LIGO-E970173-00-V

PROCESS SYSTEMS INTERNATIONAL, INC. WESTBOROUGH, MA					ENGINEERING CALCULATIONS	NO: V049-1- 162 PAGE 1 OF 18
REV.	DEO #	DATE	BY:	CHECK	TITLE:	
0	0559	10/13/97	RDC	DM	**Support Design for Adapters LB-1A & LB-1C**	
					BY: R. D. Ciatto	DEPT.: 744

PROJECT: LIGO Vacuum Equipment

PROJECT NO: V59049

PURPOSE: Support design for the B-1 adapters is essentially the same as the design of supports for the B-9 beam tube manifolds. However, as shown in this calculation, the axial unbalanced loads for LB-1A and LB-1C are higher than they are for other B-1 or B-9 spools. The purpose of this calculation is to address the higher unbalanced load.

METHOD: Hand calculations are performed to determine the maximum member and anchor bolt tensile and shear forces. Forces are compared to those for B-9. Final member forces are compared to AISC allowables. Anchor forces are compared to allowable forces published by Hilti for the HVA concrete anchor system.

ASSUMPTIONS: See calculation.

INPUTS: See calculation for unbalanced forces derived form other calculations.

NOV 14 1997

REFERENCES:
1. Hilti Product Technical Guide, 1995.
2. AISC Code, 9th edition, Allowable Stress Design.
3. Amer. Concrete Inst., ACI 318-89, Building Code Rq'mts for Reinforced Concrete.
4. Doc. No. V049-1-049, Design of Support for Beam Tube Manifold B-9.

CALCULATIONS: (SEE ATTACHED)

CONCLUSIONS: The vertical members for the supports for LB-1A and LB-1B will be larger than those for other similar members and shear bars will be used at the base plates connected to diagonal members to transfer the axial load into the concrete floor.

NOTES: Modifications resulting from this evaluation are implemented in RFC V049 – 078.

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REVISION HISTORY

Rev. 0 Original Issue - Oct. 1997

Summary of Results

Support Assemblies for Louisiana Spools LB-1A & LB-1C.

Anchors - Use 4 1"∅ Hilti HVA Standard concrete anchors at base plates connected to diagonal members. Use HAS standard rod with 8 1/4" embedment.

Use 4"∅ Hilti HVA anchors with 12 3/8" embedment at vertical members. Use Super rod.

Vertical members

TS 6x4x1/2 (6" dimension shall be parallel to beam tube centerline.)
A500 Grade C (50 ksi yield stress)

Alternate: TS 8x4x1/2 A500 Grade B (46 ksi yield stress)

Base plates for these members are 12"x12"

