Millathane® 76

A MILLABLE POLYESTER POLYURETHANE RUBBER

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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 elastomer, sold under the trade name **MILLATHANE**®, has grown to be the sales leader 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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MILLATHANE® 76

A General Purpose Millable Polyester Polyurethane Rubber

All **Millathane** polyurethanes can be compounded and processed by the use of conventional rubber manufacturing equipment to produce high quality abrasion resistant polyurethane parts. **Millathane 76** is a millable polyester polyurethane with improved processing properties over a wide Mooney viscosity range and offers many important features:

- Compression, transfer, injection molded in a hardness range of 30 to 90 durometer A.
- Vulcanized by sulfur or peroxide cure systems.
- Excellent damping properties in vibration control and oil and fuel resistance for automotive applications.
- Comparable to nitrile in oil and fuel resistance, but better low temperature properties, excellent ozone and abrasion resistance.
- Replaces conventional elastomers like natural rubber, nitrile, and EPDM.
- High tear strength and good stress relaxation properties.

Millathane 76 is a very suitable choice for use in products such as bushings, small copier rolls; automotive applications — bumpers, o-rings, hydraulic seals, belts, gaskets, solid tires — and many other high performance polyurethane applications.

TYPICAL POLYMER PROPERTIES

Chemical type	Polyester polyurethane
Physical form	Solid bale or milled sheets*
Color	Light to dark amber
Specific gravity	1.22
Mooney viscosity range (ML 1+4 @ 100° C)	25 to 70
Standard Mooney viscosity (ML 1+4 @ 100° C)	35 ± 10
Storage stability	Excellent
Health hazard	None

*Milled sheets contain 1.5 phr of carbodiimide for improved hydrolysis resistance.

TYPICAL PHYSICAL PROPERTIES

Hardness range	30 to 90 A
Tensile strength	4500 psi, 31 MPa
Elongation	500%
Tear strength	Very good (sulfur cure)
Compression set	Very good (peroxide cure)
Low temperature	-40°C (-40°F) brittle point
Heat aging 100°C	Good (sulfur cure)
	Very good (peroxide cure)
Ozone resistance	Excellent
Weathering	Good
Resilience	10 to 20%

MILLATHANE 76 END USE APPLICATIONS

Printing rollers	Industrial solid tires
Drive belts	Vibration isolators
O-rings	Suspension bushings
Specialty hose	Conveyor belting
Can tester pads	Copier rolls
Grease seals	Dust covers
Packing gaskets	Chute linings
Suction cups	Hydraulic seals
Seals	

CRYSTALLIZATION OF MILLATHANE 76

Millathane 76 undergoes a reversible change called crystallization where the polymer chains align themselves into a crystal network. This causes **Millathane 76** to become very hard and white in color. Crystallization occurs when **Millathane 76** is stored for long periods at temperatures slightly below 23°C (72°F) or for a short period at temperatures below freezing 0°C (32°F).

CAUTION: NEVER ATTEMPT TO MIX CRYSTALLIZED MILLATHANE 76. Serious damage to mills or internal mixers may result. Warm the raw polymer at elevated temperatures up to 100°C (212°F) until the natural color of the urethane returns. Partially crystallized **Millathane 76** will result in undispersed lumps of polymer in the mix.

VULCANIZATION OF MILLATHANE® 76

Millathane 76 can be vulcanized by sulfur or peroxide cured systems.

- Sulfur cured vulcanizates — have higher tensile and tear strength, better flexing, and lower heat build-up compared to peroxide cured systems.
- Peroxide cured vulcanizates — have better compression set, heat aging, and resistance to reversion.
- NOTE — abrasion properties and resistance to hydrocarbons is not changed by choice of cure system.

COMPARISON OF SULFUR VS PEROXIDE

PROPERTY	SULFUR	PEROXIDE
Tensile strength	+	-
Tear strength	+	-
Compression set	-	+
Heat aging	-	+
Reversion resistance	-	+
Flexing properties	+	-
Lower heat build-up	+	-
Abrasion resistance	+	+
Solvent resistance	+	+

SULFUR CURING SYSTEM

- The best sulfur curing system for **Millathane 76** is the combination of MBTS, MBT, Thanecure® ZM, zinc stearate, and sulfur.
- It produces the best physical properties and processing safety.
- NOTE — zinc oxide and stearic acid are neither necessary nor desirable for curing **Millathane 76**.
- A formulation containing **Millathane 76** and 30 phr N330 black was used in the laboratory experiments, along with the following ingredients.

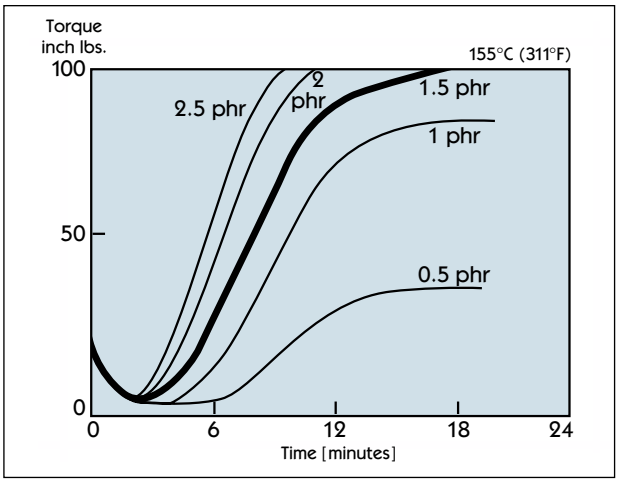
INGREDIENT	PHR	FUNCTION
Thanecure ZM	1.0	zinc activator
Sulfur	1.5	curing agent
MBTS	4.0	primary accelerator
MBT	2.0	secondary accelerator
Zinc stearate	0.5	activator; release agent

EFFECT OF SULFUR

Like many oil resistant synthetic rubbers, **Millathane 76** requires a treated grade of sulfur to ensure proper dispersion.

- Various grades should be used containing magnesium carbonate or sulfur dispersed in a polymeric binder.
- Increasing the concentration of sulfur produces a faster rate and a higher state of cure, improves abrasion resistance, gives better dynamic properties, and increases hardness (see Effect of Sulfur graph below).
- Heat aging properties are poorer at high sulfur levels.
- NOTE — a minimum of 1.5 phr of sulfur is needed to obtain the state of cure necessary for high abrasion resistance and optimum physical properties. The effect of sulfur on cure rate and physical properties can be seen in the following table and graph.

EFFECT OF SULFUR ON RATE OF CURE



EFFECT OF SULFUR ON PHYSICAL PROPERTIES

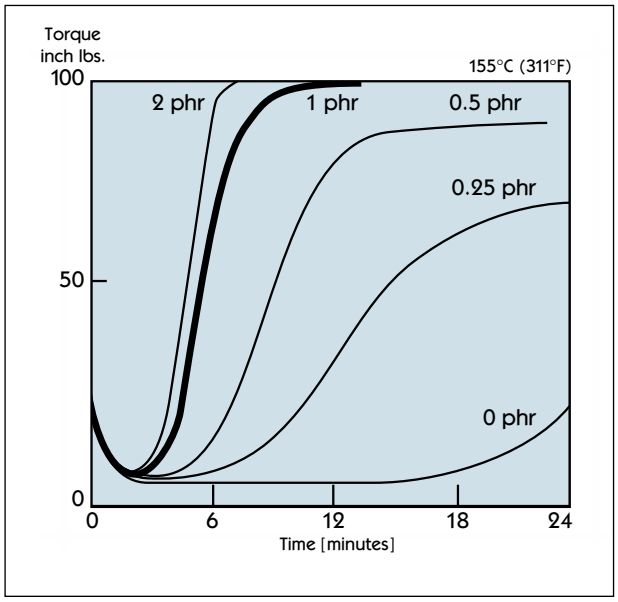
Parts Sulfur	0.5	1.0	1.5	2.0	2.5
Hardness, Durometer A	62	70	70	72	70
100% Modulus, psi	293	480	539	571	577
MPa	2.0	3.3	3.7	3.9	4.0
200% Modulus, psi	609	1082	1231	1293	1297
MPa	4.2	7.5	8.5	8.9	8.9
300% Modulus, psi	1072	1909	2159	2243	2228
MPa	7.3	13.2	14.9	15.5	15.4
Tensile Strength, psi	3782	4809	4751	4852	4656
MPa	26.1	33.2	32.8	33.5	32.1
Elongation, %	673	588	554	562	546
Tear Strength, Die C, pli	316	341	350	353	336
kN/m	55.3	59.7	61.3	61.8	58.8
Compression Set, (22 hrs. @ 70° C [158°F]), %	40.0	27.1	32.9	38.4	58.8
Cure Time @ 155°C (311°F), TC90, min.	10.0	8.8	7.8	8.0	7.0

EFFECT OF THANECURE® ZM

Thanecure ZM is an activator for a sulfur cure of **Millathane®** millable polyurethanes consisting of a partial complex of zinc chloride and MBTS.

- For most applications — 1.0 phr Thanecure ZM provides a good balance between cure rate and processing safety.
- For a faster cure — Thanecure ZM can be increased to 3.0 phr, and still maintain processing safety, and compression set resistance will be improved.
- Since zinc oxide is not compatible with **Millathane 76**, Thanecure ZM activator (containing zinc) needs to be used to ensure proper cure of **Millathane 76** compounds.
- Other zinc containing accelerators (zinc diethyldithio-carbamate and zinc dimethyldithiocarbamate) have been used over a range of 0.2 to 1.0 phr, but do not give as satisfactory a cure as Thanecure ZM.
- NOTE — the improvement in rate and state of cure of **Millathane 76** can be seen in the following graph.

