**Fermilab**

Particle Physics Division 12-01-01

# Mechanical Department Engineering Note

Number: MD-Eng-55 Date: August 23, 2004

Project: NuMi

Project Internal Reference:

Title: Target Hall Air Duct Support Frame

Author(s): Ingrid Fang

Reviewer(s): Zhijing Tang Tang Zhijing 9-3-04

Key Words: NuMi, Target Hall and Air Duct

Abstract/Summary:

The NuMi Target Hall Air Duct consists of a Main Duct and three Branch Ducts. The major part of the Main Duct near the Fan will be supported by these Support Frames at two places while the rest of the Main Duct will be supported by the Branch Ducts.

The Air Duct is designed to take 297 lbs/ft at 20 feet span. It is made of 14 gauge galvanized steel sheet with cross section of 54"W x 36"H. Additional corner angles L2x2x1/4" are welded to the Duct internally. Stiffener angles L2-1/2x 2-1/2 x 3/16" are also welded to the duct externally at 2 feet intervals as additional reinforcement.

In order to ease the Air Duct installation, the Air Duct Support Frame is designed to take the maximum load at a maximum span of 20 feet. Thus, the Support Frame can be used anywhere within the design limit.

The design analysis was performed according to both AISC "Allowable Stress Design" code and ASCE "Minimum Design Loads for Buildings and Other Structures". The results show that all members will safely support the floor extension within the allowable stress limits.

Applicable Codes:

1. AISC Manual of Steel Construction, Allowable Stress Design, Ninth Edition

2. ASCE Minimum Design Loads for Buildings and Other Structures.

3. ANSI/AWS D1.1-98, Structural Welding Code – Steel

4. Hilti North America Product Technical Guide

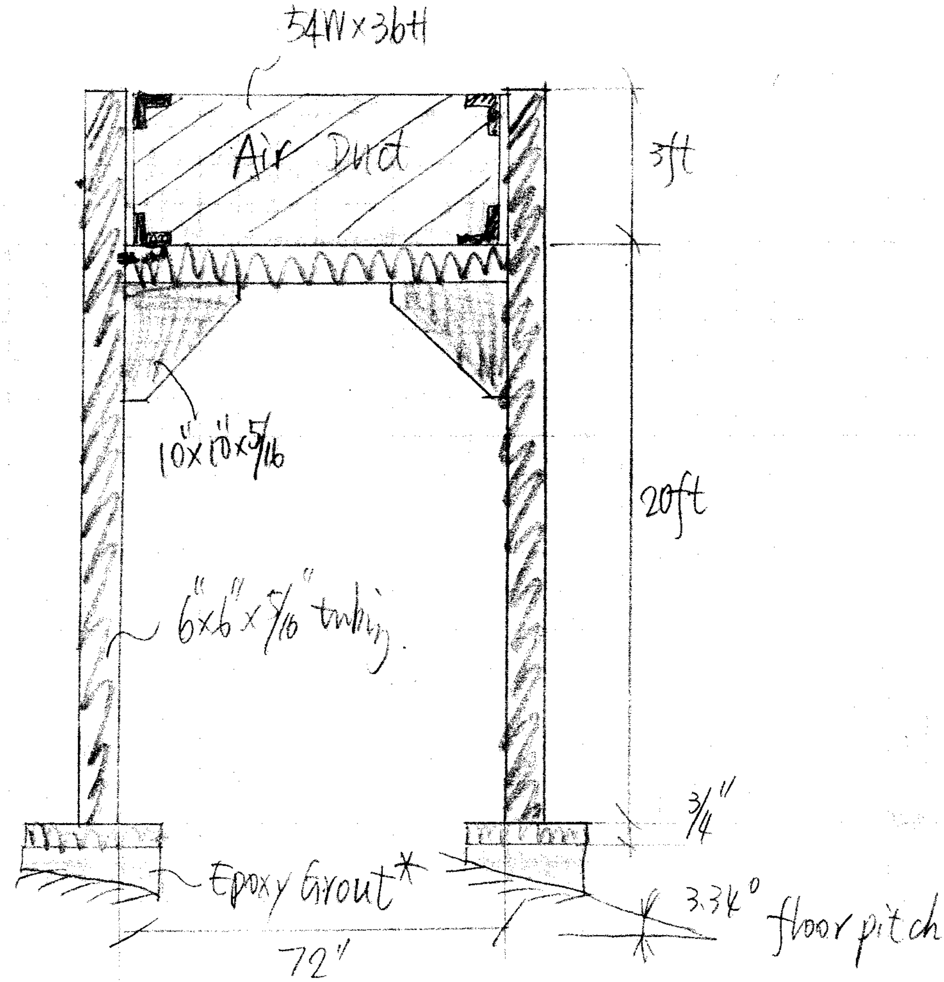
1. Introduction.

The Numi Target Hall air duct consists of a main duct and three branch ducts. The major part of the main duct near the fan will be supported by these support frames at two places while the rest of the main duct will be supported by the branch ducts.

The air duct is designed to take 297 lbs/ft at 20 feet span. It is made of 14 gauge Galvanized steel sheet with cross section of 54" W x 36" H. Additional corner angles L2x2x1/4 are welded to the duct internally. Stiffener angles L2½x2½x3/16 are also welded to the duct externally at 2 feet intervals as additional rein-forcement.

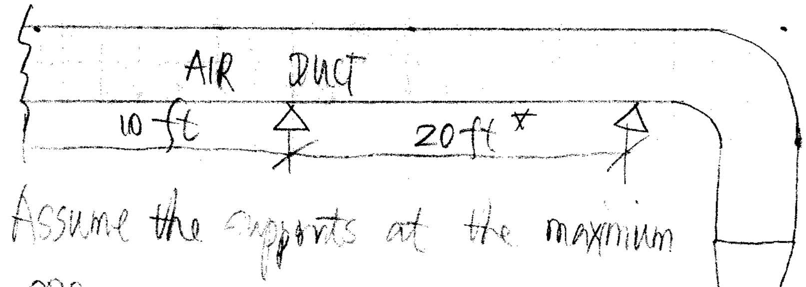
In order to ease the air duct installation, the air duct support frame is designed to take the maximum load at a maximum span of 20 feet. Thus, the support frame can be used anywhere within the design limit.

2. Design the air duct support frame

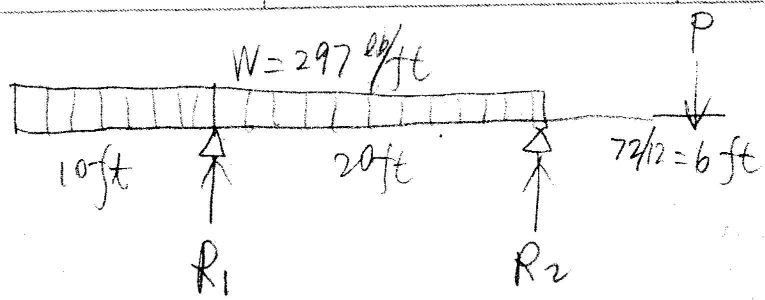



* Set the frame at ture vertical position. Use the Epoxy Grout under the base plate to level the floor pitch.

a. Find the design load



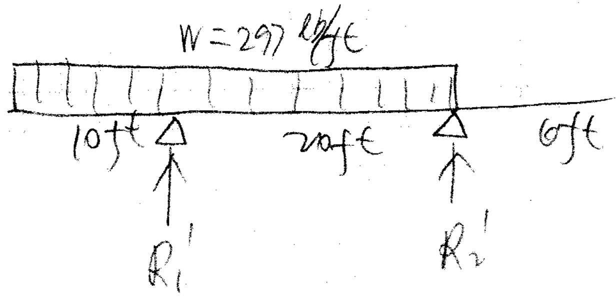

* Assume the supports at the maximum span



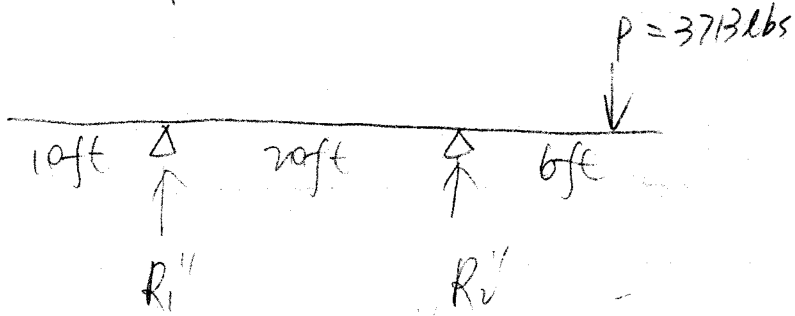

Where $P = WL$

$$= 297 \text{ lb/ft} \times (113+37)/12 = 3713 \text{ lbs}$$

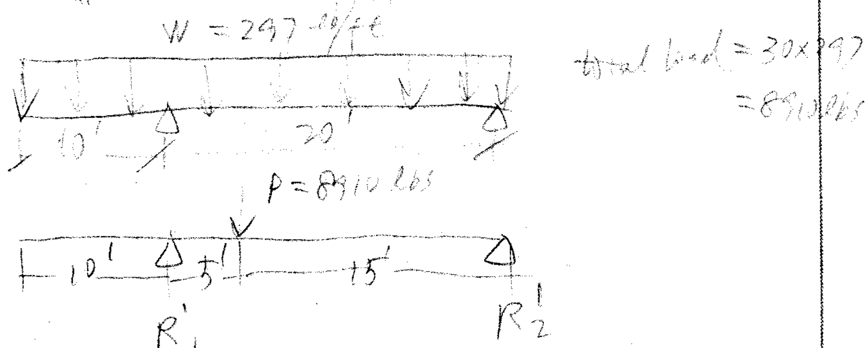
Case 1:




Case 2:




From case 1:




$\Sigma R_2 = 0 \qquad 20R_1 = 15P \quad R_1' = 6683 \text{ lbs}$

$R_2' = P - R_1 = 8910 - 6683 = 2227 \text{ lbs}$

From case 2:

$$R_1'' = -\frac{Pa}{L} = \frac{3713\times 6}{20} = -1113.9 \text{ lb}$$

$$R_2'' = \frac{P}{L}(L+a) = \frac{3713\times(20+6)}{20} = 4827 \text{ lbs}$$

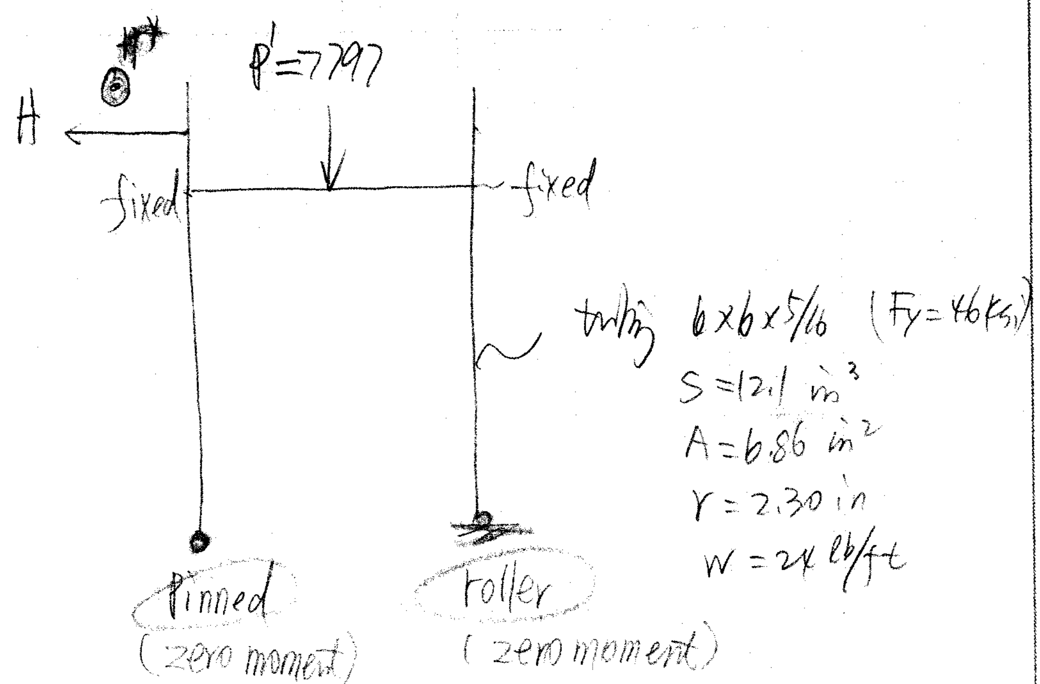
$\Sigma R_1 = R_1' + R_1''$

$= 6683 - 1113.9 = 5569$ lbs

$\Sigma R_2 = R_2' + R_2''$

$= 2227 + 4827 = 7797$ lbs — (governs)

Thus, load on the support frame will be




$H = 10\% V = 10\% \times 7797 \approx 800$ lbs

* ⊙H — will be designed seperately. See page 12

Build A truss frame in Ansys, find the following:

For column: $M_{max} = 182400$ lb-in

For beam: $M_{max} = 201600$ lb-in

ELEMENTS

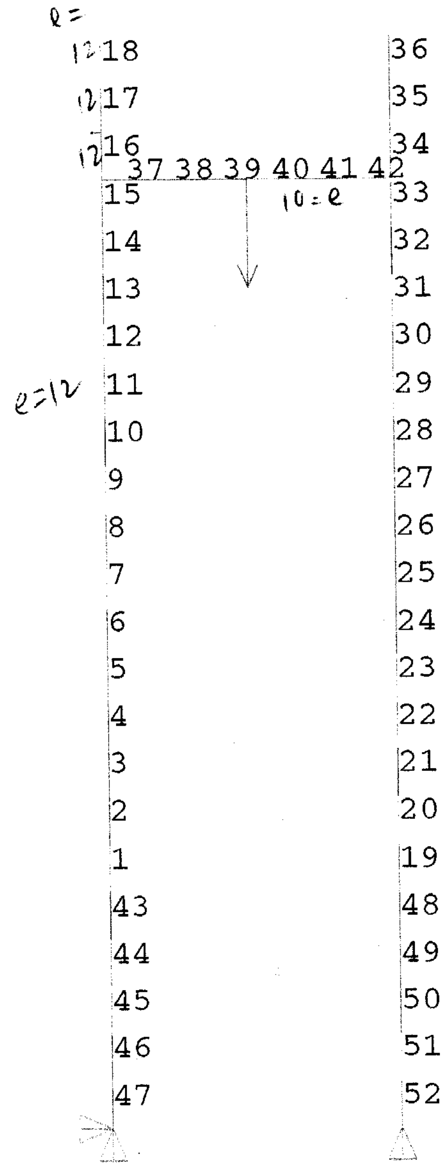
ELEM NUM

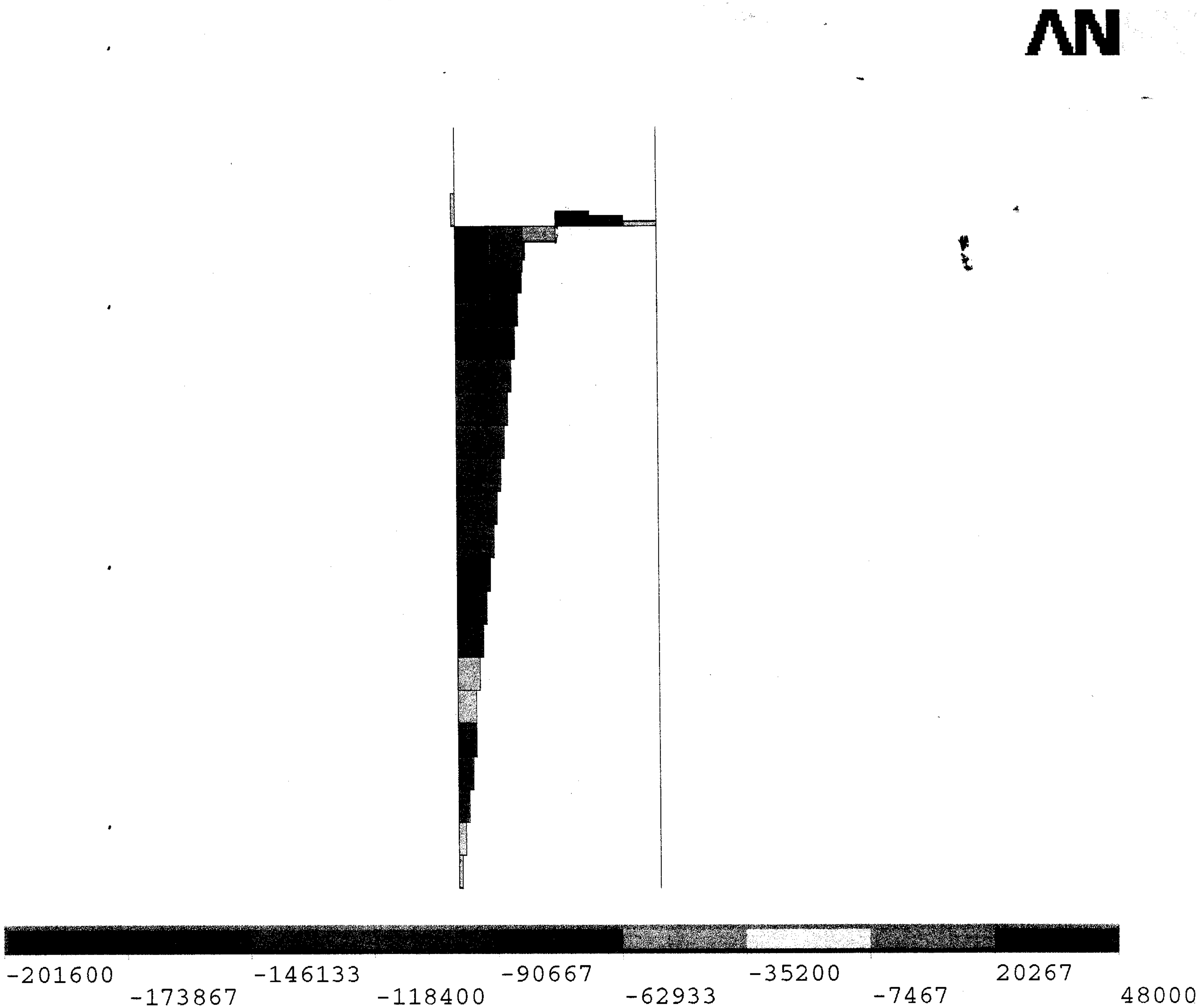
U

F

AN

AUG 5 2004
10:25:59




AN
-201600
-173867
-146133
-118400
-90667
-62933
-35200
-7467
20267
48000

PRINT ELEMENT TABLE ITEMS PER ELEMENT

***** POST1 ELEMENT TABLE LISTING *****

| STAT ELEM | CURRENT MMZ |
|---|---|
| 1 | -48000. |
| 2 | -57600. |
| 3 | -67200. |
| 4 | -76800. |
| 5 | -86400. |
| 6 | -96000. |
| 7 | -0.10560E+06 |
| 8 | -0.11520E+06 |
| 9 | -0.12480E+06 |
| 10 | -0.13440E+06 |
| 11 | -0.14400E+06 |
| 12 | -0.15360E+06 |
| 13 | -0.16320E+06 |
| 14 | -0.17280E+06 |
| 15 | -0.18240E+06 |
| 16 | 9600.0 |
| 17 | 0.78580E-08 |
| 18 | 0.75670E-08 |
| 19 | 0.46928E-06 |
| 20 | 0.69619E-06 |
| 21 | 0.92485E-06 |
| 22 | 0.11016E-05 |
| 23 | 0.13532E-05 |
| 24 | 0.15177E-05 |
| 25 | 0.13524E-05 |
| 26 | 0.15403E-05 |
| 27 | 0.12389E-05 |
| 28 | 0.15325E-05 |
| 29 | 0.16879E-05 |
| 30 | 0.19953E-05 |
| 31 | 0.22278E-05 |
| 32 | 0.23539E-05 |
| 33 | 0.24331E-05 |
| 34 | -0.35732E-07 |
| 35 | 0.22257E-07 |
| 36 | -0.75597E-08 |
| 37 | -0.20160E+06 |
| 38 | -0.12122E+06 |
| 39 | -40836. |
| 40 | 39546. |
| 41 | 26364. |

***** POST1 ELEMENT TABLE LISTING *****

| STAT ELEM | CURRENT MMZ |
|---|---|
| 42 | 13182. |
| 43 | 48000. |
| 44 | 38400. |
| 45 | 28800. |
| 46 | 19200. |
| 47 | 9600.0 |
| 48 | -0.44191E-06 |
| 49 | -0.21690E-06 |
| 50 | -0.35798E-06 |
| 51 | 0.13876E-06 |
| 52 | -0.10259E-07 |

