs and it occurs under regulatory hypothetical accident drop condition in corner drop orientation for cold thermal environment. To evaluate the cask drain port assembly, the maximum applicable loading per Table 3 of Reference 2 is used. The loading that the drain port assembly is examined for is the tributary load caused by the maximum impact limiter reaction under regulatory hypothetical accident drop condition in slap-down (7.5°) orientation for cold thermal environment.

REFERENCES

(1) Energy*Solutions* Drawing No. C-002-165024-001, Revision 0, "3-60 Cask General Arrangement and Details."

(2) Energy*Solutions* Document No. ST-557, Rev. 1, Drop Analyses of the 3-60B Cask Package Using LS-DYNA Program.

(3) Roark's Formulas for Stress & Strain, 6th Edition.

MATERIAL PROPERTIES

Cask Shell and Attachments

Specification: ASTM A-240 Type 304L

Minimum Yield Strength, S_y = 25,000 psi

Minimum Ultimate Strength, S_u = 70,000 psi

Bolts

Specification: ASTM A-193, Grade B5

Minimum Yield Strength, S_y = 80,000 psi

Minimum Ultimate Strength, S_u = 100,000 psi

ALLOWABLE STRESSES

The following allowable values are utilized for the evaluations performed in this document:

Material Type	Normal Stress Allowable, psi	Shear Stress Allowable, psi
ASTM A-240 Type 304L	70,000	42,000
ASTM A-193, Grade B5	100,000	60,000

The allowable stresses in the weld are conservatively taken to be the same as the base metal.

STRUCTURAL EVALUATION

A. <u>Cask Tie-Down Lugs/Brackets for the Installation of the Impact Limiters</u>

Each impact limiter is attached to the cask at eight locations, as detailed per Reference 1, using 7/8" diameter bolts. Figure – 1 of this document shows the location and detail of a typical cask tie-down lug/bracket. Each bracket consists of a 1" × 5" × 4" top plate and two ½"×5" ×6" gusset plates. To install the 7/8" diameter bolt, the top plate is equipped with a 1 1/8" diameter hole centered in one direction and 1 ½" from the edge of the plate.

As stated earlier the maximum attachment force is 56,890 lbs. Conservatively an attachment force of 60,000 lbs is used for the evaluation herein. Evaluating the top plate using an expression from Roark (Reference 3) for a rectangular plate simply supported along three sides and free on the other side with the uniform pressure (q) applied over entire plate, Table 26, case 2a,

a/b = 4/5 = 0.8

ß = 0.538

q = 0,000/(4×5) = 3,000 psi

The maximum bending stress is:

$$\sigma_{max} = \frac{\beta q b^2}{t^2} = \frac{0.538 \times 3{,}000 \times 5^2}{1^2} = 40{,}350 \text{ psi} < 70{,}000 \text{ psi} \qquad \text{O.K.}$$

Calculating the bearing stress on the top plate using the washer projection on the plate. The bearing stress is:

$f_{bearing} = 60{,}000/[(p/4) \times (1.75^2 - 1.25^2)] = 50{,}930 \text{ psi} < 70{,}000 \text{ psi}$ O.K.

Assuming each gusset plate to react to ½ of the 60,000 psi load, the gusset plate bending stress is:

$$\sigma_{max} = \frac{(60{,}000 \times 0.5) \times 2.5 \times 6}{0.5 \times 6^2} = 25{,}000 \text{ psi} < 70{,}000 \text{ psi} \qquad \text{O.K.}$$

Examining the weld connecting the 1" top plate to the cask outer shell, assuming simply supported edge and using the tributary shear load (F),

F = 3,000×(0.5×2.5×5) = 18,750 lbs

Using 5/16" continuous fillet weld all around connecting the 1" top plate to the 1 ¼" cask outer shell, assuming credit only for 4" of weld on top and bottom of the plate and conservatively ignoring the end welds, the weld shear stress is:

$$\tau = \frac{18{,}750}{0.707 \times 0.3125 \times 2 \times 4} = 10{,}608 \text{ psi} < 42{,}000 \text{ psi} \qquad \text{O.K.}$$

Using 5/16" continuous fillet weld all around connecting the ½" gusset plates to the 1 ¼" cask outer shell, considering a 45° bevel at corner of the gusset plate to allow for the 5/16" weld connecting the 1" top plate to 1 ¼" cask outer shell and assuming credit for a 5 ½" long line weld on each side of the gusset plate and conservatively ignoring the end welds, the weld shear stress is calculated using the following tributary loads:

The tributary shear load reacted by the gusset plate (V) is:

$$V = 3{,}000 \times [(4 \times 5 - 0.5 \times 2.5 \times 5) \times 0.5] = 20{,}625 \text{ lbs.}$$

Consider the load V centered on the 4" wide gusset plate, the bending moment is:

M = 20,625 ×2 = 41,250 in-lbs.

$$\tau = \left[\left(\frac{20{,}625}{2 \times 5.5 \times 0.707 \times 0.3125}\right)^2 + \left(\frac{41{,}250}{\frac{5.5^2}{3} \times 0.707 \times 0.3125}\right)^2\right]^{0.5} = 20{,}368 \text{ psi} < 42{,}000 \text{ psi} \qquad \text{O.K.}$$

Examining the weld connecting the 1" top plate to the ½" gusset plates, assuming simply supported edges and using the tributary shear load (V), same as above,

$$V = 3{,}000 \times [(4 \times 5 - 0.5 \times 2.5 \times 5) \times 0.5] = 20{,}625 \text{ lbs.}$$

Using full penetration groove weld connecting the 1" top plate to the ½" gusset plates, allow for corner bevel and assuming 3" weld length, the weld shear stress is:

$$\tau = \frac{20{,}625}{0.5 \times 3} = 13{,}750 \text{ psi} < 42{,}000 \text{ psi} \qquad \text{O.K.}$$

Using the area of the 7/8" diameter tie-down bolt, the maximum bolt tensile stress is:

$$f_t = \frac{60,000}{\frac{\pi}{4} \times 0.875^2} = 99,780 \text{ psi} < 100,000 \text{ psi}$$ O.K.

B. Impact Limiter Tie-Down Attachment

As stated earlier, each impact limiter is bolted to the cask at eight locations as per Reference 1. Figure – 2 of this document shows the arrangement and detail of the impact limiter tie-down attachment. The tie-down attachment consists of a 1 ¾" ×53" I.D. ×59" O.D ring plate and sixteen ½" × 3" × 10" gusset plates. A pair of gusset plates connects the 1 ¾" ring to the ½" thick impact limiter inner plate at each bolt location as per Reference 1.

Examining the 1 ¾" ring using an expression from Roark (Reference 3) for a rectangular plate with three edges simply supported and one edge free with uniform load applied over entire plate, Table 26, case 2a,

a = 3, b = 2 ½", a/b = 1.2

By interpolation ß = 0.71

q = 60,000/(3×2.5) = 8,000 psi

$$\sigma_{max} = \frac{0.71 \times 8,000 \times 2.5^2}{1.75^2} = 11,592 < 70,000 \text{ psi}$$ O.K.

Assuming each gusset plate reacts to one-half of the 60,000 lb load, the gusset plate bending stress is:

$$\sigma_{max} = \frac{(60,000 \times 0.5) \times 1.5 \times 6}{0.5 \times 10^2} = 5,400 \text{ psi} < 70,000 \text{ psi}$$ O.K.

Using 5/16" continuous fillet weld all around connecting the 1" gusset plate to the ½" thick impact limiter inner plate, considering a 45° bevel at corner of the gusset plates to allow for the 5/16" weld connecting the 1 ¾" ring plate to ½" impact limiter inner ring and assuming credit for a 9 ½" long line weld on each side of the gusset plate and conservatively ignoring the end welds, the weld shear stress is:

The shear load reacted by the gusset plate (V) is:

V = 60,000×0.5 = 30,000 lbs

The bending moment is:

M = 30,000 ×1.5 = 45,000 in-lbs.

$$\tau = [(\frac{30,000}{2 \times 9.5 \times 0.707 \times 0.3125})^2 + (\frac{45,000}{\frac{9.5^2}{3} \times 0.707 \times 0.3125})^2]^{0.5} = 9,844 \text{ psi} < 42,000 \text{ psi} \quad \text{O.K.}$$

Considering 5/16" continuous fillet weld all around and on both sides to connect the 1 ¾" thick ring plate to ½" thick impact limiter inner plate, conservatively ignoring the gusset plate contribution and assuming only 6" of this weld to react to the shear load of 60,000 lbs, the weld shear stress is:

$$\tau = \frac{60,000}{0.707 \times 0.3125 \times 2 \times 6} = 22,631 \text{ psi} < 42,000 \text{ psi} \quad \text{O.K.}$$

Examining the weld connecting the 1 ¾" ring plate to each ½" gusset plate,

$V = 60,000 \times 0.5 = 30,000$ lbs

Using full penetration groove weld connecting the 1 ¾" ring plate to each ½" gusset plate, allow for corner bevel and assuming 2" weld length, the weld shear stress is:

$$\tau = \frac{30,000}{0.5 \times 2} = 30,000 \text{ psi} < 42,000 \text{ psi} \quad \text{O.K.}$$