EFFECT OF THANECURE ZM ON RATE OF CURE



EFFECT OF THANECURE ZM ON PHYSICAL PROPERTIES

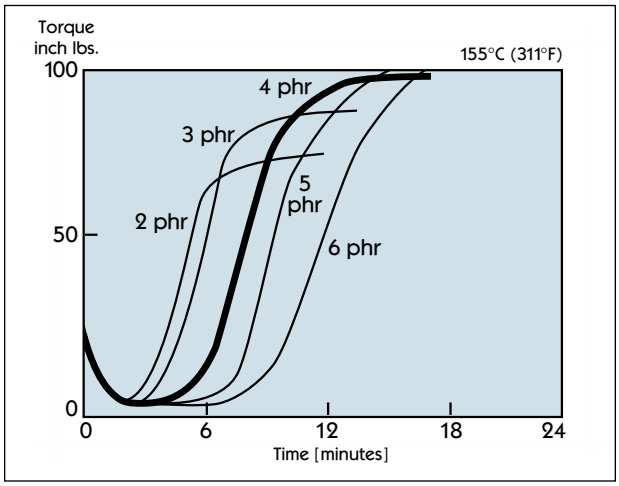
Parts Thanecure ZM	**0.0**	**0.25**	**0.5**	**1.0**	**2.0**
Hardness, Durometer A	64	68	69	69	70
100% Modulus, psi	356	437	467	513	538
MPa	2.5	3.0	3.2	3.5	3.7
200% Modulus, psi	774	973	1065	1166	1235
MPa	5.3	6.7	7.3	8.0	8.5
300% Modulus, psi	1376	1717	1882	2026	2127
MPa	9.5	11.8	13.0	14.0	14.7
Tensile Strength, psi	3997	4891	4820	4996	4431
MPa	27.6	33.7	33.2	34.5	30.6
Elongation, %	628	646	600	593	546
Tear Strength, Die C, pli	371	334	357	355	343
kN/m	65.0	58.5	62.5	62.2	60.1
Compression Set, (22 hrs. @ 70° C [158°F]), %	49.4	40.6	32.1	24.8	29.0
Cure Time @ 155°C (311°F), TC90, min.	34.2	16.1	12.4	7.0	6.3

EFFECT OF MBTS AND MBT

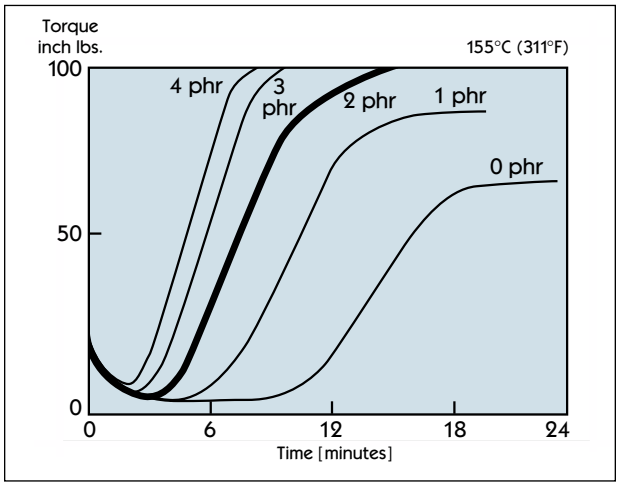
The combination of thiazole accelerators, MBTS and MBT, enable the best possible cure for **Millathane® 76**.

- An increase in MBTS results in a higher state of cure and increased processing safety.
- An increase in MBT decreases scorch time and increases the state of cure.
- The combination of 4.0 phr MBTS with 2.0 phr MBT allows the best balance of cure time and scorch time, along with the best resistance to compression set.
- NOTE — an increase in either MBTS or MBT has little effect on the rate of cure (see rheometer curves).

EFFECT OF MBTS ON RATE OF CURE



EFFECT OF MBT ON RATE OF CURE



EFFECT OF MBTS ON PHYSICAL PROPERTIES

Parts MBTS	2.0	3.0	4.0	5.0	6.0
Hardness, Durometer A	65	66	68	69	69
100% Modulus, psi	390	460	530	570	585
MPa	2.7	3.2	3.7	3.9	4.0
200% Modulus, psi	830	1015	1220	1310	1375
MPa	5.7	7.0	8.4	9.0	9.5
300% Modulus, psi	1500	1820	2150	2290	2380
MPa	10.3	12.6	14.8	15.8	16.4
Tensile Strength, psi	5060	4940	5060	4490	4640
MPa	34.9	34.1	34.9	31.0	32.0
Elongation, %	690	620	590	520	515
Tear Strength, Die C, pli	320	370	380	360	350
kN/m	56.0	64.5	66.5	63.0	61.3
Compression Set, (22 hrs. @ 70° C [158°F]), %	36.0	31.5	32.5	30.0	29.7
Cure Time @ 155°C (311°F), TC90, min.	5.0	6.8	8.2	9.6	10.8
ts2, min.	2.4	3.0	3.5	3.8	4.4

EFFECT OF MBT ON PHYSICAL PROPERTIES

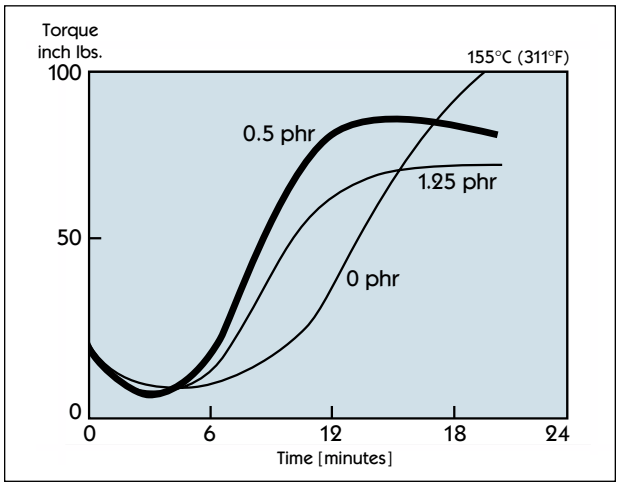
Parts MBT	0.0	1.0	2.0	3.0	4.0
Hardness, Durometer A	63	67	68	68	68
100% Modulus, psi	420	505	525	535	545
MPa	2.0	3.5	3.6	3.7	3.8
200% Modulus, psi	930	1150	1200	1215	1250
MPa	6.1	7.9	8.3	8.4	8.6
300% Modulus, psi	1645	2035	2130	2180	2205
MPa	11.3	14.0	14.7	15.0	15.2
Tensile Strength, psi	4370	4750	4710	4785	4985
MPa	30.1	32.8	34.5	33.0	34.3
Elongation, %	615	575	550	545	555
Tear Strength, Die C, pli	345	350	360	345	350
kN/m	60.4	61.3	63.0	60.4	61.3
Compression Set, (22 hrs. @ 70° C [158°F]), %	36.0	38.0	34.5	32.0	30.5
Cure Time @ 155°C (311°F), TC90, min.	12.0	10.0	8.2	7.0	7.0
ts2, min.	6.4	4.4	3.4	3.0	1.6

EFFECT OF ZINC STEARATE

Zinc stearate has replaced cadmium stearate due to toxicity concerns with cadmium compounds.

- Used as a coactivator with Thanecure® ZM it shortens cure times and improves compression set.
- The most useful range of zinc stearate is between 0.25 phr and 0.75 phr with 0.5 phr as optimum.
- Zinc stearate also functions as a process aid and release agent, and helps prevent sticking to mill or internal mixer surfaces.

EFFECT OF ZINC STEARATE ON RATE OF CURE



EFFECT OF ZINC STEARATE ON PHYSICAL PROPERTIES

Parts Zinc Stearate	**0.0**	**0.25**	**0.5**	**0.75**	**1.25**
Hardness, Durometer A	70	70	70	71	70
100% Modulus, psi	600	614	585	524	525
MPa	4.1	4.2	4.0	3.6	3.6
200% Modulus, psi	1407	1412	1390	1181	1203
MPa	9.7	9.7	9.6	8.1	8.3
300% Modulus, psi	2451	2419	2310	2069	2094
MPa	16.9	16.7	15.9	14.3	14.4
Tensile Strength, psi	4860	4912	4790	4731	4675
MPa	33.5	33.9	33.0	32.6	32.2
Elongation, %	540	559	565	559	555
Tear Strength, Die C, pli	356	343	363	372	374
kN/m	62.3	60.0	63.6	65.1	65.5
Compression Set, (22 hrs. @ 70° C [158°F]), %	33.8	34.6	32.5	31.4	29.6
Cure Time @ 155°C (311°F), TC90, min.	14.1	8.4	8.0	8.0	10.4

PEROXIDE CURING SYSTEM

Curing of **Millathane® 76** can easily be done with many types of peroxides. **Millathane 76** peroxide vulcanizates have superior compression set, greater heat stability, and are more resistant to reversion than sulfur cures.

EFFECT OF PEROXIDE CONCENTRATION

Increasing the peroxide concentration has a dramatic effect on the physical properties of **Millathane 76**.

- **Millathane 76**, when cured with 3 phr of Di-Cup 40C (40% dicumyl peroxide), produces excellent physical properties that meet or exceed ASTM D2000 BG specifications.
- When curing it at levels higher than 3 phr — modulus, hardness, and compression set resistance INCREASE — but processing safety, tensile, elongation, and tear strength DECREASE.
- Moreover, curing **Millathane 76** with 2 phr of Di-Cup 40C will result in very satisfactory vulcanizates — with lower modulus, high tear strength, higher elongation, and good compression set.
- NOTE — (1) when using black or non-black fillers, the closer that compound is to a pure gum the less peroxide is required. And (2) when using peroxides other than dicumyl peroxide it's wise to evaluate a few different levels to determine the optimum concentration.

Millathane 76 can also be cured with other commercially available peroxides such as the following:

Varox DBPH-50 —
45% 2,5-dimethyl-2,5-di (t-butylperoxy) hexane

Vul-Cup 40KE—
40% 2,2'-di (t-butylperoxy) diisopropylbenzene

Luperco 130XL —
45% 2,5-dimethyl-2,5-di (t-butylperoxy) hexyne-3

COMPARISON OF PEROXIDES

PEROXIDES	Di-Cup 40C	Varox DBPH-50	Vul-Cup 40KE	Luperco 130XL
Peroxides, phr	3.0	2.5	2.5	3.0
Millathane 76	100.0	100.0	100.0	100.0
Stearic acid	0.25	0.25	0.25	0.25
Poly AC 617A	0.5	0.5	0.5	0.5
N-550	35.0	35.0	35.0	35.0
TP-95	3.0	3.0	3.0	3.0
PHYSICAL PROPERTIES				
Cure time @ 182°C (360°F)	5'	7'	7'	12'
Hardness, Durometer A	66	66	64	66
100% Modulus, psi	587	684	641	654
MPa	4.1	4.7	4.4	4.5
200% Modulus, psi	1979	2250	2104	2221
MPa	13.6	15.5	14.5	15.3
300% Modulus, psi	——	——	3410	3579
MPa	——	——	23.5	24.7
Tensile strength,psi	3305	3501	3825	3596
MPa	22.8	24.1	26.4	24.8
Elongation, %	296	289	340	300
Tear strength, Die C,pli	299	291	337	286
kN/m	52.4	51.0	59.0	50.1
Compression set 22 hours @ 100°C (212°F)	24.0%	28.2%	25.9%	25.7%
HEAT AGED 70 HOURS @ 100°C (212°F)				
Hardness, points change	+4	+4	+4	+4
Change in tensile ,%	+20.7	+12.3	– 0.6	+1.2
MPa	27.5	27.1	26.2	25.1
Change in elongation, %	–13.4	– 6.9	–16.8	–18.0

EFFECT OF PEROXIDE CONCENTRATION ON MILLATHANE 76

FORMULATION					
Millathane 76	100.0	100.0	100.0	100.0	100.0
Stearic Acid	0.5	0.5	0.5	0.5	0.5
N-220 Black	20.0	20.0	20.0	20.0	20.0
Di-Cup 40C	1.0	2.0	3.0	4.0	5.0
Cure 15' @ 160°C (320°F)					
PHYSICAL PROPERTIES					
Hardness, Durometer A	60	60	65	68	70
100% Modulus, psi	181	278	405	676	815
MPa	1.3	1.9	2.8	4.7	5.6
200% Modulus, psi	325	764	1393	2504	—
MPa	2.2	5.3	9.6	17.3	—
300% Modulus, psi	667	1757	3045	—	—
MPa	4.6	1.2	2.1	—	—
Tensile Strength, psi	3211	4141	4234	4384	2955
MPa	22.1	28.6	29.2	30.2	20.4
Elongation, %	659	475	367	277	194
Tear strength, Die C, pli	233	335	333	341	245
KN/m	40.8	58.7	58.3	59.7	42.9
Compression Set, 22 Hrs. @ 100°C (212°F), %	44	29	22	17	16

PROCESSING OF MILLATHANE® 76

Millathane 76 has been designed for ease of processing using the standard mixing, calender, extrusion and molding equipment found in rubber manufacturing plants. Compounders prefer its unique properties — it bands easily and has a very short breakdown period, after which the rubber decreases in viscosity. The extent of polymer breakdown depends on the time and temperature of mixing and on the equipment used. What follows is a summary of suggested processing procedures for open mill and internal mixing, calendering, extruding, and molding.

