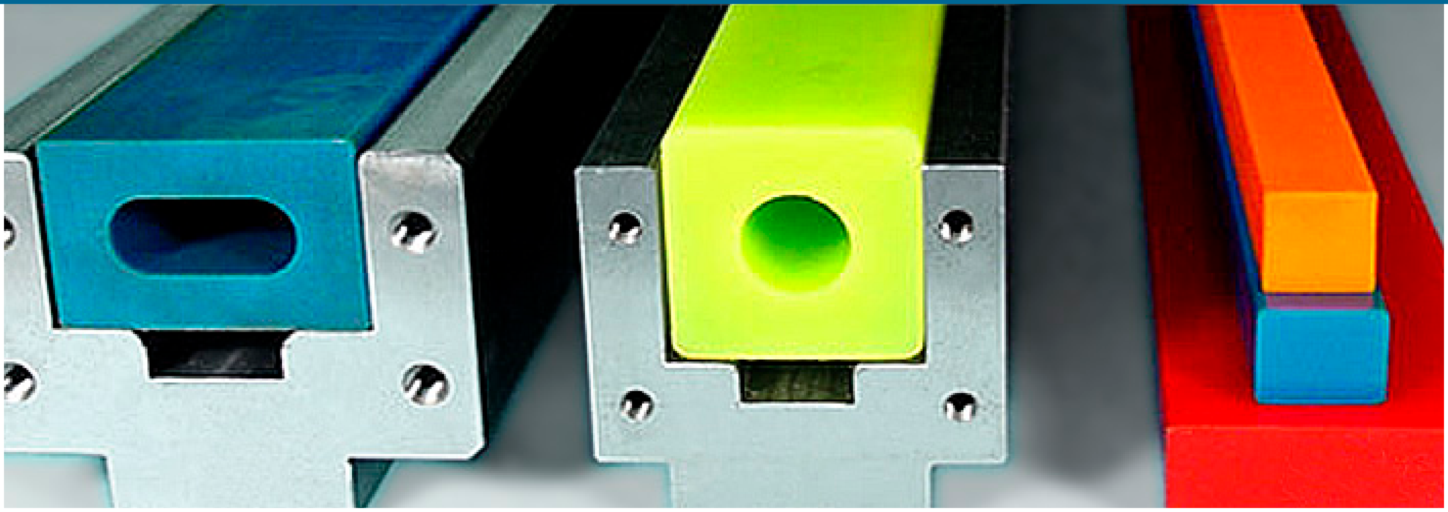


Engineering Information

Polyurethanes or Urethanes are a family of elastomers, similar to rubbers, offering a unique combination of properties. When designing these products, it is important to note that these properties and some of the terminology differ considerably from metals or plastics. Elastomers are extensible and deform easily, and some properties change as the part is stressed. The combination of many outstanding properties within the single material makes a urethane distinctive from conventional rubbers and plastics. Urethane elastomers are often considered as a bridge between rubbers and structural plastics because they combine many of the desirable properties of both.

Poly-Pro Polyurethanes are thermosetting materials characterized by unusual toughness. They combine resilience and high load-bearing capacity with resistance to impact, abrasion and compression set and degradation by oxygen, ozone and oil. They are liquid polymers which are mixed with curing agents and poured into molds of any cross section or size to produce parts with consistent properties throughout. Since it is a low pressure molding process, large and inexpensive molds are often fabricated with sheet metal, aluminum, urethane or wood.

Our Polyurethanes are available from 20A (soft as gum rubber) to 75D (hard as a bowling ball).
Compounding and processing methods and conditions have a major bearing on the performance of a given product. A myriad of compounds can be produced in the same hardness, using a variety of chemical backbones. Even a minor variation in the ratios of the chemicals can result in a major variation in performance of that product for a particular application. Knowing a particular application, the molder can vary his compound to optimize some of the properties. Proper application engineering is very important for the success of a product.

The physical properties listed are for the standard compounds designed for our common applications. These are not to be construed as a warranty for any particular application. Application of sound Engineering principles and practices should be used.

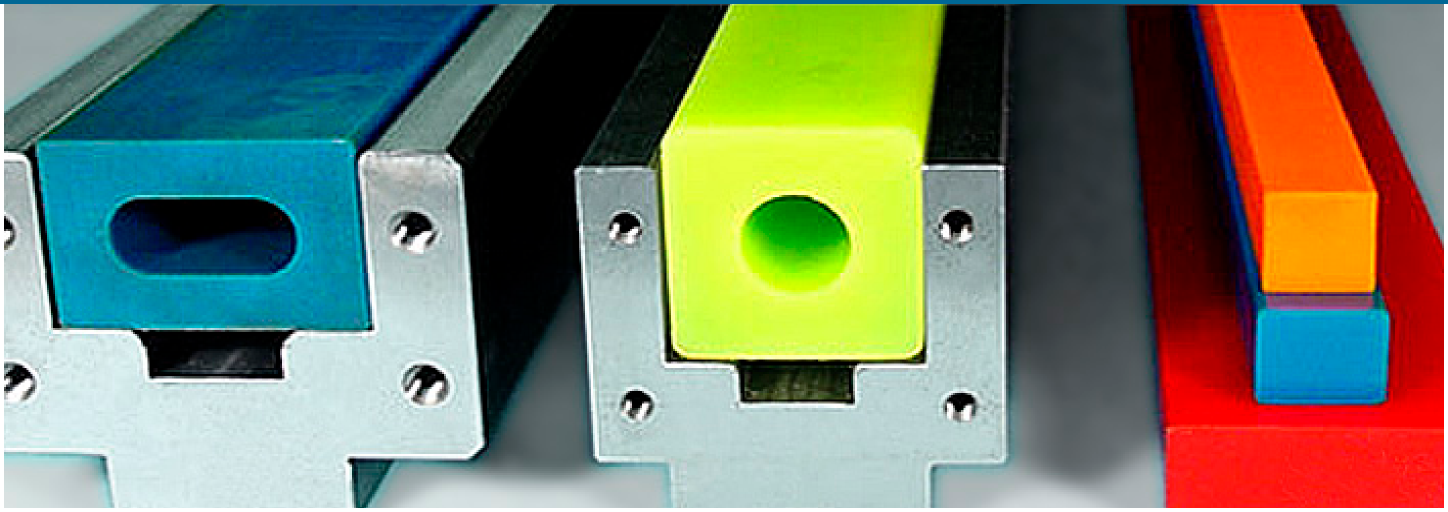
Caveat emptor...buyer beware: All urethanes are not created equal. Unlike thermoplastics, a thermoset urethane is 'created' by the molder. Not all urethanes are created equal. The type of polymer and the type and ratio of curative play a very crucial role in the performance of the product. A urethane molded product can be compounded in a garage by using very minimal equipment (a paint mixer stick, a can, an oven and a scale is all that is needed to be a molder. They can get a bit more sophisticated and use an electric drill for mixing. The investment will still be in 3 digits !). Because of this, there are lots of companies that call themselves Urethane molders. But the performance and consistency of their products will be debatable as compared to some molders that use sophisticated metering and mixing machinery.

Types of Polyurethanes:

Cast Polyurethanes based on TDI, MDI,PPDI, polyethers, polyesters and polycaprolactones as building blocks, offer a wide variety of application possibilities and advantages.

Polyethers perform well in dynamic applications and in hydrolytic environments. They have better dynamic properties. They are extensively used in applications such as die-forming pads, press brake dies, die springs, fork lift tires, roller coaster wheels, rolls for steel and paper mills.

Polyesters have superior cut, tear and abrasion resistance as well as better resistance to oil and solvents. Typical applications include hydraulic seals, scraper blades, rolls for graphic arts, pipeline pigs, chute liners, etc.



Typical Engineering Properties

- Hardness
- Stress-Strain
- Compression and shape factor
- Urethanes in compression
- Dynamic properties
- Compression set, creep
- Resilience
- Tear resistance
- Abrasion resistance
- Flexing
- Shear
- Physical constants
- Electrical properties
- Electro Static dissipation
- Frictional properties
- Impact resistance

Die-Thane Grade	DT-5	DT-15	DT-25	DT-35	DT-40
Hardness, Durometer (ASTM D 2240)	75D	95A	90A	80A	60A
Color	Black	Amber	Red	Green	Natural
Max Recommended Deflection	5%	15%	25%	35%	40%
Tensile Strength,PSI (ASTM D 412)	10000	5000	4500	3500	3000
Tensile Modulus,PSI (ASTM D 412)					
@ 50% Elongation	2000	900	500	220	150
@ 100%	4000	1800	1100	400	280
@ 300%	-	3400	2100	630	390
Elongation at break (%) (ASTM D 412)	275	425	450	800	530
Tear Strength, PLI (ASTM D 470)	115	150	75	70	25
%, 22 Hrs., @ 150 F (Method A)	10	45	27	45	6
Abrasion Index, % NBS (National Bureau of Standards) (ASTM D 1630)	450	400	175	140	45
Compression Modules, PSI, Pressure to produce 10% Deflection at shape Factor=1.0	4000	2000	1200	850	100

Engineering Property - Hardness

Hardness, as applied to elastomers, is defined as the relative resistance of a surface to indention by an indenter of specified dimension under a specified load. The most commonly used measuring instrument is a durometer. Shown in Figure 1 is a pocket-size instrument. Numerical hardness values are derived from the depth of penetration. The harder the sample, the further it will push back the indenter point and the higher the readings as shown in Figure 2.

On the durometer A scale, 0 is very soft, and 100 is infinitely hard. Values are usually read immediately after firm contact has been established. The hardness range of elastomers is so broad that a single durometer cannot indicate practical measurable differences of hardness. For this reason durometers are available in more than one scale model, (e.g., A and D scale durometers). The A scale durometer is widely used throughout the rubber industry. The durometer D model, which has a stiffer spring and a more pointed indenter, is used to measure the hardness of hard rubbers.

FIGURE 1 POCKET-SIZE DUROMETER, TYPE A

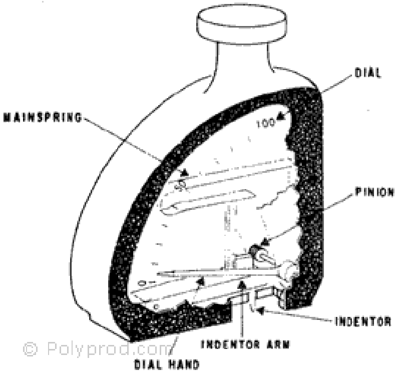


FIGURE 2 SCHEMATIC DRAWING POCKET-SIZE DUROMETER

Mechanical limitations of durometers and the way people use them cause hardness measurements to be inconsistent. It is not uncommon to find a difference of 5 points in individual hardness readings of an elastomer specimen. Table-top durometers can measure hardness more accurately, but they are not as convenient and are not used routinely.

Frequently, hardness is assumed to correlate with stiffness (modulus), but this is not always true. Variations of a few points in hardness can show a marked difference in compression-deflection.

A statistical determination has been made of the relationship between hardness and 100% modulus of Poly-Pro Urethanes measured with durometers on the A and D scales. As expected as shown in Table II, the A scale is more reliable for predicting the modulus of the softer stocks; the D scale should be used with the harder stocks.

