SDC SOLENOID DESIGN NOTE # 198 (EAR # 81)

TITLE: Lifting Fixture Calculation for SDC Solenoid Prototype Vacuum Shell

AUTHOR: Ang Lee, Ron Fast and Chuck Grozis

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This design note contains a calculation of the lifting fixture for the SDC Solenoid prototype vacuum shell. Two lifting positions, vertical and horizontal, are considered in this calculation. It is assumed that there are three brackets 2" thick equally spaced around the each bulkhead . The bracket is bolted to the bulkhead by using some of the holes with which the bulkhead and shells are connected together . Total weight of structure is assumed to be 9 metric tones which includes the inner shell, outer shell, bulkhead, fixture and internal cold mass. The calculation result shows that only three 0.5" diameter stainless steel bolts for each bracket are needed to lift the vessel either vertically orhorizontally. In the actual design, a pattern of six bolts (three attached to the inner shell and other three attached to the outer shell) are used for each bracket, giving an additional safety margin*. This calculation also suggested a 0.52 " minimum length engagement of screw threads for the aluminum material (ref. 1). Finally, a conservative calculation shows that a 2" thick steel bracket has acceptable safety margin.

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*Note: according to the Fermilab safety standard for under the hook lifting fixture , the design load has to be 3 times actual load. Therefore, ten 0.5" diameter bolts are needed for each bracket if this rule applies. User should justify his own condition accordingly.

Reference: E. Oberg, F. Jones, H. Horton and H. Ryffel, " Machinery's Handbook", 23rd Edition, Industrial Press Inc. N.Y., 1990, pp 1278-1279

Appendix: Calculation details

A) Bolt Calculation

B) Minimum Length Engagement for Aluminum

C) Bracket Calculation

"F" (.257 ø) DRILL 3/8 DEEP
BOTTOM TAP 5/16-18 UNC
18-HOLES. EQUALLY SPACED

DIA.

270°

90°

180°

60.0°

27.5°

22.5°

25.0°

48.75°

2.5°

ø160.708 B.C.

R74.055±.032

R75.827±.032

ø135.464 B.C.

120.0°(3 PLCS.)

10.0°

2.50°±.05°
NOTE 1

1.25°±.05°
NOTE 1

9/16 DRILL THRU
144 HOLES
NOTES 1, 3

9/16 DRILL THRU
144 HOLES
NOTES 1, 2

ø83.24 MIN. HOLE THRU
TAP M85 x 2 THRU. AFTER
C-BORES, 14 HOLES

DETAIL "B"

A

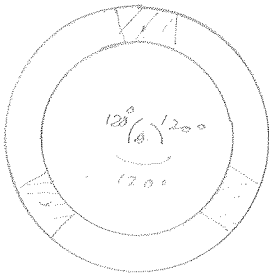
F

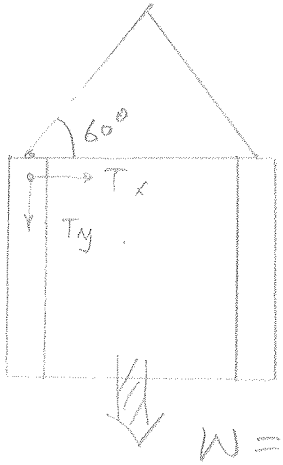
G

32

- 2 -

Appendix A : Bolt Calculation





Assuming: 1): W = 9 (metric Tones)

2): Three bracket equally spaced.

3) Bolt size = 0.5"

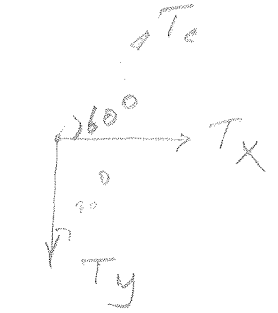
4): Bolt streigth = 75,000 psi

which gives

$\sigma_{(allowable)} = \frac{75000}{4} = 18750$ psi

$\tau_{(allowable)} = \frac{0.4}{0.6} \sigma_{(allowable)} = 12,500$ (psi)

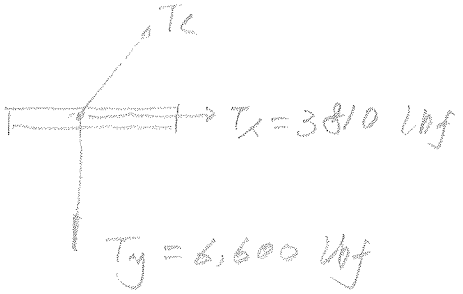
FIND: N (number of bolt needed).



For each Bracket,

$$T_y = \frac{W}{3} = \frac{9 \times 2200}{3} = 6,600 \text{ lbf}$$

$$T_x = \tan 30 \cdot T_y = 3810 \text{ lbf}$$



stress area A_s for the bolt with diameter 0.5"

$$A_s = 0.75 \left(\frac{\pi}{4} \times 0.5^2 \right) = 0.1473 \text{ (in}^2\text{)}$$

For bolt with both tension and shear, a following relation has to be satisfied

$$\left[\frac{\sigma_{(working)}}{\sigma_{(allowable)}} \right]^2 + \left[\frac{\tau_{working}}{\tau_{(allowable)}} \right]^2 \leq 1 \quad (1)$$

For $\sigma_{(working)} = \dfrac{\dfrac{T_N}{A_s}}{N}$

For $\tau_{(working)} = \dfrac{\dfrac{I_x}{A_s}}{N}$

Then Equation 1 can be rewritten as.

$$\left[\frac{\frac{T_N}{A_s \cdot N}}{\sigma_{(allowable)}}\right]^2 + \left[\frac{\frac{I_x}{A_s \cdot N}}{\tau_{(allowable)}}\right]^2 \leq 1$$

OR $$\frac{1}{N^2}\left[\left(\frac{\frac{T_N}{A_s}}{\sigma_{(allowable)}}\right)^2 + \left(\frac{\frac{T_x}{A_s}}{\tau_{(allowable)}}\right)^2\right] \leq 1.$$

$$N \geq \sqrt{\left(\frac{\frac{T_y}{A_s}}{\sigma_{(allowable)}}\right)^2 + \left(\frac{\frac{T_x}{A_s}}{\tau_{(allowable)}}\right)^2}$$

$$= \sqrt{\left(\frac{\frac{6,600}{0.1427}}{18,750}\right)^2 + \left(\frac{\frac{3810}{0.1427}}{12,500}\right)^2}$$

$$= 3.16$$

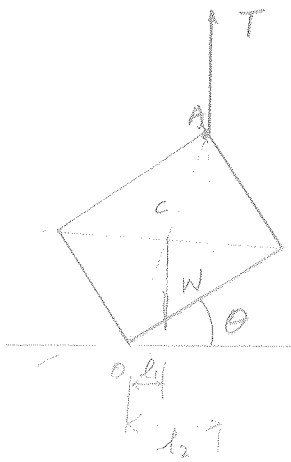
Ans $\boxed{N \geq 3}$

*NOTE: Actual design is going to use six bolts pattern

6

For position :

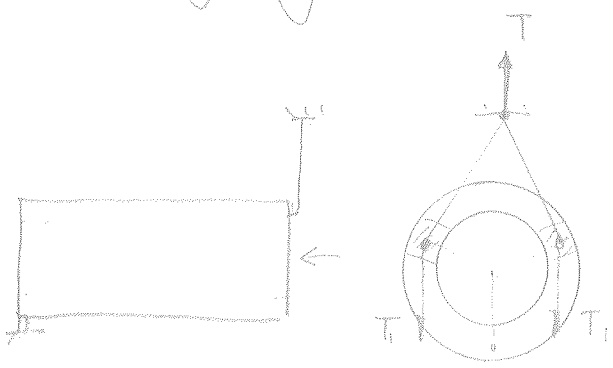
Vessel will go from vertical position to horizontal position.



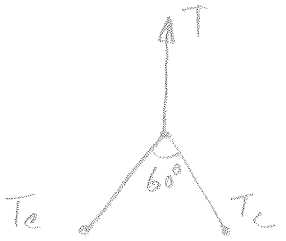
$W \cdot l_1 = T \cdot l_2$.

