Engineering Property - Resilience

Resilience is defined as the ratio of energy given up in recovery from deformation to the energy required to produce the deformation, usually expressed in percent. Hysteresis is the percent energy loss per cycle loss per cycle of deformation. Hysteresis is the result of internal friction and is the conversion of mechanical energy into heat. Heat build-up is measured as the temperature rise resulting from hysteresis.

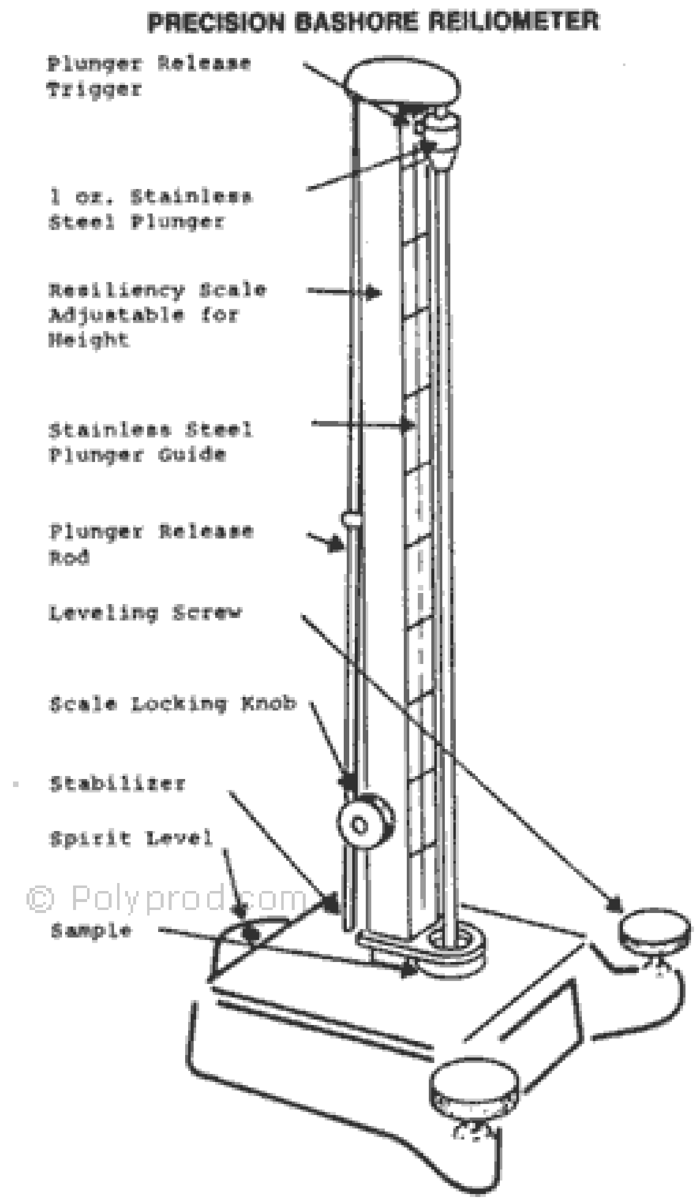
In general, resilience is determined in one of four ways from a low speed stress-strain loop, by impact tests, by free vibration or forced vibration methods.

Low Speed Stress-Strain is obtained by loading and unloading a specimen in tension, compression or shear using a low rate of strain and large deformation. Since most practical applications involve vibratory stresses of relatively high frequency and low amplitude, the low-speed stress-strain loop is not often used for measuring hysteresis.

The most widely used methods for measuring resilience by impact involve rebound in some form. A very simple test consists of dropping a metal plunger from known height onto a firmly supported rubber specimen and measuring the height of rebound, as with the Bashore Resiliometer.

An impact test, however, is not equal to a vibration test since there is no cyclic interchange of potential and kinetic energy. A widely used instrument that measures vibratory resilience is the Yerzley Oscillograph. This instrument is popular because it involves a relatively high speed deformation (many time faster tan a stress-strain loop, although considerably slower than with impact resilience tests) through one or more complete vibration cycles and yields precise and reproducible data.

