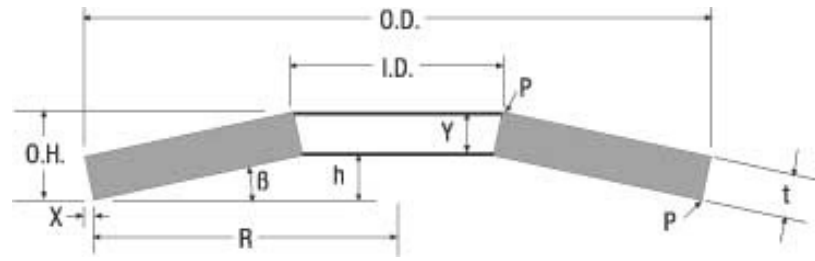


# How to Design Your Own Springs

## Nomenclature

- O.D = Maximum outside diameter (upper surface)
- I.D. = Minimum inside diameter (bottom surface)
- h = Conical disc height (cone height)
- O.H. = Overall height (Y + h)
- t = Actual thickness of disc
- $\beta$  = Cone angle of disc
- R = Radius from center line to load bearing circle (bottom surface)
- M = Ratio surface



- $\mu$  = Poisson's ratio
- E = Young's modulus (30,000,000 for steel)
- f = Deflection of disc
- a = Ratio of diameters (O.D. / I.D.)
- P = Load in lbs at a given deflection
- Pf = Load in lbs. flat
- X =  $\sin\beta(t)$
- Y =  $\cos\beta(t)$

The load deflection formula was developed by J. Almen and A. Laszlo, and published in the Transactions of American Society of Engineers, May, 1936, and is rendered as shown.

### Load in Pounds at a given deflection:

$$P = \frac{E(f)}{(1 - \mu^2) MR^2} * \left[ \left( h - \frac{f}{2} \right) (h - 1) (t + f^2) \right] \text{ where } M = \left( \frac{6}{\text{??????}} \right) \left( \frac{(\alpha f)^2}{\text{??????}} \right)$$

**Disc spring at flat-** In the flattened condition, the deflection f is equal to the conical height h and the equation becomes:

$$P_1 = \frac{Eht^3}{(1 - \mu^2) MR^2}$$

To calculate the load accurately, the following important factors must be considered.

A well designed disc spring has radii at all corners to reduce stress concentrations at the edges. A suitable radius is approximately equal to t/6. This radius further reduces dimension R (see Figure 1).

Usually the overall height of the disc spring is specified because it is easy to measure and control. The cone height h, on the other hand, is difficult to measure (see Figure 2).

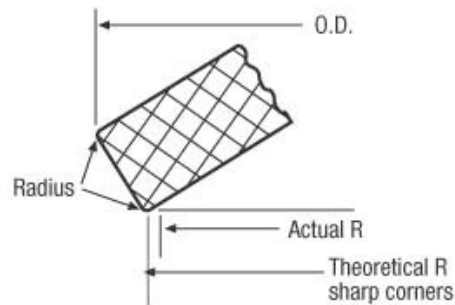


Figure 1.

For an approximate calculation,  $h = (\text{overall height} - t)$  is acceptable. However, this is not accurate. In fact,  $h = (\text{overall height} - Y)$ , where  $Y = \cos\beta \cdot t$ . For small thicknesses (under 2 mm) this is not significant. With thicker disc springs, this becomes a major factor for accurate load and stress calculations. This has not been adequately considered in previous technical literature.

If the disc spring is made as in Figure 4-A, which is unusual, then  $R = O.D. / 2$ . Most disc springs are made as in Figure 4-B. Therefore the load bearing radius is not equal to half of the Disc springs 8mm and thicker are made with a bearing flat at upper I.D. and lower O.D. as standard (see Figure 5). This bearing flat assures more uniform loading and better alignment of the disc stack. The flat is approximately equal to  $O.D. / 150$ . For load calculations, R must be calculated to the inner edge of the flat.