$T = \frac{W \cdot l_1}{l_2} = W \cdot \frac{OS}{AO} = \frac{W}{2}$

For any Angle α.



For $\alpha = 0°$,



$2T_c \cdot \cos 30° = T = \frac{1}{2}W$

$T_c = \frac{\frac{1}{2}W}{2\cos 30°} = \frac{\frac{6,600}{2}}{2 \cdot \cos 30°}$

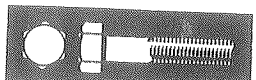
$= 1905$ (lbf). (For each Bracket)

Assuming 3 bolts For each Bracket,

$\tau = \frac{\frac{T_c}{3}}{A_s} = \frac{1905}{3 \times 0.147} = 4320$ psi

$\leq 12,500$ psi. OK

Hex Head Cap Screws



Hex Head Stainless Steel Cap Screws

18-8 STAINLESS STEEL. Minimum tensile strength 75,000 psi. Length is measured from base of head. Thread length for sizes through 6" long = twice the diameter + ¼"; over 6" long = twice the diameter + ½". Sizes too short for this formula are fully threaded. Head width is measured across the flats.
Sold only in full package quantities, except where indicated by symbol ◆.

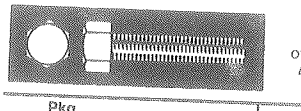
Coarse Thread

Lg.	Pkg. Qty.	No.	NET/100
10-24 Head Width: 5/16" Head Height: 0.120"			
3/8"	100	92198A240	$7.76
1/2"	100	92198A242	8.26
5/8"	100	92198A244	8.96
3/4"	100	92198A245	9.67
1"	100	92198A247	10.83
1/4"-20 Head Width: 7/16" Head Height: 5/32"			
3/8"	100	92198A535	$9.89
1/2"	100	92198A537	5.77
5/8"	100	92198A539	6.00
3/4"	100	92198A540	6.60
7/8"	100	92198A541	7.20
1"	100	92198A542	7.50
1 1/4"	100	92198A544	9.44
1 1/2"	100	92198A546	10.47
1 3/4"	100	92198A548	11.78
2"	100	92198A550	12.54
2 1/4"	100	92198A551	14.49
2 1/2"	100	92198A552 ◆	15.52
2 3/4"	100	92198A553 ◆	17.24
3"	100	92198A554 ◆	18.61
3 1/4"	100	92198A555 ◆	19.61
3 1/2"	100	92198A556 ◆	23.11
3 3/4"	100	92198A557 ◆	23.98
4"	100	92198A558 ◆	24.84
4 1/2"	100	92198A560 ◆	32.61
5"	100	92198A562 ◆	36.17
6"	100	92198A566 ◆	68.09
5/16"-18 Head Width: 1/2" Head Height: 13/64"			
3/8"	100	92198A576 ◆	$21.67
1/2"	100	92198A578	9.27
5/8"	100	92198A580	10.51
3/4"	100	92198A581	11.00
7/8"	100	92198A582	11.36
1"	100	92198A583	12.42
1 1/4"	100	92198A585	15.07
1 1/2"	100	92198A687 ◆	$16.59
1 3/4"	100	92198A689 ◆	18.98
2"	100	92198A691 ◆	21.33
2 1/4"	100	92198A692 ◆	23.03
2 1/2"	100	92198A693 ◆	25.23
2 3/4"	100	92198A694 ◆	27.96
3"	100	92198A695 ◆	30.99
3 1/4"	50	92198A696 ◆	31.57
3 1/2"	50	92198A697 ◆	36.14
4"	50	92198A699 ◆	40.82
4 1/2"	50	92198A701 ◆	48.76
5"	50	92198A703 ◆	64.08
3/8"-16 Head Width: 9/16" Head Height: 15/64"			
1/2"	100	92198A619	$13.70
5/8"	100	92198A621	14.79
3/4"	100	92198A622	15.58
7/8"	100	92198A623	16.40
1"	100	92198A624 ◆	17.83
1 1/4"	100	92198A626 ◆	20.73
1 1/2"	100	92198A628 ◆	23.82
1 3/4"	100	92198A630 ◆	25.52
2"	100	92198A632 ◆	29.83
2 1/4"	50	92198A633	33.06
2 1/2"	50	92198A634 ◆	36.69
2 3/4"	50	92198A635 ◆	39.31
3"	50	92198A636 ◆	41.72
3 1/4"	50	92198A637 ◆	46.08
3 1/2"	50	92198A638 ◆	51.87
4"	50	92198A640 ◆	59.58
4 1/2"	50	92198A642 ◆	70.24
5"	50	92198A644 ◆	77.41
5 1/2"	50	92198A646 ◆	93.72
6"	50	92198A648 ◆	105.95
8"	1	92198A652	257.45
10"	1	92198A656	300.91
7/16"-14 Head Width: 5/8" Head Height: 9/32"			
3/4"	100	92198A667 ◆	$43.67
1"	100	92198A669 ◆	47.22
1 1/4"	50	92198A671 ◆	47.44
1 1/2"	50	92198A673 ◆	52.44
1 3/4"	50	92198A675 ◆	58.22
2"	50	92198A677 ◆	64.22
2 1/2"	50	92198A679 ◆	76.56
3"	50	92198A681 ◆	89.67
1/2"-13 Head Width: 3/4" Head Height: 5/16"			
3/4"	50	92198A710	$31.17
7/8"	50	92198A711	32.94
1"	50	92198A712 ◆	33.93
1 1/4"	50	92198A714 ◆	38.09
1 1/2"	50	92198A716 ◆	42.36
1 3/4"	50	92198A718 ◆	47.02
2"	50	92198A720 ◆	52.72
2 1/4"	50	92198A721 ◆	56.20
2 1/2"	50	92198A722 ◆	63.19
2 3/4"	50	92198A723 ◆	70.04
3"	50	92198A724 ◆	74.06
3 1/2"	25	92198A726 ◆	88.89
4"	25	92198A728 ◆	98.06
4 1/2"	25	92198A730 ◆	115.11
5"	25	92198A732 ◆	128.17
6"	25	92198A736 ◆	163.33
5/8"-11 Head Width: 15/16" Head Height: 25/64"			
1"	25	92198A794	$64.40
1 1/4"	25	92198A796 ◆	67.62
1 1/2"	25	92198A798 ◆	72.44
1 3/4"	25	92198A800 ◆	80.39
2"	25	92198A802 ◆	85.68
2 1/4"	25	92198A803 ◆	92.92
2 1/2"	25	92198A804 ◆	99.71
3"	25	92198A806 ◆	116.03
3 1/2"	25	92198A808 ◆	136.73
5/8"-11 Head Width: [illegible] Head Height: [illegible] (Cont.)			
4"	25	92198A810 ◆	[illegible]
4 1/2"	25	92198A812 ◆	[illegible]
5"	25	92198A814 ◆	[illegible]
3/4"-10 Head Width: [illegible] Head Height: [illegible]			
1"	20	92198A835 ◆	[illegible]
1 1/4"	20	92198A837 ◆	[illegible]
1 1/2"	20	92198A839 ◆	[illegible]
2"	20	92198A843 ◆	[illegible]
2 1/2"	20	92198A845 ◆	[illegible]
3"	20	92198A847 ◆	[illegible]
3 1/4"	20	92198A848 ◆	[illegible]
3 1/2"	20	92198A849 ◆	[illegible]
3 3/4"	20	92198A850 ◆	[illegible]
4"	20	92198A851 ◆	[illegible]
4 1/2"	20	92198A853 ◆	[illegible]
NET EACH			
7/8"-9 Head Width: [illegible] Head Height: [illegible]			
1 1/2"	15	92198A876 ◆	[illegible]
2"	15	92198A880 ◆	[illegible]
2 1/2"	15	92198A882 ◆	[illegible]
3"	15	92198A884 ◆	[illegible]
3 1/2"	15	92198A886 ◆	[illegible]
4"	15	92198A888 ◆	[illegible]
6"	15	92198A895 ◆	[illegible]
7"	15	92198A898 ◆	[illegible]
1"-8 Head Width: [illegible] Head Height: [illegible]			
2"	10	92198A912 ◆	[illegible]
3"	10	92198A916 ◆	[illegible]
3 1/2"	10	92198A918 ◆	[illegible]
4"	10	92198A920 ◆	[illegible]
5 1/2"	10	92198A926 ◆	[illegible]
7"	10	92198A930 ◆	[illegible]

