Millathane® CM

A MILLABLE POLYETHER URETHANE RUBBER

(Formerly known as Adiprene® CM)

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TSE

TSE INDUSTRIES, INC.

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CLEARWATER, FLORIDA

For the past forty years, TSE Industries has been an industry leader in new, innovative solutions for the rubber industry. Our millable polyurethane gums, sold under the trade name **MILLATHANE**® have grown to be the sales leaders in the world today.

TSE Industries has recently completed its Phase Five Expansion encompassing 300,000 square feet spread over twenty acres in Clearwater, Florida. A large part of this is dedicated to significantly expanding our Research and Development efforts so that we will remain the Technology Leaders into the 22nd Century.

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The recommendations for the use of our products are based on tests believed to be reliable. However, we do not guarantee the results to be obtained by others under different conditions. Nothing in this brochure is intended as a recommendation to use our products so as to infringe on any patent.

***Note: Caytur 4 is now known as Thanecure® ZM. Caytur is a registered trademark of Chemtura Corporation. Thanecure is a registered trademark of TSE Industries, Inc.*

*USE OF ZINC STEARATE

Please Note: Although zinc stearate is shown in these formulas, the data was generated using cadmium stearate. The two stearates will give generally comparable properties, but we do not recommend the use of cadmium stearate because of the health risks associated with cadmium compounds.

MILLATHANE® CM**

A Millable Polyether Urethane Rubber

INTRODUCTION

MILLATHANE CM is a sulfur and peroxide curable polyether urethane rubber. Its outstanding property is its great resistance to abrasion, which makes it of special interest for articles that are subjected to high wear in service. It has a unique combination of excellent properties, such as low temperature characteristics, and resistance to heat deterioration, ozone cracking, weathering and swelling in oils or solvents. This bulletin contains information on the compounding and processing techniques for **MILLATHANE CM** urethane rubber.

MILLATHANE CM

- can be processed on conventional equipment
- is vulcanized with sulfur and rubber accelerators
- requires reinforcing fillers for best physical properties
- stocks containing **MILLATHANE CM** can be processed with safety comparable to natural rubber or SBR stocks.

Important properties characteristic of **MILLATHANE CM** urethane rubber include:

- Very good-safe processing (45 minutes Mooney Scorch at 250°F (121°C) in most stocks)
- High tensile strength. 4000 to 5000 psi (27 to 34 MPa) in practical compounds
- Good elongation
- Good tear strength – (400-500 lb/in [69-87 kN/m])
- Good compression set resistance – (20-25%)
- Outstanding low temperature properties – brittle point below -90°F (-68°C)
- Strength at elevated temperature – Good retention at 300°F (149°C)
- Excellent heat aging characteristics to 250°F (121°C)
- Very good ozone and weathering resistance
- Oil and fuel resistance – comparable to nitrile rubber
- Generally good chemical resistance; (poor in concentrated acids)
- Very resilient dynamic properties
- Hardness range from 50 to 90 durometer A
- Unsurpassed radiation resistance

MILLATHANE CM RAW POLYMER PROPERTIES

Chemical type	Polyether polyurethane
Physical form	Slabs
Color	Orange
Specific gravity	1.06
Mooney viscosity (MS (1+10) at 100°C)	30 to 60
Solubility	Soluble in tetrahydrofuran, methyl ethyl ketone, and dimethylformamide; swollen by chlorinated solvents and petroleum fractions
Odor	Faint, characteristic
Storage stability	Excellent
Health hazard	None

MILLATHANE CM END USE APPLICATIONS

The unusual combination of excellent properties found in **MILLATHANE CM** makes it possible to design and fabricate products with less material than has been possible using other elastomers. Some of the applications suggested by the properties of **MILLATHANE CM** are given below:

Footwear	Soles and heels
Electrical	Abrasion resistant cable jackets
Oil well supplies	Pipe protectors, pistons, valve inserts, scrapers
Belts	Conveyor and V-belt covers
Hose	Sandblast and suction hose tubes, air-drill and jack hammer covers
Coated fabrics	Diaphragms, tarpaulins
Rolls	Textile cots, high pressure rolls
Solid tires	Industrial trucks, caster wheels
Misc. molded goods	Packing, gaskets
Aerospace/military	Wing deicing bladders, seals, boots and dust covers

**Formerly known as Adiprene® CM

PROCESSING OF MILLATHANE® CM

MILLATHANE CM can be processed satisfactorily on conventional rubber processing equipment. Special handling precautions regarding scheduling and moisture are unnecessary. Mooney Scorch values on the laboratory-mixed stocks in this bulletin were all 40 minutes or more to a ten point rise in viscosity, using a small rotor at 250˚F (121˚C).

BREAKDOWN AND MIXING

Preliminary breakdown is essential in processing **MILLATHANE CM** since this polymer, as received, is tough and nervy. Breakdown of crude polymer results in a desirable decrease in viscosity and nerve. The extent of polymer breakdown depends on the time and temperature of mixing as well as on the equipment used, as illustrated in Figures 1 and 2. The decrease in raw polymer viscosity manifests itself in a reduced compound viscosity and superior transfer molding characteristics, without affecting vulcanizate properties, as shown in Table I and Figure 3. The remaining processing may be carried out in conventional cycles without the generation of excessive heat. For Banbury mixing, it is recommended that a dump temperature in the range of 250˚F to 300˚F (121˚C to 149˚C) be used in the mixing steps. In line with standard practices, final stock mixing temperatures should not exceed 225˚F (107˚C). In mixing factory batches, it is advisable to check Mooney Viscosity before the final stock is mixed. If the viscosity is above the range ordinarily processible in the plant, a remill step should be included in the mixing sequence.

A typical No. 3D (32 rpm) Banbury mix of a stock of **MILLATHANE CM** urethane rubber is illustrated in Table II.

Once the viscosity of **MILLATHANE CM** compounds has been reduced to the processible range through proper mixing techniques, standard factory procedures may be followed for extruding and calendering.

Figure 1
EFFECT OF MILLING TIME ON VISCOSITY DROP

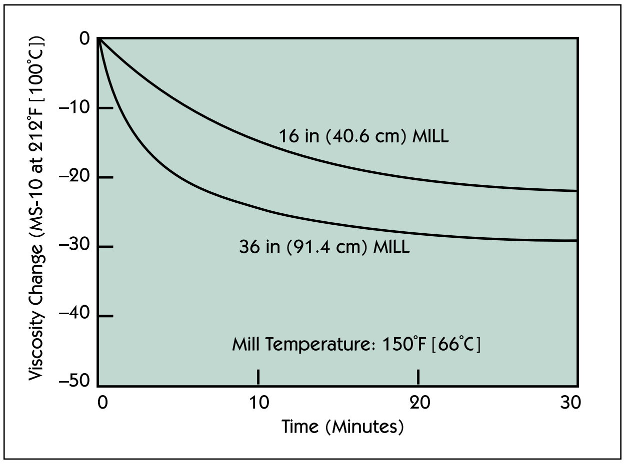
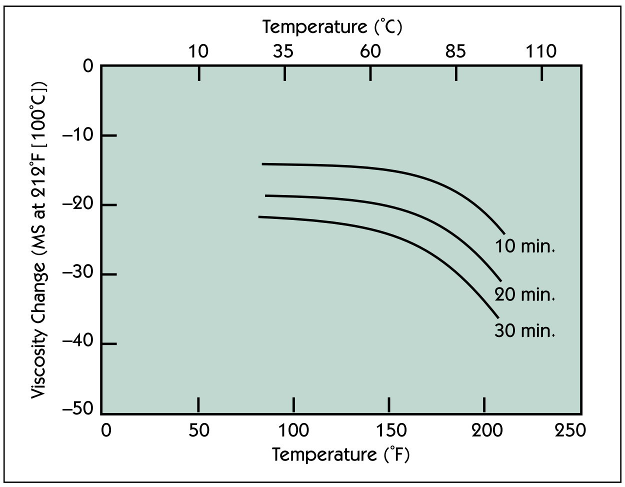


Figure 2
EFFECT OF MILLING TEMPERATURE ON VISCOSITY DROP



MILLATHANE CM TEST FORMULATION

MILLATHANE CM	100.0
N330 Carbon black	30.0
Coumarone-indene resin	15.0
MBTS	4.0
MBT	1.0
Sulfur	0.75
CAYTUR 4	0.35
Zinc stearate*	0.5

Table I
EFFECT OF MILL TIME ON VULCANIZATE PROPERTIES

Minutes[1]	0	5	15	30
Mooney Viscosity				
MS 1+10 at 212˚F (100˚C)	64	57	46	42
Mooney Scorch				
MS at 250˚F (121˚C)				
Minimum	40	39	34	32
Minutes to 10 point rise	43	43	43	44
Cure: 60 minutes at 142˚C				
Physical Properties				
Hardness, durometer A	68	67	68	68
300% Modulus, psi	1800	1850	1850	1850
[MPa]	[12.4]	[12.7]	[12.7]	[12.7]
Tensile strength, psi	4900	5050	5000	5150
[MPa]	[33.8]	[34.8]	[34.5]	[35.5]
Elongation at break, %	550	570	560	580
Tear strength, ASTM D-624 Die C,				
lb./in	370	375	380	360
[kN/m]	[64.7]	[65.6]	[66.4]	[62.9]
NBS Abrasion Index	365	355	355	330
Compression Set, Method B, %				
After 22 hours at 158˚F (70˚C)	24	22	24	25

[1] Raw Polymer Breakdown Time, 150˚F (66˚C), 16m [40.6 cm] Mill (before compounding).

Table II
BANBURY MIXING OF MILLATHANE CM

Conditions

Water on full through shell and rotor, 32 RPM

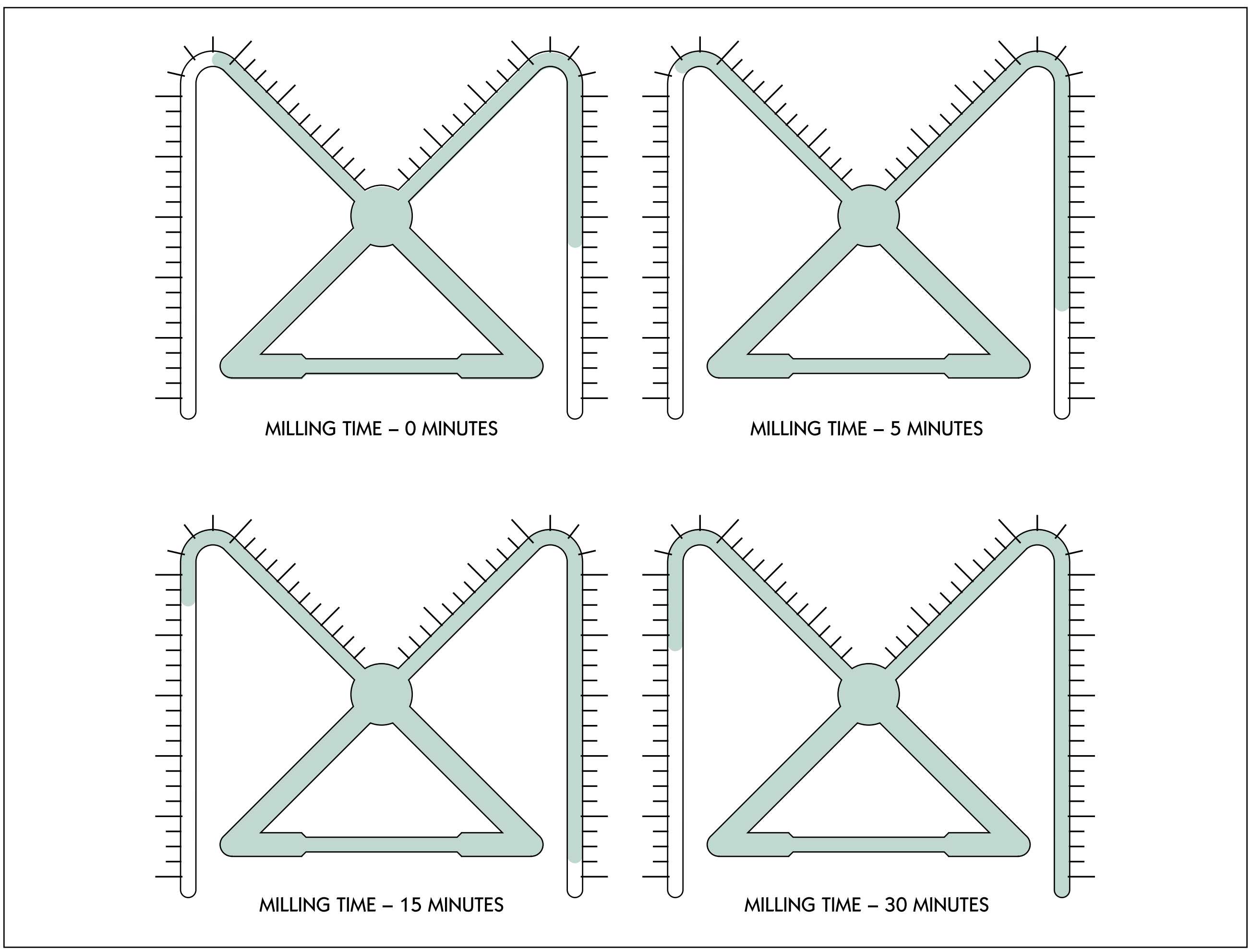
Ram pressure 50 psi (3.5 kg/sq. cm., 0.34 mPa)

Temperature˚F (˚C)	Mix Cycle	Time,Minutes
55 (13)	Add polymer	0
150 (66)	Add Zinc stearate*, Caytur 4, 1/2 black, 1/2 softener	1
200 (93)	Add remaining black and softener	3
265 (130)	Dump	5

Final Mix

Dump at 200˚F (93˚C), 3 minutes

FIGURE 3
EFFECT OF POLYMER BREAKDOWN ON TRANSFER MOLDING CHARACTERISTICS



EXTRUSION

Exceptionally smooth extrusion of **MILLATHANE CM** may be obtained through proper temperature control of the extruder. Excessive heat should be avoided at the barrel and screw sections in order to prevent thermal softening with resultant sticking and loss of back pressure.