**SUMMARY**

Precise load and stress calculations require the determination of the disc spring angle  $\beta$ . Since this is not easily determined by physical measurement, we have developed a computer program that calculates the precise angle and arrives at the exact dimension for conical height h. This then determines accurate load and stress with accuracy. Please contact our Engineering Department for more information.

Load and stress formulas are correct only with the assumption that the spring will be worked within the elastic limit of the material.

**Dynamic Loading & Fatigue Life**

Dynamic Loading of disc springs occurs when the load continuously changes from preload to final load.

The "stress-time" curve of such disc springs which pulsate uniformly is sinusoidal. This is not true in cases of impact loading and therefore it is difficult to predict their life and behavior.

Disc spring life may be differentiated into two categories:

1. Limited Life: Cycles vary without failure between 40,000 and 2,000,000 cycles.
2. Unlimited Life: Cycles in excess of  $2 \cdot 10^6$  without failure. For virtually indefinite life, the table below indicates the appropriate values required given in

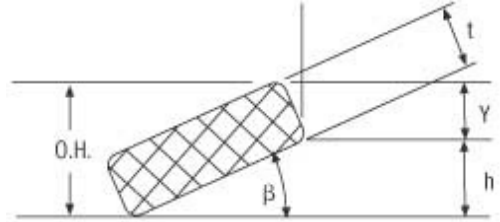


Figure 2.

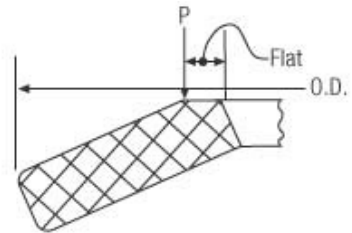


Figure 3.

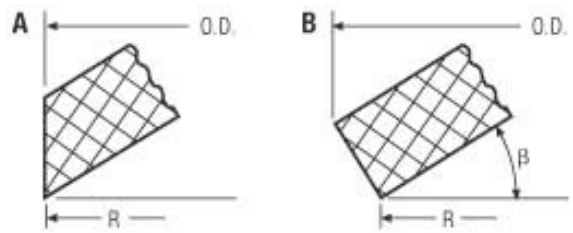


Figure 4.

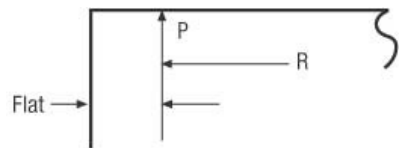
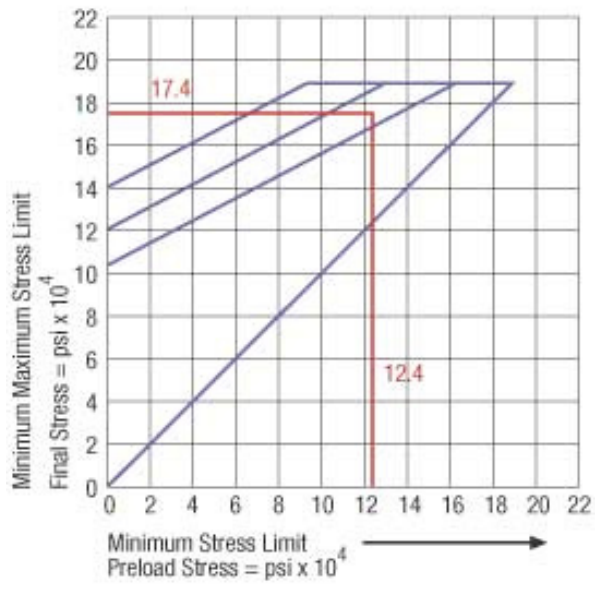


Figure 5.

Graph 1: Disc Springs with  $1 < .039''$



percent of travel, relating preload to final load AND considering the disc spring thickness.

Preload in % of h	Max Deflection in % of h	
	Disk Thickness	
	$\leq .039"$	$\geq .157"$
15	50	44
25	56	49
50	67	64

**Fatigue Life**

Fatigue life for disc springs is defined by the effective number of stress cycles that can be sustained prior to failure under certain conditions. This depends on the minimum stress, maximum stress and stress range.

