ELASTOMERS

ELASTOMER SELECTION

Elastomers are used in the design of isolators due to their unique ability to provide effective control of dynamic forces. As engineering materials, elastomers are able to undergo rapid cyclic deformations at discrete frequencies, or over a range of frequencies. This is due to the inherent properties of rubber, mainly: flexibility, high elongation and a combination of resilience and damping. The dynamic mechanical properties are dependent upon temperature, frequency, extent of deformation (strain) and compounding variables. The key to providing an effective elastomer for dynamic applications lies in the compounding of available elastomer materials; i.e., polymer gums, fillers, plasticizer, etc..

Rubber compounding is the art and science of selecting and combining elastomers and additives to obtain a unique mixture that will produce the necessary physical and chemical properties required in the finished product. The objectives are: 1) to produce the right mechanical properties to satisfy service requirements; 2) to attain processing characteristics necessary for efficient utilization of available tooling and equipment; and 3) to achieve 1) and 2) at the lowest cost. Frequently, this is a balancing act, but for our business, performance (quality) is generally of overriding interest.

A typical formulation usually consists of about ten ingredients. Each ingredient has a specific function, with each having an impact on performance, processability and price. Rather than comparing the results of all possible compound variations that could be made, we will discuss some general properties and characteristics of our materials.

Depending on the service conditions, a standard compound would be recommended or, if absolutely necessary, a special compound would be developed to meet a particular requirement.

To select the elastomer that best suits the application, all service conditions must be defined thoroughly. These include operating temperature range, environmental conditions, service fluids, etc., as well as loads, desired performance and dynamic conditions (shock and vibration). Operating temperature ranges are the anticipated service temperatures in which the parts will function. Operating temperature range will affect isolator performance and life expectancy. Environmental conditions such as ozone, humidity, sunlight and radiation should also be defined. Many elastomers have poor resistance to some environments and will deteriorate quickly when attacked. A third important area to identify is exposure to service fluids. Some of the common fluids we encounter are hydraulic fluids, lubricating oils and fuels. Improper selection of an elastomer exposed to such fluids inevitably leads to problems. Another aspect of fluid exposure is the fluid temperature and degree of contact, i.e., occasional splash, immersion spray, etc.. With these conditions known, elastomer selection would be determined based on the overall best resistance to any adverse condition.

The accompanying tables list the most common elastomers and describes some of their advantages and disadvantages. A more detailed look at physicals, environmental resistance and chemical resistance is contained in APPENDIX A.

Once the elastomer has been selected, a number of tests will be performed to determine that the batch of compound meets the physical requirements as specified. Occasionally, the customer will have predetermined specifications such as MIL–STD–417A, while industrial customers frequently specify elastomers in accordance with ASTM D2000 (SAE J200), which is a standard classification system of elastomers.

During development of an elastomer, many tests are performed to get an accurate estimation of how a product will perform in service. Once into production, the elastomer is checked by Quality Control to determine that it meets the specified properties from batch to batch, over the life of the project.

ISOLATOR DESIGN

Dynamic performance of the elastomer alone is estimated by Dynamic Modulus tests. (See Attachments I and II for typical dynamic modulus test data.)

Dynamic modulus (in shear) is related to the shear stiffness of an isolator. Loss tangent is the amount of damping in the material and is approximately the inverse of the maximum transmissibility. The following definitions of damping terms may be helpful:

$$T_{max} \sim \frac{1}{2(C/C_c)} = \frac{1}{2\zeta} = \frac{1}{\tan \delta}$$

where

T_{max} = Transmissibility at resonance

ζ = (C/C_c) = Damping Ratio

Tan δ = Loss Tangent (also referred to as η, or Loss Factor)

Dynamic modulus and loss tangent are a function of strain (vibratory input), frequency (strain rate), and temperature. Two important characteristics should be noted:

Dynamic modulus decreases with increasing strain;
Optimum damping generally occurs from about 2-5% strain. Damping decreases for higher and lower values of strain.

Attachment III shows the temperature sensitivity of the Dynamic Spring Rate (related to Dynamic Modulus) and of the Damping Coefficient (related to loss tangent) for several compounds.(ref., Harris and Crede). Note that both the stiffness and damping are dependent upon temperature. Attachment IV shows the temperature sensitivity of dynamic modulus for several Barry compounds. Of the compounds shown, the Barry Hi-Damp would be selected for a low temperature application, since the increase in stiffness is less at low temperature.

Elastomeric isolators are always stiffer for dynamic conditions (shock and vibration) than for static conditions (load deflection). Typical dynamic-to- static stiffness ratios are 1.3-1.7. Damping tends to increase the dynamic-to- static stiffness ratio and also increases drift.

Also, since dynamic modulus is a function of frequency and strain, the dynamic-to-static stiffness ratio is also a function of these parameters.