If the head and die are too cold, there is considerable resistance to flow which produces a rough or wavy surface on the extrusion.

The following extruder temperatures are based on successful extruding operations both in the laboratory and in production:

SUGGESTED EXTRUSION TEMPERATURES

Screw	Cold Water
Barrel	140-160°F (60-71°C)
Head	170-190°F (77-88°C)
Die	190-210°F (88-99°C)

CALENDERING

Calendered sheets of compounds of **MILLATHANE CM** which are free from roughness and cold checks are obtained at calender temperatures above 140°F (60°C). As the temperatures are increased, better sheet smoothness is obtained. With some types of loading, compounds of **MILLATHANE CM** may tend to stick to the calender rolls when temperatures in the range of 180° to 200°F (82° to 93°C) are used. However, calender roll release can be improved considerably through the addition of 3 to 4 parts of a microcrystalline wax or a low molecular weight polyethylene and heating the calender rolls to 180° to 210°F (82° to 99°C).

While the building tack of uncured compounds of **MILLATHANE CM** urethane rubber is quite low at room temperatures, sufficient building tack for calender ply-up operations is obtainable at elevated temperatures. The bottom roll should be heated to provide necessary building tack during calender ply-up operations.

FRICTIONING

The construction of an all-**MILLATHANE CM** unit is often desirable —for example, in the case of conveyor belts or other fabric inserted items. Better over-all abrasion resistance is thus obtained and the extra solvent wiping or cementing procedures required to satisfactorily bond **MILLATHANE CM** to other elastomers often can be eliminated.

The formulation given in Table III is suggested for friction applications:

Table III
FRICTION COMPOUND FORMULATION

MILLATHANE CM	100.0
MT Carbon black	20.0
Polyisobutylene Tackifier[1]	20.0
Coumarone-indene resin[2]	20.0
Sulfur	0.75
MBTS	4.0
MBT	1.0
CAYTUR 4	0.7
Zinc Stearate*	0.5

[1] Vistanex LMMS was used.
[2] Cumar W 2 1/2 was used.

Cure 60 minutes at 287°F (142°C)

Physical Properties	
Hardness, durometer A	45
Modulus at 100%, psi (MPa)	160 (1.1)
Modulus at 300%, psi (MPa)	425 (2.9)
Tensile strength, psi (MPa)	2950 (20.3)
Elongation at break, %	600
Tear strength, ASTM D-624, Die C, lb./in. (kN/m)	150 (26.2)

Before mixing, the **MILLATHANE CM** should be pre-broken at temperatures between 150°F and 250°F (66°C and 121°C) for the proper reduction in viscosity (See page 4).

SUGGESTED CALENDER TEMPERATURES

Top roll	200° to 220°F (93° to 104°C)
Middle roll	230° to 250°F (110° to 121°C)
Bottom roll	140° to 150°F (60° to 66°C)

MOLDING

Compounds of **MILLATHANE CM** can be molded by conventional methods. Excellent mold definition is obtainable in press cures. The linear shrinkage of vulcanizates of **MILLATHANE CM** varies somewhat with the type of loading but, in general, this value is approximately 1.5%, which is comparable to that of Neoprene.

Optimum press cures are obtained with the sulfur system at temperatures from 287°F (142°C) to 307°F (153°C), with curing times ranging from 90 to 30 minutes. With the peroxide curing system, temperatures from 307°F (153°C) to 320°F (160°C) are suggested with cycles ranging from 45 to 15 minutes.

Excellent mold release is provided by Crystal® 1053.

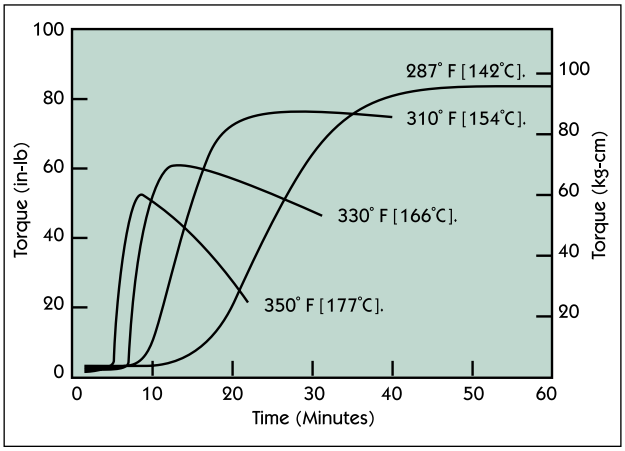
CURING

MILLATHANE CM urethane rubber may be cured by conventional methods.

PRESS CURING

The choice of time and temperature for curing molded goods is of the utmost importance. The best properties of **MILLATHANE CM** are obtained by curing at low temperatures. Although curing cycles may be reduced by curing at higher temperatures, there is usually a sacrifice in physical properties and an increased tendency towards reversion, as shown by the oscillating disc rheometer curves in Figure 4. The decrease in physical properties with increase in curing temperatures is shown in Table IV.

Figure 4
EFFECT OF CURING TEMPERATURE ON RATE AND STATE OF CURE



EFFECT OF CURING TEMPERATURE FORMULATION

MILLATHANE CM	100.0
N330 Carbon black	30.0
Coumarone-indene resin	15.0
MBTS	4.0
MBT	1.0
Sulfur	0.75
CAYTUR 4	0.35
Zinc stearate*	0.5

OPEN STEAM CURING

Compounds of **MILLATHANE CM** cured in open steam must be wrapped.
Steam-cured compounds are frequently softer than press cured compounds. (See Table V)

TABLE V
EFFECT OF CURING METHOD FORMULATION

MILLATHANE CM	100.0
N330 Carbon black	30
Coumarone-indene resin	15
Sulfur	0.75
MBTS	4
MBT	1
CAYTUR 4	0.35
Zinc stearate*	0.5

	Press 60 minutes at 287°F (142°C)	Open Steam 60 minutes at 60 psi [.41 MPa]
PHYSICAL PROPERTIES		
Hardness, durometer A	65	59
300% Modulus, psi [MPa]	2150 [14.8]	1750 [12.1]
Tensile strength, psi [MPa]	4600 [31.7]	5200 [35.9]
Elongation at break, %	480	560

Table IV
EFFECT OF CURING TEMPERATURE

Cure Temperature, °F (°C)	287 (142)	310 (154)	330 (166)	350 (177)
Cure Time, minutes	60	25	15	10
PHYSICAL PROPERTIES				
Hardness, durometer A	65	65	64	63
300% Modulus, psi [MPa]	1575 [10.8]	1300 [8.9]	1175 [8.1]	1025 [7.1]
500% Modulus, psi [MPa]	3550 [24.5]	3000 [20.7]	2700 [18.6]	2275 [15.7]
Tensile strength, psi [MPa]	5050 [34.8]	4900 [33.8]	4700 [32.4]	4125 [28.4]
Elongation at break, %	570	620	650	680
Compression Set, Method B, % after 22 hours at 158°F (70°C)	23	31	34	38

ADHESION

For bonding uncured **MILLATHANE CM** to itself, a solvent wash with methyl ethyl ketone will usually suffice in providing green building tack, unless the bond is to be put under considerable strain during curing. For severe green tack requirements, good results have been obtained by using the following cement formation:

ADHESION COMPOUND FORMULATION

MILLATHANE CM	100.0
N330 Carbon black	30.0
MBTS	4.0
MBT	1.0
Sulfur	2.0
Hercolyn D	25.0
Flexalyn 80M	31.0
Methyl ethyl ketone	742.0

ADHESION TO OTHER ELASTOMERS

In order to obtain a good bond between **MILLATHANE CM** and other elastomers, an adhesive must be applied to unvulcanized stocks. Upon co-vulcanization, the bond is affected. An adhesive that gives excellent cured adhesion of **MILLATHANE CM** urethane rubber is CHEMLOK 231[1], as shown by the data in Table VI.

Table VI
ADHESION STRENGTHS OF RUBBER MATERIALS

Substrate	Peel Strength (lb/in [kN/m])
MILLATHANE CM	>150 [26.2]
SBR	20 [3.5]
Natural rubber	25 [4.4]
Nitrile rubber	75 [13.1]
Neoprene WRT	15 [2.6]

ADHESION TO METALS

Compounds of **MILLATHANE CM** may be satisfactorily bonded to various metals. There are several commercially available cements which provide a high degree of adhesion[2]. An example of the bond strength that can be obtained is shown in the following tabulation comparing adhesion values to sandblasted aluminum and steel, using CHEMLOK 218.

	Aluminum	Steel
Unaged, pulled at R.T.	>195 lb./in. (34.1 kN/m)	>172 lb./in. (30.1 kN/m)

(In both cases the stock tore before the bond failed)

The surfaces to be bonded to **MILLATHANE CM** urethane rubber must be free from grease and moisture.

[1] Lord Corporation
[2] Chemlok 218, Chemlok 231 over 205

BASIC COMPOUNDING

VULCANIZATION

MILLATHANE CM, like natural rubber and SBR, can be cured with sulfur. With some modification, many conventional sulfur-accelerator curing systems can be used to obtain practical cures for **MILLATHANE CM**. One system which has produced desirable physical properties is a combination of sulfur, MBTS, MBT, CAYTUR 4 and zinc stearate*. It should be noted that zinc oxide and stearic acid are not necessary for activation. The following combination gives a desirable balance of physical properties:

VULCANIZATION FORMULATION

Sulfur	0.75
MBTS	4.0
MBT	1.0
CAYTUR 4	0.35
Zinc stearate*	0.5

The effect of varying these ingredients from the combination shown above is discussed below:

SULFUR

Increasing the concentration of sulfur produces a faster rate and a higher state of cure — better abrasion resistance, better dynamic properties, and high hardness — equivalent compression set, and somewhat poorer aging properties. Decreasing the sulfur content results in a drastically reduced state of cure. (See Figure 5 and Table VII)

Figure 5
EFFECT OF SULFUR ON RATE OF CURE

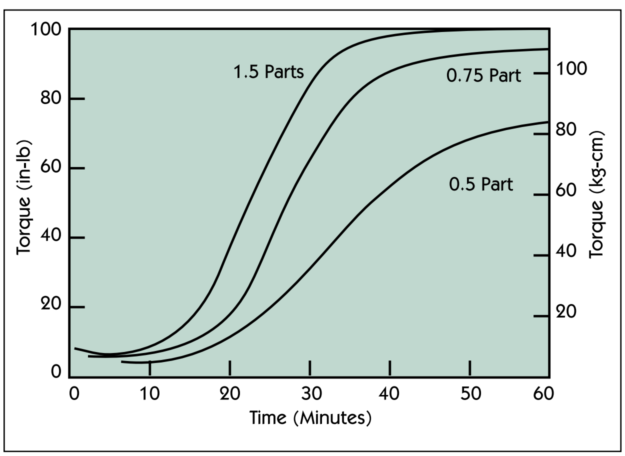


Table VII
EFFECT OF SULFUR CONCENTRATION ON PHYSICAL PROPERTIES

	1	2	3
MILLATHANE CM	100	100	100
N330 Carbon black	30	30	30
Coumarone-indene resin	15	15	15
MBTS	4	4	4
MBT	1	1	1
Zinc stearate*	0.75	0.75	0.75
CAYTUR 4	0.35	0.35	0.35
Sulfur	0.5	0.75	1.5
CURE: 60 minutes at 142°C			
Original Physical Properties			
Hardness, durometer A	65	65	68
300% Modulus, psi	1625	2125	2200
[MPa]	[11.2]	[14.7]	[15.2]
Tensile strength, psi	4825	4500	4275
[MPa]	[33.3]	[31.0]	[29.5]
Elongation at break, %	570	480	460
Compression Set, Method B, %			
After 22 hrs. at 158°F (70°C)	32	19	21
NBS Abrasion Index	250	335	380
Goodrich Flexometer, Heat			
Build-up, Internal Temp, °C	165	135	125
ΔT, °C (Platen)	75	60	58
After 7 Days at 212°F (100°C)			
Hardness, durometer A	63	68	69
300% Modulus, psi	1800	2825	---
[MPa]	[12.4]	[19.5]	---
Tensile strength, psi	4075	4050	3400
[MPa]	[28.1]	[27.9]	[23.4]
Elongation at break, %	500	390	290

MBTS AND MBT

A combination of MBTS and MBT gives the best balance of properties. An increase in the level of MBTS results in more processing safety and a high state of cure, as shown in Figure 6. On the other hand, an increase in the level of MBT results in a decrease in processing safety and a higher state of cure, as shown in Figure 7.

An increase in either MBTS or MBT has little or no effect on the rate of cure. The data shown in the figures were obtained on the following compound.

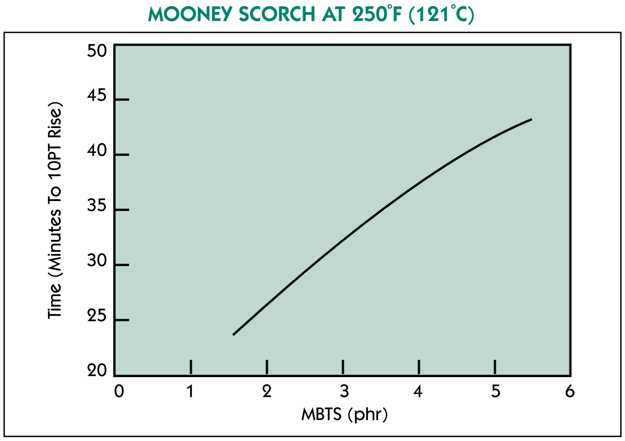
BASE COMPOUND FOR MBTS AND MBT

MILLATHANE CM	100
N330 Carbon black	30
Coumarone-indene resin	15
Sulfur	0.75
CAYTUR 4	0.35
Zinc stearate*	0.5
MBTS	As shown
MBT	As shown

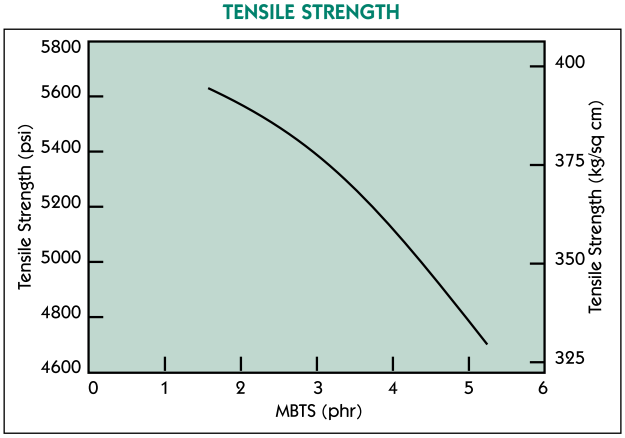
The best balanced system is one containing a high MBTS to MBT ratio, such as 4 to 1.

