Electrical Resistivity

All carbon blacks, under normal conditions, have some capacity to conduct electricity; however, the conductivity varies substantially with the grade and the loading. The large particle size and low degree of particle aggregation of Thermax® N990 allows for a larger interaggregate distance at a given loading. This results in higher compound resistivity and a higher percolation threshold, the loading at which compound conductivity begins to increase considerably. For these reasons, N990 is typically used in rubber applications requiring insulative, static dissipative, or semi-conductive properties. In the automotive industry, problems with electrochemical corrosion of aluminum or magnesium and electrochemical degradation of coolant or radiator hose can be mitigated by utilizing compounds with high electrical resistivity. In the following pages, the electrical resistivity of EPDM compounds loaded with different carbon blacks and natural rubber (NR) compounds loaded with different fillers is compared.

The benefits of N990 found in the studies were:

- Significantly higher electrical resistivity as compared to furnace blacks at a given loading
- High loadability while maintaining insulative properties due to the high percolation threshold
- At very high loadings, compounds tended to be static dissipative
- Ability to blend with furnace grades to balance processing, physicals, and resistivity

The EPDM compound test formulations are provided in Table 1. N990 at 75 phr loading was compared to N762, N650, and N550 at 50 phr loading. The compounding and testing were performed by Akron Rubber Development Laboratory in Akron, OH.

Table 1. EPDM Test Formulations

Ingredient	**1**	**2**	**3**	**4**
Royalene 525	100	100	100	100
N550	50	-	-	-
N650	-	50	-	-
N762	-	-	50	-
N990	**-**	**-**	**-**	**75**
ASTM Type 103 Oil	50	50	50	50
Zinc Oxide	5	5	5	5
Stearic Acid	1	1	1	1
MBT	0.5	0.5	0.5	0.5
TMTD	1	1	1	1
Sulfur	1.5	1.5	1.5	1.5
Total	**209**	**209**	**209**	**234**

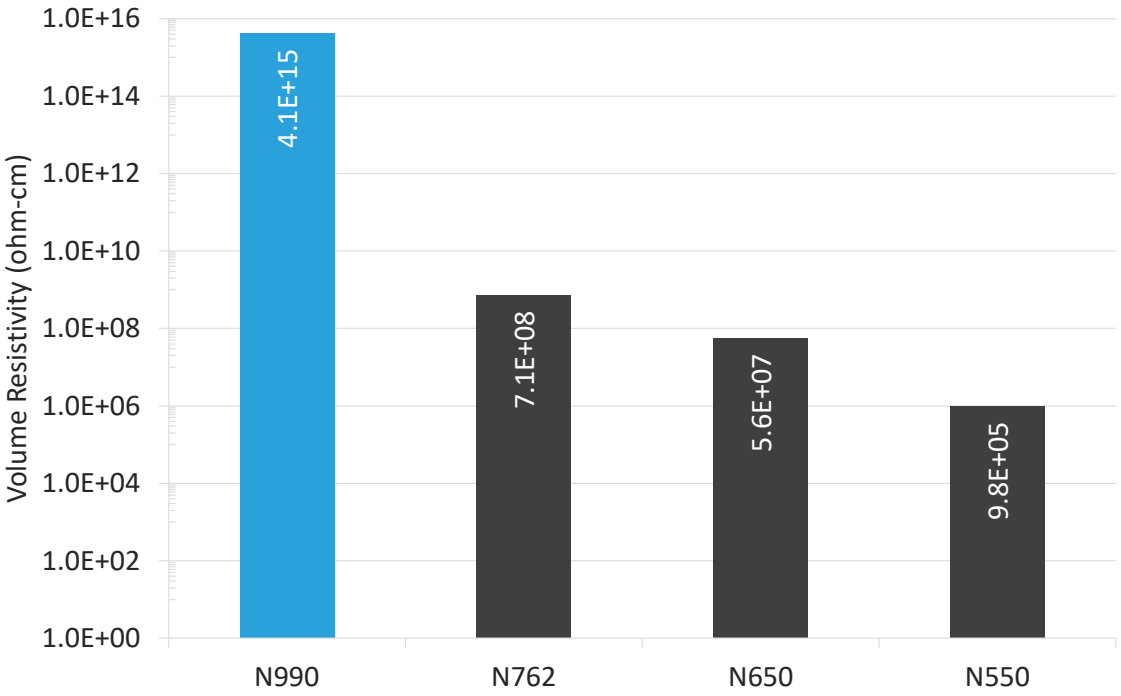

Figure 1. Volume resistivity of EPDM compounds loaded with different grades of carbon black. Applied voltage was 500 VDC for N990, N762, and N650 and 7.5 VDC for N550. The N990 compound was insulative whereas the furnace grade compounds were semi-conductive.

The NR compound test formulations can be found in Table 2. The electrical resistivity of compounds filled with N990 was compared to those containing clay, whiting, and N765. The effects on resistivity after the immersion of compounds in water were also measured.

