1.0 Selection of load conditions, spring operational and production parameters.

1.1 Working cycle operational parameters

1.2 Method of loading

1.3 Working temperature T [° F]

<table>
<thead>
<tr>
<th>Fatig loading</th>
<th>200.0</th>
</tr>
</thead>
</table>

1.4 Working environment

<table>
<thead>
<tr>
<th>Non corrosive</th>
</tr>
</thead>
</table>

1.5 Method of stress curvature correction

<table>
<thead>
<tr>
<th>Correction by Wahl</th>
</tr>
</thead>
</table>

1.6 Spring design

1.7 Spring type

A ... Close-wound spring

1.8 Direction of spring loading

C ... In coiling direction

1.9 Surface treatment

Shot peened springs

1.10 Direction of coil winding

Right

1.11 Design of working leg

1.12 Type of leg

A ... Straight tangential leg

1.13 Method of fixing the leg

E ... Fixed clamped leg

1.14 Design of support leg

1.15 Type of leg

A ... Straight tangential leg

1.16 Method of fixing the leg

E ... Fixed clamped leg

1.17 Static loaded spring

1.18 Operational loading mode

Light service
1.19 Desired level of safety $s_s$ 1,00

1.20 **Fatig loaded spring**

1.21 Operational loading mode Continuous loading

1.22 Desired spring service life in thousands of cycles $N$ Infinite life

1.23 Desired level of safety $s_f$ 1,30

2.0 Options of spring material.

2.1 Production method: Cold formed springs

2.2 Spring material: Hard drawn steel wire ASTM A227

2.3 Field of use of the selected material

2.4 Suitability for fatigue load

2.5 Relative strength

2.6 Corrosion resistance Insufficient

2.7 Max. operational temperature 250 [$^\circ\text{F}$]

2.8 Delivered wire diameters 0.031 - 0.625 [in]

2.9 Mechanical and physical properties of the material

2.10 Modulus of elasticity in tension $E_{20}$ 28700 [ksi]

2.11 Modulus of elasticity at operational temperature $E$ 28043 [ksi]

2.12 Density $\rho$ 490 [lb/ft$^3$]

2.13 Strength characteristics of the material

2.14 Ultimate tensile strength $S_u$ 175 [ksi]

2.15 Permissible bending stress $\sigma_A$ 122,5 [ksi]

2.16 Endurance limit in bending $\sigma_e$ 70 [ksi]

2.17 Endurance limit by finite life $\sigma_f$ 70 [ksi]

3.0 Spring design.

3.1 Force arms Deviat. [%]

3.2 Arm of working force $R_f$ 1,500 10,0 [in]

3.3 Arm of supporting force $R_s$ 1,500 10,0 [in]

3.4 Desired moments of the working cycle

3.5 Maximum working moment $M_0$ 20,0 10,0 [lb ft]

3.6 Minimum working moment $M_1$ 10,0 30,0 [lb ft]

3.7 Desired angular deflections of spring working leg

3.8 Leg angular deflection of fully loaded spring $\alpha_0$ 120,0 10,0 [°]

3.9 Angle of working stroke $\alpha_{A1}$ 60 50 [°]

3.10 Leg angular deflection of preloaded spring $\alpha_1$ 60 59 [°]
3.11 **Filters of the designed solution**

- Maximum permissible spring outer diameter $D_{\text{max}}$ = 5.000 [in]
- Minimum permissible spring inner diameter $D_{\text{min}}$ = 1.000 [in]
- Maximum permissible length of coiled section $L_{\text{max}}$ = 10,000 [in]
- Permissible division of the number of active coils $1/10$
- Permissible exceeding of spring limit dimensions $0.0$
- Keep to the required level of safety with the strength check Yes
- Quality criterion Combined
- Number of design iteration Medium

