## Resilience: designing for springs

One of the most remarkable properties of acetal copolymer is its resilience, which has led to the material being called the spring steel of thermoplastics. The resin has the ability to spring back rapidly to its original position after deformation or deflection, even after several years under strain.

This key characteristic, together with other short and long-term properties of the material, has led to the wide use of this resin by design engineers for applications as diverse as levers and material handling components, which must absorb the shock of starting moments.

### Designing from data

With any thermoplastic material, the traditional constants of classic elasticity formulae are in fact variables dependent on time, temperature, humidity, and stress levels. The behavior of acetal copolymer resin over a wide range of environmental and operating conditions has been exhaustively researched and documented, providing detailed design data in the form of families of curves.

Once the relevant design stresses and moduli have been obtained from these data, calculations may be based on conventional plastic theory. Provided that strains are not excessive, beam, coil spring, or more complex analyses can be undertaken in the normal way. It is often advisable to undertake two or more sets of calculations to evaluate the performance of the component at different extremes of environment.

In the case of spring design, limitations are imposed by the fact that the component to be made from acetal copolymer may be required either to return quickly to its original position or to maintain a minimum pressure in a deflected position over a period of time. For low strains and short loading periods, recovery is quick and complete; whereas for high strains and long loading periods, recovery is slower and some permanent set may occur.

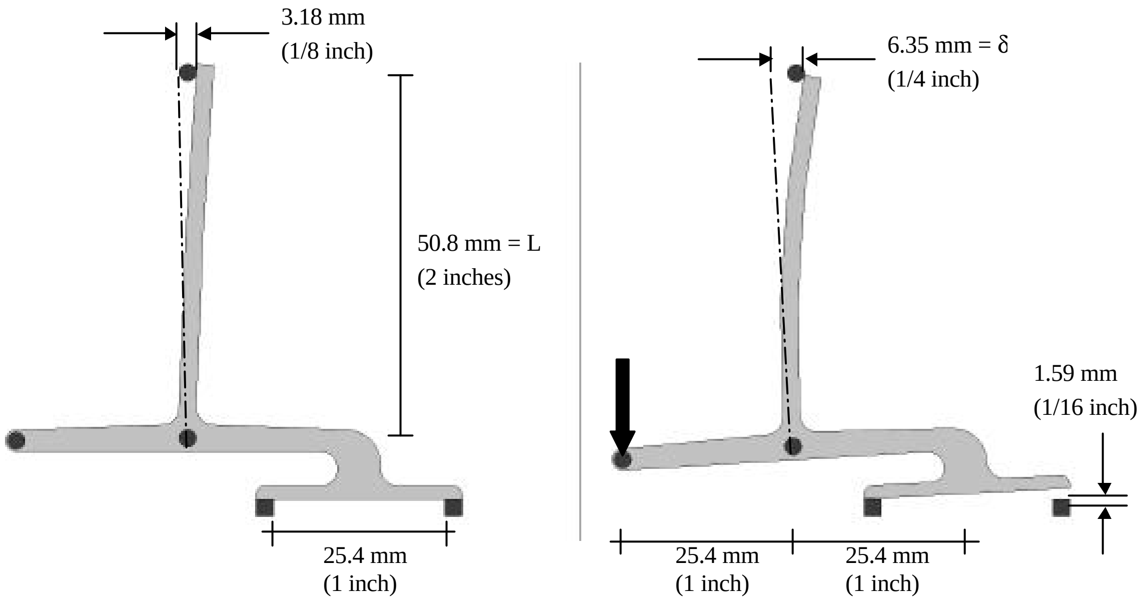
The latter condition is basically a problem of creep under load, and a limiting strain, at which the effects of creep are only slight, is often specified as a guide. For operating conditions requiring constant load or rapid recovery, a figure of 1% is used. For more intermittent loading, 2% may be allowable.

A typical series of design calculations for a spring is shown below:

### Typical spring calculations

A meter valve mechanism (Figure 1) comprises a valve flap with an integral spring and operating lever. The valve has a diameter of 25.4mm (1 inch), and provides a constant seal against 34.5 kN/m$^2$ (5 psi) due to the initial spring deflection of 3.18 mm (1/8 inch). The valve is opened 1.59mm (1/16 inch) for one hour in every 24, with a working life of three years at 20°C.

**Figure 1 - Meter valve mechanism used in example spring calculations**



Summarized below are the design calculations necessary to determine the width (b) and thickness (d) of the beam spring and the amount of pre-set to be molded into the spring.

