Fermilab

Particle Physics Division

Mechanical Department Engineering Note

Number: MD-ENG-206 Date: 9/17/2009

Project: DECAM

Project Internal Reference:

Title: Telescope Simulator Base

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Reviewer(s): Dave Pushka

Key Words: DECAM, DES, Telescope Simulator. Structural Equipment Supports

Abstract/Summary:

The DES Telescope Simulator consists of two motorized rings which allow for the rotation and tilt of the DECAM camera. This engineering note investigates the stability and load carrying capacities of a stand that will support these positioning rings.

The supporting members are A500 Grade B steel rectangular tubes connected by A36 steel plates that are welded to one tube and bolted to the connecting tube. This combination of shop welded and field bolted connections is necessary since a completely assembled stand will not fit through the Lab A doorway. Subassemblies that will fit through this doorway will be shop fabricated and then bolted together in Lab A to form a completed stand. The stand will be bolted to the Lab A floor slab through the use of "Hilti Drop-in" anchors.

DES TELESCOPE SIMULATOR — SIMULATOR BASE — R. J. WOODS APR. 16, 2009

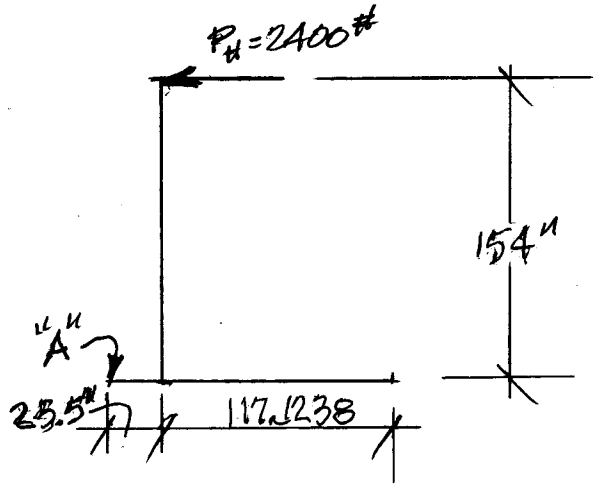
REVISED BASE DESIGN:

VERTICAL LOAD:

TELESCOPE & RINGS 48,000# (24,000# PER SIDE)

HORIZONTAL LOAD = 10% VERT. LOAD 4,800# (2400# PER SIDE)

FRAME STABILITY:



OVERTURNING MOMENT ABOUT "A" = 154(2400#)
= 369,600 #-IN

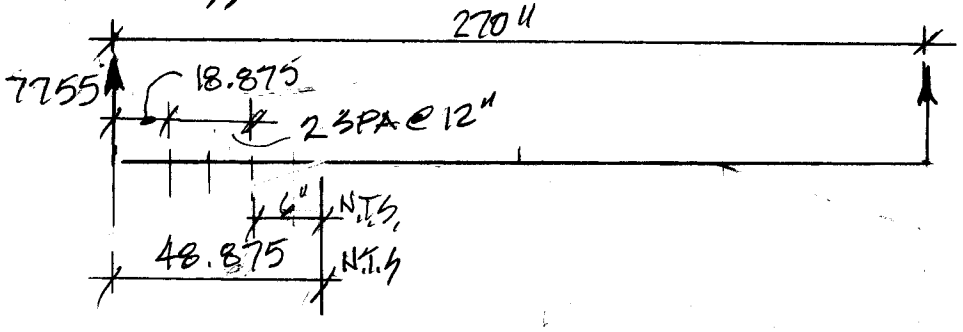
REACTION @ "B" (IGNORING RESISTING MOMENT DUE TO VERT. LOAD)

369,600/(25.5+117.1238) = 2591.5#

DESIGN FOR A SAFETY FACTOR OF 3:

P_V = 3(2591)
= 7773#

REAR CROSS TUBE TO FLOOR CONNECTIONS:



ANGLE BRACKET ON SIDE WITH 2 ANCHORS TAKES 1/2 OF THIS LOAD:

7773/2 = 3887# TRY 5/8"ϕ HILTI DROP-IN:

FOR 2 BOLTS, LOAD ON EA. BOLT = 3887/2 = 1944#

CHECK FOR COMBINED TENSION & SHEAR:

$F_{T\,ALLOW}$ @ 12" SPAC. & 4000 PSI CONC = 2920# (HILTI CATALOG)

$F_{S\,ALLOW}$ @ 12" SPAC & 4000 PSI CONC = 3250# (HILTI CATALOG)

f_t = 1944#

f_s = 2400/7 BOLTS = 343#

$1944/2920 + 343/3250 \overset{?}{\leq} 1$

$0.666 + 0.106 = 0.772 < 1.0$ OK

USE 5/8"ϕ HILTI DROP-IN ANCHORS

ASSUME 3 BOLTS ON REAR BRACKET TAKE FULL OVERTURNING LOAD:

