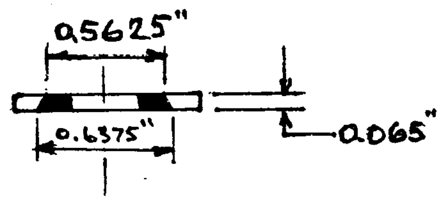
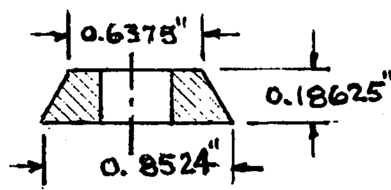
FRUSTUM 1: WASHER



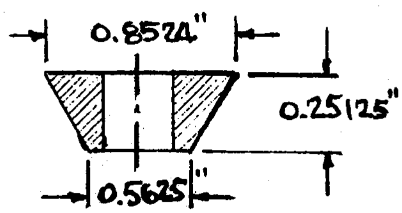

$E = 30$ Mpsi, $t = 0.065$,
$D = 0.5625 + 2(0.065)\,0.577$
$= 0.6375$ in
$k = 78.58$ Mlb/in, BY COMPUTER

FRUSTUM 2: CAP PORTION




$E = 14$ Mpsi, $t = 0.18625$ in
$D = 0.6375 + 2(0.18625)\,0.577$
$= 0.8524$ in
$k = 23.43$ Mlb/in, BY COMPUTER

FRUSTUM 3: FRAME AND CAP




$E = 14$ Mpsi, $t = 0.25125$ in
$k = 14.31$ Mlb/in, BY COMPUTER

$$k_m = \frac{1}{\frac{1}{78.58} + \frac{1}{23.43} + \frac{1}{14.31}} = 7.98 \text{ Mlb/in}$$ Ans.

FOR BOLT $L_T = 2(3/8) + (1/4) = 1$ in
SO IT IS THREADED ALL THE WAY.
SINCE $A_t = 0.0775$ in$^2$

$$k_b = \frac{0.0775(30)}{0.5025} = 4.63 \text{ Mlb/in}$$ Ans.

8-32 FIG. 8-22. $t_1 = 0.25$ in,
$h = 0.25 + 0.065 = 0.315$ in
$\ell = h + d/2 = 0.315 + (3/16) = 0.5025$ in
$D_1 = 1.5(0.375) + 0.577(0.5025) = 0.8524$ in
$D_2 = 1.5(0.375) = 0.5625$ in.
$\ell/2 = 0.5025/2 = 0.25125$ in

**8-33** (a) $F'_b = RF'_{bmax} \sin\theta$

Half the external moment is contributed by the line load in the interval $0 \leqq \theta \leqq \pi$

$$\frac{M}{2} = \int_0^{\pi} F'_b R^2 \sin\theta \, d\theta$$

$$= \int_0^{\pi} F'_{bmax} R^2 \sin^2\theta \, d\theta$$

$$\frac{M}{2} = \frac{\pi}{2} F'_{bmax} R^2$$

from which $F'_{bmax} = \dfrac{M}{\pi R^2}$

$$F_{max} = \int_{\phi_1}^{\phi_2} F'_b R \sin\theta \, d\theta$$

$$= \frac{M}{\pi R^2}\int_{\phi_1}^{\phi_2} R \sin\theta \, d\theta$$

$$= \frac{M}{\pi R}(\cos\phi_1 - \cos\phi_2)$$

Noting $\phi_1 = 75°$, $\phi_2 = 105°$

$$F_{max} = \frac{12\ 000}{\pi(8/2)}(\cos 75° - \cos 105°)$$

$$= 494 \text{ lb} \qquad \underline{\text{Ans}}.$$

(b)

$$F_{max} = F'_{bmax} R\Delta\phi = \frac{M}{\pi R^2} \cdot R \cdot \frac{2\pi}{N} = \frac{2M}{RN}$$

$$F_{max} = \frac{2(12\ 000)}{(8/2)(12)} = 500 \text{ lb} \qquad \underline{\text{Ans}}.$$