Fine Thread

Lg.	Pkg. Qty.	No.	NET/100
10-32 Head Width: 5/16" Head Height: 0.120"			
3/8"	100	91246A240	$7.76
1/2"	100	91246A242	8.26
5/8"	100	91246A244	8.96
3/4"	100	91246A245	9.67
7/8"	100	91246A246	10.30
1"	100	91246A247	10.83
1/4"-28 Head Width: 7/16" Head Height: 5/32"			
3/8"	100	91246A535	$12.56
1/2"	100	91246A537	10.22
5/8"	100	91246A539	10.78
3/4"	100	91246A540	11.00
7/8"	100	91246A541	12.67
1"	100	91246A542	12.89
1 1/8"	100	91246A543 ◆	$16.00
1 1/4"	100	91246A544 ◆	15.44
1 1/2"	100	91246A546 ◆	18.00
1 3/4"	100	91246A548 ◆	20.33
2"	100	91246A550 ◆	23.44
2 1/4"	100	91246A551 ◆	25.89
2 1/2"	100	91246A552 ◆	27.56
5/16"-24 Head Width: 1/2" Head Height: 13/64"			
1/2"	100	91246A578 ◆	$18.11
3/4"	100	91246A581 ◆	18.44
1"	100	91246A583 ◆	20.89
1 1/4"	100	91246A585 ◆	23.33
1 1/2"	100	91246A587 ◆	$24.78
1 3/4"	100	91246A589 ◆	32.67
2"	100	91246A591 ◆	35.22
2 1/2"	100	91246A593 ◆	40.89
3/8"-24 Head Width: 9/16" Head Height: 15/64"			
5/8"	100	91246A621 ◆	$26.67
3/4"	100	91246A622 ◆	26.78
1"	100	91246A624 ◆	30.00
1 1/4"	100	91246A626 ◆	31.00
1 1/2"	100	91246A628 ◆	38.33
1 3/4"	100	91246A630 ◆	43.89
2"	100	91246A632 ◆	45.89
3/8"-24 Head Width: [illegible] Head Height: [illegible] (Cont.)			
2 1/2"	50	91246A634 ◆	[illegible]
3"	50	91246A636 ◆	[illegible]
1/2"-20 Head Width: [illegible] Head Height: [illegible]			
3/4"	50	91246A710 ◆	[illegible]
1"	50	91246A712 ◆	[illegible]
1 1/2"	50	91246A716 ◆	[illegible]
2"	50	91246A720 ◆	[illegible]
2 1/2"	50	91246A722 ◆	[illegible]
3 1/2"	50	91246A726 ◆	[illegible]
5/8"-18 Head Width: [illegible] Head Height: [illegible]			
1 1/2"	25	91246A798 ◆	[illegible]
2 1/2"	25	91246A804 ◆	[illegible]

◆ Available in broken packages. Prices shown are for full package quantities. Broken package prices are approximately 25% higher.



Hex Head Fully Threaded Stainless Steel Tap Bolts

18-8 STAINLESS STEEL. Minimum tensile strength is 75,000 psi. Length is measured from the base of the head. The head width is measured across the flats.
All sizes are available in full or broken package quantities. Prices shown are for full packages. Broken package quantity prices are approximately 25% higher.

Lg.	Pkg. Qty.	No.	NET/100
1/4"-20 Head Width: 7/16" Head Height: 5/32"			
1"	100	92240A542	$17.11
1 1/4"	100	92240A544	19.22
1 1/2"	100	92240A546	22.00
1 3/4"	100	92240A548	24.78
2"	100	92240A550	27.44
2 1/4"	100	92240A551	30.22
2 1/2"	100	92240A552	33.00
3"	100	92240A554	42.42
3 1/2"	100	92240A556	57.00
5/16"-18 Head Width: 1/2" Head Height: 13/64"			
1 1/4"	100	92240A585	$28.78
1 1/2"	100	92240A587	34.96
1 3/4"	100	92240A589	36.22
2"	100	92240A591	44.73
3"	100	92240A595	58.56
4"	50	92240A599	94.78
3/8"-16 Head Width: 9/16" Head Height: 15/64"			
1 1/2"	100	92240A628	$47.11
1 3/4"	100	92240A630	51.89
2"	100	92240A632	56.67
2 1/4"	50	92240A633	67.71
2 1/2"	50	92240A634	72.98
3"	50	92240A636	91.07
4"	50	92240A640	129.78
1/2"-13 Head Width: 3/4" Head Height: 5/16"			
1 3/4"	50	92240A718	$104.27
2"	50	92240A720	113.53
2 1/4"	50	92240A721	135.06
2 1/2"	50	92240A722	144.65
2 3/4"	50	92240A723	153.47
3"	50	92240A724	162.67
3 1/2"	50	92240A726	179.67
4"	50	92240A728	206.67

Appendix B: Minimum length engagement for aluminum

3-31-9c.

Minmum length engagement of screw threads for the aluminum.

Thread engagement Length Le

$$Le = \frac{2 \times At}{\pi \times Kn\,max \left(\frac{1}{2} + 0.57735\, n\,(Esmin - Kn\,max)\right)}$$

$$At = 0.7854 \left(D - \frac{0.9743}{n}\right)^2$$

$$= 0.7854 \times \left(0.5 - \frac{0.9743}{13}\right)^2 = 0.1418 \text{ in}^2$$

Knmax : maximum minor diameter of External thread = 0.434"

n : number of thread per inch 13.

Esmin : min pitch diameter of external thread = 0.4411

$$Le = \frac{2 \times 0.1418}{\pi \times 0.434 \times \left(\frac{1}{2} + 0.57735 \times 13\,(0.4411 - 0.434)\right)}$$

$$= 0.375"$$

For diffrent material, if the internal thread material is lower than external thread material, then factor J should be applied

$$L_{MIN} = L_e \times J$$

$$J = \frac{A_s \times \text{Tensile strength of External thread Material}}{A_N \times \text{Tensile strength of Internal thread Material}}$$

$$\frac{A_s}{A_n} = \frac{\pi \times n \times L_e \times K_{n\,max} \left[\frac{1}{2n} + 0.57735 \left[E_{s\,min} - K_{n\,max}\right]\right]}{\pi \times n \times L_e \times D_{s\,min} \left[\frac{1}{2n} + 0.57735 \left(D_{s\,min} - E_{n\,max}\right)\right]}$$

$$= \frac{0.434}{0.4069} \cdot \frac{\left[\frac{1}{2 \times 13} + 0.57735 \left(0.4[illegible] - 0.434\right)\right]}{\left[\frac{1}{2 \times 13} + 0.57735 \left(0.4891 - 0.4594\right)\right]} = 0.8177$$

$$J = 0.8177 \times \frac{75{,}000}{44{,}000} = 1.4$$

$$\boxed{L_{MIN} = 1.4 \times 0.375 = 0.52 \text{ in}}$$

Working Strength of Bolts. — When the nut on a bolt is tightened, an initial tensile load is placed on the bolt which must be taken into account in determining its safe working strength or external load-carrying capacity. The total load on the bolt theoretically varies from a maximum equal to the sum of the initial and external loads (when the bolt is absolutely rigid and the parts held together are elastic) to a minimum equal to either the initial or external loads, whichever is the greater (where the bolt is elastic and the parts held together are absolutely rigid). Since no material is absolutely rigid, in practice the total load values fall somewhere between these maximum and minimum limits, depending upon the relative elasticity of the bolt and joint members.