Figure 6
EFFECT OF MBTS ON PHYSICAL PROPERTIES
(MBT constant at one part)

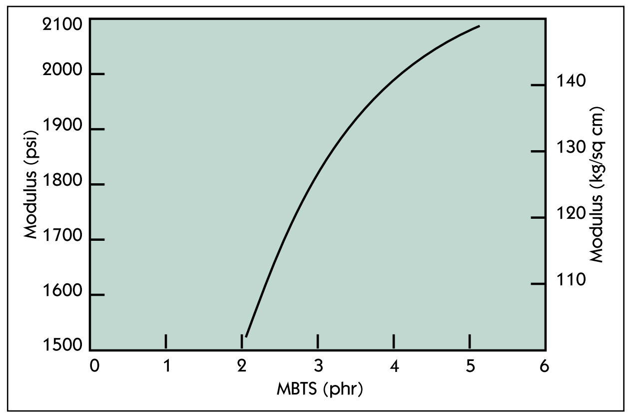
MOONEY SCORCH AT 250˚F (121˚C)



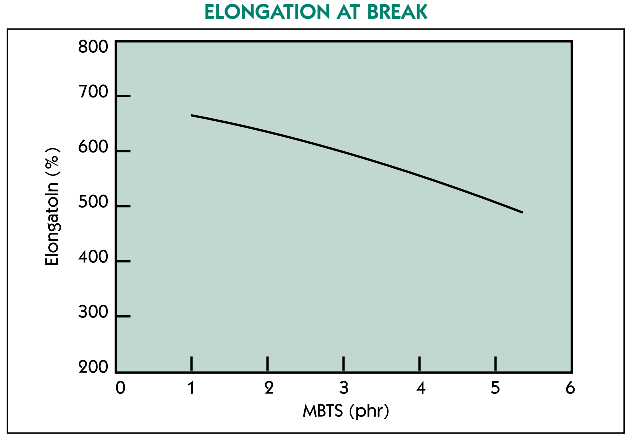
TENSILE STRENGTH



300% MODULUS



ELONGATION AT BREAK



CURE RATE

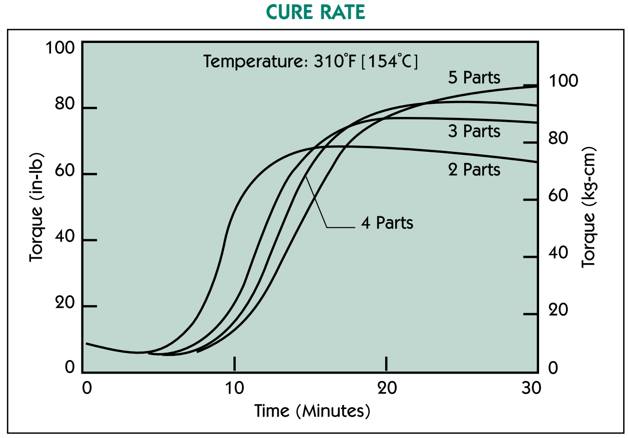
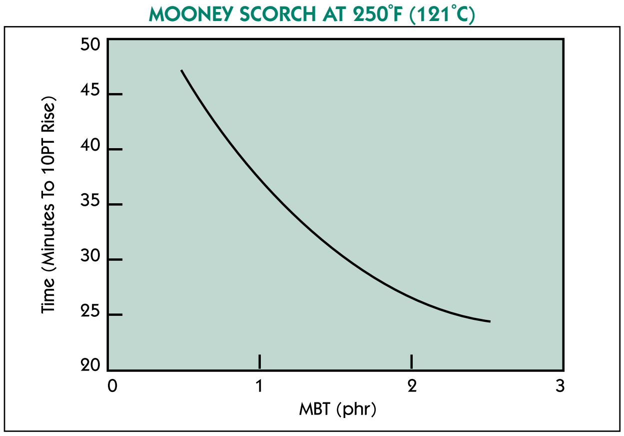
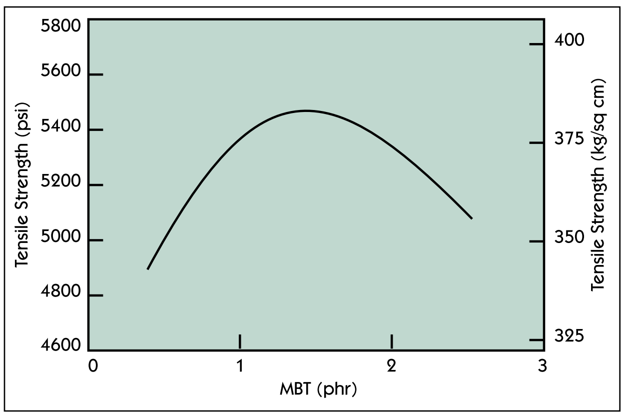


Figure 7
EFFECT OF MBT ON PHYSICAL PROPERTIES
(MBTS constant at four parts)

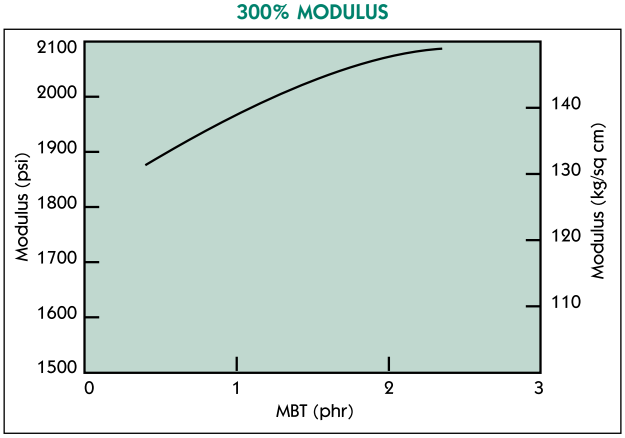
MOONEY SCORCH AT 250˚F (121˚C)



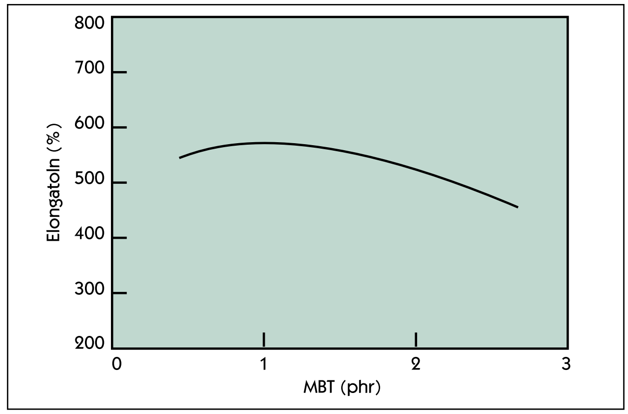
TENSILE STRENGTH



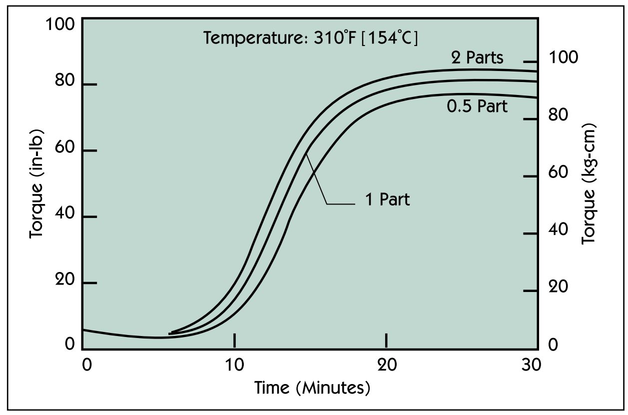
300% MODULUS



ELONGATION AT BREAK



CURE RATE



CAYTUR 4**

An activator containing zinc should be used to insure faster rates of cure in reasonable periods of time. Zinc diethyldithiocarbamate and zinc dibutyldithiocarbamate over the range of 0.1 to 1.0 phr have been used, but they do not give cures as satisfactory as the $ZnCl_2$/MBTS complex known as CAYTUR 4.

The improvement in the rate of cure of **MILLATHANE CM** imparted by the addition of CAYTUR 4 is shown by the data in Table VIII and the oscillating disc rheometer curves in Figure 8. As the concentration of CAYTUR 4 increases from 0.2 to 0.5 part per 100 parts of polymer, the rate of cure increases with no sacrifice in processing safety at 250˚F (121˚C).

For most practical applications, 0.35 part of CAYTUR 4 provides a good balance between cure rate and processing safety. As the concentration of CAYTUR 4 increases above 0.5 part, the cure rate improves only slightly but at the expense of processing safety.

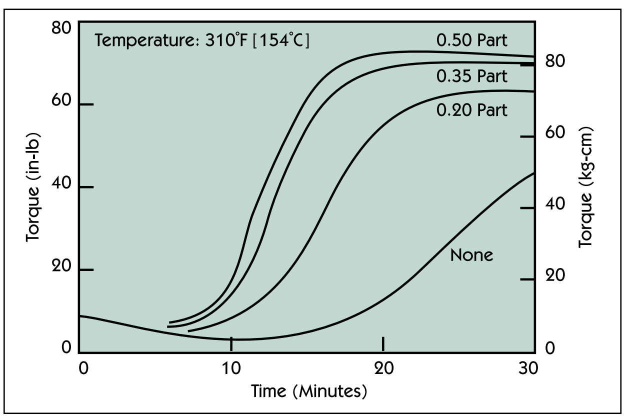
***Note: Caytur 4 is now known as Thanecure® ZM. Caytur is a registered trademark of Chemtura Corporation. Thanecure is a registered trademark of TSE Industries, Inc.*

Table VIII
EFFECT OF CAYTUR 4** ON PHYSICAL PROPERTIES

MILLATHANE CM	100
N330 Carbon black	30
Coumarone-indene resin	15
MBTS	4
MBT	1
Sulfur	0.75
CAYTUR 4	As shown
Zinc stearate*	0.5

CAYTUR 4	0	0.20	0.35	0.50
Mooney Scorch				
Time to 10 point rise, minutes				
At 250°F (121°C)	>30	>30	>30	>30
At 275°F (135°C)	30	25	20	18
Physical properties				
Cure: 60 minutes at 287°F (142°C)				
Hardness, durometer A	68	67	68	68
300% Modulus, psi	900	1900	2000	2200
[MPa]	[6.2]	[13.1]	[13.8]	[15.2]
Tensile strength, psi	3700	4700	5000	5105
[MPa]	[25.5]	[32.0]	[34.5]	[35.2]
Elongation at break, %	550	570	560	580
Tear strength,				
ASTM D-624 Die C, lb./in	370	375	380	360
[MPa]	[64.7]	[65.6]	[66.4]	[62.9]
NBS Abrasion Index	365	355	355	330
Compression Set, Method B,				
% after 22 hrs at 158°F (70°C)	24	22	24	25

Figure 8
EFFECT OF CAYTUR 4 ON RATE OF CURE

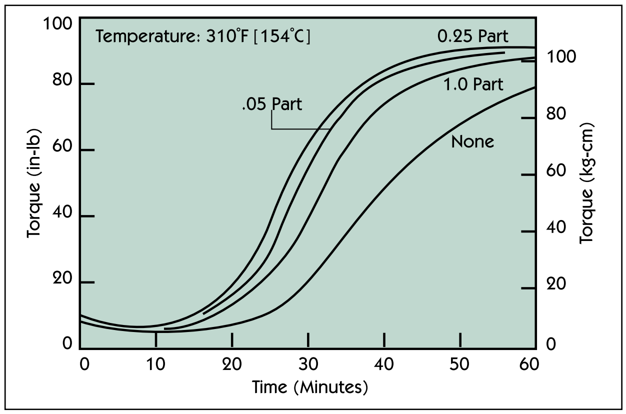


ZINC STEARATE*

Zinc stearate*, when used as a co-activator with CAYTUR 4 in the preferred sulfur curing system, permits shorter cure times with improved dynamic properties of the vulcanizate. Optimum modulus and tensile strength are obtained in approximately half the cure time when small amounts of zinc stearate* are used in conjunction with the usual 0.35 part/100 of CAYTUR 4. This increased rate of cure is illustrated by the oscillating disk rheometer curves in Figure 9. The curves also illustrate the diminishing effect of increased concentration. More than 0.5 part/100 of polymer appear to retard the cure and tend to interfere with adhesion to other elastomers.

In addition to increasing the rate of cure, zinc stearate* activation also produces a tighter cure. This improved state of cure at practical curing times is reflected in lower compression set and lower heat build-up.

Figure 9
EFFECT OF ZINC STEARATE ON RATE OF CURE



A RAPID CURING SYSTEM

The curing time of **MILLATHANE CM** urethane rubber with sulfur may be shortened through an adjustment in the concentration of sulfur and CAYTUR 4 rubber accelerator. Increasing the level of sulfur to 1.5 phr from the standard 0.75 and simultaneously increasing the level of CAYTUR 4 to 1.0 phr from 0.35 will reduce curing cycles by 50% at any temperature.

The processing safety and compression set resistance are not as great as the slower system, but are sufficient for most general industrial applications. In addition to the faster cure rate, the modified curing system provides a higher state of cure in both black and silica filled stock, as shown in Tables IX and X and Figures 10 through 13.