(c) $F = F_{max} \sin\theta$

$$M = 2F_{max}R[(1)\sin^2 90° + 2\sin^2 60° + 2\sin^2 30° + (1)\sin^2(0)]$$

$$= 6F_{max}R$$

from which

$$F_{max} = \frac{M}{6R} = \frac{12\ 000}{6(8/2)} = 500 \text{ lb} \qquad \underline{\text{Ans}}.$$

The simple general equation resulted in part (b)

$$F_{max} = \frac{2M}{RN}$$

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**8-34** THIS IS AN EXERCISE IN ESTIMATION FOR THE PURPOSE OF UNDERSTANDING THE CHANCE OF OVER-PROOFLOADING IS PRESENT

8-34 (CONT.)

IS A 4% CHANCE OF ONE OR MORE FASTENERS BEING OVER-PROOF LOADED. DESPITE THE APPROXIMATION, THIS IS A CAUTION THAT WHEN USING "MINIMUM" PROPERTIES AND LUBRICATED ASSEMBLY, AND COUNTING ON AVOIDING OVER-PROOF LOADING, IT IS A "SURE THING" THAT YOU CANNOT COUNT ON IT.

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8-35 M20 150 8.8 COARSE THREADS, 3.4 mm WASHER UNDER BOLT AND NUT. JOIST FLANGES 16 mm THICK, HOUSING FLANGE 20 mm THICK. $E = 135$ GPA.

(a) TO AVOID CONFUSION IN THIS PROBLEM WE WILL CALL PRELOAD $P_i$. RESERVING $F_i$ FOR THE CDF OF ORDERED FAILURE.

TABLE 8-11 : $S_p = 600$ MPa

EQ. (8-41)

$$P_i = 0.9 A_t S_p = 0.9(245)600(10^{-3})$$

$$= 132.3 \text{ kN}$$

$$T = 0.18(132.3)20 = 476 \text{ N·m} \quad \underline{\text{Ans.}}$$

(b) THIS OPENS AN INTERESTING PART OF STATISTICS CALLED ORDER STATISTICS, WHICH ADDRESSES ISSUES REGARDLESS OF THE DISTRIBUTION IDENTITY. THE CDF OF THE SMALLEST AND LARGEST ORDERED PRELOAD IS GIVEN BY,

MEDIAN

$$\tilde{F}_1 = \frac{i - 0.3}{n + 0.4} = \frac{1 - 0.3}{4 + 0.4} = 0.1591$$

$$\tilde{F}_4 = \frac{4 - 0.3}{4 + 0.4} = 0.8409$$

IF OUR PRELOAD IS NORMALLY-DISTRIBUTED, FROM TABLE E-10 $\tilde{z}_1 = -0.9981$ AND $\tilde{z}_4 = +0.9981$. THE STANDARD DEVIATION OF $\mathbf{P}$ IS

$$C_P \mu_P = 0.09(132.3) = 11.907 \text{ kN}$$

$$\tilde{P}_1 = \mu_P + \tilde{z}_1 \sigma_P = 132.3 + (-0.9981)11.907$$

$$= 120.4 \text{ kN}$$

$$\tilde{P}_4 = \mu_P + \tilde{z}_4 \quad = 132.3 + 0.9981(11.907)$$

$$= 144.2 \text{ kN}$$

THIS MEANS THAT ON MANY OBSERVATIONS OF FIRST AND FOUTH PRELOADS HALF WILL EXCEED 120.4 kN (AND 144.2 kN) AND HALF WILL NOT. THIS DESCRIBES THE BEHAVIOR OF MEDIANS.

