Effect of Thermax® N990 on EPDM Electrical Percolation Threshold

Electrical resistivity is an important property for various applications including wire and cable, battery, fuel cell, and automotive profiles. With increasing electrification of the transportation sector comes more specifications surrounding electrical resistivity of rubber and plastic parts. In addition, some rubber parts, such as automotive profiles, have electrical resistivity specifications in order to avoid electrochemical degradation of the rubber and electrochemical corrosion of aluminum parts.

Carbon black is typically utilized at high loadings in rubber compounds to provide mechanical reinforcement; however, the addition of carbon black also increases the conductivity of the compound. The size, structure, and surface chemistry of the carbon black all impact the electrical percolation threshold which is the carbon black loading at which the compound transitions from insulative to conductive. The large particle size and low structure of Thermax® N990 results in a larger interaggregate distance at a given loading and a higher percolation threshold. In this study, the transition from insulative to conductive behavior was investigated for EPDM compounds loaded with N990 and N550/N990 blends.

When replacing clay, the benefits of Thermax® N990 include:

- Increased modulus
- Lower compression set
- Ability to tailor electrical resistivity to application
- Reduced compound density
- Reduced wear of extruder and mixer components

When using a higher proportion of N990 relative to N550, the benefits include:

- Reduced viscosity
- Longer scorch time
- Increased elongation at break
- Higher electrical percolation threshold
- Greater extension of compound resulting in potential cost savings

By adjusting the composition of the filler system, the various performance targets of the compound can be met.

The EPDM formulations can be found in Tables 1 to 3. To maintain constant hardness N990 replaced the clay at a 1.0:1.0 ratio and N550 replaced the clay at a 2.0:1.0 ratio. N550/N990 blends of 25:75 and 50:50 were used. Mooney viscosity, MDR, Garvey die, Shore A hardness, tensile, compression set, and electrical resistivity tests were run on all compounds. All compounds had excellent performance in Garvey die testing. Testing results can be found in the figures on the following pages.

Table 1. Test formulations for N990 compounds

Ingredient	Control	A	B	C	D	E	F	G
Keltan 5470	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Paraffinic Oil	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Carbowax 3350	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Natka 1200 Clay	70.0	60.0	50.0	40.0	30.0	20.0	10.0	0.0
N550	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thermax® N990	**90.0**	**100.0**	**110.0**	**120.0**	**130.0**	**140.0**	**150.0**	**160.0**
ZnO	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Stearic Acid	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Sulfur	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
BBTS	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
TMTD 75%	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
ZDBC	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total	**323.9**	**323.9**	**323.9**	**323.9**	**323.9**	**323.9**	**323.9**	**323.9**
%CB by weight	**27.8**	**30.9**	**34.0**	**37.0**	**40.1**	**43.2**	**46.3**	**49.4**

Table 2. Test formulations for 25:75 N550/N990 compounds

Ingredient	H	I	J	K	L
Keltan 5470	100.0	100.0	100.0	100.0	100.0
Paraffinic Oil	50.0	50.0	50.0	50.0	50.0
Carbowax 3350	3.0	3.0	3.0	3.0	3.0
Natka 1200 Clay	55.0	40.0	25.0	10.0	0.0
N550	20.0	23.0	26.0	29.0	31.0
Thermax® N990	**60.0**	**69.0**	**78.0**	**87.0**	**93.0**
ZnO	5.0	5.0	5.0	5.0	5.0
Stearic Acid	1.5	1.5	1.5	1.5	1.5
Sulfur	1.5	1.5	1.5	1.5	1.5
BBTS	1.5	1.5	1.5	1.5	1.5
TMTD 75%	0.4	0.4	0.4	0.4	0.4
ZDBC	1.0	1.0	1.0	1.0	1.0
Total	**298.9**	**295.9**	**292.9**	**289.9**	**287.9**
%CB by weight	**26.8**	**31.1**	**35.5**	**40.0**	**43.1**

