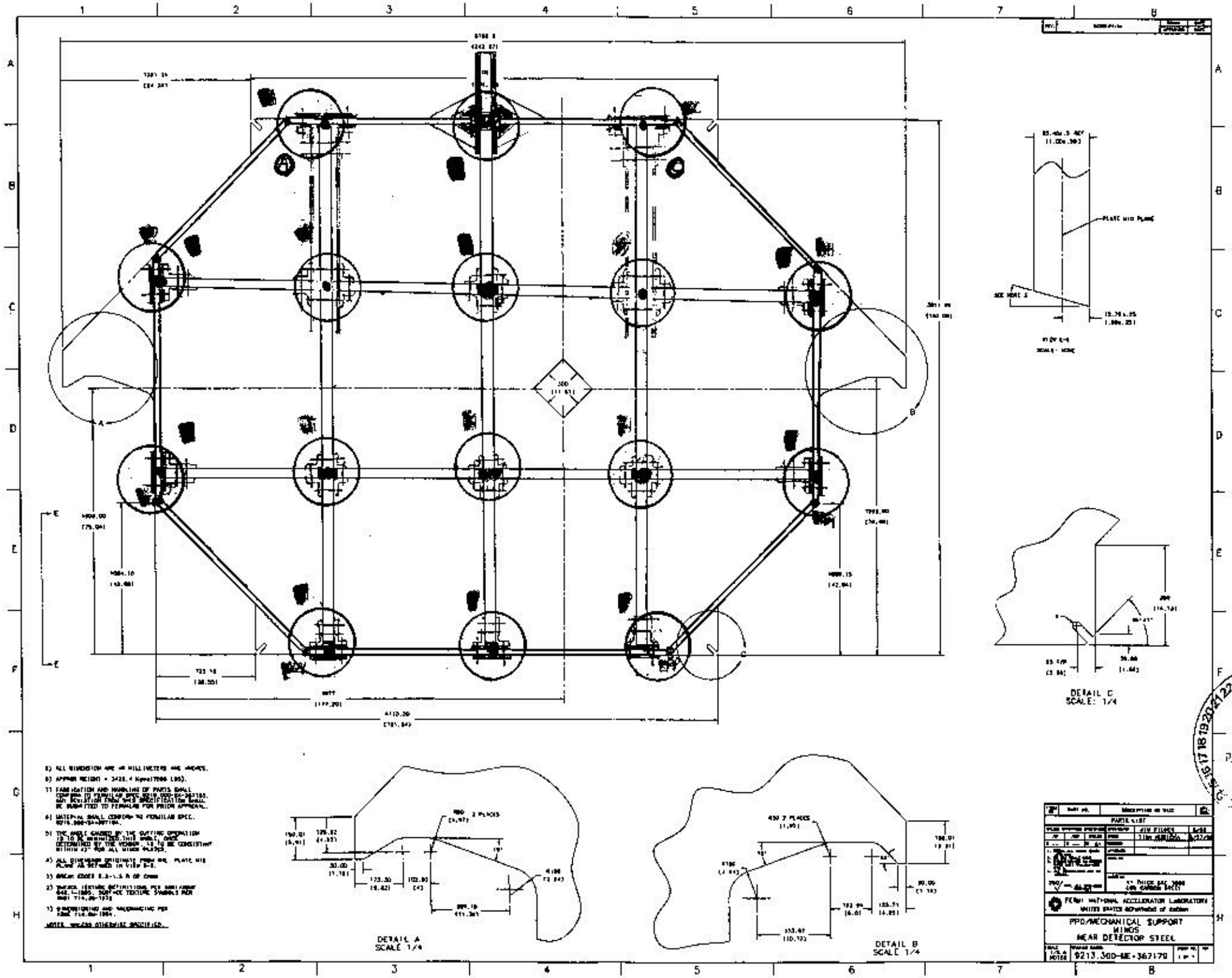

DETAIL A
SCALE 1/4
DETAIL B
SCALE 1/4
DETAIL C
SCALE: 1/4
PARTS LIST
FERMI NATIONAL ACCELERATOR LABORATORY
PPD/MECHANICAL SUPPORT
MINOS
NEAR DETECTOR STEEL
9213.30D-ME-367170
SEP 1998

— [redacted] KEY ELEMENTS AT THE TUBING TO TUBING CONNECTIONS:

[redacted] CC, DD, II, NN, PP, MM & HH

11J	12i	73J	74i
24J	25i	86J	87i
38J	39i	100J	101i
51J	52i	113J	114i

— KEY ELEMENTS AT THE BEAM TO BEAM CONNECTIONS:

E, F, G, J, K & L

244J	284J	253J	293J	262J	302J
245i	285i	254i	294i	263i	303i

— KEY ELEMENTS AT THE TUBING TO BEAM CONNECTIONS

[redacted] N, O, [redacted], [redacted], H & M

171J	141i	273J	313J
202J	203i	234i	274i
233J			

[redacted] KEY ELEMENTS AT PICK UP POINT B

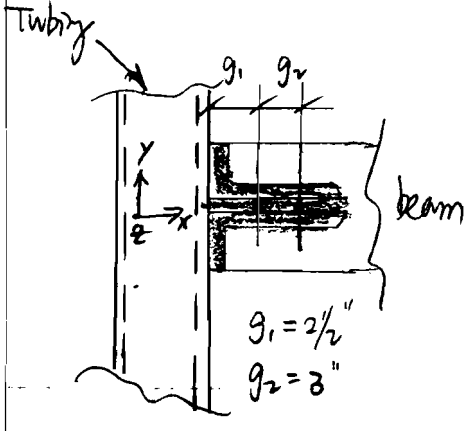
124J 1i

DESIGN CONNECTION AT POINT D, I, N, O, P, M & H.

[redacted]

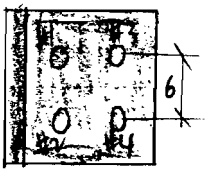
According to Ansys results, the worst combination loads at those points are listed below.

Element 202-0°	$F_x = 6645.8$ lb
Element 141-0°	$F_y = 101.38$ lb
Element 202-90°	$F_z = 653.96$ lb
Element 141-90°	$M_x = 5568.3$ lb-in
Element 273-90°	$M_y = 12354$ lb-in (design for welds)
Element 141-0°	$M_z = 3194.6$ lb-in