ENGINEERING PROPERTIES OF ELASTOMERS - TECHNOLOGY

Modulus of Elasticity

Ratio of unit stress to corresponding unit strain in tension, compression or shear. For elastomers, the modulus of elasticity is constant for small deflections and over a limited temperature range. Poisson's ration, the relationship of the lateral to the longitudinal deformation for an elastomer specimen under stress, is approximately 0.5. This means that elastomers are practically incompressible.

Modulus or Percent Modulus

Describes the stress attained in extension of a given amount. This modulus does not refer to the elastic modulus, but to the stress level at which a given strain is observed. For instance, a 300 % modulus is the tensile stress required to produce a 300 % elongation, based on the initial cross section. This provides a very rough indication of the stiffness of a material.

Dynamic Modulus

Under cyclic stress application, the elastic behavior of elastomers deviates more and more from the ideal. The intermolecular changes can no longer take place as rapidly as changes in stress. The phase angle increases. Dynamic modulus decreases with increasing strain. Dynamic modulus is the most precise method available to us to measure stiffness and damping characteristics of elastomers.

Hardness

The hardness of an elastomer is a measure of its relative resistance to indentation. Hardness is the resistance to elastic deformation. It is a surface phenomenon and cannot be accurately correlated to stiffness properties. Shore A durometer from 20 to 95 is the unit for measurement.

Resilience

Referred to as "snap", it is the ratio of the amount of energy given up on recovery from deformation to the amount of energy required to produce the deformation. Expressed as a percent of rebound height from a free fall of a standard test object. The higher the percent figure, the greater the resilience. High resilience implies a small phase angle, or a small amount of damping.

Hysteresis

The difference between the amount of energy required for deformation and the amount of energy recovered upon unloading. It is the difference in area of a load deflection curve and the unloading curve. High hysteresis indicates a large phase angle, or a large amount of damping.

Creep or Drift

A time effect which results in an increasing in deformation without an accompanying increase in load. This property is temperature sensitive.

$$\% \text{ Rel. Creep} = \frac{\text{Total Deformation} - \text{Initial Deformation}}{\text{Initial Deformation}} \times 100$$

Stress Relaxation

When vulcanized rubber is held at a constant deformation, the stresses set up gradually decrease with time as the cross linked network approaches an equilibrium condition. This is stress relaxation.

Compression Set

Provides a measure of the ability of an elastomer compound to retain its elastic properties during prolonged action of compression stress. Compression set is the amount of deformation never recovered after a load is removed. Measurements are made under constant load or constant deflection.

Damping (Hysteresis)

Phenomenon by which energy is dissipated in the form of heat in a dynamic system. Results from the molecular structure of an elastomer subjected to motion.

Temperature Sensitivity

Effects of high and low temperature compared to room temperature on the modulus and damping characteristics of an elastomer.

Fluid Exposure

Effects of fluids (fuels, chemicals, etc.) on the performance of elastomers.