The values in Table II are graphically shown below

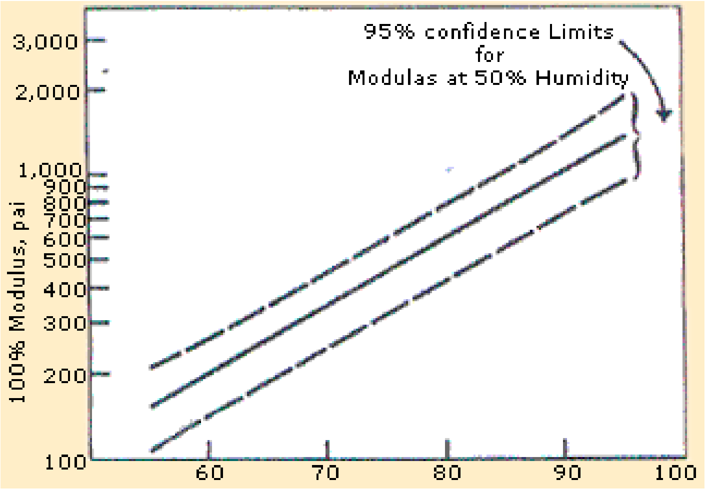


FIGURE 3 HARDNESS – DUROMETER A

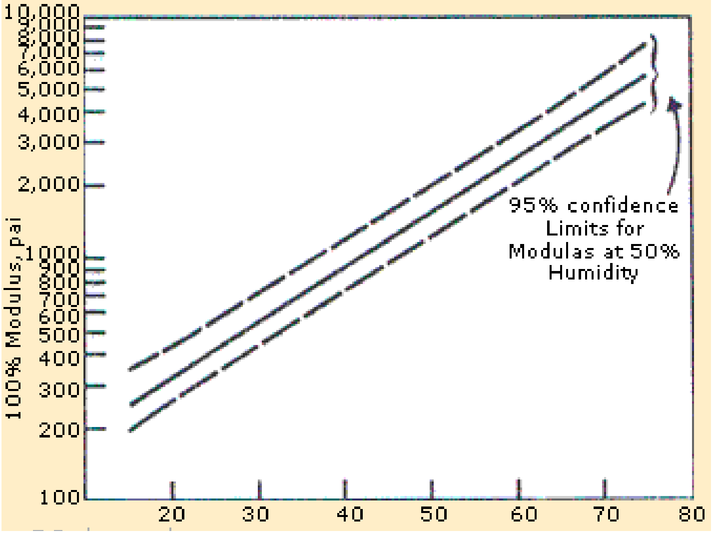


FIGURE 4

Typical hardness values for P.P.C Urethanes are:

PPC Compound Number	Urethane Durometer A	Hardness Durometer D
P80	78-80	-
P90	88-93	40
P95	88-93	40
P560	45-50	5000
P575	-	70-7

Engineering Property - Hardness

Table II

Hardness A	95% Confidence limits	Avg 100% Modulus psi	Hardness D	95% Confidence limits
55	105-205	150	-	-
60	140-265	200	10	175-275
64	180-330	250	14	195-330
68	210-400	300	18	240-400
73	295-530	400	23	315-520
77	365-650	500	27	390-630
80	430-795	600	31	480-760
83	500-910	700	34	560-880
86	580-1060	800	36	630-1000
88	645-1200	900	38	700-1120
90	700-1350	1000	40	760-1250
92	800-1550	1150	43	900-1400
1	1	2000	55	1650-2500
1	1	2500	59	2000-3800
1	1	3000	63	2400-3800
1	1	4000	69	3200-5100
1	1	5000	73	3900-6400

Table III

Durometer A	Durometer D
50	-
60	-
70	18
75	25
80	30
85	35
90	40
95	48

The reliability of predicting modulus from either A or D scale is approximately +33%, for 95% confidence limits. In the low modulus range of less than 500 psi, predictability is 25%.

The A scale should be used with moduli of 500 psi and under. The D scale is more useful for predicting moduli of more than 1000 psi. Either scale may be used for the Intermediate areas as in Table II.

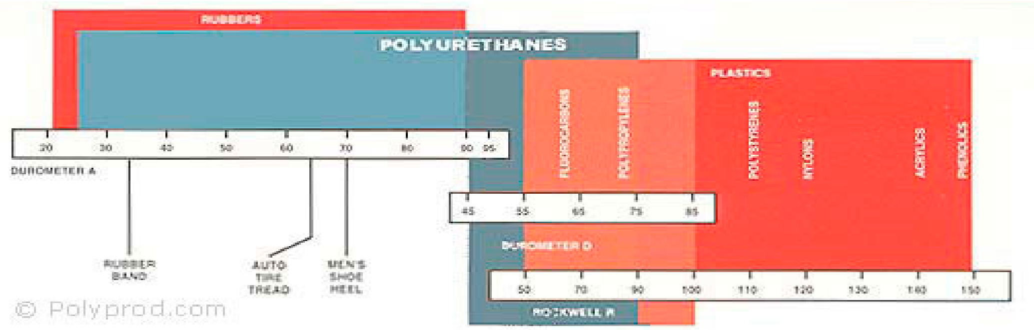
One hundred per cent modulus can be predicted to within +115 at a level of 400 psi, ranging up to +315 at 1150 psi using the A scale; using the D scale predictability ranges from + 100 at 400 psi to + 1200 to 5000 psi.

A linear relationship between durometer A and D does not exist. Approximate equivalent readings for durometer A and durometer D are shown in Table III. Because of differences in indenter tip shape difference between A and D readings can vary widely for different materials.

Hardness above 95 on the A scale should not be specified because the upper accuracy limit of the instrument is being approached. Accuracy at the lower end of the D scale is also limiting and values below 25D are questionable.

Most Urethane compositions lie between durometer 58A and 75D as shown in Figure 5. No other type of rubber offers unique properties over this hardnesses can be made by blending polymers. Softer polymers can be made by incorporation of plasticizers, changing curing agents, or by making cellular products.

Hardness Scale



Engineering Property - Stress-Strain

Tensile strength and ultimate elongation, while sometimes useful for compound development and control, are of lesser importance to the design engineer. Elastomeric parts are seldom loaded in tension and then only to a small fraction of their ultimate strength or elongation. Tensile strength and elongation generally cannot be correlated with performance in service. The relationship of stress to strain is more useful because it shows how an elastomer responds to loading.

Tensile properties are measured by recording axial stress in a standard ASTM dumbbell specimen at a constant rate of strain. Tensile strength and elongation, as applied to rubber, are defined as follows:

Tensile Strength is the force per unit of the original cross-sectional area which is applied at the time of the rupture of a specimen.

Elongation or Strain is the extension between bench marks produced by a tensile force applied to a specimen and is expressed as a percentage of the original distance between the marks. Ultimate elongation is the elongation at the moment of rupture.

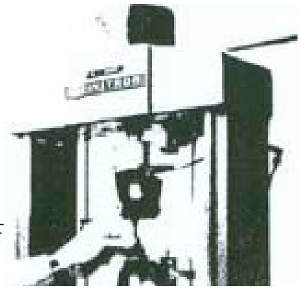
Modulus is the stress in pounds per square inch (of original cross-section) required to produce a certain elongation.

If a tensile stress of 1800 psi produces an elongation of 300%, the compound is said to have a 300% modulus of 1000 psi. In rubber, unlike steel, stress and strain in tension are not proportional; and, therefore, the term modulus has a different meaning. When applied to steel, modulus is stress divided by strain a ratio and a constant. Applied to rubber, modulus means stress at a certain strain – not a ratio and not a constant, merely the coordinates of a point on the stress-strain curve.

Procedures for conducting stress-strain tests are standardized and described in ASTM D-412. Dumbbell shaped specimens four or five inches long are die-cut from flat sheet and marked in the narrow section with bench marks one and two inches apart (Figure 1). Ends of the specimen are placed in the grips of a testing machine (Figure 2). The lower grip is power driven at 20 inches per minute and stretches the specimen until it breaks. As the distance between bench marks widens, measurement is made between their centers to determine elongation.

POCKET-SIZE DUROMETER, TYPE A

TESTING MACHINE



Stress-strain properties are useful in compound development and for manufacturing control. As control tools, stress-strain properties reveal whether or not the ingredients have been mixed properly or if contaminants are present. Property changes by environmental conditions are easily detected by a change in stress-strain properties. For a product which has been put in production, modulus and elongation measurements can be used as quality control tools. They are sensitive to manufacturing variations and indicate if the product has been properly processed.

Natural rubber must be loaded with carbon black to obtain a modulus approaching that of Poly-Pro urethane rubber with no filler (Figure 3). Tensile stress-strain curves for compounds of Poly-Pro are shown in Figure 4. The tensile strength of commercial compositions of Poly-Pro will vary from 2000 psi to over 11,000 psi. Elongation will vary from 250% to 800%. Generally, tensile strength increases with an increase in hardness.

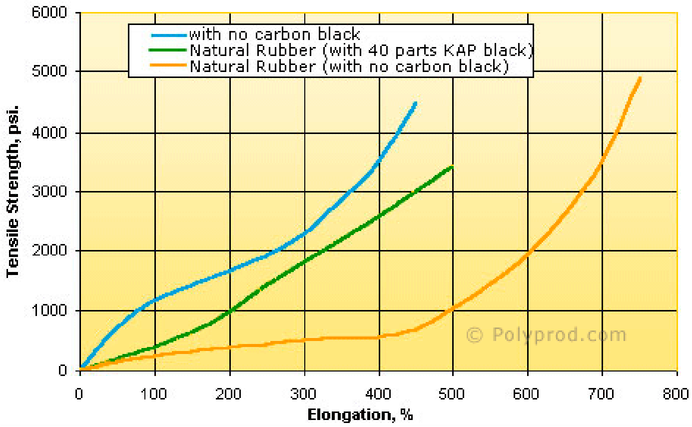


FIGURE 3 STRESS-STRAIN OF POLY-PRO P 90 COMPARED TO NATURAL RUBBER

Figure 4 also shows that Die-Thane elastomers retain extensibility at high hardness. Elongation at break of a 75 durometer D, achieved with P.P.C compound P-675 is usually 250%.

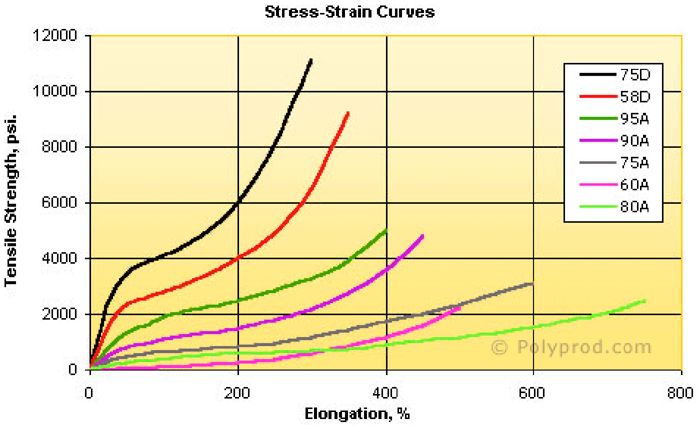


FIGURE 4 STRESS-STRAIN CURVES

Engineering Property - Stress-Strain

The response of materials at low modull is more important to the design engineer than the design engineer than the ultimate tensile strength. As shown in Figure 5, tests from the same material can yield widely varying tensile strengths based on small differences in elongation. In this case, an elongation at break of only 50% can result in a 2200 psi change in tensile strength. The variability in tensile strength can be due to small volds in the specimen or a small invisible nick in the sample. Stress at 100% modulus yields very consistent results and are reproducible compared to other tensile properties.

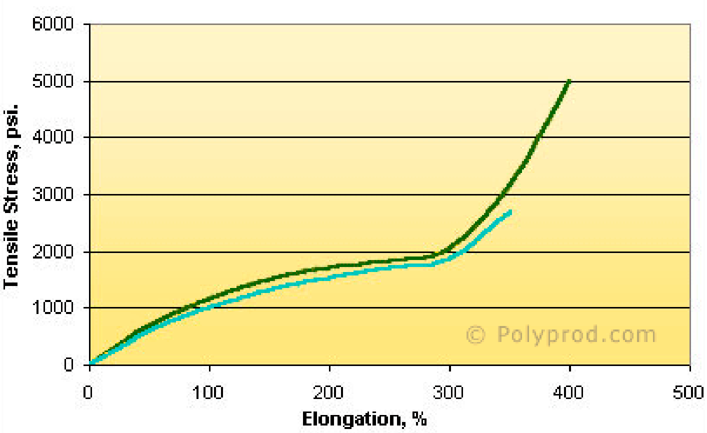


FIGURE 5 INFLUENCE OF SLIGHT CHANGES IN ELONGATION

In many non-rubber materials, Young's Modulus may be taken in tension or compression, the values being approximately the same; it is the ratio of stress to strain, expressed in psi per unit strain. In rubber, the assumption that tension modulus equals compression modulus is valid only for extremely small deformation and for certain shapes, such as specified in ASTM D-797, " Young's Modulus in flexure of Natural, and Synthetic Elastomers" and STMD-1053, (Sec.7) "Measuring Low-Temperature Stiffening by the Gohman Torsinal Apparatus".

