Helical Springs
Made of Round Wire
Quality Specifications for Cold Coiled Tension Springs

This standard applies to cold coiled tension springs made of patented-drawn or heat treated spring wires up to \( d = 17 \) mm wire diameter. Over \( d = 17 \) mm wire diameter and from as little as \( 10 \) mm wire diameter when severe stressing is involved, tension springs may be hot coiled without initial tension from drawn or rolled non-heat-treated spring wires, and heat treated after coiling. The latter method is rarely used and therefore no tolerances for it are specified. If required, information can be obtained from the spring manufacturer.

The materials listed in Section 3.6 and the under-mentioned limiting values also apply to this standard:

- Mean coil diameter \( D_m \) to 150 mm
- Number of working coils \( i_f \geq 3 \)
- Free length of spring \( L_0 \) to 1500 mm
- Coiling ratio \( w \) to 20

Dimensions in mm

1. Representation

![Diagram of a helical spring with various dimensions labeled](image)

Figure 1. Tension spring

2. Formula symbols, dimension letters, denominations and units

- \( a_0 \): Quantity used for determining the variations for loop position (effect of coiling ratio and number of coils)
- \( k_f \): Factor used for determining variations of load and spring length (effect of working coils)
- \( m \): Hook opening in \( \text{mm} \)
- \( s_1 \) to \( s_n \): Deflections corresponding to loads \( P_1 \) to \( P_n \)
- \( c = \frac{dF}{ds} \): Spring rate in \( \text{N/mm} \)
- \( d \): Wire diameter in \( \text{mm} \)
- \( d_{\text{max}} \): Nominal dimension of wire diameter according to DIN 2076 or DIN 1757 increased by the upper allowance in \( \text{mm} \)
- \( i_f \): Number of working coils
- \( i_g \): Total number of coils

Permisible variation of load position of unloaded spring in \( \text{o} \)
Permmissible variation of coil diameter \( (D_1, D_1, D_{\text{m}}) \) of unloaded spring in \( \text{mm} \)
Permmissible variation of load \( F \) at given spring length \( L \) in \( \text{N} \)

Continued on pages 2 to 10
Explanations on page 10
### 3. Execution

#### 3.1. Coiling direction

If no specific coiling direction is required, this should be left "at option". Right-hand or left-hand coiling must be separately agreed.

#### 3.2. Form of loop

For transmitting the load, the forms of loop and the connecting components shown in Figures 2 to 74 are commonly used. When the choice of loop form is being decided, it should be borne in mind that the smallest inside radius of the loop should not be smaller than the wire diameter $d$.

The position of the loop opening shown in Figure 1 is displaced through 90°; the total number of coils ends at 1/4. The loop opening should be dimensioned in the drawing. If the hook opening $m$ is not specified, a closed loop must be provided to prevent tangling (particularly with small springs). For production reasons, the position of the end of the wire is left to the manufacturer's choice. If $m$ is specified, the loop opening should be $\geq 2d$.

For loops of which the outside diameter should theoretically not exceed the outside diameter of the body of the spring (Figures 2, 3, 7 and 9) the following provisional reference values apply to the maximum loop projection beyond the generating line of the body of the spring, provided that $L_H$ is not larger than $1.5 D_1$:

### 3.3. Loop or hook openings and exact total number of coils

<table>
<thead>
<tr>
<th>Quality</th>
<th>Quality</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>grade 1</td>
<td>grade 2</td>
<td>grade 3</td>
</tr>
<tr>
<td>$w &lt; 6$</td>
<td>$0.5d$</td>
<td>$d$</td>
</tr>
<tr>
<td>$w = 6-12$</td>
<td>$0.75d$</td>
<td>$1.5d$</td>
</tr>
<tr>
<td>$w &gt; 12$</td>
<td>by agreement with the manufacturer</td>
<td></td>
</tr>
</tbody>
</table>

In the case of springs with end fittings which are screwed in or rolled in, Figures 10 to 13, $L_H = L +$ number of coils rendered non-active through the rolling-in or screwing-in of end fittings.

#### 3.4. Space between working coils

In tension springs with initial tension, the coils are in contact with one another. In tension springs without initial tension, the coils are not always in contact with one another, depending on the conditions of manufacture. Increased length tolerances arise (see Section 4.4.2).