The graphs 1 through 3 are presented here for evaluating fatigue life of single disc springs or series stacks not more than six springs. There are three basic groups, depending on thickness.

The horizontal axis represents Preload Stress. The vertical axis represents Final Stress. The fatigue life is found at the intersection of these points on the graph.

The zone in which they fall outside the zones, their life is not generally predictable.

The horizontal border line enclosing the top portion of the graph (zone) represents the yield strength of the spring steel material.

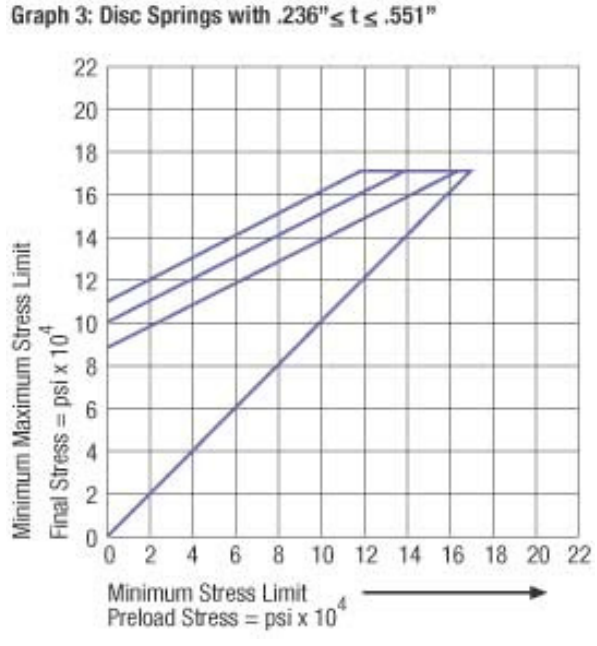
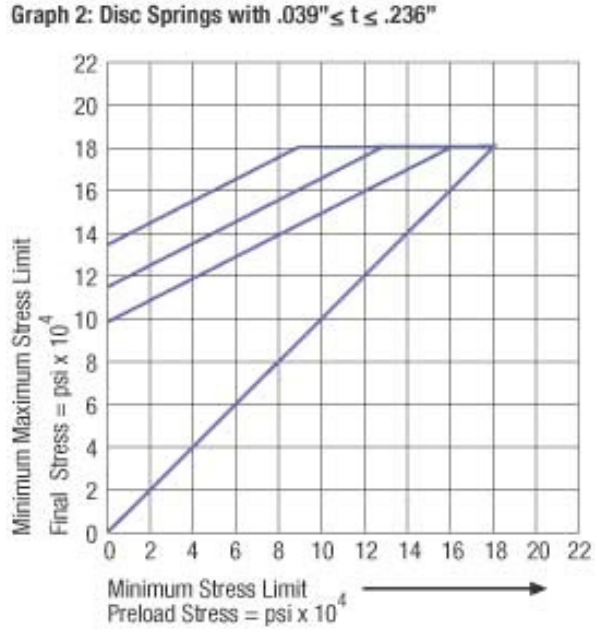
Intersection points of min/max stress limits which fall outside the graph/zone boundaries are to be avoided as the indicate spring failure is likely at an early stage.

The graphs were developed based on empirical test data. The test loads were sinusoidally executed.

**How To Use The Graphs**

1. For standard catalog disc springs:
  - A. Determine preload stress, see pages 6-8 for values
  - B. Determine final load stress, see pages 6-8 for values.

The intersection of the stress coordinates will indicate the range of fatigue life that may be expected.



2. For non-standard or special disc springs:

A. Determine the preload stress from formula for points S! and S!. Use the HIGHER of the two values for preload and final load.

B. Repeat above procedure for Final Stress. Use the HIGHER value.

Example: AM 188207: .709 x .323 x .0276

Preload Stress at Deflection  $f = .5h$  : 124000 psi

Final Load Stress at Deflection  $f = .75h$  : 174000 psi

Intersection Point between nearby 2MIO-Cycles-Line:

Predicted Cycles : 1.5 MIO