ELASTOMERS: PROPERTIES AND USE IN ISOLATION SYSTEMS

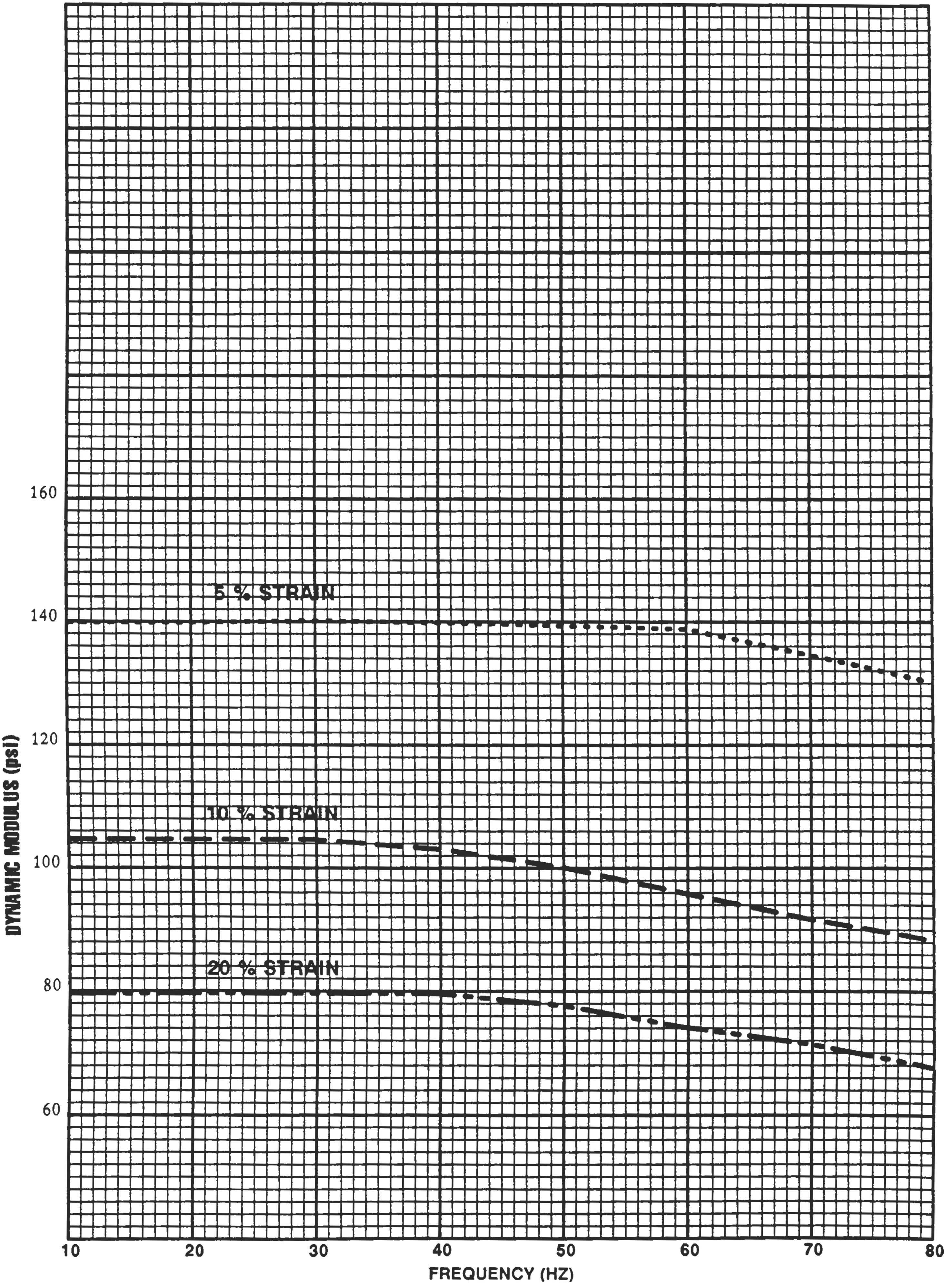
TYPE	ADVANTAGES	DISADVANTAGES
Natural Rubber	Low cost, excellent bond, high tensile and tear strength, high fatigue life.	Poor low temperature performance, poor fuel/oil/solvent resistance. Low damping. Poor heat resistance.
Neoprene	Oil resistant, excellent bond, good physical properties.	Poor low temperature performance, low damping
Butyl	High damping, ozone resistant	Poor low temperature performance
Nitrile	Fuel resistant	Poor low temperature performance, poor ozone resistance.
LT (Polybutadiene)	Moderate/high damping Good temperature performance	Damping and temperature performance somewhat inferior to silicone. Low fuel/oil resistance.
Silicone	Variable damping, excellent temperature performance from -100 F to + 450 F	Can be difficult to bond, low physical properties low fuel resistance.
Fluorosilicone	Variable damping, good temperature performance from -65 F to + 300 F	High cost, difficult to bond, low physical properties
Fluoroelastomer	Excellent high temp-temperature performance to 400 F to 600 F, depending on time; fuel resistant; high damping	High cost, difficult to bond, very poor low temperature performance
EPDM	Excellent weather/ozone resistance; performance temperature to 300 F	Poor oil/solvent resistance; poor low temperature

Additional specialty elastomers are constantly being reviewed for special applications.

The attached Elastomer Properties Guide has valuable information. For specific requirements, consult the Barry Controls Materials & Processes Group.

