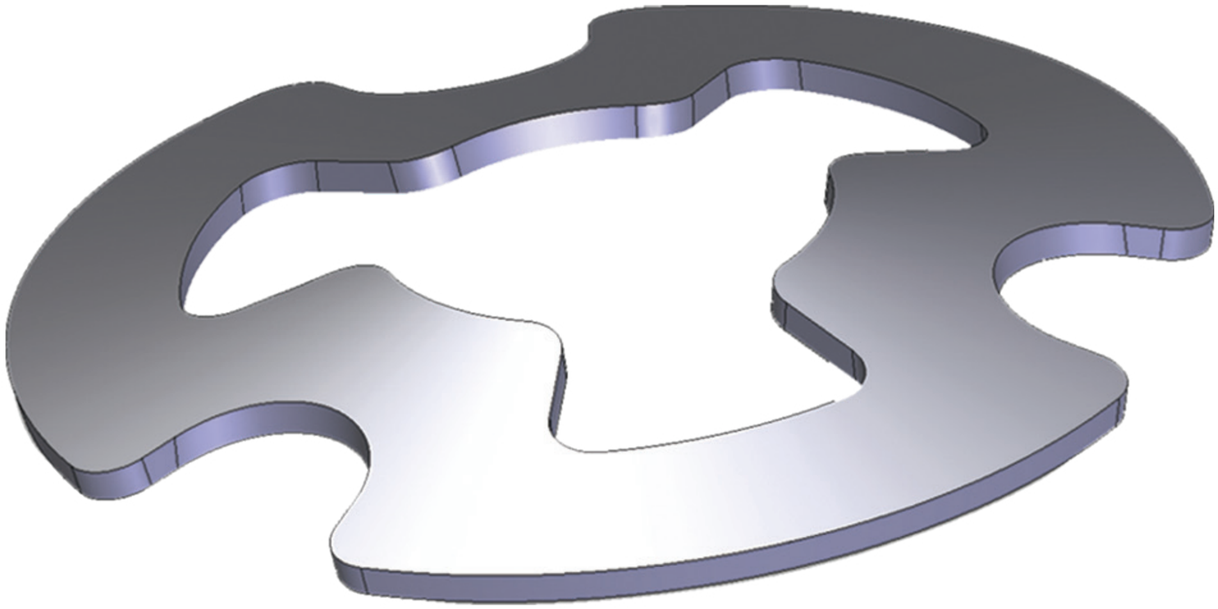
CloverDome

Technical Brochure



APPLICATIONS:

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Customized Spring Washers

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Introduction

The CloverDome™ is very different from similar spring washer products. Its overall height is roughly 10% of its diameter. The height of a Belleville washer is only 3% of its diameter. This translates in two to three times more deflection to work with. The result is a spring rate lower than that of stiff Belleville washer, but significantly higher than the spring rate of a coil spring, for an equal amount of deflection. When compressed to 75% of its height the CloverDome™ "recovers" to its original height and does not "flatten out.

The CloverDome™ is a conical formed disc spring that utilizes stress-relieving cutouts on both the inner diameter and the outer diameter. These patented cutouts allow the CloverDome to achieve 2 to 3 times the deflection of current disc springs. This added deflection makes the CloverDome suitable in applications where disc springs fall short of desired deflection or where the space occupied by coil springs is not tolerable. CloverDomes can also be stacked in a variety of methods to achieve force versus deflection (FD) curves that are not possible using a single spring.