The use of the faster curing system is recommended in most instances where the slight sacrifice in processing safety and compression set can be tolerated.

***Note: Caytur 4 is now known as Thanecure® ZM. Caytur is a registered trademark of Chemtura Corporation. Thanecure is a registered trademark of TSE Industries, Inc.*

Table IX
COMPARISON OF CURING SYSTEMS IN BLACK FILLED COMPOUND

MILLATHANE CM	100
N330 Carbon black	30
Cumar W 2 1/2	15
MBTS	4
MBT	1
Zinc stearate*	0.5
Sulfur	As shown
CAYTUR 4	As shown

	A	B
Sulfur	0.75	1.5
CAYTUR 4	0.35	1

Mooney Scorch, MS at 250˚F (121˚C)		
Minimum	30	32
Minutes to a 10 point rise	>30	23

Physical Properties		
Cure time at 287˚F (142˚C), in min.	**60**	**30**
Hardness, Durometer A	63	66
100% Modulus, psi (MPa)	300 (2.1)	350 (2.4)
300% Modulus, psi (MPa)	1500 (10.3)	2000 (13.8)
500% Modulus, psi (MPa)	3500 (24.1)	4500 (31.0)
Tensile strength, psi (MPa)	5350 (36.9)	5800 (39.9)
Elongation, %	570	570
Compression Set, Method B, 22 hours / 70˚C, %	28	35
NBS Abrasion Index	300	350
Graves Tear, lb/in (kg/cm)	250 (44.5)	275 (48.9)

Physical Properties		
Cure Time at 310˚F (154˚C), in min.	**30**	**15**
Hardness, Durometer A	65	64
100% Modulus, psi (MPa)	275 (1.9)	400 (2.6)
300% Modulus, psi (MPa)	1350 (9.3)	1800 (12.4)
500% Modulus, psi (MPa)	3100 (21.4)	4250 (29.3)
Tensile strength, psi (MPa)	4900 (33.8)	5600 (38.6)
Elongation, %	620	550
Compression Set, Method B, 22 hours / 70˚C, %	35	35
NBS Abrasion Index	300	350
Graves Tear, lb/in (kg/cm)	250 (43.7)	250 (43.7)

Figure 10
OSCILLATING DISC RHEOMETER BLACK LOADED MILLATHANE CM

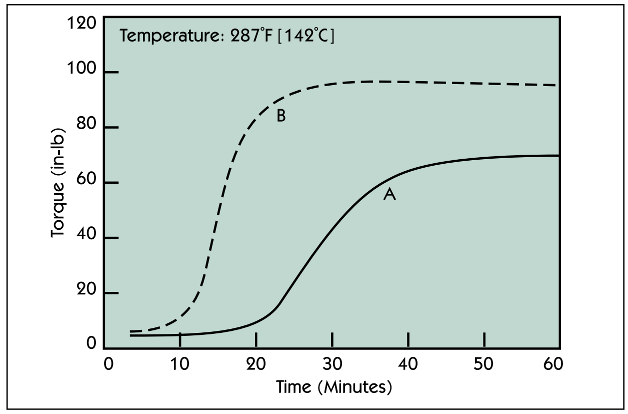


Figure 11
OSCILLATING DISC RHEOMETER BLACK LOADED MILLATHANE CM

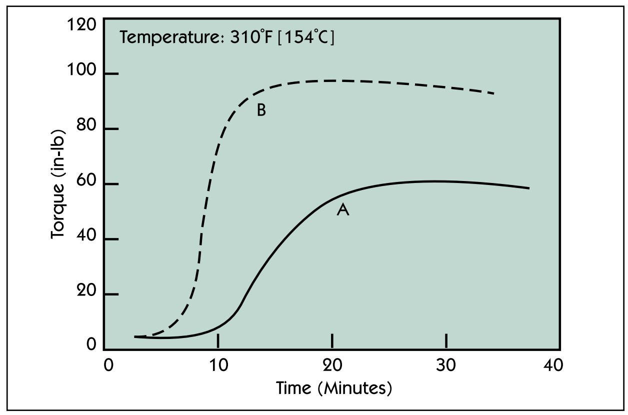


Figure 12
OSCILLATING DISC RHEOMETER SILICA LOADED MILLATHANE CM

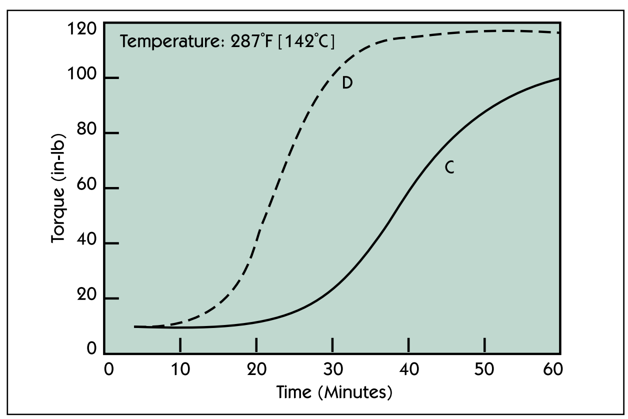


Figure 13
OSCILLATING DISC RHEOMETER
SILICA LOADED MILLATHANE CM

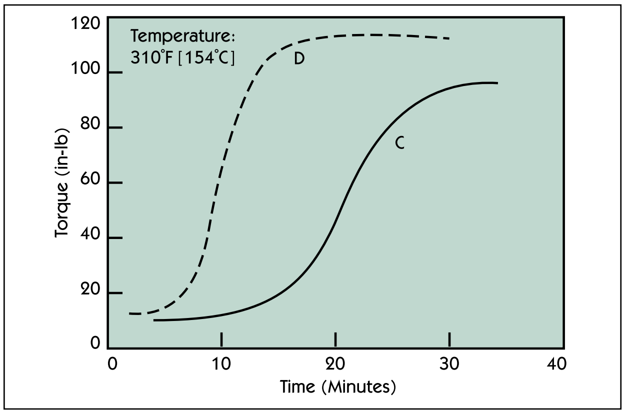


Table X
COMPARISON OF CURING SYSTEMS IN SILICA FILLED COMPOUND

MILLATHANE CM	100
Hi-Sil 233	45
Cumar W 2 1/2	15
MBTS	4
MBT	As shown
Sulfur	As shown
CAYTUR 4	As shown
Zinc stearate*	0.5

	C	**D**
Sulfur	0.75	1.5
CAYTUR 4	0.35	1
MBT	1	2
Mooney Scorch, MS at 250˚F (121˚C)		
Minimum	56	55
Minutes to a 10 point rise	>30	22
Physical Properties		
Cure Time at 310˚F (154˚C), in min.	**30**	**15**
Hardness, Durometer A	75	75
100% Modulus, psi (MPa)	300 (2.1)	325 (2.2)
300% Modulus, psi (MPa)	1050 (7.2)	1000 (6.9)
500% Modulus, psi (MPa)	2600 (17.9)	2850 (19.7)
Tensile strength, psi (MPa)	5000 (34.5)	5200 (35.9)
Elongation, %	630	600
Compression Set, Method B, 22 hours /70˚C, %	40	70
Graves Tear, lb/in (kN/m)	325 (56.8)	300 (52.4)

PEROXIDES

Compounds of **MILLATHANE CM** urethane rubber may be vulcanized with organic peroxides such as dicumyl peroxide. Normally, 1.5 phr is used. Curing temperatures above 290˚F (143˚C) are required because dicumyl peroxide is relatively inactive below this temperature. A comparison of a dicumylperoxide cure with a sulfur cured vulcanizate is shown in Table XI.

Although coumarone indene resins are efficient plasticizers in sulfur cured stocks, they cannot be used effectively with dicumylperoxide because of an interaction with the curing agent.

Plasticizers containing unsaturation generally should not be used with dicumylperoxide. Peroxide cures tend to give lower compression set than sulfur cures. Compounds containing dicumylperoxide, while safe handling below 250˚F (131˚C), become increasingly scorchy as the temperature increases.

Table XI
COMPARISON OF SULFUR AND PEROXIDE CURES

MILLATHANE CM	100	100	100
N330 Carbon black	30	30	30
Butyl Oleate	10	10	10
MBTS	4	-	-
MBT	1	-	-
Sulfur	0.75	-	-
CAYTUR 4	0.35	-	-
Zinc stearate*	0.5	-	-
Dicumylperoxide[1]	--	1.2	1.6
Cure 20 Minutes at 310˚F (154˚C)			
Physical Properties			
Hardness, durometer A	55	51	53
300% Modulus, psi (MPa)	725 (5.0)	625 (4.3)	1125 (7.8)
Tensile Strength, psi (MPa)	2900 (20.0)	2100 (14.5)	2500 (17.2)
Elongation at break, %	710	640	510
Compression set, Method B, 22 hours at 158˚F (70˚C), %	68	40	35

[1] Di-Cup 40 C was used

PLASTICIZERS

A number of materials function as plasticizers for **MILLATHANE CM**. These plasticizers improve the processibility and lower the cured modulus and hardness without seriously affecting other properties of the stock unless used in excessive amounts.

The high polarity of **MILLATHANE CM** urethane rubber limits the choice of plasticizers to those having polar groupings or a high aromatic content. The choice of a particular plasticizer depends in part on its volatility at the processing temperatures encountered during mixing. Phthalate esters and coumarone-indene resins have shown good plasticizing characteristics in factory operations.

The formulation in Table XII was used to compare the various plasticizers, and all compounds were cured for 60 minutes at 287°F (142°C). The various plasticizers evaluated are identified in Table XIII. Outstanding in this group is 1-D Heavy Oil[1] which provides a substantial reduction in modulus without appreciably lowering tensile strength.

[1]Neville Chemical Company

Table XII
TEST FORMULATION FOR PLASTICIZERS

	Parts by Weight
MILLATHANE CM	100
N330 Carbon black	30
Plasticizer	15
MBTS	4
MBT	1
Sulfur	0.75
CAYTUR 4	0.35
Zinc stearate*	0.50

Table XIII
IDENTIFICATION OF PLASTICIZERS EVALUATED

Trade Name	Chemical Name	Manufacturer	Sp. Gr.
Benzoflex T-150	Triethylene glycol dibenzoate	Velsicol Chemical Corp	1.17
TCP	Tricresyl phosphate	Ashland Chemical Co.	1.17
Cumar W 2 1/2	Coumarone indene resin	Neville Chemical Co.	1.14
1-D Heavy Oil	Coumarone indene	Neville Chemical Co.	1.05
DOP	Dioctyl phthalate	Dow Chemical/C.P. Hall	0.99
Hercoflex 600	Pentaerythritol fatty acid ester	Hercules, Inc.	1.00
Monoplex DPS	Dioctyl sebacat	Rohm and Haas Co.	0.91
Plasticizer SC	Triglycol ester of vegetable oil fatty acid	Drew Chemical Co	0.97
Plastolein 9057	di-iso-octyl azelate	Emery Industries	0.92
Sundex 790	Aromatic hydrocarbon oil	Sun Oil Co.	0.98
TP-95 Plasticizer	Di (Butoxy-ethoxy-ethyl) adipate	Rohm & Haas	1.01

As shown in Table XIV all the plasticizers reduce modulus, increase elongation and reduce hardness.

Table XIV
EFFECT OF PLASTICIZERS ON PHYSICAL PROPERTIES

Plasticizer	300 % Modulus Psi (MPa)	Tensile Strength Psi (MPa)	Elongation at Break, %	Hardness Durometer A
No Plasticizer	2825 (19.5)	4000 (27.6)	420	70
Benzoflex T-150	2000 (13.8)	4500 (31.0)	480	61
TCP	2050 (14.1)	4050 (27.9)	480	64
Cumar W 2 1/2	2275 (15.7)	5000 (34.5)	510	67
1-D Heavy Oil	1250 (8.6)	4600 (31.7)	610	60
DOP	1900 (13.1)	3800 (26.2)	470	62
Hercoflex 600	1850 (12.8)	4025 (27.8)	470	60
Monoplex DOS	1750 (12.1)	3500 (24.1)	460	61
Plasticizer SC	1750 (12.1)	4050 (27.9)	480	60
Plastolein 9057	1850 (12.8)	4000 (27.6)	470	60
Sundex 790	1700 (11.7)	4550 (31.4)	540	62
TP-95 Plasticizer	1725 (11.9)	3975 (27.4)	510	55

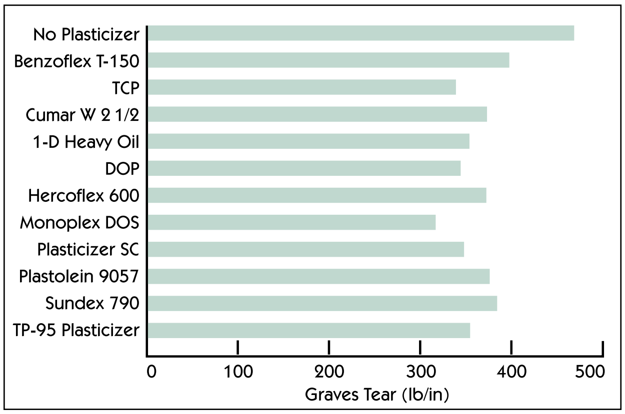
AGING CHARACTERISTICS

No one plasticizer seriously impairs aging resistance of **MILLATHANE CM** although there are differences among them with respect to percent of change in properties after aging. The effect of various plasticizers on the aging of **MILLATHANE CM** urethane rubber vulcanizate is shown in Table XV.

TEAR RESISTANCE

All of the plasticizers evaluated reduce tear strength somewhat from that of the unplasticized control, as shown in Figure 14.

Figure 14
EFFECT OF PLASTICIZERS ON TEAR STRENGTH



MOONEY VISCOSITY

MILLATHANE CM is a tough polymer which, if unplasticized, may reach high temperatures during processing.
All of the plasticizers evaluated gave a viscosity reduction of 10 points of more, with consequent reduction in processing temperatures. 1-D Heavy Oil offers the greatest reduction in viscosity.