MIXING ON OPEN MILLS

1. **Millathane 76** should be dropped onto a cool, tight mill with the mill set for a 0.25 inch (7.5 mm) sheet and cooling water turned on. NOTE — cold water should be circulated through the mill to minimize heat build-up. With roll temperature of 38˚C (100˚F) to 50˚C (125˚F) it will band rapidly within 2 to 4 minutes forming a comparatively smooth rolling bank. The band will continue to improve by adding internal lubricants, zinc stearate, and colors to the batch as rapidly as possible.
2. Next, part of the fillers (carbon blacks, silica, clays, etc.) are added and allowed to mix. The rest of the fillers, plasticizers and processing aids may be added alternately and worked into the batch. We recommend that sulfur be mixed into the batch at this time to obtain the best possible dispersion. NOTE — care should be taken when using small particle carbon black so that roll temperatures stay as cool as possible, not going above 82˚C (180˚F).
3. Next, add the MBTS, MBT, Thanecure® ZM, or peroxide vulcanizing agents — only if the roll temperatures are below 82˚C (180˚F). If the roll temperatures are higher than this, it is recommended that the stock be slabbed off and cooled before adding the vulcanizing agents.
4. Finally when mixing is completed, stock is slabbed off and cooled either by air or water dip. NOTE — if a slab dip is used, it should be checked to ensure that the slab dip did not affect the cure.

CAUTION: ZINC STEARATE SHOULD NOT BE USED FOR DIPS OR DUSTING. An anti-tack slab dip of **Crystal® 2000** or a solution of talc or soapstone in water, makes an effective dip for **Millathane 76** rubber. If a water dip or spray cooling is used, care must be taken that the stock is completely dry before stacking.

TYPICAL MILL MIXING CYCLE

Set mill for .25 inch (7.5 mm) sheet and turn on cooling water.

ROLL TEMPERATURE	
38˚C-50˚C (100˚F-125˚F)	Breakdown of **Millathane 76** rubber.
50˚C-65˚C (125˚F-150˚F)	Stearic acid/zinc stearate.
65˚C-82˚C (150˚F-180˚F)	Add processing aids, part of the fillers (carbon black, silicas, waxes). Times vary with amounts.
65˚C-82˚C (150˚F-180˚F)	Add plasticizers slowly and rest of filler. Add sulfur and work in.
65˚C-82˚C (150˚F-180˚F)	Add curing agents (MBTS, Thanecure® ZM, MBT, or peroxide). Cut 6 times, each way. Batch-off, and cool.

MIXING IN INTERNAL MIXERS

1. **Millathane 76** rubber is loaded into the mixer and broken down for one minute.
2. Add all the internal lubricants and mix for approximately 1.5 minutes.
3. Add processing aids and one-half the fillers and mix for an additional 1.5 minutes.
4. Add the balance of the fillers and other aids and mix batch for 1 or 2 minutes.
5. When the amp meter and stock temperature have leveled off, the batch is ready to dump. Another indicator is the characteristic "slurping" sound of a good mix. Note — at this point, stock temperature should not exceed 135˚C (275˚F).
6. A second pass through the internal mixer is recommended for the incorporation of curatives. Thanecure ZM, MBTS, MBT, and sulfur are added to the **Millathane 76** masterbatch and mixed quickly, keeping mixing temperature and drop temperature below 105˚C (220˚F). **NOTE — Single pass mixing of Millathane compounds containing curatives is not recommended because of the heat build-up generated in mixing. Millathane** compounds will scorch easily and have poor shelf life if curatives are incorporated at temperatures greater than 105˚C (220˚F).

TYPICAL INTERNAL MIXING OF MILLATHANE 76

Speed: 20 RPM	Ram Pressure: Float	Water: Full
TEMPERATURE	**MATERIALS ADDED**	**TIME, MIN.**
38˚C-52˚C (100˚F-125˚F)	Breakdown of **Millathane 76**	0-1.0
52˚C-60˚C (125˚F-140˚F)	Steric acid/zinc stearate	1-1.5
60˚C-82˚C (140˚F-180˚F)	One-half the fillers, processing aids	1.5-3.0
82˚C-100˚C (180˚F-212˚F)	Balance of the fillers/plasticizer colorants	3.5-5.5
121˚C-135˚C (250˚F-275˚F)	Dump	4.0-7.0

COMPRESSION AND TRANSFER MOLDING

Properly compounded **Millathane 76®** can be molded by compression, injection, and transfer molding procedures. Excellent mold definition is obtainable in press-cures. The linear shrinkage of parts made from **Millathane 76** varies with the amount of filler loading, but is approximately 1.5%.

PRESS CURES

The choice of time and temperature for curing molded goods is of utmost importance. The best properties of **Millathane 76** are obtained by curing at low temperatures.

- Optimum press-cures are obtained using the sulfur system at temperatures from 141˚C to 160˚C (286˚F to 320˚F), with curing times generally ranging from 7 to 30 minutes.
- Peroxide curing systems cycles will range from 5 to 40 minutes depending on choice of peroxide and cure temperature (149˚C to 181˚C [300˚F to 358˚F]).
- **Crystal® 1053** is an excellent, easy-to-use, water-based mold release agent for **Millathane 76** providing a high level of slip and multiple releases.

NOTE — curing cycles times may be reduced by curing at higher temperatures, but with some sacrifice to the physical properties and the rate of reversion increases rapidly at higher temperatures. This rate of reversion can be determined based on the following rheometer charts using sulfur or peroxide cures.

NOTE — the rheo-graphs indicate that peroxide curing is more reversion resistant than sulfur at any given temperature. These rheometer curves also give the molder information for the proper time and temperature necessary for vulcanization and achieve fast production cycles.

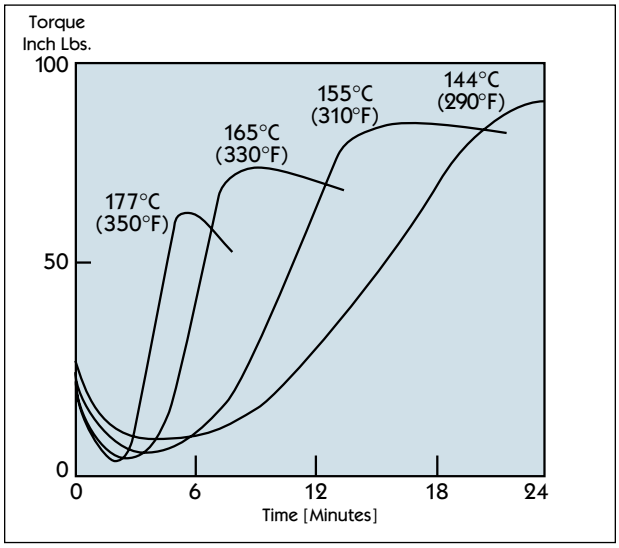
FORMULATION

Millathane 76	100.0
Zinc Stearate	0.5
N-330 Black	30.0
Cumar P-10	10.0
MBTS	4.0
MBT	2.0
Thanecure® ZM	1.0
Sulfur	1.5

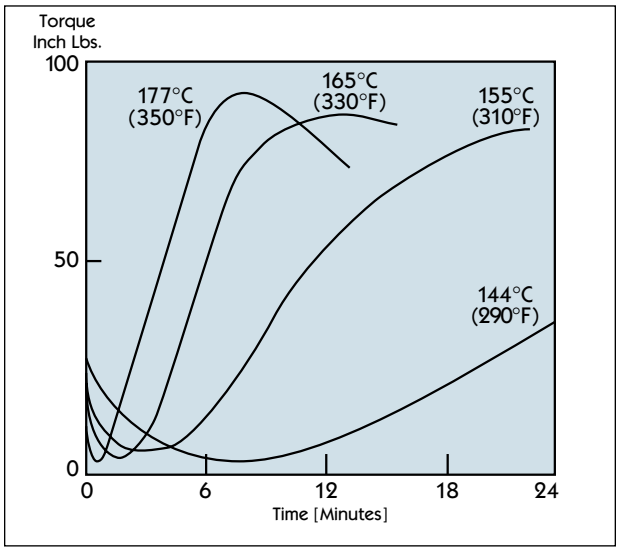
EFFECT OF CURING TEMPERATURE

Cure Temperatures	**144˚C (290˚F)**	**155˚C (310˚F)**	**165˚C (330˚F)**	**177˚C (350˚F)**
Cure Time-minutes	15	10	8	4
Hardness, Durometer A	64	65	62	62
Tensile Strength,psi	4870	4793	4698	4459
MPa	33.6	33.0	32.4	30.7
Elongation at Break, %	680	687	687	690
Tear (Die C), psi	366	372	360	340
kN/m	64.1	65.1	63.0	59.5

EFFECT OF CURING TEMPERATURE ON RATE AND STATE OF CURE SULFUR SYSTEM



EFFECT OF CURING TEMPERATURE ON RATE AND STATE OF CURE PEROXIDE SYSTEM



INJECTION MOLDING

Injection molding of **Millathane 76** can be accomplished without difficulty.