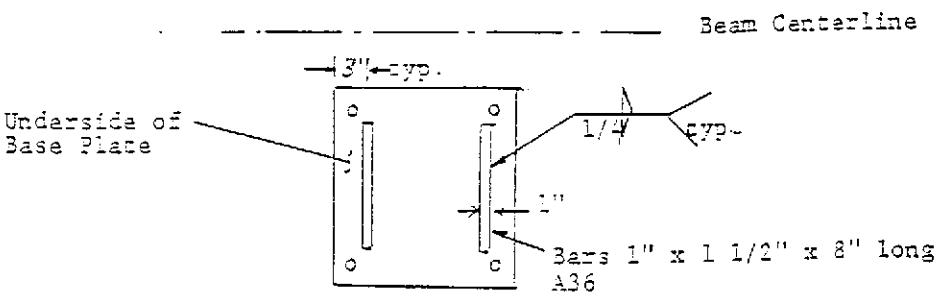
Diagonal members

TS 4x4x1/2 A500 Grade B

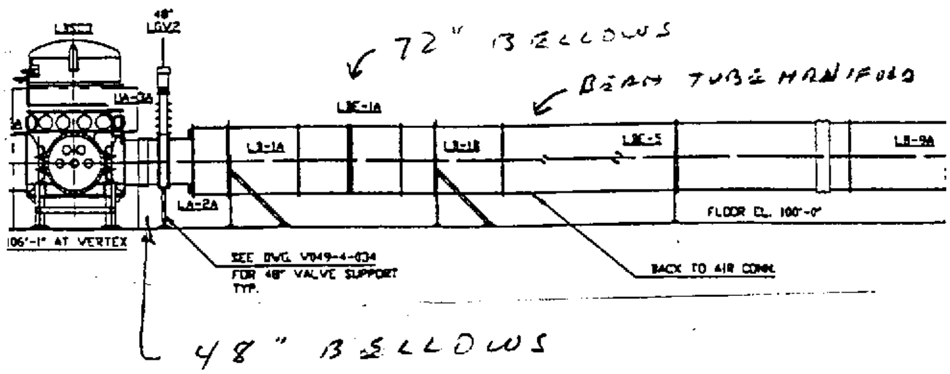
Scarify concrete floor at base plates connected to diagonal members.

Welds - See Dwg. V049-1-B1, Sheet 1.

Use the following shear bars on base plate connected to diagonal members.



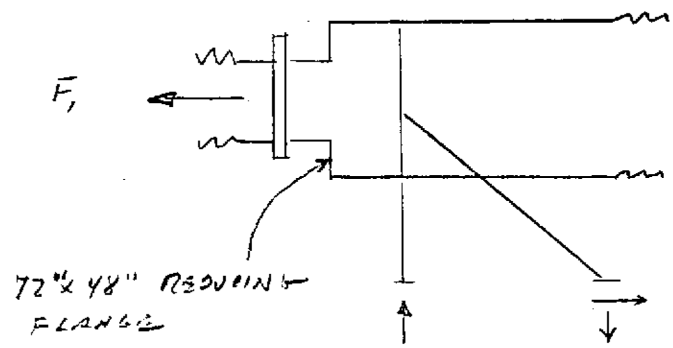
Louisiana Partial Assembly: A-2, B-1, BE-1



Ref: Dwg. V049-5-003, Sheet 2

Unbalanced forces

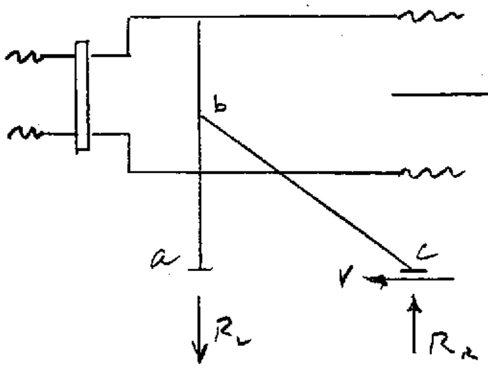
Gate valve closed, Beam tube manifold vented



$F_1 = 32.17k$

Ref: Calc. No. V049-1-095, Page 1.

Gate valve closed, BSC side vented



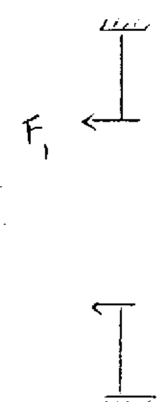
$F_2 = 64.1k$

Ref: Calc. No. V049-1-032, Page 5.

Adapter A2

Tensile force on 72"x48" reducing flange

Force per inch



$T = F_1/(\Pi D)$

$D = 72.25$ "

$T = 32.17/(\Pi \times 72.25) = .14$ k/in

= 140 lb/in

<362 lb/in max design load

Ref: Calc V049-1-042, Page 17.

Check bending in the reducing flange

ID = 48 1/4”

Diameter at bolt circle: BC = 78”

Thickness: t = 1”

Use Timoshenko, Plates & Shells, Table 3, P. 62.

a = 78/2 = 39” outside radius

b = 48.25/2 = 24.125 inside radius

a/b = 39/24.1 = 1.6

for F_1, use case 9 (beam tube manifold vented).

$k \approx .35$

$\sigma_{max} = kP/h^2$

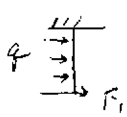
h = thickness = 1”

$\sigma max = .35 \times 32.17 = 11.2$ ksi ok

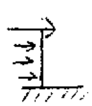
For BSC side vented, add cases 9 and 10.

Case 10: k = .30

$\sigma_{max} = kqa^2/h^2 = .30 \times 14.7 \times 39^2/1 = 6.7$ ksi



$\sigma_{total} = 11.2 + 6.7 = 17.9$ ksi ok



Support

The maximum support reactions are imposed by F_2, when the BSC side of the gate valve is vented.