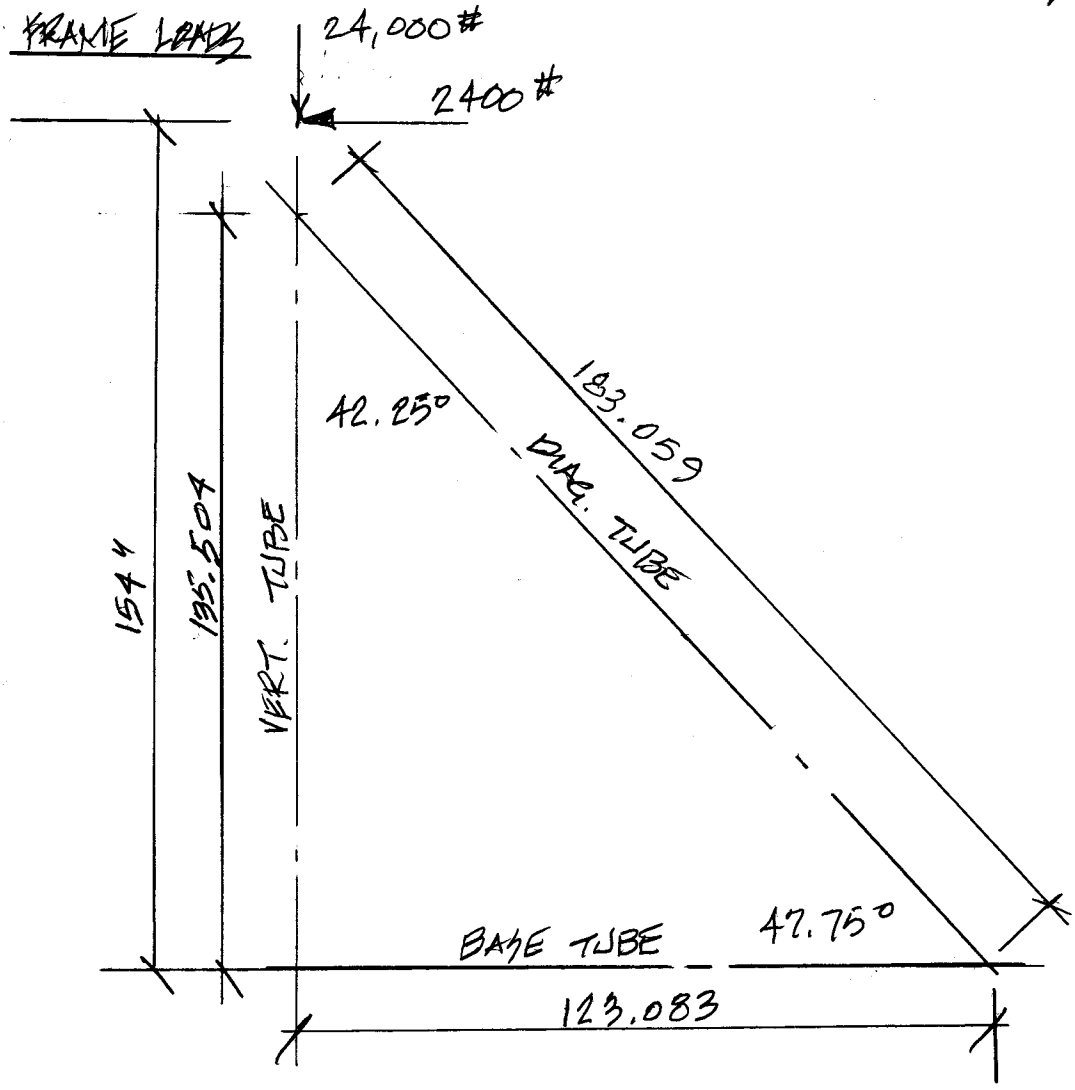
7773# /3 = 2591#

$2591/2920 + 343/3250 \overset{?}{\leq} 1$

$0.887+ + 0.106 = 0.993 < 1.0$ OK

USE 5/8"ϕ HILTI DROP-IN ANCHORS

FRAME LOADS



LOAD ON DIAG. TUBE:

2400 / SIN 42.25 = 3569.5#

REACTION ON VERT TUBE =

3569.5 (COS 42.25) = 2642.2#

LOAD ON SIDE DIAG. TUBE (NOT SHOWN):

2400 / SIN 36 = 4083#

REACTION ON VERT. TUBE =

4083 (COS 36) = 3303#

LOAD ON VERT. TUBE:

24,000# + 3303# + 2642 + 2000# DRIVE LOAD =

31945#

LOADS ON RECTANGULAR TUBES:

VERTICAL TUBE:

VERTICAL LOAD = 27,303 #

TUBE = HSS 12" x 6" x 5/16"