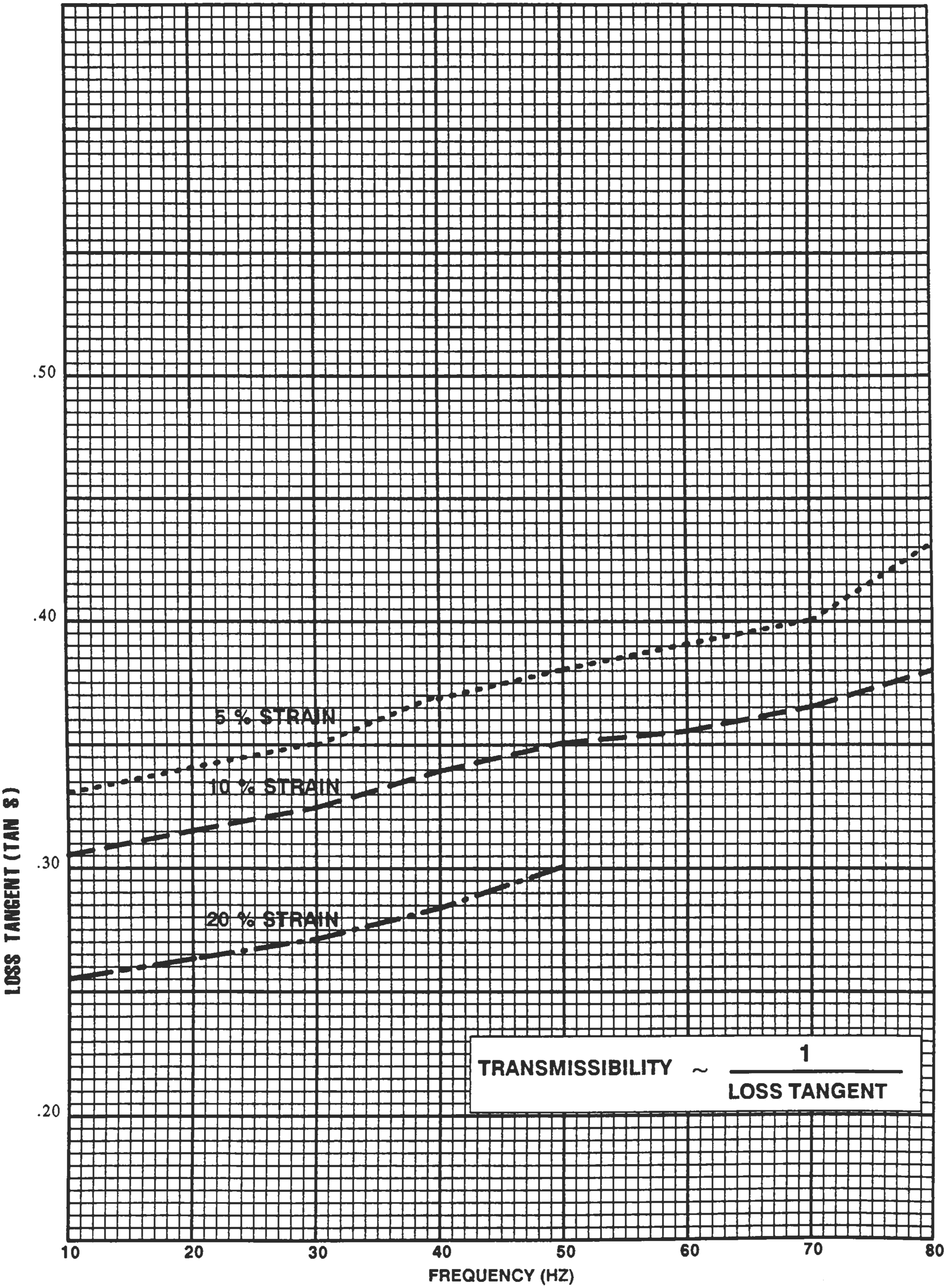
ATTACHMENT I

DYNAMIC MODULUS VS. FREQUENCY AT THREE VALUES OF STRAIN



ATTACHMENT II

LOSS TANGENT VS. FREQUENCY AT THREE VALUES OF STRAIN



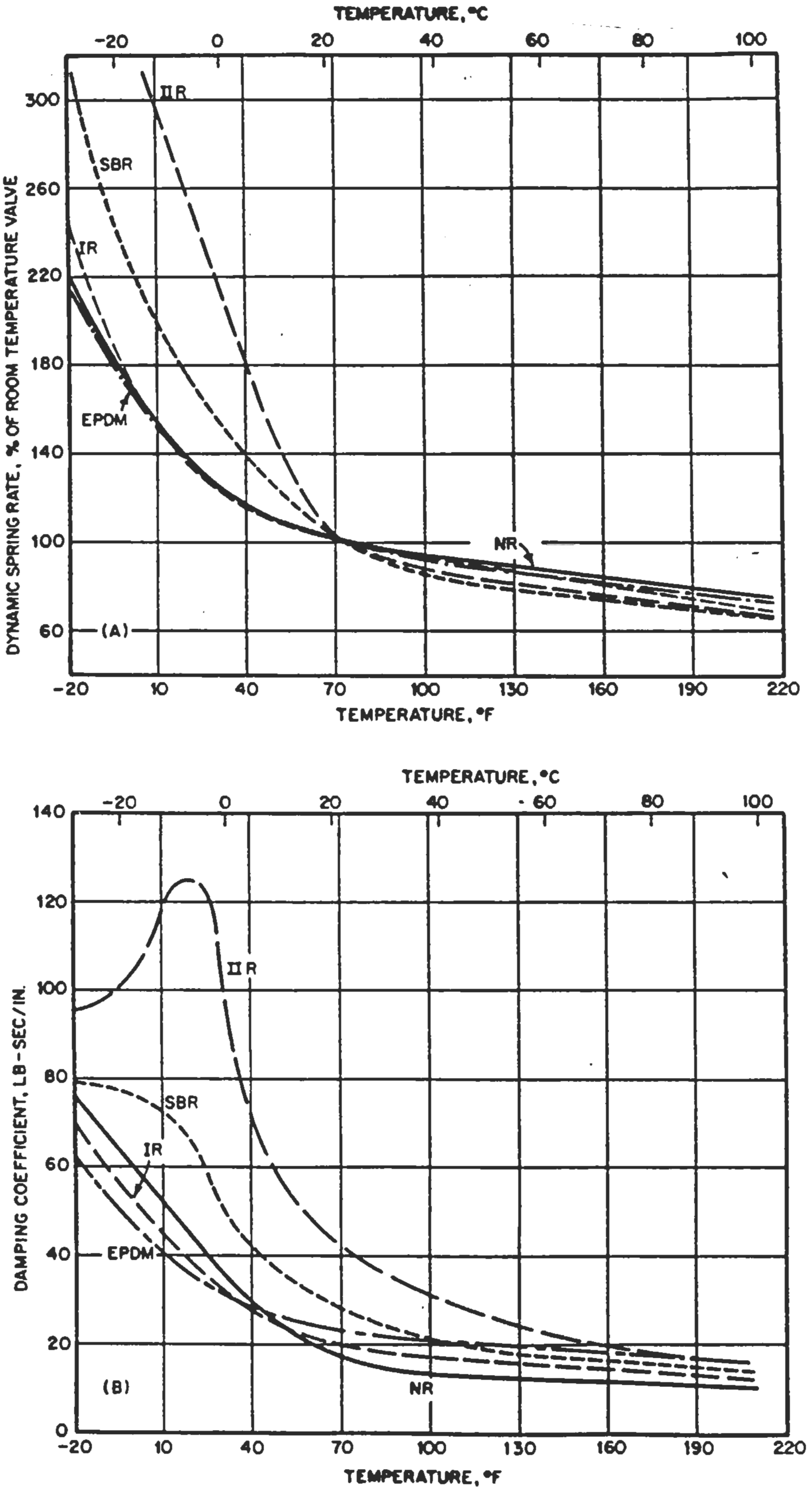