IT IS POSSIBLE TO DESCRIBE MEAN VALUES AS WELL.

$$\bar{F}_1 = \frac{i}{n+1} = \frac{1}{4+1} = 0.2$$

$$\bar{F}_4 = \frac{4}{4+1} = 0.8$$

FROM TABLE E-10, $\bar{z}_1 = -0.8415$ AND $\bar{z}_4 = +0.8415$

$$\bar{P}_1 = 132.3 + (-0.8415(11.907)$$

$$= 122.3 \text{ kN}$$

$$\bar{P}_4 = 132.3 + 0.8415(11.907)$$

$$= 142.3 \text{ kN}$$

THIS MEANS THAT ON MANY OBSERVATIONS OF THE FIRST FAILURE, THE MEAN VALUE WOULD APPROACH 122.3 kN.

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8-36 (a) 150 M20 × 2.5 GRADE 8.8 COARSE PITCH BOLTS, LUBRICATED.

TABLE 8-2, $A_t = 245 \text{ mm}^2$

TABLE 8-11, $S_p = 600$ MPa

$A_d = \pi(20)^2/4 = 314.1 \text{ mm}^2$

$F_p = 245(0.600) = 147$ kN

$F_i = 0.90 F_p = 0.90(147) = 132.3$ kN

$T = 0.18(132.3)20 = 476$ N·m $\underline{\text{Ans.}}$

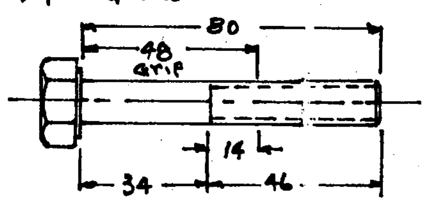
(b) $L \geq L_G + H = 48 + 18 = 66$ mm

SET $L = 80$ mm, TABLE E-17

$L_T = 2D + 6 = 2(20) + 6 = 46$ mm

$l_d = L - L_T = 80 - 46 = 34$ mm

$l_T = L_G - l_d = 48 - 34 = 14$ mm




NOT TO SCALE

**9-1** EQ. (9-3):

$F = 0.707 h l \tau = 0.707(5/16)4(20)$
$= 17.7$ kip Ans.

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**9-2** TABLE 9-7: $\tau_{all} = 21.0$ kpsi

$f = 14.85h$ kip/in
$= 14.85(5/16) = 4.64$ kip/in
$F = fl = 4.64(4) = 18.56$ kip Ans.

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**9-3** TABLE E-20:
1018 HR; $S_{ut} = 58$ kpsi, $S_y = 32$ kpsi
1018 CR; $S_{ut} = 64$ kpsi, $S_y = 54$ kpsi
COLD-ROLLED PROPERTIES DEGRADE TO HOT-ROLLED PROPERTIES IN THE NEIGHBORHOOD OF THE WELD.

TABLE 9-5:
$\tau_{all} = \min(0.30 S_{ut}, 0.40 S_y)$
$= \min(0.30[58], 0.40[32])$
$= \min(17.4, 12.8] = 12.8$ kpsi
FOR BOTH MATERIALS.

EQ (9-3): $F = 0.707 h l \tau_{all}$
$F = 0.707(5/16)4(12.8) = 11.3$ kip Ans.

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**9-4** EQ. (9-3)

$$\tau = \frac{\sqrt{2}F}{hl} = \frac{\sqrt{2}(32)}{(5/16)2(4)} = 18.1 \text{ kpsi}$$ Ans.

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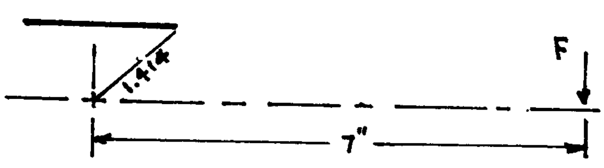
**9-5** $b = d = 2$ in




(a) PRIMARY SHEAR

$$\tau' = \frac{V}{A} = \frac{F}{1.414(5/16)2} = 1.13F \text{ kpsi}$$

SECONDARY SHEAR Table 9-2

$$J_u = \frac{d(3b^2+d^2)}{6} = \frac{2(3\cdot 2^2+2^2)}{6}$$
$= 0.5\underline{3}$ in$^3$