However, the frequency is not the same order of magnitude as that of many applications involving vibration. Free Vibration Technique can use the Yerzley Oscillograph, which makes use of an unbalanced horizontal lever which strikes a cylindrical specimen of rubber and traces the resultant motion on a chart (Figure 2).



Since the chart is mounted on a revolving drum, the trace has the form of a sine wave as shown in Figure 3.

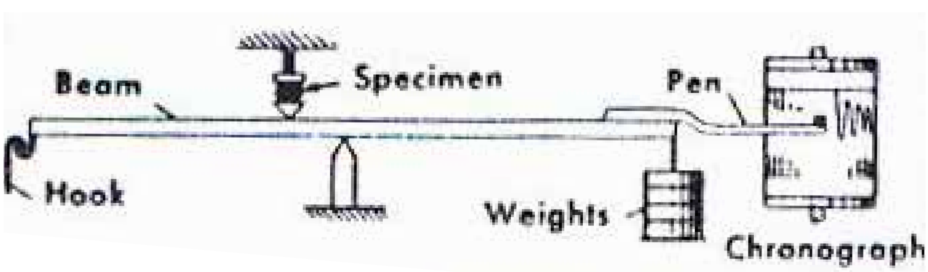


FIGURE 2 YERZLEY OSCILLOGRAPH

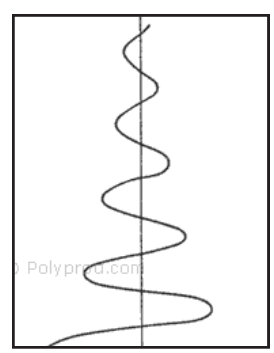


FIGURE 3 DAMPED-FREE VIBRATORY MOTION

Engineering Property - Resilience

The apparatus consists of a balanced beam supported on knife edges, with weights which are added to one end to strain the specimen on the opposite side of the knife edges. When the weights are released, a trace of the damping curve is automatically recorded. No significant test values can be obtained on materials which have a moduli greater than 280 psi in compression with 10% deformation. Yerzley tests are, therefore, limited to the softer urethane rubbers (Durometer 90A or below).

The Bashore rebound test can be used on rubber of all hardnesses, but does not yield results which are as precise and distinguishing as Yerzley resilience. Impact may cause a rise in temperature resulting from heat generated within the specimen. Resilience is a function of temperature and usually increases when rubber is heated.

Forced Vibration methods may be used to measure resilience, but they are usually employed to determine heat build-up in the specimen. Three flexometers described in ASTM D-623 are most commonly used for this measurement. These are known as Goodyear, Firestone and St. Joe Flexometers. They are most frequently used to compare various compositions with one whose performance has been determined by actual use.

There is a tendency to assume that a composition having high Hysteresis will be unsatisfactory for almost any use. This is not necessarily true. In certain vibration damping applications, compounds having relatively low resilience may be desirable because their damping effect limits the maximum amplitude which may develop in service.

For vibration damping purpose, resilience requirements are determined largely by the frequency and amplitude of vibration. Hysteresis in a low resilience compound would cause excessive heat build-up in the part. In this case, a highly resilient composition should be used.

Damping refers to the reduction amplitude in a free vibration system. Damping is a result of hysteresis and the two terms are frequently used interchangeably.

Heat generation measured by the temperature rise, or the equilibrium temperature, for a sample under forced vibration at non-resonance is more nearly related to the requirements of actual service than is resilience. The temperature rise at a given amplitude depends upon both the resilience and the compression/deflection of the rubber compound. The resilience determines the proportion of the vibrational energy which is converted into heat, but the actual value of the vibrational energy at a given amplitude is proportional to the dynamic modulus.

Effects of Amplitude and of Frequency on Vibration Properties

If there is no appreciable rise in temperature of the rubber, the dynamic modulus and dynamic resilience are independent of frequency for the ordinary range of mechanical frequencies. Any rise in temperature of the rubber due to internal heat generation will increase with frequency, tending to lower the dynamic modulus and raise the resilience. The dynamic properties of gum compounds are usually not affected by amplitude; but with filled compounds, the dynamic modulus decreases with the increases with the increase in amplitude even if the temperature in the rubber is constant. Any rise in temperature contributes to this effect. Resilience is not affected by the amplitude except indirectly by temperature changes.

