



## 1. How do you figure out how many active coils a spring has?

In any spring, some portion of the end coils will probably be inactive. The number of inactive coils varies depending on the spring end configuration and mating component geometry. The following equations give approximate active coil counts, assuming that the springs are compressed between parallel plates.

For closed ends (ground or unground):  $N_a \approx N_t - 2$   
 For open ground ends:  $N_a \approx N_t - 1$   
 For open unground ends:  $N_a \approx N_t$

In practice, the number of inactive coils varies slightly as a spring is compressed. If the spring output at two

operating heights is known, the number of active coils over the operating height range can be calculated using the following equation for any end configuration.

$$N_a = \frac{Gd^4 (h_1 - h_2)}{8 (OD - d)^3 (P_2 - P_1)}$$

G = shear modulus of the spring material  
 d = wire diameter  
 OD = spring outside diameter  
 h<sub>1</sub>, h<sub>2</sub> = spring operating heights  
 P<sub>1</sub>, P<sub>2</sub> = spring force at heights h<sub>1</sub> and h<sub>2</sub>, respectively.

## 2. What is the difference between closed and closed ground ends?

Springs can be coiled with a variety of end configurations. If the space between the coils is reduced to the point where the wire at the tip makes contact with the next coil, the end is said to be “closed”. If there is no reduction in pitch at the end coils, the end is referred to as “open”. Between these two extremes is an end type known as “semi-closed” in which the space between coils is reduced, but there is a gap between the tip and next coil. The most common configuration in industrial springs is closed ends.

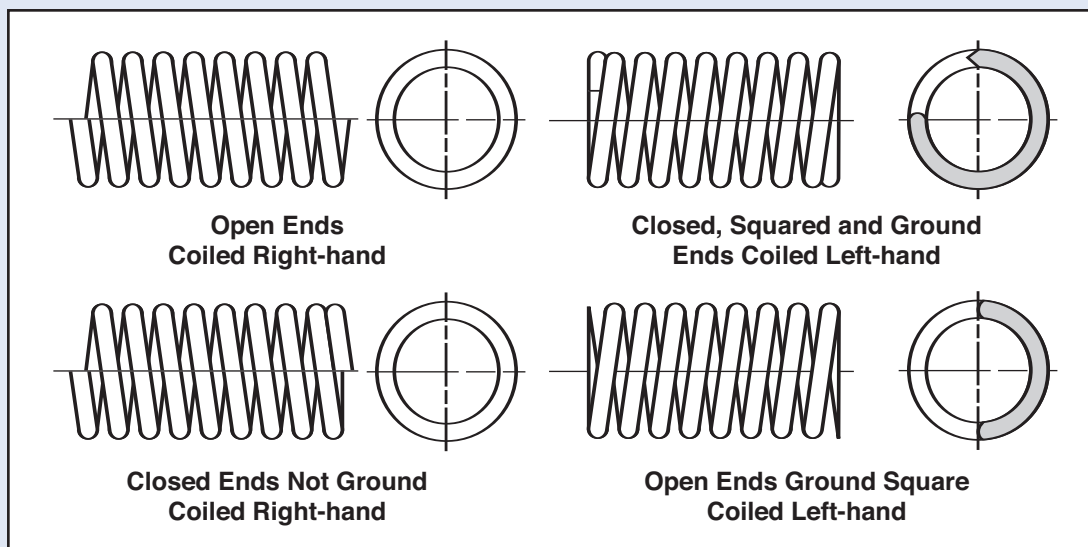
An additional grinding operation may be applied to any of the end configurations listed above. Grinding removes material for the spring end coils to create a flat surface perpendicular to the spring axis. This may be done for a variety of reasons including more even distribution of the spring force to the working assembly

and improved ease of assembly since the spring is more likely to stand upright unassisted (particularly with smaller index springs).

Springs can be manufactured with any of the as-coiled configurations listed below. Any of these configurations can be provided either in the ground or unground condition.

Stock springs are listed in the catalog with specific ends (C = Closed, CG = Closed & Ground or O = Open). If you need a different type of end than what is listed, we can custom manufacture for you (see page 358 for Custom Springs).

The figure below shows schematics of both open and closed ends in both the ground and unground conditions.