3.21 **Options of solutions**

- Sort design result by Qualities of solutions
- Run design calculation

### Results section

4.0 **Summarized list of designed spring parameters.**

<table>
<thead>
<tr>
<th>ID</th>
<th>$D_e$</th>
<th>$D_i$</th>
<th>$d$</th>
<th>$n$</th>
<th>$\delta_9$</th>
<th>$\alpha_1$</th>
<th>$\alpha_8$</th>
<th>$R_f$</th>
<th>$M_1$</th>
<th>$\sigma_8$</th>
<th>$S_8$</th>
<th>$S_f$</th>
<th>$m$</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.408</td>
<td>2.714</td>
<td>0.3065</td>
<td>15.40</td>
<td>142</td>
<td>72.5</td>
<td>118.7</td>
<td>1.510</td>
<td>11.0</td>
<td>18.0</td>
<td>76</td>
<td>1.45</td>
<td>1.31</td>
<td>2.546</td>
</tr>
</tbody>
</table>

4.1 Refresh results from the selected spring design

4.2 **Spring loading**

- Arm of working / supporting force $R_f / R_s$ = 1.5103 / 1.5103 [in]
- Minimum / maximum working moment $M_1 / M_3$ = 11,000 / 18,000 [lb ft]
- Minimum / maximum working force $F_1 / F_8$ = 87.40 / 143.02 [lb]

4.6 **Spring dimensions**

- Mean spring diameter $D$ = 2.4076 [in]
- Recommended limits of wire diameter $d_{\text{min}} / d_{\text{max}}$ = 0.1505 / 0.6019 [in]
- Wire diameter $d$ = 0.3065 [in]
- Outer / inner spring diameter $D_e / D_i$ = 2.7141 / 2.1011 [in]
4.11 Spring index  c  7.86
4.12 Number of active coils  n  15.4
4.13 Angle between legs in a free state  δ₀  141.7 °
4.14 Theoretic length of coiled section  Lₖ  5,0266 [in]
4.15 Pitch between coils of free spring  t  0.3065 [in]
4.16 **Dimensions of spring legs**
4.17 Length of working / supporting leg  L₋₁ / L₋₂  1,530 / 1,530 [in]
4.18 Bending radius on the working / supporting leg  r₁ / r₂  0.000 / 0.000 [in]

**Parameters of preloaded spring**
4.20 Angular deflections of working leg / corrected  α₆ / α₆c  72.52 / 72.52 °
4.21 Angle between spring legs  δ₆  69.2 °
4.22 Spring stress  σ₆  46.70 ksi

**Parameters of fully loaded spring**
4.24 Angular deflections of working leg / corrected  α₈ / α₈c  118.67 / 118.67 °
4.25 Angle between spring legs  δ₈  23.0 °
4.26 Angle of spring working stroke  α₄₁  46.15 °
4.27 Spring stress  σ₈  76.41 ksi
4.28 Max. outer / min. inner spring diameter  D₈ₑ / D₈ᵢ  2,714 / 2,0506 [in]
4.29 Maximum theoretic length of coiled section  L₋₈  5,1276 [in]

**Parameters of spring limit state**
4.31 Spring limit loading  F₉ / M₉  207.5 / 26.1 [lb] / [lb ft]
4.32 Angular deflections of working leg / corrected  α₉ / α₉c  172.20 / 172.20 °
4.33 Angle between spring legs  δ₉  -30.5 °

**Spring mechanical and physical properties**
4.35 Torque spring rate  k  1.82 [lb in/°]
4.36 Spring deformation energy  W₈  18.64 [ft lb]
4.37 Developed wire length  l  121.7 [in]
4.38 Spring weight  m  2,546 [lb]
4.39 **Spring strength check**