LOW TEMPERATURE PROPERTIES

The ester plasticizers in general gave good low temperature flexibility. Only one plasticizer, Cumar W 2 1/2, gave a stock which stiffened at a higher temperature than the control. In Figure 15 the various plasticized stocks are compared on the basis of the temperature reduction required to increase the modulus of rigidity in torsion to 10,000 psi (68.9 MPa) using the Clash-Berg test.

All stocks, including the control, passed the Solenoid brittleness test at -78˚F (-61˚C).

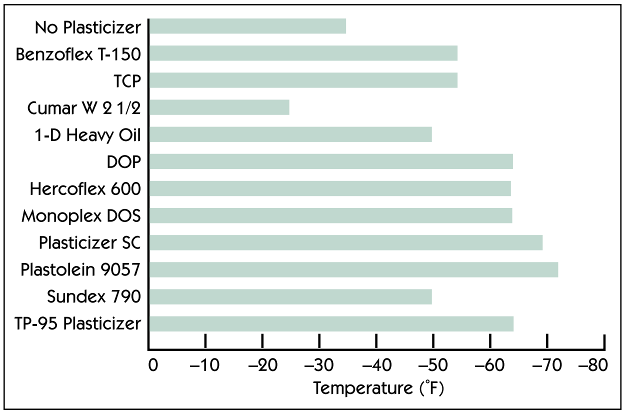
FILLERS

Unlike liquid urethane elastomers, **MILLATHANE CM** urethane rubber requires reinforcing fillers to develop optimum strength and abrasion resistance. However, pronounced reinforcement is obtained with low concentrations of carbon black and to a lesser extent with certain mineral fillers.

Table XV
AGING CHARACTERISTICS
AGED IN AIR AT 212˚F (100˚C) FOR 4 DAYS

Plasticizer	300% Modulus psi (MPa)	% Change	Tensile Strength psi (MPa)	% Change	Elongation of Break %	% Change	Hardness Durometer A	Points Change
No plasticizer	--	--	3650 (25.2)	-17	290	-31	73	+3
Benzoflex T-150	2500 (17.2)	+25	3600 (24.8)	-20	350	-27	62	+1
TCP	2650 (18.3)	+29	3650 (25.2)	-10	360	-25	65	-1
Cumar W 2 1/2	2500 (17.2)	+10	4425 (30.5)	-11	440	-13	65	-2
1-D Heavy Oil	1800 (12.4)	+44	3200 (22.1)	-30	470	-23	63	+3
DOP	2625 (18.1)	+38	3300 (22.8)	-13	350	-26	63	+1
Hercoflex 600	2500 (17.2)	+35	3550 (24.5)	-12	370	-21	63	+3
Monoplex DOS	2350 (16.2)	+34	2650 (18.3)	-24	310	-33	63	+2
Plasticizer SC	2300 (15.9)	+31	3450 (23.8)	-15	370	-23	59	-1
Plastolein 9057	2500 (17.2)	+35	3050 (21.0)	-24	310	-34	63	+3
Sundex 790	2250 (15.5)	+32	4050 (27.9)	-11	430	-20	62	0
TP-95 Plasticizer	2400 (16.5)	+39	3500 (24.1)	-12	360	-30	63	+8

Figure 15
EFFECT OF PLASTICIZERS ON CLASH-BERG TORSIONAL STIFFNESS



CARBON BLACK

MILLATHANE CM responds to various types of carbon black loading in the same manner as does SBR. The qualitative effect of various carbon blacks on several properties of vulcanizates of **MILLATHANE CM** is shown in Table XIX. More extensive filler loading tables and curves are included in the Appendix (Page 23).

All of the carbon blacks investigated in this study imparted some reinforcement to stocks of **MILLATHANE CM** with optimum effect at a loading of about 30 phr. N220, N330 and N339 carbon blacks were more effective than N774 and N990 carbon blacks.

Cumar W 2 1/2 was used as the plasticizer throughout the evaluation. In nonloaded stocks, Cumar W 2 1/2 was found to enhance tensile strength and tear resistance at room temperature.

NON-BLACK FILLERS

The non-black mineral fillers are mostly non-reinforcing in **MILLATHANE CM**, except for a fine silica[1] and to some extent a fine magnesium silicate[2]. Fine silica is comparable to carbon black in its effect on tensile strength but gives less improvement in tear and abrasion resistance. The fillers retard the cure considerably and have an adverse effect on resistance to compression set at levels greater than 30 phr. (See Appendix, page 23).

[1] Hi-Sil 233

[2] Mistron Vapor

Table XVI
EFFECTS OF VARIOUS CARBON BLACKS ON INDIVIDUAL PROPERTIES OF TYPICAL VULCANIZATES OF MILLATHANE CM

In order of Increasing Viscosity	In order of Increasing Hardness
N990	N990
N774	N774
N650	N650
N339	N339
N330	N330
N220	N220

In order of increasing Modulus	In order of Increasing Tensile Strength
N990	N774
N774	N650
N650	N990
N339	N339
N330	N330
N220	N220

In order of Increasing Elongation at Break	In order of Increasing Tear Strength
N220	N990
N330	N774
N650	N650
N339	N339
N774	N330
N990	N220

In order of Increasing Resistance to Compression Set	In order of Increasing Abrasion Resistance
N339	N990
N220	N774
N650	N650
N774	N339
N330	N330
N990	N220

VULCANIZATE PROPERTIES

A number of properties of typical vulcanizates of **MILLATHANE CM** are discussed more specifically to guide the compounder in his selection of an elastomer for specific end product applications.

ABRASION RESISTANCE

The outstanding resistance of urethane rubbers to abrasive wear is well known. It is significant that compounds of **MILLATHANE CM** urethane rubber can be processed on factory equipment and still retain the innate toughness desired for maximum service life. As with other elastomers, **MILLATHANE CM** is compounded for maximum abrasion resistance by using reinforcing fillers, such as N330, N220 and N339 carbon blacks. Of the non-black fillers, the silica type, (e.g. Hi-Sil-233) is best.

The following compound is desirable for applications requiring maximum resistance to abrasion commensurate with other desired properties:

COMPOUND FOR ABRASION RESISTANCE

MILLATHANE CM	100
N330 Carbon black	30
Coumarone-indene resin	15
MBTS	4
MBT	1
CAYTUR 4	0.35
Sulfur	0.75
Zinc stearate*	0.5

When properly cured, this compound will have an abrasion index of 300, measured by the National Bureau of Standard Abrasion Apparatus (ASTM D-1630).

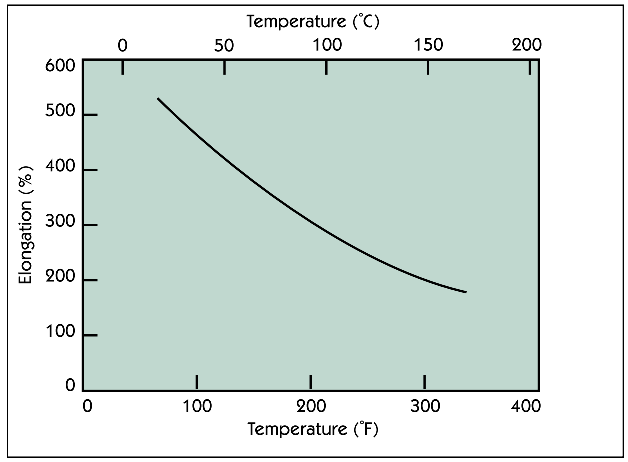
Numerous tests on products, such as hose, packings, shoes and conveyor belts, have confirmed the high abrasion resistance of **MILLATHANE CM** when compared with high quality vulcanizates based on other elastomers.

ELEVATED TEMPERATURE RESISTANCE

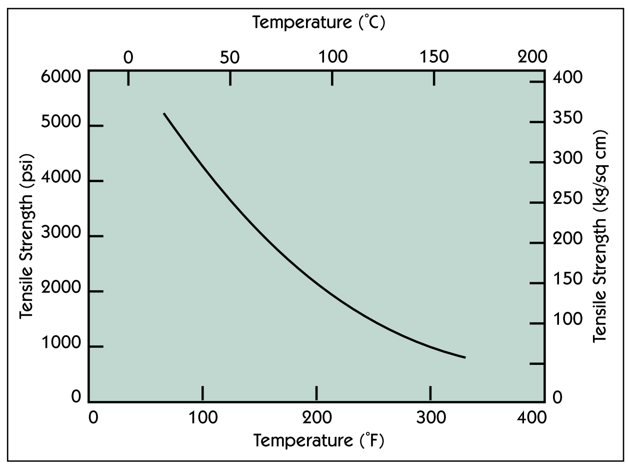
MILLATHANE CM has good properties in a temperature range of 250°F to 300°F (121°C to 149°C). The properties measured at elevated temperatures are shown in Figure 16. In each chart, a single curve represents the performance of a typical vulcanizate of **MILLATHANE CM**. The data shown in Figure 16 were obtained at the temperature indicated, as soon as the specimen reached equilibrium.

Figure 16
PHYSICAL PROPERTIES AT ELEVATED TEMPERATURES

ELONGATION AT BREAK



TENSILE STRENGTH



HEAT RESISTANCE

Vulcanizates of **MILLATHANE CM** display acceptable retention of properties after aging at temperatures up to 250°F (121°C). Figure 17 indicates that although there is a gradual decrease in tensile strength and ultimate elongation as aging temperatures are increased, the properties retained are still ample to provide adequate performance for many applications.

LOW TEMPERATURE PERFORMANCE

Vulcanizates of **MILLATHANE CM** resist stiffening and embrittlement at subnormal temperatures. Conventional low-temperature plasticizers offer a means of improving these properties even further, as shown in Figure 15 on page 17 and Table XVII below. Since vulcanizates of **MILLATHANE CM** urethane rubber do not crystallize, products having low temperature performance comparable to those of natural rubber can be produced.

FLUID RESISTANCE

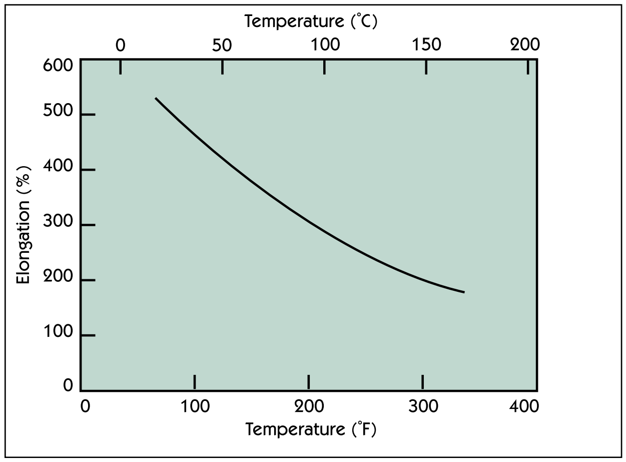
Vulcanizates of **MILLATHANE CM** have good resistance to deterioration in the presence of hydrocarbon oils and fuels, as well as a number of other classes of chemicals to which rubber products are often exposed. They compare very favorably in the respect with nitrile rubber compositions, as shown in Table XVIII. Vulcanizates of **MILLATHANE CM** urethane rubber have good retention of physical properties after immersion.

A typical N330 carbon black stock cured with dicumylperoxide and aged in ASTM Oil No. 903 for 70 hours at 212°F (100°C) retained 73% of its tensile strength and 86% of its elongation.

In Table XVIII, the swelling of a typical vulcanizate of **MILLATHANE CM** is compared to that of a high acrylonitrile NBR vulcanizate in a variety of fluids. Except where otherwise indicated, the immersion tests were conducted at 75°F (24°C).

Figure 17
PHYSICAL PROPERTIES AFTER 7 DAYS ACCELERATED AGING

ELONGATION AT BREAK



TENSILE STRENGTH

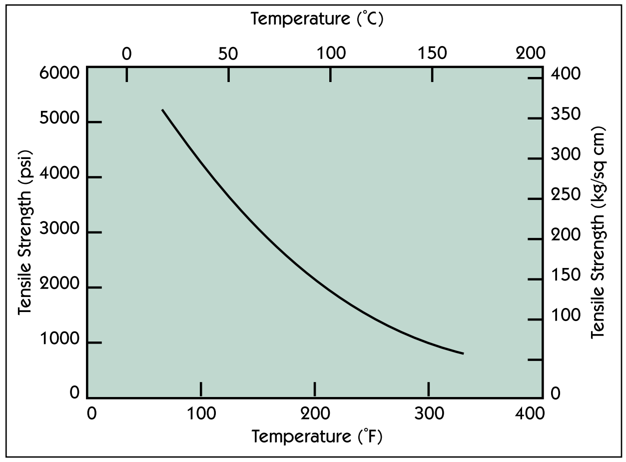


Table XVII
LOW TEMPERATURE PROPERTIES

	MILLATHANE CM No Plasticizer	MILLATHANE CM + 10 parts Butyl Oleate	Natural Rubber No Plasticizer
Du Pont Solenoid Brittleness Test ASTM D 746-44T, °F, (°C)	OK at -80 (-62)	OK at -80 (-62)	Broke at -80 (-62)
Temperature required to reach 10,000 psi [68.9 MPa] modulus in torsion, °F, (°C)	-35 (-37)	-55 (-48)	-64 (-54)

Table XVIII
A COMPARISON OF THE EFFECTS OF VARIOUS CHEMICALS ON THE SWELL OF MILLATHANE CM AND NITRILE RUBBER

	—Percent Swell at Equilibrium—	
	Nitrile Rubber	**MILLATHANE CM**
OILS AND FUELS		
ASTM 901 Oil at R.T.	0	0
ASTM 901 Oil at 212 °F [100°C]	0	0
ASTM 903 Oil at R.T	10	4
ASTM 903 Oil at 212 °F [100°C]	17	15
ASTM Ref. Fuel B	30	35
Kerosene at R. T.	10	15
Kerosene at 158°F [70°C]	10	20
JP-4	19	20
SOLVENTS AND CHEMICALS		
Cyclohexane	17	30
Aniline	315	265
Ethyl alcohol	4	65
Trichloroethylene	165	210
Methylene chloride	200	200
Tricresylphosphate	190	45
Carbon tetrachloride	9	125
Toluene	144	145
Dioctyl sebacate	10	10
Amyl acetate	115	125
Methyl ethyl ketone	180	125
Naphtha	15	20
Turpentine	30	55
ACIDS AND BASES		
Glacial acetic acid	60	230
Concentrated hydrochloric acid	26	Dissolved
50% Sulfuric acid	0	Dissolved
20% Nitric acid	10 Very Stiff	Dissolved
20% Sodium hydroxide	0	0
MISCELLANEOUS		
Wagner 21B Brake Fluid	40	120
Esso Type A Transmission Fluid	4	0
Water at 212°F (100°C)	20	10

OZONE RESISTANCE AND WEATHERING

Carbon black-loaded vulcanizates of **MILLATHANE CM** have very good ozone resistance and weatherability, as shown by laboratory ozone chamber tests, and outdoor exposure of test specimens in Florida. The effect of two concentrations of ozone is shown in Table XIX.