Table 3. Test formulations for 50:50 N550/N990 compounds

Ingredient	M	N	O	P
Keltan 5470	100.0	100.0	100.0	100.0
Paraffinic Oil	50.0	50.0	50.0	50.0
Carbowax 3350	3.0	3.0	3.0	3.0
Natka 1200 Clay	55.0	40.0	25.0	10.0
N550	32.0	37.0	42.0	47.0
Thermax® N990	**32.0**	**37.0**	**42.0**	**47.0**
ZnO	5.0	5.0	5.0	5.0
Stearic Acid	1.5	1.5	1.5	1.5
Sulfur	1.5	1.5	1.5	1.5
BBTS	1.5	1.5	1.5	1.5
TMTD 75%	0.4	0.4	0.4	0.4
ZDBC	1.0	1.0	1.0	1.0
Total	**282.9**	**277.9**	**272.9**	**267.9**
%CB by weight	**22.6**	**26.6**	**30.8**	**35.1**

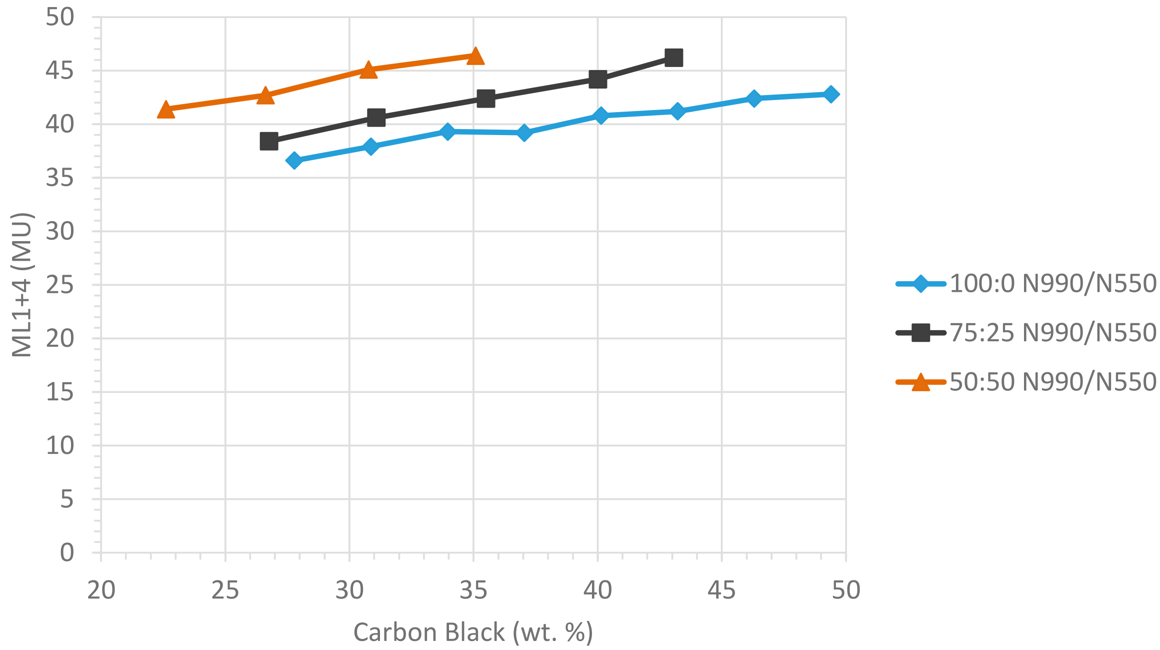

Figure 1. Mooney viscosity versus carbon black content for the compounds measured at 100°C. Mooney viscosity tended to increase slightly as carbon black content increased, replacing clay. At a given carbon black level, Mooney viscosity was lower for compounds with higher N990 to N550 ratios.