MINIMUM VALUES

ELEM 37
VALUE -0.20160E+06

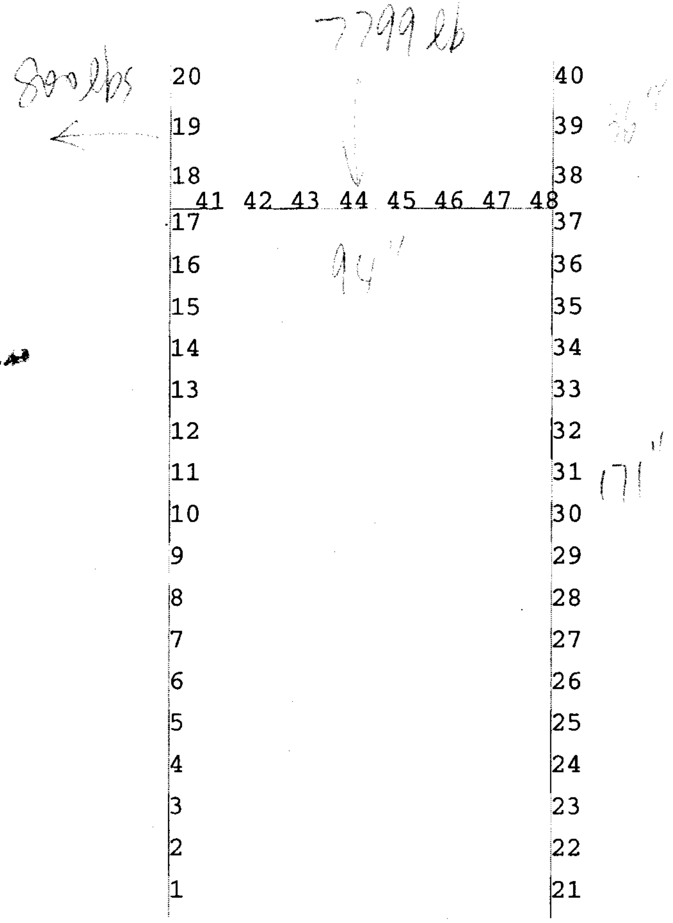
MAXIMUM VALUES
ELEM 43
VALUE 48000.

1

ELEMENTS

ELEM NUM

AUG 25 2004
11:03:49



PRINT ELEMENT TABLE ITEMS PER ELEMENT

***** POST1 ELEMENT TABLE LISTING *****

| STAT ELEM | CURRENT MOMI | CURRENT MOMJ |
|---|---|---|
| 1 | 0.46566E-09 | -8047.1 |
| 2 | -8047.1 | -16094. |
| 3 | -16094. | -24141. |
| 4 | -24141. | -32188. |
| 5 | -32188. | -40235. |
| 6 | -40235. | -48282. |
| 7 | -48282. | -56329. |
| 8 | -56329. | -64376. |
| 9 | -64376. | -72424. |
| 10 | -72424. | -80471. |
| 11 | -80471. | -88518. |
| 12 | -88518. | -96565. |
| 13 | -96565. | -0.10461E+06 |
| 14 | -0.10461E+06 | -0.11266E+06 |
| 15 | -0.11266E+06 | -0.12071E+06 |
| 16 | -0.12071E+06 | -0.12875E+06 |
| 17 | -0.12875E+06 | -0.13680E+06 |
| 18 | 9600.0 | 0.46421E-08 |
| 19 | 0.23865E-08 | -0.47730E-08 |
| 20 | 0.24083E-08 | 0.26339E-08 |
| 21 | -0.71595E-08 | -0.80327E-08 |
| 22 | -0.13271E-07 | -0.47963E-07 |
| 23 | -0.67288E-07 | -0.10384E-06 |
| 24 | -0.10902E-06 | -0.18429E-06 |
| 25 | -0.13225E-06 | -0.18999E-06 |
| 26 | -0.19104E-06 | -0.25867E-06 |
| 27 | -0.26426E-06 | -0.35064E-06 |
| 28 | -0.34575E-06 | -0.42608E-06 |
| 29 | -0.42957E-06 | -0.51176E-06 |
| 30 | -0.51112E-06 | -0.57218E-06 |
| 31 | -0.58633E-06 | -0.64529E-06 |
| 32 | -0.64424E-06 | -0.70827E-06 |
| 33 | -0.91520E-06 | -0.10157E-05 |
| 34 | -0.77201E-06 | -0.91468E-06 |
| 35 | -0.91054E-06 | -0.10101E-05 |
| 36 | -0.10191E-05 | -0.11506E-05 |
| 37 | -0.11365E-05 | -0.13033E-05 |
| 38 | -0.10245E-07 | -0.18626E-08 |
| 39 | -0.69849E-09 | -0.60536E-08 |
| 40 | -0.79162E-08 | 0.83819E-08 |
| 41 | -0.14640E+06 | -81100. |

***** POST1 ELEMENT TABLE LISTING *****

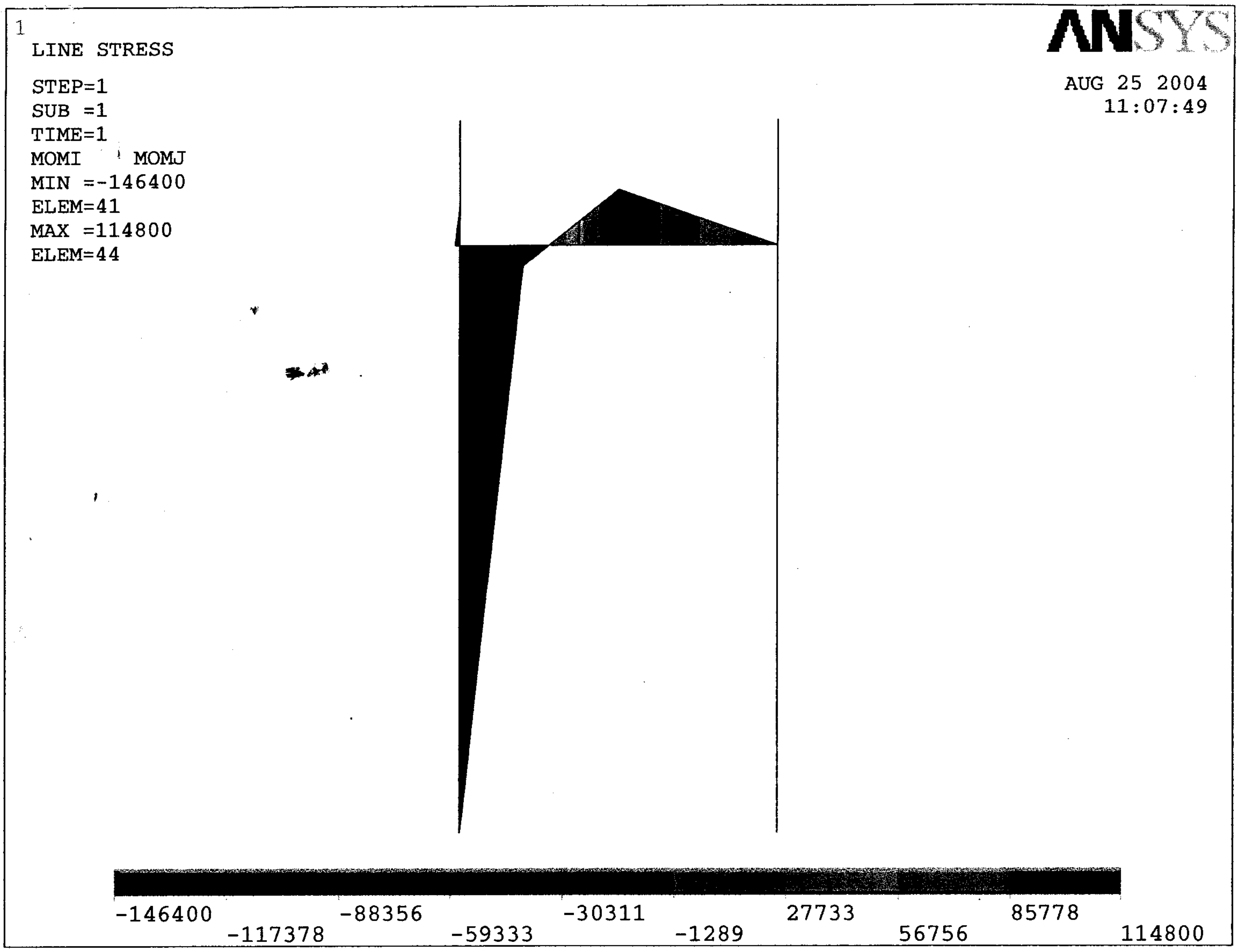
| STAT ELEM | CURRENT MOMI | CURRENT MOMJ |
|---|---|---|
| 42 | -81100. | -15800. |
| 43 | -15800. | 49500. |
| 44 | 49500. | 0.11480E+06 |
| 45 | 0.11480E+06 | 86100. |
| 46 | 86100. | 57400. |
| 47 | 57400. | 28700. |
| 48 | 28700. | 0.12973E-05 |

MINIMUM VALUES

| | | |
|---|---|---|
| ELEM | 41 | 17 |
| VALUE | -0.14640E+06 | -0.13680E+06 |

MAXIMUM VALUES

| ELEM | 45 | 44 |
| --- | --- | --- |
| VALUE | 0.11480E+06 | 0.11480E+06 |


1
LINE STRESS
STEP=1
SUB =1
TIME=1
MOMI MOMJ
MIN =-146400
ELEM=41
MAX =114800
ELEM=44
ANSYS
AUG 25 2004
11:07:49
-146400
-117378
-88356
-59333
-30311
-1289
27733
56756
85778
114800

b. check for column

b1: Bending stress:

Allowable: $L_b = 20\,ft = 240''$

$L_c = (1950 + \frac{M_1}{M_2} \times 1200)\ \frac{b}{F_y}$ (the $\frac{M_1}{M_2} \times 1200$ term is crossed out and marked 0)

$= 1950 \times \frac{b}{F_y} = \frac{1950 \times 6}{46} = 254\ in$

$L_b > L_c$ compact section

$F_b = 0.66 F_y = 0.66 \times 46 = 30.36\ ksi$

Actual: $f_b = \frac{M}{S}$ where $M = 182400\ lb\text{-}in$

$S = 12.1\ in^3$

$= \frac{182400}{12.1}$

$= 15\ ksi$

b2: Compressive stress:

$F = \frac{1}{2}P' + W_{column}$

$= \frac{1}{2} \times 7797 + 26 \times 24$

$= 4644\ lb \approx 5000\ lbs$

Actual: $f_a = \frac{F}{A} = \frac{5000}{6.86} = 0.728\ ksi$

Allowable:

$\frac{Kl}{r}$ where $K = 1.2$

$l = 240$ in

$r = 2.31$ in

$$\frac{Kl}{r} = \frac{1.2 \times 240}{2.31} = 125$$

$Cc = 111.6$ for $Fy = 46$ ksi

$$\frac{Kl}{r} > Cc$$

$$Fa = \sqrt{\frac{12\pi^2 E}{Fy}} = \sqrt{\frac{12\pi^2 \times 29 \times 10^6}{46}} = 8.64 \text{ ksi}$$

b3. Combined stresses:

$$\frac{fa}{Fa} = \frac{0.728}{8.64} = 0.084 < 0.15$$

$$\frac{fa}{Fa} + \frac{fb}{Fb} \le 1$$

$$0.084 + \frac{15}{30.36} = 0.58 < 1$$

<u>OK</u>

C. Check for beam bending:

Allowable. $Lb = 6ft = 72''$

$Lc = 254''$ from previous calculation

$Lb < Lc$ compact section

$F_b = 0.66 F_y$
$= 0.66 \times 46$
$= 30.36$ ksi

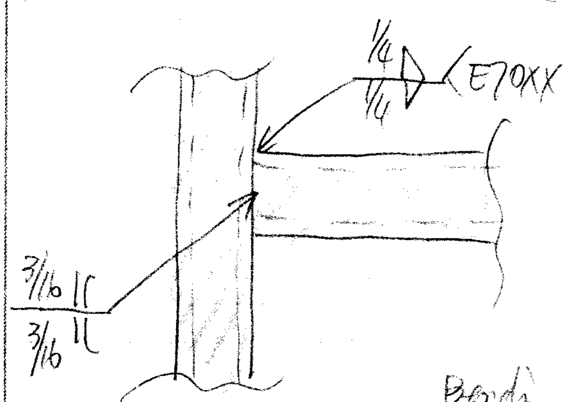
Actual: $f_b = \frac{M}{S}$ where $M = 201600$ lb-in, $S = 12.1$ in$^3$

$= \frac{201600}{12.1}$

$= 16.6$ ksi

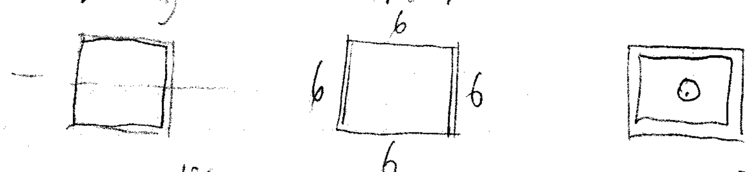
$SF = \frac{F_b}{f_b} = \frac{30.36}{16.6} = 1.8$ OK

d. Design the connection between the Horizontal member (beam) & vertical member (column)




load: $M = 201600$ lb-in
Shear = 5000 lb-in
Tension = 800 lb-in

Bending | Shear | Tension




$S = bd + \frac{d^2}{3}$
$= 6 \times 6 + \frac{6^2}{3} = 48$ in

$\sigma = \frac{M}{S}$
$= \frac{201600}{48} = 4200$ lb/in

$f_v = \frac{F}{A}$
$= \frac{5000}{6+6}$
$= 417$ lb/in

$f_t = \frac{F}{A}$
$= \frac{800}{6 \times 4}$
$= 33$ lb/in

The resultant fr

$$fr = \sqrt{(\sigma + ft)^2 + fr^2}$$

$$= \sqrt{(4200+33)^2 + 417^2}$$

$$= 4253.49 \ lb/in$$

$$\doteq 4.3 \ Kips/in < 3.7 \ Kips/in \quad N.G.$$

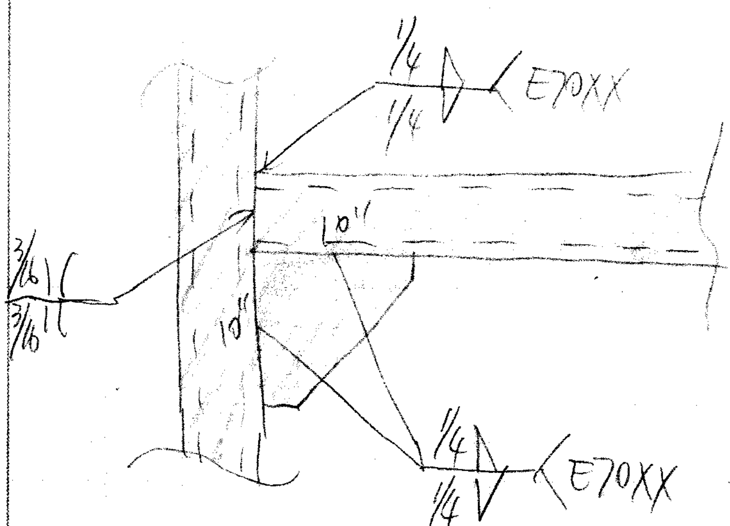
Find the allowable load on weld

$e = 0.707 \times 1/4 = 0.176$ in (governs)

$e = 5/8 \times 5/16 = 0.195$ in

$e \times 0.3 \times 70 = 0.176 \times 0.3 \times 70 = 3.7$ Kip/in

propose to add two gusset plates. A36 10"×10"×5/16"




Load: M = 201600 lb·in

Shear = 5000 lb

Tension = 800 lbs

Bending: $S_1 = \frac{d^2}{3} = \frac{10^2}{3} = 33 \ in^2$

$$\sigma = \frac{M}{S+S_1} = \frac{201600}{(48+33)} = 2478.6 \ lb/in$$

Shear: $f_v = \frac{F}{A + A_1}$ where $F = 5000$ lbs

$A = 6+6 = 12$ in

$A_1 = 10+10 = 20$ in

$= \frac{5000}{12+20}$

$= 156$ lb/in

Tension: $f_t = \frac{F}{A + A_1}$ where $F = 800$ lbs

$A = 6 \times 4 = 24$ in

$A_1 = 10+10 = 20$ in

$= \frac{800}{24+20}$

$= 18$ lb/in

the resultant $f_r$

$$f_r = \sqrt{(\sigma + f_t)^2 + f_v^2}$$

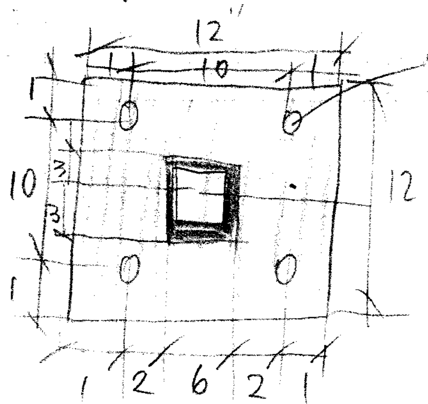
$$= \sqrt{(2478.6 + 18)^2 + 156^2}$$

$= 2496.6$ lb/in

$= 2.5$ Kips/in $< 3.7$ Kips/in

OK

e. Design the base plate — 12" × 12" × 3/4" — A36

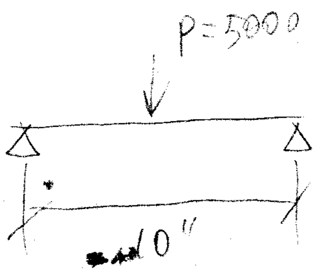



Φ3/4 for Kwik Bolt II expension Anchor

HilTi Φ5/8" carbon steel

Min Embendment = 2 1/4"

e1: Bending stress.




$$M = \frac{PL}{4} = \frac{5000 \times 10}{4} = 12500 \text{ lb-in}$$

$$S = \frac{ab^2}{6} = \frac{10 \times 0.75^2}{6} = 0.9375 \text{ in}^3$$

$$\sigma_b = \frac{M}{S} = \frac{12500}{0.9375} = 13.33 \text{ ksi}$$

Allowable:

$$\frac{b}{t} = \frac{12}{0.75} = 16$$

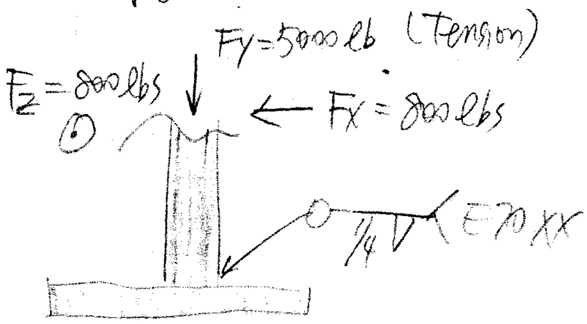
$$\frac{190}{\sqrt{F_y}} = \frac{190}{\sqrt{36}} = 31.6 \qquad F_y = 36 \text{ ksi for A36}$$

$$\because \frac{b}{t} < \frac{190}{\sqrt{F_y}} \quad \therefore \text{ compact section}$$

$$F_b = 0.75 F_y$$
$$= 0.75 \times 36$$
$$= 27 \text{ ksi}$$

$$SF = \frac{F_b}{\sigma_b} = \frac{27}{13.33} = 2.0 \qquad \underline{\underline{OK}}$$

e2: Design the connection between column and the base plate




$$f_{vx} = \frac{F}{A} = \frac{800}{6+6} = 66.6 \text{ lb/in}$$

$$f_{vz} = \frac{F}{A} = \frac{800}{6+6} = 66.6 \text{ lb/in}$$

$$f_r = \sqrt{f_{vz}^2 + f_{vx}^2}$$
$$= \sqrt{2} \times 66.6 = 94 \text{ lb/in}$$

Allowable on the weld:

$$0.3 \times 70 \times 1/4 \times 0.707 = 3.7 \text{ kips/in}$$

$$SF = \frac{3.7}{0.094} = 39 \quad \underline{\underline{OK}}$$

e3: Base plate connection design on CONCRETE

According to HILTI Anchor Catalog, for 5/8" Kwik Bolt II Expension Anchor, carbon steel, minimum embedment equals 2¾".