Modulus of elasticity in tension for three vulcanizates of Die-Thane compounds are given below. The values given are the-slopes of the stress-strain curves, as near to the point of origin as could be measured and should be considered only approximate. The values were measured at 720 F (220 C).

Die-Thane DT-25	7,000 psi
Die-Thane DT-15	11,000 psi
Die-Thane DT-5	52,000 psi

Engineering Property - Compression & Shape Factor

When a load is applied to an elastomer, it “flows” in accordance with the force exerted on it and within the limits provided by the mass of the material itself or by the dimensions of its container. In rubber technology this is called compression. Although this term is correct in the framework of normal rubber usage, it may be misleading to the engineer. It does not mean that the elastomer will undergo a change in volume under pressure.

Rather, it means the elastomer will deflect, or undergo a change in shape. This distinction is important. An elastomer is an incompressible fluid, capable of changing its shape to the limit of its strength under load. It will react to a load placed upon it by tending to exert force uniformly in all directions. This is illustrated in Figure 1. Even though the elastomer is changed in shape under load, it is compelled by the characteristic of elasticity to return to its original shape once the load is removed.

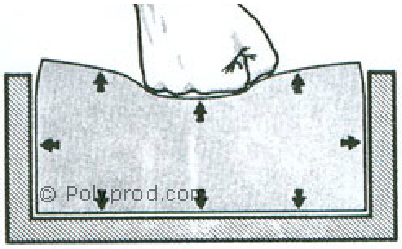


FIGURE 1 URETHANE ELASTOMERS IN EFFECT AN INCOMPRESSIBLE “FLUID”, REACTS TO LOAD BY EXERTING FORCE IN ALL DIRECTIONS.

Compression strain can be considered to be extensions of tensile strain which are continuous through the origin. However, the compressive samples must be free to move, i.e., the faces must be lubricated. Generally, rubber in compression is bonded to the surface or surface friction restricts movement. Compression curves are usually smooth and do not exhibit the “S” shape usually found in tensile tests. Compressive strain (Figure 2) is limited to less than 100% and, therefore, the curve becomes asymptotic to the 100% line.

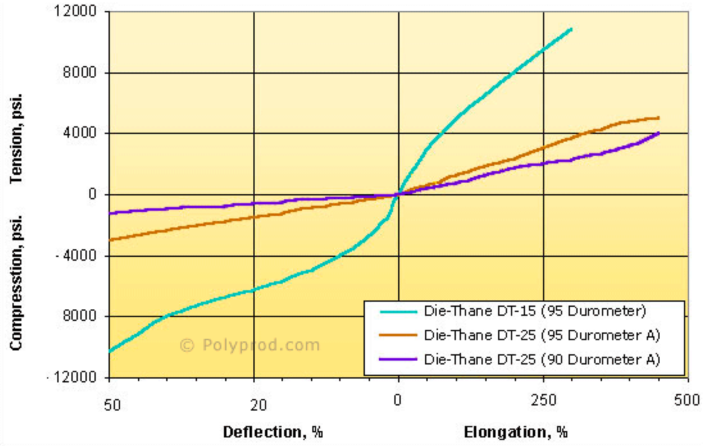


FIGURE 2 CONTINUTITY OF TENSION AND COMPRESSION TESTS

While the ability to deform under compressive stress and then recover is a characteristic property of elastomers, other factors, notably the shape of the part, affect the way an elastomer deforms in compression. To illustrate, consider two blocks cut from the same piece of rubber. One is a cylinder with the proportions of an ice-hockey puck, the other is a block of the same height and cross-sectional area, but rectangular in shape. If equal weights are placed on the blocks, subjecting them to the same compressive stress, the rectangular block will deflect more than the cylinder (Figure 3). Since the blocks will not change in volume, the reduction in height is caused by the freedom of the sides to bulge. The rectangular block deflects more than the cylindrical one because the sides of the rectangular block provide a greater area free to bulge.

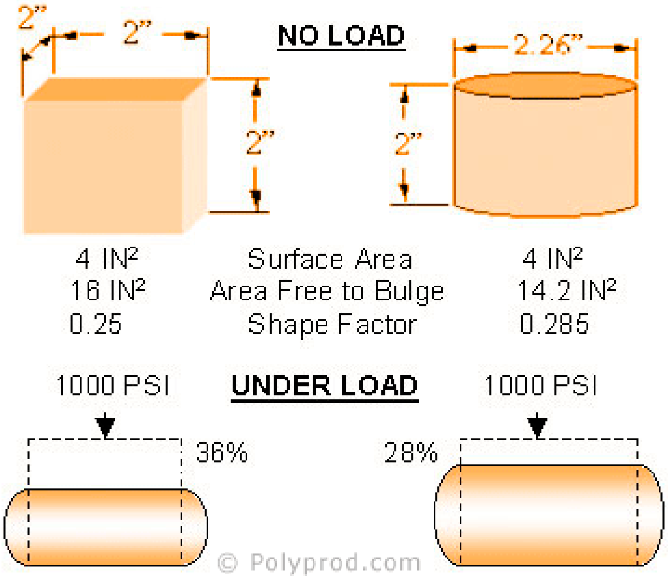


FIGURE 3 SHAPE FACTOR: RATIO OF THE AREA OF ONE LOADED SURFACE TO THE TOTAL AREA OF UNLOADED SURFACES FREE TO EXPAND

The designer of elastomeric parts allows for this behavior by using a concept called shape factor. Shape factor describes the role of the shape in determining how a part with parallel load faces will behave under compressive forces.

The concept of shape factor is useful for the design engineer. If the elastomeric part does not deflect enough to do its job, the designer can reduce the shape factor by increasing the thickness of the pad. In reality, he does no more than increase the area free to expand under load. If the pad deflects too much, he may decrease the area free to expand or he may increase the hardness of the elastomer.

Engineering Property - Urethanes in Compression

Urethane elastomers have higher load bearing capacity than do conventional elastomers of comparable hardness. This permits design of smaller parts, with possible savings in weight and materials cost. Compression-deflection curves for 1 – Thane and natural rubber vulcanization of equivalent hardness (80 durometer A) are compared in Figure 1. This figure illustrates that urethanes can be loaded beyond conventional limits for rubber. Die-Thane DT-25 has sustained short-term loadings of greater than 20,000 psi and Die-Thane DT-15 has been loaded to 68,000 psi without fracturing.

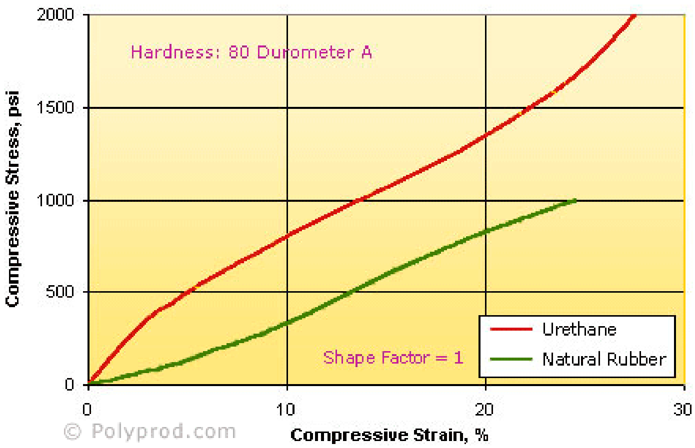


FIGURE 1 COMPRESION OF DIE-THANE DT-25 NATURAL RUBBER IN COMPRESSION

Effect of Load Surface Conditions

When an elastomeric piece is compressed between parallel plates, the surfaces in contact with the plates tend to spread laterally, increasing the effective load bearing area. If this lateral movement of the surface is restricted, the compression deflection behavior of the piece is changed. Restriction of lateral movement greatly stiffens the part.

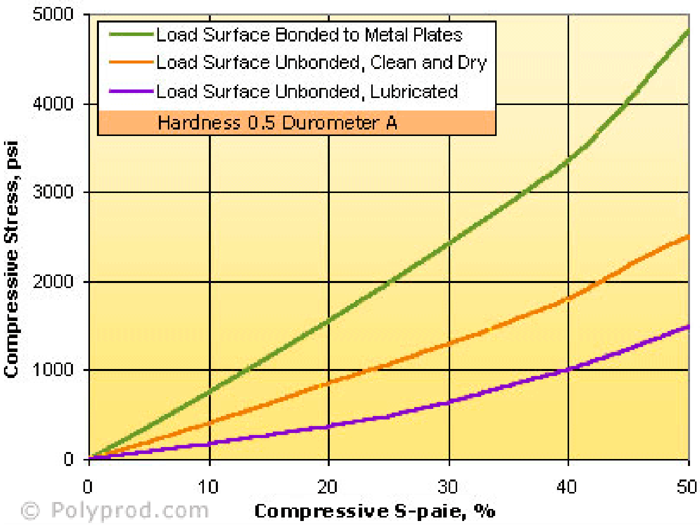


FIGURE 2 SURFACE CONDITION EFFECTS ON COMPRESSION

Figure 2 illustrates this effect quite clearly. A lubricated surface offers essentially no resistance to lateral movement. Lubrication at the metal-rubber surface may excessively strain the part because extreme deformation may occur. A clean, dry loading surface offers some resistance due to friction; if the surface is bonded to the metal plates, no lateral movement is possible and insures reproducible compression values. These differences in contact surface result in three distinct compressive stress-strain relationships for the same piece of rubber. The loading bearing capability of Die-Thane can be altered by a factor of 5 to 1 by changing the surface conditions.

Effect of Shape

Shape factor is defined as the ratio of the area of one loaded surface to the total area of the unloaded surfaces which are free to bulge. Parts made from the same compound and having the same shape factor behave identically in compression, regardless of actual size or shape.

Effective use of compression-deflection data is dependent on knowledge of test conditions under which the data were taken. The values presented are for normal room temperature and static or slow speed operation. Other temperatures and dynamic loadings would change these values completely. Shape factors below 0.25 may permit buckling; therefore, higher shape factors should be used.

As shape factor increases, the unit load required to produce a given strain also increases. There is, however, no mathematical relationship between shape factor and compressive modulus; the relationship must be determined empirically. Figure 3 and 4 show compression-deflection curves for Die-Thane of hardnesses and shape factors. These curves were obtained with bonded surface. The compression-deflection characteristics of a fabricated item of a particular hardness may vary up to ? 10% from the curves shown. Deviations arise primarily from inaccuracies in measuring hardness of an elastomer compound.

Deformations are usually limited from 15% to 25%, which is the predictable straight line portion of the shape factor curves. Deformations above 25% impose higher stresses which induce much higher set and increase creep in the part.

Engineering Property - Urethanes in Compression

Use of Compression Stress-Strain Curves in Design

The following examples show how the compression stress-strain curves can be used in the design of urethane parts. Shape factor for blocks and cylinders is calculated as follows:

EXAMPLE 1

For rectangular shaped prisms

where l = length
W = width
T = thickness
D = diameter
H = height

$$\text{Shape factor} = \frac{lw}{2t(l + w)}$$

For discs and cylinders

$$\text{Shape factor} = \frac{d}{4\,h}$$

This relationship is limited to the following:

1. pieces which have parallel loading faces;
2. pieces whole thickness is not more than twice the smallest lateral dimensions; and
3. pieces whose loading surfaces are restrained from lateral movement.

(b) In Figure 3 we find that the compressive stress-strain curve of a 70 A durometer urethane part with a shape factor of 2 crosses the 1000 psi stress abscissa at 11% strain. Therefore, the pad will deflect 11% of one inch or 0.11 inch.