$J = 0.707 h J_u = 0.707(5/16)5.\underline{3}$
$= 1.18$ in$^4$

$$\tau_x'' = \tau_y'' = \frac{Mr_y}{J} = \frac{7F(1)}{1.18}$$
$= 5.93F$ kpsi

MAXIMUM SHEAR

$$\tau_{max} = \sqrt{\tau_x''^2 + \tau_y''^2}$$
$$= F\sqrt{5.93^2 + (1.13+5.93)^2}$$
$= 9.22F$ kpsi

$$F = \frac{\tau_{all}}{9.22} = \frac{20}{9.22} = 2.17 \text{ kip}$$ Ans.

(b) E7010, Table 9-3, $\tau_{all} = 21$ kpsi
Table E-20:
MEMBER 1; $S_{ut} = 55$ kpsi, $S_y = 30$ kpsi
MEMBER 2; $S_{ut} = 50$ kpsi, $S_y = 27.5$ kpsi
E7010; $S_{ut} = 70$ kpsi, $S_y = 57$ kpsi
MEMBER 2 CONTROLS

Table 9-5:
$\tau_{all} = \min[0.30(50), 0.40(27.5)]$
$= \min[15, 11] = 11$ kpsi

ALLOWABLE LOAD

$$F = \frac{\tau_{all}}{9.22} = \frac{11}{9.22} = 1.19 \text{ kip}$$ Ans.

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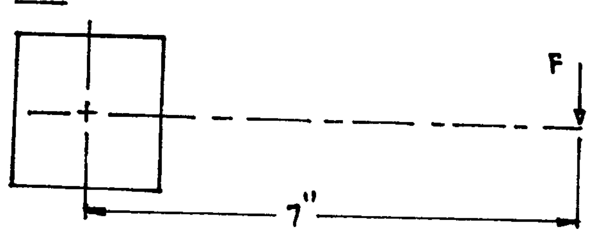
**9-6** $b = d = 2$ in




PRIMARY SHEAR

$$\tau' = \frac{V}{A} = \frac{F}{4(0.707)5/16(2)} = 0.566F$$

**9-6 (CONT.)**

**SECONDARY SHEAR** TABLE 9-2:

$$J_u = \frac{(b+d)^3}{6} = \frac{(2+2)^3}{6} = 10.67\,in^3$$

$$J = 0.707h\,J_u = 0.707(5/16)\,10.67 = 2.36\,in^4$$

$$\tau''_x = \tau''_y = \frac{M r_y}{J} = \frac{(7F)(1)}{2.36} = 2.97F$$

**MAXIMUM SHEAR**

$$\tau_{max} = \sqrt{\tau''^2_x + \tau''^2_y}$$

$$= F\sqrt{2.97^2 + (0.556 + 2.97)^2}$$

$$= 4.62\,F \text{ kpsi}$$

$$F = \frac{\tau_{all}}{4.62}$$

WHICH IS TWICE $\tau_{max}/9.22$ OF Prob. 9-5.

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**9-7** ALTERNATING LOAD FATIGUE.

THROAT AREA OF WELDMENT

$$A = 0.707(6)(60+50+60) = 721\,mm^2$$

MEMBERS ENDURANCE LIMIT

$S_{ut} = 320$ MPa, $S'_e = 0.506(320) = 161.9$ MPa

$$k_a = 271(320)^{-0.995} = 0.872$$

$k_b = 1$ (DIRECT SHEAR)

$$k_c = 0.256(320)^{0.125} = 0.531$$

$k_d = 1$

$$k_e = \frac{1}{K_{fs}} = \frac{1}{2.7} = 0.370$$

$$S_{se} = 0.872(1)0.531(0.37)161.9 = 27.7\,MPa$$

ELECTRODE: 6010

$$S_{ut} = 62(6.89) = 427\,MPa$$

$$S'_e = 0.506(427) = 216\,MPa$$

$$k_a = 271(427)^{-0.905} = 0.654$$

$k_b = 1$ (DIRECT SHEAR)

