Natural Frequency

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{kg}{W}} = \frac{1}{2\pi}\sqrt{\frac{g}{x_{st}}}$$

where f_n = natural frequency in cycles-per-second (Hz)

k = spring constant (lbs/in, N/m)

m = mass of load (lb mass, kg mass)

g = gravitational constant, 386 in/sec^2 or 9.8 m/sec^2

W = weight of load, $m \bullet g$ (lb or N)

x_{st} = static deflectionof the spring (in or m)

$$f_n \approx \frac{3.13}{\sqrt{x_{st}}} \text{ cycles/sec} = \frac{188}{\sqrt{x_{st}}} \text{ cycles/min if } x_{st} \text{ is in inch}$$

$$\approx \frac{5}{\sqrt{x_{st}}} \text{ cycles/sec} = \frac{300}{\sqrt{x_{st}}} \text{ cycles/min if } x_{st} \text{ is in cm}$$

Damped Natural Frequency

$$f_{dn} = f_n \sqrt{1 - \left(\frac{c}{c_{cr}}\right)^2} = f_n \sqrt{\frac{1-\delta^2}{4\pi^2}}$$

where δ = $2\pi\,(c/c_{cr}) = \log\,(A_n/A_{n-1})$ logarithmic decrement

c = damping constant (lb-sec/in or N-sec/m)

c_{cr} = critical damping constant = $2\sqrt{km}$

A_n = n^{th} amplitude of vibration

Natural Frequency of Torsional Vibrations

$$f_t = \frac{1}{2\pi}\sqrt{\frac{k_t}{I}}$$

where k_t = torsional stiffness (lb-in/rad or N-m/rad)

I = polar mass moment of inertia (lb-in-sec^2 or kg-m^2)

(continued)

Transmissibility

$$\mu_F = \mu_x = \frac{m_f}{m + m_f} \sqrt{\frac{1 + \left(\frac{\delta}{\pi} \frac{f}{f_n}\right)^2}{\left(1 - \frac{f^2}{f_n^2}\right)^2 + \left(\frac{\delta}{\pi} \frac{f}{f_n}\right)^2}}$$

μ_F = force transmissibility

μ_x = motion transmissibility

m = mass of load

m_f = mass of base (foundation)

For $m_f = \infty$:

$\mu_F < 1$ for $f \geqslant 1.41\ f_n$

For $m_f = \infty$ and $\delta \approx o$ (negligible damping):

$$\mu_F = \frac{1}{\pm\left(1 - \frac{f^2}{f_n^2}\right)}$$

At resonance ($f/f_n = 1$), with some damping:

$$(\mu_F)_{max} = (\mu_x)_{max} \approx \frac{m_f}{m + m_f} \frac{\pi}{\delta}$$

PHYSICAL PROPERTIES OF FIVE STANDARD STRUCTURAL RUBBER COMPOUNDS

Compound Numbers**	R-325-BFK	R-430-BFK	R-530-BFK	R-630-BFK	R-725-BFK
Shear modules, lb per sq in.	50	70	95	140	195
Logarithmic decrement of amplitude* (referred to base 10)	.041	.055	.14	.23	.35
Successive amplitude ratio*	.91	.88	.72	.59	.45
Percent energy loss due to hysteresis, per cycle of vibration	17	22	47	65	80
Specific heat	.47	.43	.40	.38	.35
Thermal conductivity in B.T.U., per sq ft per hr for a temp gradient of 1°F per in. thickness	.97	1.04	1.08	1.15	1.26
Velocity of sound in rubber rods, ft per sec	115	165	210	345	750

* The logarithmic decrement given here represents the negative of the power to which 10 must be raised in order to obtain the ratio of any two consecutive amplitudes (on the same side of zero deflection) as unexcited vibration dies out. For instance, if the logarithmic decrement is 0.2, the ratio of one amplitude to the preceding one is

$$10^{-0.2} = \frac{1}{10^{0.2}} = \frac{1}{1.585} = 0.631 = \text{successive amplitude ratio.}$$

(Ordinarily, logarithmic decrement is referred to natural logarithm base e, and if such values are required, they would be 2.30 times the values given here.)