Allowable Tension = 2130 lbs
Allowable Shear = 3070 lbs

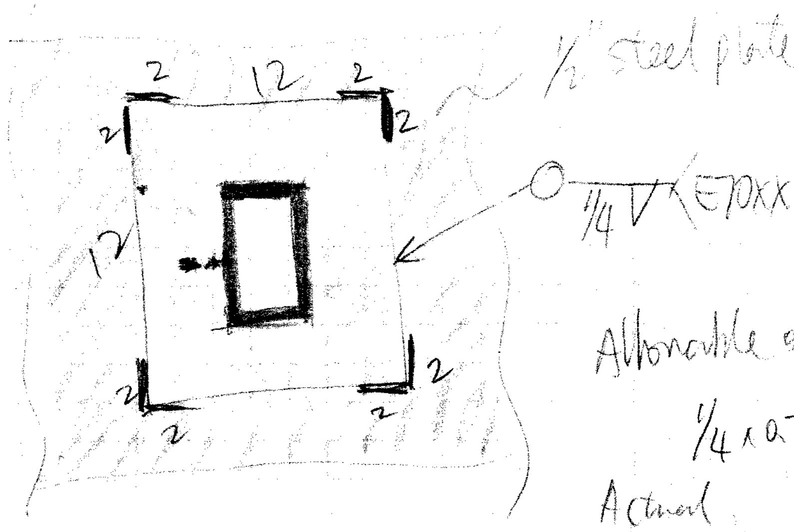
$S = 5\frac{1}{2}$ — 100% ($f_A = 1$)
C – edge for tension = $4\frac{1}{2}$ — 100% ($f_{RN} = 1$)
C – edge for shear = 9 — 100% ($f_{RV} = 1$)

$$\text{Actual shear force} = \sqrt{f_{VX}^2 + f_{VZ}^2}$$
$$= \sqrt{800^2 + 800^2}$$
$$= 1131.2 \text{ lbs} < 3070 \text{ lbs}$$

$\underline{\underline{OK}}$

USE EPOXY GROUT TO SET THE ~~FRAME~~ AT TURE VERTICAL POSITION. THE FLOOR PITCHS AT 3.4 DEGREES.

## e4: BASE PLATE CONNECTION DESIGN ON STEEL




Allowable on weld:

$\frac{1}{4} \times 0.707 \times 0.30 \times 70 = 3.7 \text{ kip/in}$

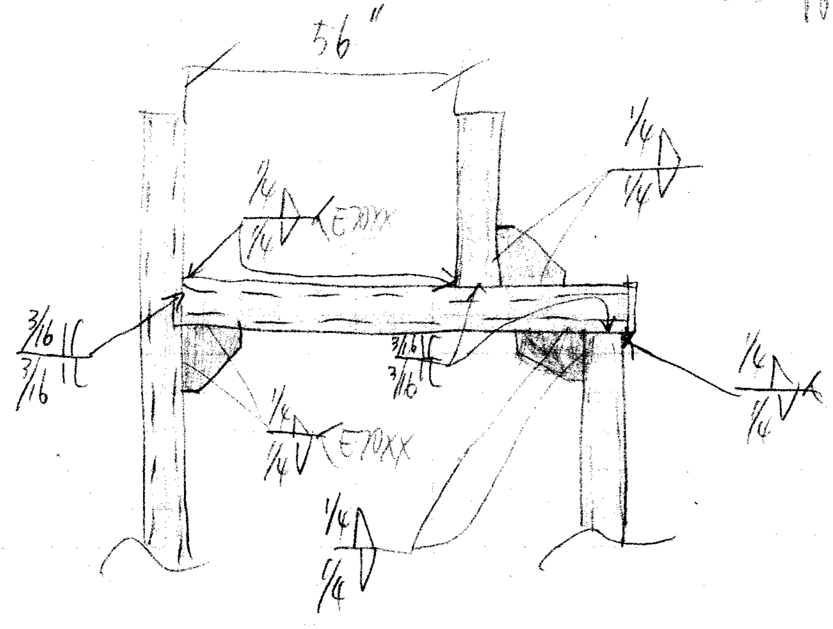
Actual

$f_v = \frac{P}{A} = \frac{800}{(2+2) \times 2} = 100 \text{ lb/in}$

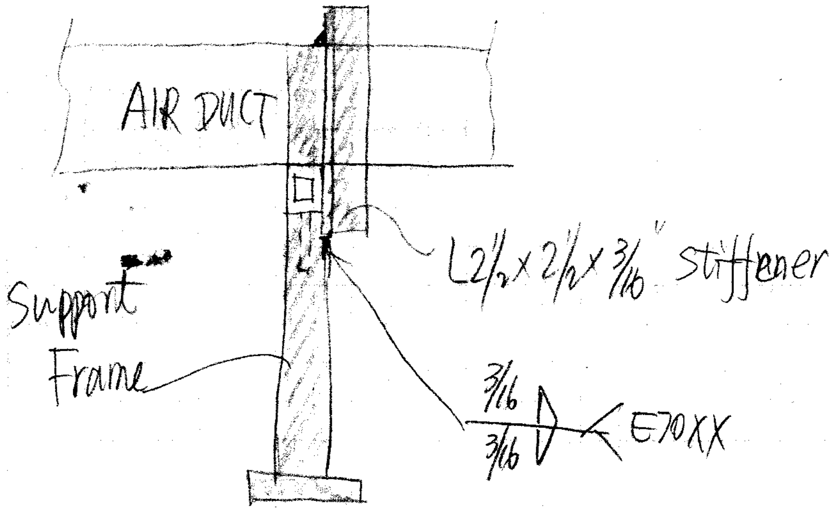
$\approx 0.1 \text{ kip/in}$

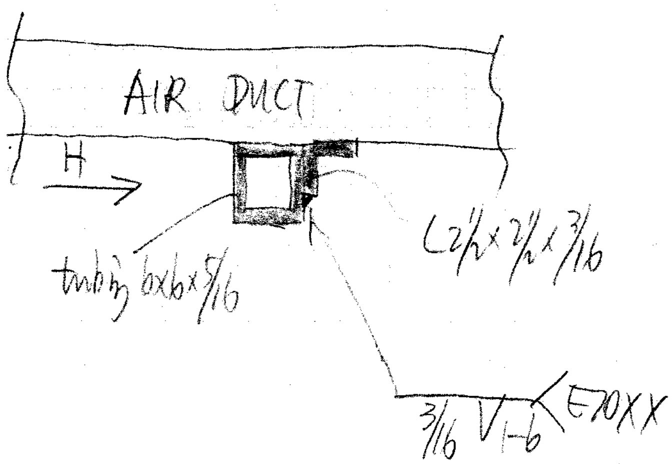
$SF = \frac{3.7}{0.1} = 3.7$ OK

## e5: EXTRA GUSSET PLATE FOR THE SUPPORTS NEAR THE FAN



f: CONNECTION BETWEEN THE FRAME & THE DUCT STIFFENER




The support frame will be welded to the Duct stiffener to take the horizontal load

$H = 800$ lbs

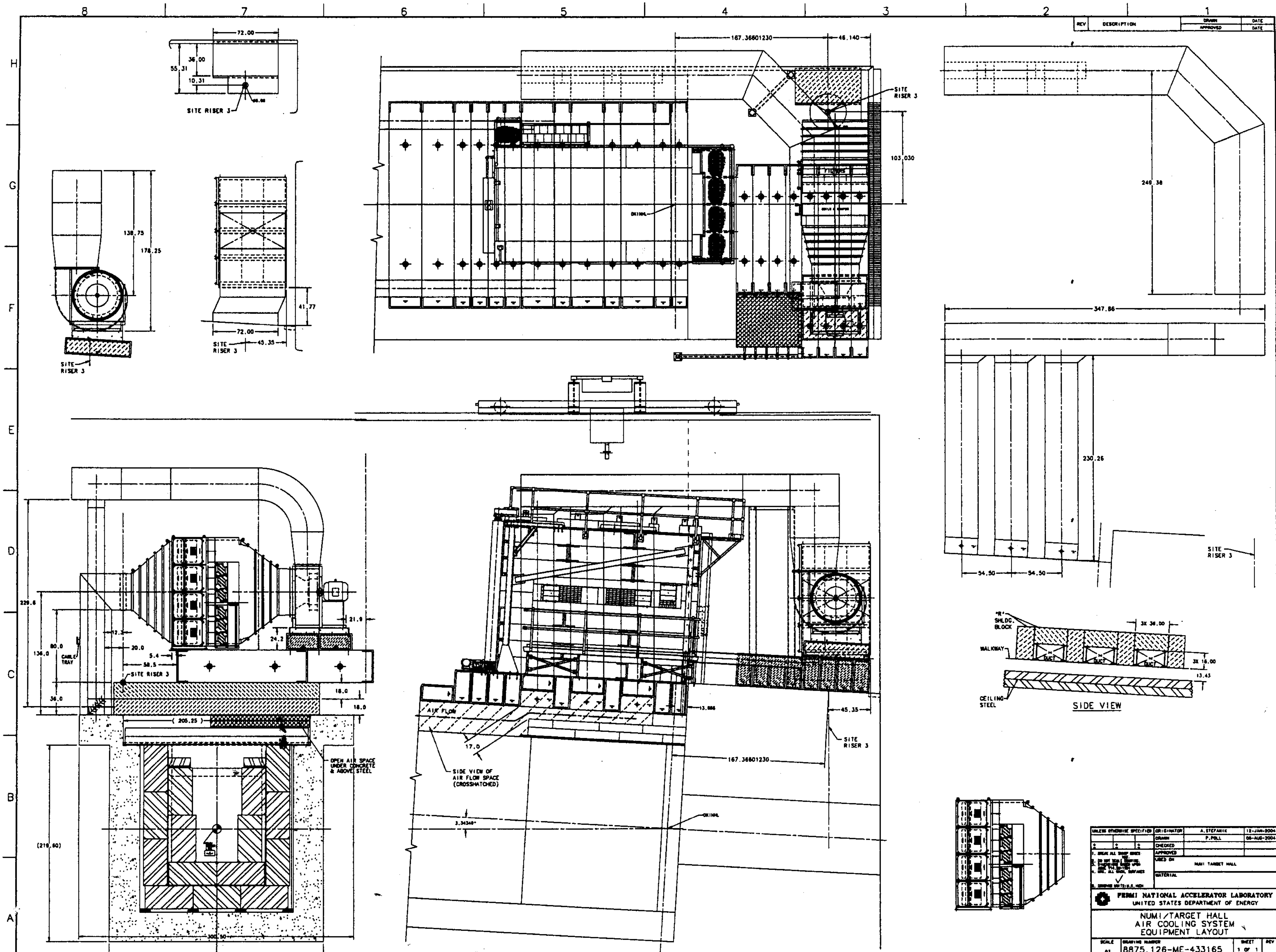
Find allowable force on weld:

$$\frac{3}{16} \times 0.707 \times 0.30 \times 70 = 2.78 \text{ kips/in}$$

Find actual force:

$$\frac{800}{2+2+4} = \frac{800}{8} = 100 \text{ lb/in} = 0.1 \text{ kip/in}$$

$$SF = \frac{2.78}{0.1} = 27.8 \quad \text{ok}$$




Plotted by pollpoll on 12-Aug-04 , File: AIR_SYSTEM_HALL_LAYOUT.pff

— Check Column Stress (Branch Duct)

