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Technical Information for Performance Solutions

Topics:

Anti-static Millathane® Millable Urethane Compounds

Millathane millable polyurethanes are polar polymers and, as such, are inherently not very good for electrical insulating applications. They can, however, be used for applications requiring static dissipation properties, and these properties can be modified by compounding with conductive fillers and plasticizers. Applications that can use antistatic (electrically static dissipative, ESD) compounds are belting, rollers and electronic parts and assembly items such as suction cups for moving microchips, hard drive seals, etc.

Generally, rubber compounds can be classified for electrical conductivity as follows:

Conductive	up to 10^6 ohm/square (surface resistance)
Static dissipative	10^6 to 10^9 ohm/sq
Antistatic	10^9 to 10^{12} ohm/sq
Insulative	$>10^{12}$ ohm/sq

The primary method of improving conductivity (reducing electrical resistance) in rubber compounds is by adding conductive carbon blacks, such as N472 (XC-72 from Cabot). A study evaluating levels of N472 black vs. DBEEA (TP-95) plasticizer, and these ingredients' effect on electrical conductivity as well as other properties, is the main focus of this report. Surface resistivity was measured using the parallel bar sensing method of ASTM D-257. Some limited information is also provided on other methods to achieve static conductivity.

Compounding Millathane Millable Urethane for Conductivity/ Anti-static Properties

Cure System

All grades of Millathane millable urethane rubber can be cured with peroxides, but several are also curable with a sulfur cure system. Several studies have shown that a sulfur cure system (consisting of MBTS, MBT, Thanecure® ZM and sulfur, with zinc stearate as an activator) will give roughly an order of magnitude lower electrical resistivity (better conductivity) than peroxide cures (e.g., $10^{10} \rightarrow 10^9$ ohm/sq).

Carbon Black

XC-72 is a commonly used conductive carbon black and was used in this study. Ensaco 250 (from R.T. Vanderbilt) was also evaluated in one compound and gave similar properties to XC-72 in all properties tested (data not shown in this report).

Antistatic Plasticizers

Several plasticizers contribute to antistatic properties, including Struktol AW-1 (Struktol Co.) and Rhenosin RC-100 (Rhein Chemie). TP-95 has also been shown to reduce electrical resistivity somewhat, as the data from the XC-72/TP-95 study, on the following page, will show. These antistatic plasticizers are valuable additives where non-black antistatic compounds are desirable, although achieving low resistivity values, $<10^8$, can be difficult with non-black compounds that only use these plasticizers for antistatic properties.

XC-72/TP-95 Study in Millathane® 76

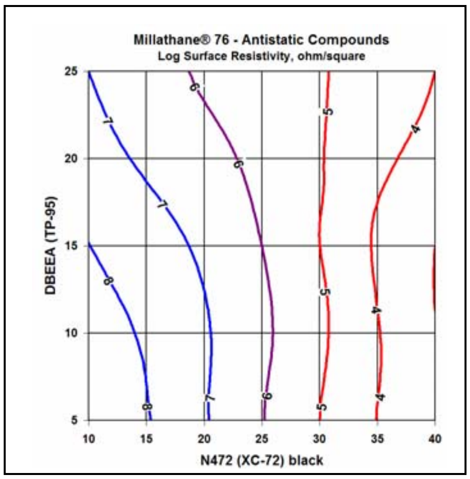
A study was conducted in a sulfur-cured Millathane 76 compound where the XC-72 carbon black was varied from 10 to 40 parts and the TP-95 was varied from 5 to 25 parts in an experimental design. The formulation used is shown to the right. This compound uses the standard sulfur cure system used for millable urethanes. A peroxide cure could also be used (DiCup or DBPH, for example) and would give resistivity values somewhat higher than the sulfur cures.