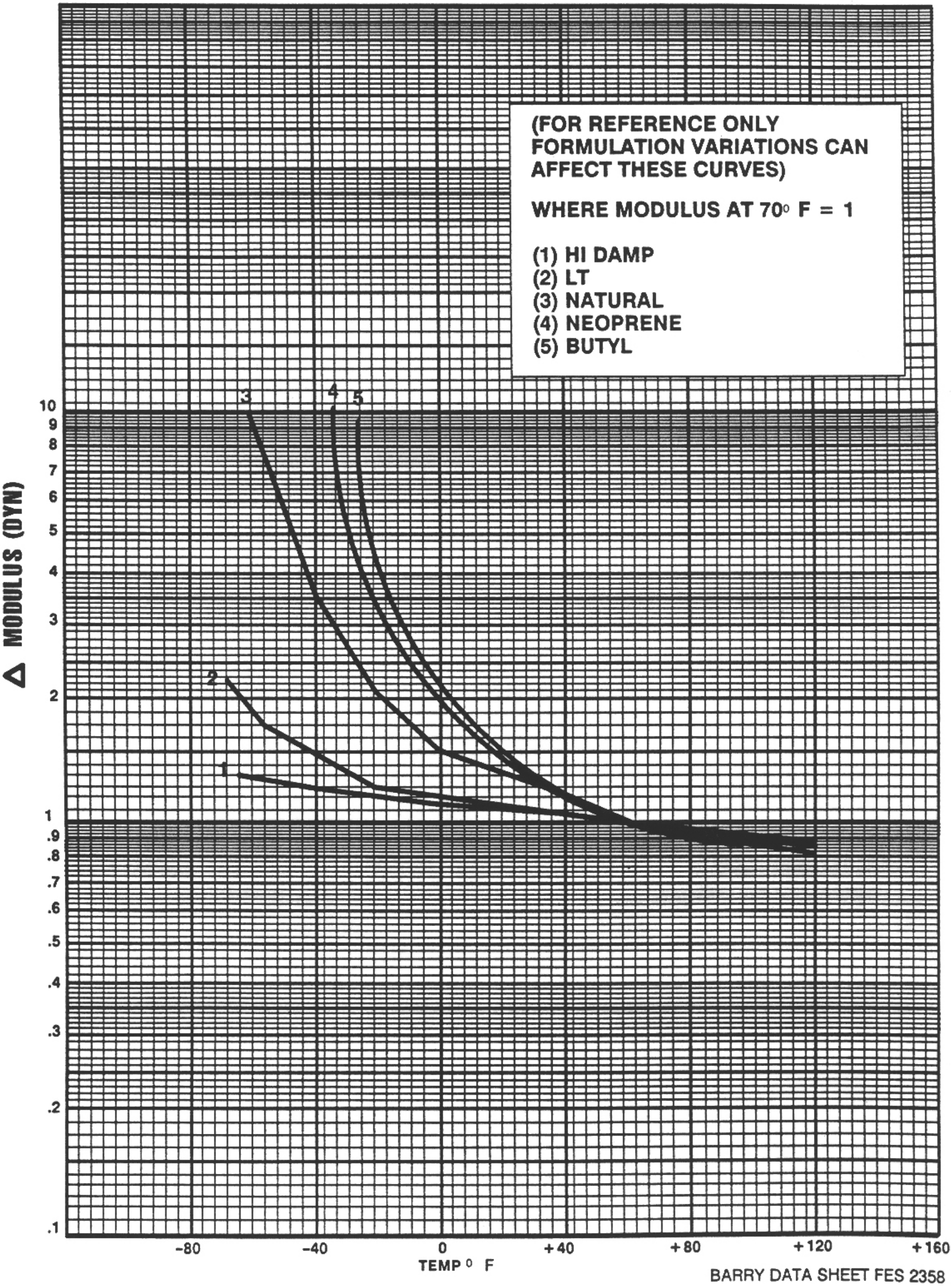


Fig. 35.9. The effect of temperature on (*A*) the dynamic spring rate and (*B*) the damping coefficient of typical isolator compounds using several polymers.