The members will be evaluated by comparison to the support assembly of spool B-9 which was evaluated in calc. no. V049-1-089. The unbalanced load for B-9 is

$$F_r = 38.13k$$

Ref: V049-1-089, Page 8A.

Forces must be factored by : $F_2/F_r = 64.1/38.13 = 1.68$

Member ab (TS4x4x1/2, A500 Grade B) corresponds to members 13 & 15 of STAAD model for B-9.

Per Eq. H2-1 of the AISC code, the interaction for members 13 & 15 is .70 <1.0. Multiply by 1.68:

$$I = 1.68 \times .70 = 1.18 > 1.0$$

Hence, this member must be modified for the Louisiana installation.

Member bc corredponds to members 16 & 17 in B-9. Interaction is .652 for member 16 and it is .647 for member 17.

$$I = 1.68 \times .652 = 1.10 > 1.0$$

Review of the STAAD output shows high bending at joint b, but lower stress at base plate ends of these members.

Check members 12 & 14 in STAAD model.

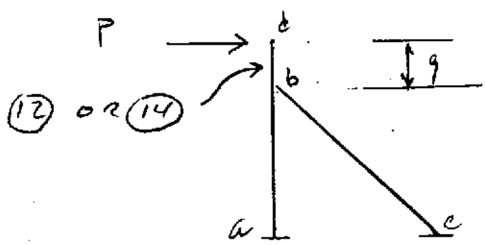
$I = 1.0$ for spool B-9
$I = 1.68 > 1.0$ for B-1 in Louisiana.

For this short member the high stress is due to bending at the same location, point b. The maximum axial stress is only

$f_t = 4628$ psi in members 16 & 17.

∴ the vertical member will be changed to a deeper section to resist the bending.

Check bending in members 12 & 14 of STAAD model for spool B-9.



$P = 38.13/2 = 19.1k$

Ref: V049-1-089, Page 10.

$M = 9P = 171.6$ in –k

The member is a TS 4x4x1/2,

$S = 6.13\ in^3$

$f_b = M/S = 171.6/6.13 = 28.0$ ksi

This agrees with bending stress in STAAD output for case 2, which is vacuum load, the largest load. See V049-1-089, p. 29 for bending about member Y – axis.

For member bd in spool B-1, the moment arm is 10 in, the force is:

$P = F_2/2 = 64.1/2 = 32.1$ k

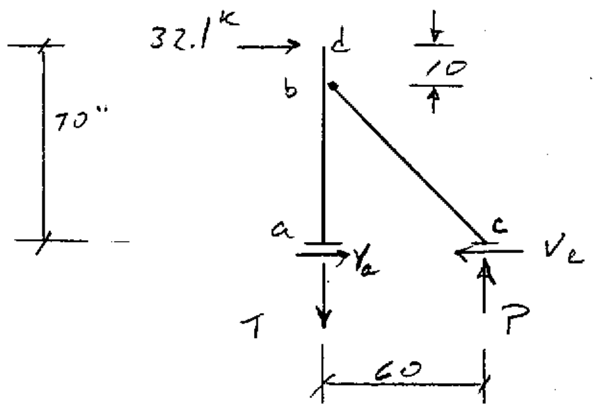
The bending moment at point d in bd is

$M = 10 \times 32.1 = 321$ in-k

Change member abd to a TS 6x4x1/2, $S_x = 11.8\ in^3$.

$f_b = M/S_x = 321/11.8 = 27.2$ ksi

Get other forces in the frame. Let member abd take all bending.



Let member bc be pin-ended which is conservative for abd. Forces are:

$60P = 70 \times 32.1$
$P = 37.45$ k
$T = 37.45$ k
$60V_a = 10 \times 32.1$
$V_a = 5.4$ k
$V_c = 32.1 + 5.4 = 37.5$ k

Compression in member bc

$$F = .707(P + V_b) = .707(37.45 + 37.5) = 53.0 \text{ k}$$

Keep TS 4x4x1/2 for bc. Compressive stress is

$$f_a = F/A = 53.0/6.36 = 8.33 \text{ ksi}$$

Length of bc

$$L = 60/.707 = 84.9 \text{ in} = 7.1 \text{ ft}$$

Alllowable column load is

$P_{cr} = 134 \text{ k} > 53 \text{ k}$ ok

Ref: AISC, Page 3-43.