Geometry of the CloverDome

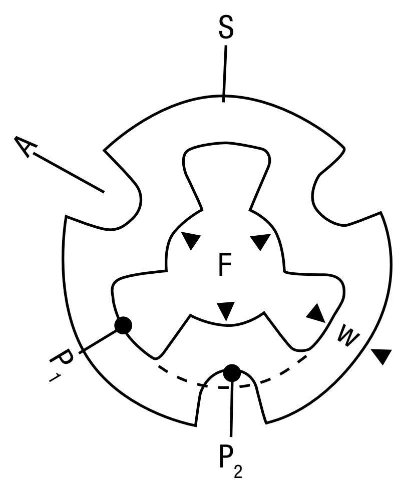


FIG 1

CloverDome Spring Rates

The unique spring rate of the CloverDome™ bridges the large gap between very stiff Belleville disc springs and resilient coil springs. To demonstrate the different spring rates between CloverDome™, Belleville, Curved, Wave and Finger springs, a simple equation referred to as "Coefficient of Compliance" (CC) is shown in Table 1. The Coefficient of Compliance (CC) can be determined by experimental means or if the material thickness has been determined.

The equation below shows how to calculate the CC when the material thickness has previously been determined. Generally the CC is approximated using data derived experimentally. The CC is a relative method for comparing springs. The common disc spring is stiffer and would have a very low CC while highly compliant coil springs will have a higher CC. The coefficient is calculated as follows:

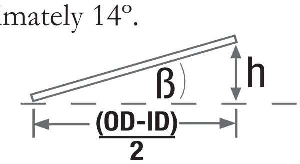
Table 1

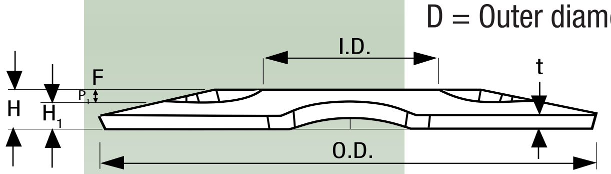
	Inch	Inch	thickness thousands of an inch	Force, lbs. @75% defl.	Inch Defl. @ 75% Compression	Inch total travel	Spring rate lbs./inch @75% defl.	Coefficient of Compliance	Mean Val.
TYPE	**OD**	**ID**	**t**	**f**	**DEFLECTION**	**TRAVEL**	**K**	**CC**	**m**
CLOVER	0.400	0.156	11	13	0.022	0.029	608	14	12.260
CLOVER	0.560	0.200	15	31	0.034	0.045	925	12	
CLOVER	0.714	0.255	15	20	0.041	0.055	493	13	
CLOVER	0.896	0.320	25	102	0.053	0.070	1928	10	
BELV.	0.394	0.205	10	14	0.009	0.012	1555	4	4.180
BELV.	0.551	0.283	14	29	0.013	0.018	2230	4	
BELV.	0.709	0.244	16	33	0.018	0.024	1833	4	
BELV.	0.886	0.441	24	100	0.024	0.032	4167	4	
WAVE	0.367	0.265	6	5	0.010	0.024	490	3	3.500
WAVE	0.618	0.440	8	6	0.013	0.032	431	3	
WAVE	0.734	0.531	9	7	0.016	0.041	419	3	
WAVE	0.925	0.719	10	5	0.022	0.056	245	5	

Deflection

The angle of the conical form will determine the amount of total deflection the CloverDome will yield. This cone angle is dependent upon the ratio of the OD to the ID and the thickness of the material. Testing has shown that as material thickness increases the cone angle decreases. OD to ID ratios of 2.0 will also yield a lower cone angle when compared to OD to ID ratios of 2.5 and higher. The actual cone angle is difficult to predict and these calculations should only be used as approximations. The following figure is a guide to approximating the height of the formed part. OD to ID ratios approximately 2.0 with material thickness greater than .030" should use an angle of approximately 13º. While OD to ID ratios of 2.5 and greater with material thickness less than .030" should use angles of approximately 14º.

1.) $$\sin \beta = \frac{h}{\frac{(OD-ID)}{2}}$$





O.D. = Outside Diameter
I.D. = Inside Diameter
t = Thickness
H = Approx. Free Height
H_1 = Loaded Height
P_1 = Load at Deflection F
F = Deflection $H-H_1$

FIG 2

Spring Rate

The desired spring rate is used for calculating the material thickness. To determine the spring rate we must know what the desired loads are for the CloverDome as well as the OD and ID. First we must determine the amount of deflection a particular OD and ID combination will generate. This can be determined from the previous section on calculating deflection. Once the deflection is calculated we can then determine the spring rate by dividing the desired load by the calculated deflection. This will approximate the spring rate as if it were linear. We know from figure 3 (on page 5) that the spring characteristics are very often non-linear. This approximation is necessary to calculate the properties of the CloverDome. This spring rate is theoretical and should only be used to approximate designs.