The deflection (δ) resulting from a point load (w) at the free end of a cantilever beam is given by:

(1) $$d = \frac{wL^3}{3EI}$$

and the maximum bending stress (f) is given by:

(2) $$f = \frac{Md}{2I}$$

Where L = length of beam (mm or in)
E = modulus (kN/m$^2$ or psi)
$I = \frac{bd^3}{12}$ = moment of inertia of beam (mm$^4$ or in$^4$)
M = wL = bending moment
b = width of beam
d = thickness of beam

From (1) and (2):

$$e = \frac{f}{E} = \frac{3dd}{2L^2}$$

where e = strain.

The thickness of the beam is limited by the strain induced under conditions of maximum deflection. Taking 0.02 as the limiting strain for the ‘valve open’ position gives:

$$0.02 = \frac{3 \cdot d \cdot 6.35\text{mm}}{2 \cdot (50.8\text{mm})^2}$$

ie. d = 5.4 mm (0.21 in)

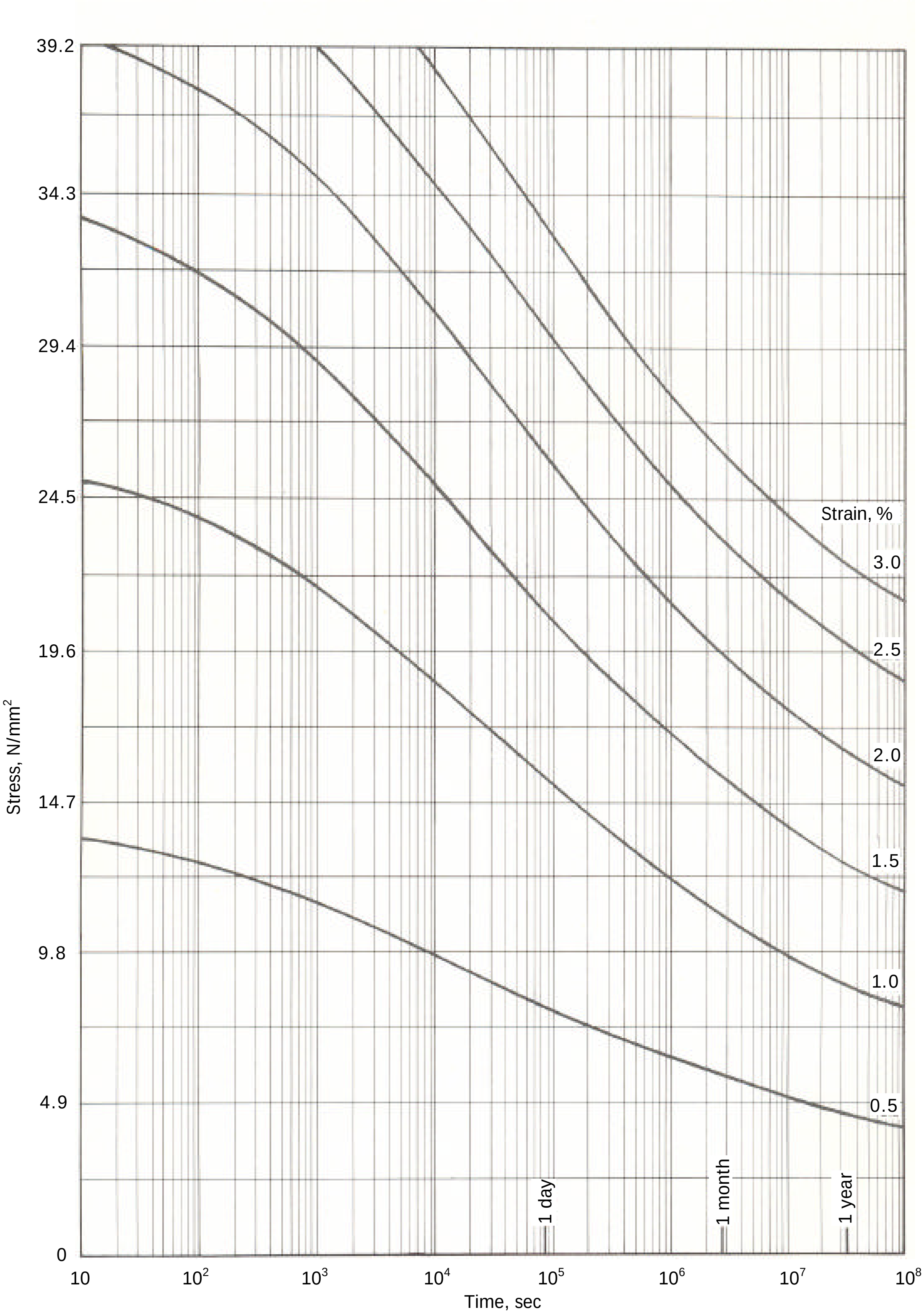
The width of beam necessary to provide the required closing force continuously for three years at 20°C is given by formula (2). From isometric stress vs. time curves
(Figure 2), the design stress at 1.0% is found to be 8.0 N/mm$^2$ (1160psi).