- Proper Mooney viscosity of the base polymer is a critical first step in developing a compound at a given hardness, which will have all the necessary flow parameters.
  NOTE — generally, **Millathane 76** is used for most injection molding compounds at a lower Mooney of 25 to 35.
- Process aids should be incorporated while maintaining a balance of filler and plasticizer to obtain a good compound. Consult the formulations in this bulletin for various durometer hardnesses.
- Cure times can be varied by adjusting temperature or by suitable choice of peroxide or sulfur curative levels. The vulcanization section (page 18) of this bulletin contains information on the effect of curatives on cure times.

- As with other synthetic elastomers, time, temperature, and pressure parameters must be analyzed before going into production.

The conditions below would be a good starting point for injection molding.

SUGGESTED INJECTION MOLDING TEMPERATURES

Screw & Barrel	70˚C-80˚C (158˚F-176˚F)
Accumulator	95˚C-105˚C (203˚F-221˚F)
Mold Temperature	170˚C-185˚C (338˚F-365˚F)
Cure Time	45-90 Seconds
Injection Pressure	200 Bar
Injection Speed	350 mm/Second

CALENDERING

Millathane® 76 is similar to butyl rubber during calendering because it does not dissipate trapped air as well as other polymers. Therefore, it is necessary to calender the sheet as blister-free as possible in order to eliminate trapped air in the finished product.

Important points to remember during calendering:

- Use a double bank where possible.
- Use differential speed on calender, if possible. The top and middle roll should be run at an even speed, the bottom roll should be run slightly faster.
- To eliminate air, run at the highest temperature possible.
- Incorporate process aids and 10-20 phr coarse particle size filler, i.e., N990 carbon black or clay (for non-black).
- Make sure enough heat is put on the calender rolls with proper temperatures. **Millathane 76** can be calendered blister-free.
- Temperature ranges
  - Normal range — is 38˚C to 88˚C (100˚F to 190˚F) depending on the type filler and loading level.
  - For 70 to 90 durometer compounds — roll temperatures generally should be 66˚C to 88˚C (151˚F to190˚F).
  - 20 to 40 durometer compounds usually take temperatures of 38˚C to 66˚C (100˚F to 150˚F).
  - 50 to 70 durometer compounds, that contain large amounts of plasticizer, can be calendered at temperatures lower than would be normally expected for compounds of the 70 to 90 durometer hardness ranges.
  - NOTE — with some types of fillers, **Millathane 76** compounds may tend to stick to the calender rolls when temperatures in the range of 82˚C to 104˚C (180˚F to 219˚F) are used.
- Calender roll release can be improved considerably through the addition of mill release agents, and/or internal lubricants (i.e., stearic acid, fatty acid esters, low molecular weight polyethylene wax), or by the use of **Crystal® 2000** as a slab dip. While the building tack of uncured compounds of **Millathane 76** is quite low at room temperatures, sufficient building tack for calender ply-up operations is obtainable by heating the bottom roll.
- For belt cover stock, rollers, and similar products, **Millathane 76** compounds should be calendered at approximately 20 to 40 thousandths (.02 -.04) of an inch. Thick gauge stock should be plied up on the calender. As the stock enters the liner, it should be as cool as possible to avoid excessive heat being trapped and retained in the roll which could cause scorching of the stock. If possible, pass the calendered sheet over a cooling drum before wrapping in a liner.

SUGGESTED CALENDER TEMPERATURES

Top Roll	93˚C to 104˚C (199˚F to 219˚F)
Middle Roll	110˚C to 121˚C (230˚F to 250˚F)
Bottom Roll	60˚C to 88˚C (140˚F to 190˚F)

EXTRUSION

Millathane 76 can be extruded only to make preforms for compression, transfer, or injection molding. This can be easily accomplished, if the following recommendations are followed.

- Coarse particle size carbon blacks and silica fillers produce the best extrusions.
- A minimum of 20 phr filler should be used.
- Plasticizers should be kept to a minimum.
- When plasticizers are used, they should be of the high viscosity type like high viscosity coumarone indenes and highly aromatic oils. NOTE — low viscosity oils or plasticizers can cause excessive blistering and bagging of the extrusion.
- Extrusion compounds should be designed to have at least a 35-minute scorch safety time, which will allow recycling of the stock while the die is being set, permitting use of the reworked stock.
- Exceptionally smooth extrusions can 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, resulting in sticking and loss of backpressure. NOTE — if the head and die are too cold, there is considerable resistance to flow, which will produce a rough or wavy surface on the extrusion.

SUGGESTED EXTRUSION TEMPERATURES

Screw	Cold Water
Barrel	60˚C-71˚C (140˚F-160˚F)
Head	77˚C-88˚C (171˚F-190˚F)
Die	88˚C-99˚°C (190˚F-210˚F)

BASIC COMPOUNDING

EVALUATION OF PLASTICIZERS

Plasticizers should be used in all **Millathane® 76** compounds to better incorporate fillers and improve processing.

Points to note about different plasticizers:

- Some plasticizers are not compatible with **Millathane 76**.
  - Naphthenic oils
  - All paraffinic oils
- However, a number of ester plasticizers perform very well.
  - All the plasticizers, except Cumar P10, retard the rate of cure.
  - All reduce the compound viscosity and enhance the low temperature properties.
  - Coumarone indene resins are highly recommended for sulfur-cured **Millathane 76** compounds.

A number of plasticizers were evaluated for their effect on softening and compatibility in **Millathane 76**. The test formulation and physical properties are shown below.

FORMULATION

Millathane 76	100.0
Zinc Stearate	0.5
N-550 Black	40.0
MBTS	4.0
MBT	2.0
Thanecure® ZM	1.0
Sulfur	1.5
Plasticizer	10.0

IDENTIFICATION OF PLASTICIZERS

TRADE NAME	CHEMICAL NAME	MANUFACTURER
TCP	Tricresyl phosphate	Merrand Int'l Corp.
Benzoflex 9-88SG	Triethylene glycol-dibenzoate	Vesicol Chemical
Plasthall 7050	Monomeric diester	C. P. Hall Co.
TP-95	Di-(Butoxyethoxyethyl) adipate	Rohm and Haas
TP-759	Ether/ester type	Rohm and Haas
Cumar P-10	Coumarone indene resin	Neville Chemical

PHYSICAL PROPERTIES OF VARIOUS PLASTICIZERS

PLASTICIZER	NONE	TP-95	TP-759	CUMAR P10	TCP	BENZOFLEX 9-88SG	PLASTHALL 7050
Cure Time @ 155°C (311°F)	8'	10'	11'	7'	10'	10'	10'
Hardness, Durometer A	75	63	58	62	65	65	65
100% Modulus, psi	801	398	353	334	456	484	420
MPa	5.5	2.7	2.4	2.3	3.1	3.3	2.9
200% Modulus, psi	1849	948	936	709	1055	1139	1003
MPa	13.1	6.5	6.5	4.9	7.3	7.9	6.9
300% Modulus, psi	2761	1634	1601	1204	1764	1881	1683
MPa	19.0	11.3	11.0	8.3	12.2	13.0	11.6
Tensile Strength, psi	3653	3393	3232	3269	3455	3522	3305
MPa	25.2	23.4	22.3	22.5	23.8	24.3	22.8
Elongation, %	490	542	560	621	541	541	542
Tear Strength, Die C, pli	360	341	291	322	378	375	340
kN/m	63.0	59.7	51.0	56.4	66.2	65.7	59.5
Brittle Point, °C	-35	-35	—	—	-35	-35	—
Heat Aged 70 hrs.@ 100°C (212°F)							
Weight Loss, %	1.5	1.9	1.6	5.0	1.9	2.7	2.6
Hardness Points, change	+7	+7	+12	+18	+8	+15	+15
Compression Set, % 22 hrs. @70°C (158°F)	32.3	44.2	50.0	35.8	36.4	31.2	38.0

LOW DUROMETER COMPOUNDS

Many applications exist for **Millathane® 76** compounds in a low durometer range from 25A to 40A. These include — printing rolls, copier rolls, can tester pads, spinner rings, belting, suction cups, vibration damping bumpers, and other specialized applications. The reason it's chosen for these low hardness applications — its excellent cut and tear strength, abrasion resistance, and overall toughness.

Millathane 76 has distinct advantages over cast urethanes for rubber molders:

- Molders can make polyurethane parts in this durometer range with better physical properties.
- Productivity is increased because of the short cycle times for **Millathane 76** compared to one-hour cure times and lengthy post cures required for cast urethanes.

To the right are actual sulfur-cured production formulations, which have excellent physical properties, short cycle times, and allow ease of processing.

25 DUROMETER

NON-BLACK SULFUR CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	25
AC Poly 617A	2.0	100% Modulus, psi	76
Akrofax 11LG	2.5	MPa	0.5
Cumar P-10	5.0	200% Modulus, psi	122
TP-95	28.0	MPa	0.8
Stantone Green	0.3	300% Modulus, psi	182
Zinc Stearate	0.5	MPa	1.3
MBTS	4.0	Tensile Strength, psi	1906
MBT	2.0	MPa	13.1
Thanecure® ZM	1.0	Elongation, %	578
Sulfur	1.5	Tear Die C, pli	94
CURE: 15' @ 149°C (300°F)		kN/m	16.5

30 DUROMETER

BLACK SULFUR CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	30
AC Poly 617A	2.0	100% Modulus, psi	112
Akrofax 11LG	2.5	MPa	0.8
Cumar P-10	5.0	200% Modulus, psi	175
TP-95	17.4	MPa	1.2
N-550 Black	5.0	300% Modulus, psi	248
Zinc Stearate	0.5	MPa	1.7
MBTS	4.0	Tensile Strength, psi	3101
MBT	2.0	MPa	21.4
Thanecure ZM	1.0	Elongation, %	641
Sulfur	1.5	Tear Die C, pli	156
CURE: 15' @ 149°C (300°F)		kN/m	27.3

40 DUROMETER

NON-BLACK SULFUR CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	40
AC Poly 617A	2.0	100% Modulus, psi	113
Akrofax 11LG	2.5	MPa	0.8
Cumar P-10	5.0	200% Modulus, psi	178
TP-95	8.0	MPa	1.2
Hi Sil 233	5.5	300% Modulus, psi	257
Red Oxide	5.0	MPa	1.8
Zinc Stearate	0.5	Tensile Strength, psi	3482
MBTS	4.0	MPa	24.0
MBT	2.0	Elongation, %	740
Thanecure ZM	1.0	Tear Die C, pli	154
Sulfur	1.5	kN/m	27.0
CURE: 15' @ 149°C (300°F)			

FORMULATIONS FOR VARIOUS HARDNESS

The **Millathane® 76** formulations presented on the following pages cover a hardness range from 50A to 90A. These formulas were developed with ease of processing, while maintaining excellent physical properties. Both sulfur and peroxide cures as well as black and non-black formulations are included. Use these for high abrasion **Millathane 76** applications, check our website — www.TSE-Industries.com or call us at 800-237-7634 for technical service.