ATTACHMENT III

ATTACHMENT IV

CHANGE IN DYNAMIC MODULUS VS TEMPERATURE FOR VARIOUS ELASTOMERS



BARRY DATA SHEET FES 2358

ATTACHMENT A

ELASTOMER TYPE	RECOMMENDED USAGE	ADVANTAGES	DISADVANTAGES
SILICONE	Broadest useful temperature range of any elastomer with medium to high damping. Do not use if butyl or another elastomer would be adequate.	Broadest useful temperature range low-temperature flex best of all elastomers Can be medium-to high damping Good resistance to compression set Resistant to aging and ozone Excellent high-temperature properties Good flex resistance	Fair physical strength Fair bond strength Affected by silicone fluids, aromatic chlorinated solvents, not good for ML 5606
FLUOROSILICONE	Increased fluid resistance over silicone Poorer bonding	Much higher resistance to petroleum oils or fuels O.K. for gas, chlorinated solvents, jet fuel (JP-4), diester oils (ML 7808)	Affected by acetone, low molecular weight ketones or phosphatic esters, strong oxidizing acids or alkalies, hydrazine-based fluids Very expensive
CHLOROBUTYL	This would be used in place of butyl if easier processing and bonding is needed. Higher damping than butyl would be a penalty	Higher damping than butyl Better bonding than butyl Better high-temperature resistance than butyl	Affected by gasoline, oil, degreaser solvents Medium physical properties Medium bonding Affected by aliphatic or aromatic hydrocarbons, hydrocarbon solvents, paraffin oils, esters, ketones, diester-based synthetic lubricants, acetone, MEK, and silicone fluids
BUTYL	If the improvements in heat resistance, ozone, aging, and oil resistance with neoprene over NR are not enough, butyl would be the next choice over neoprene. A slight penalty in increased damping would result. Butyl, uniquely, has the best resistance to gas leakage	Excellent gas impermeability Excellent dielectric properties Oxidation and ozone resistant Medium damping Good heat-aging resistance Good moisture resistance O.K. for hydrazine fuels, organic and inorganic acids, phosphate-ester fluids	Same as for Chlorobutyl, above
EPDM	Developed as a probable replacement for butyls. Better heat and oil resistance than the butyls. Damping more like NR. Gas impermeability and bonding inferior to butyls.	Damping like NR Good low-temperature flexibility Excellent ozone and oxidation resistance Good resistance to hydrocarbon oils Better high-temperature resistance than chlorobutyl O.K. for hydrazine fluids Can be blended with butyl or NR Probable replacement for butyl and chlorobutyl	Difficult bonding Poor gas impermeability Affected by petroleum products and non-polar solvents Difficult to compound for lower than 40 durometer
NR	Use whenever possible because it is inexpensive, easy to mold and bond, and has good physical properties.	General-purpose elastomer Inexpensive Best fatigue resistance Good overall mechanical properties Low damping Good low-temperature flexibility	Not good at high temperatures Relatively poor fluid and aging resistance
NEOPRENE	Similar to NR with improved heat, ozone and aging resistance. Also slightly better oil resistance. One drawback would be poorer low-temperature flexibility than NR.	Similar low damping as NR with improved oil and heat resistance Good resistance to ozone, weather, natural aging, non-aromatic petroleum, organic acids, freon, alcohol, and glycols Will not support combustion	Not good for chromic,nitric, and sulfuric acids, hydrogen peroxides, aromatic-organic hydocarbons, ketones, phosphatic esters, hydraulic fluids Low-temperature flexibility poorer than NR
NITRILE	For specific environments, nitrile might be chosen over neoprene.	Resistance to petroleum oil and gasoline superior to NR and SBR Preferred seal for nitrogen or helium Resistance to aromatic hydrocarbons better than neoprene Resistance to heat aging better than NR	Poor ozone resistance Affected by oxygenated solvents (acetone, MEK), phosphate ester, hydraulic oils (skydrol, cellulube), oxidizing acids, halogenated solvents (carbon tet, trichloroethylene Low-temperature flexibility poorer than NR
SBR	Used to be used in place of NR because it was cheaper. Now there is no real advantage.	Used mostly in tires-originally intended as replacement for NR With heat aging, gets stiffer as opposed to NR	No real advantage over NR Higher damping than NR In most cases, NR would be used in place of SBR