** Table from *U.S. Rubber Engineering Guide* #850 p. 25

COMPARATIVE PROPERTIES OF RUBBER AND RELATED MATERIALS

SAE Abbreviation	Butyl HR	Ethylene Propylene EPT	Hypalon CSM	Natural Rubber NR	Neoprene (Chloro-prene) CR	Nitrol (GR-A) NBR	Silicone SI	Styrene Butadiene (GR-S) SBR	Urethane PU	Flouro-Elastomer (Viton) HK
Cost Relative to Natural Rubber	110%	110%	150%	100%	110%	125%	850%	85%	450%	2000%
Tensile of Compounded Stocks	2000 psi	3000 psi	3000 psi	3500 psi	3000 psi	2500 psi	800 psi	2500 psi	8000 psi	2000 psi
Durometer	40-75	30-100	55-95	30-90	30-90	40-95	45-85	40-90	65-95	50-90
Elongation	fair	good	fair	excellent	excellent	good	fair	good	good	good
Aging	excellent	excellent	excellent	good	excellent	excellent	excellent	good	excellent	excellent
Heat Aging	excellent	excellent	good	good	very good	excellent	excellent	good	excellent	excellent
Sunlight Aging	good	excellent	excellent	poor	good	poor	good	poor	excellent	excellent
Lubricating Oil Resistance	poor	poor	good	poor	good	excellent	fair	poor	good	good
Aromatic Oil Resistance	poor	poor	poor	poor	fair	good	poor	poor	good	good
Animal-Vegetable Oils Resistance	excellent	poor	good	fair	excellent	good	good	fair	fair	good
Flame Resistance	poor	poor	excellent	poor	good	poor	fair	poor	poor	good
Tear Resistance	good	good	excellent	good	good	fair	poor	fair	excellent	fair
Abrasion Resistance	good	good	excellent	excellent	excellent	good	poor	good	excellent	fair
Compression Set Resistance	fair	fair	good	good	fair	good	fair	fair	excellent	good
Permeability to Gases	very low	good	good	fair	low	fair	fair	fair	good	excellent
Dielectric Strength	good	good	good	excellent	fair	poor	good	excellent	fair	good
Freedom from Odor	good	fair	excellent	excellent	good	fair	fair	fair	good	fair
Maximum Temperature (°F)	250	300	250	210	260	260	600	215	250	500
Minimum Temperature (°F)	-50	-50	-50	-65	-50	-60	-150	-60	-60	-40