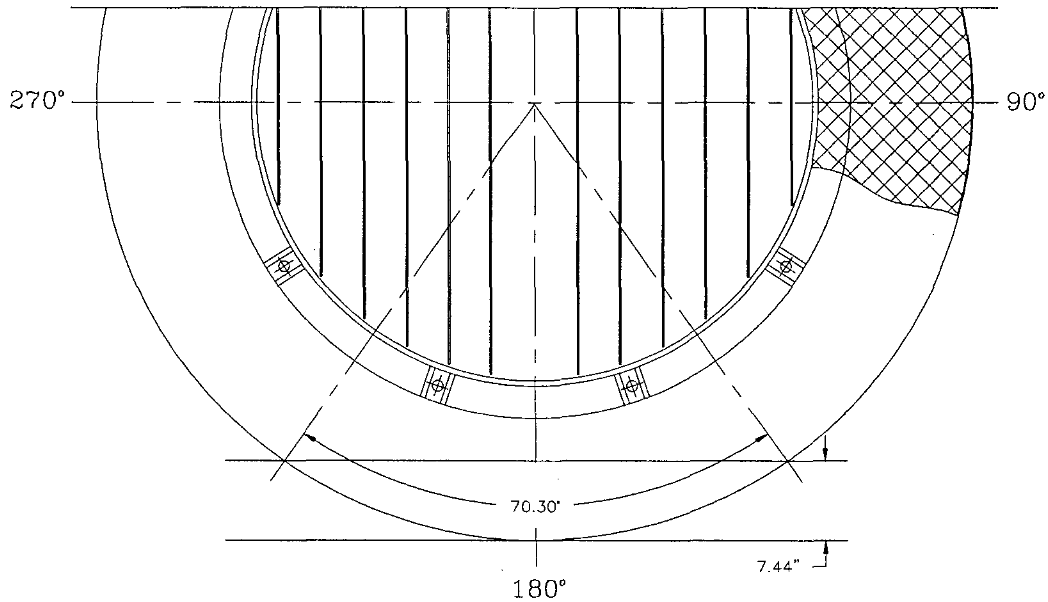
C. Cask Drain Port Assembly

The 3-60B cask is equipped with a drain line that is detailed per Reference 1. Figure – 3 of this document shows the drain line connecting to the ¾" thick cask inner bottom cover. The drain line has a 2 ½" outside diameter and 1" inside diameter.

Examining this line for the maximum load that the drain port assembly is subjected to under regulatory hypothetical accident drop condition in slap-down (7.5°) orientation for cold thermal environment. Per Table 3 of Reference 2, the maximum impact limiter reaction for this loading condition is 2.009×10^6 lbs.

Using 22" impact limiter coverage of the cask bottom end, for a maximum impact limiter crush of 7.44" in for the above slap-down drop (per Table 3, of Reference 2) a nominal 70° impact zone could be assumed as shown in the following sketch, conservatively calculating the estimated pressure on the cask body using a smaller 30° impact zone:

$$q = \frac{2.009 \times 10^6}{22 \times (\frac{51 \times \pi}{360}) \times 30} = 6,840 \text{ psi}$$



END VIEW
(TYPICAL FOR FRONT AND REAR LIMITERS)

Using a 4 ½" diameter nozzle diameter on the side wall, the tributary shear load on the drain port assembly is:

$$F = 6{,}840 \times \frac{\pi}{4} \times 4.5^2 = 108{,}786 \text{ lbs.}$$

The weld connecting the drain port to the cask outer shell is as shown in Figure 3. Using an allowable base material and weld shear stress equal to $0.6 \times S_u = 0.6 \times 70{,}000 = 42{,}000$ psi and conservatively assuming credit only for the ¼" partial penetration groove weld, the maximum shear load that this weld can withstand is,

$$V = 42{,}000 \times [\pi \times 4.5 \times (0.25 - 0.125)] = 74{,}220 \; lbs.$$

Therefore the ratio of the maximum shear load that this weld can withstand to the tributary shear load applied to the drain port ($\frac{V}{F}$) is:

$$\frac{V}{F} = \frac{74{,}220}{108{,}786} = 0.68 > 0.50$$

Since the above ratio of V/F is larger than 0.5 and also the above weld strength calculation is based on conservative weld effective throat, it is conservative to assume that the shear load of 108,786 lbs. is reacted equally by the welds connecting the drain port to the cask outer shell and inner bottom cover. The drain line shear stress is:

$$\tau = \frac{108{,}786 \times 0.5}{(\pi/4)\times(2.5^2 - 1^2)} = 13{,}192 \text{ psi} < 42{,}000 \text{ psi}$$ O.K.

Figure Withheld Under 10 CFR 2.390

Figure – 1: 3-60B Cask Tie-Down/Bracket Details for the Installation of the Impact Limiter

Figure Withheld Under 10 CFR 2.390

IMPACT LIMITER

Figure – 2: 3-60B Cask - Impact Limiter Tie-Down Attachment Details

Figure Withheld Under 10 CFR 2.390

Figure – 3: 3-60B Cask – Drain Port Assembly Details