According to "Rectangular Industrial Duct Construction STANDARDS" Sheet Metal and Air Conditioning Contractor's National Association, INC, Table F, page 7-61 for 12" DUCT HEIGHT, 14 gauge sheet metal

$I = 31.88 \text{ in}^4$

$S = 5.31 \text{ in}^3$

$r = \sqrt{\frac{I}{A}}$ where $A = A_{angle} + A_{duct}$

$= (0.938 \times 4) + [0.0667 \times (36+54) \times 2]$

$= \sqrt{\frac{31.88}{4.512}}$

$= 0.983 \times 4 + 12.006$

$= 2.658 \text{ in}$

$= 4.512 \text{ in}^2$

$\frac{Kl}{r} = \frac{1.2 \times 240}{2.658}$ where $K = 1.2$

$l = 20' = 240''$

$= 108.35$

$r = 2.658 \text{ in}$

According to ASTM A-924/A-924M or A-653/A-653M structural steel grades, $F_y = 33$ ksi

$C_c = 131.7$ for $F_y = 33$ ksi

$\frac{Kl}{r} < C_c$ $\therefore$ $\frac{Kl/r}{C_c} = \frac{108.35}{131.7} = 0.822$

$\therefore C_a = 0.348$

$W_{BRANCH} = W_{sheet} + W_{Angle} + W_{stiffener}$

$= \left[\frac{(36+36+16+16)}{12} \times 20 \times 3.125\right] + \left[3.19 \times 20 \times 4\right]$

$+ \left[104/12 \times 10 \times 1.65\right]$

$= 543.75 + 255.2 + 148.5$

$= 947.45$ lbs

Thus, Consider it's own weight. Check uplifting case

when $L = 7$ ft  $R_1 = 1444.1 + 947.45 = 2391.45$ lbs

$R_2 = 947.45 - 773.98 = 173.47$ lbs  OK

$R_3 = 4586.8 + 947.45 = 5534.25$ lbs (governs)

when $L = 6$ ft  $R_1 = 1339.2 + 947.45 = 2286.65$ lbs

$R_2 = 947.45 - 144.46 = 802.9$ lbs  OK

$R_3 = 3765.2 + 947.45 = 4712.65$ lbs

when $L = 5$ ft  $R_1 = 1250.4 + 947.45 = 2197.85$ lbs

$R_2 = 947.45 + 388.20 = 1335$ lbs  OK

$R_3 = 3024.3 + 947.45 = 3971.75$ lbs

This means overhanging length can not exceed 7 ft to prevent the Branch Ducts from up lifting. Otherwise, Additional Support will be needed during the duct installation when $L = 10ft$ $R_1 = 1855.7$ lbs

$R_2 = -3243.6$ lbs (up lifting)

$R_3 = 7535.8$ lbs N.G

when $L = 7ft$ $R_1 = 1444.1$ lbs

$R_2 = -773.98$ lbs (compare to it's own weight)

$R_3 = 4586.8$ lbs

when $L = 6ft$. $R_1 = 1339.2$ lbs

$R_2 = -144.46$ lbs (compare to it's own weight)

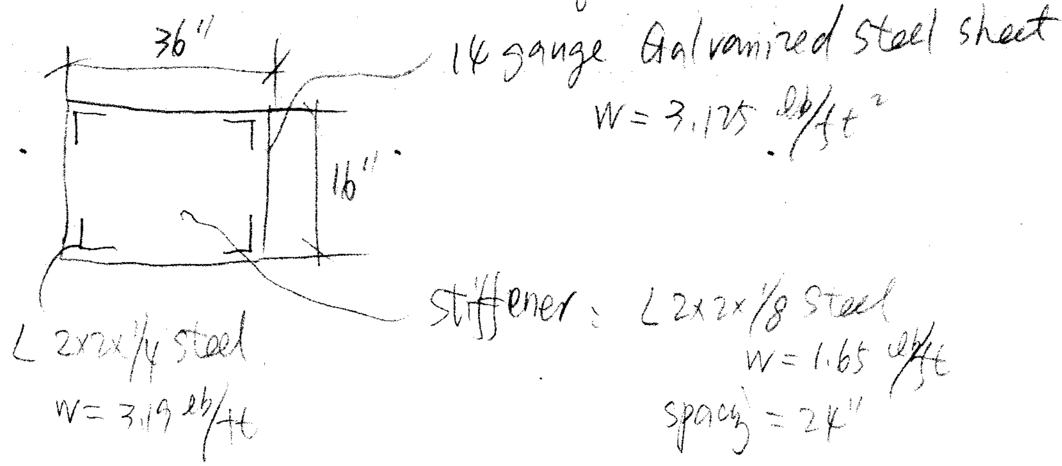
$R_3 = 3765.2$ lbs

when $L = 5ft$ $R_1 = 1250.4$ lbs

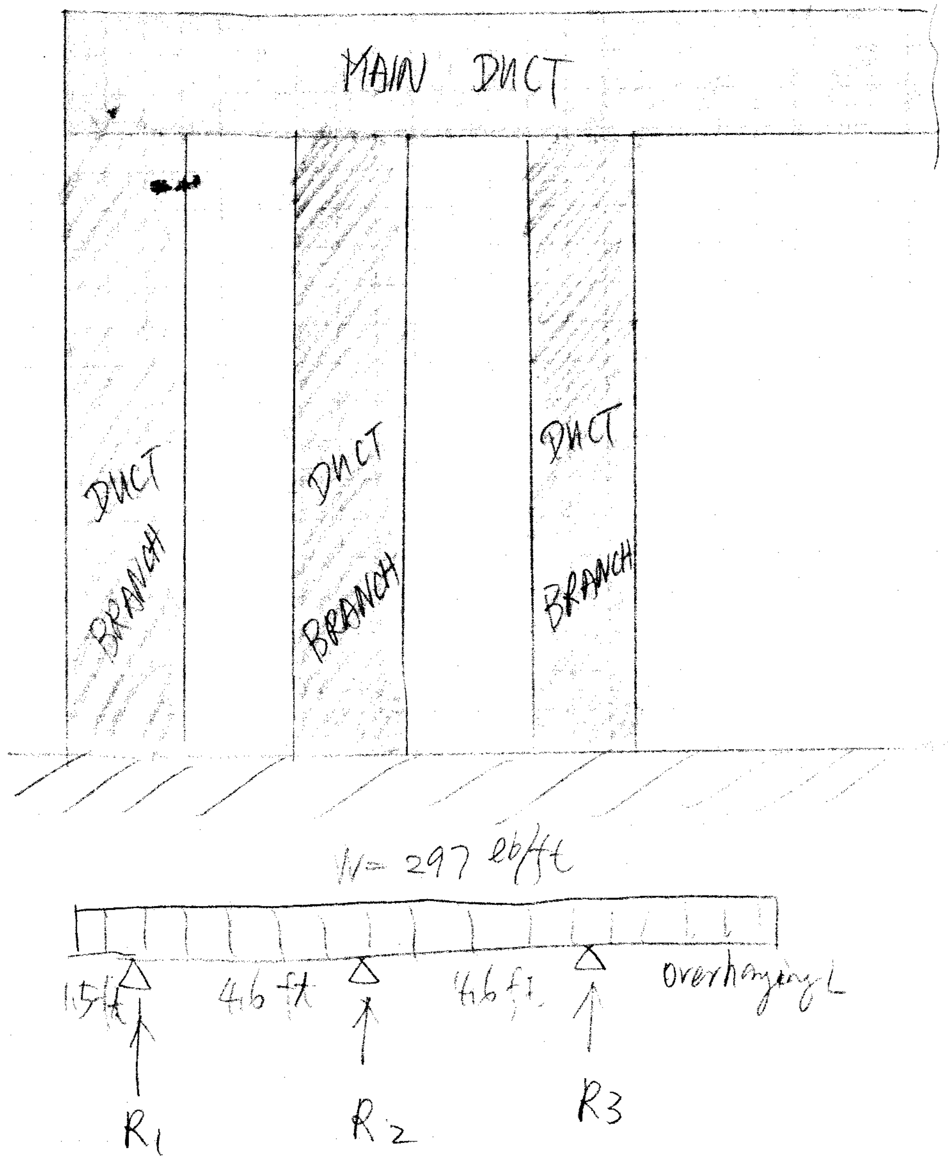
$R_2 = 388.20$ lbs (No up lifting)

$R_3 = 3024.3$ lbs

Consider Column's own weight



3. CHECK BRANCH DUCTS AS MAIN DUCT'S SUPPORTS




From Ansys, know:

when $L = 20$ ft $\quad R_1 = 4276.9$ lbs

$R_2 = -17771$ lbs (uplifting)

$R_3 = 22612$ lbs N.G

PRINT REACTION SOLUTIONS PER NODE

***** POST1 TOTAL REACTION SOLUTION LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

| NODE | FX | FY | MZ |
|---|---|---|---|
| 2 | 0.0000 | 4276.9 | |
| 3 | | -17771. | |
| 7 | | 22612. | |

TOTAL VALUES

| | | | |
|---|---|---|---|
| VALUE | 0.0000 | 9117.9 | 0.0000 |

Overhanging = 20 ft

PRINT REACTION SOLUTIONS PER NODE

***** POST1 TOTAL REACTION SOLUTION LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

| NODE | FX | FY | MZ |
|---|---|---|---|
| 2 | 0.0000 | 1855.7 | |
| 3 | | -3243.6 | |
| 7 | | 7535.8 | |

TOTAL VALUES

| | | | |
|---|---|---|---|
| VALUE | 0.0000 | 6147.9 | 0.0000 |

overhanging = 10 ft

length of overhanging = 5 ft

Reaction forces 1250.4

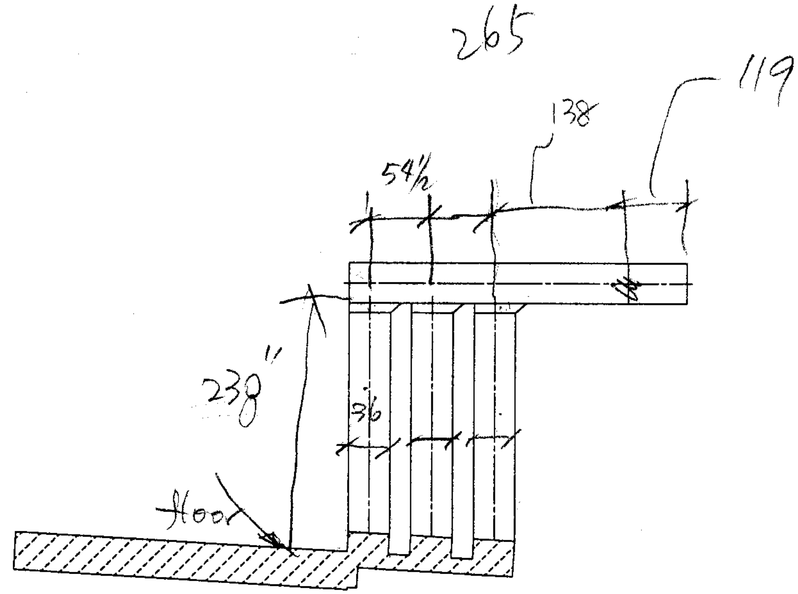
388.20

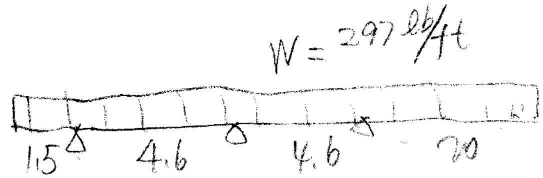
3024.3

| $l$ | $F_1$ | $F_2$ | $F_3$ |
|---|---|---|---|
| 6 | 1339.2 | -144.46 | 3765.2 |
| 7 | 1444.1 | -773.98 | 4586.8 |
| 8 | | | |
| 9 | | | |
| 10 | | | |