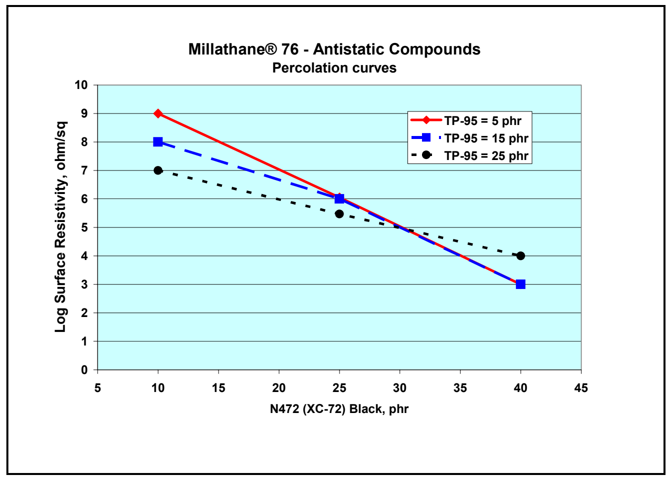
Millathane 76	100.0
Zinc stearate	0.50
XC-72 black	10 – 40
TP-95	5 – 25
Struktol WB222	1.0
Millstab™ P	1.0
MBTS	4.0
MBT	2.0
Thanecure® ZM	1.0
Sulfur	1.5

Electrical (Surface) Resistivity

The contour plot below shows that the resistivity decreases about 5 decades (e.g., from 10^8 to 10^3 at 15 phr TP-95) as the conductive carbon black increases from 10 to 40 parts. The plot also indicates that at the lower levels of black (<25 phr), increased levels of TP-95 gave lower resistivity, but at the higher levels of black the effect was slightly reversed, giving slightly higher resistivity with higher levels of TP-95. Percolation curves, showing electrical resistivity vs. XC-72 black level at three plasticizer levels, are also shown below.

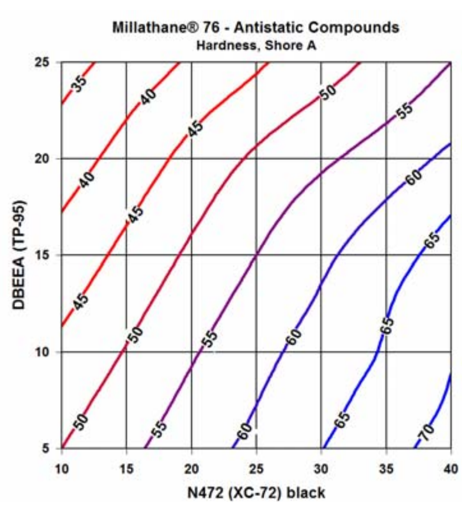
Millathane® Factoid: *TSE will have a booth at the Rubber Division ACS Expo in Louisville, Kentucky, October 14—16. Stop in to say Hi!*

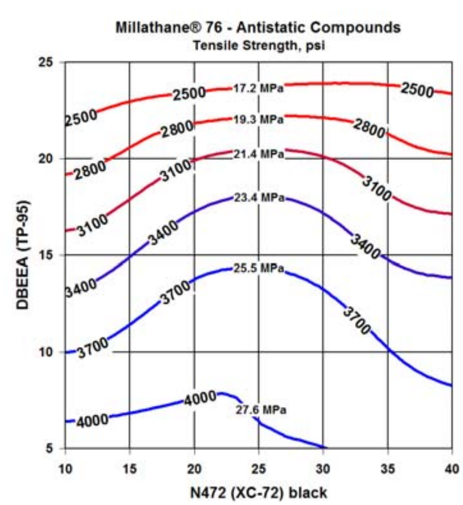




Physical Properties

Compounds in this evaluation ranged in hardness from 33 to 73 Shore A, with the trends as expected: hardness increases with increasing XC-72 black and decreases with increasing TP-95 plasticizer. The contour plot, below, can be used as a guide for compounding to a specific hardness. Tensile stress (modulus) values showed the same trends as hardness. Tensile strength was primarily influenced by the plasticizer as seen in the contour plot below, decreasing as the level of DBEEA increased. With the N472 black, there appeared to be a maximum tensile at about 25 phr of N472, with a slight drop-off at lower and higher levels.