Angle : $\angle 4 \times 7 \times \frac{3}{8} \times 8\frac{1}{2}$

Bolt : A325 – $\frac{3}{4}''$ dia – $\frac{13}{16}''$ in holes



Therefore,

Shear in x-direction = 6645.8 lb

Tension in y-direction = 101.38 lb

Shear in z-direction = 653.96 lb

Tension on top bolts caused by M_x

$$\frac{5568.3}{6} = 928.05 \text{ lb}$$

Compression on bottom bolts caused by M_x

$$\frac{5568.3}{6} = 928.05 \text{ lb}$$

Tension on right side bolts caused by M_z

$$\frac{3194.6}{3} = 1064.86 \text{ lb}$$

Compression on left side bolts caused by M_z

$$\frac{3194.6}{3} = 1064.86 \text{ lb}$$

Then,

- Combined shear in x-z plane

$$\sqrt{6645.8^2 + 653.96^2} = 6677.897 \text{ lb}$$

- Combined shear at each bolt

$$\frac{1}{4} \times 6677.897 = 1669.47 \text{ lb}$$

- Combined shear at each connected angle

$$\frac{1}{2} \times 6677.897 = 3338.95 \text{ lb}$$

- Combined Tension/compression on Bolt #1

$$\left(\frac{1}{4} \times 101.38\right) + \left(\frac{1}{2} \times 928.05\right) + \left(\frac{1}{2} \times 1064.86\right) = 1021.8 \text{ lb}$$

- Combined Tension/compression on Bolt #2

$$\left(\frac{1}{4} \times 101.38\right) - \left(\frac{1}{2} \times 928.05\right) + \left(\frac{1}{2} \times 1064.86\right) = 93.75 \text{ lb}$$

- Combined Tension/compression on Bolt #3

$$\left(\frac{1}{4} \times 101.38\right) + \left(\frac{1}{2} \times 928.05\right) - \left(\frac{1}{2} \times 1064.86\right) = -43.06 \text{ lb}$$

- Combined Tension/compression on Bolt #4

$$\left(\frac{1}{4} \times 101.38\right) - \left(\frac{1}{2} \times 928.05\right) - \left(\frac{1}{2} \times 1064.86\right) = -971.1 \text{ lb}$$

Bolts #1 & #2 are critical because they carry the largest tension load.

O FIND THE COMPUTED SHEAR STRESS f_v (ksi)

From Table 1-A, AISC, ASD, page 4-3, knowing

A325 3/4" dia Bolt $\rightarrow$ $A = 0.4418\ in^2$

$f_v = \frac{P}{A}$ where $P = 1669.47\ lb$

$A = 0.4418\ in^2$

$f_v = \frac{1669.47}{0.4418} = 3.778\ ksi$

O FIND THE ALLOWABLE SHEAR STRESS F_v (ksi)

From Table J3.2, AISC, ASD, page 5-73.

when the connection is the bearing type and the threads in the shear plane,

$F_v = 21\ ksi$ —— governs

According to ANSI/ASME B30.20-1993 Below the Hook Lifting Devices, knowing

$F_v = \frac{1}{3} F_y$ where $F_y = 92\ ksi$ for A325

$F_v = \frac{1}{3} \times 92 = 30.6\ ksi$

O FIND THE SAFETY FACTOR ON SHEAR STRESS

$F_v = 21\ ksi$

$f_v = 3.778\ ksi$

$SF = \frac{F_v}{f_v} = \frac{21}{3.778} = 3.2$

○ FIND THE COMPUTED TENSILE STRESS f_t (ksi)

$$f_t = \frac{P}{A} \quad \text{where } P = 1021.8\,lb$$
$$A = 0.4418\,in^2$$

$$f_t = \frac{1021.8}{0.4418} = 2.312 \text{ (ksi)}$$

○ FIND THE ALLOWABLE TENSILE STRESS F_t (ksi)

From Table J3.3, AISC, ASD, page 5-74, knowing, when the connection is the bearing type and the threads in the shear plane,

$$F_t = \sqrt{(44)^2 - 4.39 f_v^2}$$

where $f_v = 3.778$ ksi

$$F_t = \sqrt{44^2 - 4.39 \times 3.778^2} = 43.28 \text{ ksi}$$

According to ANSI/ASME B30.20-1993, Below the Hook Lifting Devices, knowing

$$F_t = \frac{1}{3} F_y \quad \text{where } F_y = 92 \text{ ksi for A325}$$

$$F_t = \frac{1}{3} \times 92 = 30.6 \text{ ksi}$$ — governs

○ FIND THE SAFETY FACTOR ON TENSILE STRESS

$f_t = 2.312$ ksi

$F_t = 30.6$ ksi

$$SF = \frac{F_t}{f_t} = \frac{30.6}{2.312} = 13.2$$

0 FIND THE BOLT BEARING STRESS ON CONNECTING MATERIAL F_p (ksi)

For W12x16:

From Table 1-E, AISC, ASD, page 4-6, knowing

When $t_w = 0.22$, Bearing allowable load per bolt

$52.2 \times 0.22 = 11.484$ kips

From "STRUCTRAL STEEL DESIGN" chapter 18, page 596

knowing.

$$F_p = \frac{P/n}{dt}$$

where P — shear force, lb

n — number of the fastener

t — thickness of the material

d — nominal fastener diameter

When $P = 11.484 \times 10^3$ lb

$n = 1$

$t = 0.22$ in

$d = 0.75$ in

$$F_p = \frac{11.484 \times 10^3 / 1}{0.75 \times 0.22} = 69.6 \text{ ksi}$$

For Angles:

From Table 1-E, AISC, ASD, page 4-6, knowing

when $t = 0.75$, Bearing allowable load per bolt

$52.2 \times 0.75 = 39.15$ kips

$$F_p = \frac{P/n}{dt}$$ when $P = 39.15$ kips

$n = 1$

$d = 0.75$ in

$t = 0.75$ in

$$F_p = \frac{39.15/1}{0.75 \times 0.75} = 69.6 \text{ ksi}$$

According to ANSI/ASME, B30.20 – 1993 Below the Hook Lifting Devices

$$F_p = \frac{1}{3} F_y \quad \text{where } F_y = 36 \text{ ksi for A36}$$

$$F_p = \frac{1}{3} \times 36 = 12 \text{ ksi} \text{ — governs}$$

O FIND THE COMPUTED BOLT BEARING STRESS ON CONNECTING MATERIAL f_p (ksi)

For W12x16. Knowing,

$$f_p = \frac{P/n}{dt}$$

when $P = 6677.9$ lb

$n = 4$

$d = 0.75$ in

$t = 0.22$ in

$$f_p = \frac{6677.9/4}{0.75 \times 0.22} = 10.118 \text{ ksi} \text{ — governs}$$

For Angles, knowing,

$$f_p = \frac{P/n}{dt}$$

when $P = 6677.897$ lb

$n = 4$

$d = 0.75$ in

$t = 0.375 \times 2 = 0.75$ in

$$f_p = \frac{6677.9/4}{0.75 \times 0.75} = 2.967 \text{ ksi}$$

- FIND THE SAFETY FACTOR ON BOLT BEARING STRESS

$f_p = 10.118$ ksi

$F_p = 12$ ksi

$SF = \frac{12}{10.118} = 1.2$

- FIND THE ALLOWABLE SHEAR STRESS ON THE NET AREA OF THE CONNECTION ANGLE R_V (ksi)

According to AISC, ASD, J4, page 4-10, for single angle, knowing:

$R_V = 0.3F_u$ where $F_u = 58$ ksi for A36

$R_V = 0.3 \times 58 = 17.4$ ksi

According to ANSI/ASME, B30.20-1993 Below the Hook Lifting Devices

$R_V = \frac{1}{3}F_y$ where $F_y = 36$ ksi for A36

$R_V = \frac{1}{3} \times 36 = 12$ ksi —— governs

- FIND THE COMPUTED SHEAR STRESS ON THE NET AREA OF THE CONNECTION ANGLE γ_V (ksi)

For single angle.

