Material: Hard drawn wire

$\sigma_{yp} = 0.75\,\sigma_{ut}$ (Table 13-10 pg 853 of text)

$D = 10$ mm, $d = 2$ mm $\Rightarrow C = 5$

$R_1 = 6$ mm

$R_2 = 3$ mm

$N_a = 120$

F_i = preload = ~~300N~~ 30N

$L_H = 264$ mm ~ distance between hooks

Assume A227

$\sigma_{ut} = 1500$ MPa ~ chart

$\sigma_{yp} = 1125$ MPa

$\tau_{yp} = .45\,\sigma_{ut}$ ~ (Table 13-10 pg 853)

$\tau_{yp} = 675$ MPa

Will need both σ_{yp} (bending) and τ_{yp} (shear)

$$k = \frac{dG}{8N_a C^3}$$

$$k = \frac{(2\times10^{-3})(79.3\times10^{9})}{(8)(120)(5)^3}\ (m^3)\left(\frac{N}{m^2}\right)$$

$$k = 1320\ N/m$$

Initial Stress in Coil

$$\tau_i = \frac{8F_i}{\pi d^2} C K_s$$

$K_s \approx 1.1$ ~ chart

$$\tau_i = \frac{(8)(30)(5)(1.1)}{(\pi)(.002)^2} \left(\frac{N}{m^2}\right)$$

$$\tau_i = 105 \text{ MPa} < \tau_{all}$$

Force required to yield the coil:

$$\tau_{yp} = 675 \times 10^6 \left(\frac{N}{m^2}\right) = \frac{(8 F_{yp})(5)(1.1)}{\pi (.002)^2} = \tau_{all}$$

$$\Rightarrow \boxed{F_{yp} = 193 \text{ N}} \text{ coil}$$

Above is the force required to yield the coil.
We have an extension spring. We, therefore, need to check the bending stress (hook) and torsional stress in the bend (Fig 13-23 / pg 853)

Eqns 13.23 & 13.24 pg 852

$$\sigma_A = \sigma_{bending} = \sigma_{yp} = 1125 \text{ MPa}$$

$$= K_b \frac{16 C F}{\pi d^2} + \frac{4 F}{\pi d^2}$$

$$K_b = \frac{4C_1^2 - C_1 - 1}{4C_1(C_1 - 1)}$$

$$K_1 = \frac{2R_1}{d}$$

$R_1 = 6.0 \text{ mm}$
$R_2 = 3.0 \text{ mm}$

$$C_1 = \frac{2 \times 6}{2}$$

$$\boxed{C_1 = 6}$$

$$K_b = \frac{(4)(36) - 6 - 1}{(4)(6)(5)}$$

$$\boxed{K_b = 1.14}$$

$$1125 \times 10^6 \frac{N}{m^2} = (1.14)\frac{(16)(5)(F)}{(\pi)(.002)^2} + \frac{4F}{(\pi)(.002)^2}$$

$\Rightarrow \boxed{F_{Hook} = 148\ N}$ ~ This is the force which will yield the hook

$\tau_B = \tau_{yp} = 675 \times 10^6 \frac{N}{m^2}$ ~ max stress in bend

$$= K_{w2}\frac{8DF}{\pi d^3} = K_{w2}\left(\frac{8CF}{\pi d^2}\right)$$

$$K_{w2} = \frac{4C_2 - 1}{4C_2 - 4}$$

$$C_2 = \frac{2R_2}{d}$$

$$C_2 = \frac{(2)(3)}{(2)}$$

$$\boxed{C_2 = 3}$$

$$K_{w2} = \frac{(4)(3)-1}{(4)(3)-4} = \frac{12-1}{12-4} = \frac{11}{8}$$

$$\boxed{K_{w2} = 1.38}$$

$$\tau_B = (1.38)\frac{(8)(S)(F)}{(\pi)(.002)^2} = 675 \times 10^6 \frac{N}{m^2}$$

$F = 154$ N – force to yield bend

$F =$ 159 N ~ bend, 148 N ~ hook, 193 N ~ coil } to yield

$F > 148$, hook yields

$\therefore$ $F_{max,\,all} = 148$ N

Final length

Spring must overcome preload, F_i, before spring will stretch

$$\delta = F/k$$

$$F = F_{max} - F_i$$
$$= 148 - 30$$

$F = 118$ N

$$\delta = \frac{118}{1320}\frac{N}{N/m} = .089\ m$$

$L = \delta + \delta_H$ $\quad \delta_H$ ~ initial

$= 89 + 264$ (mm)

$L \doteq 353$ mm