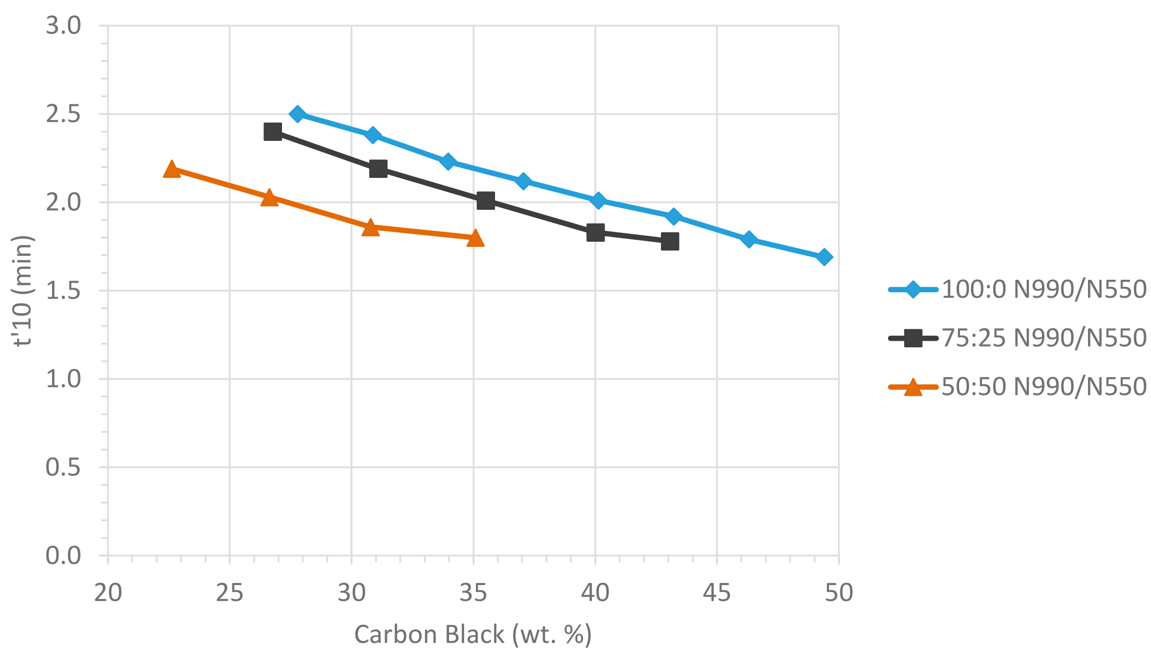

Figure 2. Scorch time, t'10, versus carbon black content for the compounds measured at 160°C. Scorch times tended to decrease as carbon black content increased. At a given carbon black level, scorch times were longer for compounds with higher N990 to N550 ratios.

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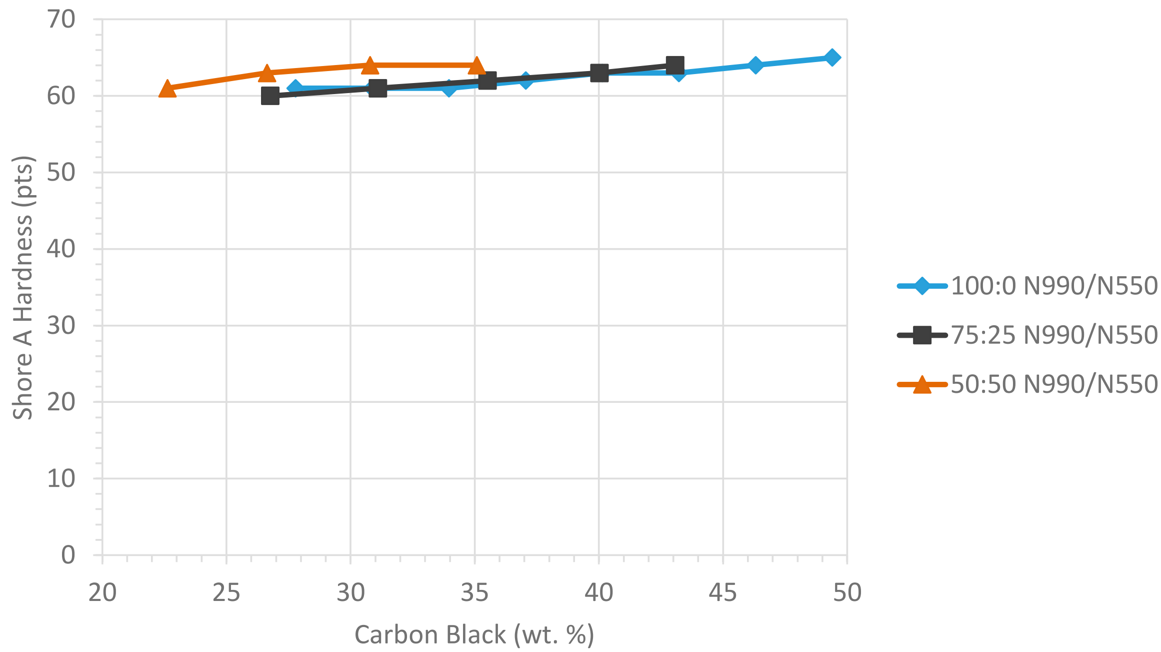