Table 2. NR Test Formulations

Ingredient	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Pale Creep NR	100	100	100	100	100	100	100
Dixie Clay	-	50	-	-	-	-	-
Calcined Clay	-	-	50	-	-	-	-
Whiting	-	-	-	50	-	-	-
N990	**-**	**-**	**-**	**-**	**25**	**50**	**-**
N765	-	-	-	-	-	-	25
Zinc Oxide	5	5	5	5	5	5	5
Stearic Acid	2	2	2	2	2	2	2
MBTS	1	1	1	1	1	1	1
ZDMC	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sulfur	3	3	3	3	3	3	3
Total	**111.1**	**161.1**	**161.1**	**161.1**	**136.1**	**161.1**	**136.1**

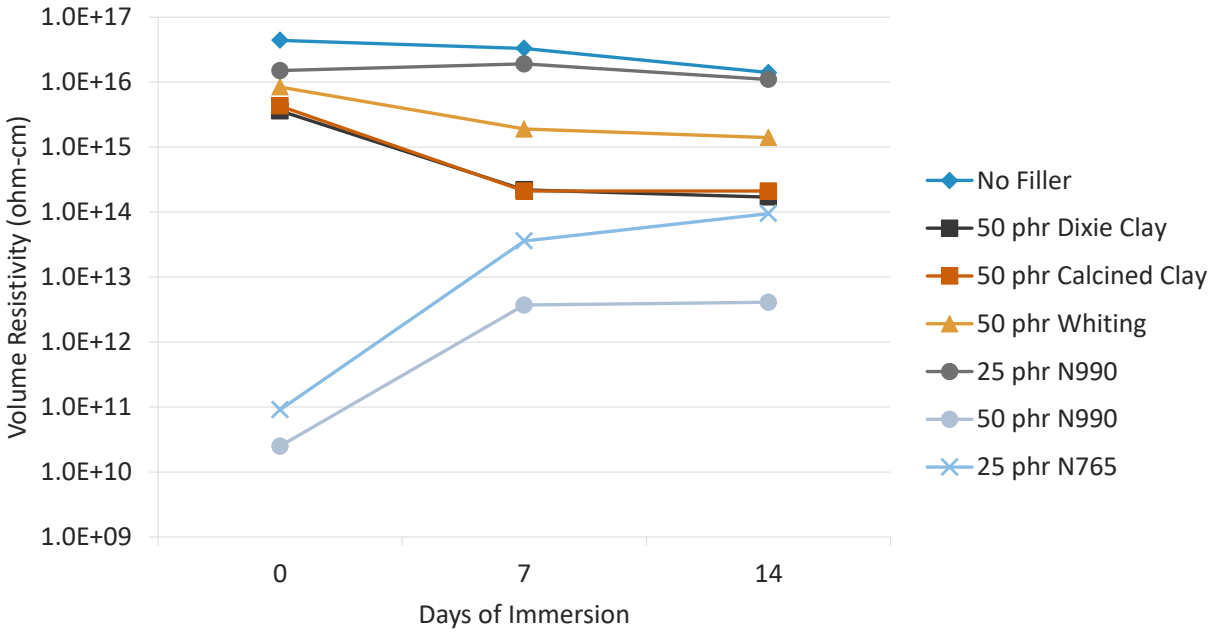

Figure 2. Volume resistivity versus days immersed in water at 70°C. At an N990 loading of 25 phr, the compound was almost as insulative as the control with no filler and had significantly higher resistivity as compared to N765. At an N990 loading of 50 phr, the compound remained insulative.

Thermax® N990 was compared to a low conductivity furnace black (LCCB) in an EPDM compound. The properties of the two carbon blacks are shown in Table 3, the EPDM formulations are shown in Table 4, and the test results are shown in Table 5. The LCCB provided greater reinforcement to the compound as evidenced by the hardness, tensile modulus, and tensile strength. The N990 provided lower viscosity, higher elongation, and higher electrical resistivity. The compound with LCCB had resistivity on the order of 10^4 ohm·cm, which is on the border between the conductive and static dissipative regions, whereas N990 had resistivity on the order of 10^7 ohm·cm, which is firmly in the static dissipative region. The N990 is commonly blended with furnace blacks to balance the processing, physical, and resistivity property requirements.

Table 3. Comparison of N990 and Low Conductivity Furnace Black

Property	Units	Thermax® N990	LCCB
Ash Content	%	0.1	0.2
Heat Loss	%	0	0.1
Sieve Residue, 325 mesh	ppm	3	27
Toluene Extract	%	0.18	0.16
N_2 Surface Area	m^2/g	9.5	26.6
Oil Absorption Number	$cm^3/100g$	38	123
pH	[ ]	10	6.4

Table 4. EPDM Test Formulations for Comparison between N990 and LCCB

Ingredient	1	2
Vistalon 7000	100	100
N990	**160**	**-**
LCCB	-	160
Sunpar 2280	30	30
Zinc Oxide	5	5
Stearic Acid	1	1
TMTD	1.5	1.5
TMTM	1.5	1.5
ZDBC	1.5	1.5
DTDM	2	2
Sulfur	0.2	0.2
Total	**302.7**	**302.7**

Table 5. Properties of EPDM compounds loaded with N990 and LCCB

Mooney, small rotor	Units	N990	LCCB
MS1+4, 100°C	MU	77.7	96.4
t5, 125°C	min	26.4	19.4
ODR, 166°C, 3° arc			
Tc90	min	11.7	7.4
Physical Properties			
Shore A Hardness	pts	79	87
Stress at 100% Strain	MPa	3.5	12.3
Tensile Strength	MPa	11.2	18.2
Elongation at Break	%	575	195
Electrical Testing, 12 V			
Volume Resistivity	ohm·cm	4.5E+07	2.3E+04
Surface Resistivity	ohm/sq	2.4E+08	4.9E+04