Shear force $= 3338.95$ lb

$S_{net} = t[L - n(d + \frac{1}{16})]$

$= 0.375 \times [8.5 - 2(0.75 + 1/16)]$

$= 2.578$ in^2

$$\gamma_v = \frac{3338.95}{2.578} = 1.295 \text{ ksi}$$

O FIND THE SAFETY FACTOR ON SHEAR STRESS ON THE NET AREA OF THE CONNECTION ANGLE

$\gamma_v = 1.295$ ksi

$R_v = 12$ ksi

$$SF = \frac{12}{1.295} = 9.3$$

O FIND THE ALLOWABLE BENDING STRESS ON THE NET AREA OF THE CONNECTION ANGLE F_b (ksi)

According to AISC, ASD. page 5-46

For non-compact section angles,

$F_b = 0.60 F_y$ where $F_y = 36$ ksi for A36

$F_b = 0.60 \times 36 = 21.6$ ksi

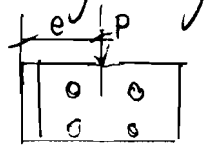
According to ANSI/ASME B30.20-1985 Below the Hook Lifting Devices

$F_b = \frac{1}{3} F_y$ where $F_y = 36$ ksi for A36

$F_b = \frac{1}{3} \times 36 = 12$ ksi —— governs

O FIND THE COMPUTED BENDING STRESS ON THE NET AREA OF THE CONNECTION ANGLE. f_b (ksi).

For single angle,



$P = 3338.95$ lb

$e = 2\frac{1}{2} + 1\frac{1}{2} = 4$ in

$M = Pe$

$= 3338.95 \times 4 = 13355.8$ lb-in

$$S_{net} = \frac{t_p d^2}{6} - \frac{b^2 n (n^2-1)\,[t_p \times (\text{Bolt dia} + 0.125)]}{6d}$$ page 4-88, ASC, ASS

Where t_p = plate thickness, in

d = plate depth, in

n = number of bolts in one vertical row

b = fastener spacing vertically, in

Thus, $t_p = 0.375$ in

$d = 8.5$ in

$n = 2$

$b = 6$ in

$S_{net} = 3.1259$ in^3

$$f_b = \frac{M}{S_{net}} = \frac{13355.8}{3.1259} = 4.272 \text{ ksi}.$$

O FIND THE SAFETY FACTOR ON BENDING STRESS ON THE NET AREA OF THE CONNECTION ANGLE.

$f_b = 4.272$ ksi

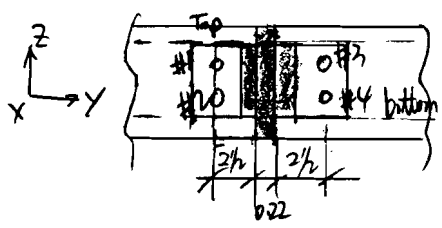
$F_b = 12$ ksi

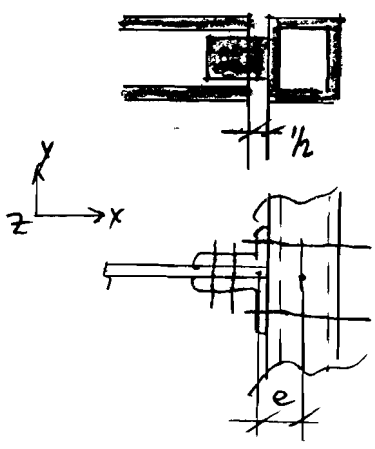
$$SF = \frac{12}{4.272} = 2.8$$

[redacted]

According to Ansys results, the worst combination loading condition at those points are listed below

Element 202 – 0°	$F_x = 6645.8$ lb
Element 141 – 0°	$F_y = 101.38$ lb
Element 202 – 90°	$F_z = 653.96$ lb
Element 141 – 90°	$M_x = 5568.3$ lb-in
Element 273 – 90°	$M_y = 12354$ lb-in (design for welds)
Element 141 – 0°	$M_z = 3194.6$ lb-in





DUE TO THE ECCENTRICITY:

1) Tension / compression caused by F_y

$$F_y \times e = T \times d$$

where $e = \frac{1}{2} \times (4) + \frac{1}{2}(0.375)$

$= 2.1875$ in

$d = 2 \times 2\frac{1}{2} + 0.22$

$= 5.22$ in

$F_y = 101.38$ lb

$$T = \frac{F_y e}{d} = \frac{101.38 \times 2.1875}{5.22}$$

$= 42.48$ lb

2) Tension / compression caused by F_z.

$$F_z \times e = T' \times d$$

where $F_z = 653.96$ lb

$e = 2.1875$ in

$d = 6$ in

$$T' = \frac{F_z \times e}{d} = \frac{653.96 \times 2.1875}{6} = 238.4229 \text{ lb}$$

In addition to above. loading also occurs:

Tension in x-direction = 6645.8 lb

Shear in y-direction = 101.38 lb

Shear in z-direction = 653.96 lb

Shear caused by M_x = $\frac{5568.3}{(2\frac{1}{2}+0.22+2\frac{1}{2})}$ = 1066.72 lb

Tension on the left bolts caused by M_z

$$\frac{3194.6}{(2\frac{1}{2}+0.22+2\frac{1}{2})} = 614.34 \text{ lb}$$

Compression on the right side bolts caused by M_z

$$\frac{3194.6}{(2\frac{1}{2}+0.22+2\frac{1}{2})} = 614.34$$

Therefore:

— Combined shear in z-direction

$$653.96 + 1066.72 = 1720.68 \text{ lb}$$

— resultant shear in y-z plane

$$\sqrt{1720.68^2 + 101.38^2} = 1723.66 \text{ lb}$$

- Combined Tension / compression on Bolt #1

$$\left(\tfrac{1}{4}\times 42.48\right) - \left(\tfrac{1}{4}\times 238.4229\right) + \left(\tfrac{1}{4}\times 6645.8\right) + \left(\tfrac{1}{2}\times 614.34\right)$$

$$= 1930.25 \text{ lb}$$

- Combined Tension / compression on Bolt #2

$$\left(\tfrac{1}{4}\times 42.48\right) + \left(\tfrac{1}{4}\times 238.4229\right) + \left(\tfrac{1}{4}\times 6645.8\right) + \left(\tfrac{1}{2}\times 614.34\right)$$

$$= 2038.84 \text{ lb}$$

- Combined Tension / compression on Bolt #3

$$\left(-\tfrac{1}{4}\times 42.48\right) - \left(\tfrac{1}{4}\times 238.4229\right) + \left(\tfrac{1}{4}\times 6645.8\right) - \left(\tfrac{1}{2}\times 614.34\right)$$

$$= 1284.05 \text{ lb}$$

- Combined Tension / compression on Bolt #4

$$\left(-\tfrac{1}{4}\times 42.48\right) + \left(\tfrac{1}{4}\times 238.4229\right) + \left(\tfrac{1}{4}\times 6645.8\right) - \left(\tfrac{1}{2}\times 614.34\right)$$

$$= 1403.27 \text{ lb}$$

Bolt #1 & #2 are critical because they carry the largest tension load.