50 DUROMETER

NON-BLACK SULFUR CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer A	50
Zinc stearate	0.5	100% Modulus, psi	225
AC Poly 617A	2.0	MPa	1.6
Hi-Sil 233	10.0	200% Modulus, psi	381
Titanium dioxide	5.0	MPa	2.6
MBTS	4.0	300% Modulus, psi	662
MBT	1.0	MPa	4.6
Thanecure® ZM	1.0	Tensile Strength, psi	4993
Sulfur	1.5	MPa	34.4
CURE: 10' @ 155°C (311°F)		Elongation, %	643
		Tear Die C, pli	269
		kN/m	47.1

BLACK SULFUR CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer A	47
Zinc stearate	0.5	100% Modulus, psi	191
AC Poly 617A	2.0	MPa	1.3
Hi-Sil 233	10.0	200% Modulus, psi	339
Calcium carbonate	20.0	MPa	2.3
N-550 black	3.0	300% Modulus, psi	608
Akrofax 11LG	3.0	MPa	4.2
TP-95	15.0	Tensile Strength, psi	3448
MBTS	4.0	MPa	23.8
MBT	2.0	Elongation, %	600
Thanecure ZM	1.0	Tear Die C, pli	181
Sulfur	2.0	kN/m	31.7
CURE: 13' @ 155°C (311°F)			

NON-BLACK PEROXIDE CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	50
Stearic acid	0.5	100% Modulus, psi	186
AC Poly 617A	1.0	MPa	1.3
Hi-Sil 233	10.0	200% Modulus, psi	331
TP-95	20.0	MPa	2.3
Akrofax 758	3.0	300% Modulus, psi	563
Di-Cup 40C	3.0	MPa	3.9
CURE: 15' @ 160°C (320°F)		Tensile Strength, psi	1648
		MPa	11.4
		Elongation, %	448
		Tear Die C, pli	139
		kN/m	23.3

BLACK PEROXIDE CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	50
Stearic acid	0.5	100% Modulus, psi	218
N-550 black	30.0	MPa	1.5
TP-95	20.0	200% Modulus, psi	598
Akrofax 758	5.0	MPa	4.1
Di-Cup 40C	2.0	300% Modulus, psi	1133
CURE: 15' @ 160°C (320°F)		MPa	7.8
		Tensile Strength, psi	2511
		MPa	17.3
		Elongation, %	491
		Tear Die C, pli	241
		kN/m	42.2

60 DUROMETER

NON-BLACK SULFUR CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	60
Zinc stearate	0.5	100% Modulus, psi	455
Translink 555	30.0	MPa	3.1
TP-95	5.0	200% Modulus, psi	1315
MBTS	4.0	MPa	9.1
MBT	2.0	300% Modulus, psi	2366
Thanecure ZM	1.0	MPa	16.3
Sulfur	2.0	Tensile Strength, psi	4413
CURE: 10' @ 155°C (311°F)		MPa	30.4
		Elongation, %	502
		Tear Die C, pli	380
		kN/m	66.6

BLACK SULFUR CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	60
Zinc stearate	0.5	100% Modulus, psi	329
N-550 black	15.0	MPa	2.3
TP-95	5.0	200% Modulus, psi	723
MBTS	4.0	MPa	5.0
MBT	2.0	300% Modulus, psi	1272
Thanecure ZM	1.0	MPa	8.8
Sulfur	1.5	Tensile Strength, psi	4171
CURE: 10' @ 155°C (311°F)		MPa	28.8
		Elongation, %	564
		Tear Die C, pli	342
		kN/m	59.9

NON-BLACK PEROXIDE CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	60
Stearic acid	0.5	100% Modulus, psi	244
Silane A-172	0.5	MPa	1.7
Hi-Sil 233	20.0	200% Modulus, psi	409
Sartomer SR-297	5.0	MPa	2.8
Di-Cup 40C	3.0	300% Modulus, psi	685
CURE: 15' @ 160°C (320°F)		MPa	4.7
		Tensile Strength, psi	2832
		MPa	19.5
		Elongation, %	649
		Tear Die C, pli	230
		kN/m	40.3

BLACK PEROXIDE CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	65
Stearic acid	0.5	100% Modulus, psi	405
N-220 black	20.0	MPa	2.8
Di-Cup 40C	3.0	200% Modulus, psi	1393
CURE: 15' @ 160°C (320°F)		MPa	9.6
		300% Modulus, psi	3045
		MPa	21.0
		Tensile Strength, psi	4234
		MPa	29.2
		Elongation, %	367
		Tear Die C, pli	333
		kN/m	58.3

70 DUROMETER

NON-BLACK SULFUR CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane® 76	100.0	Hardness, Durometer, A	68
Zinc stearate	0.5	100% Modulus, psi	570
AC Poly 617A	1.0	MPa	3.9
Translink 555	55.0	200% Modulus, psi	1680
Cumar P-10	5.0	MPa	11.6
MBTS	4.0	300% Modulus, psi	2640
MBT	2.0	MPa	18.2
Thanecure® ZM	1.0	Tensile Strength, psi	3800
Sulfur	1.5	MPa	26.2
CURE: 15' @ 155°C (311°F)		Elongation, %	490
		Tear Die C, pli	355
		kN/m	62.2

BLACK SULFUR CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	70
Zinc stearate	0.5	100% Modulus, psi	669
N-550 black	35.0	MPa	4.6
TP-95	5.0	200% Modulus, psi	1438
MBTS	4.0	MPa	9.9
MBT	2.0	300% Modulus, psi	2354
Thanecure ZM	1.0	MPa	16.2
Sulfur	1.5	Tensile Strength, psi	3433
CURE: 10' @ 155°C (311°F)		MPa	23.7
		Elongation, %	490
		Tear Die C, pli	346
		kN/m	60.6

NON-BLACK PEROXIDE CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	70
Stearic acid	0.5	100% Modulus, psi	480
Hi-Sil 233	30.0	MPa	3.3
Sartomer SR-297	3.0	200% Modulus, psi	984
Di-Cup 40C	2.0	MPa	6.8
CURE: 15' @ 160°C (320°F)		300% Modulus, psi	2059
		MPa	14.2
		Tensile Strength, psi	3560
		MPa	24.6
		Elongation, %	386
		Tear Die C, pli	256
		kN/m	44.8

BLACK PEROXIDE CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	70
Stearic acid	0.5	100% Modulus, psi	462
Struktol WB222	0.2	MPa	3.2
TP-95	4.0	200% Modulus, psi	1572
N-550 black	35.0	MPa	10.8
Di-Cup 40C	2.0	300% Modulus, psi	2805
CURE: 15' @ 160°C (320°F)		MPa	19.3
		Tensile Strength, psi	3429
		MPa	23.6
		Elongation, %	363
		Tear Die C, pli	318
		kN/m	55.7

80 DUROMETER

NON-BLACK SULFUR CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	80
Zinc stearate	0.5	100% Modulus, psi	250
Cumar P10	10.0	MPa	1.7
Hi-Sil 233	50.0	200% Modulus, psi	436
AC Poly 617A	2.0	MPa	3.0
MBTS	4.0	300% Modulus, psi	7.38
MBT	2.0	MPa	5.1
Thanecure ZM	1.0	Tensile Strength, psi	2922
Sulfur	1.5	MPa	20.2
CURE: 15' @ 155°C (311°F)		Elongation, %	671
		Tear Die C, pli	294
		kN/m	51.5

BLACK SULFUR CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	80
Zinc stearate	0.5	100% Modulus, psi	812
TP-95	10.0	MPa	5.6
N-330 black	51.0	200% Modulus, psi	1731
AC Poly 617A	1.5	MPa	11.9
MBTS	4.0	300% Modulus, psi	2522
MBT	2.0	MPa	17.4
Thanecure ZM	1.0	Tensile Strength, psi	3499
Sulfur	1.5	MPa	24.1
CURE: 15' @ 155°C (311°F)		Elongation, %	495
		Tear Die C, pli	365
		kN/m	63.9

NON-BLACK PEROXIDE CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	80
Stearic acid	0.5	100% Modulus, psi	807
SR-297	7.5	MPa	5.6
Hi-Sil 233	25.0	200% Modulus, psi	1754
AC Poly 617A	2.0	MPa	12.1
Di-Cup 40C	3.0	300% Modulus, psi	—
CURE: 15' @ 160°C (320°F)		MPa	—
		Tensile Strength, psi	3341
		MPa	23.0
		Elongation, %	296
		Tear Die C, pli	202
		kN/m	35.4

BLACK PEROXIDE CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	80
Stearic acid	0.5	100% Modulus, psi	986
TP-95	10.0	MPa	6.8
N-774	70.0	200% Modulus, psi	2349
SR 297	7.5	MPa	16.2
Di-Cup 40C	3.0	300% Modulus, psi	—
CURE: 15' @ 160°C (320°F)		MPa	—
		Tensile Strength, psi	2642
		MPa	18.2
		Elongation, %	251
		Tear Die C, pli	200
		kN/m	35.0

90 DUROMETER

NON-BLACK SULFUR CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane® 76	100.0	Hardness, Durometer, A	90
Zinc stearate	0.5	100% Modulus, psi	726
Mistron Vapor	60.0	MPa	5.0
Cumar P10	5.0	200% Modulus, psi	973
Hi-Sil 233	30.0	MPa	6.7
Pliolite S6B	10.0	300% Modulus, psi	1140
MBTS	4.0	MPa	7.9
MBT	2.0	Tensile Strength, psi	1810
Thanecure® ZM	1.0	MPa	12.4
Sulfur	2.0	Elongation, %	510
CURE: 15' @ 155°C (311°F)		Tear Die C, pli	322
		kN/m	56.4

BLACK SULFUR CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	88
Zinc stearate	0.5	100% Modulus, psi	1300
Struktol WB222	0.5	MPa	9.0
Cumar R-3	10.0	200% Modulus, psi	2170
N-550 black	60.0	MPa	15.0
AC Poly 617A	1.0	300% Modulus, psi	2450
MBTS	4.0	MPa	16.9
MBT	2.0	Tensile Strength, psi	2600
Thanecure ZM	1.0	MPa	17.9
Sulfur	1.5	Elongation, %	350
CURE: 15' @ 155°C (311°F)		Tear Die C, pli	360
		kN/m	63.0

NON-BLACK PEROXIDE CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	90
Stearic acid	0.5	100% Modulus, psi	1138
Poly-AC 617A	2.0	MPa	7.9
Hi-Sil 233	60.0	200% Modulus, psi	1735
SR-297	7.5	MPa	112.0
Di-Cup 40C	3.0	300% Modulus, psi	2568
Diethyleneglycol	1.0	MPa	17.7
CURE: 7' @ 160°C (311°F)		Tensile Strength, psi	2568
		MPa	17.7
		Elongation, %	300
		Tear Die C, pli	331
		kN/m	58.07

BLACK PEROXIDE CURE

FORMULATION		PHYSICAL PROPERTIES	
Millathane 76	100.0	Hardness, Durometer, A	90
Stearic acid	0.5	100% Modulus, psi	1648
SR 350	10.0	MPa	11.4
N-330	50.0	200% Modulus, psi	3114
AC POLY 617 A	1.0	MPa	21.5
Di-Cup 40C	3.0	300% Modulus, psi	—
CURE: 15' @ 160°C (311°F)		MPa	—
		Tensile Strength, psi	3161
		MPa	21.9
		Elongation, %	201
		Tear Die C, pli	254
		kN/m	44.5

CARBON BLACK LOADING STUDIES

To the right, 6 different carbon blacks are evaluated in **Millathane 76** at various loadings. The blacks range from the high reinforcing N-220 (ISAF) black to the large particle N-990 (MT) black. The tables show that modulus, hardness, tear strengths, and abrasion properties are directly related to the particle size of the carbon black.