Anti-static Formulations

Data on the compounds tested in this study are as follows:

XC-72 black	40	40	40	25	10	10
TP-95	5	15	25	15	5	25

Mooney Viscosity, ML(1+4)/100ºC	78	45	32	30	43	27

MDR, 20'/160ºC

ML, lb-in	2.1	1.3	1.0	0.5	0.5	0.1
dNm	2.4	1.5	1.1	0.6	0.5	0.1
MH, lb-in	15.8	11.3	6.8	7.1	8.6	3.8
dNm	17.8	12.8	7.7	8.1	9.7	4.3
ts1, minutes	1.8	2.1	3.4	3.0	2.4	4.3
t90, minutes	6.3	7.3	8.9	7.8	6.1	9.7

Press Cure, t90 at 160°C; minutes ->	6	7	9	8	6	10
Hardness, Shore A	72	66	55	55	50	33
TSE-100*, psi	595	385	265	210	190	80
MPa	4.1	2.7	1.8	1.4	1.3	0.6
TSE-200, psi	1260	845	600	455	365	150
MPa	8.7	5.8	4.1	3.1	2.5	1.0
TSE-300, psi	1910	1380	985	795	660	270
MPa	13.2	9.5	6.8	5.5	4.6	1.9
Tensile Strength, psi	3880	3300	2350	3390	4110	2190
MPa	26.8	22.8	16.2	23.4	28.3	15.1
Elongation, %	590	600	595	700	670	730

Tear, Die C, lb/in	280	221	157	164.5	177	72
kN/m	49.0	38.7	27.5	28.8	31.0	12.6
Tear, Die B, lb/in	490	413	300	256.5	319	102
kN/m	85.8	72.3	52.5	44.9	55.8	17.9

*TSE-xxx=Tensile Stress at xxx% Elongation

Bashore Resilience, %	22	26	25	28	23	30
DIN Abrasion, mm³ loss	114	58	66	65	53	*
Compression Set, 22 hr/70°C, %	38	36	52	43	37	50
Log Surface Resistivity, ohm/sq	3	3	4	6	9	7

* Could not test

MILLATHANE® FACTOID:* *Son of GLOB™,* *based upon Millathane millable urethane rubber, can be useful for removing remnants of sticky compounds from rubber mills. Call us for a sample!

Summary

Millathane millable urethanes can be compounded to have antistatic/conductive properties, typically by the use of conductive carbon blacks such as XC-72 or Ensaco 250, achieving surface resistivity values as low as 10^3 ohm/sq. Compounds had excellent properties, even down to the 33 Shore A compound, and had excellent abrasion resistance. Non-black compounds can get anti-static properties by the use of anti-static plasticizers, although the compounds would have higher resistivity valves than black compounds. Look for information on non-black anti-static Millathane compounds in a future TIPS publication.

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ASK Doctor Millathane®

Dear Dr. Millathane,
I'm developing several colored compounds based upon millable urethanes, and was wondering if you had any suggestions regarding pigments before I got started.
Scarlett Red

Dear Miss Red,
Generally, you can use the same pigments for Millathane® millable urethanes that are used in other types of rubber, but there are some things to keep in mind. The main concern with colorants in millable urethanes is that if significant amounts of polymer bound pigments are used, the effect of that polymer on the urethane compound has to be taken into consideration, as some rubber types (e.g., EPDM, SBR) are not very compatible with millable urethanes. Small amounts of polymer bound pigments are generally not a problem, where the amount of added polymer is less than 1 part. Using powdered pigments eliminates that potential concern.

To get the best dispersion with powered pigments, they should be added early in the mix cycle or even in a separate pass if dispersion is difficult with that pigment or the application is critical (as with thin walled parts that may be stretched during use).
Keep in mind that sulfur cures will inherently be somewhat yellowish or even brownish without any pigment, depending on the compound and curing conditions. Peroxide cures will be much better for color and color stability. Higher temperature curing will generally give somewhat darker compounds for both sulfur and peroxide cures, so for best color it's desirable to keep the curing temperature as low as practical.

Also, it's best to keep the level of titanium dioxide to a minimum, as high levels of titanium dioxide can reduce abrasion resistance, which is probably the main reason you're using Millathane millable urethane in the first place.

Dr. Millathane

If you have any Millathane millable urethane questions you'd like answered, please send an email to millathaneinfo@tse-industries.com.