- Shear in the bolt

$$\tfrac{1}{4}\times 1723.66 = 430.915 \text{ lb}$$

O FIND THE ALLOWABLE SHEAR STRESS ON THE BOLT F_v (ksi)

From Table J3.2 AISC, ASD, page 5-73, knowing: when connection is the bearing type and threads in the shear plane, knowing

$F_v = 21$ ksi — governs

According to ANSI/ASME B30.20 -1985 Below the Hook Lifting Devices.

$F_v = \frac{1}{3} F_y$. $F_y = 92$ ksi for A325

$F_v = \frac{1}{3} \times 92 = 30.6$ ksi

○ FIND THE COMPUTED SHEAR STRESS f_v (ksi)

From Table I-A AISC, ASD, page 4-3

knowing: A325 Bolt $\rightarrow$ $A = 0.4418$ in^2

Thus, $f_v = \frac{430.915}{0.4418} = 0.975$ (ksi)

○ FIND THE SAFETY FACTOR ON BOLT SHEAR STRESS

$f_v = 0.975$ (ksi)

$F_v = 21$ (ksi)

$SF = \frac{21}{0.975} = 21.5$

○ FIND THE ALLOWABLE TENSION STRESS ON BOLT (F_t) (ksi)

From Table J3.3 AISC, ASD, page 5-74,

When, the connection is bearing type and the threads in the shear plane

$F_t = \sqrt{(44)^2 - 4.39 f_v^2}$

where $f_v = 0.975$ ksi

thus, $F_t = \sqrt{44^2 - 4.39 \times 0.975^2}$

$= 43.95$ ksi

According to ANSI/ASME B30.20-1985 Below the Hook Lifting Devices,

$F_t = \frac{1}{3} F_y$ when $F_y = 92$ ksi for A325

$F_t = \frac{1}{3} \times 92 = 30.6$ ksi — governs

O FIND THE COMPUTED TENSION STRESS ON THE BOLT f_t (ksi)

$$f_t = \frac{2038.84}{0.4418} = 4.614 \text{ ksi}$$

O FIND THE SAFETY FACTOR ON BOLT TENSILE STRESS

$f_t = 4.614$ ksi

$F_t = 30.6$ ksi

$$SF = \frac{30.6}{4.614} = 6.6$$

O FIND THE ALLOWABLE BEARING STRESS ON THE CONNECTING MATERIALS F_p (ksi)

For tubing 12x4,

from Table 1-E, AISC, ASD, page 4-6

when $t = 0.3125 \times 2 = 0.625$ in

Bearing allowable load per bolt is

$$52.2 \times 0.625 = 32.625 \text{ kips}$$

Bearing: $F_p = \dfrac{P/n}{dt}$

where $P = 32.625$ kips

$n = 1$

$d = 0.75$ in

$t = 0.625$ in

$$F_p = \frac{32.625}{0.75 \times 0.625} = 69.6 \text{ ksi}$$

For Angles,

$t = 0.375$ in

From Table 1-E, AISC, ASD page 4-6

when $t = 0.375$ in, Bearing allowable load per bolt is $52.2 \times 0.375 = 19.575$ kips

Bearing: $F_p = \dfrac{P/n}{dt}$

where $P = 19.575$ kips

$n = 1$

$d = 0.75$ in

$t = 0.375$ in

$$F_p = \frac{19.575}{0.75 \times 0.375} = 69.6 \text{ ksi}$$

According to ANSI/ASME B30.20-1993, Below the Hook Lifting Devices

$F_p = \frac{1}{3} F_y$ where $F_y = 36$ ksi for A36

$F_p = \frac{1}{3} \times 36 = 12$ ksi ——— governs

O FIND THE COMPUTED BOLT BEARING STRESS ON CONNECTING MATERILS f_p (Ksi)

For tubing 12x4:

$$f_p = \frac{P/n}{dt}$$

"STRUCTURAL STEEL DESIGN"
chap. 18. page 596

where n — number of the Bolts
d — nominal fastener diameter
t — the thickness of the material

knowing. $P = 1723.66$ lb
$n = 4$
$d = 0.75$ in
$t = 0.625$ in

then $f_p = \dfrac{1723.66/4}{0.75 \times 0.625} = 0.919$ ksi

For Angle (single Angle)

$$f_p = \frac{P/n}{dt}$$

where $P = \dfrac{1723.66}{2} = 861.83$ lb
$n = 2$
$d = 0.75$
$t = 0.375$

then $f_p = \frac{P/n}{dt}$

$$= \frac{861.83/2}{0.75 \times 0.375} = 1.532 \text{ ksi} - \text{governs}$$

O FIND THE SAFETY FACTOR ON BOLT BEARING STRESS

$f_p = 1.532$ ksi

$F_p = 12$ ksi

$$SF = \frac{12}{1.532} = 7.8$$

O FIND THE ALLOWABLE SHEAR STRESS ON THE NET AREA OF THE CONNECTION ANGLE R_v (ksi)

According to AISC. ASD, J4, page 4-10.

$R_v = 0.3 F_u$ for single angle

Where $F_u = 58$ ksi for A36

thus $R_v = 0.3 \times 58 = 17.4$ ksi

According to ANSI/ASME B30.20-1985 Below the Hook Lifting Devices

$R_v = \frac{1}{3} F_y$ where $F_y = 36$ ksi for A36

$R_v = \frac{1}{3} \times 36 = 12$ ksi —— governs

○ FIND THE COMPUTED SHEAR STRESS ON THE NET AREA OF THE CONNECTION ANGLE γ_v (ksi)

For single angle,

$$\text{shear force} = \frac{1}{2} \times 1723.66 = 861.83 \text{ lb}$$

$$\text{net area} = t\left[L - n\left(d + \frac{1}{16}\right)\right]$$

$$= 0.375 \times \left[8.5 - 2\left(0.75 + \frac{1}{16}\right)\right]$$

$$= 2.578 \text{ in}^2$$

$$\gamma_v = \frac{861.83}{2.578} = 0.334 \text{ ksi}$$

○ FIND THE SAFETY FACTOR ON SHEAR STRESS ON THE NET AREA OF THE CONNECTION ANGLE

$$\gamma_v = 0.334 \text{ ksi}$$

$$R_v = 12 \text{ ksi}$$

$$SF = \frac{12}{0.334} = 36$$

○ FIND THE ALLOWABLE BENDING STRESS ON THE NET AREA OF THE CONNECTION ANGLE.