LENGTH = 135.504" = 11.29'

a) CHECK TABLE B5.1 P 5-32 AISC

$b/t = 12/0.3125$

$= 38.4$

$190/\sqrt{F_y} = 190/\sqrt{46}$

$= 28.0 > 38.4$ NON-COMPACT

IS $b/t < 238/\sqrt{F_y}$

$238/\sqrt{46}$

$35.1 < 38.4 \therefore$ TUBE IS SLENDER

$h = 12" - (2 \times 5/16")$

$= 11.375"$

$h/t = 11.375/0.3125$

$= 36.4 < 70 \therefore K_c = 1.0$ (AISC P. 5-99)

FROM APPENDIX B, B5.2.b b_e/t = VALUE PERMITTED IN SECT. B5.1 (P5-35): (P. 5-99 AISC)

B5.1.d WIDTH b = TOTAL WIDTH $- 3(t)$

$= 6. - 3(0.3125)$

$= 5.0625"$

$= 12 - 3(0.3125)$

$= 11.0625$

EFFECTIVE AREA $= 2((5.0625)(0.3125) + (11.0625)(0.3125))$

$= 10.08 \text{ IN}^2$

$Q_a = \frac{\text{EFFECTIVE AREA}}{\text{ACTUAL AREA}}$ (A-B5-16) P 5-100

$= \frac{10.08}{10.6} = 0.95$

FROM A-B5.2.c (P. 5-101)

$Q = Q_a(1.0)$

$= 0.95$

$C_c' = \sqrt{\frac{2\pi^2 E}{Q F_y}} = \sqrt{\frac{2(\pi)^2(29{,}000)}{0.95(46)}} = 115$

$KL/r = \frac{1.0(135.5)}{2.51} = 53 < 115$

$$\therefore F_a = \frac{\phi\left[1 - \frac{(KL/r)^2}{2(C_c')^2}\right]F_y}{5/3 + \frac{3(KL/r)}{8C_c'} - \frac{(KL/r)^3}{8(C_c')^3}} \quad \text{(A-B5-11)}$$

$$= \frac{0.95\left[1 - \frac{53^2}{2(115)^2}\right]46}{5/3 + \frac{3(53)}{8(115)} - \frac{53^3}{8(115)^3}}$$

$$= 21.4 \text{ KSI}$$

$$f_a = \frac{31,945}{10.6} = 3014 \text{ psi} = 3.0 \text{ KSI} < 21 \text{ AKSI}$$

OK

USE HSS 12 x 6 x 5/16

BOLTED CONNECTION @ BOTTOM:

LOAD = 31,945 # = 32.0 K

OF 3/4" ϕ BOLTS = 6

FROM TABLE 1-D P. 4-5:

ALLOW. DOUBLE SHEAR = 18.6 K/BOLT

18.6 x 6 = 111.6 K > 32.0 K

OK

TUBE SHEAR FROM BOLTS:

LOAD / BOLT = 32.0/6 = 5.3 K/BOLT

SHEAR AREA = 5/16 (1.5)" = 0.469 IN²

FOR DOUBLE SHEAR:

0.469(2) = 0.9375 IN²

$F_v = 0.40 F_y$ (F2-1) P. 5-48

= 0.40(46)

= 10.4 KSI

10.4 (0.9375) = 9.75 K/BOLT > 5.3 K/BOLT

OK

BOLT BEARING:

FROM TABLE 1-E P 4-6

FOR F_u = 58 KSI, 5/16 MATERIAL THICKNESS

ALLOW. BEARING = 16.3 K/BOLT > 5.3 K/BOLT

OK

USE 6 - 3/4" ϕ BOLTS

DIAG. TUBE:

SEE VERT TUBE ABOVE FOR SLENDER TUBE CALCULATION

$Q_2 = 0.95$

$C_c' = 115$

$Kl/r = \frac{1.0(183.1)}{2.51} = 73 < 115$

COMPRESSION:

$$\therefore F_a = \frac{0.95\left[1 - \frac{73^2}{2(115)^2}\right]46}{5/3 + \frac{3(73)}{8(115)} - \frac{73^3}{8(115)^3}}$$

$= 18.6$ KSI

$f_a = 3569.5/10.6 = 337$ PSI $< 18{,}600$ PSI OK

TENSION:

ALLOWABLE LOAD: CHAPTER D P. 5-40

A) $0.60F_y = 0.60(46)$
$= 27.6$ KSI

$27.6(10.6\ IN^2) = 293^K$

B) $0.50F_u = 0.50(58)$
$= 29.0$ KSI

NET AREA $= 10.6 - 4(0.8125 \times .3125)$
$= 9.58\ IN^2$

$29.0(9.58\ IN^2) = \underline{278^K}$ ← USE

ACTUAL LOAD $= 3.6^K < 278^K$ OK

BOLTED CONNECTIONS:

FROM TABLE J3.2 P. 5-73:

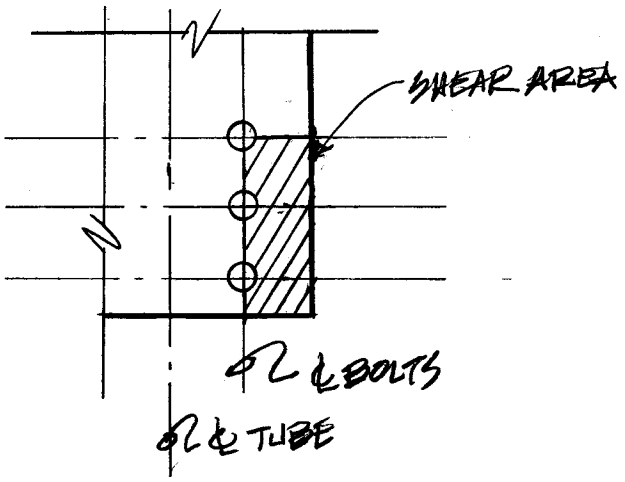
FOR A325 BOLTS, $F_v = 21.0$ KSI

ALLOW. LOAD/BOLT $= 21.0(0.4418) = 9.3^K$/BOLT

ACTUAL LOAD $= 3.6^K/6 = 0.6^K < 9.3^K$ OK

CHECK SHEAR RUPTURE ON TUBE:

EFFECTIVE AREA:



$$\text{AREA} = 0.3125\left((3" - 0.8125)2 + 1.5" - 0.8125/2\right)$$
$$= 0.3125(4.375 + 1.094)$$
$$= 1.709\,in^2$$

$F_V = 0.30F_u$ (J4-1 p.5-77)

$= 0.30(58)$

$= 17.4$ KSI

ALLOW. LOAD $= 1.709(17.4)$

$= 29.74^K = 29{,}740^\#$

(EA. SIDE OF TUBE)

$29{,}740 \times 2 = 59480^\#$

FOR DOUBLE SHEAR:

TOTAL ALLOW. SHEAR $= 2(59{,}480^\#)$

$= 118{,}960^\# > 3.6^K$

OK

USE HSS $12 \times 6 \times 5/16$ W/ 6-A325 BOLTS EA. END

WELDS FROM TUBES TO PLATES:

WELD SIZE = 1/4" FILLET E70XX ELECTRODES

ALLOWABLE LOAD PER INCH $= 0.3(70)(1/4)(.707)$

$= 3.7^K$/IN OF WELD

LOAD @ TOP OF VERT. TUBE:

VERT. LOAD = 24,000# (CARRIED BY COLUMN)
DRIVE LOAD = 2,000#
VERT. LOAD FROM FRAME TUBE BRACE = 2642#
1/2 TO EA. SIDE PLATE = 1321#

TOTAL PLATE LOAD = 2,000 + 1321# = 3321#
HORIZ. LOAD = 2,400#/2 = 1200#

1" OF 1/4" WELD PROVIDES = 1(3.7K)
= 3,700# ALLOWL.

12" WELD PER SIDE = 12(3.7)(2)
= 88,000# ALLOWL

$3321/88000 + 1200/88000 \overset{?}{\leq} 1$
$0.038 + 0.014 = 0.052 < 1.0$
OK

USE MIN. 12" 1/4" WELD EA. SIDE OF PLATE

LOAD @ BOT. OF VERT. TUBE:

VERT LOAD = 24000# + 2642# + 3303# + 2000#
= 31,945#
HORIZ LOAD = 0 K
FOR 1/4" WELD, LENGTH = 32/3.7
= 8.7"
10" PER SIDE OF 2 PLATES = 2 x 2 x 10
= 40" WELD
> 8.7K ok

WELD @ BOTTOM OF DIAG TUBE:

VERT. LOAD = 3303# (1652# EA. SIDE)
HORIZ LOAD = 2400# (1200# EA. SIDE)
10" WELD EA. SIDE OF PLATE = 2(10)(3.7)
$1652/74{,}000 + 1200/74000 \overset{?}{\leq} 1$ = 74K
$0.022 + 0.016 = 0.038 < 1.0$
OK

USE 10" 1/4" WELD EA. SIDE OF EA. PLATE

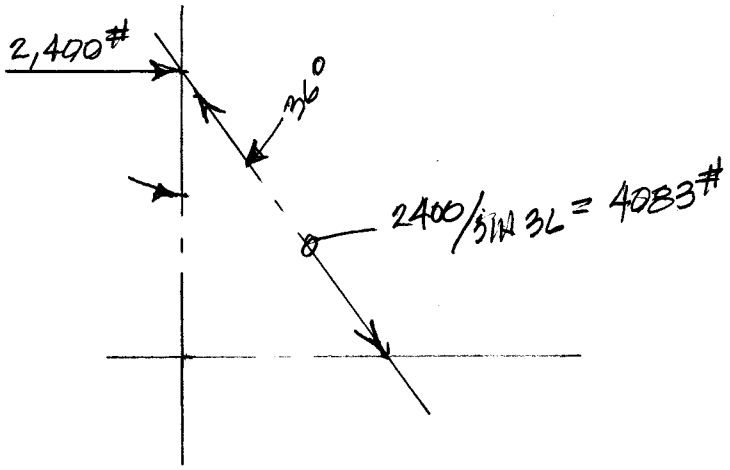
EXTERIOR DIAG. BRACE:

SIZE: HSS 8x6x5/16 LENGTH = 136.8" = 11.4'

$b/t = 8/0.3125$
$= 25.6$
$190/\sqrt{F_y} = 190/\sqrt{46}$
$= 28.0 > 25.6$
∴ TUBE IS COMPACT

COMPRESSION:
FROM P 3-48 AISC:
ALLOW. LOAD FOR 12'-0 LENGTH = 172^k

ACTUAL LOAD:

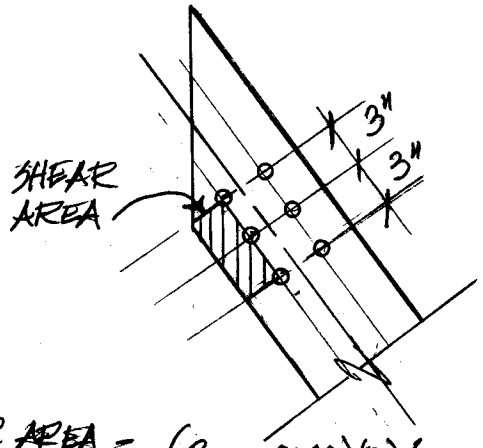


4083# < 172,000# ok

TENSION:
$F_t = 0.60 F_y$ DI p. 5-40
$= 0.60(46)$
$= 27.6$ KSI
$A_{TUBE} = 8.11 IN^2$

$P_{ALLOW} = 8.11(27.6)$
$= 224^k > 4.1^k$ ok

CHECK SHEAR RUPTURE ON TUBE :



SHEAR AREA = $(3 - .8125)(2)(0.3125)$
$= 1.37$ INC

$F_V = 0.30 F_u$ (J4-1 p 5-77)
$= 0.30(58)$
$= 17.4$ KSI

ALLOWABLE LOAD = $17.4(1.37)$
$= 23.8^K$
(EA. SIDE OF TUBE)

$23,800 \times 2 = 47600\#$

FOR DOUBLE SHEAR :

TOTAL ALLOW. LOAD = $2(47,600)$
$= 95,200\# > 74,083\#$
OK

USE HSS $8 \times 6 \times 5/16$ W/ 6 A325 BOLTS

WELD OF CONN. PLATE TO VERT. TUBE
LENGTH OF WELD = 8.5"
ALLOWABLE LOAD PER INCH = $0.3(70)(1/4)(.707)$
$= 3.7^K/IN$

$8.5(3.7) = 31.5^K$ EA. PLATE
FOR 2 PLATES, ALLOW. LOAD = $31.5(2)$
$= 63^K$

VERT. LOAD = $2400/\tan 36$
$= 3303\#$
HORIZ LOAD = $2400\#$

$3303/63000 + 2400/63000 =$
$0.052 + 0.038 = 0.090 < 1.0$ OK

USE 8.5" OF 1/4" WELD EA. PLATE

CHECK EXPANSION ANCHORS AT BASE OF TUBE:

VERT LOAD = 3303#

HORIZ. LOAD = 2400#

FOR 3/4" ϕ HILTI DROP-IN ANCHORS:
MIN. ANCHOR SPACING TO USE FULL ALLOWABLE LOAD = 12"

ACTUAL SPACING = 9"

FROM P. 136 "HILTI TECHNICAL GUIDE" USE LOAD FACTOR OF 0.77

ALLOW. TENSION = 4065 (0.77)
= 3130 #/BOLT

ALLOW. SHEAR = 5000 # (0.77)
= 3850 #/BOLT

TOTAL ALLOW. LOAD TENSION = 4(3130)
= 12,520#

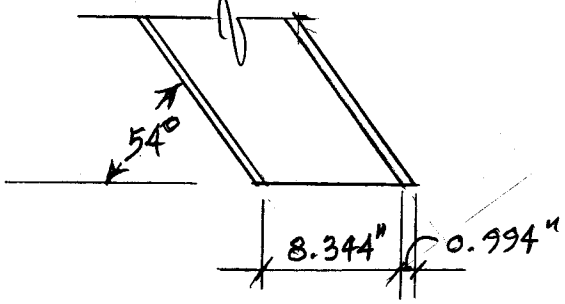
TOTAL ALLOW LOAD SHEAR = 4(3850)
= 15,400 #

$3303/12{,}520 + 2400/15400 \overset{?}{\leq} 1.0$

$0.264 + 0.156 = 0.420 < 1.0$ ok

WELD FROM DIAG. TUBE TO BASE PLATE:

BOTTOM OF TUBE:



TOTAL WELD LENGTH =
2(8.344) + 2(4.75) =
26.2"