180

238-3/16



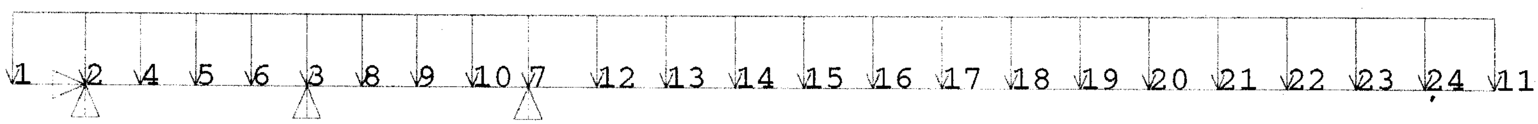
1

ELEMENTS

U

PRES
24.75

AUG 5 2004
10:42:47



Allowable Compressive stress $F_a = C_a F_y$

$= 0.348 \times 33$

$= 11.48$ ksi

Actual $f_a = \frac{F}{A}$ where $F = 5534.25$ lbs

$A = 4.512$ in$^2$

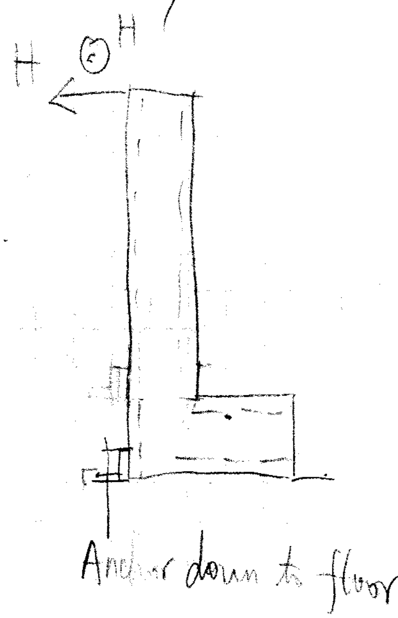
$= \frac{5534.25}{4.512}$

$= 1.226$ ksi $< 11.48$ ksi OK

$SF = \frac{F_a}{f_a} = \frac{11.48}{1.226} = 9.3$

This means the Branch Ducts will safely support the remainder of the Main Duct.

— Design the Branch Duct foot stop bracket due to side way load.




H = 800 lbs

Contractor will weld a angle around the end of the Branch Duct and Anchor the angle down to the floor.

Sheet Products Home | U. S. Steel Home

HR Sheet | CR Sheet | Coated Sheet | Contacts | Glossary | Metric Conversions | Search

Appliance | Automotive | Construction | SCEA | USSI

Sheet Products Home

Coated Sheet

- Hot-Dip Galvanized
- Galvannealed
- ACRYZINC®
- Galvanized Culvert
- GALVALUME®
- ACRYLUME®
- Terne & NI-TERNE
- Electrolytic Zinc & Zinc-Iron Alloy Coated
- Prepainted Coated

**Sheet Products > Coated Sheet > U. S. Steel Hot-Dip Galvanized Sheet > Application Considerations**

Properties | Coating Thickness | Surface Finish | Surface Treatment

## Properties of the Base Steel

U. S. Steel Galvanized Sheet is available in six metallurgical designations, providing different degrees of formability and strength to the base sheet.

**Commercial Steel (CS)**

This designation is for the basic product, useful for many applications requiring the strength of steel combined with the workability needed for bending and moderate forming. It provides the strength and formability levels that most users need for general purpose applications.

CS sheet is subject to a phenomenon called aging; therefore, if the sheet must be free from strain lines (stretcher strains, flutes, etc.) after fabrication, it should be roller leveled just before the forming operation.

**Forming Steel (FS)**

The primary difference between FS and CS sheet is that FS sheet is processed to be more formable, i.e., easier to bend, etc. FS sheet is slightly more formable than CS and is typically used for applications where breakage (splitting) might be encountered when CS sheet is not quite formable enough to make a part. Often, FS is selected to allow easier bending with less springback. FS sheet is produced from specially selected steels, processed for improved and more uniform formability properties.

FS sheet is subject to the same aging phenomenon as CS sheet; therefore, to avoid strain lines, FS sheet should be roller leveled just before the forming operation.

**Deep Drawing Steel (DDS)**

DDS sheet is produced from aluminum-killed steel employing special steelmaking practices. It can be produced using restricted low-carbon steels or interstitial-free steels depending on the application requirement and the producing facility. It has forming characteristics superior to CS and FS sheet. These characteristics make it excellent for applications involving deep drawing or combinations of drawing and stretching.

DDS sheet is non-aging. DDS sheet is recommended for use when improved drawability is required and the effects of aging (slight hardening, loss of ductility, and strain lines) are undesirable or roller-leveling equipment is not available.

**Extra Deep Drawing Steel (EDDS)**

Coated sheet of this quality is characterized by excellent uniformity and exceptional formability. EDDS Sheet is produced from vacuum degassed steel to achieve a very low carbon content. Also, stabilizing elements such as titanium and niobium (columbium) are added during steel production to combine with the residual amounts of carbon and nitrogen remaining in the degassed steel to make it "interstitial-free". The final product is excellent for deep drawn parts in that the sheet exhibits a high resistance to thinning during drawing.

EDDS Sheet is non-aging. Thus, coil breaks, strain lines and fluting during fabrication are not encountered.

**Structural Steel (SS)**

SS sheet is recommended for applications in which specific mechanical properties are required for strength in a finished part, usually in load-bearing structures. Orders for SS usually require that minimum yield and tensile strengths be met by the steel producer. The required strength level is achieved through the use of carbon, manganese, phosphorus, and/or nitrogen additions during steelmaking. When specifying a SS grade, the user should carefully consider the compatibility of the specified properties with forming requirements. *In general, steels produced to meet increasing yield strength levels have a corresponding decrease in ductility or formability.*

**High Strength Low Alloy (HSLA) Steel**

HSLA steel sheet is defined as having a specified minimum yield strengths of 35 ksi or higher. HSLA steels are produced to meet minimum yield and/or tensile strength levels. Often, these steels are intended for applications that require more ductility (% elongation) and/or weldability than Structural Steels. For this reason, they are generally produced using micro-alloying technology wherein additions of elements such as titanium, niobium (columbium) and vanadium are added during steelmaking. The most common types of HSLA steel sheets exhibit yield strengths in the range of 35 to 70 ksi. Typically, the tensile strength is 10 to 15 ksi higher than the yield strength. Higher strength steels are available, but they often exhibit relatively low formability.

**ASTM References for Hot-Dip Galvanized Sheet**

The general requirements, including tolerances for thickness, width, camber, shape, etc., for hot-dip galvanized sheet are presented in ASTM Specification A924. Specific product designations for hot-dip coated galvanized sheet are listed in ASTM Specification A653. Included in this specification are steel chemistry requirements, typical mechanical properties for the general grades CS, FS, DDS, and EDDS designations, strength and formability requirements for SS and HSLAS steels, and coating weight requirements for the different coating designations.

The following table contains **typical** values for U. S. Steel product when purchased to the above-listed designators. These numbers represent typical data. A broad range can be expected because the final sheet thickness has a significant influence on the mechanical properties and formability. *Normally, the yield strength value tends to increase and the formability values tend to decrease as the steel sheet thickness decreases.*

**Typical Mechanical Properties* for U. S. Steel Hot-Dip Galvanized Sheet**

| Steel Designation | Yield Strength (ksi) | Tensile Strength (ksi) | Elongation (%) | Hardness $R_B$ | Plastic Strain Ratio $r_m$ |
|---|---|---|---|---|---|
| CS | 48 | 59 | 28 | 62 | 1.0 |
| FS | 40 | 53 | 31 | 55 | 1.0 |
| DDS | 26 | 48 | 38 | 46 | 1.6 |
| EDDS | 22 | 44 | 42 | 41 | 1.7 |

*The typical mechanical property values presented in this table are nonmandatory. They are intended solely to provide the purchaser with as much information as possible to make an informed decision on the steel to be specified. Since the mechanical properties often vary as a function of steel thickness, the yield strength for thicker steels may be lower than the number listed; similarly, the yield strength for thinner sheets may be higher than this number.

**Mechanical Property Requirements for ASTM A653 Structural Steel Grades (Minimum Values)**

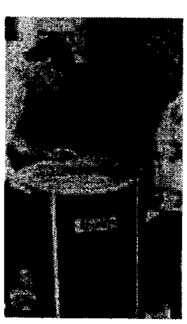
| Grade | Yield Strength (ksi) | Tensile Strength (ksi) | Elongation (%) |
|---|---|---|---|
| 33 | 33 | 45 | 20 |
| 37 | 37 | 52 | 18 |
| 40 | 40 | 55 | 16 |
| 50 A Class 1 | 50 | 65 | 12 |
| 50 B Class 2 | 50 | ··· | 12 |
| 50 Class 3 | 50 | 70 (B) | 12 |
| 80 | 80 | 82 (A) | ··· |

Where an ellipsis (···) appears in the table, there is no requirement.

A - For sheet thicknesses of 0.028 and thinner, no tension test is required if the hardness result is Rockwell B 85 or greater.
B - As there is no discontinuous yield curve, the yield strength should be taken as the stress at 0.5% elongation under load or 0.2% offset.