According to AISC, ASD, page 5-46

For non-compact section angles,

$F_b = 0.60\,F_y$ When $F_y = 36$ ksi for A36

$$F_b = 0.60 \times 36 = 21.6 \text{ ksi}$$

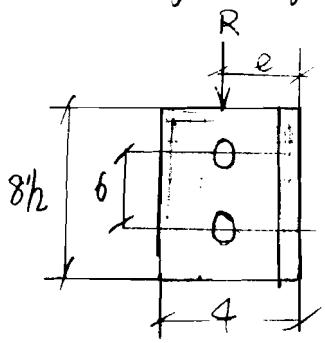
According to ANSI/ASME B30.20 – 1983 Below the Hook Lifting Devices

$$F_b = \frac{1}{3}F_y \quad \text{when } F_y = 36 \text{ ksi for A36}$$

$$F_b = \frac{1}{3} \times 36 = 12 \text{ ksi} \quad \text{——— governs}$$

○ FIND THE COMPUTED BENDING STRESS ON THE NET AREA OF THE CONNECTION ANGLE.

For single angle,



$M = R \times e$

where $R = 861.83$ lb

$e = 2\frac{1}{2}$ in

$M = 861.83 \times 2.5 = 2154.6$ lb-in

$S_{net} = 3.1259 \text{ in}^3$

$$f_b = \frac{M}{S_{net}} = \frac{2154.6}{3.1259} = 0.689 \text{ ksi}$$

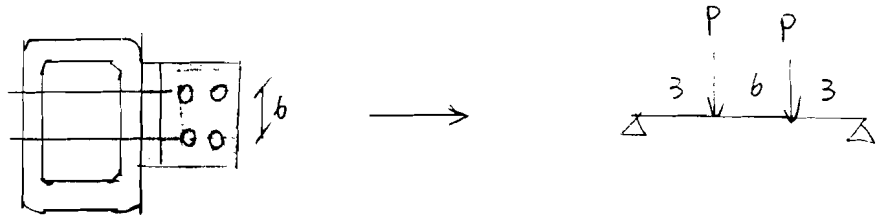
○ FIND THE SAFETY FACTOR ON BENDING STRESS ON THE NET AREA OF THE CONNECTION ANGLE.

$f_b = 0.689$ ksi

$F_b = 12$ ksi

$$SF = \frac{12}{0.689} = 17.4$$

— CHECK THE DEFLECTION ON SIDE WALL OF 12x4 TUBING:



From previous study, knowing $P = 2038.84\ lb$

According to AISC, ASD, Beam Diagrames, page 2-298, knowing. The maximum deflection at center is

$$\Delta_{max} = \frac{Pa}{24EI}(3l^2 - 4a^2)$$

where $P = 2038.84\ lb$

$a = 3\ in$

$E = 29 \times 10^6$

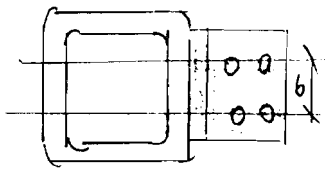
$I = \frac{bh^3}{12} = \frac{4 \times (0.3125)^3}{12} = 0.010\ in^4$

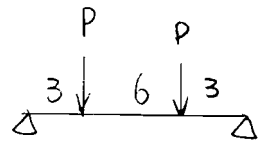
$l = 12\ in$

$$\Delta_{max} = \frac{2038.84 \times 3}{24 \times 29 \times 10^6 \times 0.010}(3 \times 12^2 - 4 \times 3^2)$$

$$= 0.348\ in$$

— CHECK THE BENDING STRESS ON SIDE WALL OF 12x4 TUBING





From previous study, knowing $P = 2038.84$ lb

According to AISC, ASD, Beam Diagrams, page 2-298, knowing, the maximum moment between the loads is

$$M_{max} = Pa$$

where $P = 2038.84$ lb

$a = 3$ in

$$M_{max} = 2038.84 \times 3 = 6116.52 \text{ lb-in}$$

According to ANSI/ASME, B30.20-1998. Below the Hook Lifting Devices, knowing, the allowable bending stress is $\frac{1}{3}F_y$. where $F_y = 36$ ksi for A36.

therefore, $f_b = \frac{1}{3} \times 36 = 12$ ksi

- FIND THE REQUIRED SECTION MODULUS S_x (in^3)

$$F_b = \frac{M}{S_x} \longrightarrow S_x = \frac{M}{f_b}$$

where $M = 6116.52$ lb-in

$f_b = 12000$ psi

$$S_X = \frac{6116.52}{12000} = 0.510 \text{ in}^3$$

Knowing: the tubing wall section modulus is

$$(S_X)_{wall} = \frac{bh^2}{6}$$

where $b = 4$ in

$h = 0.3125$ in

$$(S_X)_{wall} = \frac{4 \times 0.3125^2}{6} = 0.065 \text{ in}^3$$

Therefore:

$$\Delta S_X = S_X - (S_X)_{wall}$$

$$= 0.510 - 0.065 = 0.445 \text{ in}^3$$

O FIND THE PLATE THICKNESS DUE TO THE REQUIRED SECTION MODULUS ΔS_X.

Knowing $\Delta S_X = 0.445 \text{ in}^3$

$$\Delta S_X = \frac{bh^2}{6}$$

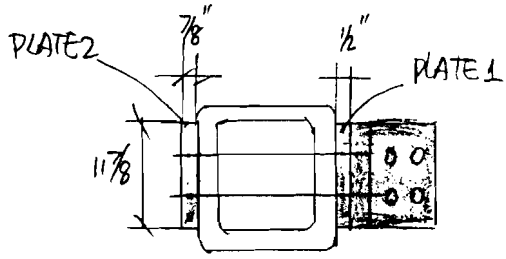
where $b = 4$ in

$\Delta S_X = 0.445 \text{ in}^3$

$$h = \sqrt{\frac{6 S_X}{b}} = \sqrt{\frac{6 \times 0.445}{4}} = 0.817$$

use 7/8" plate

– CHECK THE DEFLECTION AFTER ADDING THE PLATE.



From previous study, knowing:

$$\Delta_{max} = \frac{Pa}{24EI}(3l^2 - 4a^2)$$

where $P = 2038.84$ lb

$a = 3$ in

$E = 29 \times 10^6$

$$I = \frac{bh^3}{12} = \frac{4 \times (0.312^3 + 0.875^3)}{12} = 0.23 \text{ in}^4$$

$l = 12$ in

$$\Delta_{max} = \frac{2038.84 \times 3}{24 \times 29 \times 10^6 \times 0.233} \times (3 \times 12^2 - 4 \times 3^2)$$

$$= 0.015 \text{ in}$$

The allowable deflection is

$$\frac{l}{480} = \frac{12}{480} = 0.025 \text{ in}$$

$$SF = \frac{0.025}{0.015} = 1.7.$$

The sketch shown above is acceptable.

According to suggested assembly torque value for Bolt 3/4" A325 to produce corresponding Bolt load, knowing the clamp load is 21300 lb.

Therefore, the required the torque needs to be investigated.