2.) $$K = F/h$$

F = Desired max load
h = Total theoretical deflection
K = Spring Rate

Coefficient of Compliance $CC = \frac{t^3}{(K \times OD^2)}$

Where:
t = material thickness in thousands of an inch, i.e. .016" = 16
K = spring rate (load / deflection in inches)
D = Outer diameter of the disc (foot print)

Example using two near same size discs

Belleville washer
D = .709"
T = .016
K = 33lb / .018" = 1833 lb/in.
$$CC = \frac{4096}{(1833 \times .502)} = 4.45$$

CloverDome
D = .714"
T = .015
K = 20.22lb / .041" = 493.17 lb/in.
$$CC = \frac{3375}{(493.17 \times .5097)} = 13.44$$

Force vs. Deflection Curves

The shape of the force versus deflection curves (FD curves) can be approximated using figure 3 below. The ratio h to t is used to determine the shape of the particular curve. Ratios of 3.5 and higher yield a regressive curve while ratios of .5 yield a progressive curve.

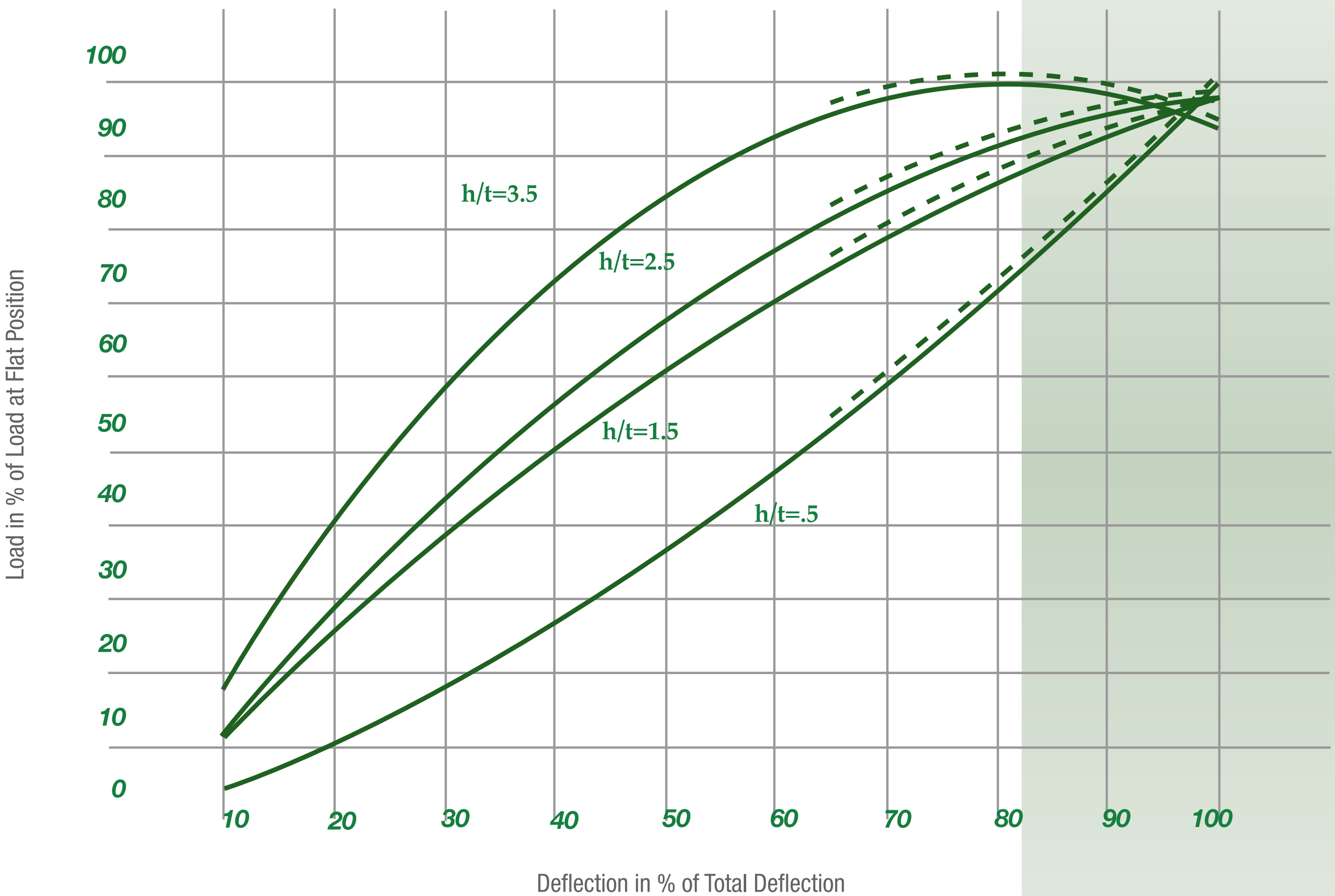


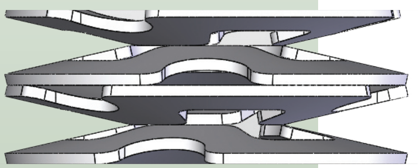
FIG 3

Series Stacking

Series stacking of CloverDomes is utilized when the deflection of a single spring is not sufficient. Equation 3 illustrates the effects of placing CloverDomes in series stacks. The force for the stack remains constant while the number of parts in the stack multiplies the deflection.

3.) $$D = D_1 + D_2 + D_3 \ldots Dn$$

Where
n = number of springs stacked in a series
D = Deflection per part



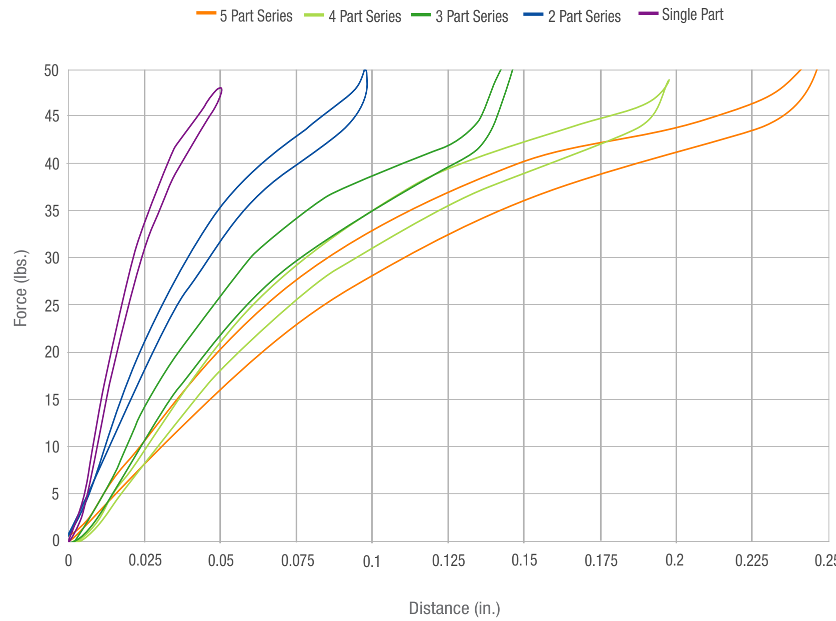


FIG 4

Parallel Stacking

Parallel stacks of CloverDomes can be used to achieve forces that can not be reached using single springs. Equation 4 illustrates the effects of adding springs in parallel. The force of each spring added to the stack is added to the total load while the total deflection of the stack remains constant.