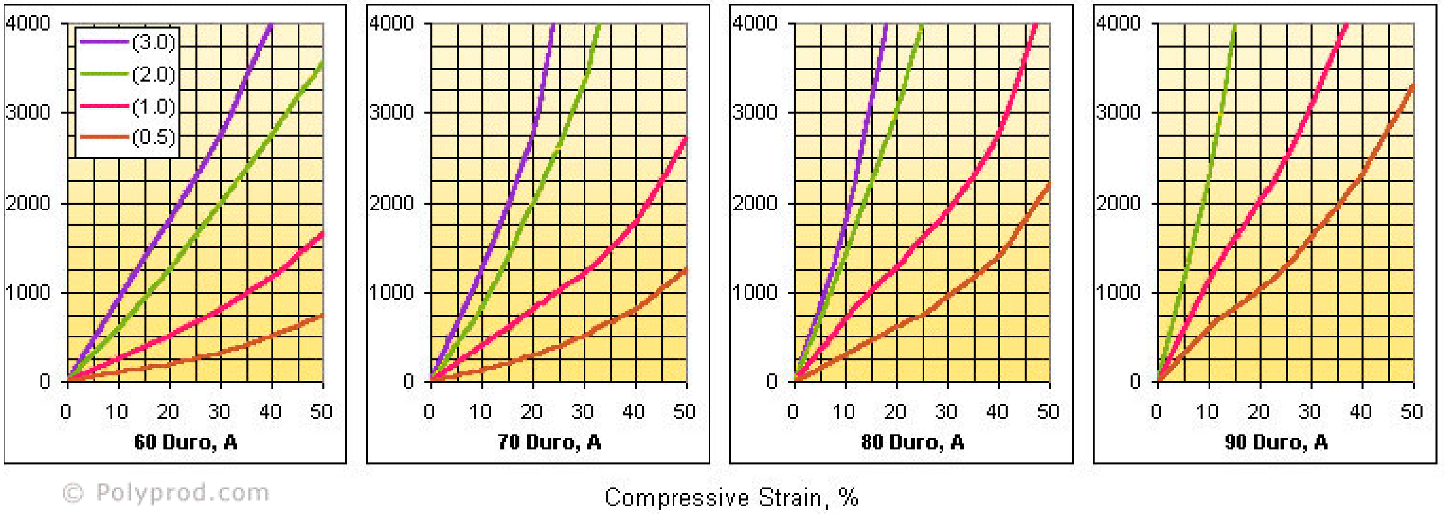


FIGURE 3 COMPRESSION-DEFLECTION CHARACTERISTICS OF SOFT URETHANES

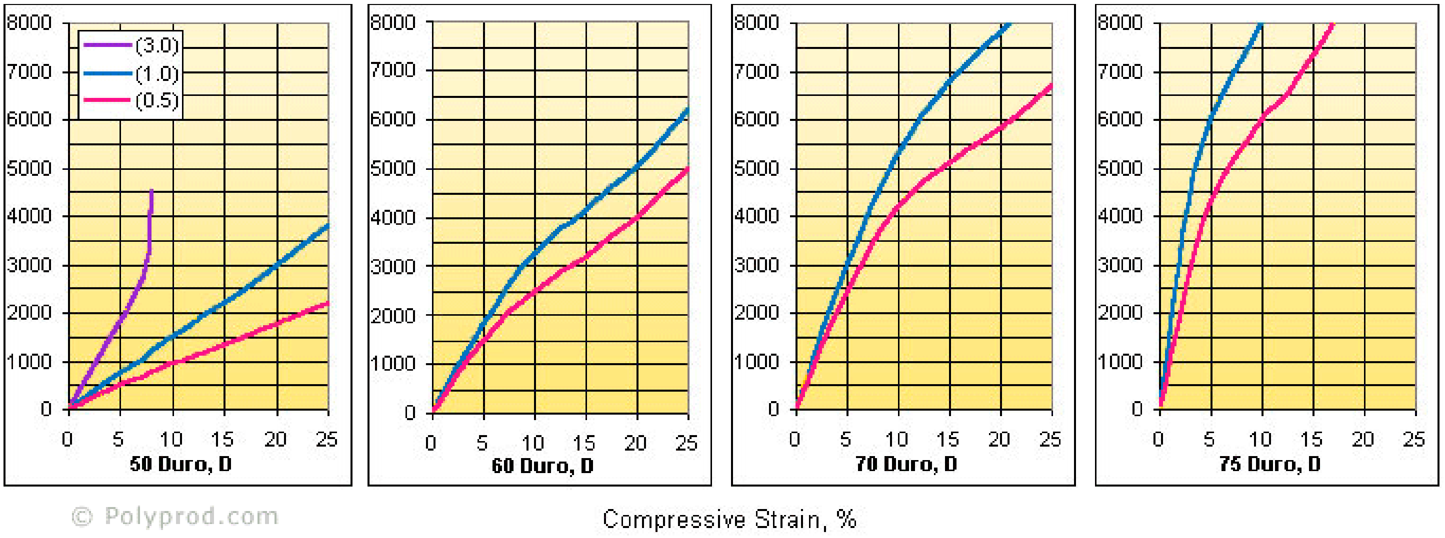


FIGURE 4 COMPRESSION-DEFLECTION CHARACTERISTICS OF HARD URETHANES

Engineering Property - Urethanes in Compression

EXAMPLE 2

Problem: What happens if the pad thickness is doubled in Example 1?

Solution:

(a) Shape factor of the piece is now:

$$\frac{(8)\ \ (8)}{(2)\ \ (2)\ \ (8+8)} = \frac{64}{64} = 1$$

(b) From Figure 3, the compressive strain at 1000 psi stress for a 70 durometer A part with a shape of 1 is 25%. In this case, the pad will deflect 25% of two inches, or 0.50 inch. (In practice, parts made of conventional elastomers are generally designed so that compressive strain does not exceed 15%).

As a general rule, the harder the elastomer, the greater its load-bearing capacity. The manner in which load-bearing properties Die-Thane change with hardness at various deformations is shown in Figures 5 through 7.

EXAMPLE 3

Problem: Assume a pad which is one inch square by one-half inch thick and bears a 2500 lb. Compressive load. The pad may not deflect more than 0.05 deflect more than 0.05 inches because of space limitations. What hardness Die-Thane should be specified?

Solution:

(3) Shape factor of the piece is:

$$\frac{(1)\ (1)}{(2)\ (1/2)\ (1+1)} = \frac{1}{2} = 0.5$$

(b) Unit compressive stress is:

$$\frac{2500}{(1)\ (1)} = 2500\text{ psi}$$

(c) Compressive strain is:x

$$\frac{0.05}{0.5} \times 100 = 10\%$$

(d) On scanning the compressive stress-strain curves we find in Figure 4 that vulcanizates which are 60 D hard or harder will bear a compressive stress of 2500 psi with 10% or less deflection.

Figure - 5

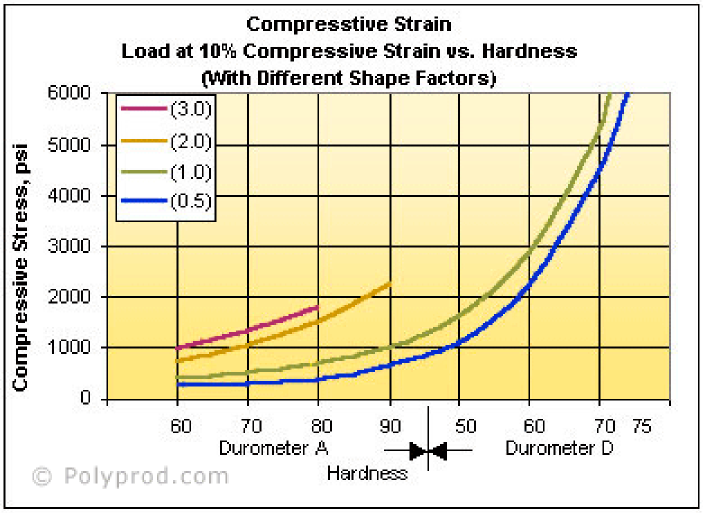


Figure - 6

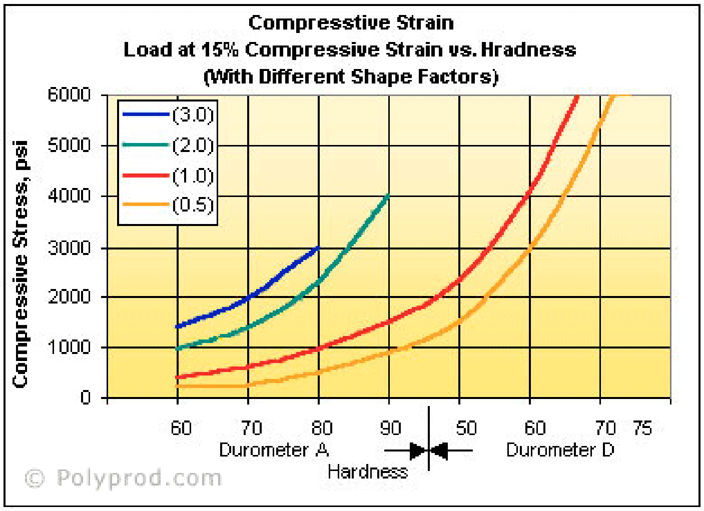
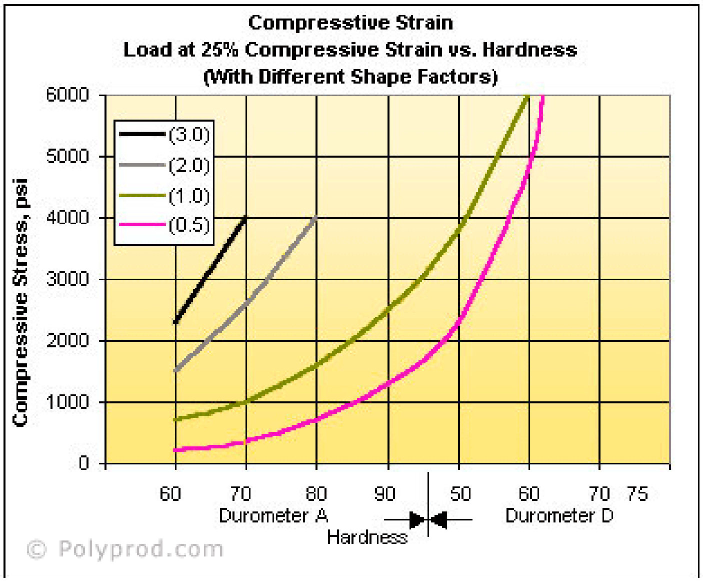


Figure - 7



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

Engineering Property - Compression Set, Creep & Stress Relaxation

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.

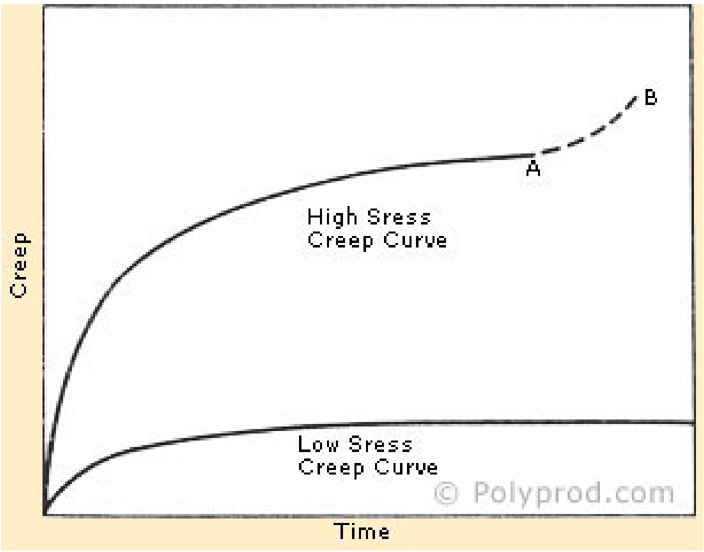


FIGURE 1 CHARACTERISTIC CREEP CURVE

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.

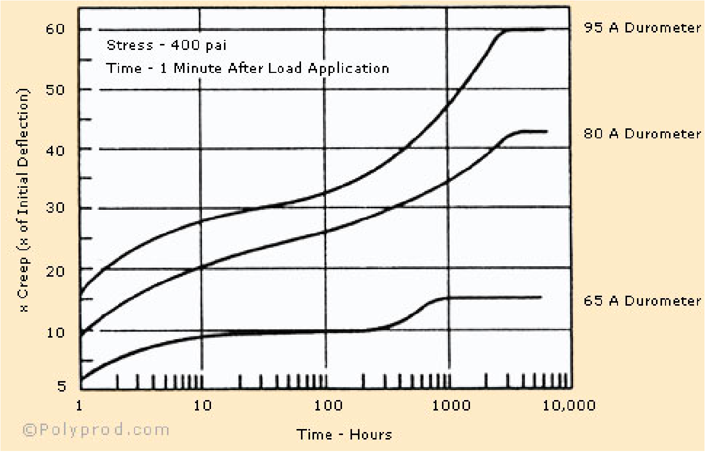


FIGURE 2 CREEP IN COMPRESSION

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).