#### 3.5. Length of tension springs

The length of the spring body with initial tension wound in is given by

$$L_K = (i + 1) D_{max}$$

The length of the unloaded spring, measured to the inside of the loops, is given by

$$L_D = L_K + \frac{2}{Q} L_H + \text{value from Table 3.}$$

Manufacturing ranges for $L_H$ are indicated in Figures 2 to 6 and 9.

#### 3.6. Material

**Group 1**

- DIN 17223 Part 1 Round spring steel wire, quality specifications; patented drawn spring wire made of unalloyed steels
- 17223 Part 2; quenched and tempered spring wire and quenched and tempered valve spring wire made of unalloyed steels
- 17224 (Preliminary Standard) Stainless steel wire and strip for springs, quality specifications

**Group 2**

- DIN 17225 (Preliminary Standard) High-temperature steels for springs, quality properties
- DIN 1762 Part 1 Rod, bar and wire of copper and wrought copper alloys, strength properties
- DIN 17672 Part 2; technical conditions of delivery
- DIN 17682 Round spring wire of wrought copper alloys; strength properties, technical conditions of delivery

#### 3.7. Surface protection

The springs are usually protected by oiling or greasing. Other forms of corrosion protection are to be agreed with the manufacturer.
Figure 2. Open loop $L_H = 0.55 \, D_i$ to $0.8 \, D_i$

Figure 3. Full loop $L_H = 0.8 \, D_i$ to $1.1 \, D_i$

Figure 4. Double loop $L_H = 0.8 \, D_i$ to $1.1 \, D_i$

Figure 5. Full loop at side $L_H = D_i$

Figure 6. Double loop at side $L_H = D_i$

Figure 7. Raised hook

Figure 8. Raised hook at side

Figure 9. Full loop with offset $L_H = 1.1 \, D_i$

Figure 10. Swivel hook

Figure 11. Rolled-in stud
Figure 12. Threaded plug engaging 2 to 4 coils

Figure 13. Thread-on plate engaging 2 to 4 coils

Figure 14. Angled full loop

**Representation of spring**

<table>
<thead>
<tr>
<th>Type of loop according to Figure</th>
<th>Number of coils following the comma</th>
<th>Loop openings mutually offset in the direction of a right-handed helix</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0°</td>
</tr>
<tr>
<td></td>
<td>.00 (0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.25 (1/4)</td>
<td>90°</td>
</tr>
<tr>
<td></td>
<td>.50 (1/2)</td>
<td>180°</td>
</tr>
<tr>
<td></td>
<td>.75 (3/4)</td>
<td>270°</td>
</tr>
<tr>
<td></td>
<td>.100 (1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.25 (1/4)</td>
<td>90°</td>
</tr>
<tr>
<td></td>
<td>.50 (1/2)</td>
<td>180°</td>
</tr>
<tr>
<td></td>
<td>.75 (3/4)</td>
<td>270°</td>
</tr>
<tr>
<td></td>
<td>.100 (1)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 15.
Most commonly used positions of loop openings and the related data regarding total number of coils. (To be entered in Proforma B according to DIN 2099 Part 2, Item 3).
4. Quality grades, permissible variations

The quality grades 1, 2 and 3 are specified (for coefficients Q see Table 2). All the permissible variations listed below apply only to material Group 1. For material Group 2, permissible variations are to be agreed between manufacturer and user.

The choice between quality grades 1, 2 and 3 will be governed by the duty requirements. The quality grade required and the permissible variations are to be expressly agreed or stated in the drawing preprint (see also DIN 2099 Part 2).

In the absence of information to this effect, quality grade 2 shall apply.

In the interests of rationalized manufacture quality grade 1 should be specified only when the particular application calls for it. For this purpose not all the sizes in Sections 4.1 to 4.5 necessarily belong to a single quality grade. If variations smaller than "1" are required, agreement to this effect must be reached with the manufacturer.

