"The flexibility factor is the length of straight pipe having the same flexibility as the component divided by the the centerline length of the component." - Companion Guide Vol.1 pg 523

$OD := 6.625 \cdot in \quad wt := 0.28 \cdot in \quad Ro := \frac{OD}{2} \quad Ri := Ro - wt$

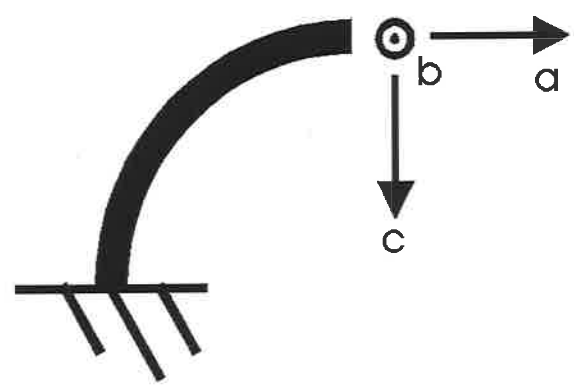
$A := \pi \cdot \left(Ro^2 - Ri^2\right) \quad I := \frac{\pi}{4} \cdot \left(Ro^4 - Ri^4\right)$

$E := 2.95 \cdot 10^7 \cdot psi \quad \nu := 0.292 \quad G := \frac{E}{2 \cdot (1 + \nu)}$

$R := 9 \cdot in$

$\theta := \frac{\pi}{2} \quad \alpha := \frac{4}{3} \cdot \frac{\left(Ro^3 - Ri^3\right)}{\left(Ro^2 + Ri^2\right) \cdot (Ro - Ri)}$

$h := \frac{wt \cdot R}{\left(\frac{OD - wt}{2}\right)^2} \quad k := \frac{1.65}{h} \quad k = 6.59 \quad Ki := k \quad Ko := k$




The following equations come from MEC-21

1. $\phi bPa := \frac{Ki \cdot R^2}{E \cdot I} \cdot (\sin(\theta) - \theta)$ $\delta aMb := \phi bPa$

2. $\phi bPc := \frac{Ki \cdot R^2}{E \cdot I} \cdot (\cos(\theta) - 1)$ $\delta cMb := \phi bPc$

3. $\delta cPc := \frac{Ki \cdot R^3}{E \cdot I} \cdot \left(\frac{\theta}{2} - \frac{\sin(2 \cdot \theta)}{4}\right) + \left[\frac{\alpha \cdot R}{A \cdot G} \cdot \left(\frac{\theta}{2} + \frac{\sin(2 \cdot \theta)}{4}\right)\right]$

4. $\phi bMb := \frac{Ki \cdot R \cdot \theta}{E \cdot I}$

5. $\delta bPb := \frac{R^3}{E \cdot I} \cdot \left[(Ko) \cdot \left(\frac{\theta}{2} - \frac{\sin(2 \cdot \theta)}{4}\right) + (1 + \nu) \cdot \left[(\theta) - 2 \cdot \sin(\theta) + \frac{\theta}{2} + \frac{\sin(2 \cdot \theta)}{4}\right]\right] + \left(\frac{\alpha \cdot R \cdot \theta}{A \cdot G}\right)$

6. $\delta bMa := \frac{R^2}{E \cdot I} \cdot \left[((1 + \nu)) \cdot \left[\left(\frac{\theta}{2}\right) + \frac{\sin(2 \cdot \theta)}{4} - \sin(\theta)\right] + Ko \cdot \left(\frac{\theta}{2} + \frac{\sin(2 \cdot \theta)}{4}\right)\right]$ $\phi aPb := \delta bMa$

7. $\delta bMc := \frac{R^2}{E \cdot I} \cdot \left[\frac{Ko \cdot (\sin(\theta))^2}{2} + (1 + \nu) - (1 + \nu) \cdot \left[\frac{(\sin(\theta))^2}{2} + \cos(\theta)\right]\right]$ $\phi cPb := \delta bMc$