Engineering Property - Compression Set, Creep & Stress Relaxation

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.

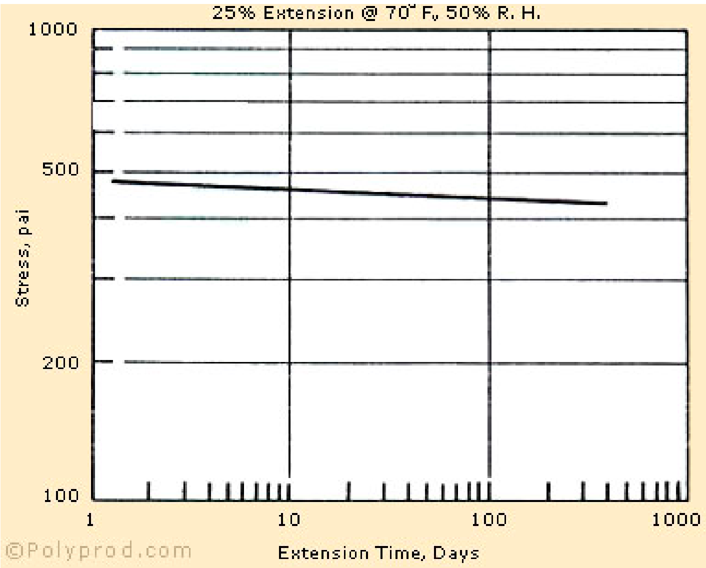


FIGURE 3 STRESS RELAXATION OF Die-Thane DT-25 12.5 phr MBCA

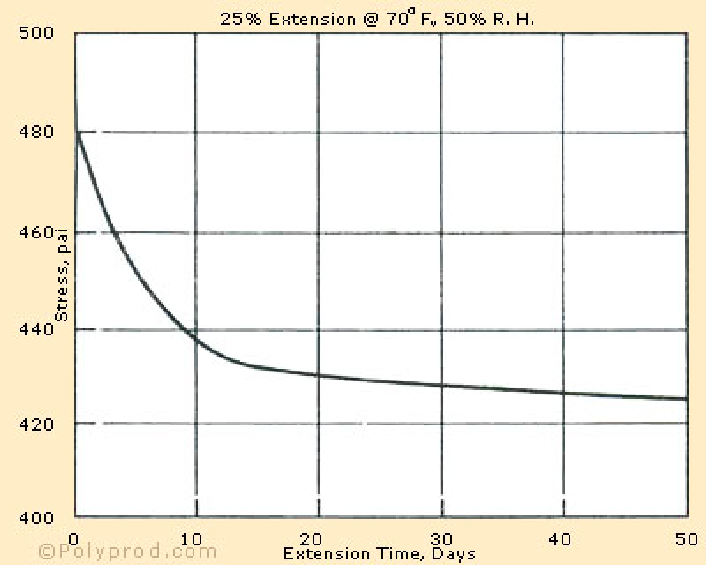


FIGURE 4 STRESS RELAXATION OF Die-Thane DT-25 12.5 phr MBCA

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.

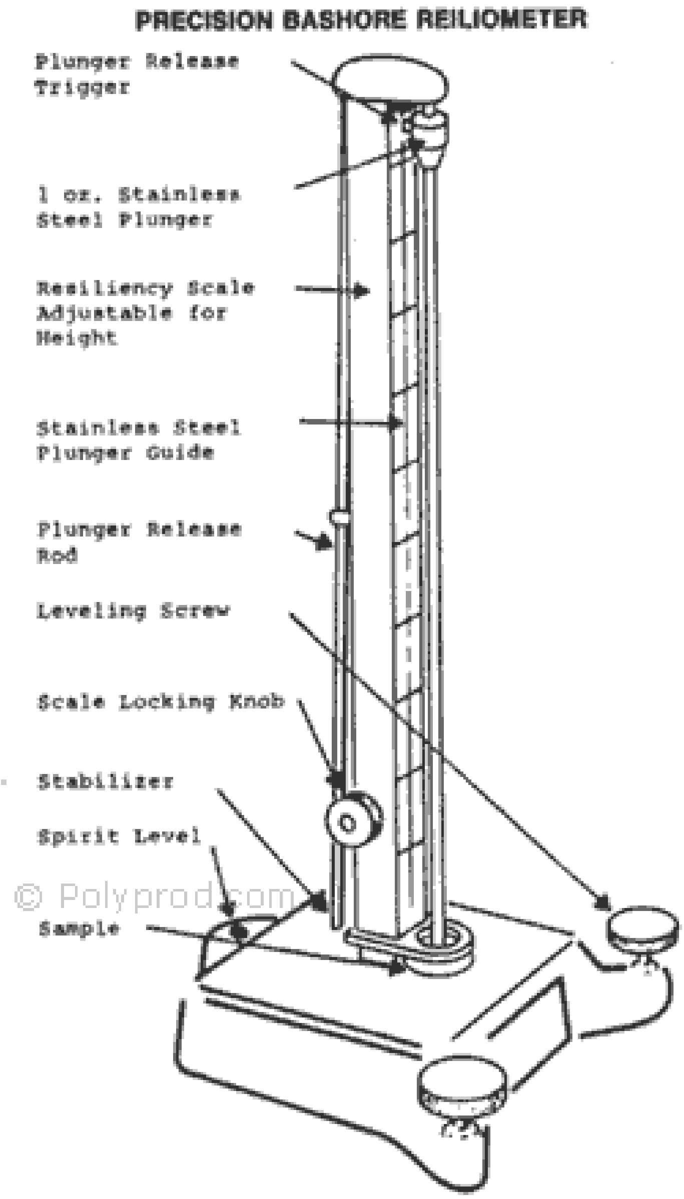
In general, resilience is determined in one of four ways from a low speed stress-strain loop, by impact tests, by free vibration or forced vibration methods.

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.

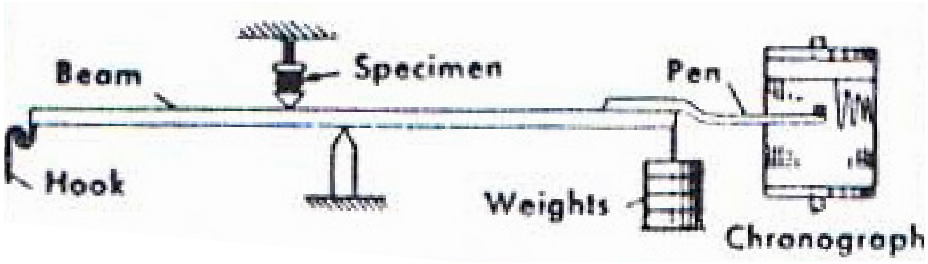


FIGURE 2 YERZLEY OSCILLOGRAPH

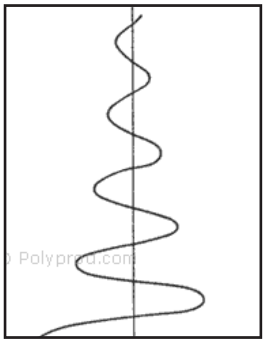


FIGURE 3 DAMPED-FREE VIBRATORY MOTION

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.

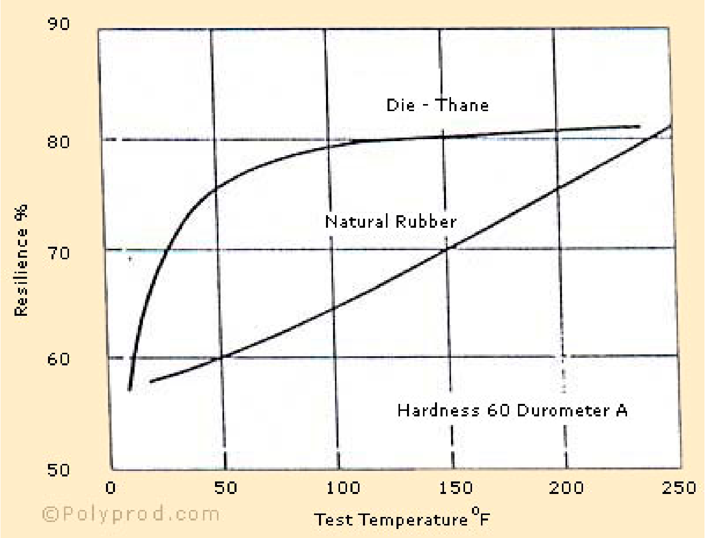


FIGURE 4 RESILIENCE OF Die-Thane AND NATURAL RUBBER AT VARIOUS TEMPERATURES

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.

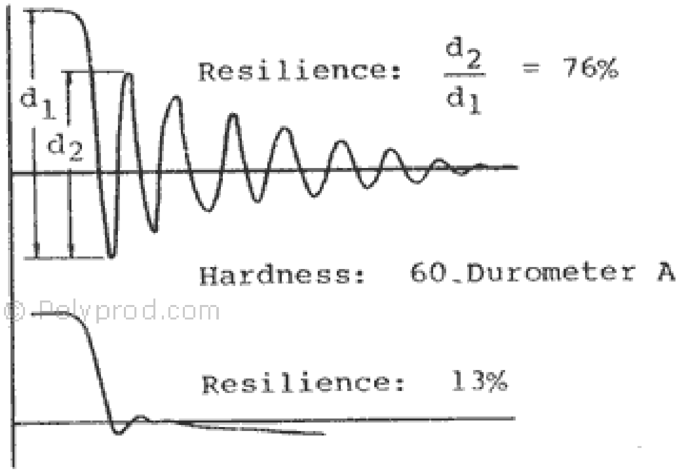


FIGURE 6

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.

Engineering Property - Tear Resistance

Tear resistance is a complex result of other basic properties, such as modulus and tensile strength. Many laboratory methods have been devised to measure this property. The tests now being used to measure the tear resistance of elastomers are useful for laboratory comparisons, but correlation between test results and service performance is often quite difficult. The various tests produce different results when used with Die-Thane urethane rubbers. The following tear tests for Die-Thane have been compared:

- ASTM D-470
- Instron Split Tear
- ASTM D-751-52t (Modified Trapezoid)
- ASTM D-624 Die C (Graves)
- ASTM D-624 Die B (Winkelmann)
- ASTM D-1938 (Trousers)

ASTM D-1938 and the Instron split tear tests are least dependent on tensile strength and give the most realistic evaluation of the tear strength of Die-Thane. Specimens used in each test are shown in Figure 1. The D-1938 is similar to the Instron Tear.