The advantages of the finer particle size carbon blacks

- stronger reinforcement
- higher tensile tear strength
- increased abrasion

The advantages of the larger particle size blacks

- Lower heat build-up (hysteresis)
- Better compression set
- Easier mixing and processing

The following formulation was used for this carbon black study.

FORMULATION

Millathane 76	100.0
Zinc Stearate	0.5
Poly AC 617A	1.0
TP-95	10.0
Thanecure ZM	1.0
MBTS	4.0
MBT	2.0
Sulfur	1.5
Carbon Black	As Shown

CARBON BLACK, N-220 (ISAF)

Press Cured 15' @ 154°C (309°F)

PHYSICAL PROPERTIES

Parts per 100 polymer	20	40	60
Hardness, Durometer A	60	78	88
100% Modulus, psi	352	690	1111
MPa	2.4	4.8	7.7
200% Modulus, psi	740	1600	2252
MPa	5.1	11.0	15.5
300% Modulus, psi	1311	2534	2941
MPa	9.0	17.5	20.3
Tensile Strength, psi	4714	4252	3222
MPa	32.5	29.3	22.2
Elongation, %	620	521	365
Tear Strength, pli	368	378	375
kN/m	64.4	66.2	65.7
Compression Set, % 22 hrs @ 70°C (158°F)	42.5	44.2	47.9
Taber Abrasion mg loss, H-18 wheel, 1000 g load	6.5	6.5	8.0

CARBON BLACK, N-550 (FEF)

Press Cured 10' @ 154°C (309°F)

PHYSICAL PROPERTIES

Parts per 100 polymer	20	40	60
Hardness, Durometer A	60	75	85
100% Modulus, psi	329	666	1591
MPa	2.3	4.6	11.0
200% Modulus, psi	723	1438	2595
MPa	5.0	9.9	18.0
300% Modulus, psi	1272	2354	2982
MPa	8.8	16.2	20.6
Tensile Strength, psi	4171	3433	3067
MPa	28.8	23.7	21.2
Elongation, %	564	490	331
Tear Strength, pli	342	346	377
kN/m	59.9	60.6	66.0
Compression Set, % 22 hrs @ 70°C (158°F)	51.7	43.3	46.7
Taber Abrasion mg loss, H-18 wheel, 1000 g load	7.0	4.0	7.0

CARBON BLACK, N-330 (HAF)

Press Cured 10' @ 155°C (311°F)

PHYSICAL PROPERTIES

Parts per 100 polymer	20	40	60
Hardness, Durometer A	65	75	88
100% Modulus, psi	478	683	1076
MPa	3.3	4.7	7.4
200% Modulus, psi	920	1442	2211
MPa	6.3	9.9	15.2
300% Modulus, psi	1519	2220	2923
MPa	10.5	15.3	20.2
Tensile Strength, psi	4009	3886	3280
MPa	27.6	26.8	22.1
Elongation, %	590	531	390
Tear Strength, pli	351	347	329
kN/m	61.5	60.8	57.6
Compression Set, % 22 hrs @ 70°C (158°F)	42.3	46.8	43.6
Taber Abrasion mg loss, H-18 wheel, 1000 g load	6.0	5.0	8.0

CARBON BLACK, N-774 (SRF)

Press Cured 11' @ 154°C (309°F)

PHYSICAL PROPERTIES

Parts per 100 polymer	20	40	60
Hardness, Durometer A	66	68	82
100% Modulus, psi	263	337	832
MPa	1.8	2.3	5.7
200% Modulus, psi	521	723	1690
MPa	3.6	5.0	11.7
300% Modulus, psi	991	1207	2338
MPa	6.3	8.3	16.1
Tensile Strength, psi	3473	3116	3118
MPa	24.0	21.5	21.5
Elongation, %	677	646	481
Tear Strength, pli	312	333	362
kN/m	54.7	58.3	63.4
Compression Set, % 22 hrs @ 70°C (158°F)	49.9	52.2	54.9
Taber Abrasion mg loss, H-18 wheel, 1000 g load	8.0	7.0	8.0

CARBON BLACK, N-326 (HS-HAF)

Press Cured 11' @ 154°C (309°F)

PHYSICAL PROPERTIES

Parts per 100 polymer	20	40	60
Hardness, Durometer A	58	74	80
100% Modulus, psi	219	598	663
MPa	1.5	4.1	4.6
200% Modulus, psi	409	1176	1328
MPa	2.8	8.1	9.2
300% Modulus, psi	1072	1823	1933
MPa	7.4	12.6	13.3
Tensile Strength, psi	4546	3740	2828
MPa	31.3	27.8	19.5
Elongation, %	766	569	523
Tear Strength, pli	306	394	342
kN/m	53.6	69.0	59.8
Compression Set, % 22 hrs @ 70°C (158°F)	53.8	59.2	62.7
Taber Abrasion mg loss, H-18 wheel, 1000 g load	6.0	8.0	8.0

CARBON BLACK, N-990 (MT)

Press Cured 11' @ 154°C (309°F)

PHYSICAL PROPERTIES

Parts per 100 polymer	20	40	60
Hardness, Durometer A	52	60	65
100% Modulus, psi	191	310	427
MPa	1.3	2.1	2.9
200% Modulus, psi	341	639	867
MPa	2.4	4.4	6.0
300% Modulus, psi	596	1145	1446
MPa	4.1	7.9	10.0
Tensile Strength, psi	3389	3032	2386
MPa	23.4	20.9	16.5
Elongation, %	710	629	551
Tear Strength, pli	257	309	306
kN/m	45.0	54.1	53.6
Compression Set, % 22 hrs @ 70°C (158°F)	53.6	53.9	53.8
Taber Abrasion mg loss, H-18 wheel, 1000 g load	7.0	8.0	8.0

NON-BLACK LOADING STUDIES

Some important observations and recommendations:

- The best reinforcement by non-black mineral filler in **Millathane® 76** is fumed silica, followed by precipitated silica, then magnesium silicate. Fumed silica is comparable to carbon black in its effect on tensile strength, tear properties, and abrasion resistance.
- Very high tensile strength values are obtained with Hi-Sil 233 (precipitated silica) and Cab-O-Sil and Aerosil (fumed silicas).
- Mistron Vapor incorporates readily and makes suitable blends with other pigments at very high loadings.
- To improve processing we recommend:
  - A balance of process aids such as low molecular weight polyethylene (Poly AC 617 A) and aliphatic fatty acid esters (Struktol WB222).
  - Plasticizers to improve incorporation of fillers and molding efficiency.
- The compression set results shown for all mineral fillers are somewhat high, but these values can be substantially reduced by post curing or changing to a peroxide cure.
- Some non-black fillers may retard the cure slightly.
- The addition of 1.0 phr diethylene glycol or polyethylene glycol (e.g., Carbowax 3350) can reduce the cure time and improve physical properties.

On the following pages, seven mineral pigments are evaluated at various loading levels in **Millathane 76**.

FORMULATION

Millathane 76	100.0
Zinc stearate	0.5
Poly AC 617A	1.0
MBTS	4.0
MBT	2.0
Thanecure® ZM	1.0
TP-95	10.0
Sulfur	2.0
Non-Black Filler	As Shown

NON-BLACK, HISIL 233

Press Cured 25' @ 149°C (300°F)

PHYSICAL PROPERTIES

Parts per 100 polymer	**20**	**40**	**60**
Hardness, Durometer A	50	63	77
100% Modulus, psi	172	227	321
MPa	1.2	1.6	2.2
200% Modulus, psi	292	417	518
MPa	2.0	2.9	3.6
300% Modulus, psi	474	671	762
MPa	3.3	4.6	5.3
Tensile Strength, psi	3780	2969	1950
MPa	26.1	20.5	13.5
Elongation, %	750	720	640
Tear Strength, pli	230	330	340
kN/m	4.3	57.8	59.5
Compression Set, % 22 hrs @ 70°C (158°F)	64.2	82.6	91.0
Taber Abrasion mg loss, H-18 wheel, 1000 g load	13	19	23

NON-BLACK, AEROSIL 200

Press Cured 10' @ 155°C (311°F)

PHYSICAL PROPERTIES

Parts per 100 polymer	**20**	**40**	**60**
Hardness, Durometer A	57	65	80
100% Modulus, psi	196	214	332
MPa	1.4	1.5	2.3
200% Modulus, psi	333	363	641
MPa	2.3	2.5	4.4
300% Modulus, psi	549	613	1082
MPa	3.8	4.2	7.5
Tensile Strength, psi	4718	4429	3630
MPa	32.5	30.5	25.0
Elongation, %	699	722	683
Tear Strength, pli	255	299	440
kN/m	44.7	52.4	85.8
Compression Set, % 22 hrs @ 70°C (158°F)	50.8	55.6	59.9
Taber Abrasion mg loss, H-18 wheel, 1000 g load	5	12	18

NON-BLACK, MISTRON VAPOR

Press Cured 15' @ 155°C (311°F)

PHYSICAL PROPERTIES

Parts per 100 polymer	**20**	**40**	**60**
Hardness, Durometer A	53	55	65
100% Modulus, psi	228	291	380
MPa	1.6	2.0	2.6
200% Modulus, psi	349	435	547
MPa	2.4	3.0	3.8
300% Modulus, psi	498	610	741
MPa	3.4	4.2	5.1
Tensile Strength, psi	3251	3226	3107
MPa	22.4	22.2	21.4
Elongation, %	635	654	656
Tear Strength, pli	202	209	248
kN/m	35.4	36.6	43.4
Compression Set, % 22 hrs @ 70°C (158°F)	53.7	59.2	62.8
Taber Abrasion mg loss, H-18 wheel, 1000 g load	14	27	38

NON-BLACK, TRANSLINK 555 (SILANE TREATED HARD CLAY)

Press Cured 11' @ 154°C (309°F)