Some experiments made at Cornell University to determine the initial stress due to tightening nuts on bolts sufficiently to make a packed joint steam tight, showed that experienced machinists tighten nuts with a pull roughly proportional to the bolt diameter. It was also found that the stress due to nut tightening was often sufficient to break a ¾-inch bolt, but not larger sizes, assuming that the nut is tightened by an experienced mechanic. It may be concluded, therefore, that bolts smaller than ⅝ inch should not be used for holding cylinder heads or other parts requiring a tight joint. As a result of these tests, the following empirical formula was established for the working strength of bolts used for packed joints or joints where the elasticity of a gasket is greater than the elasticity of the studs or bolts.

$$W = S_t(0.55\,d^2 - 0.25\,d)$$

In this formula, W = working strength of bolt or permissible load, in pounds after allowance is made for initial load due to tightening; S_t = allowable working stress in tension, pounds per square inch; and d = nominal outside diameter of stud or bolt, inches. A somewhat more convenient formula, and one which gives approximately the same results, is:

$$W = S_t(A - 0.25\,d)$$

In this formula, W, S_t and d are as previously given, and A = area at the root of the thread, square inches.

Example. — What is the working strength of a 1-inch bolt which is screwed up tightly in a packed joint when the allowable working stress is 10,000 psi?

$$W = 10{,}000(0.55 \times 1 - 0.25 \times 1) = 3000 \text{ pounds approx.}$$

Formulas for Stress Areas and Length of Engagement of Screw Threads. — The critical areas of stress of mating screw threads are: (1) The effective cross-sectional area, or tensile stress area, of the external thread; (2) the shear area of the external thread, which depends principally on the minor diameter of the tapped hole; and (3) the shear area of the internal thread, which depends principally on the major diameter of the external thread. The relation of these three stress areas to each other is an important factor in determining how a threaded connection will fail, whether by breakage in the threaded section of the screw (or bolt) or by stripping of either the external or internal thread.

If failure of a threaded assembly should occur, it is preferable for the screw to break rather than have either the external or internal thread strip. In other words, the length of engagement of mating threads should be sufficient to carry the full load necessary to break the screw without the threads stripping.

If mating internal and external threads are manufactured of materials having equal tensile strengths, then to prevent stripping of the external thread, the length of engagement should be not less than that given by Formula 1:

$$L_e = \frac{2 \times A_s}{3.1416\,K_n\text{max}\left[\frac{1}{2} + 0.57735n(E_s\text{min} - K_n\text{max})\right]} \qquad (1)$$

In this formula, the factor of 2 means that it is assumed that the area in shear of the screw must be twice the tensile stress area to develop the full strength of the screw (this value is slightly larger than required and thus provides a small factor of safety against stripping); L_e = length of engagement, in inches; n = number of threads per inch; $K_n\text{max}$ = maximum minor diameter of internal thread; $E_s\text{min}$ = minimum pitch diameter of external thread for the class of thread specified; and A_s = tensile stress area of screw thread given by Formula (2a) or (2b) or the thread tables on pages 1484 to 1493 for Unified threads which are based on Formula (2a).

For steels of up to 100,000 psi ultimate tensile strength,

$$A_s = 0.7854\left(D - \frac{0.9743}{n}\right)^2 \qquad (2a)$$

For steels of over 100,000 psi ultimate tensile strength,

$$A_s = 3.1416\left(\frac{E_s\text{min}}{2} - \frac{0.16238}{n}\right)^2 \qquad (2b)$$

In these formulas, D = basic major diameter of threads and the other symbols have the same meaning as before.

Stripping of Internal Thread: If the internal thread is made of material of lower strength than the external thread, stripping of the internal thread may take place before the screw breaks. To determine whether this condition exists it is necessary to calculate the factor J for the relative strength of the external and internal threads given by Formula (3):

$$J = \frac{A_s \times \text{tensile strength of external thread material}}{A_n \times \text{tensile strength of internal thread material}} \qquad (3)$$

If J is less than or equal to 1, the length of engagement determined by Formula (1) is adequate to prevent stripping of the internal thread; if J is greater than 1, the required length of engagement Q to prevent stripping of the internal thread is obtained by multiplying the length of engagement L_e, Formula (1), by J:

$$Q = JL_e \qquad (4)$$

In Formula (3), A_s and A_n are the shear areas of the external and internal threads, respectively, given by Formulas (5) and (6):

$$A_s = 3.1416\,nL_eK_n\text{max}\left[\frac{1}{2n} + 0.57735(E_s\text{min} - K_n\text{max})\right] \qquad (5)$$

$$A_n = 3.1416\,nL_eD_s\text{min}\left[\frac{1}{2n} + 0.57735(D_s\text{min} - E_n\text{max})\right] \qquad (6)$$

In these formulas, n = threads per inch; L_e = length of engagement from Formula (1); $K_n\text{max}$ = maximum minor diameter of internal thread; $E_s\text{min}$ = minimum pitch diameter of the external thread for the class of thread specified; $D_s\text{min}$ = minimum major diameter of the external thread; and $E_n\text{max}$ = maximum pitch diameter of internal thread.

Load to Break Threaded Portion of Screws and Bolts. — The direct tensile load P to break the threaded portion of a screw or bolt (assuming that no shearing or torsional stresses are acting) can be determined from the following formula:

$$P = SA_s$$

where, P = load in pounds to break screw; S = ultimate tensile strength of material of screw or bolt in pounds per square inch; and A_s = tensile stress area in square inches from Formulas (2a), (2b) or from the screw thread tables.

system, the tolerances of the product were practically absorbed by the combined tool and gage tolerances, leaving little for a working tolerance in manufacture. Somewhat greater tolerances are now provided for nut threads. As contrasted with the old "classes of fit" 1, 2, and 3, for each of which the pitch diameter tolerance on the external and internal threads were equal, the Classes 1B, 2B, and 3B (internal) threads in the new standard have, respectively, a 30 per cent larger pitch diameter tolerance than the 1A, 2A, and 3A (external) threads. Relatively more tolerance is provided for fine threads than for coarse threads of the same pitch. In cases where previous tolerances were more liberal than required, they were reduced.

Thread Form. — The Design Profiles for Unified screw threads, shown on page 1481, define the maximum material condition for external and internal threads with no allowance and are derived from the Basic Profile, shown on page 1474.

UN External Screw Threads: A flat root contour is specified, but it is necessary to provide for some threading tool crest wear, hence a rounded root contour cleared beyond the $0.25p$ flat width of the Basic Profile is optional.

UNR External Screw Threads: In order to reduce the rate of threading tool crest wear and to improve fatigue strength of a flat root thread, the Design Profile of the UNR thread has a smooth, continuous, non-reversing contour with a radius of curvature not less than $0.108p$ at any point and blends tangentially into the flanks and any straight segment. At the maximum material condition, the point of tangency is specified to be at a distance not less than $0.625H$ (where H is the height of a sharp V-thread) below the basic major diameter.

UN and UNR External Screw Threads: The Design Profiles of both UN and UNR external screw threads have flat crests. However, in practice, product threads are produced with partially or completely rounded crests. A rounded crest tangent at $0.125p$ flat is shown as an option on page 1481.

UN Internal Screw Thread: In practice it is necessary to provide for some threading tool crest wear, therefore the root of the Design Profile is rounded and cleared beyond the $0.125p$ flat width of the Basic Profile.

There is no internal UNR screw thread.

