1) 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

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

G = 11.7 x 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

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

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

$y_s = L_f - L_s = 1.016$ in

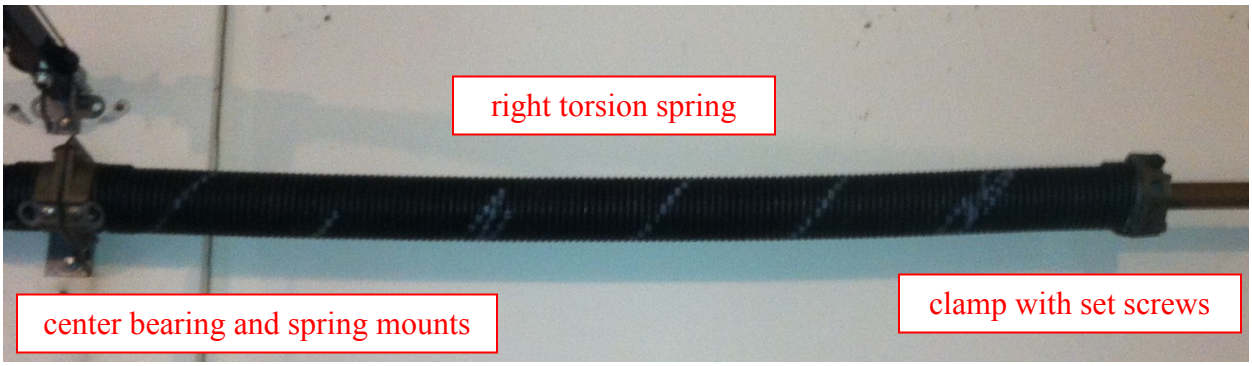
$F_s = k\ y_s = 67.45$ lbf > F_y will be VERY close to yield at shut length

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

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

2) 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 not a preferred wire size 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 x 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

$M = k_T\ \theta = 187.7$ 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

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