4.40 Curvature correction factor \( K_s \)

4.41 Corrected stress of fully loaded spring \( \sigma_{BC} \) [ksi]

4.42 Permissible bending stress \( \sigma_A \) [ksi]

4.43 Level of safety

4.49 **Strength check of a spring exposed to fatigue loading**

4.50 Corrected stress in spring coils \( \sigma_{BC} \) [ksi]

4.51 Corrected stress on leg at the point of bending \( \sigma_{Br} \) [ksi]

4.52 Max. fatigue strength for the given loading \( \sigma_{max} \) [ksi]

4.53 Level of safety

5.0 **Parameters of designed spring for specific working load.**

5.1 **Spring parameters for the given working loading**

5.2 Spring loading \( \frac{M_x}{F_x} \) [lb ft] / [lb]

5.3 Angular deflections of working leg / corrected \( \alpha_x / \alpha_{xc} \) [°]

5.4 Angle between spring legs \( \delta_x \) [°]

5.5 Spring stress \( \sigma_x \) [ksi]

5.6 **Spring parameters for the given angular leg deflection**

5.7 Angular deflections of working leg \( \alpha_x \) [°]

5.8 Angle between spring legs \( \delta_x \) [°]

5.9 Spring produced force / moment \( \frac{F_x}{M_x} \) [lb] / [lb ft]

5.10 Spring stress \( \sigma_x \) [ksi]

6.0 **Check of loading capacity of a spring exposed to fatigue loading.**

6.1 Curvature correction factor \( K \)

6.2 Corrected stress of preloaded spring \( \sigma_{1C} \) [ksi]

6.3 Corrected stress of fully loaded spring \( \sigma_{BC} \) [ksi]

6.4 Ultimate tensile strength \( S_u \) [ksi]

6.5 Permissible bending stress \( \sigma_A \) [ksi]

6.6 Endurance limit in bending \( \sigma_e \) [ksi]

6.7 Endurance limit by finite life \( \sigma_f \) [ksi]

6.8 Max. fatigue strength for the given loading \( \sigma_{max} \) [ksi]

6.9 Level of safety

---

**Diagram:**

- **Spring parameters for the given working loading:**
  - \( M_x / F_x \) = 15,00 / 119,2 [lb ft] / [lb]
  - \( \alpha_x / \alpha_{xc} \) = 98,89 / 98,89 [°]
  - \( \delta_x \) = 42,8 [°]
  - \( \sigma_x \) = 63,68 [ksi]

- **Spring parameters for the given angular leg deflection:**
  - \( \alpha_x \) = 100,0 [°]
  - \( \delta_x \) = 41,7 [°]
  - \( F_x / M_x \) = 120,5 / 15,17 [lb] / [lb ft]
  - \( \sigma_x \) = 64,39 [ksi]

- **Check of loading capacity of a spring exposed to fatigue loading:**
  - \( \sigma_{max} \) = 110,5 [ksi]
  - Level of safety = 1,309
7.0  **Spring check calculation.**