$$k_c = 0.258(427)^{0.125} = 0.550$$

$k_d = 1$

$$k_e = 1/K_{fs} = 1/2.7 = 0.370$$

$$S_{se} = 0.654(1)0.55(0.37)\,216 = 28.7\,MPa$$

MEMBERS CONTROL. FOR A fos OF 1

$$F_a = \tau_a A = 27.7(721)10^{-3} = [illegible]\,kN$$

$= [illegible]$ kip $= F_{max}$ **Ans.**

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**9-8** FROM PROBLEM 9-7

$$A = \frac{721\,mm^2}{645} = 1.18\,in^2$$

$$l = (60+50+60) = 170\,mm = 6.69\,in$$

$F_{max} = [illegible]$ kN $= [illegible]$ kip

FROM TABLE 9-8, CONFIGURATION 25, CATEGORY F, AND K = −1

$$(\tau_{max})_{all} = \frac{\tau_{sr}}{1-K} = \frac{8}{1-(-1)} = 4\text{ kpsi}$$

$$= 27.6\,MPa$$

SINCE $(\tau_{max})_{all} \doteq \tau_{max}$, i.e. $27.6 \doteq 27.7$ MPa THE WELD IS BARELY SATISFACTORY. THE WELDING CODE IS COMING AT THIS PROBLEM FROM A DIFFERENT PERSPECTIVE. IN THIS CASE THE RESULTS ARE COMPARABLE. IF WELDING CODE PREVAILS THE ALLOWABLE MAXIMUM LOAD $F_{max}$ IS

$$F_{max} = 4(1.18) = 4.72\text{ kip} \quad \textbf{Ans.}$$

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**9-9** $\tau' = 0$ (WHY)

TABLE 9-2: $J_u = 2\pi r^3 = 2\pi(4)^3 = 4.02\,cm^3$

$$J = 0.707h\,J_u = 0.707(0.5)4.02 = 142\,cm^4$$

$M = 200F$ N·m (F in kN)

$$\tau'' = \frac{Mr}{2J} = \frac{(200F)4}{2(142)} = 2.82F$$

$$F = \frac{\tau_{all}}{\tau''} = \frac{140}{2.82} = 49.2\,kN \quad \textbf{Ans.}$$

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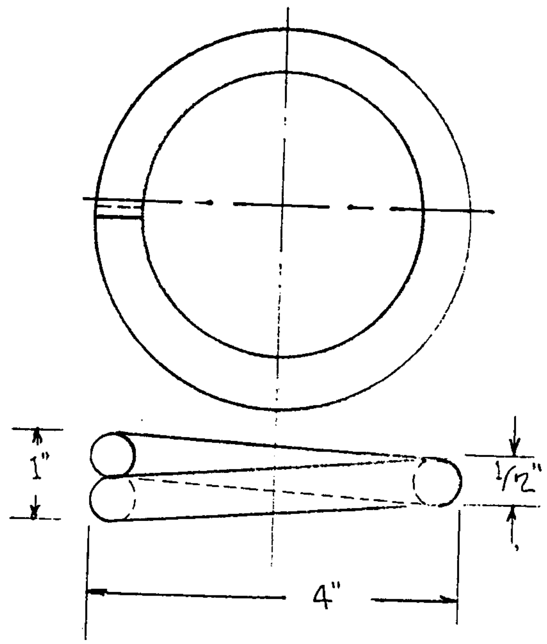
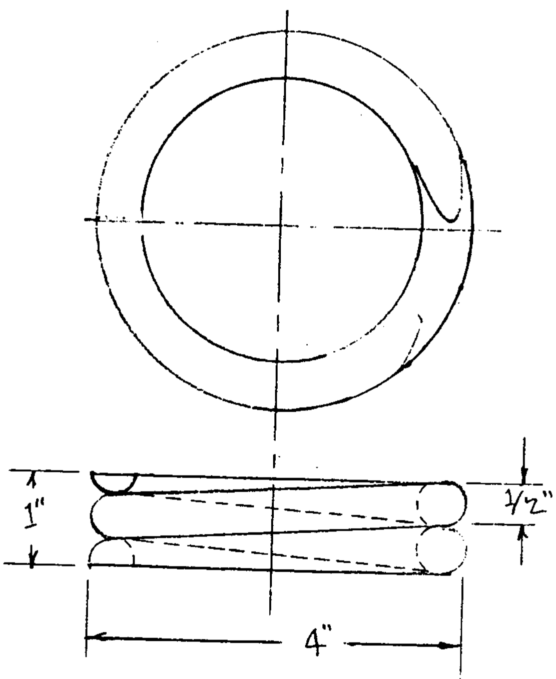
**10-1**




