Antistatic Millathane® Millable Urethane Compounds

Millathane® millable polyurethanes are polar polymers and are inherently poor for electrical insulating applications. They can, however, be used for applications requiring static dissipation properties. 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 and hard drive seals.

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® FOR CONDUCTIVITY/ ANTISTATIC 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., 1010 → 109 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, <108, can be difficult with non-black compounds that only use these plasticizers for antistatic properties.

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Antistatic Millathane® Millable Urethane Compounds (cont.)

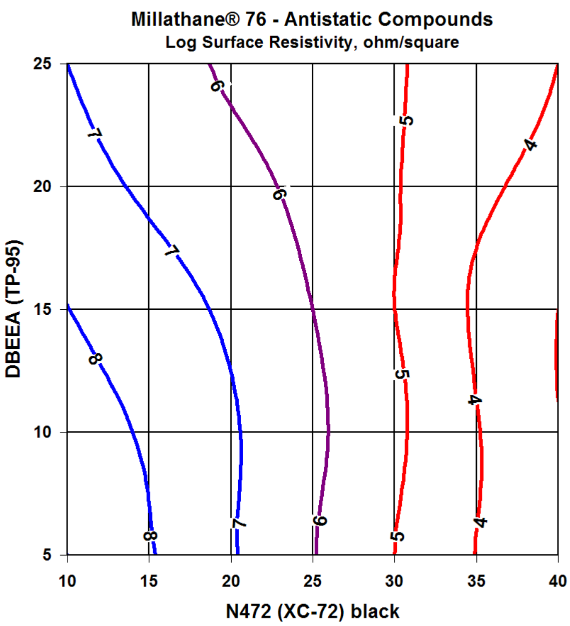
XC-72/TP-95 STUDY IN MILLATHANE® 76

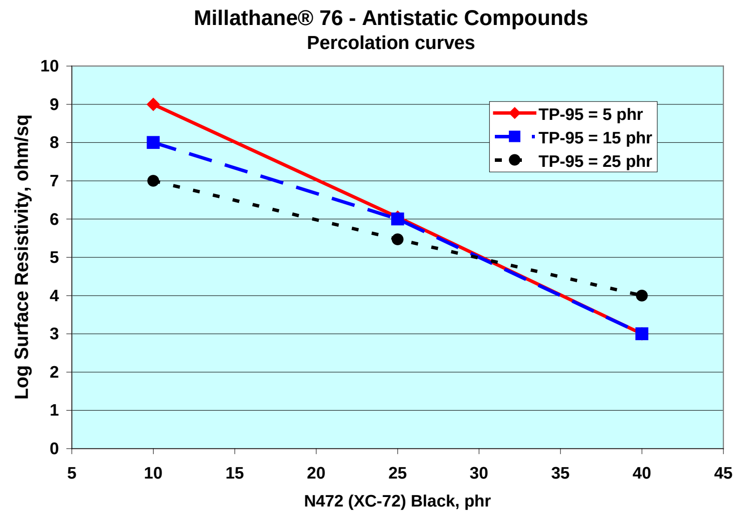
A study was conducted in a sulfur-cured Millathane® 76 compound where the XC-72 carbon black was varied from 10 to 40 parts and the TP-95 was varied from 5 to 25 parts in an experimental design. The formulation used is shown to the right. This compound uses the standard sulfur cure system used for millable 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 108 to 103 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.





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

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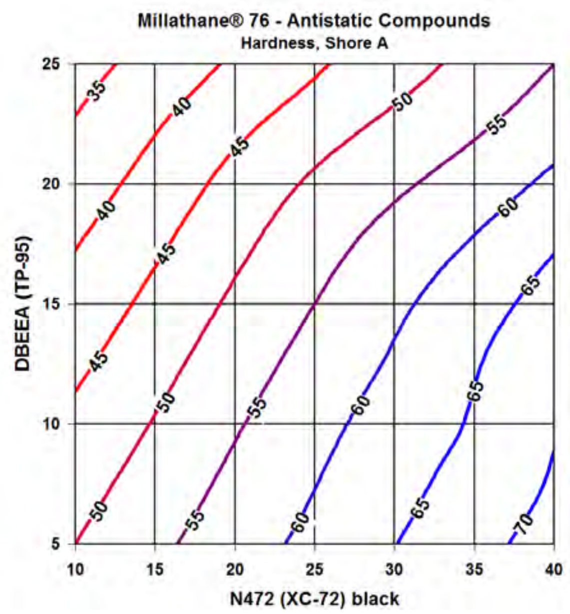
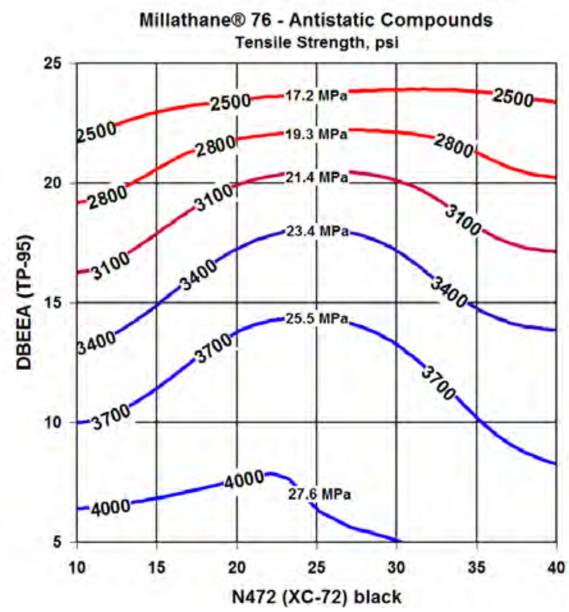
Antistatic Millathane® Millable Urethane Compounds (cont.)

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.





ANTISTATIC FORMULATIONS

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

XC-72 Black	40	40	40	25	10	10
TP-95 (DBEEA)	5	15	25	15	5	25
Mooney Viscosity, ML (1+4)/100ºC	78	45	32	30	43	27
MDR, 20'/160ºC						
ML, lb-in (dNm)	2.1 (2.4)	1.3 (1.5)	1.0 (1.1)	0.5 (0.6)	0.5 (0.5)	0.1 (0.1)
MH, lb-in (dNm)	15.8 (17.8)	11.3 (12.8)	6.8 (7.7)	7.1 (8.1)	8.6 (9.7)	3.8 (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 (MPa)	595 (4.1)	385 (2.7)	265 (1.8)	210 (1.4)	190 (1.3)	80 (0.6)
TSE-200*, psi (MPa)	1260 (8.7)	845 (5.8)	600 (4.1)	455 (3.1)	365 (2.5)	150 (1.0)
TSE-300*, psi (MPa)	1910 (13.2)	1380 (9.5)	985 (6.8)	795 (5.5)	660 (4.6)	270 (1.9)
Tensile Strength, psi (MPa)	3880 (26.8)	3300 (22.8)	2350 (16.2)	3390 (23.4)	4110 (28.3)	2190 (15.1)
Elongation, %	590	600	595	700	670	730
Tear, Die C, lb/in (kN/m)	280 (49.0)	221 (38.7)	157 (27.5)	164.5 (28.8)	177 (31.0)	72 (12.6)
Tear, Die B, lb/in (kN/m)	490 (85.8)	413 (72.3)	300 (52.5)	256.5 (44.9)	319 (55.8)	102 (17.9)
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

**TSE-xxx=Tensile Stress at xxx% Elongation, **Could not test.*

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