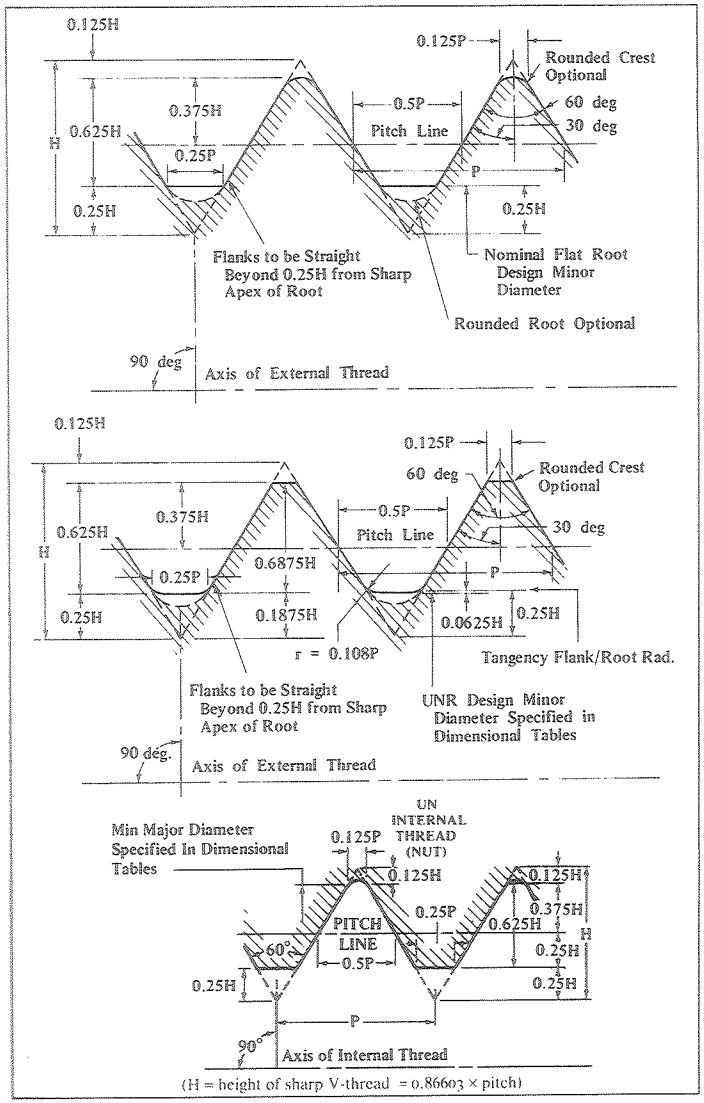
Thread Series. — Thread series are groups of diameter-pitch combinations distinguished from each other by the number of threads per inch applied to a specific diameter. The various diameter-pitch combinations of eleven standard series are shown in Table 2. The limits of size of threads in the eleven standard series together with certain selected combinations of diameter and pitch, as well as the symbols for designating the various threads, are given in Table 4.

Coarse-Thread Series: This series, UNC/UNRC, is the one most commonly used in the bulk production of bolts, screws, nuts and other general engineering applications. It is also used for threading into lower tensile strength materials such as cast iron, mild steel and softer materials (bronze, brass, aluminum, magnesium and plastics) to obtain the optimum resistance to stripping of the internal thread. It is applicable for rapid assembly or disassembly, or if corrosion or slight damage is possible.

Fine-Thread Series: This series, UNF/UNRF, is suitable for the production of bolts, screws, and nuts and for other applications where the Coarse series is not applicable. External threads of this series have greater tensile stress area than comparable sizes of the Coarse series. The Fine series is suitable when the resistance to stripping of both external and mating internal threads equals or exceeds the tensile load carrying capacity of the externally threaded member (see p. 1278). It is also used where the length of engagement is short, where a smaller lead angle is desired, where the wall thickness demands a fine pitch, or where finer adjustment is needed.

Extra-Fine-Thread Series: This series, UNEF/UNREF, is applicable where even finer pitches of threads are desirable, as for short lengths of engagement and for thin-walled tubes, nuts, ferrules, or couplings. It is also generally applicable under the conditions stated above for the fine threads.

American National Standard Unified Internal and External Screw Thread Design Profiles (Maximum Material Condition)



(H = height of sharp V-thread = 0.86603 × pitch)

Table 4 (*Continued*). Standard Series and Selected Combinations† — Unified Screw Threads

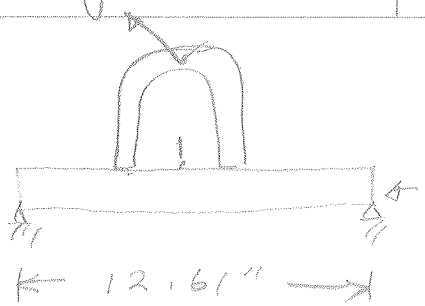
Nominal Size, Threads per Inch, and Series Designation[c]	External[c]							Internal[c]					
			Major Diameter			Pitch Diameter		UNR Minor Diam.[a] Max (Ref.)		Minor Diameter		Pitch Diameter		Major Diameter
	Class	Allowance	Max[b]	Min	Min[d]	Max[b]	Min		Class	Min	Max	Min	Max	Min
1/4–36 UNS	2A	0.0009	0.2491	0.2436	—	0.2311	0.2280	0.2161	2B	0.220	0.226	0.2320	0.2360	0.2500
1/4–40 UNS	2A	0.0009	0.2491	0.2440	—	0.2329	0.2300	0.2193	2B	0.223	0.229	0.2338	0.2376	0.2500
1/4–48 UNS	2A	0.0008	0.2492	0.2447	—	0.2357	0.2330	0.2243	2B	0.227	0.232	0.2365	0.2401	0.2500
1/4–56 UNS	2A	0.0008	0.2492	0.2451	—	0.2376	0.2350	0.2280	2B	0.231	0.235	0.2384	0.2417	0.2500
5/16–18 UNC	1A	0.0012	0.3113	0.2982	0.2982	0.2752	0.2691	0.2452	1B	0.252	0.265	0.2764	0.2843	0.3125
	2A	0.0012	0.3113	0.3026	—	0.2752	0.2712	0.2452	2B	0.252	0.265	0.2764	0.2817	0.3125
	3A	0.0000	0.3125	0.3038	—	0.2764	0.2734	0.2464	3B	0.2520	0.2630	0.2764	0.2803	0.3125
5/16–20 UN	2A	0.0012	0.3113	0.3032	—	0.2788	0.2748	0.2518	2B	0.258	0.270	0.2800	0.2852	0.3125
	3A	0.0000	0.3125	0.3044	—	0.2800	0.2770	0.2530	3B	0.2580	0.2680	0.2800	0.2839	0.3125
5/16–24 UNF	1A	0.0011	0.3114	0.3006	—	0.2843	0.2788	0.2618	1B	0.267	0.277	0.2854	0.2925	0.3125
	2A	0.0011	0.3114	0.3042	—	0.2843	0.2806	0.2618	2B	0.267	0.277	0.2854	0.2902	0.3125
	3A	0.0000	0.3125	0.3053	—	0.2854	0.2827	0.2629	3B	0.2670	0.2754	0.2854	0.2890	0.3125
5/16–27 UNS	2A	0.0010	0.3115	0.3048	—	0.2874	0.2839	0.2674	2B	0.272	0.281	0.2884	0.2929	0.3125
5/16–28 UN	2A	0.0010	0.3115	0.3050	—	0.2883	0.2849	0.2689	2B	0.274	0.282	0.2893	0.2937	0.3125
	3A	0.0000	0.3125	0.3060	—	0.2893	0.2867	0.2699	3B	0.2740	0.2807	0.2893	0.2926	0.3125
5/16–32 UNEF	2A	0.0010	0.3115	0.3055	—	0.2912	0.2880	0.2743	2B	0.279	0.286	0.2922	0.2964	0.3125
	3A	0.0000	0.3125	0.3065	—	0.2922	0.2898	0.2753	3B	0.2790	0.2847	0.2922	0.2953	0.3125
5/16–36 UNS	2A	0.0009	0.3116	0.3061	—	0.2936	0.2905	0.2785	2B	0.282	0.289	0.2945	0.2985	0.3125
5/16–40 UNS	2A	0.0009	0.3116	0.3065	—	0.2954	0.2925	0.2818	2B	0.285	0.291	0.2963	0.3001	0.3125
5/16–48 UNS	2A	0.0008	0.3117	0.3072	—	0.2982	0.2955	0.2869	2B	0.290	0.295	0.2990	0.3026	0.3125
3/8–16 UNC	1A	0.0013	0.3737	0.3595	0.3595	0.3331	0.3266	0.2992	1B	0.307	0.321	0.3344	0.3429	0.3750
	2A	0.0013	0.3737	0.3643	—	0.3331	0.3287	0.2992	2B	0.307	0.321	0.3344	0.3401	0.3750
	3A	0.0000	0.3750	0.3656	—	0.3344	0.3311	0.3005	3B	0.3070	0.3182	0.3344	0.3387	0.3750
3/8–18 UNS	2A	0.0013	0.3737	0.3650	—	0.3376	0.3333	0.3076	2B	0.315	0.328	0.3389	0.3445	0.3750
3/8–20 UN	2A	0.0012	0.3738	0.3657	—	0.3413	0.3372	0.3143	2B	0.321	0.332	0.3425	0.3479	0.3750
	3A	0.0000	0.3750	0.3669	—	0.3425	0.3394	0.3155	3B	0.3210	0.3297	0.3425	0.3465	0.3750
3/8–24 UNF	1A	0.0011	0.3739	0.3631	—	0.3468	0.3411	0.3243	1B	0.330	0.340	0.3479	0.3553	0.3750
	2A	0.0011	0.3739	0.3667	—	0.3468	0.3430	0.3243	2B	0.330	0.340	0.3479	0.3528	0.3750

