Fermilab

Particle Physics Division
Mechanical Department Engineering Note

Number: MD-ENG-03-003 Date: 6 March 2003

Project Internal Reference: none

Project: NuMI

Title: Magnet Transport Cart for the NuMI Magnets in the Pre-Target Area

Author(s): Dave Pushka

Reviewer(s): 4-15-03

Key Words: Magnet Installation

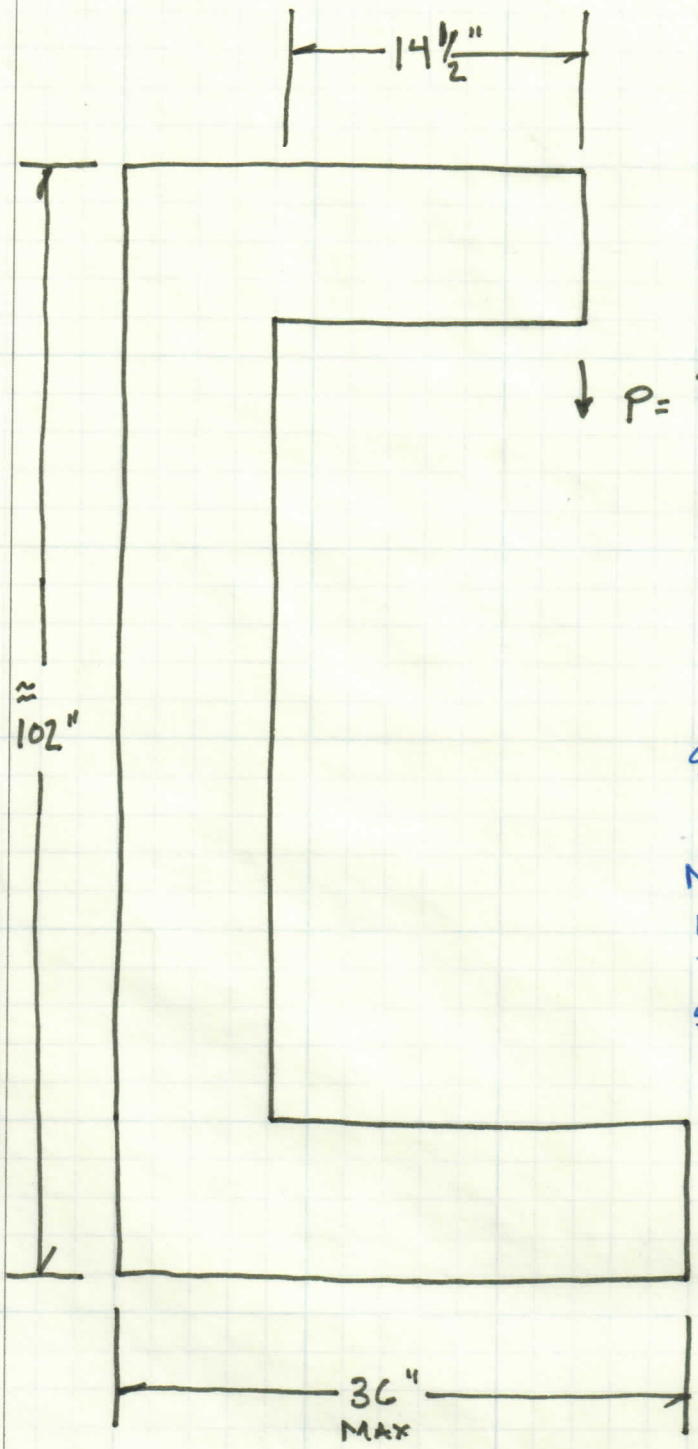
Abstract Summary: Stress and deflection calculations for the structural steel cart components designed to be used for hauling both the B2 dipole magnets and the 3Q120 quad magnets up the 15% slope and then to lift the magnets onto their stands. This cart is designed to fit only within the relatively larger confines of the pre-target portion of the enclosure.

Applicable Codes: AISC 9th edition used to define allowable stresses.

ASSEMBLY DRAWING 8875.118-ME-427027

10-25-01 DAVE PUSHKA

MAGNET INSTALLATION CART. - 'C' STRUCTURE



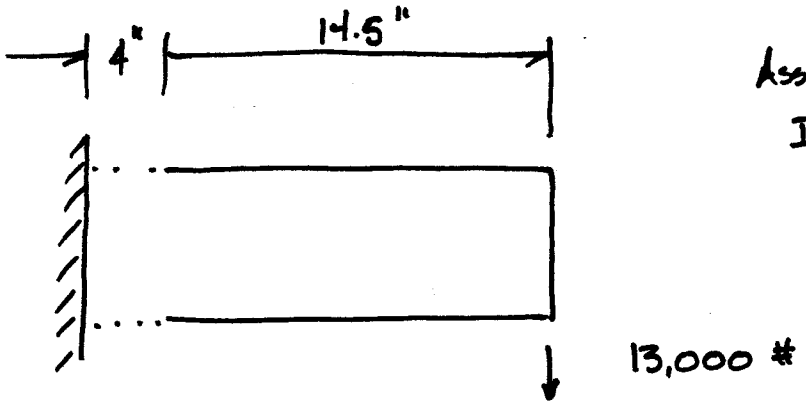
$P = \frac{26{,}000\#}{2}$ (INCLUDES 24,500# FOR 6-3-120 AND 1500# FOR FIXTURE)

SEE ME-427027

NOTE: AS OF 2-14-03, THIS FIXTURE DOES NOT NEED TO MOVE 6-3-120 MAGNETS, SO, THE FIXTURE'S TOP PIECE WAS SHORTENED FROM 14 1/2" TO 11 1/2". BUT THE CALCS WERE NOT REPEATED FOR THE SHORTER LEVER ARM & MOMENT SINCE THE NEW GEOMETRY IS LESS SEVERELY LOADED - DRP

ASSUME 8" ⌀ MECH. STRUCT A500 TUBING

TOP MEMBER OF 'C' STRUCTURE.



ASSUME 8"×8"×1/2

$I_{xx} = I_{yy} = 131.\ in^4$

$$M = Pl = 13{,}000\,\# \cdot (14.5 + 4)'' = 240{,}500 \text{ in-lbs.}$$

$$\sigma = \frac{My}{I} = \frac{(240{,}500 \text{ in-lbs})(4 \text{ in})}{131 \text{ in}^4} = 7{,}343 \text{ psi}$$

$$\delta = \frac{Pl^3}{3EI} = \frac{(13{,}000\,\#)(18.5 \text{ in}^3)^3}{3 \cdot 29 \times 10^6 \text{ psi} \cdot 131 \text{ in}^4} = 0.007 \text{ in}$$

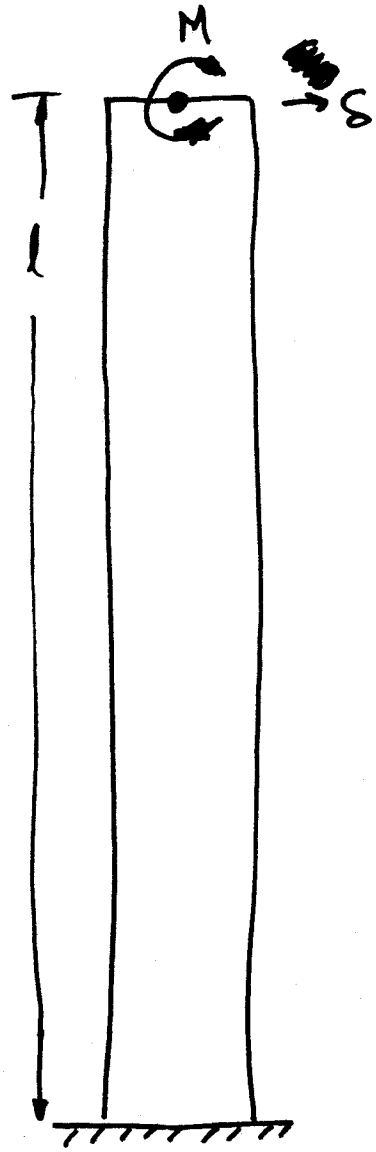
$\sigma = 7343$ psi $< F_{bx}$ $\therefore$ OK

$F_{bx} = 0.66 F_y$ for this compact section

$= .66 \cdot 46$ ksi $= 30$ ksi

$\therefore$ 8" × 8" × $\frac{1}{2}$" A500 BOX SECTION OK

VERTICAL MEMBER OF 'C' STRUCTURE



$M = 240{,}500$ in-lbs.