4.) $$F = F_1 + F_2 + F_3 \ldots Fn$$

Where
n = number of springs stacked in parallel
F = Force per part

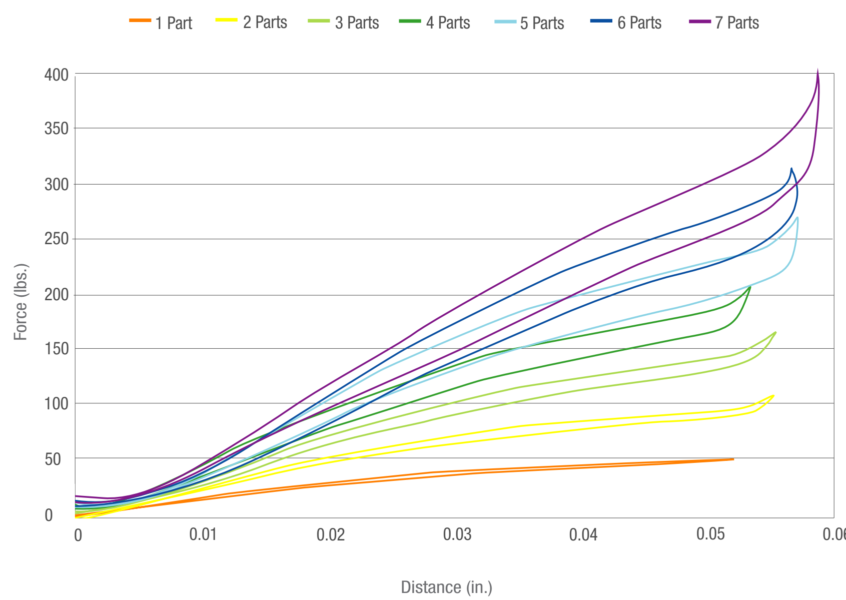
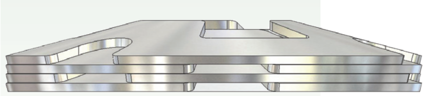


FIG 5



Material Thickness

The thickness of CloverDomes is calculated using the spring rate, approximated CC and the OD. The following equation shows how to determine the material thickness required.

3.) $$t = \sqrt[3]{CC \times K \times OD^2}$$

There are limitations to material thickness. Pre-tempered material, that is required for the CloverDome, is available in thickness' up to .060" (1.52mm). Generating parts thicker than this is generally avoided. At this time designing parts over .050" (1.27 mm) should be avoided due to manufacturing limitations and material availability. Figure 6 (below) is an example of the variation in FD curves for parts with the same OD/ID and varying thicknesses.

