compression spring

squared and ground ends

$d = 0.105$ in OK preferred wire size Table 14-2 Norton
$OD = 0.755$ in
$L_f = 2.25$ in
$N_t = 11.75$

assume A228 music wire

$N_a = N_t - 2 = 9.75$ Fig. 14-9 Norton

$D = OD - d = 0.650$ in

do not use OD in any other eqns
ID = OD - 2d

$C = D / d = 6.1905$ Eq. 14-5

$G = 11.7 \times 10^6$ psi Table A-1 Norton

$$k = \frac{d^4\ G}{8\ D^3\ N_a} = \frac{(0.105\text{ in})^4}{8\,(0.650\text{ in})^3\,(9.75)}\left(\frac{11.7\text{x}10^6\text{ lbf}}{\text{in}^2}\right) = 66.39\text{ lbf/in}$$ Eq. 14.7 Norton

$S_{ut} = A\ d^b = 266.3$ ksi $A = 184649$ psi $b = -0.1625$ Eq. 14.3 and Table 14-4 Norton

$S_{ys} = 0.45\ S_{ut} = 119.8$ ksi Table 14-8 Norton

$$K_W = \frac{4C-1}{4C-4} + \frac{0.615}{C} = 1.2438 \qquad \tau_{MAX} = K_W\,\frac{8\,F\,D}{\pi\,d^3} < S_{ys}$$ Eq 14.8b Norton

$K_W > K_S$

$$F_y < \frac{\pi\,d^3\,S_{ys}}{8\,K_W\,D} = \frac{\pi(0.105\text{ in})^3}{8(1.2438)(0.650\text{ in})}\left(\frac{119.8\text{x}10^3\text{ lbf}}{\text{in}^2}\right) = 67.36\text{ lbf}$$

$L_s = d\ N_t = 1.234$ in shut length (fully compressed) - squared and ground

$y_s = L_f - L_s = 1.016$ in

$F \neq k\,L_s$

$F_s = k\ y_s = 67.45$ lbf $> F_y$ will be VERY close to yield at shut length

$F = k\,y$

$\rho = 0.28$ lbm/in^3 Table A-1 Norton

$w = \rho\left(\pi d^2/4\right)(\pi\,D)\,N_t = 0.058$ lbf

0.283

torsion spring garage door opener

rotating shaft crosses full width of door and has drums on each end
three bearings for shaft – left, center, right
steel cables connected to bottom of door (one on each side) are wound by drums to lift door
two torsion springs – one RH and one LH
springs fixed to front wall of garage above door at center
springs connected to rotating shaft by clamps with two set screws at rotating end

d = 0.242 in <u>not a preferred wire size</u> Table 14-2 Norton
OD = 2.484 in
$N_a = 143$

7 turns of preload when door closed

assume A229 oil tempered wire

D = OD – d = 2.242 in

C = D / d = 9.2645 Eq. 14-5

$E = 30 \times 10^6$ psi Table A-1 Norton

$$k_\theta = \frac{d^4\ E}{10.8\ D\ N_a} = \frac{(0.242\ \text{in})^4}{10.8\,(2.484\ \text{in})\,(143)}\left(\frac{30\text{x}10^6\ \text{lbf}}{\text{in}^2}\right) = 26.82\ \text{in.lbf/rev}$$ Eq. 14.29 Norton

$\theta = 7$ rev

k_θ

$M = k_T\,\theta = 187.7$ in.lbf $= 15.65$ ft.lbf

$r_{DRUM} = 2$ in radius of drum for cable to lift door

each turn of drum lifts door $2\,\pi\,r_{DRUM} = 12.57$ in

$F_{CABLE} = M / r_{DRUM} = 93.87$ lbf force in cable to lift door (one cable on each side of door)

static at inside of coil $$K_{bi} = \frac{4C^2 - C - 1}{4C(C-1)} = 1.0875$$ Eq. 14.32a Norton

$$\sigma_{i\,max} = K_{bi}\frac{32\ M}{\pi\ d^3} = (1.0875)\frac{32(187.7\ \text{in.lbf})}{\pi\,(0.242\ \text{in})^3} = 146.7\ \text{ksi}$$ Eq. 14.33a Norton

$S_{ut} = A\ d^b = 190.4$ ksi $A = 146780$ psi $b = -0.1833$ Eq. 14.3 and Table 14-4 Norton

$S_y = 0.85\ S_{ut} = 161.8$ ksi Table 14-15 Norton

$N_{FS} = S_y / \sigma_{i\,max} = 1.10$