PHYSICAL PROPERTIES

Parts per 100 polymer	20	40	60
Hardness, Durometer A	50	58	65
100% Modulus, psi	220	376	578
MPa	1.5	2.6	4.0
200% Modulus, psi	525	964	1407
MPa	3.3	6.7	9.7
300% Modulus, psi	954	1705	2102
MPa	6.6	11.8	14.5
Tensile Strength, psi	3196	3154	2765
MPa	22.0	21.8	19.1
Elongation, %	586	547	450
Tear Strength, pli	296	366	353
kN/m	51.8	64.1	61.8
Compression Set, % 22 hrs @ 70°C (158°F)	48.1	53.8	70.3
Taber Abrasion mg loss, H-18 wheel, 1000 g load	7.7	11.0	12.0

NON-BLACK, SOFT CLAY

Press Cured 10' @ 155°C (311°F)

PHYSICAL PROPERTIES

Parts per 100 polymer	20	40	60
Hardness, Durometer A	50	55	60
100% Modulus, psi	197	334	361
MPa	1.4	2.3	2.5
200% Modulus, psi	340	569	646
MPa	2.3	3.9	4.5
300% Modulus, psi	519	865	949
MPa	3.6	6.0	6.5
Tensile Strength, psi	3905	3707	3097
MPa	26.9	25.6	21.4
Elongation, %	677	594	585
Tear Strength, pli	248	274	284
kN/m	43.4	48.0	49.7
Compression Set, % 22 hrs @ 70°C (158°F)	45.1	45.6	47.1
Taber Abrasion mg loss, H-18 wheel, 1000 g load	14	21	30

NON-BLACK, OYSTER SHELL CALCIUM CARBONATE

Press Cured 11' @ 154°C (309°F)

PHYSICAL PROPERTIES

Parts per 100 polymer	20	40	60
Hardness, Durometer A	48	55	60
100% Modulus, psi	181	239	272
MPa	1.3	1.7	1.9
200% Modulus, psi	285	362	391
MPa	2.0	2.5	2.7
300% Modulus, psi	419	515	535
MPa	2.9	3.6	3.7
Tensile Strength, psi	3990	3539	2701
MPa	27.5	24.4	18.6
Elongation, %	707	687	668
Tear Strength, pli	200	230	235
kN/m	36.6	38.5	41.2
Compression Set, % 22 hrs @ 70°C (158°F)	51.2	66.8	77.6
Taber Abrasion mg loss, H-18 wheel, 1000 g load	11	19	32

NON-BLACK, PRECIPATED CALCIUM CARBONATE

Press Cured 10' @ 155°C (311°F)

PHYSICAL PROPERTIES

Parts per 100 polymer	20	40	60
Hardness, Durometer A	50	55	60
100% Modulus, psi	165	190	228
MPa	1.1	1.3	1.6
200% Modulus, psi	238	251	285
MPa	1.6	1.7	2.0
300% Modulus, psi	363	367	370
MPa	2.5	2.5	2.6
Tensile Strength, psi	3754	3528	2918
MPa	25.9	24.3	20.1
Elongation, %	671	695	721
Tear Strength, pli	196	168	125
kN/m	34.3	29.4	21.9
Compression Set, % 22 hrs @ 70°C (158°F)	44.5	49.5	52.7
Taber Abrasion mg loss, H-18 wheel, 1000 g load	19	35	41

VULCANIZATE PROPERTIES

Millathane® 76, when reinforced with fine particle size carbon blacks and silica fillers have excellent abrasion resistance, exceptional oil resistance, and good heat aging resistance.

ABRASION RESISTANCE

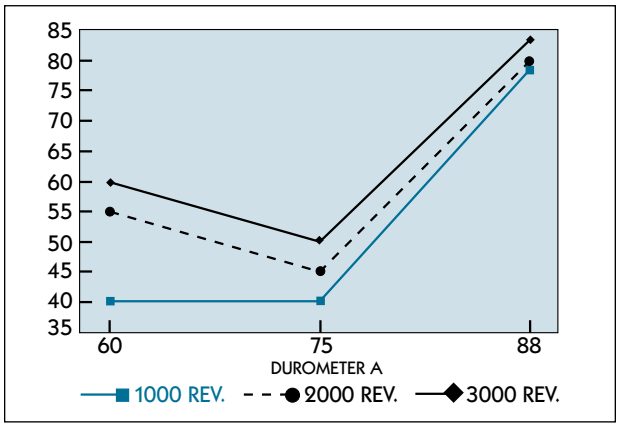
The effect of increasing hardness on abrasion resistance of **Millathane 76** can be determined by examining the following graphic on Durometer vs Taber abrasion. **Millathane 76** requires very little reinforcement to have good abrasion resistance.

Some important observations:

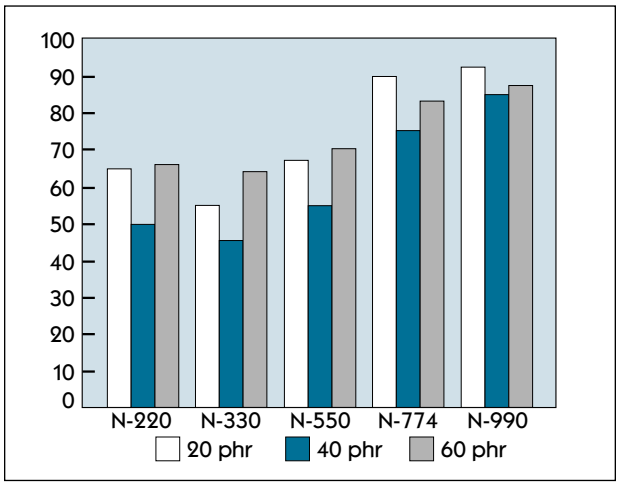
- Abrasion resistance is improved by the addition of fine particular size blacks such as N-330.
- The best abrasion resistance is obtained between 60 and 70 durometer A.
- Abrasion drops off at higher hardness because of the dilution of the polyurethane polymer due to large amounts of filler.
- Fine particular size N-220 and N-330 have better abrasion resistance than N-774 and N-990 black, as tested by Taber Abrasion.
- Comparing each carbon black at 20phr, 40 phr and 60 phr, wear resistance is best for each carbon black at a loading of 40 phr.

The effect of carbon black loading and type can be seen on the bar graph at right.

DUROMETER VS TABER ABRASION



EFFECT OF CARBON BLACK ON ABRASION



HEAT RESISTANCE

Heat aging of **Millathane 76** is good when sulfur cured and very good when peroxide cured. Listed below is a comparison of sulfur vs peroxide cured **Millathane 76** compounds, heat aged 70 hours at 100°C (212°F). After heat aging, sulfur curing has acceptable values for most applications. Changes in hardness, tensile, and elongation obtained for the peroxide cure were minimal.

HEAT AGING PROPERTIES OF MILLATHANE 76 SULFUR VS PEROXIDE CURES

SULFUR CURE FORMULATION	
Millathane 76	100.0
Zinc stearate	0.5
N-220	20.0
MBTS	4.0
MBT	2.0
Thanecure® ZM	1.0
Sulfur	1.5
CURE: 15'@ 155°C (311°F)	

PEROXIDE CURE FORMULATION	
Millathane 76	100.0
Stearic acid	0.5
N-220	20.0
Di-Cup 40C	3.0
CURE: 15'@ 155°C (311°F)	

PHYSICAL PROPERTIES	
Hardness, Durometer A	65
100% Modulus, psi	424
MPa	2.9
200% Modulus, psi	949
MPa	6.5
300% Modulus, psi	1744
MPa	12.0
Tensile strength, psi	5061
MPa	34.9
Elongation, %	568
Tear Die C, pli	372
kN/m	65.1

PHYSICAL PROPERTIES	
Hardness, Durometer A	65
100% Modulus, psi	402
MPa	2.8
200% Modulus, psi	1370
MPa	9.4
300% Modulus, psi	3188
MPa	22.0
Tensile strength, psi	4200
MPa	29.0
Elongation, %	362
Tear Die C, pli	220
kN/m	38.5

HEAT AGED 70 HOURS @ 100°C (212°F)

	Sulfur Cure	Peroxide Cure	BG Specification
Hardness points, change	+10	0	+15
Change in tensile, %	-17.7	+2.1	+30% max
Change in elongation, %	-38.7	-9.5	-50% max
Compression set, % 22 Hours @ 100°C (212°F)	65.2	16.8	50% max

COMPRESSION SET

Compression set properties for **Millathane® 76** depend greatly on the choice of a cure system. From the data in the previous table, we can conclude:

- Compression set resistance and heat-aging properties of peroxide cured **Millathane 76** meet the requirements for ASTM D2000 Grade BG.

Sulfur cured vulcanizates can be post cured 3 to 4 hours at 121˚C (250˚F) to improve compression set by as much as 30%. An example of this improvement is the sulfur cured, silica filled compound listed below.

FORMULATION

Millathane 76	100.0	MBTS	4.0
Zinc stearate	0.5	MBT	2.0
Hi-Sil 233	20.0	Thanecure® ZM	1.0
TP-95	10.0	Sulfur	1.5
Poly AC 617A	1.0		

EFFECT OF POST CURING MILLATHANE 76 ON COMPRESSION SET

CURE: 15'@ 155°C (311°F)	ORIGINAL	POST CURE 3 HOURS @ 121°C (250°F)
Hardness, Durometer A	55	56
100% Modulus, psi	187	237
MPa	1.3	1.6
200% Modulus, psi	227	446
MPa	1.6	3.1
300% Modulus, psi	557	754
MPa	3.8	5.2
Tensile strength, psi	4099	3944
MPa	28.3	27.2
Elongation, %	750	648
Tear Die C, pli	280	265
kN/m	49.0	46.4
Compression set, % 22 hours @ 100°C (212°F)	75.0	45.0

OIL RESISTANCE

Cured compounds of **Millathane 76** have exceptional resistance to swelling by hydrocarbon oils and fuels, comparable to nitrile rubber. Results from the laboratory work tabulated below indicate a very low volume swell in ASTM #3 oil with very small changes in physical properties.

FORMULATION

Millathane 76	100.0	MBT	2.0
Zinc stearate	0.5	Thanecure ZM	1.0
N-220	20.0	Sulfur	1.5
MBTS	4.0		

EFFECT OF OIL AGING

	ORIGINAL	OIL AGED 70 HOURS @ 100°C (212°F)
Hardness, Durometer A	65	65
100% Modulus, psi	424	515
MPa	2.9	3.6
200% Modulus, psi	949	1346
MPa	6.5	9.3
300% Modulus, psi	1744	2468
MPa	12.0	17.0
Tensile strength, psi	5061	5122
MPa	34.9	35.3
Elongation, %	568	508
Volume change, %	—	-1.1

CHEMICAL RESISTANCE

The information given in the following table illustrates the effect of various fluids on black filled, sulfur cured, **Millathane 76** compound. The percent volume swell was determined after 7 days immersion at room temperature or as otherwise noted.