### 3. What is a safe design stress for a compression spring?

This question does not have a single, simple answer. The answer depends heavily on the type of material used (e.g. music wire, stainless steel, chrome-silicon, etc.), material grade (e.g. commercial vs. valve spring quality, standard or high strength, etc.) and the service environment (e.g., static vs. cyclic, corrosive atmosphere, extremely high or low temperatures, etc.).

A spring that has infinite fatigue life under low deflection conditions may take a set if compressed to solid height. Another spring optimized for static life in sea water may have very poor fatigue life when cycled in air.

The design process typically begins with selecting a material type appropriate for the application environment. For static conditions, the spring designer will generally select a stress level appropriate for the selected material that will assure stable spring force output over time. For cyclic conditions, not only does the force output over time

have to be stable, but the spring must be able to survive the intended life without breaking. Finally, manufacturability limitations can also restrict design stress levels.

The best recommendation here is to understand what is desired from the spring in service and work with a Century Spring design engineer to develop the optimum design for the operating conditions. Knowing the answers to the following questions will greatly assist the spring designer.

- Will the spring operate under static or cyclic conditions? If cyclic, what are the minimum and maximum operating loads, deflections, or heights? What is the desired life?
- What is the operating environment?
- What is the operating temperature?
- Does the assembly include physical stops to limit spring deflection? If so, what are the limits?

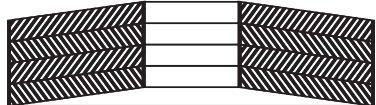
### 4. Which material gives the best corrosion resistance?

Once again, the actual operating environment plays a significant role. Many coatings are available that can provide adequate corrosion resistance for wire types that would not themselves resist corrosion. These include powder coating, phosphating with an oil dip or spray, and plating in some cases. Generally speaking, a coated spring produced from a traditional spring material will involve less cost than producing a spring from stainless steel.

When the application is such that coated spring wire will not meet the requirements of the application, the focus turns to stainless steel wire. Type 302 stainless steel is generally the first choice. This wire can yield very corrosion-resistant springs for most environments. When the application calls for high operating temperatures as well, 17-7 PH wire will also likely be considered.

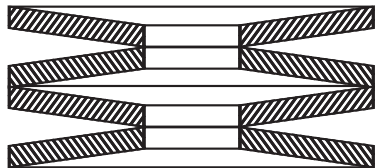
### 5. How do you calculate rate/loads for disc spring stacks?

The effective spring rate of a stack of spring washers depends on the orientation of the stack. If Belleville spring washers are stacked so that they nest together (i.e. stacked like paper cups), they are said to be in "series" with each other. When a stack of springs in series is deflected, all of the springs in the stack deflect as much as the total stack deflection. The effective spring rate for spring washers in series is simply the sum of the individual spring washer rates. This is an effective way of achieving very high force output in very limited operating space. For a stack of n spring washers in series, the effective spring rate is calculated using the following equation.



$$k_{eff} = k_1 + k_2 + k_3 \dots + k_n$$

If spring washers are stacked such that they meet OD-to-OD and ID-to-ID, the stack is said to be in "parallel". In this case, the deflection of the stack is distributed between all of the springs in the stack. The effective spring rate for the stack is lower than the softest individual spring rate in the stack. This is an effective means of gaining available deflection in limited operating space. For a stack of n spring washers in parallel, the effective spring rate is calculated using the following equation.



$$k_{eff} = \frac{k_1 \times k_2 \times k_3 \dots \times k_n}{k_1 + k_2 + k_3 \dots + k_n}$$



## 5. How do you calculate rate/loads for disc spring stacks? *(continued from previous page)*

In cases where spring washers are stacked in a combination of series and parallel, calculate the effective rates for segments of the stack in series and

then calculate the entire stack as a parallel stack considering the series segments as single springs with their respective effective spring rates.

## 6. What is free length?

For a compression spring, it is the length of the spring from one end to the other when no load is applied. For a tension spring, it is the length between the

inside diameter of the two end hooks when no load is applied.