From previous study, knowing:

$$\Delta_{max} = \frac{Pa}{24EI}(3l^2-4a^2)$$

then $$P = \frac{\Delta_{max}\, 24EI}{a(3l^2-4a^2)}$$

When $\Delta_{max} = \frac{l}{180} = \frac{12}{180} = 0.067$ in

$E = 29\times10^6$

$I = \frac{bh^3}{12} = \frac{4\times(0.312^3+0.875^3)}{12} = 0.23\ in^4$

$l = 12$ in

$a = 3$ in

$$P = \frac{0.067\times24\times29\times10^6\times0.23}{3(3\times12^2-4\times3^2)}$$

$= 8983$ lb

SUGGESTED ASSEMBLY TORQUE VALUES* TO PRODUCE CORRESPONDING BOLT LOADS

SIZE	BASIC MAJOR DIA.	STRESS AREA H-28 1957	Tensile Strength (T) Min. PROOF LOAD (P) P.S.I. SAE GRADE (1957)				SAE GRADE 2.		
							CLAMP LOAD (LBS)	ASSEMBLY TORQUE	
			2 T/P	5 T/P	7 T/P	8 T/P		DRY R=.200	LUB. R=.150
4-40	.1120	.00604	[illegible]	[illegible]	[illegible]	[illegible]	250	5 In Lbs	4 In Lbs
4-48	1120	.00661	"	"	"	"	275	6 "	5 "
6-32	.1380	.00909	"	"	"	"	375	10 "	8 "
6-40	.1380	.01015	"	"	"	"	420	12 "	9 "
8-32	1640	.01400	"	"	"	"	580	19 "	14 "
8-36	1640	.01474	"	"	"	"	610	20 "	15 "
10-24	1900	.01750	"	"	"	"	725	27 "	21 "
10-32	1900	.02000	"	"	"	"	825	31 "	23 "
1/4-20	.2500	.0318	"	"	"	"	1320	66 "	50"
1/4-28	.2500	.0364	"	"	"	"	1500	76 "	56 "
5/16-18	.3125	.0524	"	"	"	"	2160	11 Ft Lbs	8 Ft Lbs
5/16-24	.3125	.0580	"	"	"	"	2400	12 "	9 "
3/8-16	.3750	0775	"	"	"	"	3200	20 "	15 "
3/8-24	3750	0878	"	"	"	"	3620	23 "	17 "
7/16-14	.4375	1063	"	"	"	"	4390	32"	24 "
7/16-20	4375	.1187	"	"	"	"	4900	36"	27 "
1/2-13	.5000	.1419	"	"	"	"	5850	50 "	35 "
1/2-20	.5000	.1599	"	"	"	"	6600	55 "	40 "
9/16-12	.5625	.1820	"	"	"	"	7500	70"	55"
9/16-18	.5625	.2030	"	"	"	"	8400	80"	60"
5/8-11	.6250	.2260	"	"	"	"	9350	100"	73"
5/8-18	.6250	.2560	"	"	"	"	10550	110"	85"
3/4-10	.7500	.3340	"	"	"	"	13800	175"	130"
3/4-16	7500	.3730	"	"	"	"	15400	200"	150"
7/8- 9	.8750	.4620	[illegible]	"	"	"	11450	170"	125"
7/8-14	.8750	.5090	"	"	"	"	12600	180"	140"
1- 8	1.0000	.6090	"	"	"	"	15000	250"	190"
1-12	1.0000	.6630	"	"	"	"	16400	270"	210"
1-14	1.0000	.6800	"	"	"	"	16800	280"	210"
1 1/8- 7	1.1250	.7630	"	[illegible]	"	"	18900	350"	270"
1 1/8-12	1.1250	.8560	"	"	"	"	21200	400"	300"
1 1/4- 7	1.2500	.9690	"	"	"	"	24000	500"	380"
1 1/4-12	1.2500	1.0730	"	"	"	"	26600	550"	420"
1 3/8- 6	1.3750	1.1550	"	"	"	"	28600	670"	490"
1 3/8-12	1.3750	1.3150	"	"	"	"	32500	750"	560"
1 1/2- 6	1.5000	1.4050	"	"	"	"	34800	870"	650"
1 1/2-12	1.5000	1.5800	"	"	"	"	39100	980"	730"

SAE GRADE 5			SAE GRADE 8		
CLAMP LOAD (LBS)	ASSEMBLY TORQUE		CLAMP LOAD (LBS)	ASSEMBLY TORQUE	
	DRY R=.200	LUB. R=.150		DRY R=.200	LUB R=.150
380	8 In Lbs	6 In Lbs	540	12 In Lbs	9 In Lbs
420	9 "	7 "	600	13 "	10 "
580	16 "	12 "	820	23 "	17 "
640	18 "	13 "	920	25 "	19 "
900	30 "	22 "	1260	41 "	31 "
940	31 "	23 "	1320	43 "	32 "
1120	43 "	32 "	1580	60 "	45 "
1285	49 "	36 "	1500	68 "	51 "
2000	8 Ft Lbs	75 "	2850	12 Ft Lbs	9 Ft Lbs
2300	10 "	86 "	3250	14 "	10 "
3350	17 "	13 Ft Lbs	4700	25 "	18 "
3700	19 "	14 "	5200	25 "	20 "
4950	30 "	23 "	7000	45 "	35 "
5600	35 "	25 "	7900	50 "	35 "
6500	50 "	35 "	9550	70 "	55 "
7600	55 "	40 "	10650	80 "	60 "
9000	75 "	55 "	12750	110 "	90 "
10250	90 "	65 "	14375	120 "	90 "
11600	110 "	80 "	16375	150 "	110 "
13000	120 "	90 "	18250	170 "	130 "
14400	150 "	110 "	20350	220 "	170 "
16375	150 "	130 "	23000	240 "	150 "
21300	260 "	200 "	30100	350 "	250 "
23500	300 "	220 "	33500	420 "	320 "
29450	430 "	320 "	41600	600 "	460 "
32450	470 "	360 "	45900	660 "	500 "
38600	640 "	480 "	54500	900 "	680 "
42500	710 "	530 "	58700	1000 "	740 "
43400	730 "	540 "	61200	1020 "	760 "
42300	500 "	600 "	66900	1250 "	960 "
47500	580 "	660 "	77000	1440 "	1050 "
53500	1120 "	840 "	87200	1520 "	1360 "
59600	1240 "	920 "	96600	2000 "	1500 "
64.J0	1460 "	1100 "	104000	2380 "	1780 "
73000	1680 "	1260 "	118400	2720 "	2040 "
78000	1940 "	1460 "	126500	3160 "	2360 "
87700	2200 "	1640 "	142200	3560 "	2660 "

NOTES -

1. Clampload =75% x Proof x Stress Area

(*) Depending upon assembly conditions, it may be necessary to adjust suggested torque values to induce recommended clampload

(†) Grade 2 requirements for sizes ¼ thru ½ apply only to bolts and screws 6 inches and shorter in length, and to studs of all lengths. For bolts and screws longer than 6 inches, the values would be T/P 60M/33M

2. Torque (PL) = R D T
R = .200 For Dry Conditions
R = .150 For Lub Conditions
"Lubricated" includes lubricants, lubrizing, plating and hardened washers.
D=Nominal Diameter in inches.
T=Desired Clamp Load in Lbs.