8. $\phi aMa := \frac{R}{E \cdot I} \cdot \left[(1 + \nu) \cdot \left(\frac{\theta}{2} + \frac{\sin(2 \cdot \theta)}{4}\right) + Ko \cdot \left(\frac{\theta}{2} - \frac{\sin(2 \cdot \theta)}{4}\right)\right]$

9. $\phi aMc := \frac{R}{E \cdot I} \cdot [Ko - (1 + \nu)] \cdot \frac{(\sin(\theta))^2}{2}$ $\phi cMa := \phi aMc$

10. $\delta aPc := \frac{Ki \cdot R^3}{E \cdot I} \cdot \left[1 - \cos(\theta) - \frac{(\sin(\theta))^2}{2}\right] + \left[\frac{\alpha \cdot R}{2 \cdot A \cdot G} \cdot (\sin(\theta))^2\right]$ $\delta cPa := \delta aPc$

11. $\delta aPa := \frac{Ki \cdot R^3}{E \cdot I} \cdot \left[(\theta) - 2 \cdot \sin(\theta) + \frac{\theta}{2} + \frac{\sin(2 \cdot \theta)}{4}\right] + \left[\frac{\alpha \cdot R}{A \cdot G} \cdot \left(\frac{\theta}{2} + \frac{\sin(2 \cdot \theta)}{4}\right)\right]$

12. $\phi cMc := \frac{R}{E \cdot I} \cdot \left[Ko \cdot \left(\frac{\theta}{2} + \frac{\sin(2 \cdot \theta)}{4}\right) + (1 + \nu) \cdot \left(\frac{\theta}{2} - \frac{\sin(2 \cdot \theta)}{4}\right)\right]$

$$A := \begin{bmatrix} \delta aPa \cdot \frac{lbf}{in} & 0 & \delta aPc \cdot \frac{lbf}{in} & 0 & \delta aMb \cdot (lbf) & 0 \\ 0 & \delta bPb \cdot \frac{lbf}{in} & 0 & \delta bMa(lbf) & 0 & \delta bMc \cdot (lbf) \\ \delta cPa \cdot \frac{lbf}{in} & 0 & \delta cPc \cdot \frac{lbf}{in} & 0 & \delta cMb \cdot (lbf) & 0 \\ 0 & \phi aPb \cdot \left(\frac{180}{\pi} \cdot lbf\right) & 0 & \phi aMa \cdot \left(\frac{180}{\pi} \cdot lbf \cdot in\right) & 0 & \phi aMc \cdot \left(\frac{180}{\pi} \cdot lbf \cdot in\right) \\ \phi bPa \cdot \left(\frac{180}{\pi} \cdot lbf\right) & 0 & \phi bPc \cdot \left(\frac{180}{\pi} \cdot lbf\right) & 0 & \phi bMb \cdot \left(\frac{180}{\pi} \cdot lbf \cdot in\right) & 0 \\ 0 & \phi cPb \cdot \left(\frac{180}{\pi} \cdot lbf\right) & 0 & \phi cMa \cdot \left(\frac{180}{\pi} \cdot lbf \cdot in\right) & 0 & \phi cMc \cdot \left(\frac{180}{\pi} \cdot lbf \cdot in\right) \end{bmatrix}$$

Lbf & Lbf-in

in & degrees

$$F := \begin{pmatrix} 0 \\ 0 \\ 1000 \\ 0 \\ 0 \\ 0 \end{pmatrix} \qquad x := A \cdot F \qquad x = \begin{pmatrix} 3.034 \times 10^{-3} \\ 0 \\ 4.766 \times 10^{-3} \\ 0 \\ -0.037 \\ 0 \end{pmatrix} \begin{matrix} a \\ b \\ c \\ ra \\ rb \\ rc \end{matrix}$$