	Silicone	Fluoro-Silicone	Chloro-Butyl	Butyl	EPDM	NR	Neoprene	Nitrile	SBR
TYPE/TRADE NAME	PVMQ VMQ Polydimethyl-siloxane	FVMQ Fluoro-substituted silenes	CIIR Bromated Butyl	IIR Isobutylene-Isoprene copolymer	EPDM Ethylene propylene diene	NR cis-1, 4 Polyisoprene	CR Chloroprene	NBR or Buna N Nitrile-butadiene rubber	SBR Styrene-butadien rubber
Specific Gravity	.95-1.2	1.2-1.4	.92-1.1	1.1-1.3	.86-1.1	.93-1.1	1.2-1.4	1.0-1.2	.94-1.1
VARIOUS PHYSICAL PROPERTIES									
Useful Durometer Range	35-70	40-75	40-60	40-70	50-70	30-75	40-60	30-70	40-75
Tensile Strength (psi)	700-1200	900-1200	900-2200	1300-2000	1600-2200	3000-4500	2500-4000	1000-3500	900-200
Elongation at break (%)	500-1000	200-500	150-500	500-700	600-800	350-800	650-900	400-600	500
Q at resonance	2.5-8	4-7	2-4	3.5-5	4-8	3-10	4-8	3.5-5	5-10
G″/G′ ratio	.12-.4	.14-.25	.25-.5	.2-.3	.12-.25	.1-.25	.12-.25	.2-.3	.1-.2
Static Shear Modulus (psi)	80-350	100-220	100-400	100-350	120-350	60-400	100-220	60-350	100-400
Low Temperature Limit (approx. (F) 5:1 Stiffening)	-100	-70	-40	-50	-50	-60	-40	-35	-60
High Temperature Limit (F)									
Continuous	+ 350	+ 325	+ 250	+ 225	+ 250	+ 160	+ 200	+ 200	+ 160
Intermittent	+ 600	+ 500	+ 275	+ 250	+ 325	+ 250	+ 300	+ 300	+ 250
Ultimate Shear Stress (SK W2290) (psi)	150-450		550-1200	550-850	550-1200	950-1300			
Conical Peel (lbs)	90-200	70-180	90-350	150-300	100-300	90-400	300-500	300-500	150-300
Tear lb/in	50-150	55-240	90-360	150-200	100-250	200-250	200-250	200	150-200
Crescent Tear lb/in	100-200			250		860	700	225	304
Compression Set 22 hrs 158°F				10-20	9-20	10-20	24	18	
22 hrs 300°F	20-60	10-20							
70 hrs 158°F	3-5	3-5	3-10	10-30		10-15	15-20	20	20
70 hrs 212°F	8-20		10-20	75-80	40-80		35	15-20	
70 hrs 325°F	18-40	20-40	22	100	80-100	50	70	70	
70 hrs 270°F				90-95	65-70				
Creep Room Temp %/decade hrs	4	4	7	6	5	1.5-3	6	5	3-10
Gum strength	Low	Low	Medium	Medium	Low	High	High	Low	Low
Stretching Crystallization	None	None	High	High	None	High	High	Low	Low
Air Permeability (cm^3/sec-cm^{3}ATM)	20			0.02		0.5	0.1	0.13	0.25
HEAT TRANSFER PROPERTIES									
Thermal Conductivity	.1-.3	.1-.3	.05-.1	.05-.1	.2-.5	.1-.15	.1-.3	.05-.2	.2-.5
Thermal Diffusivity FT^2/hr	.004-.007	.003-.006	.003-.008	.004-.009	.003-.009	.002-.004	.003-.006	.003-.008	.002-.00
Specific Heat BTU/lb°F				.45-.5		.33-.44	.4-.5		.35-.45
Linear Shrinkage (325 F Mold Temperature), %	3-4	3-4	3.5-5	3.5-5	2.5-3	2-3	2-3	1.5-2.5	
ELECTRICAL PROPERTIES									
Dielectric Constant	3.1	6.5		2.5	2.5	2.9	6.7	15-20	2.9
Dielectric Strength V/mil	500-1000	360		600-900	500-1400	400-600	400-600	230-2	
ENVIRONMENTAL RESISTANCES									
OIL									
Medium Aniline ASTM # 1	S	S		U	U	U	F	S	U
Low Aniline ASTM # 2	S	S		U			U	S	U
Low Aniline ASTM # 3	F	S		U	F	U	U	S	U
Low Aniline MIL-H-5606	U	S		U		U	U	S	U
Normal Ester MIL-L-7808	F	S		F		U	U	F	U
Medium Aniline MIL-L-2104A									
Motor OIL 10-30W	S	S		U			F	S	U
Inerteen Transformer Oil	S	S		U			F	S	U
Phosphate Ester Skydrol 500	F	U		S	S	U	U	U	U
7000	S	S		S	S	U	U	U	U
Transformer Oil	S	S		U	F	U	S	S	U
Silicate Ester Coolanol 25	U	S		U	U		S	U	U
Coolanol 35,45	U	S							
Aliphatic Hydrocarbons	F	U		U	U	U	S	S	U
Hydraulic Silicates	U			F	S	U	S	F	U
Phosphates	S			F	S	U	S	F	U
Mineral oil MIL-M-37450	F							S	
Low Aniline Cutting Oil MIL-C-46149		S						S	
FUELS									
ASTM A	U	S		U	U		S	S	U
ASTM B	U	S		U	U	U	S	U	U
MODERATE AROMATIC									
MIL-J-5624 (JP-4, 5)	U	S		U		U	U	S	U
MIL-G-5572 (Aviation Gas)		S		U			U	U	U
Low Aromatic Kerosene	U	S		U	U	U	U	S	U
Low Aniline MIL-F-25558		S		U	U	U	S		
MIL-F-82522 (RJ4)									
Low Aromatic Auto Gas	U	S		U	U	U	S	S	U
HYDRAZINE (UDMH)	S	S	S	S	S		U	U	U