4.1. Permissible variations of wire diameters

According to DIN 2076 Round spring wire; dimensions, weights, permissible variations (also applies to spring wire of wrought copper alloys according to DIN 17682) DIN 1757 Wire of copper and wrought copper alloys, drawn; dimensions

4.2. Permissible variations A D for coil diameter of unloaded spring

See Table 1.

In drawings and in enquiry and order documents only the important coil diameter should be stated.

The permissible variations specified for D m apply both to the corresponding diameters D i and to D a.

When coiling ratios are larger than w = 20, agreement shall be reached with the manufacturer regarding diameter tolerances.

Table 1.

<table>
<thead>
<tr>
<th>D m</th>
<th>above</th>
<th>up to</th>
<th>4 to 8</th>
<th>above 8</th>
<th>above 14</th>
<th>4 to 8</th>
<th>above 8</th>
<th>above 14</th>
<th>4 to 8</th>
<th>above 8</th>
<th>above 14</th>
<th>4 to 8</th>
<th>above 8</th>
<th>above 14</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>above 8</td>
<td>above 14</td>
<td>up to 20</td>
<td></td>
<td>above 8</td>
<td>above 14</td>
<td>up to 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>0.63</td>
<td>1</td>
<td>1</td>
<td>± 0.05</td>
<td>± 0.07</td>
<td>± 0.1</td>
<td>± 0.07</td>
<td>± 0.1</td>
<td>± 0.15</td>
<td>± 0.15</td>
<td>± 0.2</td>
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<tr>
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<td>1.6</td>
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<td>± 0.07</td>
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<td>± 0.08</td>
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<td>± 0.2</td>
<td>± 0.15</td>
<td>± 0.2</td>
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<td>± 0.15</td>
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<td>± 0.2</td>
<td>± 0.3</td>
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<td>± 0.2</td>
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<td>± 0.25</td>
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<td>± 0.2</td>
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<td>± 0.35</td>
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</tr>
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<td>± 0.3</td>
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<td>± 0.35</td>
<td>± 0.4</td>
<td>± 0.4</td>
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<td>± 0.7</td>
<td></td>
</tr>
<tr>
<td>10</td>
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<td>16</td>
<td>± 0.15</td>
<td>± 0.2</td>
<td>± 0.25</td>
<td>± 0.35</td>
<td>± 0.4</td>
<td>± 0.35</td>
<td>± 0.45</td>
<td>± 0.5</td>
<td>± 0.7</td>
<td>± 0.9</td>
<td>± 1.0</td>
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<td>16</td>
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<td>± 0.25</td>
<td>± 0.3</td>
<td>± 0.35</td>
<td>± 0.4</td>
<td>± 0.3</td>
<td>± 0.45</td>
<td>± 0.5</td>
<td>± 0.7</td>
<td>± 0.9</td>
<td>± 1.0</td>
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<td>25</td>
<td>31.5</td>
<td>31.5</td>
<td>± 0.25</td>
<td>± 0.3</td>
<td>± 0.35</td>
<td>± 0.4</td>
<td>± 0.35</td>
<td>± 0.4</td>
<td>± 0.45</td>
<td>± 0.5</td>
<td>± 0.7</td>
<td>± 0.9</td>
<td>± 1.0</td>
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<td>31.5</td>
<td>40</td>
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<td>± 0.25</td>
<td>± 0.3</td>
<td>± 0.35</td>
<td>± 0.5</td>
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</tr>
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<td>50</td>
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<td>± 0.6</td>
<td>± 0.8</td>
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<td>± 0.8</td>
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<td>± 1.1</td>
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<td>± 1.4</td>
<td>± 1.8</td>
<td>± 2.4</td>
<td>± 3.0</td>
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<td>± 0.6</td>
<td>± 0.8</td>
<td>± 0.9</td>
<td>± 1.2</td>
<td>± 1.5</td>
<td>± 1.7</td>
<td>± 2.3</td>
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<tr>
<td>100</td>
<td>125</td>
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<td>± 0.8</td>
<td>± 0.9</td>
<td>± 1.2</td>
<td>± 1.5</td>
<td>± 1.7</td>
<td>± 2.3</td>
<td>± 3.0</td>
<td>± 3.5</td>
<td>± 3.8</td>
<td>± 4.4</td>
<td></td>
</tr>
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<td>125</td>
<td>160</td>
<td>160</td>
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<td>± 2.3</td>
<td>± 2.7</td>
<td>± 3.5</td>
<td>± 4.6</td>
<td>± 5.4</td>
<td>± 5.4</td>
<td>± 7.0</td>
<td>± 8.0</td>
<td>± 8.8</td>
<td>± 10.0</td>
<td></td>
</tr>
</tbody>
</table>
4.1 Permissible variations $A_F$ for load $F$ at given spring length $L$ (applies to tension springs with and without initial tension)