$l \doteq 102''$

$\sigma_B = 7343$ psi (SAME AS IN TOP MEMBER)

$$\delta = \frac{1}{2}\frac{Ml^2}{EI}$$

ASSUME SAME $8''\phi \times 1/2''$ WALL MECH. STRCT. TUBING.

$I = 131 \text{ in}^4$

$$\delta = \frac{1}{2} \cdot \frac{(240{,}500 \text{ in-lbs})(102 \text{ in})^2}{29 \times 10^6 \text{ lbs/in}^2 \cdot 131 \text{ in}^4}$$

$\delta = 0.329$ IN

THIS DEFLECTION SEEMS OKAY

$\sigma_B = 7343$ psi $< 0.66F_y = 30$ ksi

IF $8''\phi \times \frac{5}{8}$ MAT'L WERE USED, $\delta = 0.329 \times \frac{131}{153}$

$= 0.28$ in

VERTICAL MEMBER OF 'C' SECTION - CONTINUED

AXIAL LOAD IS 13,000 #

$$\text{AXIAL STRESS} = \frac{13{,}000\ \#}{14.4\ in^2} = 902\ psi = \sigma_A$$

FOR THE 8" □ x ½" WALL MATERIAL

AXIAL STRESS ADDS TO THE COMPRESSION SIDE OF THE STRESS ~~FOR~~ FROM THE MOMENT (AND SUBTRACTS FROM THE TENSILE SIDE).

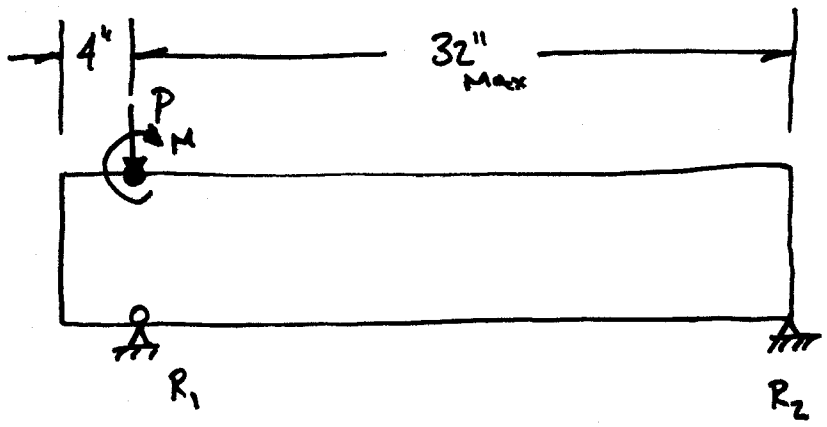
$$\sigma_{\substack{COMBINED \\ MAX}} = \sigma_B + \sigma_A = 7343 + 902\ psi = 8245\ psi$$

$$\sigma_{ALLOW} = 0.6F_y = 30\ ksi$$

$$\sigma_{\substack{COMBINED \\ MAX}} = 8245\ psi < \sigma_{ALLOW} \quad \therefore OK$$

$\therefore$ 8" x 8" x ½" BOX SECTION IS OK

BOTTOM MEMBER OF 'C' STRUCTURE.



P = 13,000 #

M = 240,500 in-lbs

$$\Sigma M_o = 0 = +M - 32 R_2 \Rightarrow \frac{240{,}500 \text{ in-lbs}}{32 \text{ in}} = R_2$$

$$R_2 = 7515 \#$$

$$\Sigma F_v = 0 = -13{,}000 + R_1 + R_2$$

$$R_1 = 13{,}000 - R_2 = 13{,}000 - 7515 = 5484 \#$$

NOTE: THERE IS NO UPLIFT AT EITHER END OF SUPPORT.

BENDING MOMENT & σ_b ARE SAME AS IN the top & vert. members AND ARE LESS than THE ALLOWABLE

$\therefore$ OK

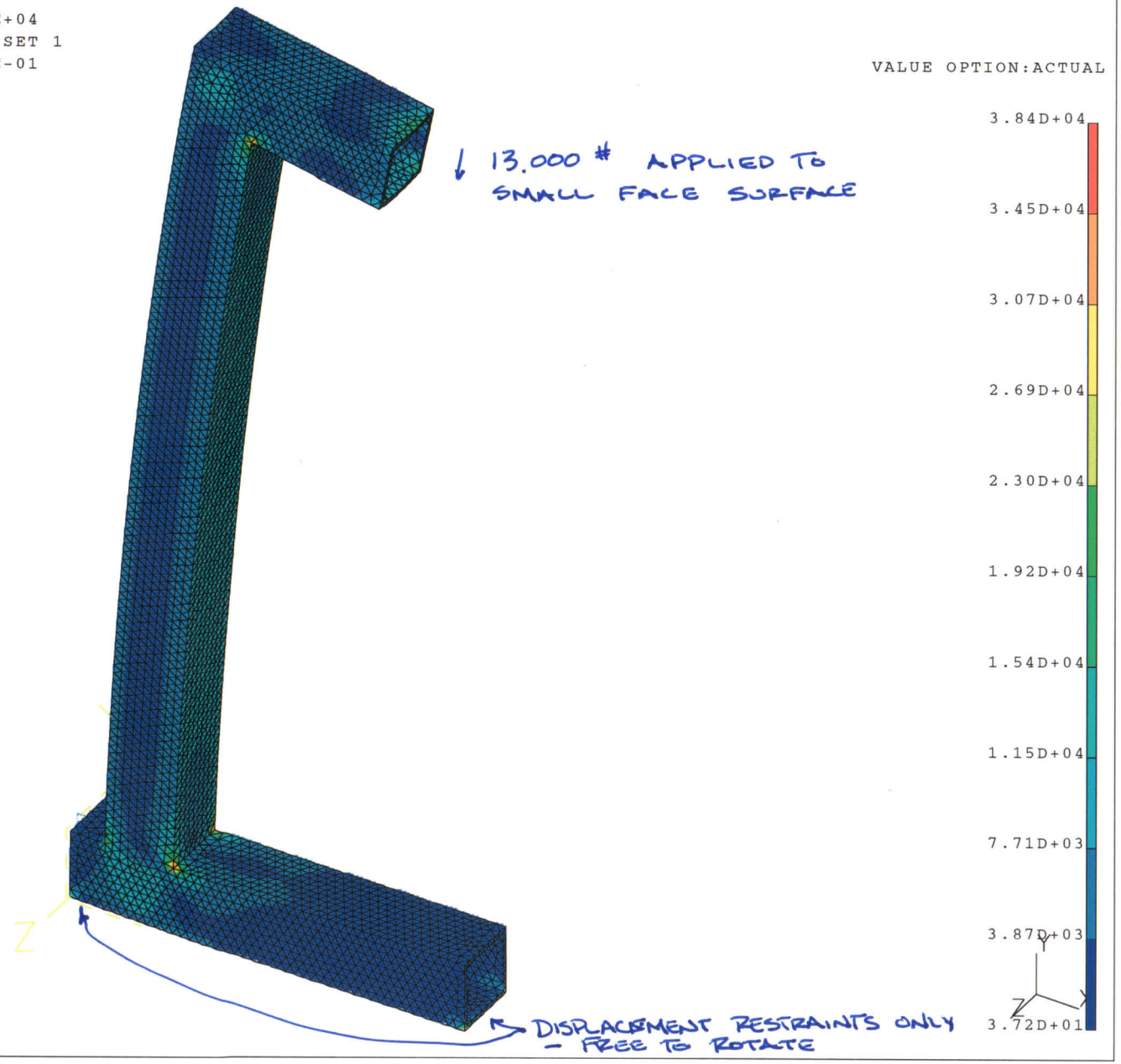
8" □ × $\frac{1}{2}$" WALL A500 BOX SECTION OK