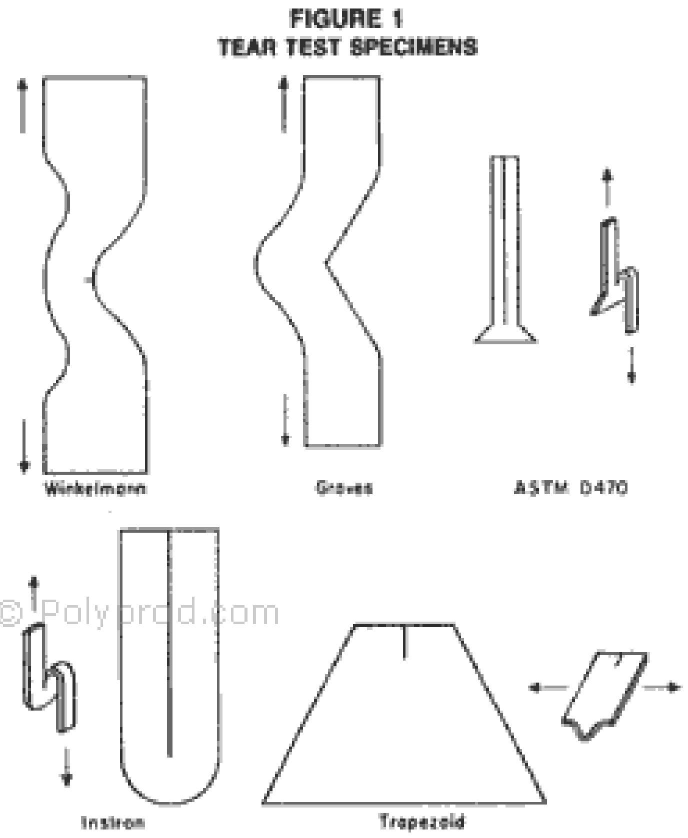


FIGURE 1 TEAR TEST SPECIMENS

Engineering Property - Abrasion Resistance

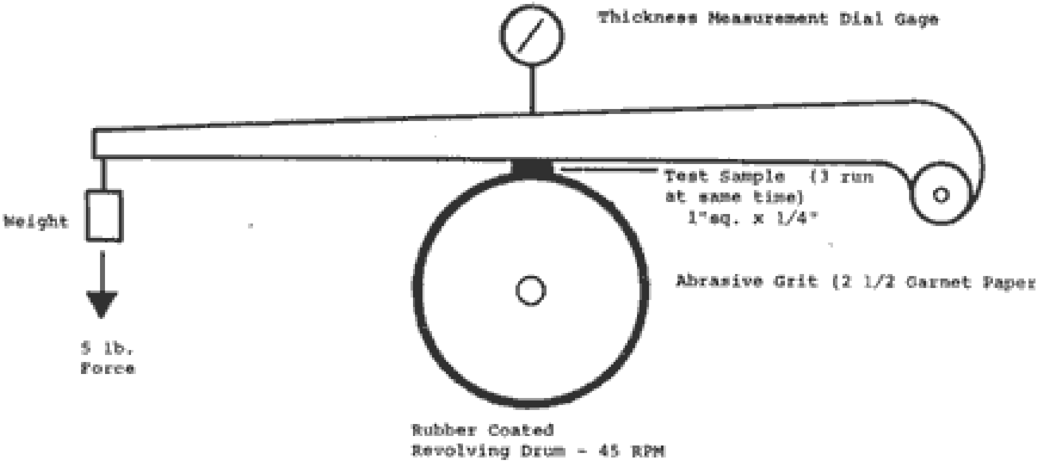
There are two types of abrasion - sliding and impingement. Sliding is the passing of an adjacent surface across the rubber surface. Impingement is wearing of the rubber exemplified by sand particles hitting the surface. Most wear in actual service occurs as a combination of both sliding and impingement.

When sliding, localized friction forces can impose high energy levels on the rubber. Abrasion and wear takes place when the rubber cannot withstand these forces.

Impingement by particles occurs in applications such as chutes, rebound plates and sandblast hoses. Elastomers can yield easily and distribute stresses imposed by particle impingement. A sandblast test shows that with a 90° impingement angle, soft resilient rubber is more abrasion resistant than steel or cast iron. However, not just any elastomer can be used. Under this same condition, a tough tire tread will wear out more rapidly than a soft elastomer. The angle of particle impingement has a significant effect on which material should be used. Laboratory abrasion tests are difficult to correlate with end-use applications. Measurement of properties can be helpful in selection of materials, but do not compare to rates in actual service which can be thousands of times greater with regard to velocities and temperatures.

There are at least 25 laboratory abrasion test devices, an indication that this type of test is difficult to correlate with service performance. The most widely recognized test device in the rubber industry is the National Bureau of Standards Abrader, a sliding type abrader. The NBS Abrader uses a constant velocity, under a fixed load using a specified abrasive grit.
See above Figure 1 for diagrammatic sketch.

It does not tell how a compound perform under widely varying conditions, not does it tell anything about cut resistance, chunking, or flat spotting.



The abrasion resistance of vulcanizates of Die-Thane urethane rubber, as measured on two laboratory tests, the National Bureau of Standards test and the Taber Abrader, are shown in Table 1.

Note these two tests give different values. The differences in performances of vulcanizates of Die-Thane can be explained however. The National Bureau of Standards tests simulates a very harsh service. In this case, the hardest vulcanizates hold up best. The Taber test is much less severe. Softer compounds perform better than the harder ones because they are more resilient and "give" under load.

In spite of the difficulties in obtaining meaningful laboratory abrasion test values. Die-Thane is considered to have excellent sliding abrasion resistance and has performed well in many applications where wear is a problem. Die-Thane has outworn conventional rubber and plastics often by a factor of as much as 8 to 1.

TABLE I

ABRASION RESISTANCE

Die-Thane	Hardness	NBS Abrasion index	Taber Abrasion
Durometer A	Durometer D	ASTM D-394, Method B	Resistance, Wt. Loss* ASTM D-1044
80	-	110	-
85	-	200	-
90	-	175	79
95	48	300	118
-	-	500	373

*mg/100 rev.; H-18 wheels, 1000 gm, wts.; 5000 rev.

Engineering Property - Flexing

When subjected to flexing, rubber products frequently fail due to the development and propagation of cracks. The cracks reduce other properties, which in turn reduce the service life of the rubber. Cracks can grow through mechanical means or by oxidative and ozone attack.

ASTM D-430, Method B, is a test designed to produce cracking by bending. The time or numbers of flexes to crack initiation are used as the measure of performance. It employs a DeMattia flexing machine which flexes a 6" x 1" x1/4" specimen having a 0.094" round grove molded transversely in the center of the strip. This machine operates at 300 cycles per minute, See Figure 1.

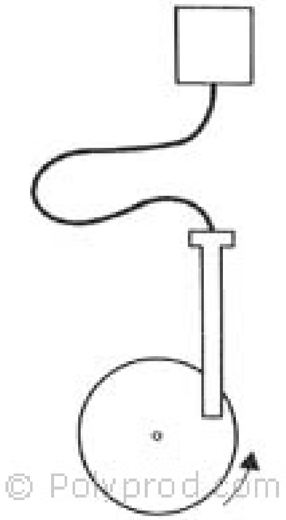


FIGURE 1 DE MATTIA FLEXER

Bends and Straightens Specimen, or Alternately Stretches and Relaxes It.

An adaptation of the bend flex method of ASTM D-430 is ASTM D-813 which requires the deliberate cutting of the bottom of the grooved specimen to initiate crack. The number of flexing cycles needed to attain a specified crack length is then observed.

ASTM D-1052 (Ross Flexer) is another method of determining the resistance of elastomers to cut growth from repeated bending. The equipment is illustrated in Figure 2. The flexed area to the test specimen bends freely over a rod 3/8" In diameter, through an angel of 90°. One end of the test specimen is griped by a holder. The other end is placed between two rollers which permit free bending movement of the test specimen during each cycle. This machine runs at 100 cycles per minute.

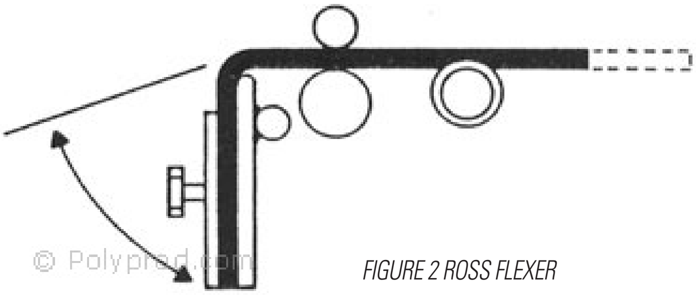


FIGURE 2 ROSS FLEXER

To obtain the ultimate in flex life with urethanes, careful attention to stoichiometry and polymer hardness must be considered. Urethanes may be specially compounded by adjustment of curing agent level to 100-100% theory (see Figures 3,4, and 5 on next page) provide best flex resistance.

Softer vulcanizates like Die-Thane DT-35 urethane rubber with MBCA curing agent have excellent flex life. In the Ross notched test, no cut growth occurred during 420,000 flexes (70 hrs.) at a rate of 100 cycles/minute. The more vigorous DeMattia test, run at 300 cycles/minute, caused failure in 24 hours using notched specimens; but un notched samples ran for 100 hours (1,800,000 flexes) with only slight cracking occurring.

Design of the part to reduce localized concentration of the stress or heat built-up will improve flex life. When an elastomeric part is flexed, very high stresses are developed in thick cross sections. Under repeated flexing, any cut in the surface of the part will grow larger because of the high local stresses concentrated at the cut. As with any elastomer, the rate of cut growth under flexing may be reduced (Figure 6) by decreasing the thickness of the part.

Unlike other elastomers, Die-Thane can be utilized practically in very thin sections because of its exceptional strength and toughness.

Internal Heat Build-Up

As mentioned in the section on resilience, heat build-but in urethane parts, resulting from internal friction under high frequency flexing, exceeds that of many conventional elastomers and is the usual cause of premature failure of urethane parts operating under flexing or high speed rotary motion under load. Because of the low thermal conductivity of urethane elastomers, heat developed by internal friction cannot be readily dissipated. Heat build-up is, 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 so the piece is not harmed.