The permissible variation for load is given by

$$A_F = \pm (s_F \cdot k_F + \frac{1.5 \cdot F}{100}) \cdot Q$$

The quantity $s_F$ can be found from Figures 16 and 17. The factor $k_F$ is obtainable from Figure 18 and the coefficient $Q$ from Table 2.

<table>
<thead>
<tr>
<th>Quality grade</th>
<th>$Q$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.63</td>
</tr>
<tr>
<td>2</td>
<td>1.00</td>
</tr>
<tr>
<td>3</td>
<td>1.60</td>
</tr>
</tbody>
</table>
Figure 17. Quantity $\alpha_F$
Influence of geometry and dimensions on variations of load and spring length for wire diameters from 1.1 to 16 mm
Figure 18. Factor \( k_r \)

Influence of working coils on variations of load and spring length

4.4. Permissible variations \( A_{L0} \) for length \( L_0 \) of unloaded spring

\( L_0 \) is to be tolerated only in agreement with Section 4.6.

4.4.1. Permissible variations \( A_{L0} \) for length \( L_0 \) of unloaded spring with initial tension

See Table 3.

4.4.2. Permissible variations \( A_{L0} \) for length \( L_0 \) of unloaded spring without initial tension (tension spring with spaced coils)

Permissible variation is

\[ A_{L0} = \left( \frac{8x + k_r - Q}{c} \right) \text{ + value for quality grade 1 from Table 3} \]

Table 3.

<table>
<thead>
<tr>
<th>( L_0 )</th>
<th>Permissible variations ( A_{L0} ) in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quality grade 1 with coilng ratio ( w )</td>
</tr>
<tr>
<td></td>
<td>4 to 8</td>
</tr>
<tr>
<td>above 400</td>
<td>±1% of ( L_0 )</td>
</tr>
<tr>
<td>above 250 to 400</td>
<td>±2.5</td>
</tr>
<tr>
<td>above 160 to 250</td>
<td>±2.0</td>
</tr>
<tr>
<td>above 100 to 160</td>
<td>±1.5</td>
</tr>
<tr>
<td>above 63 to 100</td>
<td>±1.1</td>
</tr>
<tr>
<td>above 40 to 63</td>
<td>±0.8</td>
</tr>
<tr>
<td>above 25 to 40</td>
<td>±0.5</td>
</tr>
<tr>
<td>above 10 to 16</td>
<td>±0.4</td>
</tr>
<tr>
<td>up to 10</td>
<td>±0.3</td>
</tr>
</tbody>
</table>
4.5. Permissible variations for loop position

The permissible variations for the loop position of unloaded springs are

$$a_0 = a_0 - \delta$$

where $a_0$ is found from Figure 19 and $\delta$ from Table 2.

When a spring is given an initial tension $P_0$, friction exists between the coils. This gives rise to a range in which the loop stays in whatever position it assumes (sticking range). Through this frictional effect, the loop position variation appears to be increased. This must be borne in mind during testing.

4.6. Production margin

The manufacturer needs a production margin in order to meet the loading conditions specified.

The actual numerical values of the quantities thus available as a production margin are to be stated in the drawing and counted only as reference values.

In the event of such a margin being utilized, care must be taken to ensure that the permissible shear stress is not exceeded (see DIN 2089 Part 2 Preliminary Standard).

5. Testing

5.1. Testing of spring lengths and loads

The testing of spring lengths and loads is performed on the vertically suspended spring. The permissible variations in the load indication is $\pm 2\%$.

If two test loads are stated in the drawing, the spring should be tested first at $L_1$ or $L_2$ and then at $L_1$ (presetting loss = relaxation of initial tension).