SOLID ELEMENTS, SIZE = 1

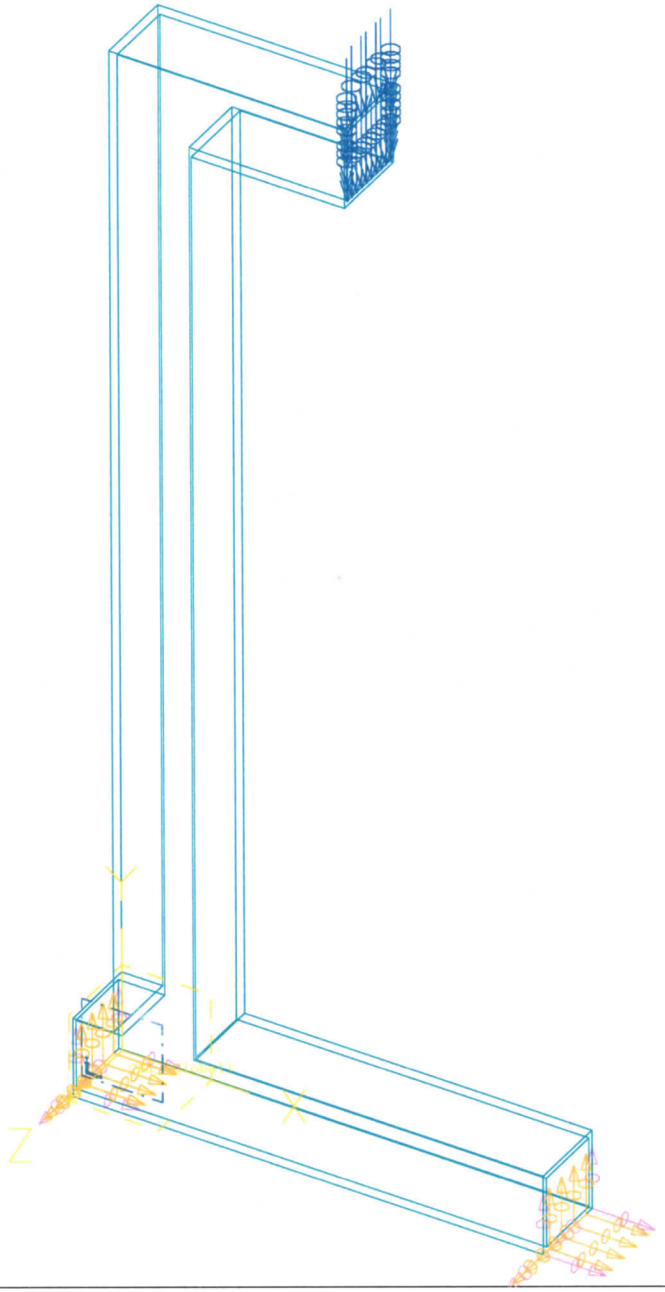
/cadwhs/server01/ms_pushka/MagnetInstalCart.mf1

RESULTS: 3- B.C. 1,STRESS_3,LOAD SET 1
STRESS - VON MISES MIN: 3.72E+01 MAX: 3.84E+04
DEFORMATION: 1- B.C. 1,DISPLACEMENT_1,LOAD SET 1
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 4.69E-01
FRAME OF REF: PART

VALUE OPTION:ACTUAL



Plotted by pushka on 14-Dec-01 , File: CartSideFrame10.pff



Plotted by pushka on 14-Dec-01 , File: CartSideFrame10.pff

SOLID
SIZE- .625

/cadwhs/server01 ... hka/MagnetInstalCart.mf1

RESULTS: 3- B.C. 1,STRESS_3,LOAD SET 1
STRESS - VON MISES MIN: 6.91E+01 MAX: 3.96E+04
DEFORMATION: 1- B.C. 1,DISPLACEMENT_1,LOAD SET 1
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 3.28E-01
FRAME OF REF: PART

MATCHS HAND CALC.!

VALUE OPTION:ACTUAL

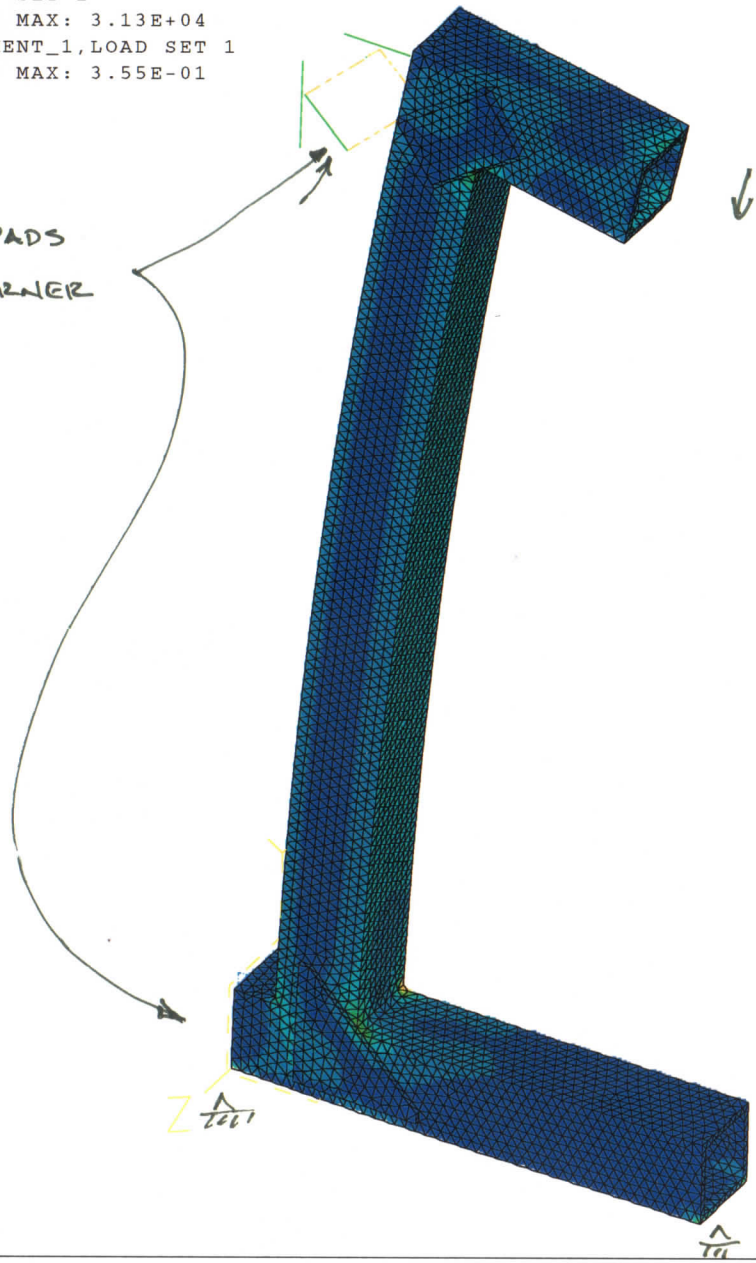
3.96D+04
3.57D+04
3.17D+04
2.78D+04
2.38D+04
1.99D+04
1.59D+04
1.19D+04
7.98D+03
4.03D+03
6.91D+01