## 7. How long will a compression spring last?

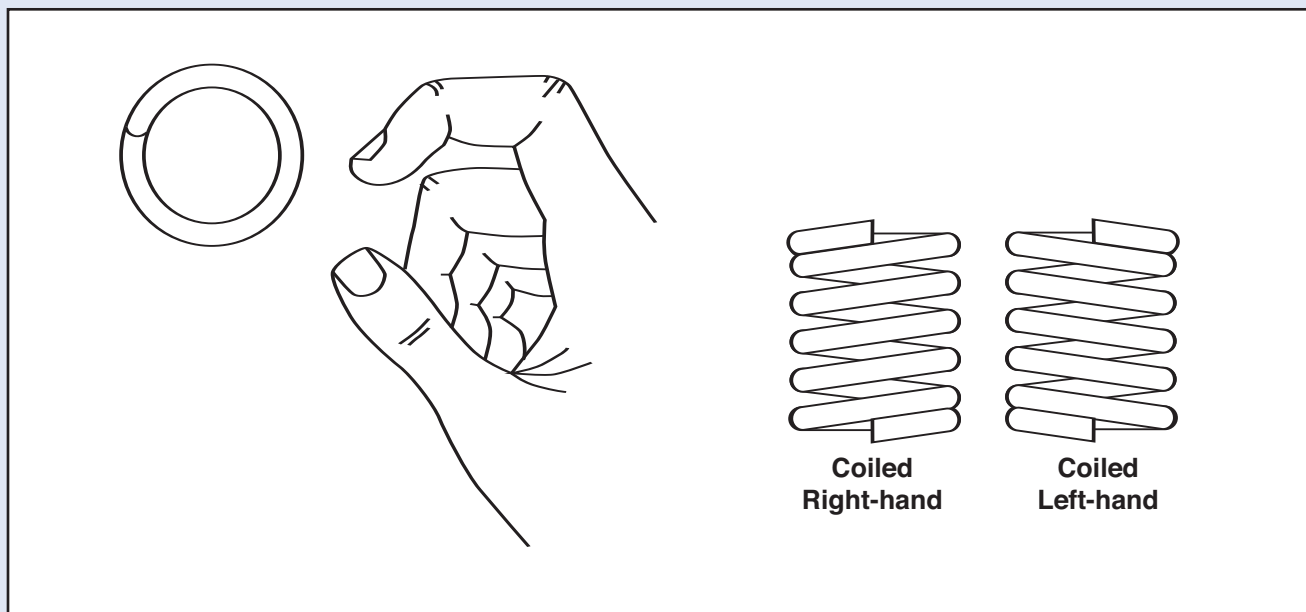
The effective life of a compression spring depends heavily on the operating environment. A spring designed for a static application with a properly chosen material should last indefinitely. In cyclic

applications, springs are generally designed for infinite life; however, application nuances such as resonant vibration could drastically reduce spring life.

## 8. How do I know if a spring is RHW or LHW?

When looking along the axis of a spring, curl your index finger so that it follows the same direction as the wire from the spring body to the wire tip nearest you. If the end coil wraps in the same direction as your

index finger (picture below) then it is that hand (right or left). See illustration below for method and a Right Hand Wound spring. For additional instruction, see top of page 292.



## 9. If I cut a spring in half, would the rate stay the same?

Cutting springs generally decreases the number of active coils. This forces an increase in spring rate.

The spring rate is proportional to  $1/N_a$ , so reducing the number of active coils by half doubles the spring rate.

## 10. What material is best for high temperature applications?

As temperature resistance increases, the material and processing cost typically increases significantly. Therefore, it is usually wise to select a material that provides resistance for the intended temperature

range with minimal excess capability. The table below lists a variety of spring materials and their maximum service temperatures.

Wire Type	Max Temp.	Wire Type	Max Temp.
Music Wire	250°F	302 Stainless	500°F
Hard Drawn Carbon	250°F	17-7 PH	600°F
Oil Tempered Carbon	300°F	NiCr A286	950°F
Chrome Vanadium	425°F	Inconel 600	700°F
Chrome Silicon	475°F	Inconel X750	1100°F

## 11. If I stack two springs, would the rate stay the same?

Stacking springs definitely changes the spring rate. The effective spring rate of the stack will be less than the softest spring in the stack. The effective spring

rate for a stack of n springs is calculated using the following equation.

$$k_{eff} = \frac{1}{1/k_1 + 1/k_2 + 1/k_3 \dots + 1/k_n}$$

## 12. Where can I find minimum tensile strength for materials?

Most spring materials are defined in ASTM specifications. In general, tensile strength varies with wire diameter. The specifications typically include a table that lists allowable tensile strength ranges for various wire diameter ranges. A list of popular material types and the corresponding ASTM specification is

given below. As an alternate source, the Spring Manufacturers Institute publishes a *Handbook of Spring Design* as well as an *Encyclopedia of Spring Design* (see page 11), both of which include tensile strength data for a variety of spring materials.

