Engineering Property - Compression Set, Creep & Stress Relaxation

Compression set, creep and stress relaxation are related to the fluid characteristics of elastomers. Set is defined as the deformation remaining after removal of the deforming stress. Creep involves the increase in deformation with time under constant stress. Stress relaxation is the decrease of stress with time at a constant deformation.

Compression Set

Compression set tests, described in ASTM D-395, are of two main types: Method A, compression set under constant load; and Method B, compression set at constant deflection of 25%.

In Method A, specimens of standard dimension are compressed between parallel steel plates under a stress of 400 psi. The test assembly is then conditioned for a selected time at the selected test temperature (such as 22 hrs. at 158°F. (70°C)) after which the specimens are removed and allowed to recover at room temperature for 30 minutes. Compression set is the difference between the original thickness of the specimen and the thickness of the specimen and the thickness after test, expressed as a percentage of the original thickness.

In determining compression set by Method B, the specimen is compressed to 75% of it original thickness. The test assembly is the conditioned for the specified time at the selected test temperature. Compression set determined by Method B is the difference between the original thickness of the specimen and the thickness after testing, as a percentage of the deflection employed.

Although the conditioning time and temperature are specified in the ASTM standard, other times and temperatures are frequently used.

Compression set is applicable particularly to the compounds used in machinery, motor mountings and vibration damping. Compression set tests are intended to measure that ability of elastomeric vulcanizates to retain elastic properties during the prolonged action of compression stresses. The actual stressing in service may involve (1) the maintenance of a definite deflection, (2) the constant application of a known load, or (3) the rapidly repeated deformation and recovery from compression forces.

There are applications where the temperatures and deformation conditions used in the permanent set test are approximated in actual service. These instances. Where apparent similarity exists, have led to a widespread tendency to overemphasize permanent set values. Since the short testing time will never approach the much greater span of desired service life, the test values will only suggest, not predict, what may be expected in service. For example, it is often thought that low compression set is always accompanied by high resilience and low creep. While trends of this type may be evident when considering extreme values for compression set, there are so many exceptions that acceptance of the general statement does more harm than good.

Typical compression set values for Die-Thane are shown TABLE I. Lowest compression set is usually obtained with 90-95% theory curing agent.

Table I

Compression Set of Die-Thane at Various Hardnesses								
Compound Hardness	A	80	85	90	95	-	-	-
	D	-	-	-	48	58	73	73
Compression Set								
Method B	22 hrs. at 158°F	45	35	27	40	40	-	-
Method A	22 hrs. at 158°F	1	1	91	102	-	302	102

(1) @ 400 psi
(2) @ 1350 psi

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Creep

When subjected to load, all elastomers exhibit an increasing deformation with time, known as creep or strain relaxation. This occurs at any stress level and takes place in compression, tension and shear loadings and varies for each type of loading. In service, creep can be minimized by using low working stresses and avoiding high temperature. No rapid method has been developed for its measurement because there is no known way of accelerating time effects without introducing inaccuracies in predicting rate of creep.

Creep is usually expressed in percent of deformation after the part is loaded rather than the unloaded dimension. Determination of creep takes place after some arbitrary short time interval such as one minute, five minutes or even one day after applying the load. Creep, expressed as a percent, equals total deformation minus initial deformation divided by initial deformation, times 100. In the initial stage, creep occurs at a relatively high rate and then continues at a very slow rate. Failure can occur after an extended period of high stress. Figure 1 illustrates characteristic creep curves. AB in the high stress creep curve indicates the failure phase where actual fracture can occur.

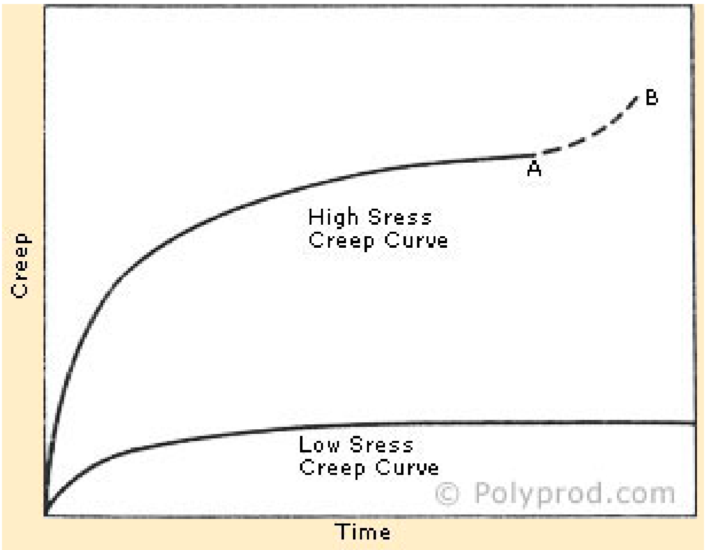

FIGURE 1 CHARACTERISTIC CREEP CURVE

Below the failure zone, when stress is removed, the part will attempt to return to its original dimension; however, it will never fully recover. The unrecoverable portion is called permanent set. Loads which allow intermittent recovery will exhibit less creep than if continuously loaded. However, continuous vibratory loading will increase creep since internal heat is generated.

Strain relaxation is important in applications such as engine mountings since it influences the alignment of various parts of the equipment. Yet, it is difficult to predict these properties for a given application without resorting to simulated service tests because several factors have an important effect on them. Chief among these are amount of strain, operating temperature and changes in these two resulting from vibration.