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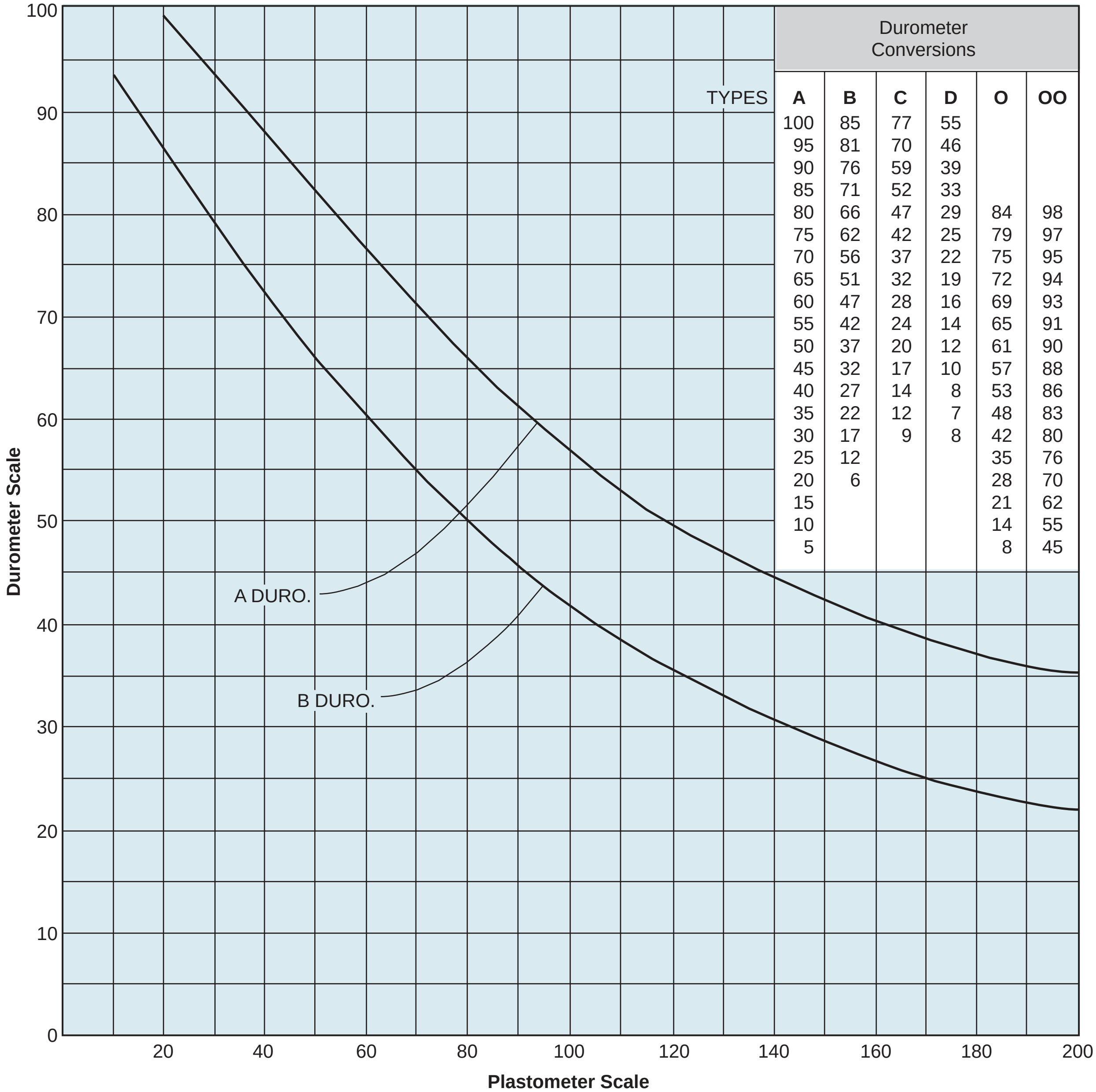
FOR RUBBER AND PLASTICS
DUROMETER — PLASTOMETER CONVERSION CHART*



Durometer Conversions

TYPES A	B	C	D	O	OO
100	85	77	55		
95	81	70	46		
90	76	59	39		
85	71	52	33		
80	66	47	29	84	98
75	62	42	25	79	97
70	56	37	22	75	95
65	51	32	19	72	94
60	47	28	16	69	93
55	42	24	14	65	91
50	37	20	12	61	90
45	32	17	10	57	88
40	27	14	8	53	86
35	22	12	7	48	83
30	17	9	8	42	80
25	12			35	76
20	6			28	70
15				21	62
10				14	55
5				8	45

Conversions Are Approximate Values Dependent on Grades and Conditions of Materials Involved

*Courtesy of Shore Mfg. Co., New York

Durometer Hardness of Some Rubber Compounds		
Hardness (Shore A)	**ASTM Designation**	**Load Rating**
30	R-325-BFK	A
40	R-430-BFK	B
50	R-530-BFK	C
60	R-630-BFK	D
70	R-725-BFK	