$$A_1 = \frac{\text{MPa}}{\text{kpsi}} \cdot \frac{\text{mm}^m}{\text{in}^m} A$$
$$= 6.894757(25.4)^m A$$
$$\doteq 6.89(25.4)^m A$$

FOR MUSIC WIRE, TABLE 10-5:
$A = 201$, $m = 0.145$; WHAT IS $A_1$?

$$A_1 = 6.89(25.4)^{0.145} 201 = 2214 \text{ MPa}\cdot\text{mm}^m$$

ACCURACY DEPENDS OF VALUES OF A AND m FOR AN r = -.9967 REGRESSION ON 34 MUSIC WIRE SIZES, WHICH IS TABULATED AS 201 $\text{kpsi}\cdot\text{in}^m$ AND $m = 0.144753 \doteq 0.145$. THE REGRESSION VALUE OF $A = \exp(5.302493)$ $= 200.8248$. THE IMPORTANT THING TO UNDERSTAND, IS THAT YOU CANNOT MULTIPLY 6.89 TIMES 201 TO GET $A_1$.

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**10-2** $A = S d^m$

$\dim(A) = \dim(S)\dim(d^m) = \text{kpsi}\cdot\text{in}^m$

$\dim(A_1) = \dim(S_1)\dim(d_1^m) = \text{MPa}\cdot\text{mm}^m$

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**10-3** GIVEN: MUSIC WIRE, $d = 0.105$ in, OD = 1.225 in, PLAIN GROUND ENDS, $N_t = 12$ coils. Page 596 TABLE:
$Q = 1$, $Q' = 1$

$$N_a = N_t - Q = 12 - 1 = 11$$
$$L_s = (N_a + Q')d = (11+1)0.105 = 1.26 \text{ in}$$

(a) TABLE 10-5: $A = 201$, $m = 0.145$

EQ. (10-17)

$$S_{ut} = \frac{201}{0.105^{0.145}} = 278.4 \text{ kpsi}$$

EQ. (10-28)

$$S_{sy} = 0.45(278.7) = 125.4 \text{ kpsi}$$
$$D = 1.225 - 0.105 = 1.120 \text{ in}$$

$$C = \frac{D}{d} = \frac{1.120}{0.105} = 10.\underline{6}$$

EQ. (10-6):

$$K_B = \frac{4(10.\underline{6}) + 2}{4(10.\underline{6}) - 3} = 1.126$$

$$(F)_{S_{sy}} = \frac{\pi d^3 S_{sy}}{8 K_B D} = \frac{\pi(0.105)^3 125.4(10^3)}{8(1.126)1.120}$$
$$= 45.2 \text{ lb}$$

10-3 (CONT.)

$$k = \frac{d^4 G}{8 D^3 N_a} = \frac{0.105^4\, 11.75(10^6)}{8(1.120)^3\, 11}$$

$$= 11.55 \text{ lb/in}$$

$$L_0 = \frac{(F)_{S_{sy}}}{k} + L_s = \frac{45.2}{11.55} + 1.26$$

$$= 5.17 \text{ in} \quad \underline{\text{Ans.}}$$

(b) $(F)_{S_{sy}} = 45.2$ Ans.