5.2. Characteristic

The characteristic (load-deflection characteristic) of tension springs, as calculated according to DIN 2089 Part 2 (Preliminary Standard), is a straight line the ordinate of which corresponds to the initial load. In practice, this characteristic is non-linear at the start, that is to say where it leaves the ordinate. For this reason it is necessary when testing a spring that the shortest test length shall be at least large enough to ensure that a visible gap appears between all the coils.

To determine the initial load, the loads $F_1$ and $F_2$ associated with deflections $s_1$ and $s_2 = 2s_1$ are measured. The initial load is then given by

$$F_0 = F_2 - (F_2 - F_1) = 2F_1 - F_2$$

The rate $c$ is

$$c = \frac{\Delta F}{s_2 - s_1}$$

where $\Delta F$ is the increase in load corresponding to an increase in deflection $\Delta s$ (see Figure 20).

Figure 20. Test diagram
Other relevant standards

DIN 1757 Wire of copper and wrought copper alloys, drawn; dimensions
DIN 2076 Round spring wire; dimensions, weights, permissible variations
DIN 2089 Part 2 (Preliminary Standard) Helical springs made of round wire and rod; calculation and design of tension springs
DIN 2095 Helical springs made of round wire; quality specifications for cold coiled compression springs
DIN 2096 Helical springs made of round bar steel; quality specifications for compression springs quenched and tempered after coiling
DIN 2099 Part 2 Helical springs made of round wire; information on tension springs; form of spring wire made of unalloyed steels
DIN 17223 Part 1 Round spring steel wire, quality specifications; patented drawn spring wire made of unalloyed steels
DIN 17223 Part 2 - quenched and tempered spring wire and quenched and tempered valve spring wire made of unalloyed steels
DIN 17224 (Preliminary Standard) Stainless steel wire and strip for springs, quality specifications
DIN 17225 (Preliminary Standard) High-temperature steels for springs, quality properties
DIN 17672 Part 1 Rod, bar and wire of copper and wrought copper alloys, strength properties
DIN 17672 Part 2 - technical conditions of delivery
DIN 17682 Round spring wire of wrought copper alloys; strength properties, technical conditions of delivery

Explanations

This Standard contains the agreement reached in the present state of the art between the industrial interests concerned in respect of the design and testing of cold coiled tension springs and the requirements to be met by such springs. Quality grades 1, 2 and 3 are distinguished, the permissible variations being, for quality grade 1, 0.53 times those of the medium quality grade 2, whilst for quality grade 3 they are 1.6 times those of grade 2. Tension springs with load and length variations corresponding to quality grade 1 can be made with an average 1% rejection rate by a manufacturer using normal production resources and the measuring methods in use at the present time. Springs of this kind must be 100% tested and this entails increased expenditure in production. Quality grade 2 should therefore be specified as preferred because this grade can be guaranteed by adopting properly organised in-manufacture spot testing instead of 100% testing. Quality grade 2 will usually yield the most favourable cost-quality ratio.

Over an extended period of time a joint operation has been conducted for the investigation and statistical examination of variation in load arising in production. According to this work, the permissible variation in load is a function of the spring dimensions D0, D, 4p and F. The mode of dependence established for tension springs applies similarly to compression springs (cf. DIN 2095). There is also a connection via the spring rate between load and length variations of tension springs without initial tension. The quality grades and permissible variations according to this Standard differ from those of the earlier issues. The quality grade designations 1, 2 and 3 have therefore been newly introduced.

In line with existing basic standards the following formula symbols have been amended:

- \( F \) Load (formerly \( P \) and \( f \) Deflection (formerly \( f \)).

The statutory unit of force Newton (N) has been specified instead of the kilopond (kp).

(Conversion:

\( 1 \text{ kp} = 9.80665 \text{ N} \),
\( 1 \text{ kp} = 10 \text{ N} \).

Further amendments compared with the earlier issue are the re-specifying of the determination of \( A_0 \), \( A_{10} \) and \( A_{100} \) for tension springs wound with initial tension. Doubt often arises in practice regarding the form of loop and the number of coils in conjunction with the relative position of the loop openings, and therefore information on these points has been included in Sections 3.2 and 3.3.)