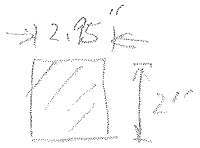
3/8–24 UNF	3A	0.0000	0.3750	0.3678	—	0.3479	0.3450	0.3254	3B	0.3380	0.3372	0.3479	0.3516	0.3750
3/8–27 UNS	2A	0.0011	0.3739	0.3672	—	0.3498	0.3462	0.3298	2B	0.335	0.344	0.3509	0.3556	0.3750
3/8–28 UN	2A	0.0011	0.3739	0.3674	—	0.3507	0.3471	0.3313	2B	0.336	0.345	0.3518	0.3564	0.3750
	3A	0.0000	0.3750	0.3685	—	0.3518	0.3491	0.3324	3B	0.3360	0.3426	0.3518	0.3553	0.3750
3/8–32 UNEF	2A	0.0010	0.3740	0.3680	—	0.3537	0.3503	0.3368	2B	0.341	0.349	0.3547	0.3591	0.3750
	3A	0.0000	0.3750	0.3690	—	0.3547	0.3522	0.3378	3B	0.3410	0.3469	0.3547	0.3580	0.3750
3/8–36 UNS	2A	0.0010	0.3740	0.3685	—	0.3560	0.3528	0.3409	2B	0.345	0.352	0.3570	0.3612	0.3750
3/8–40 UNS	2A	0.0009	0.3741	0.3690	—	0.3579	0.3548	0.3443	2B	0.348	0.354	0.3588	0.3628	0.3750
0.390–27 UNS	2A	0.0011	0.3889	0.3822	—	0.3648	0.3612	0.3448	2B	0.350	0.359	0.3659	0.3706	0.3900
7/16–14 UNC	1A	0.0014	0.4361	0.4206	—	0.3897	0.3826	0.3511	1B	0.360	0.376	0.3911	0.4003	0.4375
	2A	0.0014	0.4361	0.4258	0.4206	0.3897	0.3850	0.3511	2B	0.360	0.376	0.3911	0.3972	0.4375
	3A	0.0000	0.4375	0.4272	—	0.3911	0.3876	0.3525	3B	0.3600	0.3717	0.3911	0.3957	0.4375
7/16–16 UN	2A	0.0014	0.4361	0.4267	—	0.3955	0.3909	0.3616	2B	0.370	0.384	0.3969	0.4028	0.4375
	3A	0.0000	0.4375	0.4281	—	0.3969	0.3935	0.3630	3B	0.3700	0.3800	0.3969	0.4014	0.4375
7/16–18 UNS	2A	0.0013	0.4362	0.4275	—	0.4001	0.3958	0.3701	2B	0.377	0.390	0.4014	0.4070	0.4375
7/16–20 UNF	1A	0.0013	0.4362	0.4240	—	0.4037	0.3975	0.3767	1B	0.383	0.395	0.4050	0.4131	0.4375
	2A	0.0013	0.4362	0.4281	—	0.4037	0.3995	0.3767	2B	0.383	0.395	0.4050	0.4104	0.4375
	3A	0.0000	0.4375	0.4294	—	0.4050	0.4019	0.3780	3B	0.3830	0.3916	0.4050	0.4091	0.4375
7/16–24 UNS	2A	0.0011	0.4364	0.4292	—	0.4093	0.4055	0.3868	2B	0.392	0.402	0.4104	0.4153	0.4375
7/16–27 UNS	2A	0.0011	0.4364	0.4297	—	0.4123	0.4087	0.3923	2B	0.397	0.406	0.4134	0.4181	0.4375
7/16–28 UNEF	2A	0.0011	0.4364	0.4299	—	0.4132	0.4096	0.3938	2B	0.399	0.407	0.4143	0.4189	0.4375
	3A	0.0000	0.4375	0.4310	—	0.4143	0.4116	0.3949	3B	0.3990	0.4051	0.4143	0.4178	0.4375
7/16–32 UN	2A	0.0010	0.4365	0.4305	—	0.4162	0.4128	0.3993	2B	0.404	0.411	0.4172	0.4216	0.4375
	3A	0.0000	0.4375	0.4315	—	0.4172	0.4147	0.4003	3B	0.4040	0.4094	0.4172	0.4205	0.4375
1/2–12 UNS	2A	0.0016	0.4984	0.4870	—	0.4443	0.4389	0.3992	2B	0.410	0.428	0.4459	0.4529	0.5000
	3A	0.0000	0.5000	0.4886	—	0.4459	0.4419	0.4008	3B	0.4100	0.4223	0.4459	0.4511	0.5000
1/2–13 UNC	1A	0.0015	0.4985	0.4822	—	0.4485	0.4411	0.4069	1B	0.417	0.434	0.4500	0.4597	0.5000
	2A	0.0015	0.4985	0.4876	0.4822	0.4485	0.4435	0.4069	2B	0.417	0.434	0.4500	0.4565	0.5000
	3A	0.0000	0.5000	0.4891	—	0.4500	0.4463	0.4084	3B	0.4170	0.4284	0.4500	0.4548	0.5000
1/2–14 UNS	2A	0.0015	0.4985	0.4882	—	0.4521	0.4471	0.4135	2B	0.423	0.438	0.4536	0.4601	0.5000

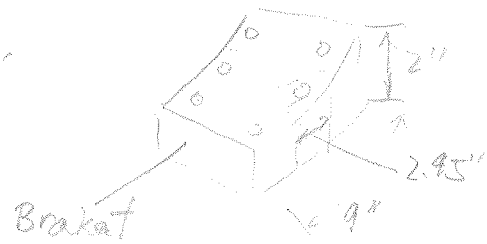
All dimensions in inches. † Use UNS threads only if Standard Series do not meet requirements (see p. 1479). See footnotes *a*, *b*, *c*, *d*, and *e* at end of table.

Appendix C: Bracket Calculation

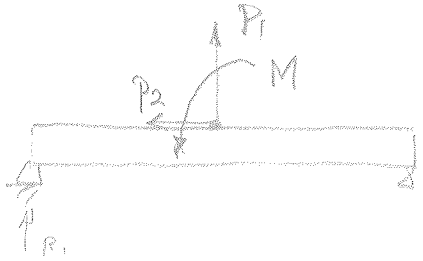
Flange Calculation 3-30-93





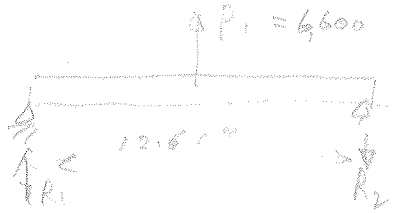


For this calculation, it is assumed that beam cross-section 2.95" x 2" only. There will be three force component P1, P2 and M



$I = \frac{2^3 \times 2.95}{12} = 1.967 \text{ in}^4$

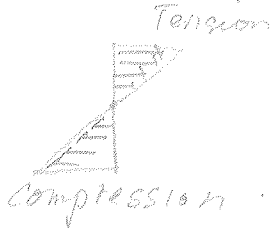
① For each Bracket, $P_1 = 6,600 \text{ (lbf)}$



$R_1 = R_2 = 3300 \text{ lbf}$.