PERCENT SWELL OF MILLATHANE 76 IN VARIOUS CHEMICALS

ACIDS	
Hydrochloric acid, 10%	3.8
Nitric acid, 10%	25.3
Phosphoric acid, 10%	4.7
Sulfuric acid, 10%	2.8
ALCOHOLS	
Butyl alcohol	16.0
Ethyl alcohol	19.0
ALKALI	
Sodium hydroxide, 10%	1.6
ESTERS	
Cellosolve Acetate	302.0
Ethyl Acetate	104.0
HALOGENATED HYDROCARBONS	
Carbon tetrachloride	33.0
Tetrachloroethylene	21.0
Trichlorethylene	121.0
KETONES	
Acetone	126.0
Methol ethyl ketone	119.0
HYDROCARBONS	
ASTM fuel B	16.4
ASTM oil #1	1.1
ASTM oil #1, 70 hrs.@ 100°C (212°F)	-2.1
ASTM oil #3	1.2
ASTM oil #3 70 hrs.@ 100°C (212°F)	-2.1
Benzene	100.0
Gasoline	8.8
Petroleum, crude 70 hrs.@ 100°C (212°F)	1.5
Toluene	59.0
Wax, petroleum 70 hrs.@ 100°C (212°F)	-5.0
Xylene	36.0
OTHER MATERIALS	
Hydraulic Fluid (Skydrol)	59.0
Linseed oil	4.4
Water	4.7

HYDROLYSIS RESISTANCE

With exposure to moisture at elevated temperatures, **Millathane 76** compounds are subject to hydrolysis. The addition of 1.5 phr of Stabaxol P to the compound will provide the necessary protection against hydrolysis.

FORMULATION

Millathane 76	100.0
Stearic acid	0.5
TAC	0.5
N-220 black	20.0
Di-Cup 40C	3.0
Stabaxol P	3.0
Total	127.0

PHYSICAL PROPERTIES

Hardness, Durometer A	60
100% Modulus, psi	221
MPa	1.5
Tensile strength, psi	3524
MPa	24.3
Elongation, %	486

After aging 70 hours at 80˚C (176˚F) in water, this compound lost only 10 points in hardness and its volume swell was 5.5%.

MILLATHANE® 76 COMPARISON WITH NITRILE RUBBER

Millathane 76, a polyester polyurethane elastomer, has exceptional abrasion resistance, oil and fuel resistance, good stress relaxation and very good flex properties.

Using the formulations in the following table, we will compare **Millathane 76** to a medium ACN nitrile compound.

- Its stress/strain properties are far superior to the nitrile compound.
- Tear strength and abrasion resistance are much better than in nitrile.
- It can replace nitrile in many roll and seal applications.
- Changes in volume swell and hardness points, after aging in Fuel B and ASTM oil #3, are nearly identical to those of nitrile rubber.

TEST FORMULATIONS

	MILLATHANE 76	NITRILE RUBBER
Millathane 76	100.0	——
Nitrile rubber	——	100.0
N-347 black	60.0	60.0
Santicizer 160	5.0	5.0
Stearic acid	1.0	1.0
Aminox	1.5	1.5
Santogard PVI	——	0.6
Zinc oxide	——	3.0
Zinc Stearate	0.5	——
MBTS	4.0	1.6
MBT	2.0	——
Thanecure® ZM	1.0	——
Sulfur	1.5	2.0
Cure time @ 149°C (300°F)	15'	25'

ORIGINAL PHYSICAL PROPERTIES

	MILLATHANE 76	NITRILE RUBBER
Hardness, Durometer A	83	82
100% Modulus, psi	856	727
MPa	5.9	5.0
200% Modulus, psi	1626	1380
MPa	11.2	9.5
300% Modulus, psi	2223	1760
MPa	15.3	12.1
Tensile strength, psi	3058	1879
MPa	21.1	13.0
Elongation, %	506	374
Tear Die C, pli	465	307
kN/m	81.4	53.8

ABRASION RESISTANCE

	MILLATHANE 76	NITRILE RUBBER
Taber Abrasion (mg loss @ 1000 rev.)	0.025	0.142

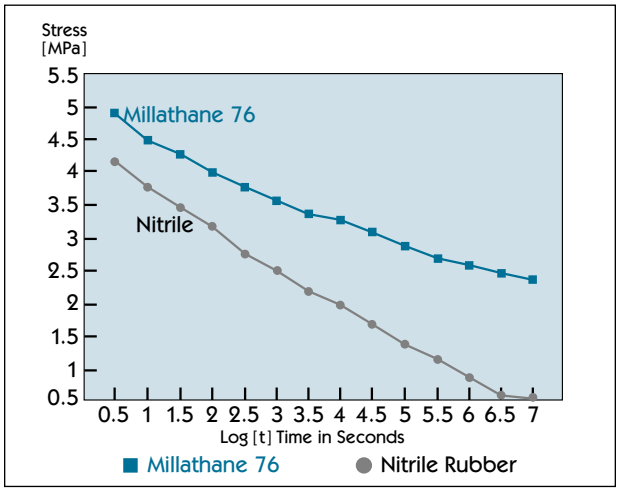
OIL AND FUEL RESISTANCE

	MILLATHANE 76	NITRILE RUBBER
Aged 70 hours Fuel B @ room temperature		
Volume change, %	+16.3	17.2
Hardness, points change	-18	-20
Aged 70 hours ASTM oil #3 @ 100°C (212°F)		
Volume change, %	+4.2	+5.0
Hardness, points change	+3	-5

STRESS RELAXATION

Stress relaxation tests were performed on these test formulations of **Millathane 76** and nitrile rubber. The results below graphically illustrate that **Millathane 76** is both more elastic and has less stress relaxation than nitrile rubber.

MILLATHANE 76 VS NITRILE RUBBER



DYNAMIC FLEXIBILITY OF MILLATHANE 76

The dynamic flex properties of **Millathane 76** are suitable for most applications — rolls, drive belts, bumpers, etc. The results shown below in the DeMattia flexibility testing (non-pierced specimens flexed at 300 cpm) performed on the test formulations of **Millathane 76** and nitrile rubber prove that it has better resistance to flexcracking than the nitrile rubber.

DEMATTIA FLEXIBILITY CRACK GROWTH,IN. ASTM D 813

	MILLATHANE 76			NITRILE RUBBER		
No. of cycles	#1	#2	#3	#1	#2	#3
30,000	0.00	0.00	0.00	0.00	0.32	0.00
40,000	0.04	0.00	0.00	0.04	0.61	0.23
60,000	0.11	0.00	0.00	1.00	——	——
80,000	0.20	0.19	0.00	——	——	——
100,000	0.36	0.63	0.00	——	——	——
130,000	0.66	——	0.06	——	——	——
170,000	——	——	0.27	——	——	——
200,000	——	——	0.40	——	——	——
220,000	——	——	0.52	——	——	——

ADHESION TO METALS

Millathane®76 rubber compounds can be effectively bonded to metal.

Some cleaning tips to ensure a lasting bond:

- To ensure consistent bonding results, metal surfaces must be thoroughly cleaned before application of the adhesive. Protective oils, cutting oils, greases, etc. should be removed by solvent degreasing or alkaline cleaning.
- Rust, scale or tightly adherent oxide coatings must be removed by suitable mechanical or chemical cleaning methods.
- Grit blasting is the most widely used method of mechanical cleaning, but machining, grinding, or wire brushing may be used. Steel grit is used for fast cleaning of steel, cast iron, or other ferrous metals while aluminum oxide, sand, or other non-ferrous grit is used for blast cleaning of stainless steel, aluminum, brass, zinc or other non-ferrous metals.
- Chemical cleaning of the metal will also remove rust, scale, or tightly adherent oxide coatings. Chemical treatments are used on metal parts that would be distorted by blast cleaning or in cases where tight size tolerances must be maintained. Chemical cleaning is readily adapted to automated metal treatment and adhesive application lines.
- Phosphatizing is a commonly used treatment for steel while chromate conversion coating is commonly used for aluminum.

Below is a list of commercially available adhesives:

LORD CORP.
CHEMICAL PRODUCTS GROUP
Chemlok 233
Chemlok TyPlyBN
Chemlok 210
Chemlok 218
Chemlok 250/250X
Chemlok 205 (Primer)

ROHM AND HAAS
Thixon 408
Thixon P-5 (Primer)

NOTE — as in any bonding operation, testing should be done to see which adhesive works best in your application. If the one coat system does not produce the desired results, try the two-coat system. Some adhesives may work better in a compression mold than in transfer molding.

GLOSSARY

Akrofax 11LG	vulcanized vegetable oil	Akrochem
Akrofax 758	vulcanized vegetable oil	Akrochem
Aerosil 200	fumed silica	Degussa
Aminox	antioxidant	Crompton Corporation
Benzoflex 9-88SG	plasticizer	Vesicol Chemical Co.
Cab-O-Sil	Fumed silica	Cabot Corporation
Carbowax	polyethylene glycol	Dow Chemical
Caytur® 4	activator	TSE Industries
Chemlok	adhesive	Lord Corporation
Cab-O-Sil	Fumed silica	Cabot Corporation
Carbowax	polyethylene glycol	Dow Chemical
Cumar P-10,R-3	plasticizer	Neville Chemical
Di-Cup 40C	peroxide	GEO Specialty Chemicals
Hi-Sil 233	precipitated silicate filler	PPG Industries
Luperco 130XL	peroxide	Harwick Standard
Millathane® 76	polyurethane	TSE Industries
Mistron Vapor	magnesium silicate filler	Luzenac America, Inc.
Plasthall 7050	plasticizer	C.P. Hall
Pliolite S6B	high styrene resin	B.F. Goodrich
Poly AC 617A	microcrystalline wax	Allied Fibers & Plastics
Red iron oxide	inorganic color	Akrochem
Santicizer 160	plasticizer	Ferro Corporation
Santogard PVI	scorch retarder	Flexsys Rubber Chemicals
Sartomer SR-297,350	co-agents	Sartomer Co.
Silane A-172	coupling agent	Degussa
Stantone green	colorant	Harwick Standard
Struktol WB 222	fatty acid process aid	Struktol Co.
TCP	plasticizer (tricresyl phosphate)	Merrand International
Thanecure® ZM	activator	TSE Industries
Thixon	adhesive	Rohm and Haas
TP-95, TP-759	plasticizers	Rohm and Haas
Translink 555,77	treated clays	Engelhard
Varox DBPH-50	peroxide	R.T. Vanderbilt
Vul-Cup 40KE	peroxide	GEO Specialty Chemicals

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® ZM — 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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