Table XIX
OZONE RESISTANCE

Ozone Resistance – Tapered die, 20% Elongation	
1 PPM Concentration	170 hours to trace cracking, no further change in 270 hours
100 PPM Concentration	4 hours to trace cracking, 8 hours to slight, 170 hours to noticeable, no further change in 270 hours.

ELECTRICAL PROPERTIES

The electrical properties of **MILLATHANE CM** are not as good as those of most other elastomers, but they are adequate for certain applications. To assist the compounder in judging what performance may be expected, the electrical properties of vulcanizates of **MILLATHANE CM** are compared with those of Neoprene and natural rubber. The comparisons are based on typical insulation-type compounds.

Table XX
ELECTRICAL PROPERTIES

	Resistivity ohm-cm	Specific Inductive Capacity (at 1000 Hz)	Power Factor (at 100 Hz)
Natural rubber	1015	2.5	.005
Neoprene GN	1012	6.7	.025
MILLATHANE CM	1010	10.2	.08

TEAR STRENGTH

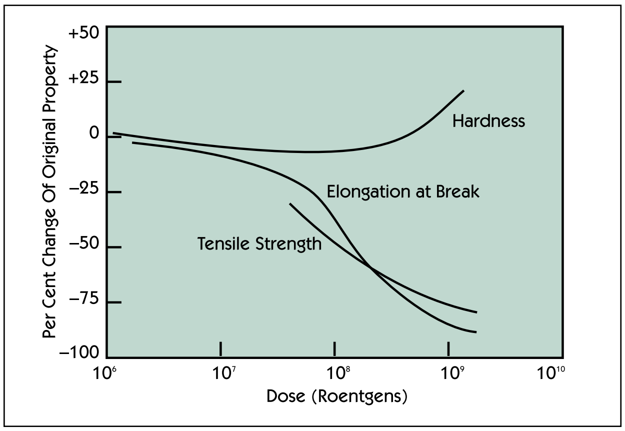
Vulcanizates of **MILLATHANE CM** have high tear strength. However, as with other elastomers, the magnitude of the tear resistance will depend on the type and degree of loading and with the amount and type of plasticizer (see Figure 14 on page 16). In general, N330 carbon black provides the best tear strength among the black fillers, and Hi-Sil-233 among the non-black fillers. The effect of various fillers on the tear strength of **MILLATHANE CM** urethane rubber is shown in the filler-loading tables in the Appendix (page 23).

RADIATION RESISTANCE[1]

MILLATHANE CM is superior to other elastomers with regard to degradation by exposure to gamma-ray radiation. Even at the relatively large doses of 1 x 10^9 Roentgens, **MILLATHANE CM** urethane rubber will give satisfactory service. Both the tensile strength and the elongation at break decrease with increasing radiation exposure; the hardness, however, decreases somewhat until, at a dose of about 15 x 10^8 Roentgens, it increases with an increase in radiation. (See Figure 18 below)
In general, compounding ingredients have been found to have little effect on radiation degradation, except that compounds which have been cured with peroxide have considerably less resistance.

[1]Data and information obtained from R. Harrington, Rubber Age, Vol. 82, page 461.

Figure 18
EFFECT OF GAMMA RADIATION ON PHYSICAL PROPERTIES



HYDROLYTIC STABILITY

MILLATHANE CM polyether urethane rubber combines the physical properties characteristic of high quality urethanes with excellent resistance to hydrolysis. This has been demonstrated by laboratory immersion tests and confirmed by field tests. Ester urethanes appear to be attacked at the water sensitive ester groups, while hydrolysis of **MILLATHANE CM** can occur only at the more hydrolytically stable urethane groups.
The effect of aging a sample of a vulcanizate of **MILLATHANE CM** in boiling water is shown in Figure 19 and Table XXI.

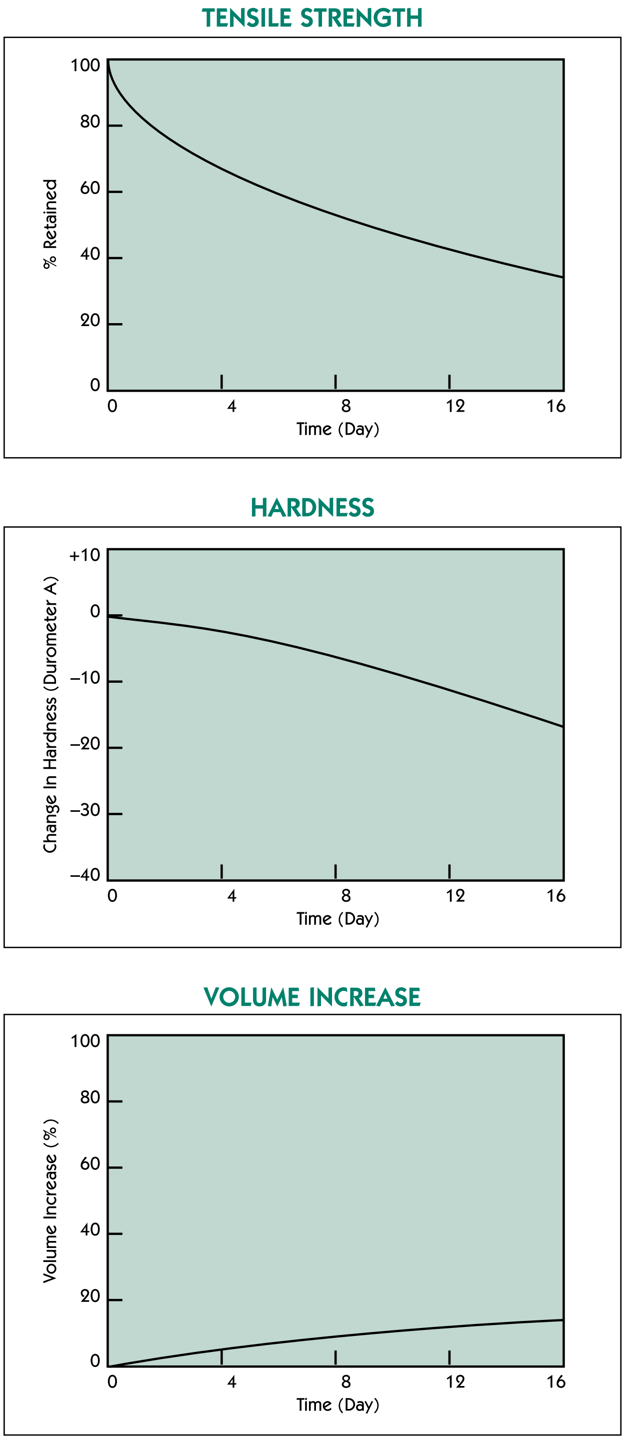
HYDROLYTIC STABILITY FORMULATION

MILLATHANE CM	100
N330 Carbon black	30.0
Coumarone-indene resin	15
MBTS	4
MBT	1
Sulfur	0.75
Caytur 4	0.35
Zinc stearate*	0.50

Table XXI
HYDROLYTIC STABILITY

Vulcanizate Properties – original	
Hardness, durometer A	64
100% Modulus, psi [MPa]	350 [2.4]
300% Modulus, psi [MPa]	1650 [11.4]
Tensile strength, psi [MPa]	5000 [34.5]
Elongation at break, %	580
After immersion in boiling water for 3 days	
Hardness, durometer A	62
(Hardness change)	(-2)
100% Modulus, psi [MPa]	300 [2.1]
300% Modulus, psi [MPa]	1450 [10.0]
Tensile strength, psi [MPa]	3075 [21.2]
(% retained)	(61)
Elongation at break, %	500
(% retained)	(86)
Volume increase, %	6
After immersion in boiling water for 7 days	
Hardness, durometer A	57
(Hardness change)	(-7)
100% Modulus, psi [MPa]	225 [1.6]
300% Modulus, psi [MPa]	1325 [9.1]
Tensile strength, psi [MPa]	2900 [20.0]
(% retained)	(58)
Elongation at break, %	490
(% retained)	(85)
Volume increase, %	10
After immersion in boiling water for 14 days	
Hardness, durometer A	50
(Hardness change)	(-14)
100% Modulus, psi [MPa]	175 [1.2]
300% Modulus, psi [MPa]	1150 [8.0]
Tensile strength, psi [MPa]	1800 [12.4]
(% retained)	(36)
Elongation at break, %	410
(% retained)	(61)
Volume increase, %	18

Figure 19
EFFECT OF AGING IN BOILING WATER



FLAME RESISTANCE

MILLATHANE CM burns readily, unless specifically compounded for flame resistance. Mineral fillers, in general, are desired, and flame resistance improves with increasing amounts of filler. The best mineral filler evaluated is a hydrated alumina. A fine particle silica, on the other hand, is quite ineffective. Petroleum or hydrocarbon plasticizers should be avoided. Good plasticizers which increase the flame resistance of **MILLATHANE CM** include chlorinated paraffins and chlorinated polyphenyls.

*USE OF ZINC STEARATE

Please Note: Although zinc stearate is shown in these formulas, the data was generated using cadmium stearate. The two stearates will give generally comparable properties, but we do not recommend the use of cadmium stearate because of the health risks associated with cadmium compounds.

APPENDIX

FORMULATION FOR FILLER EVALUATION IN MILLATHANE CM

MILLATHANE CM	100
Filler	Variable
Coumarone-indene resin	1/3 black wt.
MBTS	4
MBT	1
Sulfur	0.75
CAYTUR 4	0.35
Zinc stearate*	0.5

CURE:

Black loaded stocks: 60 minutes at 287°F [142°C]

Non-Black loaded stocks: 90 minutes at 287°F[142°C]