$M_{max} = 3300 \times \frac{12.61}{2}$

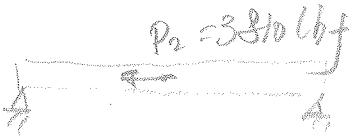
$= 20,807 \text{ lbf-in}$

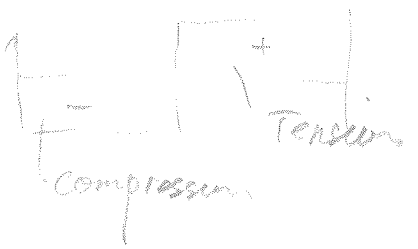


$\sigma_{Bend\,(max)} = \frac{M \cdot y}{I}$

$= \frac{20807 \times 1}{1.967} = 10,579 \text{ psi}$

For P_2

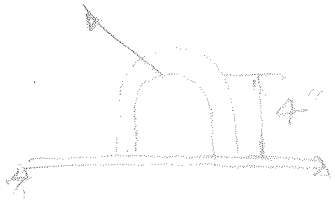




$$\sigma = \frac{3810}{2 \times 2.95} = 645 \text{ psi}$$

{ Compression (left)
Tension (right)

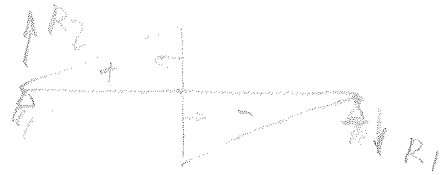
For M moment.



$\Rightarrow$

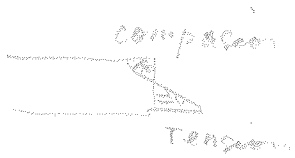
$M = 4'' \times P_2 = 4 \times 3810 = 15240$ lbf-in

$\Rightarrow$

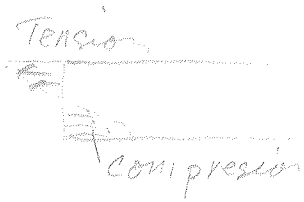


$$\sigma_{bend} = \frac{15240 \times 1}{1.996} = 7749 \text{ psi}$$

For Left side.



For Right end



Worst case:

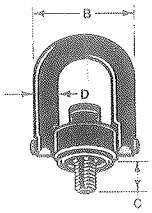
$$\sigma_{max} = 10579 + 645 + 7749 = 18973 \text{ psi}$$

$$\leq 22,000 \text{ psi}$$

(If: $\sigma_y = 36,000$ psi), * NOTE: actual width is about 9"

Lifting Eyes, Nuts, & Swivels

Heavy-Duty Safety Hoist Rings



Pivot 180° and swivel 360° to compensate for pitch, roll, and sway when lifting unbalanced loads. Reduce risks in lifting, moving, and turning heavy equipment. alloy steel construction. Load ratings are for lifts in any direction.

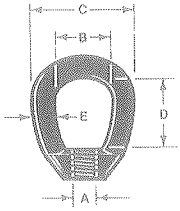
The 2949T series is made from 300 series stainless steel. It is suitable for corrosive atmospheres and environments. The 3052T series is made from alloy steel.

Available: Load limits to 75,000 lbs.; long-lifting bale models; ti-cad plating; and metric sizes. Specify requirements and 3052T999. Prices on request.

SAFETY NOTE: Some loosening may develop after prolonged service in a permanent installation. It is advisable to periodically re-tighten the mounting screws to maintain the specified torque.

Bolt Size	Thread Torque Ft. Lbs.	Inside Bale Radius	Dimensions B	C	D	Alloy Steel Work Load Limit, Lbs.	No.	NET EACH	Stainless Steel Work Load Limit, Lbs.	No.	NET EACH
5/16"-18	7	7/16"	1 5/8"	9/16"	3/8"	800	3052T55	$65.01	400	2949T11	$276.10
3/8"-16	12	7/16"	1 5/8"	9/16"	3/8"	1,000	3052T56	69.24	500	2949T12	278.68
1/2"-13	28	11/16"	2 7/16"	1 1/16"	1/2"	2,500	3052T57	79.06	1,250	2949T13	330.73
1/2"-13	28	7/8"	3 1/4"	3/4"	3/4"	2,500	3052T58	79.61	1,250	2949T14	337.18
1/2"-13	28	7/8"	3 1/4"	1 1/4"	3/4"	2,500	3052T81	79.72	1,250	2949T15	342.98
5/8"-11	60	7/8"	3 1/4"	1"	3/4"	4,000	3052T59	79.98	2,000	2949T16	337.33
5/8"-11	60	7/8"	3 1/4"	1 1/4"	3/4"	4,000	3052T61	79.98	2,000	2949T17	342.09
3/4"-10	100	7/8"	3 1/4"	1"	3/4"	5,000	3052T62	79.98	2,500	2949T18	345.75
3/4"-10	100	7/8"	3 1/4"	1 1/2"	3/4"	5,000	3052T63	79.98	2,500	2949T19	348.99
3/4"-10	100	1 13/32"	4 13/16"	1"	1"	7,000	3052T64	171.43	3,500	2949T21	737.70
3/4"-10	100	1 13/32"	4 13/16"	1 17/32"	1"	7,000	3052T82	173.86	3,500	2949T22	743.90
7/8" - 9	160	1 13/32"	4 13/16"	1"	1"	8,000	3052T65	171.43	4,000	2949T23	750.08
1" - 8	230	1 13/32"	4 29/32"	1 1/4"	1"	10,000	3052T66	179.28	5,000	2949T24	762.39
1" - 8	230	1 13/32"	4 29/32"	1 1/2"	1"	10,000	3052T67	193.25	5,000	2949T25	768.58
1" - 8	230	1 13/32"	4 29/32"	2 9/32"	1"	10,000	3052T83	197.34	5,000	2949T26	775.09
1 1/4" - 7	470	1 3/4"	6"	1 7/8"	1 1/4"	15,000	3052T68	324.66	7,500	2949T27	1254.00
2" - 4 1/2	800	2 1/4"	8"	3 1/8"	1 3/4"	30,000	3052T69	462.68			

Drop-Forged Eye Nuts



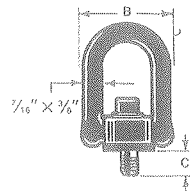
These drop-forged eye nuts are available in standard-duty galvanized steel; standard-duty 18-8 type 303 stainless steel; and heavy-duty self-colored steel.

Eye nuts are tapped with Unified National Coarse Class 2-B threads. Heavy-duty eye nuts have 1 1/2 to 2 times larger thread lengths that enable higher working load limits.

Note: Loads shown apply to eye nuts only, based on a vertical pull, and not to any connecting bolt or stud.

Thread Dia. (A)	Dimensions B	C	D	E	Work Load Limit, Lbs.	No.	NET EACH 1-23	24-Up
STANDARD-DUTY GALVANIZED STEEL								
1/4"	3/4"	1 1/4"	1 1/16"	1/4"	520	3019T14	$3.08	$2.78
5/16"	3/4"	1 1/4"	1 1/16"	1/4"	840	3019T15	3.08	2.78
3/8"	1"	1 5/8"	1 1/4"	5/16"	1240	3019T16	3.12	2.81
7/16"	1 1/4"	2"	1 1/2"	3/8"	1700	3019T17	3.14	2.83
1/2"	1 1/4"	2"	1 1/2"	3/8"	2240	3019T18	3.14	2.83
5/8"	1 1/2"	2 1/2"	2"	1/2"	3600	3019T19	3.88	3.50
							1-11	12-Up
3/4"	1 3/4"	3"	2 3/8"	5/8"	5200	3019T21	$7.21	$6.50
7/8"	2"	3 1/2"	2 5/8"	3/4"	7200	3019T22	9.57	8.55
1"	2 1/4"	4"	3 1/16"	7/8"	10000	3019T23	12.80	11.55
1 1/8"	2 1/4"	4"	3 1/16"	7/8"	12300	3019T24	15.38	13.74
1 1/4"	2 1/2"	4 1/2"	3 1/2"	1"	15500	3019T25	19.57	17.49
1 1/2"	3 1/8"	5 5/8"	4"	1 1/4"	22500	3019T27	38.19	34.13
HEAVY-DUTY SELF-COLORED								
							1-23	24-Up
3/8"	7/8"	1 1/2"	1 3/16"	5/16"	1800	3274T41	$4.14	$3.79
1/2"	1 1/8"	2"	1 5/16"	7/16"	3600	3274T42	5.19	4.81
5/8"	1 3/8"	2 1/2"	1 15/16"	9/16"	5800	3274T43	6.74	6.17
							1-11	12-Up
3/4"	1 1/2"	3"	1 7/8"	3/4"	10600	3274T44	$12.55	$11.39
1"	1 3/4"	3 3/4"	1 15/16"	1"	18800	3274T46	23.22	20.81
303 STAINLESS STEEL								
1/4"	3/4"	1 1/4"	1 1/16"	1/4"	460	3061T14	$14.25	$12.86
5/16"	3/4"	1 1/4"	1 1/16"	1/4"	780	3061T15	15.98	14.25
3/8"	1 1/4"	2"	1 1/2"	3/8"	1160	3061T17	16.43	14.83
1/2"	1 1/4"	2"	1 1/2"	3/8"	2150	3061T18	17.07	15.41
5/8"	1 1/2"	2 1/2"	2"	1/2"	3440	3061T21	20.02	18.28
3/4"	1 3/4"	3"	2 3/8"	5/8"	5140	3061T23	34.27	31.29