The resilience of Die-Thane and natural rubber of 60 Durometer A hardness over the temperature range of 0 to 250°F (-18°C to 121°C) are compared in Figure 4

The resilience of Die-Thane urethane rubber increases as temperature is increases from 0 to 50°F (-18°C to 10°C) and then becomes almost constant. Being almost constant permits more confidence in design where service temperature may vary considerably.

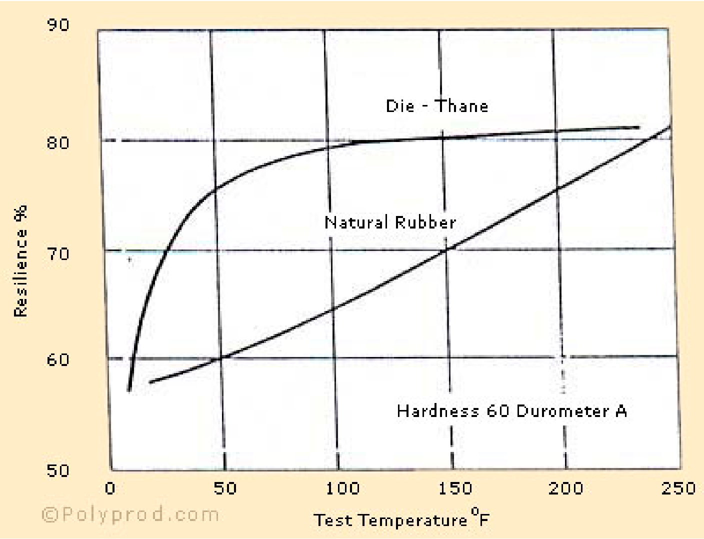


FIGURE 4 RESILIENCE OF Die-Thane AND NATURAL RUBBER AT VARIOUS TEMPERATURES

Engineering Property - Resilience

Heat build-up in urethane parts, under high frequency flexing, exceeds that of conventional elastomers and is the usual cause of premature failure under dynamic conditions. Because of the low thermal conductivity of urethane elastomers, heat developed by internal friction cannot readily be dissipated. The effect of heat build-up therefore, a very important consideration when designing with urethanes. Its adverse effects can be minimized by using thin cross-sections from which heat is more easily dissipated. The high strength and load bearing capacity of urethane elastomers makes possible the use of sections which are thin enough to dissipate heat at the same rate at which it is developed.

Values of resilience for typical compounds of Die-Thane are shown in Table 1.

TABLE I

RESILIENCE OF DIE-THANE		
Die-Thane Hardness	Yerzley Resilience	Bashore Resilience
Durometer A		
58	72	-
75	70	60
80	70	60
85	65	-
90	65	45
95	-	39
Durometer D		
58	1	-
72	1	48
75	1	50

Die-Thane urethane rubbers can be formulated to exhibit high or low resilience. Yerzley Oscillograms of compounds having high and low resilience are shown on Figure 6.

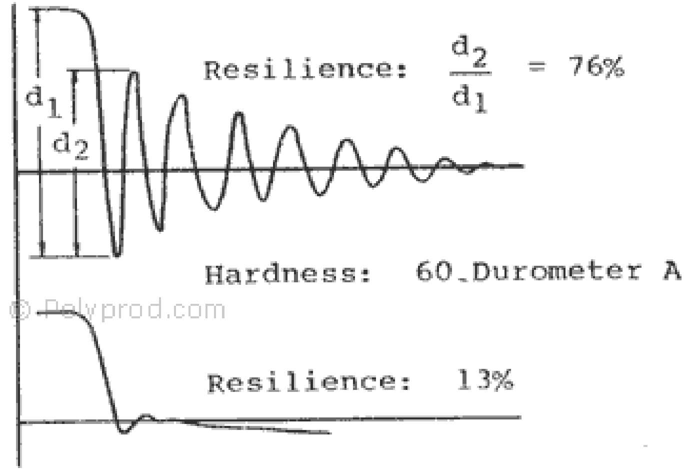


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FIGURE 6

Die-Thane provides a greater hardness range with less sacrifice in resilience than many types of elastomers. This is a characteristic because urethanes are non-reinforced while rubber requires the use of fillers to develop optimum properties.