Figure 20
EFFECT OF CARBON BLACK FILLER LOADING ON HARDNESS

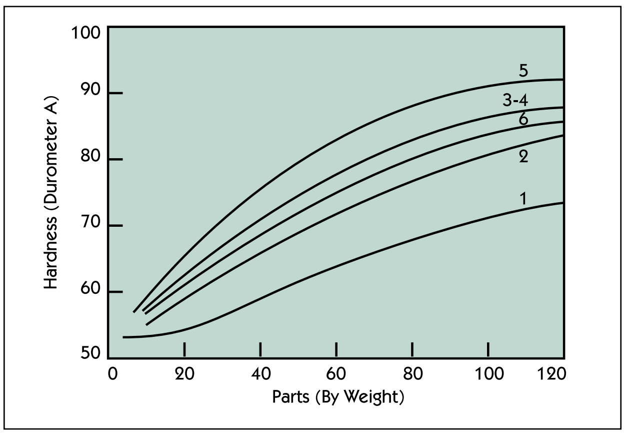


Figure 21
EFFECT OF CARBON BLACK FILLER LOADING ON MOONEY VISCOSITY

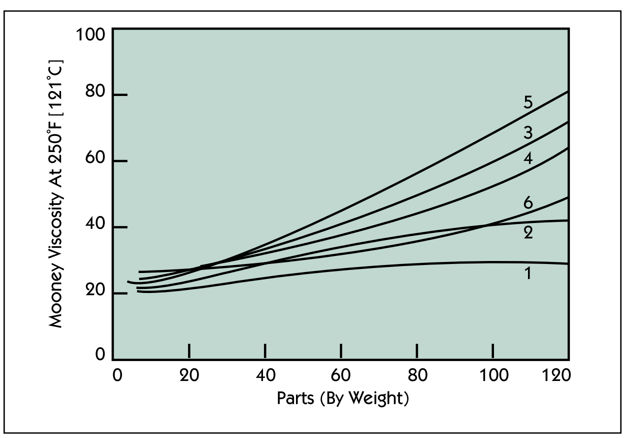


Figure 22
EFFECT OF CARBON BLACK FILLER LOADING ON 300% MODULUS

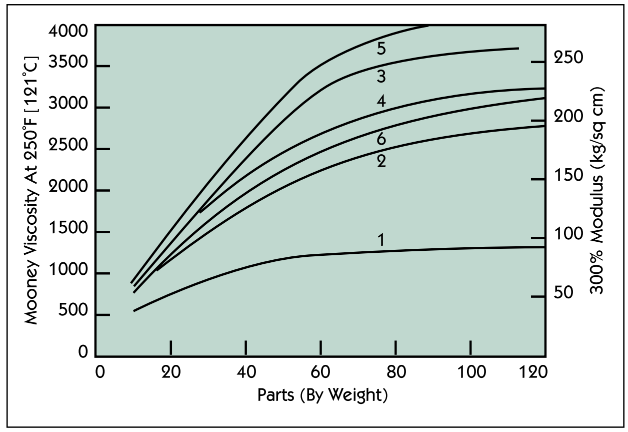


Figure 23
EFFECT OF CARBON BLACK FILLER LOADING ON TENSILE STRENGTH

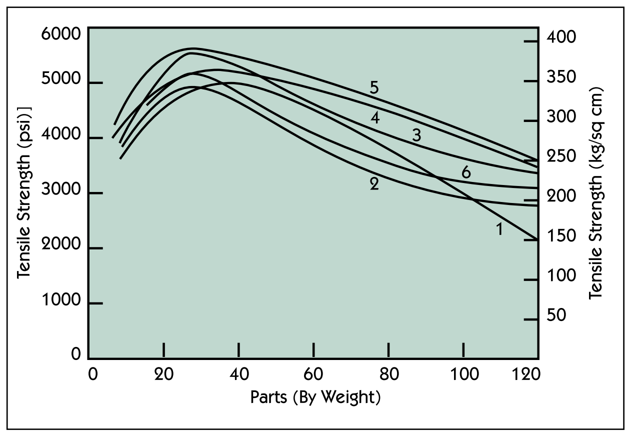


Figure 24
EFFECT OF CARBON BLACK FILLER LOADING ON ELONGATION AT BREAK

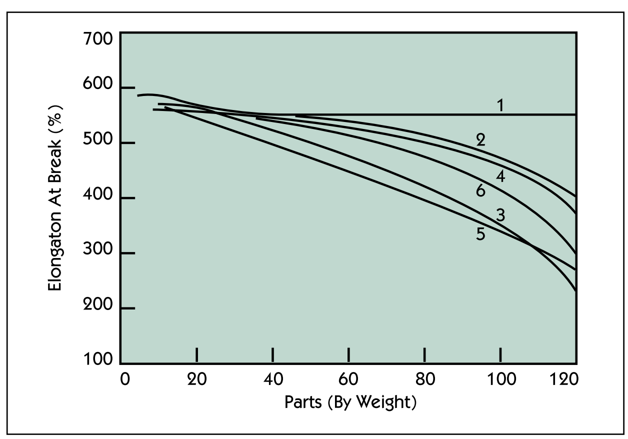


Figure 25
EFFECT OF CARBON BLACK FILLER LOADING ON COMPRESSION SET

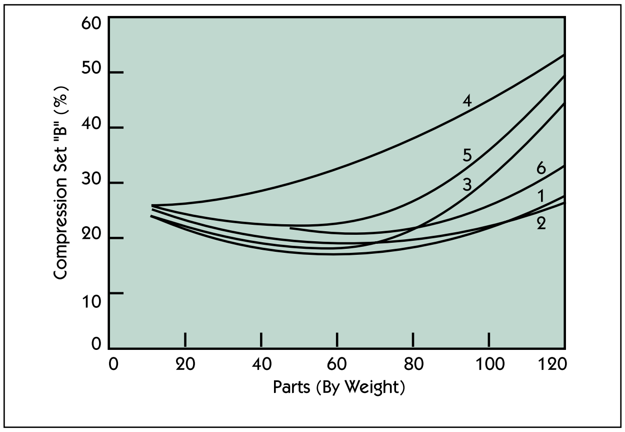


Figure 26
EFFECT OF CARBON BLACK FILLER LOADING ON TEAR STRENGTH

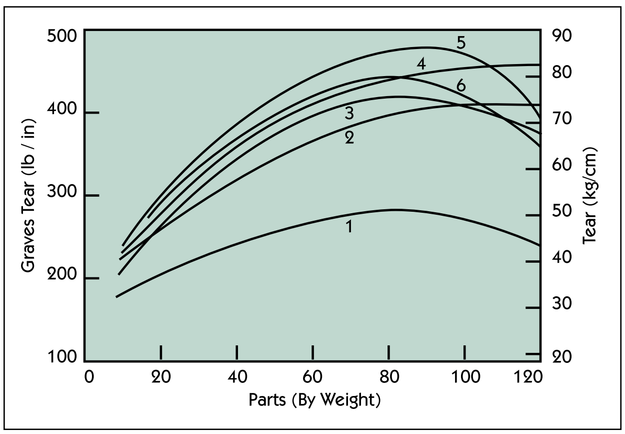
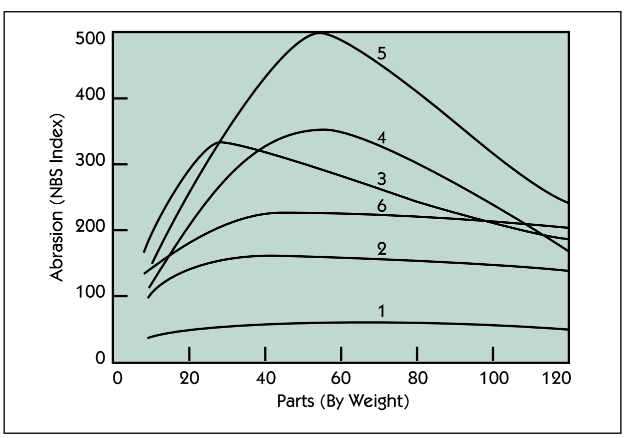


Figure 27
EFFECT OF CARBON BLACK FILLER LOADING ON ABRASION RESISTANCE



Legend

1 – N990 **3** – N330 **5** – N220
2 – N774 **4** – N339 **6** – N650

Figure 28
EFFECT OF NON-BLACK FILLER LOADING ON HARDNESS

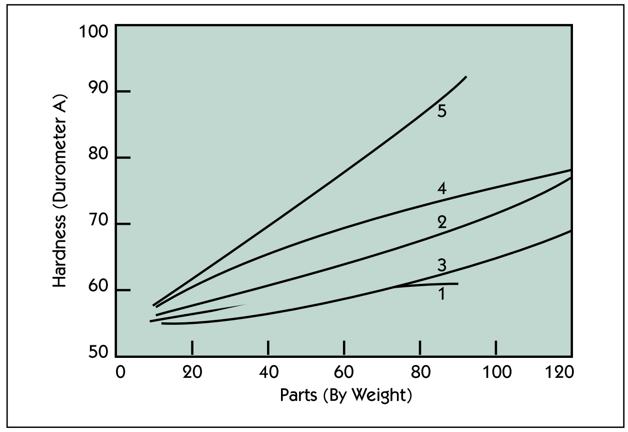


Figure 29
EFFECT OF NON-BLACK FILLER LOADING ON MOONEY VISCOSITY

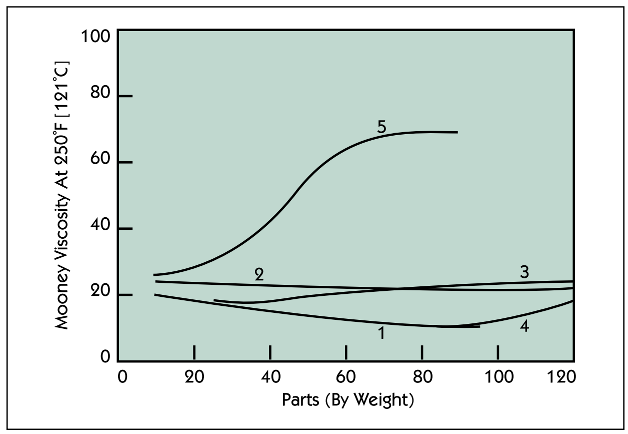
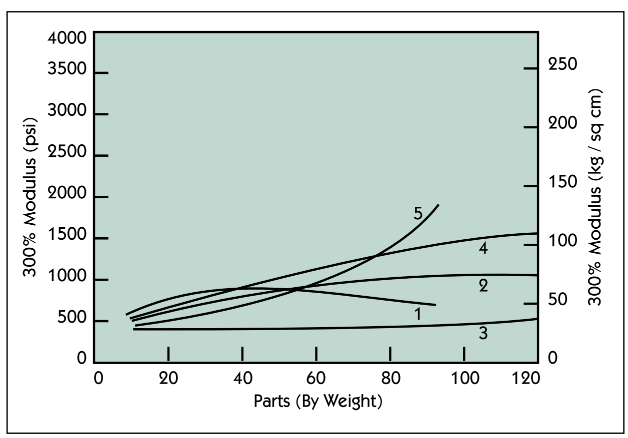


Figure 30
EFFECT OF NON-BLACK FILLER LOADING ON 300% MODULUS



Legend

1 – SUPREX CLAY **3** – ATOMITE WHITING
2 – ICEBERG CLAY **4** – MISTRON VAPOR
5 – HI-SIL 233

Figure 31
EFFECT OF N0N-BLACK FILLER LOADING ON TENSILE STRENGTH

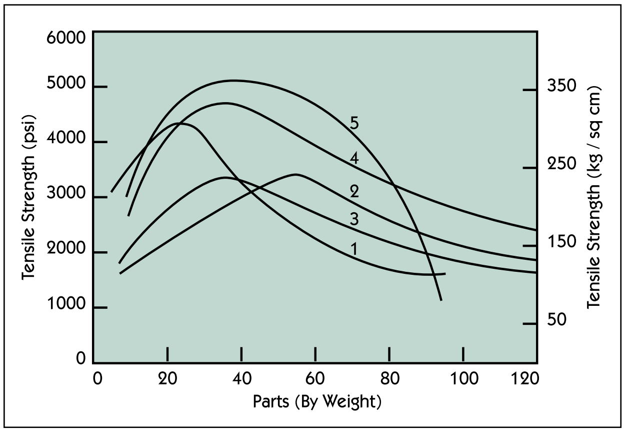


Figure 33
EFFECT OF N0N-BLACK FILLER LOADING ON COMPRESSION SET

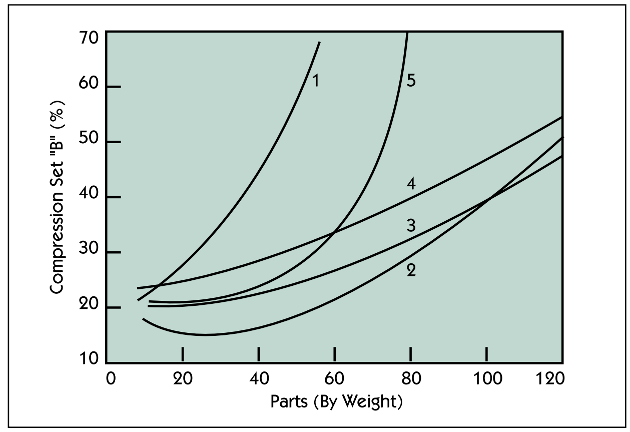


Figure 32
EFFECT OF N0N-BLACK FILLER LOADING ON ELONGATION AT BREAK

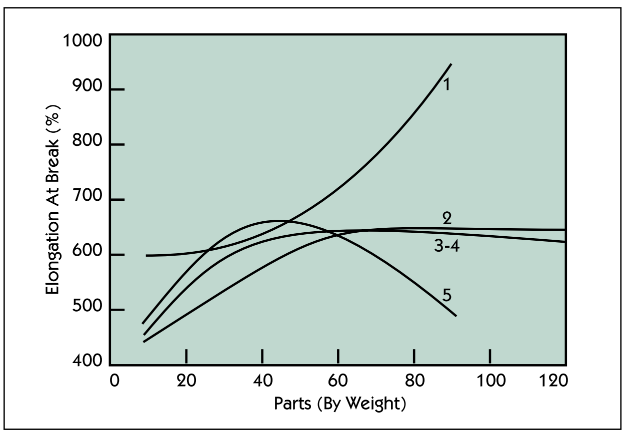
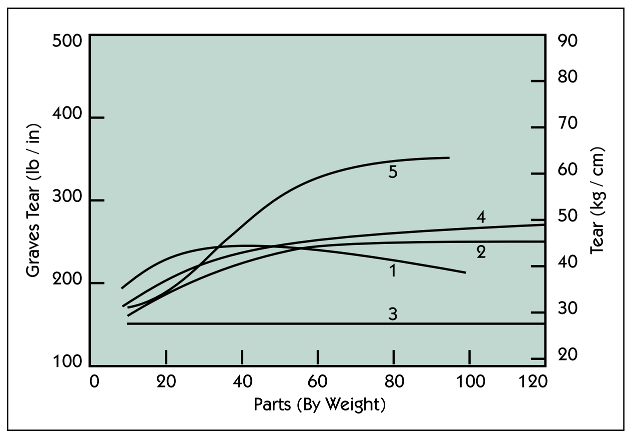


Figure 34
EFFECT OF N0N-BLACK FILLER LOADING ON TEAR STRENGTH



Legend

1 – SUPREX CLAY
2 – ICEBERG CLAY
3 – ATOMITE WHITING
4 – MISTRON VAPOR
5 – HI-SIL 233

*USE OF ZINC STEARATE

Please Note: Although zinc stearate is shown in these formulas, the data was generated using cadmium stearate. The two stearates will give generally comparable properties, but we do not recommend the use of cadmium stearate because of the health risks associated with cadmium compounds.