ALLOW WELD LOAD FOR 1/4" WELD = 3.7 k

3.7(26.2) = 96.9 k

$3303\#/96{,}900 + 2400/96{,}900 \leq 1.0$

$0.034 + 0.025 = 0.059 < 1.0$ ok

USE 1/4" WELD ALL AROUND,

BEARING OF STAND ON CONCRETE FLOOR SLAB:

FROM ACI 318-02 10.17 p 318/318R-137:

BEARING STRENGTH = $\phi(0.85 f'_c A_1)$

$\phi = 0.65$ 9.3.2.4 p 318/318R 100

$f'_c = 4000$ psi

VERTICAL LOAD = 31945# (p 3 THIS CALC)

ULTIMATE ~~LOAD~~ = 1.7(31945)

= 54307#

$A_1 = 54307/0.65(0.85(4000))$

= 24.6 in2

WIDTH OF TUBE IN BEARING =

6" − 2(0.625) = 4.75"

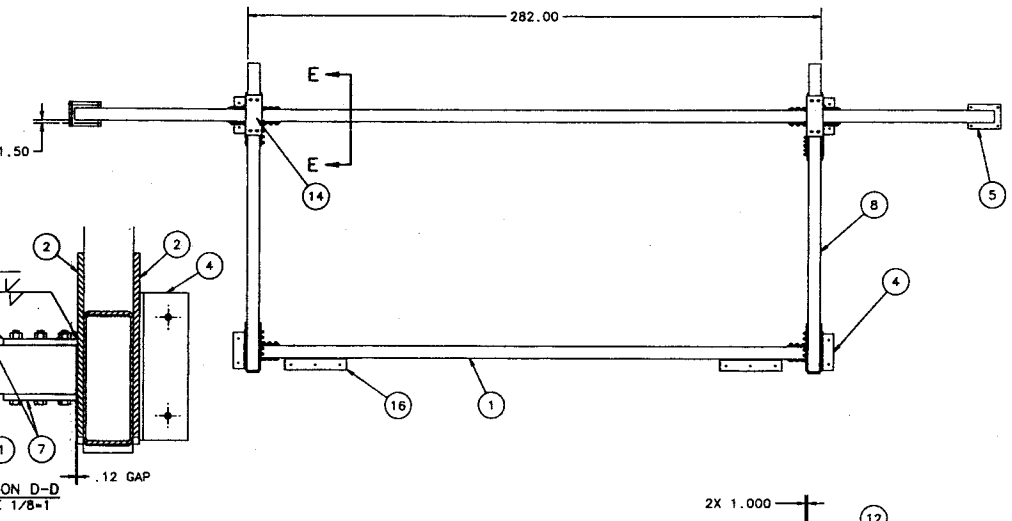
LENGTH OF BEARING = 24.6/4.75

= 5.2"

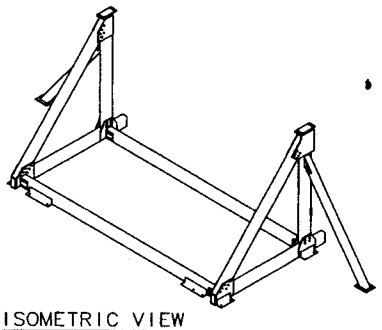
USE 24" BEARING LENGTH > 5.2"

OK

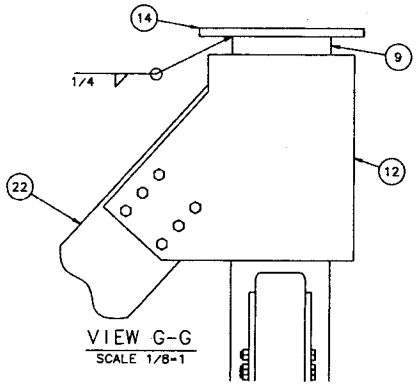
REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE



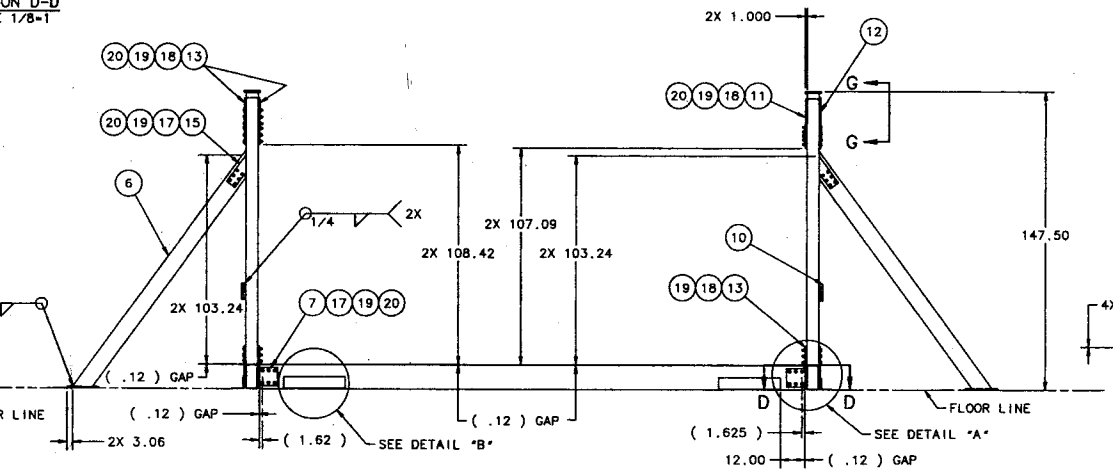
ON D-D
1/8-1

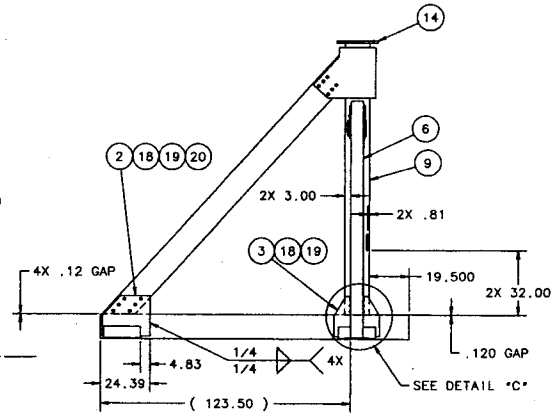


ISOMETRIC VIEW
SCALE 1/64-1



VIEW G-G
SCALE 1/8-1

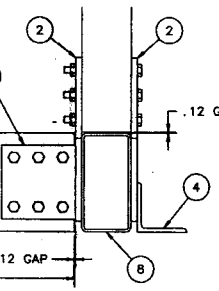




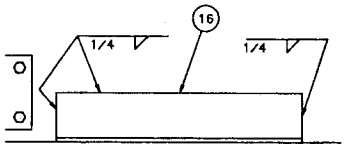
23	COML	FLOOR ANCHOR	26
22	MC-480031	WEST SIDE DIAGONAL	1
21	MC-480032	EAST SIDE DIAGONAL	1
20	COML	WASHER, HARDENED, 3/4, ASTM F436	72
19	COML	NUT HEX 3/4-10 ASTM A563 ERC	72
18	COML	A325 SCREW HEX HD 3/4-10 X 9L	36
17	COML	A325 SCREW HEX HD 3/4-10 X 8 1/2L	36
16	MC-480014	BOTTOM CLIP	2
15	MC-480029	DIAGONAL CPL USED	4
14	MC-480027	TOP PLATE	2
13	MC-480023	DIAGONAL TCON SMALL	2
12	MC-480025	DIAGONAL COPLW	1
11	MC-480026	DIAGONAL COPLWE	1
10	MC-480028	GROUNDING LUG	2
9	MC-480017	VERTICAL	2
8	MC-480019	BOTTOM 240	2
7	MC-480030	BTUBE	8
6	MC-480024	DIAGONAL BRACE	2
5	MC-480015	BASE PLATE	2
4	MC-480016	BOTTOM CLIP SMALL	4
3	MC-480021	VERTICAL SUP PL	4
2	MC-480020	DIAGONAL SUPPLL	4
1	MC-480018	BOTTOM 268	2
ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.

PARTS LIST

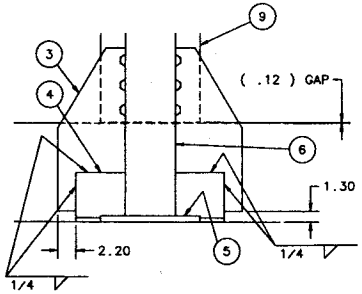
UNLESS OTHERWISE SPECIFIED			ORIGINATOR	R.J.WOODS	10-AUG-2009
.XX	.XXX	ANGLES	DRAWN	S.KINDELBERGER	01-SEP-2009
± .06	± .030	± 1°	CHECKED		
1. BREAK ALL SHARP EDGES .015 MAX. 2. DO NOT SCALE DRAWING. 3. DIMENSIONS BASED UPON ASME Y14.5M-1994. 4. MAX. ALL MACH. SURFACES 250 5. DRAWING UNITS: U.S. INCH			APPROVED		
			USED ON		
			MATERIAL	SEE PARTS LIST ABOVE	