ACI 318-89
ACI 318R-89

Building Code Requirements for Reinforced Concrete

aci

CODE

5 years or more 2.0
12 months 1.4
6 months 1.2
3 months 1.0

COMMENTARY

Equation (9-10) was developed in Reference 9.13. In Eq. (9-10) the multiplier on ξ accounts for the effect of compression reinforcement in reducing long-term deflections, and $\xi = 2.0$ represents a nominal time-dependent factor for 5 years duration of loading. The curve in Fig. 9.5.2.5 may be used to estimate values of ξ for loading periods less than five years.

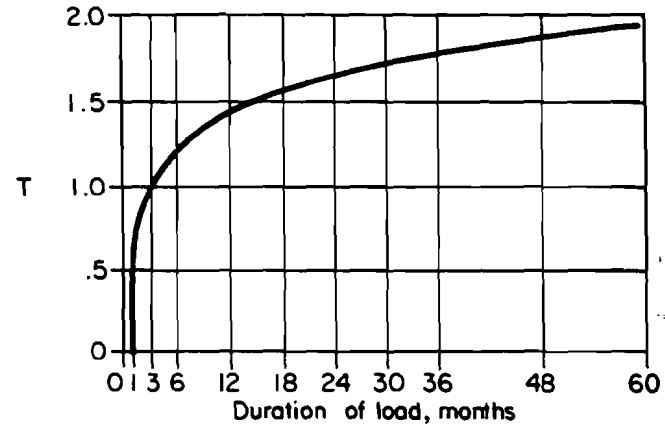


Fig. 9.5.2.5 – Multipliers for long-term deflections

If it is desired to consider creep and shrinkage separately, approximate equations provided in References 9.6, 9.7, 9.13, 9.14 may be used.

9.5.2.6 – Deflection computed in accordance with 9.5.2.2 through 9.5.2.5 shall not exceed limits stipulated in Table 9.5(b).

R9.5.2.6 – It should be noted that the limitations given in this table relate only to supported or attached nonstructural elements. For those structures in which structural members are likely to be affected by deflection or deformation of members to which they are attached in such a manner as to affect adversely the strength of the struc-

TABLE 9.5(b) — MAXIMUM PERMISSIBLE COMPUTED DEFLECTIONS

Type of member	Deflection to be considered	Deflection limitation
Flat roofs not supporting or attached to nonstructural elements likely to be damaged by large deflections	Immediate deflection due to live load L	$\frac{\ell}{180}$*
Floors not supporting or attached to nonstructural elements likely to be damaged by large deflections	Immediate deflection due to live load L	$\frac{\ell}{360}$
Roof or floor construction supporting or attached to nonstructural elements likely to be damaged by large deflections	That part of the total deflection occurring after attachment of nonstructural elements (sum of the long-time deflection due to all sustained loads and the immediate deflection due to any additional live load)‡	$\frac{\ell}{480}$†
Roof or floor construction supporting or attached to nonstructural elements not likely to be damaged by large deflections		$\frac{\ell}{240}$§

*Limit not intended to safeguard against ponding. Ponding should be checked by suitable calculations of deflection, including added deflections due to ponded water, and considering long-term effects of all sustained loads, camber, construction tolerances, and reliability of provisions for drainage.

†Limit may be exceeded if adequate measures are taken to prevent damage to supported or attached elements.

‡Long-time deflection shall be determined in accordance with 9.5.2.5 or 9.5.4.2 but may be reduced by amount of deflection calculated to occur before attachment of nonstructural elements. This amount shall be determined on basis of accepted engineering data relating to time-deflection characteristics of members similar to those being considered.

§But not greater than tolerance provided for nonstructural elements. Limit may be exceeded if camber is provided so that total deflection minus camber does not exceed limit.

According to "Design of Machine Elements" chapter 5. page 276.

Among, Torque Required to produce desired clamping force is

$T = 0.195\,dW$ for A325 unplated & uncoated Bolt

where d = nominal diameter of the Bolt = 0.75 in

W = clamping force = 8983 lb

therefore,

$$T = 0.195\,dW$$
$$= 0.195 \times 0.75 \times 8983$$
$$= 1314 \text{ lb-in}$$

In conclusion, the required torque applied on the bolt mentioned above is 1314 lb-in.

Spotts

Design of Machine Elements

6th Edition

PRENTICE-HALL

Design of Machine Elements

M.F. Spotts

6th Edition

The friction between the threads and between the nut and the abutment depends on a variety of factors, such as surface finish, degree of lubrication, alignment, materials, plating, burrs, and the like. Calculations for the induced force in the bolt will therefore vary as these factors affect the coefficient of friction. The torque wrench, although widely used, is not considered a very reliable means for obtaining an accurate value of the induced force.

A better way is to measure the bolt elongation when this is possible. The angle of twist of the nut can also be used. The nut is first firmly tightened to seat the parts on each other. It is then loosened and made finger-tight. The nut is then turned through a specified angle, which has been calculated to give the desired axial force in the bolt.

10. Torque Required to Produce Desired Clamping Force

Standard bolts with 60° threads are widely used to impart a clamping force. The force W can be determined by the power screw equation (12). For bolts $\frac{1}{2}$ in. diameter and larger, $\theta = 30°$, $\mu_1 = \mu_2$, and data from Table 5-1, the average value of the tightening torque T can be shown to be

Coarse thread, $\mu = 0.15$	$T = 0.195dW$	(19)
Coarse thread, $\mu = 0.10$	$T = 0.135dW$	(20)
Fine thread, $\mu = 0.15$	$T = 0.189dW$	(21)
Fine thread, $\mu = 0.10$	$T = 0.130dW$	(22)

Diameter d in these equations is the major or nominal diameter of the bolt. The radius for the collar was taken as the mean radius between the bolt diameter and the distance across the flats for a hex nut.

Example 6. Determine the torque required to produce a clamping force of 1,500 lb in a $\frac{1}{2}$–13 bolt with 60° threads. Take the collar radius r_c as the mean between bolt radius and radius across the flats for the nut $\mu_1 = \mu_2 = 0.15$.

Work by the exact equation (12) and check by approximate equation (19).

Solution. By Table 5-1: Pitch diameter, $pd = 0.4500$ in.

$$r_t = 0.2250 \text{ in.}$$

$$r_c = \tfrac{1}{4}(0.50 + 0.75) = 0.3125 \text{ in.}$$

Helix angle:

$$\tan\alpha = \frac{p}{\pi\, dp} = \frac{1}{13\pi 0.450} = 0.05441$$

$$\alpha = 3°7'$$

By Eq. (13):

$$\tan\theta_n = \tan\theta\cos\alpha$$

$$= 0.57735 \times 0.99852 = 0.57650$$

$$\theta_n = 29°58'$$

By Eq. (12): T

By Eq. (19): T

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11. Friction of

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12. Stress Con

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[4]See Lambert, T
on the Clamping F
[5]See Hetenyi, M
65, 1943, p. A-93.