Hence $8.0 \dfrac{\text{N}}{\text{mm}^2} = \dfrac{\text{M} \cdot 5.4\text{mm} \cdot 12}{2 \cdot \text{b} \cdot (5.4\text{mm})^3}$

But $\text{M} = \text{pA} \times \text{L} = \dfrac{34.5 \dfrac{\text{kN}}{\text{m}^2} \cdot \text{p} \cdot (25.4\text{mm})^2 \cdot 25.4\text{mm}}{4}$

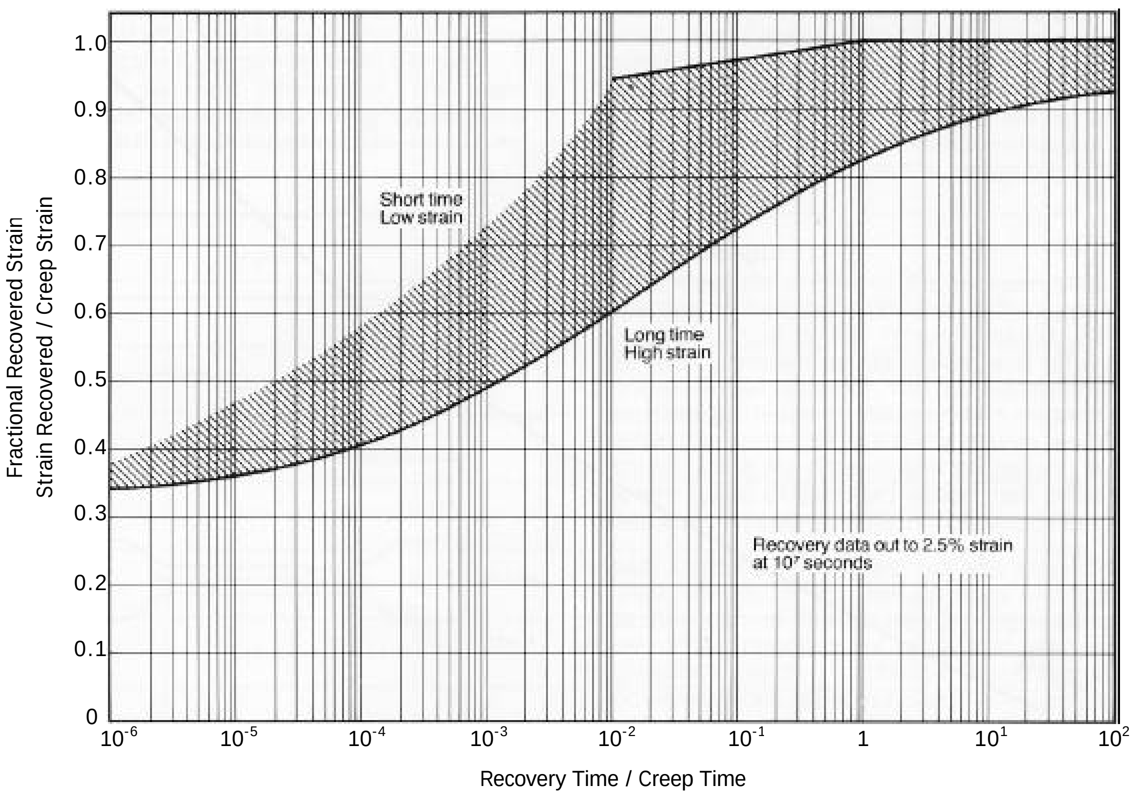
giving b = 11.4mm (0.45in)

## Figure 2 - Isometric stress vs. time curves, 20°C



If the valve is opened for one hour in every 24, the "reduced time" is 23. From data on recovery from tensile creep (Figure 3), recovery is shown to be approximately 90%. As a result, the effective deflection is reduced by 9/10 and a molded-in pre-set of 1/10 x 3.18mm = 0.32mm (1/80in) will be required. To allow for repeated flexing a pre-set of 0.40mm (1/64in) should be tried.

**Figure 3 - Recovery from Tensile Creep, 20°C**



Having determined accurately the effects of time, temperature, humidity, creep and other factors on the spring design, prototyping is recommended as the most efficient method of confirming theoretical calculations on part performance. Prototype testing is of particular importance for torsional beam springs, where stress relaxation and fatigue should be analyzed under actual operating conditions.