Example of Force Curve Variations

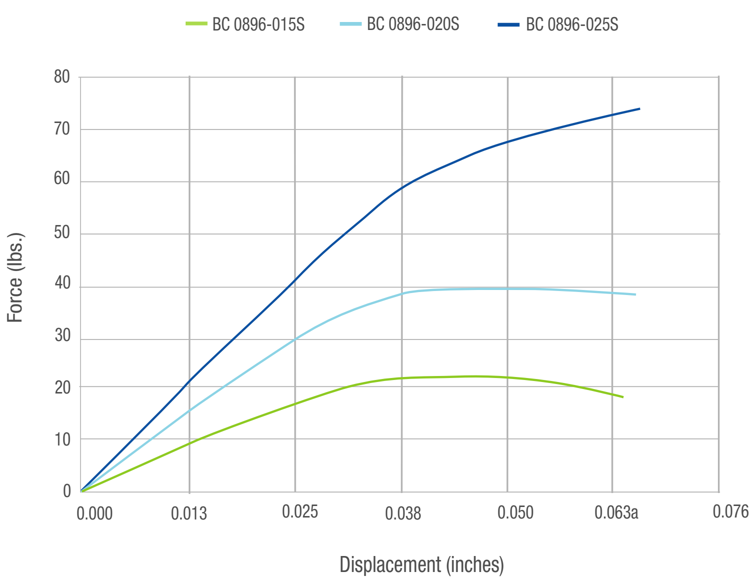


FIG 6

Cloverdome™ Part #BC 0896-025S

O.D. = .896"
I.D. = .320"
t = .025"
ß = 14°

$$h = \sin(14^\circ)\left(\frac{.896-.320}{2}\right) = .066"$$

$$H = h + t = .066" + .025" = .091"$$

$$h/t = \frac{.066"}{.025"} = 2.64$$

Cloverdome™ Part #BC 0896-020S

O.D. = .896"
I.D. = .320"
t = .020"
ß = 14°

$$h = \sin(14^\circ)\left(\frac{.896-.320}{2}\right) = .066"$$

$$H = h + t = .066" + .020" = .086"$$

$$h/t = \frac{.066"}{.020"} = 3.30$$

Cloverdome™ Part #BC 0896-015S

O.D. = .896"
I.D. = .320"
t = .015"
ß = 14°

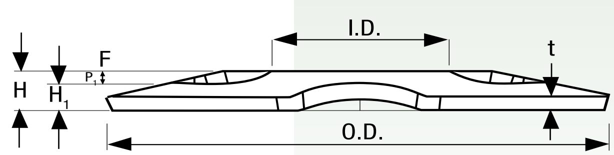
$$h = \sin(14^\circ)\left(\frac{.896-.320}{2}\right) = .066"$$

$$H = h + t = .066" + .015" = .081"$$

$$h/t = \frac{.066"}{.015"} = 5.4$$

Deduction

The trend of force / deflection curve for a thick "t" disc tends to be linear. For a thin "t" disc the curve is linear for the first portion of the curve but tends to flatten out and regress at it's apex.



Friction & Hysteresis

Fiction is generated when CloverDomes are in contact with any other surface. The friction is roughly equivalent to ± 3% of the total load. When stacking CloverDomes friction of each part stacked in parallel is taken into account. The friction generated by series stacks is much lower than parallel stacks.

Hysteresis is the difference in force from loading to unloading. Hysteresis results in an increase in force during loading and loss of force during unloading. Figure 7 illustrates hysteresis, which can be equivalent to ± 3% of the maximum force. The effects can be reduced using lubrication on the friction surfaces.

Single Part

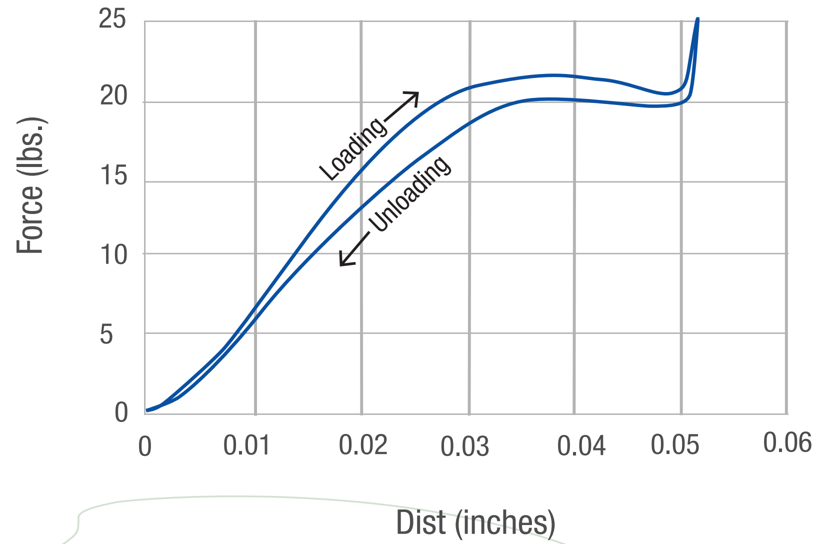


FIG 7

Specifications:

In considering an application it is important to ask the following questions:

- Size limitations on OD & ID
- Space limitations, max height (O.H.)
- Pre-load (load at initial deflection)
- Final load (load at full deflection)
- Initial deflection (measured from O.H.)
- Distance from initial to final deflection
- Static or dynamic application
- No. of cycles if dynamic
- Environment (Chemical, temperature)