Plotted by pushka on 14-Dec-01 , File: CartSideFrame9.pff

SOLID ELEMENTS SIZE = 1.0

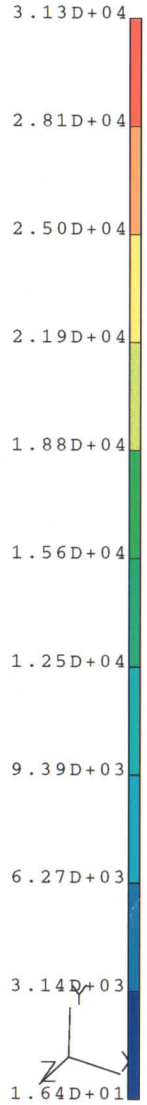
/cadwhs/server01/ms_pushka/MagnetInstalCart.mf1

RESULTS: 3- B.C. 1,STRESS_3,LOAD SET 1
STRESS - VON MISES MIN: 1.64E+01 MAX: 3.13E+04
DEFORMATION: 1- B.C. 1,DISPLACEMENT_1,LOAD SET 1
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 3.55E-01
FRAME OF REF: PART



VALUE OPTION:ACTUAL

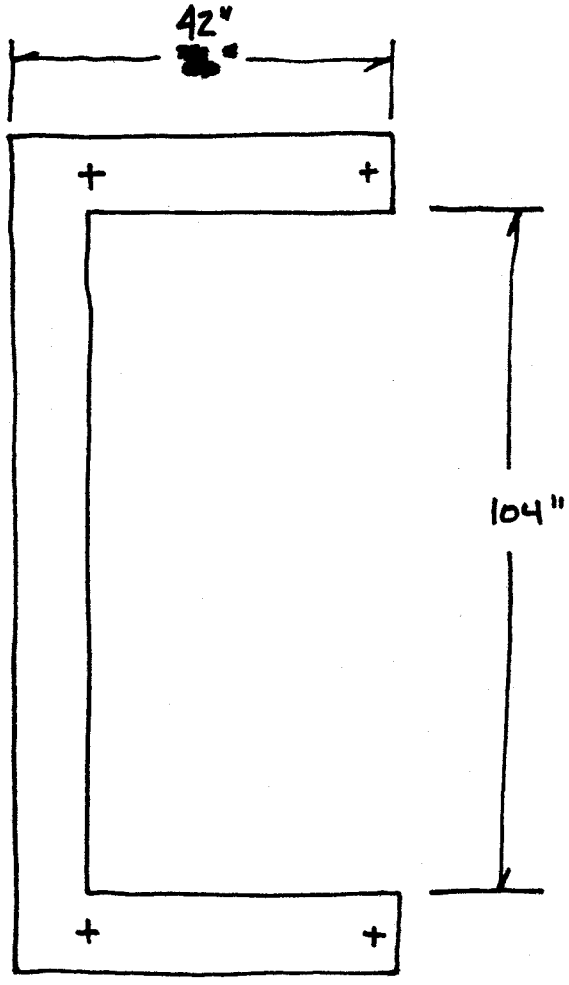
31,400 psi



Plotted by pushka on 20-Dec-01 , File: CartSideFrame11.pff

10-26-01 | DAVE PUSHKA

MAGNET INSTALLATION CART – BASE UNDER 'C' STRUCTURE



PLAN VIEW

$R_1 = 7500\#$

$R_2 = 5500\#$

$\Sigma M_0 = 0 \cdot 4(7500) + 36(5500) - 32\tfrac{1}{2} \cdot R_4$

$R_4 = \dfrac{(4 \cdot 7500) + (36 \cdot 5500)}{32\tfrac{1}{2}}$

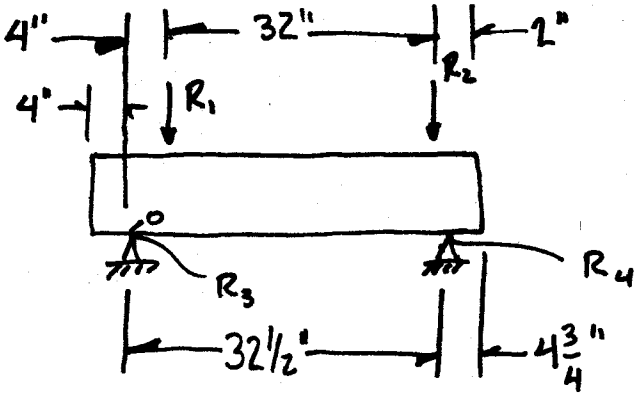
$R_4 = 7015\#$

$\Sigma F_V = 0 = -R_1 - R_2 + R_3 + R_4$

$R_3 = R_1 + R_2 - R_4$

$= 7500 + 5500 - 7015$

$R_3 = 5984$



ELEV. VIEW

∴ HILLMAN ROLLERS need to be sized for about 4 to 5 ton capacity.

∴ Use 5 ton hilman rollers

10.25.01 | DAJE PUSHKA

MAC. INST CART - FACE R

CHEK WELD AREA -

$P = 20{,}000\ \#\ = .707\ w \cdot 0.3 \cdot 70{,}000\ psi \cdot L$

$$L_{MIN} = \frac{20{,}000}{.707 \times 1/4'' \times 0.3 \times 70{,}000}$$

$= 5.38$ IN IF 1/4" FILLET WELD

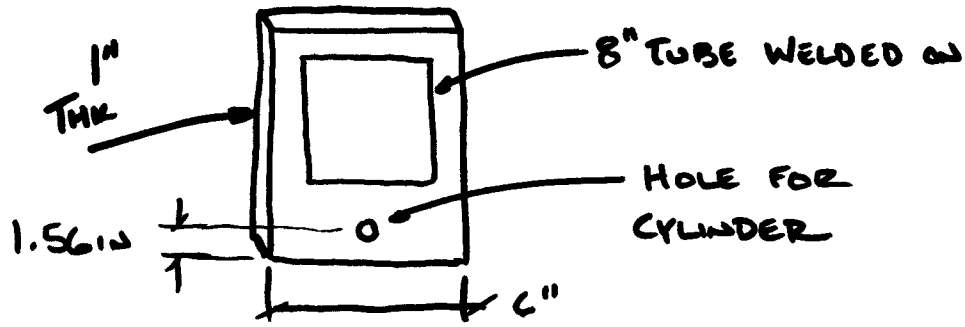
ACTUAL LENGTH $= 4 \times 8'' = 32$ IN $\therefore$ OK

SEE ME-406907

THIS IS THE WELD BETWEEN THE 8" Ø TUBE DETAILED ON MC-427459 AND THE 1" PLATE DETAILED ON MB-406909. WELD IS SHOWN ON ME-406907 AND IS CALLED OUT AS A $\frac{5}{16}$" FILLET

10-25-01 | DAVE PUSHKA

MAGNET INSTALLATION CART - FACE PLATE
SEE MB-406909



CHECK CYLINDER HOLE:

DIA = 1.25"

P = 10 TONS → 20,000 #

$\tau_{ALLOW} = \frac{F_y}{3} = \frac{36000 \text{ psi}}{3} = 12{,}000 \text{ psi}$

CHECK TENSION - $A = (1")(6" - 1.25") = 4.75 \text{ in}^2$

$\sigma = 4210 \text{ psi} < 12{,}000 \text{ psi} \therefore$ OK

CHECK SHEAR - $A = (2 \text{ SIDES})(1")(1.56 \text{ in})$
$= 3.125 \text{ in}^2$

$\tau = \frac{P}{A} = \frac{20000}{3.125} = 6410 \text{ psi}$

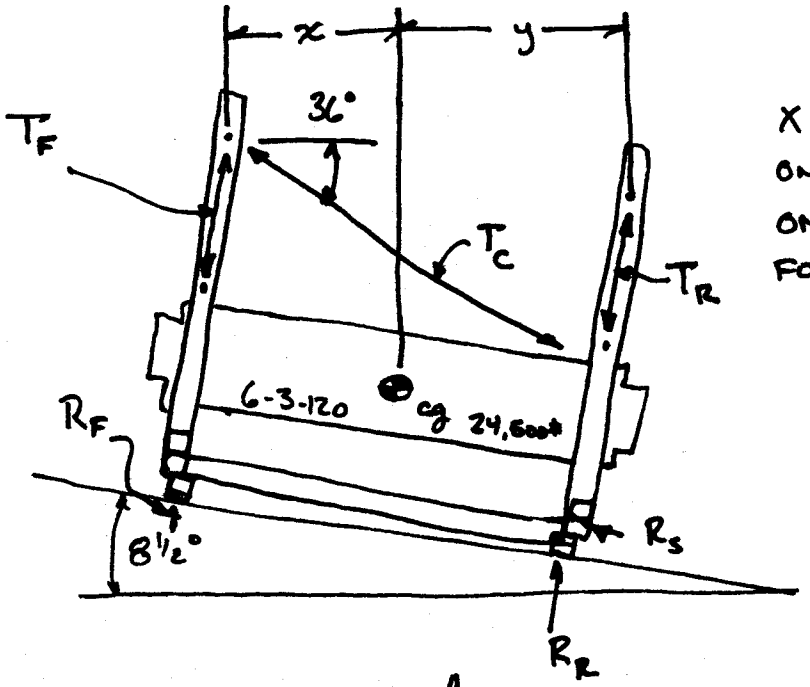
$\tau = 6410 < 12{,}000 \text{ psi} \therefore$ OK

SEE DWG MB-406909

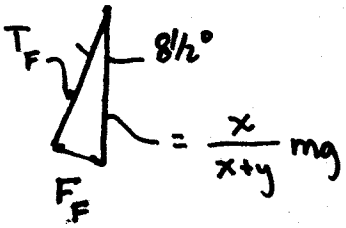
MAGNET INSTALLATION CART –

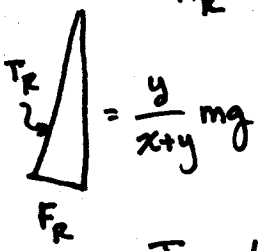
LOADS WHILE ON 8½° INCLINE

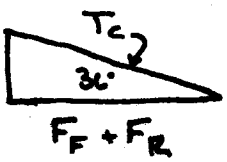
T_C IS THE TENSION MEMBER WHICH KEEPS THE MAGNET FROM SLIDING DOWN HILL OR PIVOTING ABOUT THE PINS ON THE CYLINDERS.



X BRACING ON CART OMITTED FOR CLARITY.







$$T_F = \left(\frac{x}{x+y}\right)(mg)\cos 8\tfrac{1}{2}°$$

$$T_R = \left(\frac{y}{x+y}\right)(mg)\cos 8\tfrac{1}{2}°$$

$$F_F = mg\left(\frac{x}{x+y}\right)\sin 8\tfrac{1}{2}$$

$$F_R = mg\left(\frac{y}{x+y}\right)\sin 8\tfrac{1}{2}$$

$$F_F + F_R = mg \sin 8\tfrac{1}{2}$$

$$T_C = \frac{F_F + F_R}{\cos 36}$$

$$T_C = \frac{mg \sin 8\tfrac{1}{2}}{\cos 36}$$

MAGNET INSTALLATION CART - LOADS ON INCLINE CON'T.

mg = wt of magnet + wt of fixture + wt of cart

$= 24{,}500\,\# + \underset{\text{ESTIMATE}}{2{,}000\,\#} + \underset{\text{ESTIMATE}}{3{,}000}$

$= 29{,}500\,\#$

USE $30{,}000\,\#$

$x = 46''$

$y = 65''$

$$T_F = \left(\frac{46}{46+65}\right)(30{,}000\,\#)\cos 8\tfrac{1}{2} = 12{,}295\,\#$$

$\simeq 6$ tons.

$$T_R = \left(\frac{65}{46+65}\right)(30{,}000\,\#)\cos 8\tfrac{1}{2} = 17{,}374\,\#$$

$\simeq 8\tfrac{1}{2}$ tons

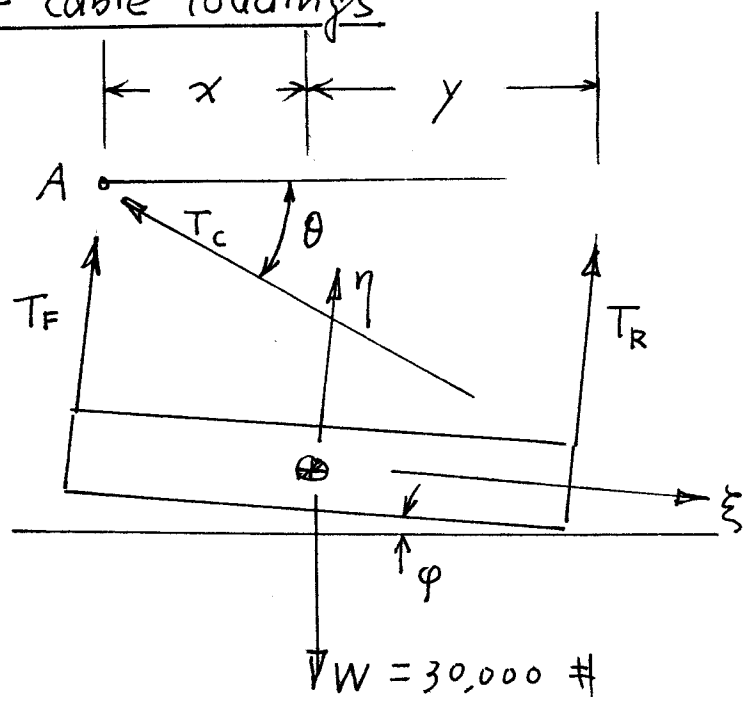
$\therefore$ 10 ton hydraulic cylinders are sufficient.

$$T_C = \frac{(30{,}000\,\#)\sin 8\tfrac{1}{2}}{\cos 36} = 5481$$

$\therefore$ USE A MAXIMUM design load of 6000# FOR THE tension X member. ME-427027 USES A CHAIN AND A 3 TON COME-A-LONG

Calculation of cable loadings

$x = 46''$
$y = 65''$
$\theta = 36°$
$\varphi = 8.5°$



Take moment about point A, we have

$$W x = T_R \cos 8.5° (x+y)$$

$$T_R = \frac{x}{x+y} \frac{W}{\cos 8.5°} = 12,570 \ \#$$

Take force along ξ direction, we have

$$W \sin 8.5° = T_c \cos(36-8.5°)$$

$$T_c = \frac{\sin 8.5°}{\cos 27.5°} W = 4,999 \ \#$$

Take force along η direction. we have

$$W \cos 8.5° = T_R + T_F + T_c \sin 27.5°$$

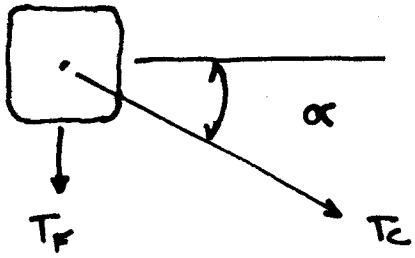
$$T_F = W \cos 8.5° - T_R - T_c \sin 27.5° = 14,792 \ \#$$

No change in selections of hydrolic cylinders and restraining chain.