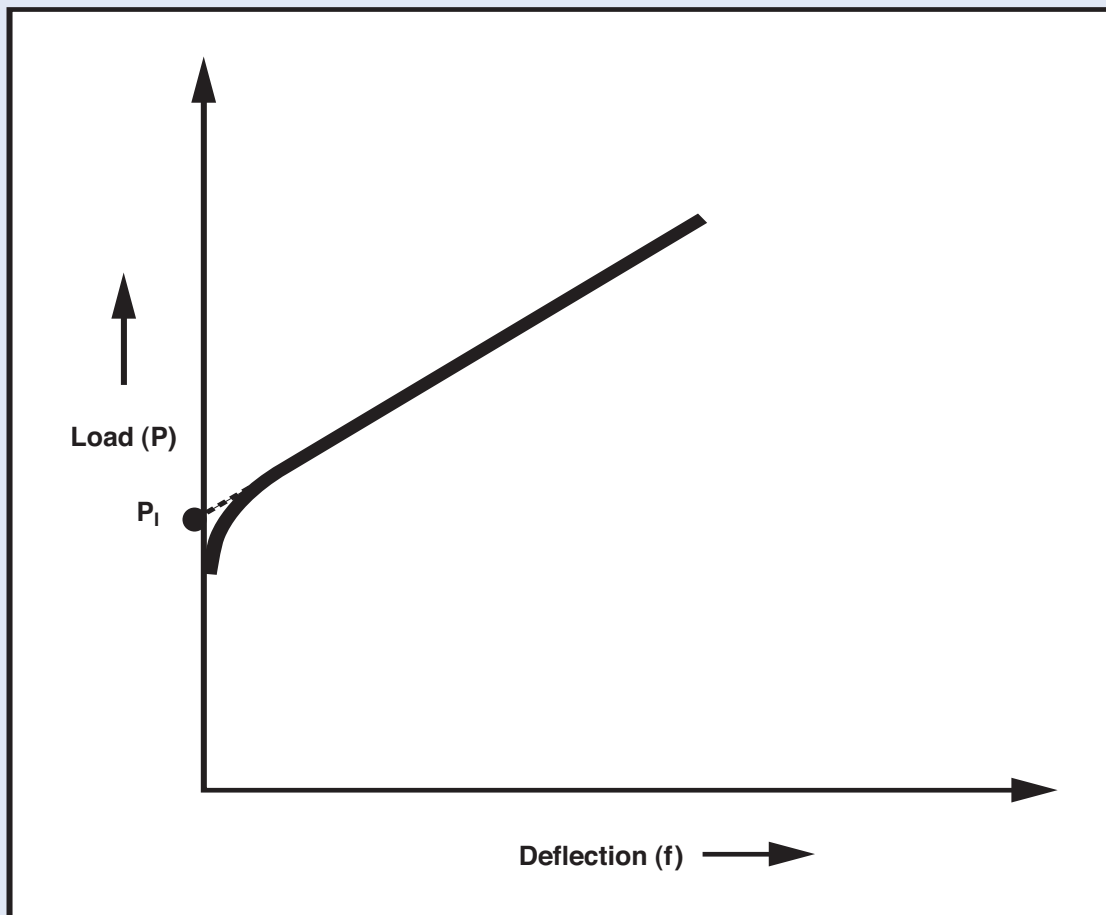
Wire Type	ASTM Spec	Wire Type	ASTM Spec
Oil Tempered Carbon (Commercial)	A229	Chrome-Vanadium (Valve)	A232
Oil Tempered Carbon (Valve)	A230	Hard Drawn Carbon	A227, A764
Chrome-Silicon (Commercial)	A401	High Tensile Hard Drawn Carbon	A679
Chrome-Silicon (Valve)	A877	Music Wire	A228
Chrome-Vanadium (Commercial)	A231	Stainless Steel	A313

## 13. What is initial tension?

Initial tension is most often discussed as it relates to extension spring. Extension springs are usually manufactured in a manner that requires a certain amount of force be applied before any deflection is realized. This minimum force is referred to as “initial

tension”. The load vs. deflection chart below shows the effect graphically. The load PI is required to overcome the spring’s initial tension. From that point, the spring force increases with deflection at the spring rate. See chart on next page.