7.1 Uploading of input data from main calculation

7.2 **Parameters of working cycle**

7.3 Arm of working / supporting force  
\[ \frac{R_t}{R_s} = 1,5103 \] [in]

7.5 Maximum working moment  
\[ M_8 = 18,00 \] [lb ft]

7.4 Maximum working force  
\[ F_8 = 143,0 \] [lb]

7.6 Angle of spring working stroke  
\[ \alpha_{it} = 46,15 \] [*]

7.7 Minimum working loading  
\[ \frac{F_1}{M_1} = 87,4 \] [lb] / [lb ft]

7.8 **Spring strength check**

7.9 Mean spring diameter  
\[ D = 2,4076 \] [in]

7.10 Recommended limits of wire diameter  
\[ \frac{d_{min}}{d_{max}} = 0,2813 \] / \ [0,6019] [in]

7.11 Wire diameter / from table  
\[ d = 0,3065 \] 0,625 [in]

7.12 Outer / inner spring diameter  
\[ \frac{D_e}{D_i} = 2,7141 \] / \ [2,1011] [in]

7.13 Spring index  
\[ c = 7,86 \] [*]

7.14 Permissible bending stress  
\[ \sigma_A = 122,5 \] [ksi]

7.15 Corrected stress in spring coils  
\[ \sigma_8c = 84,4 \] [ksi]

7.16 Bending radius on the working / supporting leg  
\[ \frac{r_1}{r_2} = 0,0000 \] / \ [0,0000] [in]

7.17 Corrected stress on leg at the point of bending  
\[ \sigma_{Br} = 84,4 \] [ksi]

7.18 Level of safety  
\[ = 1,451 \]

7.19 **Spring construction**

7.20 Recommended minimum number of active coils  
\[ n_{min} = 5,99 \]

7.21 Number of active coils  
\[ n = 15,40 \]

7.22 Angle between legs in a free state  
\[ \delta_0 = 141,7 \] [*]

7.23 Pitch between coils of free spring  
\[ t = 0,3065 \] [in]

7.24 Theoretic length of coiled section  
\[ L_K = 5,0266 \] [in]

7.25 Working angle of preloaded spring / corrected  
\[ \frac{\alpha_1}{\alpha_{1c}} = 72,52 \] / \ [72,52] [*]

7.26 Working angle of fully loaded spring / corrected  
\[ \frac{\alpha_8}{\alpha_{8c}} = 118,67 \] / \ [118,67] [*]

7.27 Angle between legs for fully loaded spring  
\[ \delta_8 = 23,0 \] [*]

7.28 Max. outer / min. inner spring diameter  
\[ \frac{D_{ed}}{D_{id}} = 2,7141 \] / \ [2,0506] [in]

7.29 Maximum theoretic length of coiled section  
\[ L_{ka} = 5,1276 \] [in]

7.30 Transfer of solution into main calculation

8.0  **Calculation of working forces of the spring.**

8.1 Uploading of input data from main calculation

8.2 **Parameters of working cycle**

8.3 Leg angular deflection of fully loaded spring  
\[ \alpha_8 = 118,67 \] [*]

8.4 Leg angular deflection of preloaded spring  
\[ \alpha_1 = 72,52 \] [*]

8.5 Angle of spring working stroke  
\[ \alpha_{it} = 46,15 \] [*]

8.6 **Spring dimensions**
### 8.0 **Dimensions of fully loaded spring**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean spring diameter</td>
<td>D [in]</td>
<td>2.4076</td>
</tr>
<tr>
<td>Wire diameter / from table</td>
<td>d [in]</td>
<td>0.3065 0.625</td>
</tr>
<tr>
<td>Outer / Inner spring diameter</td>
<td>D_e / D_i [in]</td>
<td>2.7141 2.1011</td>
</tr>
<tr>
<td>Spring index</td>
<td>c</td>
<td>7.86</td>
</tr>
<tr>
<td>Number of active coils</td>
<td>n</td>
<td>15.40</td>
</tr>
<tr>
<td>Angle between legs in a free state</td>
<td>δ_0 [°]</td>
<td>141.7</td>
</tr>
<tr>
<td>Pitch between coils of free spring</td>
<td>t [in]</td>
<td>0.3065</td>
</tr>
<tr>
<td>Theoretic length of coiled section</td>
<td>L_K [in]</td>
<td>5.0266</td>
</tr>
</tbody>
</table>

### 8.15 **Spring loading**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle between spring legs</td>
<td>δ_8 [°]</td>
<td>23.0</td>
</tr>
<tr>
<td>Max. outer / min. inner spring diameter</td>
<td>D_e / D_i [in]</td>
<td>2.7141 2.0506</td>
</tr>
<tr>
<td>Maximum theoretic length of coiled section</td>
<td>L_k8 [in]</td>
<td>5.1276</td>
</tr>
</tbody>
</table>

### 9.0 **Calculation of working angles of the spring.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean spring diameter</td>
<td>D [in]</td>
<td>2.4076</td>
</tr>
<tr>
<td>Wire diameter / from table</td>
<td>d [in]</td>
<td>0.3065 0.625</td>
</tr>
<tr>
<td>Outer / Inner spring diameter</td>
<td>D_e / D_i [in]</td>
<td>2.7141 2.1011</td>
</tr>
<tr>
<td>Spring index</td>
<td>c</td>
<td>7.86</td>
</tr>
<tr>
<td>Number of active coils</td>
<td>n</td>
<td>15.40</td>
</tr>
<tr>
<td>Angle between legs in a free state</td>
<td>δ_0 [°]</td>
<td>141.7</td>
</tr>
<tr>
<td>Pitch between coils of free spring</td>
<td>t [in]</td>
<td>0.3065</td>
</tr>
<tr>
<td>Theoretic length of coiled section</td>
<td>L_K [in]</td>
<td>5.0266</td>
</tr>
</tbody>
</table>