(c) $k = 11.55$ lb/in Ans.

(d)

$$(L_0)_{cr} = \frac{2.63 D}{\alpha} = \frac{2.63(1.120)}{0.5}$$

$$= 5.89 \text{ in}$$

MANY DESIGNERS PROVIDE $(L_0)_{cr}/L_0 \geq 5$ OR MORE. PLAIN GROUND ENDS ARE NOT OFTEN USED IN MACHINERY DUE TO BUCKLING UNCERTAINTY.

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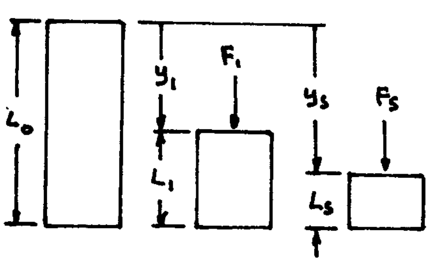
10-4 SEE Prob. 10-3. STATIC SERVICE SPRING. EQS. (10-24) TO (10-31) ONLY AS BASIS FOR ADEQUACY ASSESSMENT.

- $4 \leq C \leq 12$: $C = 10.\underline{6}$ O.K.
- $3 \leq N_a \leq 15$: $N_a = 11$, O.K.




$L_0 = 5.17$ in, $L_s = 1.26$ in

$$y_1 = \frac{F_1}{k} = \frac{30}{11.55} = 2.60 \text{ in}$$

$$L_1 = L_0 - y_1 = 5.17 - 2.60 = 2.57 \text{ in}$$

$$\xi = \frac{y_s}{y_1} - 1$$

$$= \frac{5.17 - 1.26}{2.60} - 1 = 0.50$$

- $\xi \geq 0.15$: $\xi = 0.50$, O.K.

P. 592

$$\tau_1 = K_B \frac{8 F_1 D}{\pi d^3} = 1.126 \frac{8(30)\,1.120}{\pi\, 0.105^3}$$

$$= 83\,224 \text{ psi}$$

$$n_s = \frac{S_{sy}}{\tau_1} = \frac{125.4(10^3)}{83\,224} = 1.51$$

- $n_s \geq 1.2$: $n_s = 1.51$ O.K.

$$\tau_s = \tau_1 \frac{45.2}{30} = 83\,224 \frac{45.2}{30}$$

$$= 125\,391 \text{ psi}$$

$$S_{sy}/\tau_s = 125.4(10^3)/125\,391 \doteq 1$$

- $S_{sy}/\tau_s \geq (n_s)_d$: NOT SOLID-SAFE. NOT O.K.
- $L_0 \leq (L_0)_{cr}$: $5.17 \leq 5.83$

MARGIN COULD BE HIGHER, NOT O.K.
DESIGN UNSATISFACTORY Ans.
OPERATE OVER A ROD?

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10-5 STATIC SERVICE SPRING, HD STEEL WIRE, $d = 2$ mm, OD = 22 mm, $N_t = 8.5$ turns, PLAIN AND GROUND ENDS, $\varphi = 1$, $\varphi' = 1$

PRELIMINARIES

TABLE 10-5: $A = 1783$ MPa$\cdot$mm$^m$
$m = 0.190$

$$S_{ut} = \frac{1783}{2^{0.190}} = 1563 \text{ MPa}$$

$$S_{sy} = 0.45(1563) = 703.4 \text{ MPa}$$

$$D = OD - d = 22 - 2 = 20 \text{ mm}$$

$$C = 20/2 = 10$$

$$K_B = \frac{4C + 2}{4C - 3} = \frac{4(10) + 2}{4(10) - 3} = 1.135$$