[redacted]

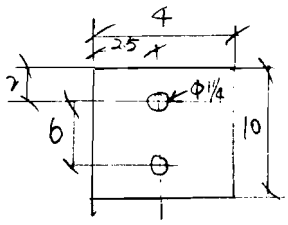


Plate: ½" × 4" × 10" × 14 (each)

[redacted] 2:

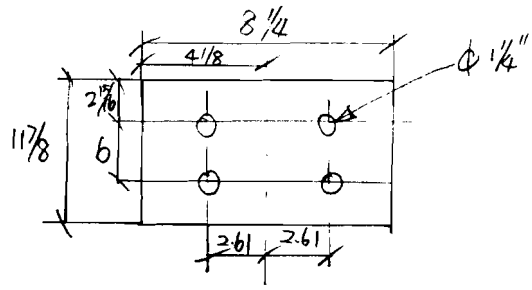


Plate: ⅞" × 8¼ × 11⅞" × 7 (each)

① CHECK THE ASSEMBLING CLEARANCES:

Bolt connected with beam web:

* Bolt: 3/4-10 UNC-2A. type 1. (medium carbon steel)

According to AISC, ASD. 4-142, 143 page. Threaded fasteners

A325 HEAVY HEX HEAD. → HEX HEIGHT 1/2"

* NUT: A194 for grade 2. for Bolt 3/4 dia.

According to AISC, ASD page 4-142, 143. Threaded fasteners.

Hardened nut, Heavy Hex → Height 3/4"

* Flat washer: F436 hardened for Bolt 3/4 dia

According to AISC, ASD page 5-290.

Flat hardened washer → Height 5/32"

* Bolt length:

According to AISC, ASD. Table C2, page 5-290.

Bolt length = the total thickness of all connected material + Grip + washer

Where: the total thickness of all connected material

$= 0.22 + 2 \times 0.375 = 0.97$ in

Grip = 1 in

washer = 5/32 in

therefore,

Bolt length = 0.97 + 1 + 5/32 = 2.126"

↳ 2 1/4" long

Bolts: 3/4 - 10UNC 2A × 2 1/4" long × 4 (each)

[redacted] connected with tubing:

Bolt length = the total thickness of all connected material + Grip + washer

where: the total thickness of all connected material

= 4 + 0.375 + 1/2 + 7/8 = 5.75 in

Grip = 1" (AISC, ASD, Table C2, page 5-290)

washer = 5/32 in

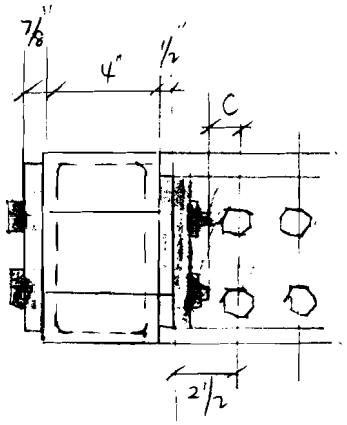
therefore,

Bolt length = 5.75 + 1 + 5/32 = 6.9 in

↳ use 7" long

Bolts: 3/4 - 10UNC 2A × 7" long × 4 (each)

- CHECK THE ASSEMBLING CLEARANCE



According to AISC, ASD, page 4-137 for A325 high strength bolt.

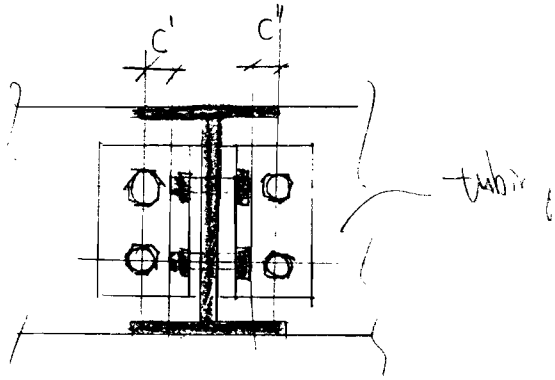
C_1 tightening clearance = 1/4 in

C_2 entering clearance = 3/4 in.

$$C = (2\tfrac{1}{2} + 0.5) - (7 - \tfrac{7}{8} - 4)$$

$$= 0.875 \text{ in} > C_2$$ use open end wrench.

— CHECK THE CLEARANCE FOR ASSEMBLING



According to AISC, ASD, page 4-137, for A325 high strength bolt tighting clearance $C_1 = 1\frac{1}{4}$ in

entering clearance $C_2 = \frac{3}{4}$ in.

$C' =$ Angle gage − the thickness of all connected material − PARTIAL BOLT LENGTH.

$= 2\frac{1}{2} - \frac{3}{8} - (2\frac{1}{4} - 2\times\frac{3}{8} - 0.22)$

$= 0.845'' > C_2$ use open end wrench

$C'' =$ Angle gage − the thickness of all connected material − Bolt Hex Height

$= 2\frac{1}{2} - 0.375 - \frac{1}{2} = 1.625'' > C_1$

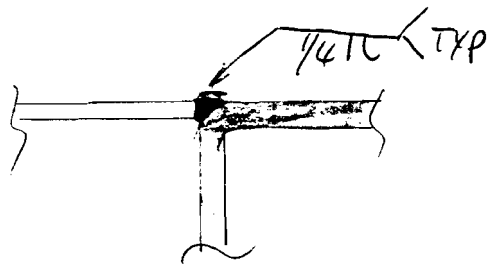
use socket wrench

In conclusion, the connection as sketched is adequate.

– DESIGN THE WELDS FOR MOMENT My

According to AISC, ASD, page 4-173, knowing:

Partial-penetration groove welds is acceptable.



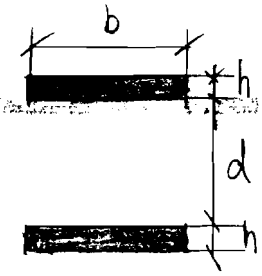
Flare-bevel-groove weld

weld: E70XX

According to Table J2.2, AISC, ASD, page 5-66, knowing for flare bevel groove, the effective throat thickness is 5/16 R.

where $R = 0.468$ in $\quad 5/16\,R = 0.143$ in $\quad$ use 1/4"

According to "Mechanical Engineering Design" Shigley 5th edition, chapter 9, Bending in welded joints, page 396



$$\sigma = \frac{1.414M}{bdh}$$

Where $h = 0.25$ in

$d = 11.99 - 2 \times 0.25 = 11.49$ in

$M = 12354$ lb·in

According to AISC, ASD, Table J2.5, page 5-70, knowing: for partial penetration groove welds under compression normal to effective area, allowable stress on welds is the same as base metal:

therefore, $\sigma = 12000\ psi$

$$b = \frac{1.44\,M}{\sigma d h}$$

$$= \frac{1.414 \times 12354}{12000 \times 11.49 \times 0.25} = 0.51\ in.$$

use 4 in

$$SF = \frac{4}{0.51} = 7.8.$$