### 9.11 **Parameters of working cycle**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working angle of preloaded spring / corrected</td>
<td>α_4 / α_1c [°]</td>
<td>72.52 72.52</td>
</tr>
<tr>
<td>Working angle of fully loaded spring / corrected</td>
<td>α_8 / α_8c [°]</td>
<td>118.67 118.67</td>
</tr>
<tr>
<td>Angle of spring working stroke</td>
<td>α_41 [°]</td>
<td>46.15</td>
</tr>
<tr>
<td>Angle between legs for fully loaded spring</td>
<td>δ_8 [°]</td>
<td>23.0</td>
</tr>
<tr>
<td>Max. outer / min. inner spring diameter</td>
<td>D_e / D_i [in]</td>
<td>2.7141 2.0506</td>
</tr>
<tr>
<td>Maximum theoretic length of coiled section</td>
<td>L_k8 [in]</td>
<td>5.1276</td>
</tr>
</tbody>
</table>

### 9.14 **Spring strength check**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected stress in spring coils</td>
<td>σ_sc [ksi]</td>
<td>84.4</td>
</tr>
<tr>
<td>Bending radius on the working / supporting leg</td>
<td>r_1 / r_2 [in]</td>
<td>0.0000 0.0000</td>
</tr>
<tr>
<td>Corrected stress on leg at the point of bending</td>
<td>σ_br [ksi]</td>
<td>84.4</td>
</tr>
<tr>
<td>Permissible bending stress</td>
<td>σ_A [ksi]</td>
<td>122.5</td>
</tr>
<tr>
<td>Level of safety</td>
<td></td>
<td>1.451</td>
</tr>
</tbody>
</table>

### 9.21 **Spring loading**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm of working / supporting force</td>
<td>R_f / R_s [in]</td>
<td>1.5103 1.5103</td>
</tr>
<tr>
<td>Minimum / maximum working moment</td>
<td>M_1 / M_8 [lb ft]</td>
<td>11.00 18.00</td>
</tr>
<tr>
<td>Minimum / maximum working force</td>
<td>F_1 / F_8 [lb]</td>
<td>87.4 143.0</td>
</tr>
</tbody>
</table>

### 9.24 **Spring strength check**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected stress in spring coils</td>
<td>σ_sc [ksi]</td>
<td>84.4</td>
</tr>
<tr>
<td>Bending radius on the working / supporting leg</td>
<td>r_1 / r_2 [in]</td>
<td>0.0000 0.0000</td>
</tr>
<tr>
<td>Corrected stress on leg at the point of bending</td>
<td>σ_br [ksi]</td>
<td>84.4</td>
</tr>
<tr>
<td>Permissible bending stress</td>
<td>σ_A [ksi]</td>
<td>122.5</td>
</tr>
</tbody>
</table>
9.26 Permissible bending stress \( \sigma_A \) [ksi] 122.5
9.27 Level of safety 1.451
9.28 Transfer of solution into main calculation

### 10.0 Graphical output, CAD systems

| 10.1 2D drawing output to: | DXF File |
| 10.2 2D Drawing scale | Automatic |

| 10.3 Angle between spring legs | 0.0 |

### 10.4 Text description (Information for BOM)

| Row 1 (BOM attribute 1) | Torsion spring |
| Row 2 (BOM attribute 2) | D=2.4076; d=0.3065; n=15.4 |
| Row 3 (BOM attribute 3) | Hard drawn steel wire ASTM A227 |

10.5 Table of parameters