Check member ab for combined tension & bending at point b.

$A = 8.36$ for TS 6x4x1/2

$f_t = T/A = 37.45/8.36 = 4.5$ ksi

$F_t = .60\ F_y = .60 \times 46 = 27.6$

$f_t/F_t = .16$

$F_b = .66F_y = .66 \times 46 = 30.4$

$f_b/F_b = 27.2/30.4 = .90$

$f_t/F_t + f_b/F_b = .16 + .90 = 1.06 > 1.0$

For the TS 6x4x1/2, use A500 Grade C, $F_y = 50$ ksi

$F_t = 27.6 \times 50/46 = 30$ ksi

$F_b = 30.4 \times 50/46 = 33$ ksi

$f_t/F_t + f_b/F_b = 4.5/30 + 27.2/33 = .15 + .82 = .97 < 1.0$ ok

As an alternate, try TS 8 x 4 x 1/2

$A = 10.4\ in^2$

$f_t = 37.45/10.4 = 3.6$ ksi

$S_x = 18.8$ in3

$f_b = 321/18.8 = 17.1$ ksi

For A500, Grade B

$f_t/F_t + f_b/F_b = 3.6/27.6 + 17.1/30.4 = .13 + .56 = .69 < 1.0$ ok

Check weld at base plate at point a. For 3/8" fillet.

$A_w = .707 \times .375\ (2x6 + 2x4) = 5.30\ in^2$

$f_v = (T + V_a)/\ A_w$

$= (37.45 + 5.4)/5.30 = 8.1$ ksi ok

Check weld in base plate at c.
Length:

$L = 2(4/.707) + 2 \times 4 = 19.3$ in

$A_w = .707 \times .25 \times 19.3 = 3.41\ in^2$

$f_v = F/A_w = 53/3.4 = 15.5\ ksi < 21.0\ ksi$

Weld of member bc at point b is ok for load, F, from review of Dwg. V049-4-B1, Sheet 1.

Anchors at base plate A. For 1" diameter HVA anchors with STD rod & 12 3/8 " embedment.

$T_{all} = 16.45$ k
$V_{all} = 16.68$ k

These values are used for 3000 psi concrete for HAS super rod with 12 3/8 " embedment.

Bolt tension (multiply by 1.25 to account for prying).

$T = 37.45 \times 1.25/4 = 11.7$ k per anchor

Shear $V = V_a/2$ (only 2 anchors are assumed to resist shear)
$= 5.4/2 = 2.7$

$T/T_{all} + V/V_{all} = 11.7/16.45 + 2.7/16.68 = .71 + .16 = .87 < 1.0$ ok

Use 5/3 shear tension interaction equation.

$(T/T_{all})^{5/3} + (V/V_{all})^{5/3} = .57 + .10 = .67 < 1.0$ ok

$f'_c = 7$ ksi for grout

$f_p << f'_c$ ok

Shear friction at floor

When floor at plate c is roughened with 1/4" indentations, per ACI 11.7.9,

$V_{nmax} = .2f'_cA_c$ (ACI 11.7.5)

$f'_c = 3000$ psi for floor in Louisiana

$Ac = 12 \times 12 = 144 \text{ in}^2$

$V_{nmax} = .2 \times 3000 \times 144 = 86.4$ k
$>> V_c = 37.5$ k ok

For a 1/4" fillet weld for shear bars,

$A_w = 8 \times .707 \times .25 \times 2 = 2.83 \text{ in}^2$

$f_v = V_c/A_w = 37.5/2.83 = 13.3 \text{ ksi} < 21 \text{ ksi}$ ok

Check 5/8"∅ bolt at point d. These are in tension only when the beam tube manifold is vented.

$F_1 = 32.17$ k

for 6 bolts,

$T = F_1/6 = 32.17/6 = 5.36$ k

$T_{all} = 13.5$ k for 5/8" ∅ A325 bolt (AISC P. 4-3) ok

Note: Shear load due to weight is low.