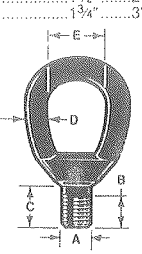
Large Opening Swivel Hoist Rings



Same as the 3052T series (Heavy-Duty Safety Hoist Rings) listed above, except swivel eye, which is forged from one piece of steel. Provides working load with four times factor of safety in all directions. Inside bale radius is .645" for 2994T41-T48; .880" for T49-T55. The swivels with 3/8"-16 screw thread meet Military Spec. MS5-1937. 12 thread torque ft.-lbs. for all hoist rings.

Work Load Limit, Lbs.	Thread Torque Ft., Lbs.	C	B	No.	NET EACH
5/16"-18 Thread					
800	7	0.56"	2.29"	2994T61	$58.31
800	7	1.06"	2.29"	2994T62	69.16
3/8"-16 Thread					
1,000	12	0.56"	2.29"	2994T63	$73.50
1,000	12	1.06"	2.29"	2994T64	74.43
1/2"-13 Thread					
2,500	28	1.00"	3.13"	2994T65	$83.62
2,500	28	1.25"	3.13"	2994T66	84.00
5/8"-11 Thread					
4,000	60	1.00"	3.13"	2994T67	$88.19
4,000	60	1.25"	3.13"	2994T68	89.20
3/4"-10 Thread					
5,000	100	1.00"	3.13"	2994T69	$88.38
5,000	100	1.25"	3.13"	2994T71	89.40

Drop-Forged Lifting Eyes



Forged carbon steel with galvanized finish.

A	Dimensions B	C	D	E	BLANK NET EACH No.	1-23	24-Up	Work Load Limit, Lbs.	THREADED NET EACH No.	1-23	24-Up
5/16"	1/4"	11/16"	1/4"	3/4"	8890T31	$1.64	$1.49	850	8890T12	$1.76	$1.59
3/8"	5/16"	7/8"	5/16"	1"	8890T32	1.96	1.77	1250	8890T14	2.10	1.89
1/2"	1/2"	1 3/32"	3/8"	1 1/4"	8890T33	3.07	2.78	2250	8890T16	3.28	2.97
5/8"	9/16"	1 7/16"	1/2"	1 1/2"	8890T34	4.00	3.62	3600	8890T18	4.28	3.87
3/4"	5/8"	1 21/32"	5/8"	1 3/4"	8890T35	6.19	5.61	5200	8890T22	6.62	6.00
						1-11	12-Up			1-11	12-Up
7/8"	13/16"	1 3/4"	3/4"	2"	8890T36	$8.59	$7.78	7200	8890T23	$9.20	$8.31
1"	1"	2 1/8"	7/8"	2 1/4"	8890T37	12.84	11.63	10000	8890T25	13.74	12.45
1 1/8"	1 1/16"	2 5/16"	1"	2 1/2"	8890T38	16.33	14.79	12500	8890T27	17.46	15.83

NOTE: Lifting eyes have Unified National Coarse Class 2A threads.

Lifting Sy

Use these pad eyes for welding onto machinery, equipment, and vehicles for n

Eye Bolt Size	Shoulder O.D.	Overall Ht.	No.	NET EACH
CARBON STEEL				
1/4"	5/8"	3/4"	3024T14	$0
5/16"	7/8"	1 1/32"	3024T16	
3/8"	1 1/8"	1 5/16"	3024T18	1
1/2"	1 1/2"	1 11/16"	3024T22	1
5/8"	2 1/8"	2 11/32"	3024T24	2
3/4"	2 5/8"	2 3/4"	3024T26	3

Swivel Lifting Plates

For temporary attachment to steel, w construction materials using lag sc machine bolt, and coil bolt. Forged steel w to heavy steel bearing plate. Shackle sw line through center of bolt. Recomm minimum bolt length is 4" for 3070T21: 5 and T27; and 7" for T28 and T29.

Bolt Size	Hole Dia.	Plate Size Thk. × Wd. × Lg.	Working Limit,
SINGLE SWIVEL MODEL: Swivels 180° in			
1/2" × 1 3/8"	1/2"	1/2" × 2 1/2" × 5"	1250
5/8" × 1 3/8"	1/2"	1/2" × 2 1/2" × 5"	1250
DOUBLE SWIVEL MODEL: Swivels 180° v			
1/2"	3/8"	3/8" × 5" dia.	900
1/2" × 2 3/4"	5/8"	5/8" × 7" dia.	1350
5/8" × 2 3/4"	5/8"	5/8" × 7" dia.	1350

Has a rectangular base, not round as sl

NOTE: ALL HOOK BOLTS LISTED BELOW

Steel and Brass Screw Hooks

Standard ceiling type screw hooks. Select from zinc-plated steel and solid brass.

Nos. 9587T13, 9587T12, and 9587T11, and 9588T76, 9588T77, and 9588T78 come 50 per box. All the rest come 100 per box.

Wire Dia.	A	B	C	D	E	Zinc-Pla No.	NE
1/4"	1/2"	7/8"	1 5/16"	1/4"	9587T18		
5/16"	9/16"	1 1/8"	1 11/16"	5/16"	9587T17		
3/8"	3/4"	1 1/4"	2 1/16"	3/8"	9587T16		
1/2"	3/4"	1 1/2"	2 9/16"	1/2"	9587T15		
5/8"	1"	2"	3 3/8"	13/16"	9587T14		
3/4"	1 5/16"	2 1/4"	3 7/8"	7/8"	9587T13		
1"	1 3/8"	2 5/8"	4 7/16"	1"	9587T12		
1 1/4"	1 3/4"	3"	4 15/16"	1 1/8"	9587T11		

Solid Brass Shoulder Hooks

Supplied 100 per box except 9588T8, which is 50 per box.

Wire Dia.	H	P	S	T
1/4"	5/16"	1/2"	11/32"	3/16"
5/16"	5/16"	5/8"	11/32"	7/32"
3/8"	3/8"	3/4"	7/16"	1/4"
1/2"	1/2"	1"	7/16"	3/8"
5/8"	9/16"	1 1/4"	9/16"	1/2"
3/4"	9/16"	1 1/2"	9/16"	1/2"
1"	3/4"	2"	3/4"	3/4"

Hook Bolts-Zinc Plated

Wire Dia.	A	B	C	D	No.	BC
HOOK BOLTS WITH ONE HEX NUT						
1/4"	5/32"	1"	1 1/8"	1 5/8"	9491T11	
5/16"	3/16"	1 1/4"	1 5/16"	2"	9491T12	
3/8"	7/32"	1 3/8"	1 1/2"	2 3/16"	9491T13	
1/2"	1/4"	1 1/2"	1 7/8"	2 5/8"	9491T14	
5/8"	5/16"	1 7/8"	2"	3 1/4"	9491T15	
3/4"	3/8"	2 1/8"	2 3/8"	4"	9491T16	
1"	3/8"	3 1/4"	3 3/8"	4 3/4"	9491T17	
1 1/4"	1/2"	3 7/8"	4 1/8"	6 1/2"	9491T18	
HOOK BOLTS WITH TWO HEX NUTS						
1/4"	1/4"	2 5/8"	3"	4"	9492T13	
5/16"	5/16"	3 7/8"	4 1/2"	6"	9492T14	
3/8"	3/8"	3 7/8"	5 1/2"	7 1/4"	9492T12	
5/8"	3/8"	5 1/2"	6 1/2"	8 1/4"	9492T15	

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