The relative effect of variables have not yet been correlated so that results of tests under one set of conditions will permit accurate prediction of creep under another set of conditions. It has been established that the higher the initial strain, the higher the creep; also, the higher the temperature, the higher the creep. In general, the degree of creep is dependent on the type of strain. Creep is greater under tension strain then under equal compression strain. Creep is also increased more under dynamic loading then under static loading because of internal heat generation.

The creep characteristic of two Die-Thane polymers, over a ten-month period, are shown on Figure 2. After approximately 3000 hours (18 hours) creep reaches a plateau and becomes almost constant. The amount of creep is a function of stress level. This involves a stress of 400 psi. Creep will continue at a very low rate after this point, which is the classic behavior of elastomers.

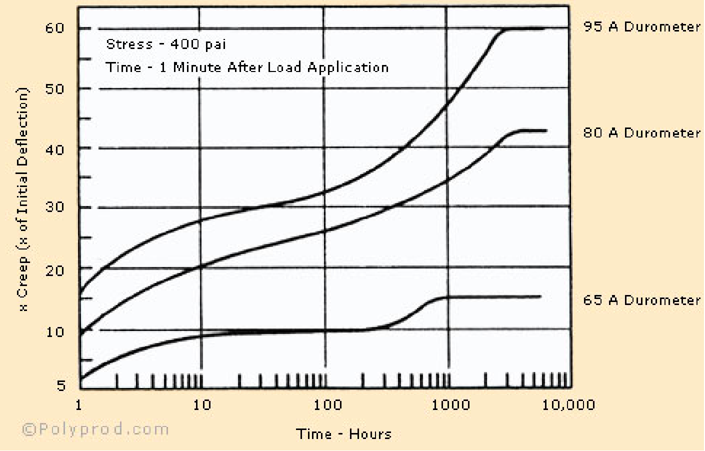

FIGURE 2 CREEP IN COMPRESSION

The actual creep of the 95 durometer A compound was 0.033 inches after ten months compared with an initial deflection of 0.200 for a sample 0.500 inches thick. After the initial loading, creep is only 6.6%.

The creep rate of rubber materials of all kinds increases at elevated temperature. Where dimensions are important, operating temperature must be kept below 150°F (66°C).

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Stress Relaxation

Stress relaxation is the loss in stress when it is held at a constant strain over a period of time. It is usually expressed in terms of percent stress remaining after an arbitrary length of time at a given temperature. It is an important property where a given level of force or tension must be maintained over a long time, such as in seals of various types.

There is no standard method for determining stress relaxation. However, many laboratories have developed relaxation cells. These cells utilize the compression set specimen and the test procedure parallels ASTM D-395 Method B. Stress relaxation for Die-Thane DT-25 is shown in Figure 3 and Figure 4.

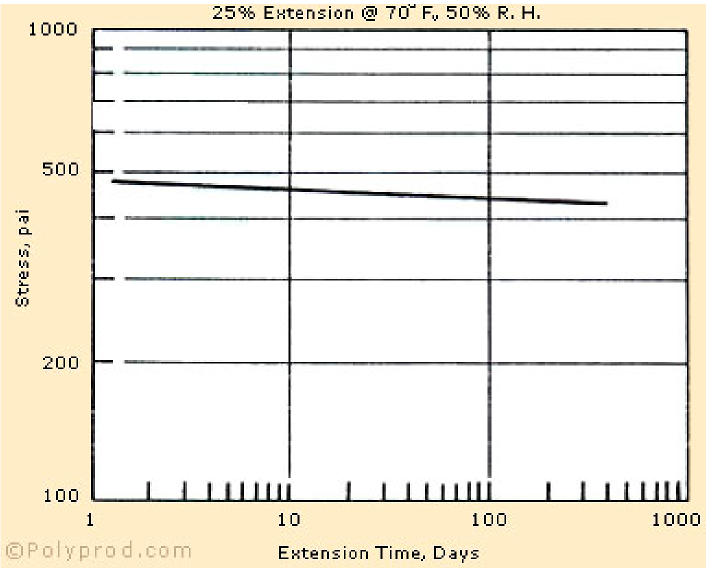

FIGURE 3 STRESS RELAXATION OF Die-Thane DT-25 12.5 phr MBCA

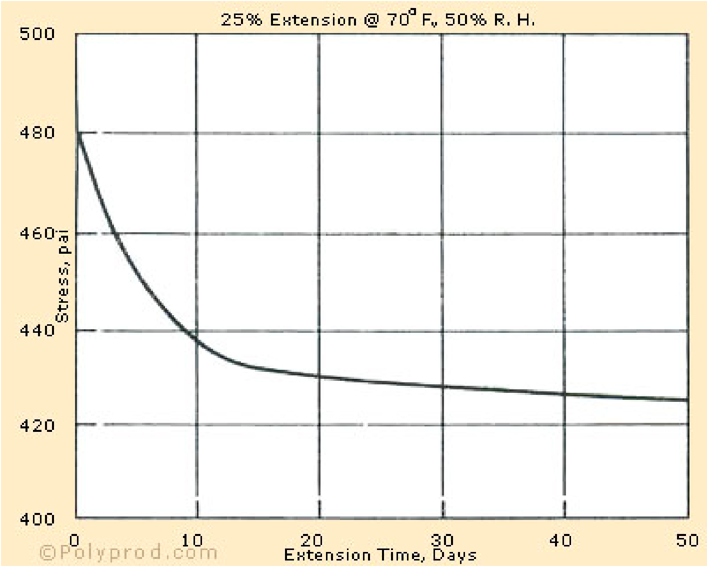

FIGURE 4 STRESS RELAXATION OF Die-Thane DT-25 12.5 phr MBCA