Table XXII
FILLER LOADING TABLE – CARBON BLACK

Filler	Parts by Weight	Volume of Filler	Sp. Gr.	Durometer Hardness	Mooney Viscosity at 250°F [121°C]	100% Modulus psi (MPa)	300% Modulus psi (MPa)	Tensile Strength psi (MPa)	Elong. %	Comp. Set, % Method B	Graves Tear Lb/in (kg/cm)	NBS Abrasion Index
--	--	--	1.08	54	25	225 [1.6]	400 [2.8]	2500 [17.2]	470	22	145 [25.4]	30
N990	10	5.6	1.12	53	20	200 [1.4]	500 [3.4]	3850 [26.5]	590	24	185 [32.4]	42
	20	11.1	1.15	54	21	225 [1.6]	700 [4.8]	4550 [31.4]	570	21	200 [35.0]	50
	30	16.7	1.18	56	23	250 [1.7]	900 [6.2]	4900 [33.8]	560	20	220 [38.5]	55
	45	25.0	1.22	60	25	300 [2.1]	1100 [7.6]	4900 [33.8]	550	17	245 [42.9]	60
	60	33.3	1.25	64	26	325 [2.2]	1225 [8.4]	4600 [31.7]	550	16	270 [47.3]	60
	75	41.7	1.27	67	28	350 [2.4]	1375 [9.5]	4050 [27.9]	550	17	280 [49.0]	55
	90	50.0	1.30	70	29	400 [2.8]	1300 [9.0]	3400 [23.4]	550	19	280 [49.0]	55
	120	66.7	1.33	74	29	450 [3.1]	1300 [9.0]	2100 [14.5]	560	29	240 [42.0]	50
N774	10	5.6	1.12	56	21	200 [1.4]	750 [5.2]	3900 [26.9]	580	25	220 [38.5]	100
	20	11.1	1.15	60	23	250 [1.7]	1125 [7.8]	4600 [31.7]	570	23	260 [45.5]	140
	30	16.7	1.18	63	26	325 [2.2]	1450 [10.0]	5000 [34.5]	560	22	295 [51.7]	150
	45	25.0	1.22	68	30	400 [2.8]	1875 [12.9]	4400 [30.3]	580	20	335 [58.7]	160
	60	33.3	1.25	71	34	500 [3.4]	2200 [15.2]	3800 [26.2]	540	19	365 [63.9]	155
	75	41.7	1.27	75	37	625 [4.3]	2450 [16.9]	3350 [23.1]	520	19	390 [68.3]	150
	90	50.0	1.30	78	39	750 [5.2]	2575 [17.8]	3050 [21.0]	500	21	405 [70.9]	145
	120	66.7	1.33	84	42	1175 [8.1]	2750 [19.0]	2750 [19.0]	400	27	410 [71.8]	135
N330	10	5.6	1.12	57	23	250 [1.7]	825 [5.7]	4100 [28.3]	580	24	225 [39.4]	190
	20	11.1	1.16	62	26	350 [2.4]	1325 [9.1]	5050 [34.8]	570	23	280 [49.0]	285
	30	16.7	1.18	66	30	425 [2.9]	1850 [12.8]	5500 [37.9]	540	22	330 [57.8]	335
	45	25.0	1.22	73	35	575 [4.0]	2550 [17.6]	5000 [34.5]	510	19	385 [67.4]	310
	60	33.3	1.25	78	41	750 [5.2]	3200 [22.1]	4500 [31.0]	480	18	420 [73.6]	280
	75	41.7	1.28	82	48	925 [6.4]	3550 [24.5]	4050 [27.9]	440	19	435 [76.2]	250
	90	50.0	1.30	85	55	1125 [7.8]	3600 [24.8]	3700 [25.5]	390	25	440 [77.1]	225
	120	66.7	1.34	88	72	1900 [13.1]	--	3300 [22.8]	220	43	370 [64.8]	190
N339	10	5.6	1.12	57	25	225 [1.6]	825 [5.7]	4200 [29.0]	570	26	225 [39.4]	120
	20	11.1	1.15	62	27	300 [2.1]	1300 [9.0]	4900 [33.8]	560	26	280 [49.0]	200
	30	16.7	1.18	66	30	400 [2.8]	1750 [12.1]	5200 [35.9]	550	27	320 [56.0]	270
	45	25.0	1.22	73	33	525 [3.6]	2300 [15.9]	5150 [35.5]	540	29	375 [65.7]	340
	60	33.31	.25	78	38	650 [4.5]	2700 [18.6]	4950 [34.1]	530	32	410 [71.8]	350
	75	41.7	1.27	82	42	800 [5.5]	2925 [20.2]	4650 [32.1]	510	33	425 [74.4]	305
	90	50.0	1.30	85	48	950 [6.6]	3075 [21.2]	4250 [29.3]	490	41	450 [78.8]	260
	120	66.7	1.33	88	62	1350 [9.3]	3250 [22.4]	3400 [23.4]	390	53	455 [79.7]	180
N220	10	5.6	1.12	59	23	250 [1.7]	925 [6.4]	4400 [30.3]	570	25	230 [40.3]	150
	20	11.1	1.16	65	26	350 [2.4]	1525 [10.5]	5400 [37.2]	550	24	285 [49.9]	250
	30	16.7	1.18	70	30	475 [3.3]	2100 [14.5]	5600 [38.6]	520	23	340 [59.5]	360
	45	25.0	1.22	77	38	650 [4.5]	2850 [19.7]	5350 [36.9]	490	22	405 [70.9]	460
	60	33.3	1.25	83	47	850 [5.9]	3450 [23.8]	5000 [34.5]	450	22	445 [77.9]	490
	75	41.7	1.27	87	54	1050 [7.2]	3800 [26.2]	4650 [32.1]	410	24	470 [82.3]	430
	90	50.0	1.30	90	62	1275 [8.8]	4000 [27.6]	4350 [30.0]	370	31	480 [84.1]	350
	120	66.7	1.34	92	80	1700 [11.7]	--	3400 [23.4]	250	48	395 [69.2]	220
N650	10	5.6	1.12	57	25	250 [1.7]	750 [5.2]	4100 [28.3]	570	25	220 [38.5]	130
	20	11.1	1.16	61	26	325 [2.2]	1175 [8.1]	4900 [33.8]	560	24	265 [46.4]	180
	30	16.7	1.18	65	29	400[2.8]	1575 [10.9]	5200 [35.9]	550	23	310 [54.3]	210
	45	25.0	1.22	70	31	550 [3.8]	2075 [14.3]	4600 [31.7]	530	22	360 [63.0]	230
	60	33.3	1.25	75	33	675 [4.7]	2450 [16.9]	4100 [28.3]	510	21	395 [69.2]	230
	75	41.7	1.28	79	36	850 [5.9]	2700 [18.6]	3650 [25.2]	490	21	415 [72.7]	225
	90	50.0	1.30	82	39	1000 [6.9]	2850 [19.7]	3400 [23.4]	450	23	420 [73.6]	215
	120	66.7	1.34	86	48	1500 [10.3]	3100 [21.4]	3100 [21.4]	300	33	375 [65.7]	190

Table XXIII
FILLER LOADING TABLE – NON-BLACK

Filler	Parts by Weight	Volume of Filler	Sp. Gr.	Durometer Hardness	Mooney Viscosity at 250°F [121°C]	100% Modulus psi (MPa)	300% Modulus psi (MPa)	Tensile Strength psi (MPa)	Elong. %	Comp. Set, % Method B	Graves Tear Lb/in (kg/cm)
Suprex Clay	10	3.8	1.14	55	20	250 [1.7]	575 [4.0]	3500 [24.1]	600	22	200 [35.0]
	20	7.7	1.19	56	18	275 [1.9]	750 [5.2]	4200 [29.0]	600	27	230 [40.3]
	30	11.5	1.23	57	16	300 [2.1]	850 [5.9]	4100 [28.2]	625	35	240 [42.0]
	45	17.3	1.29	58	15	325 [2.2]	875 [6.0]	3000 [20.7]	650	55	240 [42.0]
	60	23.1	1.34	59	13	350 [2.4]	825 [5.7]	2200 [15.2]	725	72	240 [42.0]
	75	23.8	1.38	59	12	350 [2.4]	775 [5.3]	1750 [12.1]	825	85	230 [40.3]
	90	34.6	1.42	60	11	350 [2.4]	100 [0.7]	1600 [11.0]	950	93	220 [38.5]
Iceberg **Clay**	10	3.8	1.14	56	24	250 [1.7]	525 [3.6]	1700 [11.7]	450	18	160 [28.0]
	20	7.6	1.19	57	23	275 [1.9]	625 [4.3]	2200 [15.2]	500	16	180 [31.5]
	30	11.4	1.24	59	23	300 [2.1]	725 [5.0]	2700 [18.6]	550	15	200 [35.0]
	45	17.1	1.29	61	22	350 [2.4]	850 [5.9]	3200 [22.1]	600	17	230 [40.3]
	60	22.8	1.34	64	22	375 [2.6]	950 [6.6]	3300 [22.8]	625	21	240 [42.0]
	75	28.5	1.39	66	21	400 [2.8]	1000 [6.9]	2600 [17.9]	650	27	250 [43.8]
	90	34.2	.42	70	21	450 [3.1]	1050 [7.2]	2400 [16.5]	650	34	250 [43.8]
	120	45.6	1.49	76	21	500 [3.4]	1050 [7.2]	1900 [13.1]	650	50	250 [43.8]
Hi-Sil 233	10	5.1	1.13	58	26	225 [1.6]	450 [3.1]	3100 [21.4]	475	22	170 [29.8]
	20	10.3	1.16	61	28	250 [1.7]	525 [3.6]	4400 [30.3]	550	22	180 [31.5]
	30	15.4	1.20	65	32	250 [1.7]	600 [4.1]	5000 [34.5]	625	22	210 [36.8]
	45	23.1	1.24	71	45	275 [1.9]	725 [5.0]	5000 [34.5]	650	24	270 [47.3]
	60	30.8	1.27	77	64	325 [2.2]	900 [6.2]	4700 [32.4]	650	33	330 [57.8]
	75	38.5	1.30	84	67	425 [2.9]	1250 [8.6]	3800 [26.2]	575	55	340 [59.5]
	90	46.2	1.33	90	68	725 [5.0]	1650 [11.3]	1900 [13.1]	500	85	350 [61.3]
Mistron Vapor	10	3.6	1.14	57	20	275 [1.9]	525 [3.6]	2700 [18.6]	450	24	170 [29.8]
	20	7.3	1.19	60	18	325 [2.2]	650 [4.5]	4000 [27.5]	525	25	200 [35.0]
	30	10.9	1.24	63	16	400 [2.8]	775 [5.3]	4600 [31.7]	600	27	220 [38.5]
	45	16.4	1.30	66	15	475 [3.3]	950 [6.6]	4500 [31.0]	625	30	240 [42.0]
	60	21.8	1.35	68	13	575 [4.0]	1100 [7.6]	3900 [26.9]	650	34	250 [43.8]
	75	27.3	1.40	71	12	675 [4.7]	1275 [8.8]	3400 [23.4]	650	38	260 [45.5]
	90	32.7	1.44	73	12	775 [5.3]	1400 [9.7]	3000 [20.7]	650	43	260 [45.5]
	120	43.6	1.5	77	17	1000 [6.9]	1525 [10.5]	2400 [16.5]	625	54	270 [47.3]
Atomite Whiting	10	3.7	1.14	55	20	225 [1.6]	400 [2.8]	2000 [13.8]	475	21	150 [26.3]
	20	7.4	1.19	56	18	225 [1.6]	400 [2.8]	2800 [19.3]	550	22	150 [26.3]
	30	11.1	1.24	56	17	225 [1.6]	400 [2.8]	3200 [22.1]	600	22	150 [26.3]
	45	16.6	1.30	57	18	225 [1.6]	400 [2.8]	3200 [22.1]	625	24	150 [26.3]
	60	22.1	1.35	58	20	225 [1.6]	400 [2.8]	2700 [18.6]	650	28	150 [26.3]
	75	27.7	1.40	60	21	250 [1.7]	400 [2.8]	2300 [15.9]	650	32	150 [26.3]
	90	33.2	1.43	63	22	250 [1.7]	425 [2.9]	2000 [13.8]	650	37	150 [26.3]
	120	44.3	1.50	68	23	325 [2.2]	500 [3.4]	1700 [11.7]	650	47	150 [26.3]

PROPRIETARY PRODUCTS

MILLATHANE® CM	TSE Industries, Inc.
CAYTUR®4	TSE Industries, Inc.
Atomite Whiting	Thompson-Weinman & Co.
Benzoflex® T-150	Velsicol Chemical Corp.
Brake Fluid #21B	Wagner Electric Corp.
Chemlok® 205	Lord Corp.
Chemlok® 218	Lord Corp.
Chemlok® 231	Lord Corp.
Cumar® W 2 1/2	Neville Chemical Co.
Di-Cup 40C	AKZO Nobel
DOP	Dow Chemical / C.P. Hall
1D Heavy Oil	Neville Chemical Co.
Hercoflex® 600	Hercules Inc.
Hercolyn® D	Hercules Inc.
HiSil® 233	PPG Industries
Iceberg Clay	Burgess Pigment Co.
MBT	Crompton
MBTS	Crompton
Mistron Vapor	Cyprus Mines Corp.
Monoplex DOS	Rohm & Haas Co.
Plasticizer SC	Drew Chemical Corp.
Plastolein 9057	Emery Industries
Sundex 790	Sun Oil Co.
Suprex Clay	J.M. Huber Corp.
Thixon XAB-199	Rohm & Haas
TP-95 Plasticizer	Rohm & Haas
Transmission Fluid –Type A	Exxon Corp.
Vistanex® LMMS	Emery Industries

TSE INDUSTRIES, INC., MILLATHANE DIVISION PRODUCTS LIST:

MILLATHANE® 66 — A polyester-based millable polyurethane which is peroxide curable.

MILLATHANE® 76 — A polyester-based millable polyurethane which is sulfur or peroxide curable.

MILLATHANE® 97 — A transparent polyether-based millable polyurethane which is peroxide curable.

MILLATHANE® 5004 — A polyester polyurethane with excellent processing characteristics and can be easily injection molded and must be vulcanized with peroxide (formerly known as Vibrathane® 5004).

MILLATHANE® CM — A polyether polyurethane rubber exhibiting outstanding low temperature properties and excellent hydrolytic stability (formerly known as Adiprene® CM).

MILLATHANE® E34 — A polyether-based millable polyurethane which is sulfur or peroxide curable.

MILLATHANE® HT — A polyester-based millable polyurethane which is sulfur or peroxide curable and able to withstand elevated temperatures.

CAYTUR® 4 — MBTS/zinc chloride activator for millable polyurethanes.

THANECURE® T9 — Dimeric 2,4-toluene diisocyanate can be used as vulcanization agent for polyurethane rubber; adhesion promoter for rubber to textile and PVC to textile bonding; as a cross linking component in heat activated one compound PUR elastomer systems, one component adhesive systems and one component coatings which include automotive undercoats.

CRYSTAL® 1053 — A semi-permanent mold release agent recommended for applications in rubber, composite, and thermoplastic molding. Excellent mold sealer and inhibits mold build-up.

CRYSTAL® 2000 — A semi-permanent mold release agent used as a mold lubricant and recommended for slab dip, lubricating extruded goods and prevents water spotting in open steam cure.

CRYSTAL® 4100 — A semi-permanent mold release agent used for applications in thermoplastic, epoxy, and urethane molding. Provides a high level of slip to the mold.

CRYSTAL® 7000 — A semi-permanent mold release agent which allows a greater number of releases for urethane integral skin foam.

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