MAGNET INSTALLATION CART -

LOAD ON UPPER (UPSTREAM) TOP MEMBER

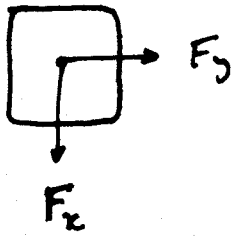
DUE TO TENSION IN CABLE



$\alpha = 36 - 8\frac{1}{2} = 27\frac{1}{2}°$

$T_C = 5481$ #

$T_F = 12,295$ #



$F_x = 12,295 + T_C \sin 27\frac{1}{2}$

$= 12,295 + 5481 \sin 27\frac{1}{2}$

$= 14,825.8$

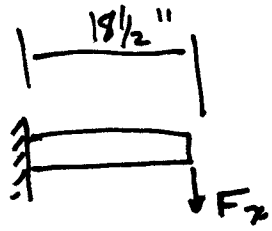
$F_y = T_C \cos 27\frac{1}{2}$

$= 5481 \cos 27\frac{1}{2}$

$= 4861$

MAC INST. CART - LOADS DUE TO CABLE TENSION:

- RE-CALC BENDING MOMENT -



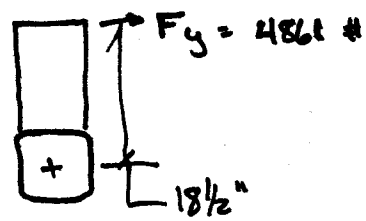
$M = 18\tfrac{1}{2}'' \times 14{,}825^{\#} = 274{,}278$ IN-LBS

$$\sigma = \frac{My}{I} = \frac{274{,}278 \times 4\text{ in}}{131.4\text{ in}^4} = 8349 \text{ psi}$$

$$\delta = \frac{14{,}825 \times (18.5\text{ in})^3}{3.29 \times 10^6 \text{ psi} \times 131.4\text{ in}^4} = 0.008 \text{ in}$$

$\sigma < \sigma_{ALLOW} = 0.66 F_y = 30$ ksi $\therefore$ OK

- CHECK TORSION -



$M = (4861^{\#})(18\tfrac{1}{2}'') = 89{,}928$ IN-LBS

$$\tau = \frac{Mr}{J} \qquad J = 217 \text{ in}^4$$
$$r = 3.03 \text{ in}$$

$$\tau = \frac{(89{,}928 \text{ in-lbs})(3.03\text{ in})}{217 \text{ in}^4} = 1255 \text{ psi}$$

$$\theta = \frac{(89{,}928 \text{ in-lbs})(102 \text{ in})}{217 \text{ in}^4 \times 11 \times 10^6 \text{ psi}} = 0.0037 \text{ rad}$$
$$= 0.2 \text{ DEG.}$$

$\therefore$ ROTATION OF COLUMN IS NOT A PROBLEM.

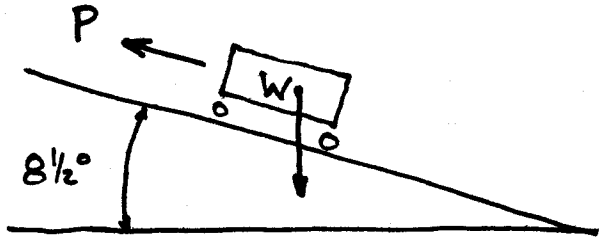
$\therefore$ 8" □ × ½" WALL BOX SECTION STILL OKAY

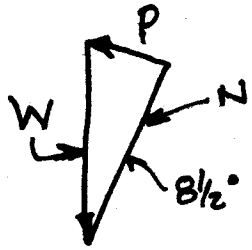
10-26-01 | DAVE PUSHKAR

MAGNET INSTALLATION CART -

FORCE REQUIRED TO MOVE UP INCLINE:

ASSUME TOTAL wt = 30,000 FOR MAGNET, LIFT. FIX. AND CART.





$P = W \sin 8\tfrac{1}{2}°$

$P = 30{,}000 \sin 8\tfrac{1}{2}°$

$P = 4434\ \#$

FRICTION TO OVERCOME ROLLING RESISTANCE ADDS TO THE REQ'D FORCE. $N = W \cos 8\tfrac{1}{2} = 29{,}670\ \#$

ASSUME 9500 per roller (max) AND $f = 0.05$

$P_{TOTAL} = P + fN = 4434\# + (0.05)(9500\ \#)$

$= 4909\ \#$

IF $f_{STATIC} = 0.2$, $P_{TOTAL} = 6334\#$ ∴ 4 ton pulling force is REQ'D.

CHECK w/ HILMAN CO.

Date: Fri, 26 Oct 2001 14:54:10 -0400
From: Marge Kistner <mkistner@hilmanrollers.com>
To: pushka@fnal.gov
Subject: Hilman Rollers - Friction Loads

[The following text is in the "iso-8859-1" character set.]
[Your display is set for the "US-ASCII" character set.]
[Some characters may be displayed incorrectly.]

Dear Mr. Pushka:

Thank you for your Hilman Roller inquiry.

The co-efficient of friction for breakaway for moving a load on a smooth, hard, level surface should not exceed 5%. On a hardened steel surface, this should be a little less. Hilman has friction test results on file that show actual ratings under ideal laboratory conditions. As job site conditions vary greatly, it is best to use 5% of the vertical dead load. In a dynamic state, the load will most often be moved slowly enough that the rating will almost always approach breakaway.

If you have any questions, please do not hesitate to contact us.

Regards,

Marge Kistner
Hilman Rollers
E-Mail: mkistner@hilmanrollers.com
Phone: (732) 462-6277 ext. 202
Fax: (732) 462-6355

$$f_{STATIC} = 0.05$$

$$\therefore P_{TOTAL} = 4434 + 0.05(9500\#)$$

$$= 4909$$

$\therefore$ MIN. WINCH SIZE IS ABOUT 3 TON CAPACITY.

MAGNET INST. CART. – LUG SIZING FOR BASE FOR PULLING UPHILL.

DESIGN FOR 5 ton capacity (ACTUAL LOAD ≈ 6300#)

ASSUME MILD STEEL, $t_{MAX} = 1''$ (OK FOR A 5 ton ANCHOR shackle throat width).