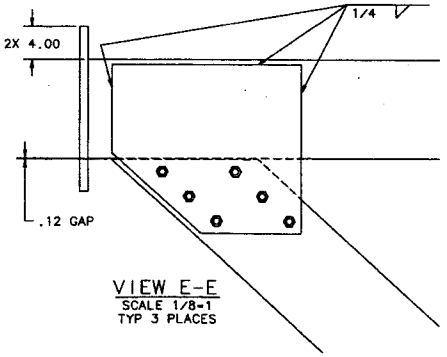
DETAIL "A"
SCALE 1/8-1
TYP 8 PLACES



DETAIL "B"
SCALE 1/8-1
TYP 6 ANGLE PIECES



DETAIL "C"
SCALE 1/8-1
TYP 4 PLACES

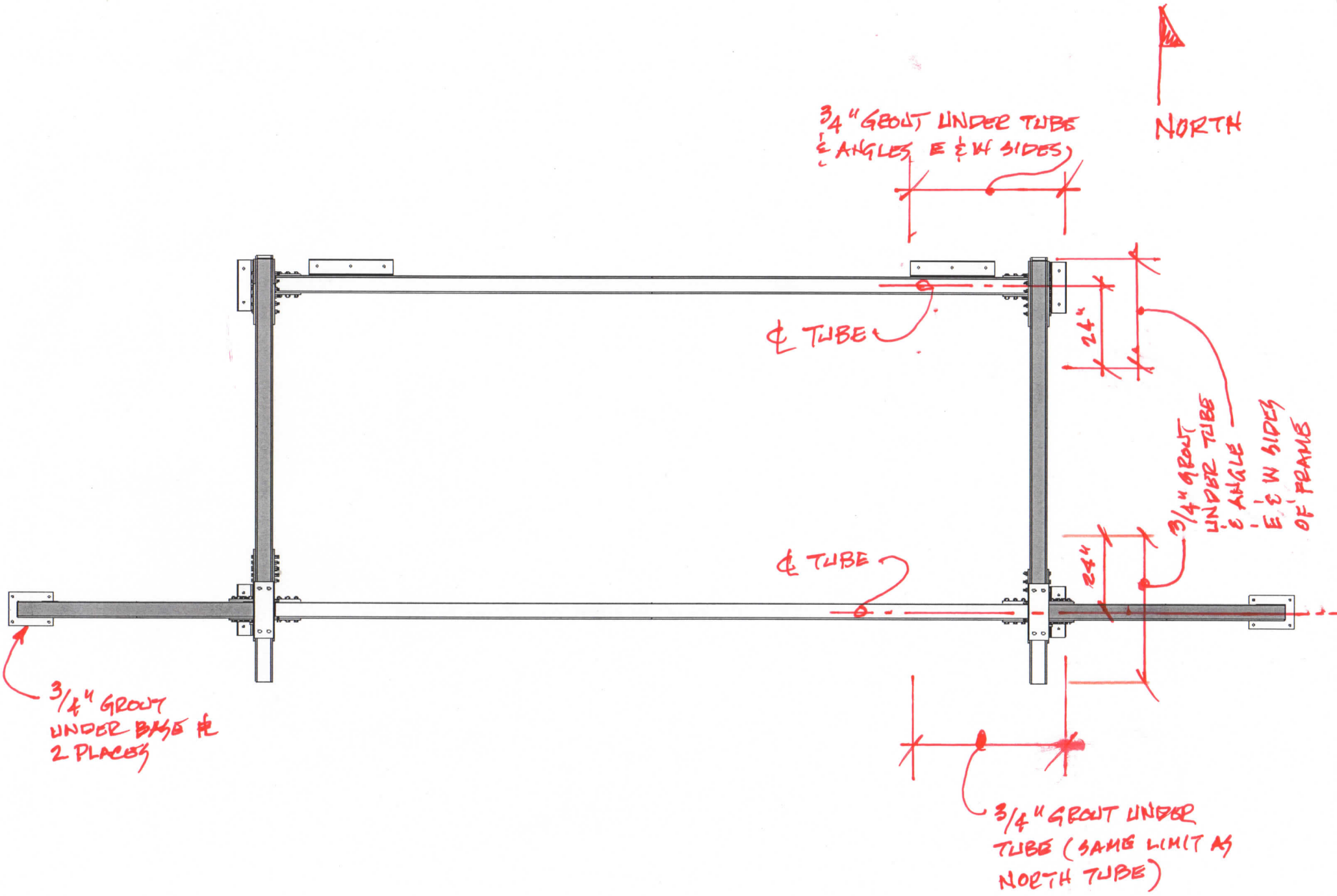


VIEW E-E
SCALE 1/8-1
TYP 3 PLACES

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

DECAM/CONCEPTS NEW STAND WELDING AND ASSEMBLY

SCALE	DRAWING NUMBER	SHEET	REV
1/32 & NOTED	4900.000-MD-480034	1 OF 1	
CREATED WITH : Ideas12NXSeries	GROUP: PPD/MECHANICAL DEPARTMENT		


NORTH
3/4" GROUT UNDER TUBE & ANGLES E & W SIDES
℄ TUBE
24"
3/4" GROUT UNDER TUBE & ANGLE E & W SIDES OF FRAME
℄ TUBE
24"
3/4" GROUT UNDER BASE ℄ 2 PLACES
3/4" GROUT UNDER TUBE (SAME LIMIT AS NORTH TUBE)