	SILICONE	FLUORO-SILICONE	CHLOROBUTYL	BUTYL	EPDM	NR	NEOPRENE	NITRILE
SOLVENTS								
Aromatic Toluene	U	S		U			U	U
Acetone	S	U		U	S			U
Low Aromatic Naptha MIL-N-15178		S		U			U	S
Water	S	S	S	S	S	S	F	F
Steam	S	S			S			
Low Aromtaic Stoddard Solvent	F	F		U			U	S
Chlorinated Hydrocarbon Trichlorethylene	F	S		U	U	U	U	U
MEK	U	F		F	S		U	U
Perchlorethylene	S	S						S
Benzene	U	F						S
Carbon Tetrachloride	U	S						S
Xylene	U	S						F
ACIDS								
Hydrochloric	F	F		S	S	F	F	F
Acetic	S	S			S			U
Nitric	S	S		S	S	U	U	F
Phosphoric	S			S	S	U	U	S
Stearic	S				S			S
Sulfuric	S	S		S	S	F	F	S
MISCELLANEOUS								
Silicone Fluids	S	S		F	S		U	S
Freon	F	S			S		S	S
Radiation	U	U		U	S	S	F	S
Hydrogen Peroxide	S	S			S			F
Ozone	S	S		S	S	U	S	U
Sun	S	S		S	S	F	F	F
Air	S	S		S	S	F	S	
Abrasion	U	U		F	S	S	S	S

S = Satisfactory - means no great loss in properties @ 212^{0} F for 7 + days (= 25% loss in physicals), for silicones - 300^{0} F for 7 days.

U = Unsatisfactory - means gross loss in properties or gross swelling (50% loss in strength or over 50% swell).

F = Fair - Basically means that the data varies so much that it is necessary to look at specific data.

HIGH-TEMPERATURE RESISTANCE
(All temperatures in ^{0}F)
(T = Tensile psi:
E = Elongation at break)

		SILICONE	FLUORO-SILICONE	CHLOROBUTYL	BUTYL	EPDM	NR	NEOPRENE	NITRILE
Maximum Continuous Temperature		350	325	250	225	250	180	200	200
Maximum Intermittent Temperature		600	500	275	250	325	250	300	300
Temp @ which 50% original Tensile Retained		450		300	270		230	210	
Temp @ which 25% original Tensile Retained		430–450		340	410		300	330	310
Unaged, Test @ Room Temp	T	1650	1200	2200	2325	1825	3850	3550	2500
	E	580	415	410	400	450	480	480	300
Unaged, Test @ 200^{0} F	T	960	870		1170		2980	1920	860
	E	390	380		270		500	360	140
8 Hrs @ 200^{0}F Test @ 200^{0}F	T	870			1240		2730	1980	925
	E	390			200		480	320	170
Unaged, Test @ 250^{0}F	T	550			930	2000	2460	1500	700
	E	200			210	300–500	480	350	120
8 Hrs @ 250^{0}F Test @ 250^{0}F	T				730		800	1680	630
	E				140		180	240	80
Unaged, Test @ 400^{0}F	T	430	540	600	640	400	500	180	230
	E	240	300	150	260	0–120	500	0–100	40
8 Hrs @ 400^{0}F Test @ 400^{0}F	T	410		440	350		125	180	130
	E	210		100	80		80	10	20
8 Hrs @ 400^{0}F Test @ 75^{0}F	T			1300					
	E			200					
3 days @ 158^{0}F Test @ 158^{0}F	T						100		
%Tensile Properties Retained	E						102		
7 days @ 158^{0}F	T				114		87	84	
%Tensile Properties Retained	E				99		69	93	
3 days @ 212^{0}F Test @ 212^{0}F	T				101		19	94	82
%Tensile Properties Retained	E				82		49	77	42
14 days @212^{0}F Test @212^{0}F	T			68	95		55	92	87
%Tensile Properties Retained	E			88	71			49	29
70 Hrs @ 250% Test @ 250^{0}F	T					102		92	93
%Tensile Properties Retained	E					102		66	71
	E		180						
%Tensile Properties Retained	T	90	73	60	60				
200)F	E		92						
%Tensile Properties Retained	T	50	48	15	15				
400^{0}F	E		72						
5 days @ 350^{0}F	T		520						
	E		230						
10 days @ 350^{0}F	T		440						