## Coating Thickness

Coating thickness (measured as coating weight in ounces per square foot or grams per square meter) is an important factor in the effective application of galvanized sheet. The coating weight should be chosen carefully, with full attention to the fabrication method and type of environment in which the sheet will be expected to serve. In general, the effectiveness of the zinc coating to protect the steel substrate from corrosion in any given environment is directly proportional to the coating thickness. For example, for any specific set of environmental conditions, a G90 coating will last about 50 percent longer than a G60 coating, maintenance, painting and all other factors being equal.



Factors in addition to corrosion resistance must be considered when selecting coating thickness. For example, the adherence of the coating generally is inversely proportional to the thickness; therefore, a thin coating is more desirable for applications involving high amounts of forming. Also, spot welding becomes more difficult as the coating thickness increases.

**Coating Thickness - English Units**

| ASTM A653 Coating Designation1) | Minimum Coating Weight oz/sq ft | | |
|---|---|---|---|
| | Triple Spot Average Total Both Sides (2) | Single Spot Test | |
| | | One Side | Total Both Sides |
| G210 | 2.10 | 0.72 | 1.80 |
| G185 | 1.85 | 0.64 | 1.60 |
| G165 | 1.65 | 0.56 | 1.40 |
| G140 | 1.40 | 0.48 | 1.20 |
| G115 | 1.15 | 0.40 | 1.00 |
| G90 | 0.90 | 0.32 | 0.80 |
| G60 | 0.60 | 0.20 | 0.50 |
| G40 | 0.40 | 0.12 | 0.30 |
| G30 | 0.30 | 0.10 | 0.25 |

**Coating Thickness - English Units**

| Coating Designation (1,3) | Minimum Coating Weight g/sq m (4) |
|---|---|
| G20/20 | 20 |
| G40/40 | 40 |
| G50/50 | 50 |
| G60/60 | 60 |
| G70/70 | 70 |
| G90/90 | 90 |
| G98/98 | 98 |

1. The coating designation number is the term by which this product is ordered.

2. The weight of coating in oz. per sq. ft. refers to the total coating on both surfaces. The triple spot average encompasses an edge-center-edge sampling to determine adequate coverage across the sheet width. Typically, about half this coating is on each side.

3. Ordered coating weight is specified on a per-side basis, e.g., 50/50 requires each surface to have a minimum coating weight of 50 g/m$^2$.

4. To convert coating weight from oz/sq ft to g/sq m the following factor can be used: g/sq m = oz/sq ft x 305.15.

*Note that, although a precise conversion between ASTM A653 "G" categories (G30, G60, etc.) and the metric categories (20/20, 40/40, etc.) cannot be made, a G60 coating category (ASTM A653) is approximately equal to a 90/90 coating category (metric).*

## Surface Finish

The hot dip galvanizing process results in a zinc coating with a crystalline structure that is clearly visible on the surface after coating. When the as-coated surface consists of large, multi-faceted grains, the finish is termed "spangled". In today's market, this large spangled appearance is called "Regular Spangle". Typically, the spangled finish has some amount of surface relief caused by the normal behavior of most metals, they shrink when they solidify.

For some applications, especially when the sheet will be painted, the spangled pattern may be undesirable for reasons of appearance or incomplete paint coverage at the spangle boundaries. If so, the size of the spangles can be controlled.

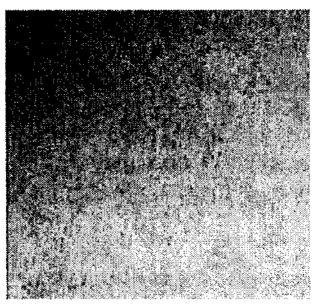
U.S. Steel supplies galvanized sheet with several different degrees of spangle appearance.

### Regular Spangle Sheet

Regular Spangle Sheet has a pattern that occurs from the normal solidification step during the hot-dip process. The coating bath of molten zinc contains small amounts of chemical elements that induce the formation of the spangled finish as the coating freezes in the cooling tower above the coating bath. These large, bright spangles are clearly visible. They provide the readily-recognized, faceted, metallic surface finish of galvanized sheet. Regular Spangle finish has a discernible amount of surface relief.

The spangle size is typically not a function of the coating thickness. Large spangles can form on both light and heavy coating-weight product. In general, however, heavier coating weights result in more surface relief at the spangle boundaries although the spangle size also affects the amount of surface relief.

### Minimum Spangle Galvanized Sheet



Minimum Spangle Galvanized Sheet has a finish in which the individual spangles are very small, often barely visible. The small spangles have much less surface relief than Regular Spangle product. Typically, this finish provides a good surface for application of paint when minimal spangle show-through is desired. In addition, the reduced amount of surface relief associated with Minimum Spangle vs. Regular Spangle allows more complete paint coverage (less tendency for small paint skips) when painting is done on a coil-paint line.

The Minimum Spangle finish can be produced by several methods. One involves blowing either a water/air or steam/air mixture against the molten zinc surface just ahead of the time that the coating solidifies. Another common method of production involves blowing zinc dust against the molten zinc just ahead of the point where solidification begins. In both methods, the spangle size is reduced by increasing the rate of nucleation as the zinc solidifies.

During the past 10 years, there has been an increasing need for minimum- to non-spangled galvanized sheet. This need combined with new technology in the production of zinc metal used for galvanizing has led to a **new method of maintaining a small to nonspangled finish.** This method involves the use of zinc coating baths that contain low amounts of impurities that contribute to the spangle pattern during solidification.

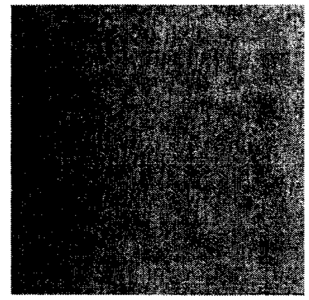
Historically, the most common impurity in zinc metal was lead, at concentrations of about 0.10%, or less, down to 0.03%. The presence of lead in zinc ores was the reason that lead was commonly present in galvanizing baths. As the zinc industry has moved to improved methods of zinc production, lead is no longer a common impurity. As a result, small to non-spangled finishes can be achieved without the need for artificial methods of nucleating grains (water/air spray and /or zinc dust). This method of making a small to non-spangled finish is called the "no-lead" process. When produced by this method, the coating exhibits a bright, reflective appearance.

Because elements such as lead impact the fluidity of the coating bath, another important aspect of the molten coating bath metal, many producers today use a bath composition that has only a very small amount of lead, less than 0.02%, often lower. This small amount of lead enhances the fluidity of the metal to achieve good "air knife wiping action".

U. S. Steel does not add lead to the coating bath. Instead, small amounts of antimony are used to achieve "good wiping action" or to make a spangled finish when needed. Improving the metal fluidity is especially important on lines that process product at low speeds, i.e., less than about 200 feet/minute. Low-speed processing is common for lines that process heavy gauge product. Also, some older light-gauge lines still operate at less than 200 feet/minute.

### Extra Smooth Galvanized Sheet

When a very uniform, smooth, matte finish is required, such as for critical exposed surfaces, both Regular and Minimum Spangle galvanized sheet can be furnished with an Extra Smooth finish. The most common finish combination is Minimum Spangle-Extra Smooth. The "extra smooth" surface is produced by a separate temper rolling operation after coating. Its appearance resembles the matte finish of uncoated cold rolled sheet. The use of Extra Smooth Galvanized Sheet is required when spangle show-through after painting is unacceptable.



## Surface Treatment

U.S. Steel Galvanized Sheet can be specified with five types of surface treatment:

- Chemical Treatment
- Oil
- Chemical Treatment and Oil
- Dry
- Phosphatized

### Chemical Treatment

"Chemical treatment" consists of the application of a thin, relatively invisible, corrosion-inhibiting inorganic chemical film on the zinc surface. This film is applied on the galvanizing line by dipping into (or spraying on) an aqueous solution of corrosion-inhibiting chemicals. The chemically treated surface is much more resistant to "white rust", the corrosion of zinc that typically occurs when the coils or bundles become wet through either water intrusion or condensation during storage or when in transit. White rust, which is simply the white-colored corrosion products of zinc, is also called "humid-storage stain".

Chemical treatment does a superior job of:

- Preventing white rust in coils.
- Maintaining brightness and delaying the onset of darkening (graying) of sheet surfaces upon exposure to the atmosphere.

A word of caution - chemical treatment is not compatible with all pretreatments used on paint lines to produce prepainted sheet. It interferes with good adhesion of the paint. In most cases, galvanized sheet intended for subsequent painting should ***not*** be ordered with chemical treatment.

### Oil

Instead of a chemical treatment, galvanized sheet can be ordered with "oil" to minimize the tendency for humid-storage stain. A thin coat of rust-preventive oil applied at the mill prevents white rust in coils and lifts during transit and short-term high-humidity storage. Oil, unlike chemical treatment, is not intended to delay darkening of the spangled surface upon use. It is generally less effective than chemical treatment as protection against humid-storage staining.

- Oil is very effective for preventing roll pickup during rollforming operations.

- Oil is generally used instead of a chemical treatment to protect the surface when the product is intended to be painted. In these applications, the sheet must be thoroughly cleaned to remove the oil prior to painting.

### Chemical Treatment and Oil

A combination of "chemical treatment and oil" can be specified when the effectiveness of the chemical treatment is desired for humid-storage stain resistance and an oil is needed for enhanced formability. Also, the application of oil over the chemical treatment provides some enhancement over "chemical treatment only" to resist humid-storage staining.

### Dry

Galvanized sheet is ordered "dry" if neither chemical treatment nor oil is compatible with the customer's requirements. Untreated zinc surfaces are very susceptible to humid-storage stain; moisture intrusion or condensation during shipment or storage will cause white rust. Galvanized sheet produced dry must be transported and stored with special precautions to preserve low-humidity conditions.

### Phosphatized

Any galvanized sheet surface finish, such as Regular Spangle or Minimum Spangle, can be "phosphatized." This product is specially pretreated at the mill to allow the user to paint in the as-received condition. The phosphate coating, which provides enhanced paint adhesion and improved corrosion resistance to the painted sheet, allows the end user to bypass the treatment step in his painting operation. The added corrosion resistance is achieved by an improved protection against undercutting of the paint film during exposure in the atmosphere.

The phosphate treatment is a relatively thick, dense, crystalline deposit of hydrated zinc phosphate compounds on the galvanized surface. After phosphating, the surface has a dull gray appearance.

| |
|---|
| Typical Applications |
| Application Considerations |
| Fabrication Considerations |
| Tolerances |

Return to top

***U. S. Steel Corporate Links***

***Search*** ***Site Map*** ***Contacts*** ***What's New*** ***Steel Links***