Engineering Property - Flexing

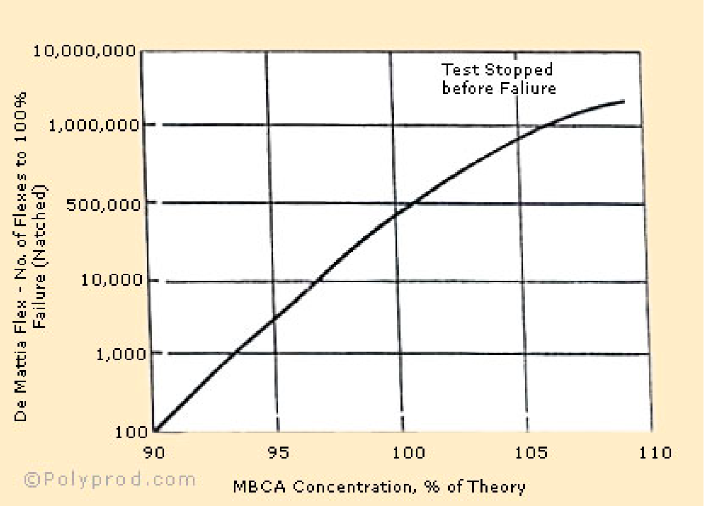


Figure 3 Die-Thane DT-35 Flex Life

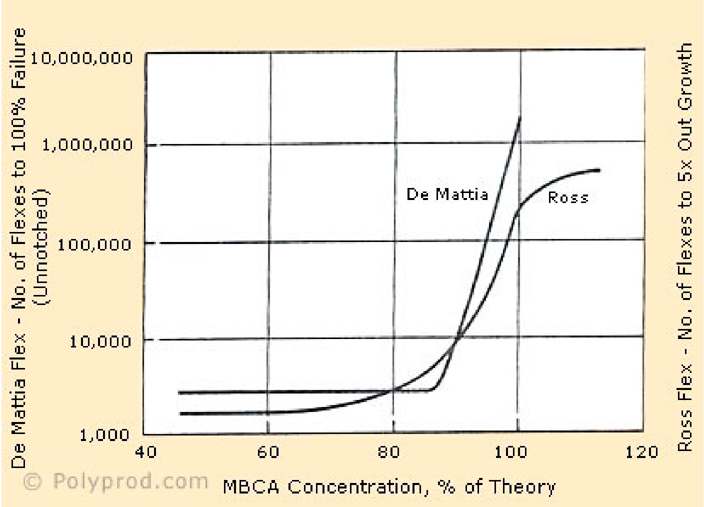


Figure 4 Die-Thane DT-25 Flex Life

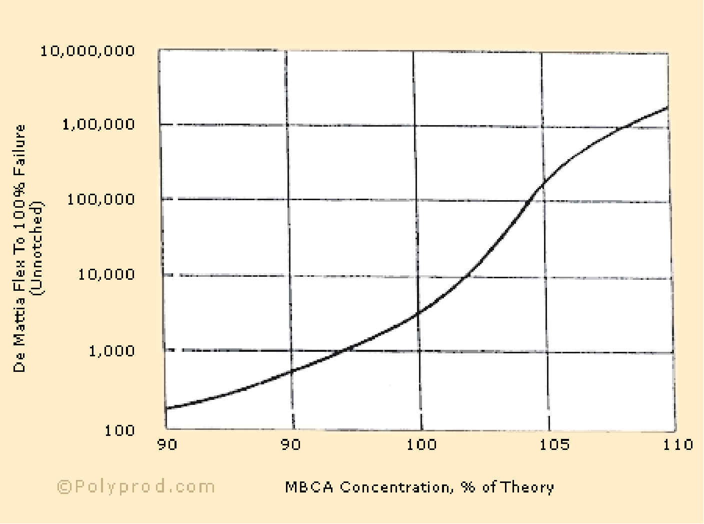


Figure 5 Die-Thane DT-15 Flex Life

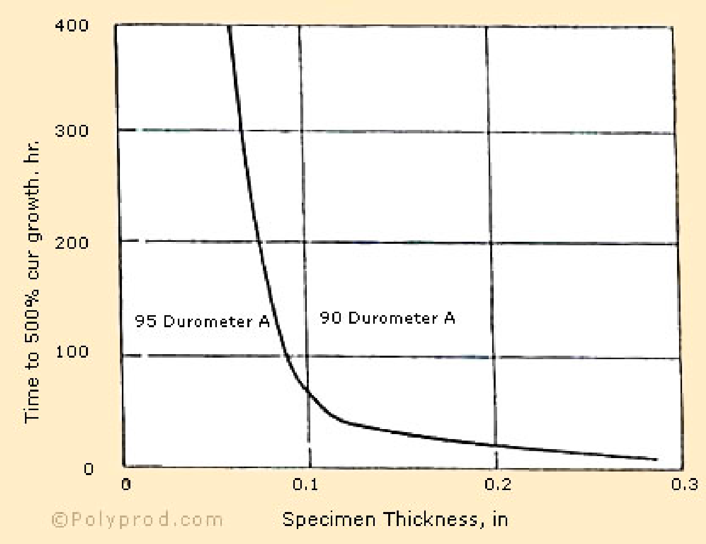


FIGURE 6 THICKNESS EFFECT ON CUT GROWTH

An example in which thinner sections actually increased the service life of a urethane elastomer part is offered by experience with industrial truck wheels made of Die-Thane urethane rubber. Early test wheels were made to the same dimensions normally used with conventional elastomers. In service, abrasion resistance was excellent but many premature failures occurred as a result of internal fracture and reduction in adhesive bond strength at the hub. Both types of failure were traced to excessive heat build up under very high loads. The problem was solved by increasing the hub size and reducing the thickness of elastomer in the tire. This change provided a thinner tire section, which dissipated internal heat more effectively. It also increased the shape factor of the area of over which the load was distributed, thus decreasing the deflection for a given load. With the new design, urethane fork truck wheels are giving outstanding performance.

Engineering Property - Shear

Mounting and suspension assemblies generally require the loading of elastomers in shear. Elastomers deflect more under a given load in shear than in compression. Since shear is essentially a combination of tensile and compression forces acting at right angles to each other, the stress-strain curve for an elastomer in shear is similar to the tensile and compressive stress-strain. Shear is the ratio of linear deformation (d) to elastomer thickness (t) as illustrated in Figure1.

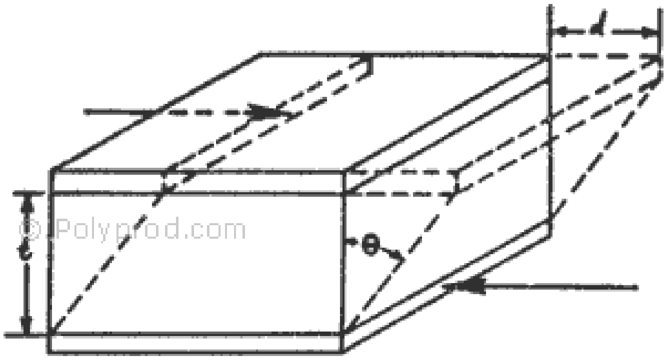


FIGURE 1 SHEAR DEFLECTION

Figure 2 shows typical shear stress-strain curve for Die-Thane urethane rubber ranging in hardness from 55A to 75D durometer.

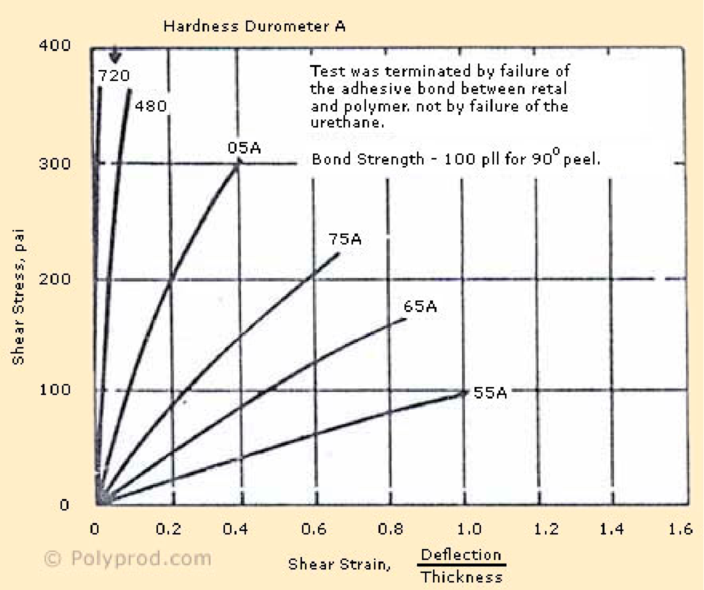


FIGURE 2

Because of its high load bearing capacity in tension and compression Die-Thane has a high load bearing capacity in shear.

Improvements in bonding Die-Thane to metal will permit greater stress than those shown in Figure 2. Presently, 300 pli adhesion can be achieved compared to those values shown which are based on 100 pli.

Past practice has limited shear strain(t) to 0.5; that is, the thickness of the rubber is twice the horizontal deflection. No specific reasons can be cited for this limitation. Some static applications of shear loading have been deformed to strains of 1.0 or more. However, under high strain, bond failures can occur imposing high stresses on the part. Useful hardnesses of urethanes are limited from 65A to 90A durometer. Below 65A conventional rubber can be used, and above 90A stresses are very unpredictable. It is common practice to enclose a shear mounting and move the loading surfaces closer together to provide a compressive load on the elastomers. Compression of 5% of the free thickness is commonly used. The effect of shear loading for a double shear pad in shown in Figure 3.

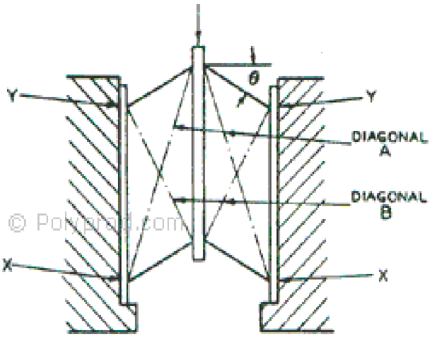


FIGURE 3

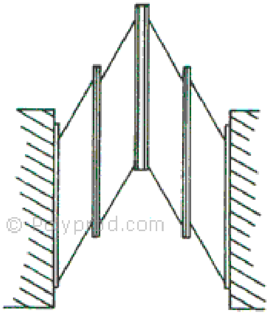


FIGURE 4

With load, the rubber tends to leave the supporting walls at the top. As the angle decreases, diagonal A decreases in length thus creating compression at X. But diagonal B increases in length causing tension at Y. Therefore, by moving the loading surface closer together, the tensile stresses are reduced.

To achieve stability, the ratio of width and length to thickness should be at least four. Lower ratios probably can be used with Die-Thane urethane rubber and still be stable. If a shear pad were so designed that the height of the rubber equaled its thickness, the rubber would tend to bend as a cantilever beam rather than as a shear mounting.

If larger deflections are required than can be accommodated by one thickness, it may be necessary to make several sandwiches in shear as shown in Figure 4.

However, the total width of the part between supports cannot be made too wide. Even though the elastomer is broken up into several sandwiches between supports, instability results in deflections greater than calculated from plain shear.

Shear bonds are affected by the thickness of the sandwich. The greater the thickness, the higher the tensile component in shear which results in less bond strength.

Engineering Property - Physical Constants of Die-Thane

Value for specific gravity, thermal conductivity, linear coefficient of thermal expansion and linear shrinkage are shown in Table I.

Results for specific gravity are based on water which is 1.0 and give a quantity numerically equal to the density in grams per cubic centimeter. The specific gravity of vulcanizates of Die-Thane urethane rubber varies depending on the polymer density and amount of MBCA used; for example, the specific gravity of Die-Thane varies from 1.12 to 1.14 as the MBCA curing agent level changes from 15 parts to 21 parts.

Thermal Conductivity

Thermal conductivity is defined as the amount of heat per unit time passing across unit area and through unit thickness of material for unit temperature differences in the direction in the direction of the thickness. The units for thermal conductivity (K Factor) are BTU per hour per square foot for temperature gradient of one degree Fahrenheit per inch thickness.

Linear Coefficient of Thermal Expansion

The coefficient of thermal expansion is the ratio of the change in length per degree to the length at 32° F. The coefficient of thermal expansion varies with temperature. The expansion of all rubbers are of the same magnitude, approximately 10 times that of structural steel. If the part dimensions are critical, as in O-rings and seals, thermal expansion of rubber should be calculated.

Linear Shrinkage

Linear shrinkage is the approximate percent change in the dimensions of a part which occurs when the part cools to room temperature. The figures for linear shrinkage shown in Table I are for conventional mixing and curing conditions. Shrinkage is normal for most rubbers and should be accounted for in mold design.

TABLE I

		Thermal Conduct		**Linear Coefficient of THERMAL EXPANSION, In/in/°F**			
Die-Thane	Specific Gravity	BTU/(hrs) (Sq ft) (°F/In)	-32° F to +32°F	32° F to 75°F	75°F to 212°F	212°F to 302°F	Linear Shrinkage %
DT25	1.10	0.917	1.43X10-4	1.01X10-4	0.95X10-4	0.90X10-4	1.0
DT15	1.13	0.862	1.27X10-4	0.89X10-4	0.89X10-4	0.69X10-4	1.7
DT5	1.19	0.754	0.79X10-4	0.81X10-4	0.75X10-4	1.08X10-4	1.7

Engineering Property - Electrical

The electrical properties of elastomers most commonly measured are as follows:

1. Resistivity
2. Dielectric Strength
3. Dielectric Constant
4. Power Factor

Materials suitable for electrical insulators have high dielectric strength and resistivity and low dielectric constant and power factor. Such a combination is rarely obtained since companion physical and chemical properties are also required. There is no single best overall material, but Die-Thane urethane rubber offers a favorable combination of properties.

Direct Current Resistancy

Direct current resistivity, or volume resistivity, is similar to insulation resistance in that both indicate the magnitude of electrical current expected to pass through the sample located between two electrodes. This test may be used to check the suitability of an elastomerie composition for electrical insulation.

Resistivity or specific resistance to electric current is usually considered to be a DC property and is measured as such. It can be defined as the resistance between opposite faces of a unit cube where precautions have been taken to allow no current flow along the other four faces of the cube.

Conductivity

Elastomer compositions are considered electrically conductive when they possess a direct current resistivity of less than 105 to 107 ohm-cm. Conductive compounds find their principal applications where the dissipation of static electricity is desired.

Dielectric Strength

The dielectric strength of an elastomer is the voltage required to puncture a sample of known thickness and is expressed as volts per mil of thickness. The rate of voltage application, the geometry of the electrodes, and the shape of the test specimen influence the results obtained.

Dielectric Constant and Power Factor

The dielectric constant, or specific inductive capacity (SIC), is a measure of an insulator's ability to store electrical energy. The dielectric constant is the ratio of the electrical capacity of a condenser using the elastomer under test as the dielectric, to the capacity of a similar condenser using air as the dielectric. One of the factors which influences the dielectric constant is frequency, and tests may be run from a low of 25 cycles per second to many megacycles per second.

The power factor of an electrical insulation material indicates its tendency to generate heat in service. If a capacitor using an elastomer as the dielectric is charged by a direct current and then immediately discharged, there is an energy loss in the form of heat. If this capacitor, is repeatedly charged and discharge by an alternating current, the electrical loss results in heating. The ratio of this loss to the energy to charge the capacitor is knows as power factor. It is expressed as a decimal fraction or a percent of the charging energy.

Die-Thane urethane rubber has been used in potting and insulation compositions at frequencies up to 100 kilohertz at temperatures at 212°F (100°C). Its natural translucency permits easy inspection of the encapsulated assemblies and the flexibility and strength of Die-Thane helps protect the assemblies from damage. The electrical properties of vulcanizates of Die-Thane measured at different temperatures and frequencies are shown in Table I.