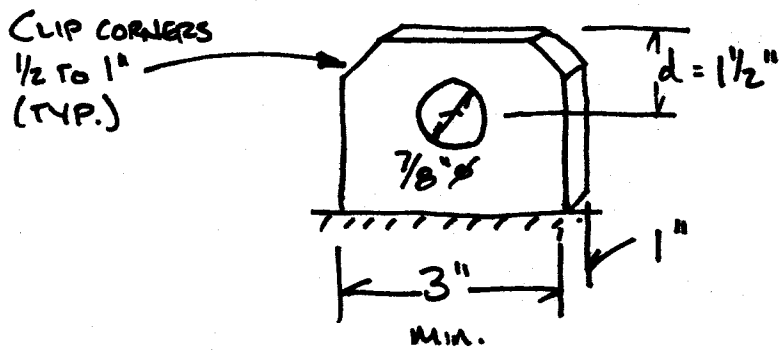
$$A_t = \frac{P}{\sigma} = \frac{10{,}000\ \#}{10{,}000\ psi} = 1\ in^2$$

$$A_{SHEAR} = \frac{P}{\tau} = \frac{10{,}000\ \#}{1/3 \cdot 30{,}000\ \#/in^2} = 1\ in^2$$

HOLE FOR USE w/ A 5/8"ø ANCHOR shackle is $\frac{7}{8}$"ø

$$W_{MIN} = \frac{1\ in^2}{1\ in} + \frac{7}{8}'' = 1\frac{7}{8}''$$

∴ USE 3" WIDTH.



$$d_{MIN} = \frac{1}{2}\frac{1\ in^2}{1\ in} + \frac{7}{16} = \frac{15}{16} \quad \therefore \text{ USE } d = 1\tfrac{1}{2}''$$

MAGNET INSTALLATION CART - LOADS ON INCLINE

CONSIDER EFFECT OF HIGHER LOADS ON DOWNSTREAM 'C' STRUCTURE DUE TO INCLINE.

LEVEL GROUND LOAD WAS 13,000 #

INCLINE LOAD (MAXIMUM) IS 17,374 #

$M = (17{,}374\#)(18\tfrac{1}{2}") = 321{,}419$ in-lbs

- TOP MEMBER → $\sigma_B = \frac{My}{I} = \frac{(321{,}419)(4)}{181} = 9814$ psi

$$\delta = \frac{Pl^3}{3EI} = 0.007 * \frac{17.3}{13.0} = 0.009"$$

deflection still acceptable & $\sigma_B < F_B = 0.66 F_y = 30{,}000$ psi

- VERTICAL MEMBER → $\sigma_B = 9814$ psi (same as top member)

$$\sigma_{AXIAL} = \frac{17{,}374\#}{14.4 \text{ in}^2} = 1206 \text{ psi}$$

$$\sigma_{\substack{COMBINED \\ (MAX)}} = 9814 + 1206 = 11{,}020 \text{ psi}$$

combined stress remains less than the allowable ∴ OK

- CHECK REACTIONS ON HILLMAN ROLLERS -

$$R_2 = \frac{(17{,}374\#)(18.5 \text{ in})}{32 \text{ in}} = 10{,}044\#$$

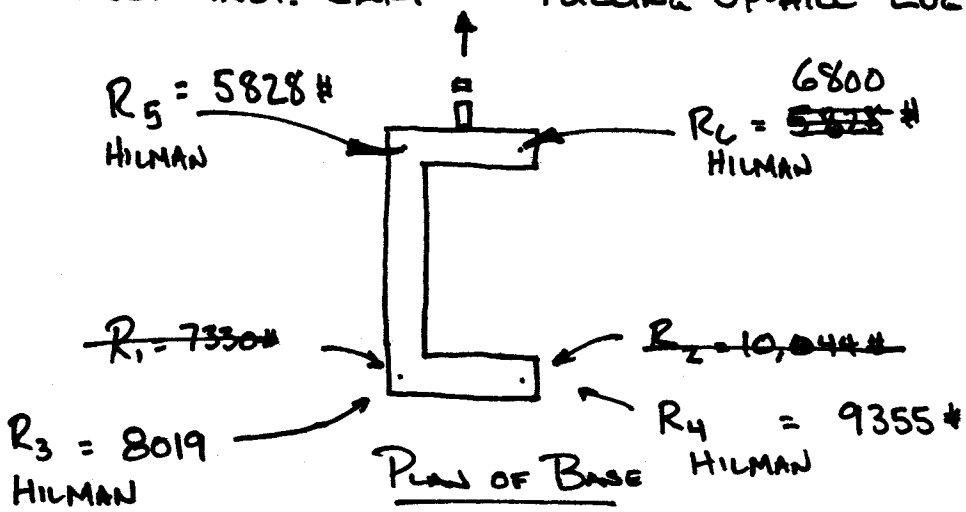
$$R_1 = 17{,}374 - R_2 = 7{,}330\#$$

$$R_4 = \frac{(4 \cdot 10{,}044) + (36 \cdot 7330)}{32\tfrac{1}{2}} = 9{,}355\#$$

$$R_3 = R_1 + R_2 - R_4 = 8019\#$$

R_3 & R_4 REMAIN LESS THAN 10,000 # ∴ 5^t HILMANS ARE OK

MAGNET INST. CART – PULLING UP-HILL LUG LOCATION



LOADS ON HILMANS R_3, R_4, R_5 & R_L.

$R_3 = 8019$ #
$R_4 = 9355$ #
} AS CALCULATED ON PAGE ____

$$\Sigma R = 30{,}000 = R_3 + R_4 + R_5 + R_L$$

$$R_5 + R_L = 12{,}626$$

ASSUME $\frac{R_5}{R_L} = \frac{R_3}{R_4}$ $\therefore$ $R_5 = R_L\left(\frac{8019}{9355}\right)$

$= .85 R_L$

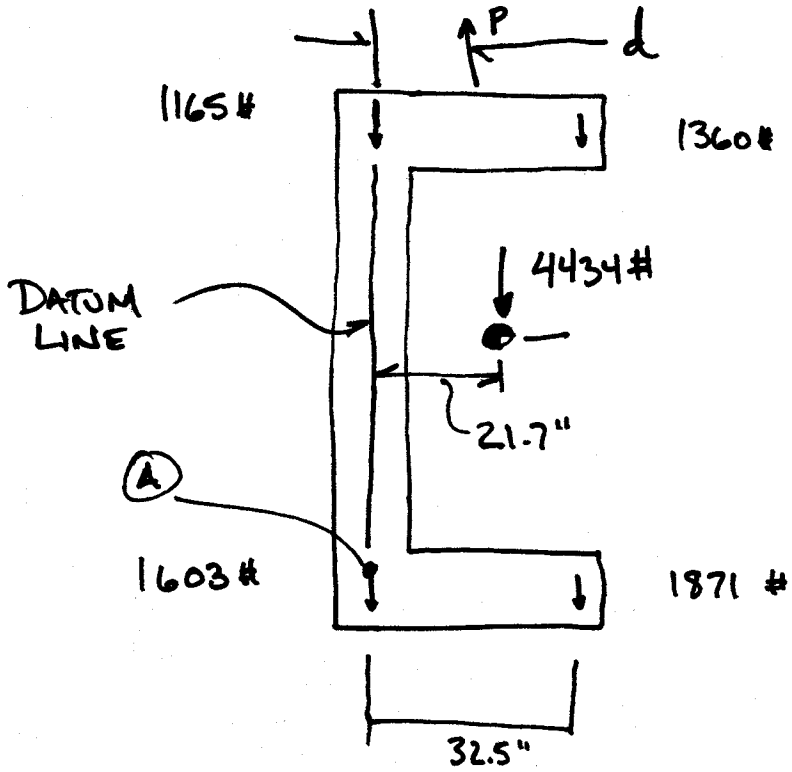
$1.85 R_L = 12{,}626$ $\therefore$ $R_L = 6800$ #

$R_5 = 5828$ #

10-26-01 | DAVE PUSHKA

MAG. INST. CART – FRICTION LOADS ON BASE

ASSUME $f = 20\%$ OF LOAD



$$P = 4434 + 1360 + 1165 + 1603 + 1871 = 8833\ \#$$

DESIRE TO AVOID CART SKEWING DUE TO PULLING UP INCLINE.

$$\Sigma M_A = dP - (21.7\text{ in} \cdot 4434\ \#) - (1871\ \# \cdot 32.5\text{ in}) - (1360 \cdot 32.5\text{ in}) = 0$$

$$d = \frac{(21.7 \cdot 4434) + 32.5(1871 + 1360)}{8833} = 22.7\text{ in}$$

CHECK IF $f = 0.05$

$$d = \frac{(21.7 \cdot 4434) + 32.5(1871 + 1360)\frac{1}{4}}{\cancel{\frac{1}{4}8833}\ 4434 + \frac{1}{4}(1360 + 1165 + 1603 + 1871)} = 20.6\text{ in}$$

MAG. INST. CART - FRICTION LOADS ON BASE - CON'T.