*continued on next page*



#### 14. What are the best materials for fatigue applications?

Since spring wire is primarily subjected to torsional stresses, maximum stress levels occur at the wire surface. As a result, material surface defects (i.e. seams, laps, pits, etc.) can dramatically reduce a spring's fatigue life. Knowing this, wire manufacturers have developed surface preparation methods to restrict the size of wire surface defects as it leaves the mill. Wire produced with these methods is rated for fatigue applications and is often referred to as "valve spring quality". Since these methods often involve costly processes, fatigue-rated spring wire is often

significantly more expensive than its commercial-grade counterpart.

The two most popular materials for fatigue applications today are Music Wire (ASTM A228) and Chrome-Silicon Valve Spring Quality (ASTM A877). At wire sizes below approximately 0.080" (2.0 mm), Music Wire offers higher tensile strength; however, Music Wire's maximum service temperature is less than that of Chrome-Silicon.

#### 15. Tolerance (OD, FL, Load, Total Coils)

Achievable spring tolerances depend heavily on spring geometry characteristics. Empirical studies have resulted in a complex series of calculations that can predict appropriate tolerances for any given spring geometry. These calculations are too involved

for this discussion and best suited for automation through software. Please consult with a Century Spring design engineer to determine appropriate tolerances for your particular design or application.

#### 16. Does it make a difference on a torsion spring whether its left or right hand wound?

Yes. To reduce the likelihood of torsion springs taking a set, the spring should be coiled in the direction that results in increased coil count as load is applied. In other words, the spring should be coiled such that it

"winds up" when load is applied. If the spring "unwinds" as load is applied, it should probably be coiled in the opposite direction.

## 17. What are the advantages of having stainless springs passivated?

For stainless steels to provide proper corrosion resistance, a chromium-rich surface layer must be present to allow the formation of an impermeable oxide. It is this impermeable oxide layer that prevents

additional oxygen from reacting with the iron to create rust. Passivating is a chemical process that assures that the surface is rich in chromium.

## 18. How are extension spring loads calculated?

Most simply, the force exhibited by an extension spring will be the spring rate times the deflection from free plus the initial tension. Mathematically,

$$P = (k \times \delta) + P_I = k \times (l - l_F) + P_I, \text{ where}$$

$P$  = Spring force,  
 $k$  = Spring rate,  
 $\delta$  = Deflection from free length,  
 $P_I$  = Initial tension,  
 $l$  = Spring length, and  
 $l_F$  = Spring free length

## 19. What does maximum safe deflection mean? (Stress value, calculated number cycles)

In a static application, this is the maximum safe deflection from free that will not result in the spring taking a permanent set. For a compression spring, the permanent set will result in reduced free length and force output. For an extension spring, the permanent set will reduce force output by reducing initial tension or increasing the free length.

In cyclic compression spring applications, this would be the maximum deflection to which a spring could be compressed from free length that still assures appropriate spring life. The cyclic condition maximum safe deflection is significantly less than the static application maximum safe deflection.

## 20. What are the differences between hard drawn, music wire?

Both hard drawn wire and music wire gain their strength through cold drawing the wire from large diameter rod to its final size. There are three significant differences. First is the chemical composition of the wire. Music wire contains more carbon and less manganese than hard drawn wire. Additionally, the allowed levels of contaminants such as phosphorus and sulfur in music wire are more restrictive. The second key difference is in the wire's strength. Because of the additional carbon, music wire can be drawn to significantly higher tensile

strengths than hard drawn wire. Finally, processing of music wire is done in a manner to provide a finished surface with smaller allowed defects than hard drawn wire. Since surface defects are one of the most common initiation sites for fatigue cracks in springs, smaller surface defects (and their corresponding reduction in stress concentration) enable music wire to be used in high cycle fatigue applications. Hard drawn wire is best suited to static or very low cycle service conditions.