TABLE I

Physical Properties		Die-Thane DT-25		Die-Thane DT-15	
Durometer Hardness		90A		50D	
Electrical Properties		0.1khz	100khz	0.1khz	100khz
Power Fact,%, (ASTM D-150)	75°F	4.70	5.92	7.25	4.35
	158°F	9.45	4.15	6.65	4.75
	212°F	12.60	3.90	8.75	4.00
Dielectric Constant (SIC) (ASTM D-150)	75°F	9.37	7.78	9.25	7.58
	158°F	11.05	9.62	11.65	9.74
	212°F	11.48	9.87	12.19	9.98
DV Volume Resistivity					

Engineering Property - Frictional Characteristics

Friction of Die-Thane polymers against non-lubricated surfaces decreases with increasing hardness as shown in Figure 1.

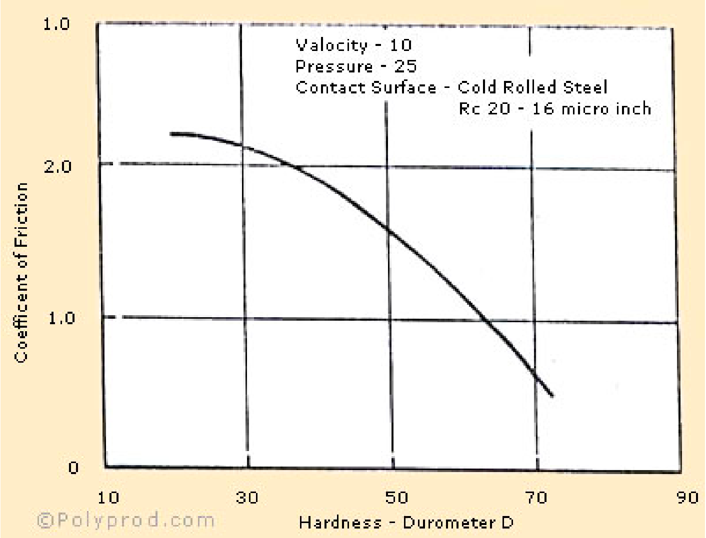


FIGURE 1 COEFFICENT OF FRICTION AT VARIOUS HARDNESS

Since harder polymers have the lowest coefficient of friction, these materials have been used where sliding resistance is important.

Of all Die-Thane Urethane rubbers, P-675 has the lowest, unlubricated coefficient of friction. This characteristic, coupled with its superior abrasion resistance and load-carrying ability, is an important reason why 75 is used for bearings and bushings. Since the hardness of compounds of P-675 approaches some plastics, comparison of P-675 with various plastics is shown in Table I.

Effect on Additives on Frictional Properties

Additives may be used to alter the frictional properties of Die-Thane polymers. With P-675 urethane rubber, powdered TEFLON® TFE fluorocarbon resin and TEFLON® TFE fluorocarbon fiber flock significantly reduce the coefficient of friction of this elastomer. The frictional due to these additives is shown in Figure 2, on the following page. P-675 without additives is used as a control.

TABLE I

COMPARISION OF P-675 WITH PLASTICS

	Die-Thane P-675	Nylon 66 2.5% Water	Acetal	Cast Phenolic Unfilled
Specific Gravity	1.20	1.14	1.42	1.30
Hardness, Rockwell	R90	R108	R120	M110
Tensile Strength, psi	9,000	11,200	10,000	7,000
Elongation at Break, %	210	200	15	-
Modulus of Elasticity in Tension, 103 psi	52	260	410	700
Flexural Modulus (Instron), 103 psi	81	175	410	-
Compressive Modulus, 103 psi	68.75	-	-	-
Impact Resistance, ft.lb./ in.Notched Izod, 75°F	15	2.0	1.4	0.3
Head Deflection Temp., % at 66 psi/at 264 psi	365/135	300/150	338/255	260/--
Taber abrasion, cs-17, 1000 g, mg loss/1000 rev.	5	7	20	-
Water Absorption, 24 Hrs. At 75°F, %	1.2	0.4	0.25	0.4

Engineering Property - Frictional Characteristics

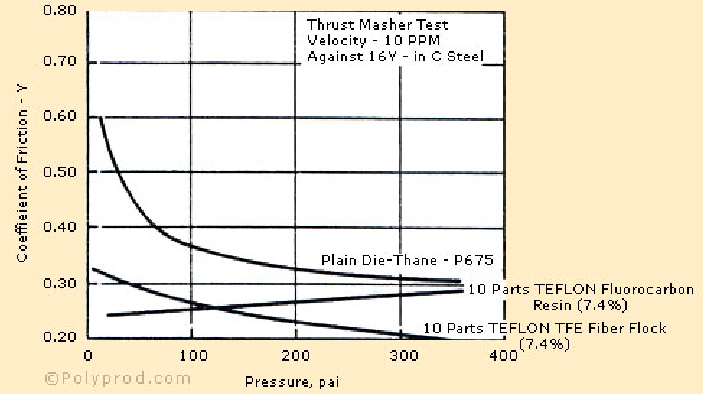


FIGURE 2 DIE-THANE P-675 EFFECT OF ADDITIVES ON COEFFICIENT OF FRICTION

The additives mentioned above will affect other physical properties of Die-Thane P-675. Changes presented on Table II.

TABLE II

DIE-THANE P-675 - EFFECT OF LUBRICANT ADDITIVES ON PHYSICAL PROPERTIES

	Die-Thane P-675	+TEFLON® Powder 10 Parts	+TEFLON® Fiber Flock 10 Parts
100% Modulus, psi	4650	4100	4100
Tensile Strength, psi	9000	5000	5200
Elongation@Break,%	210	115	125
Durometer D Hardness	73	72	72
ASTM D-470 Tear, lbs./in.	110	105	95
Nat'l Bureau of Stds. Abrasion Index, %	400	500	890
Compression Set, Method A 1350 psi, 22 Hrs. @ 158°F	10	8	4

Materials Used:

1. TEFLON® Powder - Rilube #63, Modern Industrial Plastics, Dayton, OH
3. TEFLON® Fiber -TFE TEFLON® fiber, flock, 1/64", Du Pont, Textile Fibers

All of the additives at a 10 part level (7.4% by weight of total compound) will reduce modulus, tensile and elongation. Additives which reduce the friction coefficient also improve abrasion resistance. The improvement in abrasion obtained with TEFLON® fluorocarbon fiber addition is significant and was also observed during long-term friction tests.

The 10 parts of additive is not necessarily the optimum. However, 10 parts offer significant frictional improvement over 5 parts and not significantly inferior to 15 parts. The optimum level of additive, considering a balance of physical and frictional properties, probably fails between 5 and 10 parts.

Effect of Additives on Bearing Performance

TEFLON® improves the performance of Die-Thane P-675 in bearing applications. Pressure-Velocity (PV) limit data for bearings based on Die-Thane P-675 urethane rubber, Nylon 66 and DELRIN® acetal resins are shown in Figure 3.

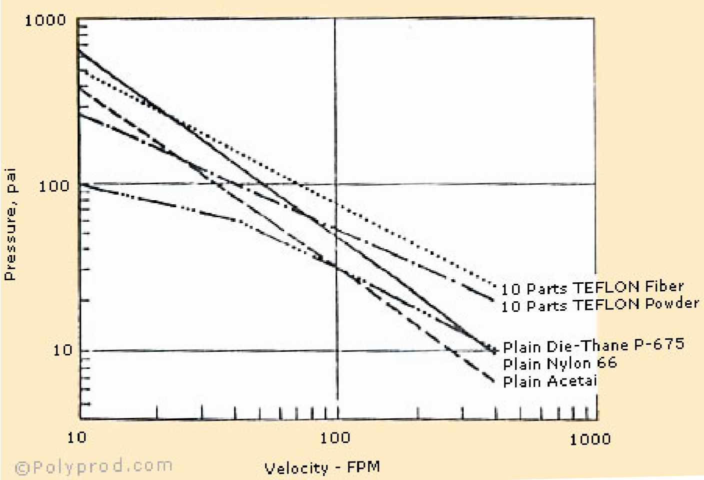


FIGURE 2 DIE-THANE P-675 EFFECT OF ADDITIVES ON COEFFICIENT OF FRICTION

These curves represent the performance limits of the bearings. Bearings can operate at any combination of pressure and velocity below the respective curves without catastrophic failure. The PV limits predict nothing about the length of service however. Although Die-Thane P-675 may be expected to outwear most thermoplastics, its performance will be influenced strongly by temperature and other environmental conditions. The best determination of bearing durability is a service test.

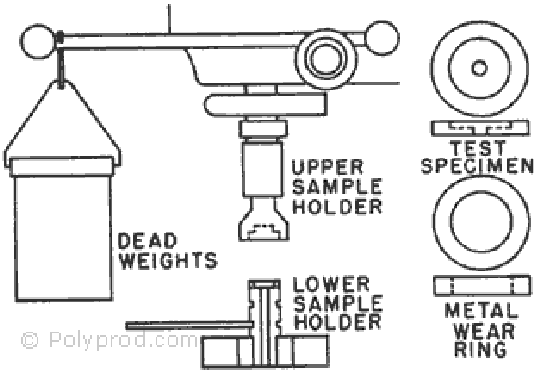


FIGURE 4 THRUST WASHER TESTER

Friction data listed in this chapter were obtained with an apparatus which utilizes a thrust washer principle and the apparatus is shown schematically in Figure 4. It consists of a table mounted drill press, variable speed drive and simple machined parts to accommodate test samples. Friction force and wear can be measured with this device. The use of standard components and small, easily fabricated test samples make this an inexpensive testing apparatus. The sample is a disc with a diameter of 1-1/3", on one side is a rim of 1/16" width; this rim constitutes the area of contact.

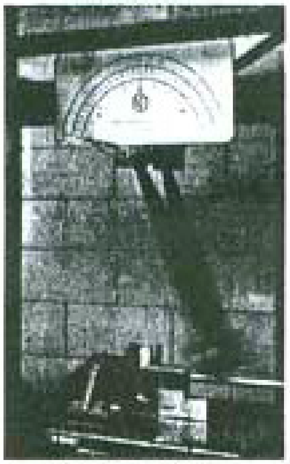
Engineering Property - Impact Resistance

The impact or shock resistance of an elastomer is determined by striking a sample with a swinging pendulum (hammer). The sample is placed at the lowest point of the arc traveled by the pendulum head. Measuring the difference in the distance of the upswing of the pendulum after the impact, compared to the same upswing with nothing in its path, determines the energy in breaking the sample which is the measure of impact strength.

In the Izod impact method. (ASTM D-256) the test place is gripped upright and struck with the pendulum 7/8" above the edge of the gripping point. The sample has a standardized notch at the edge of the vise on the side toward the hammer. The Izod Impact Tester and Izod Bar are shown in Figures 1, 2 and 3.

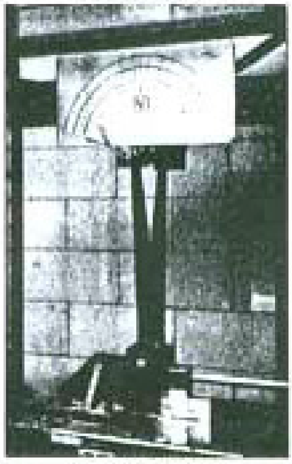
Most vulcanizates of Die-Thane urethane rubber flex and bend in this type of test. Die-Thane P-675 is a material which approaches structural plastics in hardness. Yet even at this hardness, Die-Thane P-675 has significantly better impact resistance than plastics. Values for this 75D material are compared in Table I with those of several plastics. In order to approach these high values for Die-Thane P-675, plastic materials require reinforcement with glass fibers.

FIGURE 1



IZOD TEST
Pendulum in motion

FIGURE 2



IZOD TEST
Pendulum Striking Specimen

FIGURE 3

IZOD TEST
Specimen in Holder

TABLE I

IMPACT RESISTANCE, IZOD, FT./IN					
	Nylon	**Acetal**	**Acrylic**	**Die-Thane P575**	**Die-Thane P675**
Hardness (Rockwell or Durometer)	Rockwell R108	Rockwell R120	Rockwell M103		Durometer 73D (Roxkwell R90)
Notched, 75°F	2.0	1.4	0.3	4.0	15.0
Notched, -40°F	0.5	1.2	0.3	-	1.1