∴ THE SKEWING DUE TO FRICTION IN THE ROLLERS REQUIRES VERY SMALL CHANGES TO THE POSITION OF THE LUG.

JUST LOCATE THE LUG AT ~~22"~~ 21" FROM THE DATUM LINE.

THE DATUM LINE IS THE ℄ OF THE HILMAN ROLLERS ON THE NEAR SIDE AS THE CART GOES UP.

2-14-03 | DAVE PUSHKA

CONSIDER "CHAIN" BETWEEN HYDRAULIC PULL CYLINDERS & LIFTING FIXTURE:

CAPACITY – 10 TONS (TO MATCH CYLINDER CAP)

ACTUAL LOAD $\simeq \frac{26{,}000\#}{2} = 13{,}000\# = 6\frac{1}{2}t$

CHECK BOLT IN DOUBLE SHEAR

IF A307 (GRADE 1 OR GRADE 2) A $1\frac{1}{4}$"Ø BOLT IN DOUBLE SHEAR HAS AN ALLOWABLE SHEAR OF 24,500# ∴ OK

GRADE 5 (A325) w/ THREADS IN THE SHEAR PLANE ($1\frac{1}{4}$"Ø) HAS AN ALLOWABLE SHEAR OF 51,500#

SEE DWG MB-406986 AND MB-427024

4-15-03 – NOTE, NOT NEEDED w/ B2 FIXTURE, ONLY NEEDED w/ 3Q MAGNETS FIXTURE.

∴ ACTUAL LOAD IS MUCH LOWER THAN 26,000#

ACTUAL LOAD ≈ 4100#

2-14-03 Dave Pushka

LEAD LINK — SEE DWG MB-406915

CONSIDER LINKS IN CHAIN — TENSION

$P = 20{,}000\ \#$

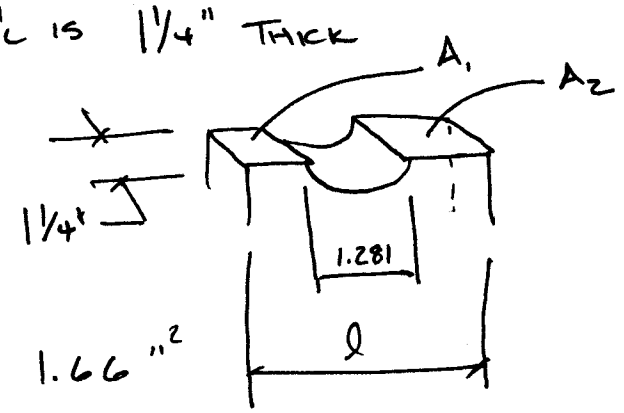
$\sigma_{MAX} = \frac{1}{3}\sigma_{yield} = \frac{1}{3}\ 36\ ksi = 12{,}000\ psi$

(USE A36 MATERIAL)

TENSION AREA => $\sigma = \frac{P}{A} \Rightarrow A = \frac{P}{\sigma_{ALLOW}}$

$$A_{REQ'D} = \frac{20{,}000\ \#}{12{,}000\ \#/in^2} = 1.66\ in^2$$

ASSUME MAT'L IS 1 1/4" THICK



$A_1 + A_2 = 1.66\ ''^2$

$1.66\ in^2 = (1.25)(l - 1.281)$

$\frac{1.66}{1.25}\ in = l - 1.281 \Rightarrow l = 1.281 + \frac{1.66}{1.25} = 2.61\ in$

∴ USE 3" WIDE STOCK, MIN. FOR TENSION → CHECK SHEAR

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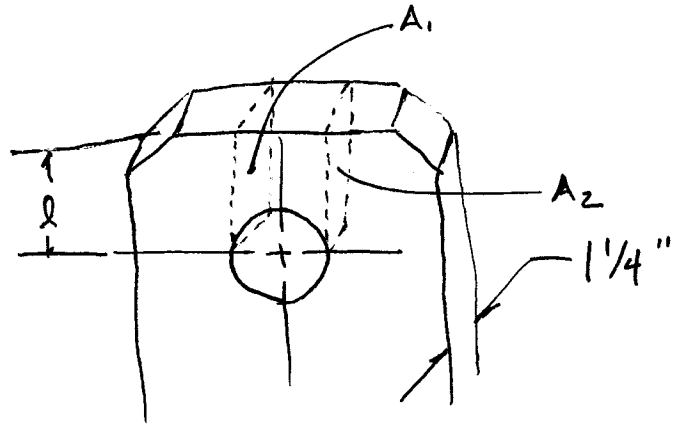
Lead Link - See MB 406915

Links in Chain - Shear



Again $\tau \le \frac{F_y}{3} \le 12{,}000$ psi

$$l = \frac{5.375 - 2.875}{2} = 1.25 \text{ in}$$

$$\text{Area} = (2)_{\text{sides}} * 1.25 \text{ in} * 1.25 \text{ in} = 3.125 \text{ in}^2$$

$P = 10$ tons $= 20{,}000$ #

$$\tau = \frac{P}{A} = \frac{20{,}000 \text{ \#}}{3.125 \text{ in}^2} = 6400 \text{ psi}$$

6400 psi < 12,000 psi ∴ OK

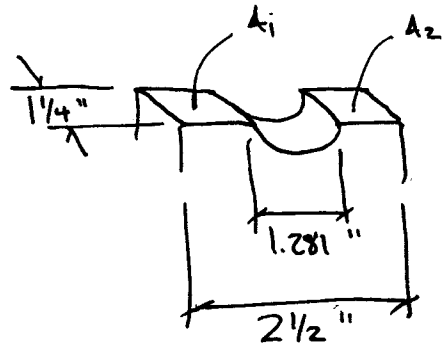
2-14-03 | DAVE PUSHKA

SECONDAY LINKS - SEE MB-406918 & MB-406932

TWO SECONDAY LINKS SHARE THE 10 TON DESIGN LOAD.

CHECK TENSION -

$$P = \frac{20{,}000\ \#}{2\ \text{LINKS}} = 10{,}000\ \#$$



$$\text{AREA} = A_1 + A_2$$

$$= (1.25)[2.5 - 1.281]$$

$$= 1.523\ \text{in}^2$$

$$\sigma = \frac{P}{A} = \frac{10000\ \#}{1.523\ \text{in}^2} = 6{,}562\ \text{psi}$$

$$\sigma_{ALLOW} = \frac{F_y}{3} = \frac{36{,}000}{3} = 12{,}000\ \text{psi}$$

$$\sigma < \sigma_{ALLOW} \therefore \text{OK}$$

BY INSPECTION, SHEAR AREA ON 2ND LINK IS SAME AS LEAD LINK, SHEAR IS OK ON LEAD LINK ∴ SHEAR IS OKAY ON 2ND LINK