Figure 3. Shore A hardness versus carbon black content for the compounds. Hardness tended to increase as carbon black content increased. All compounds had hardness values between 60 and 65 points.

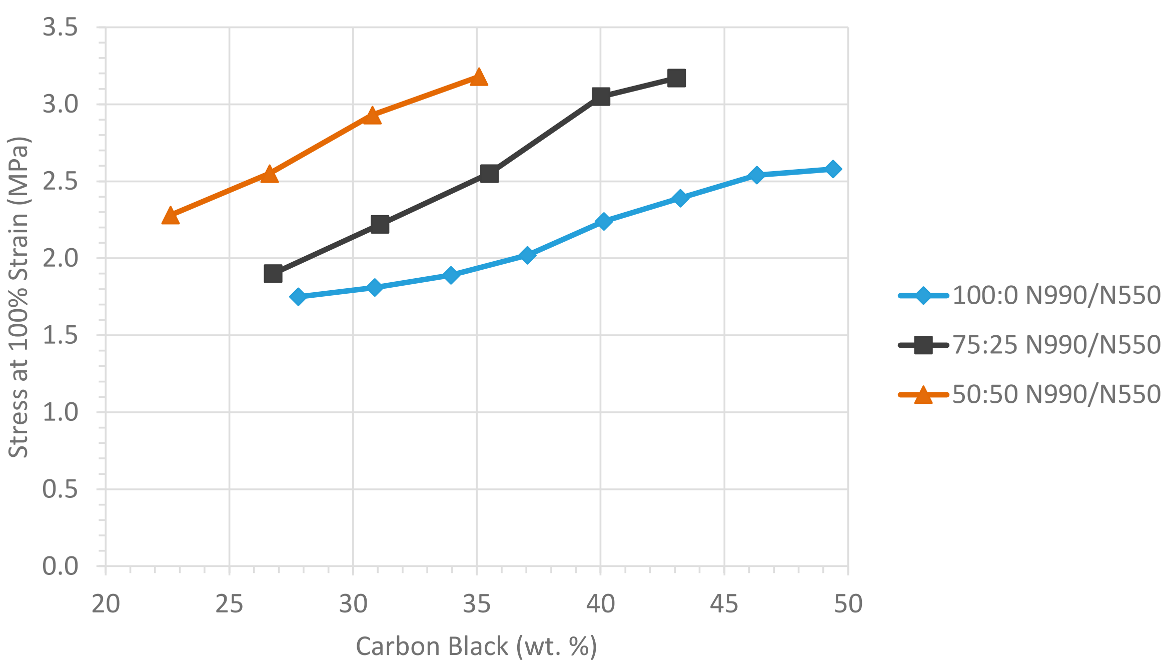

Figure 4. Stress at 100% strain versus carbon black content for the compounds. The 100% modulus tended to increase as carbon black content increased. At a given carbon black level, the 100% modulus was lower for compounds with higher N990 to N550 ratios.

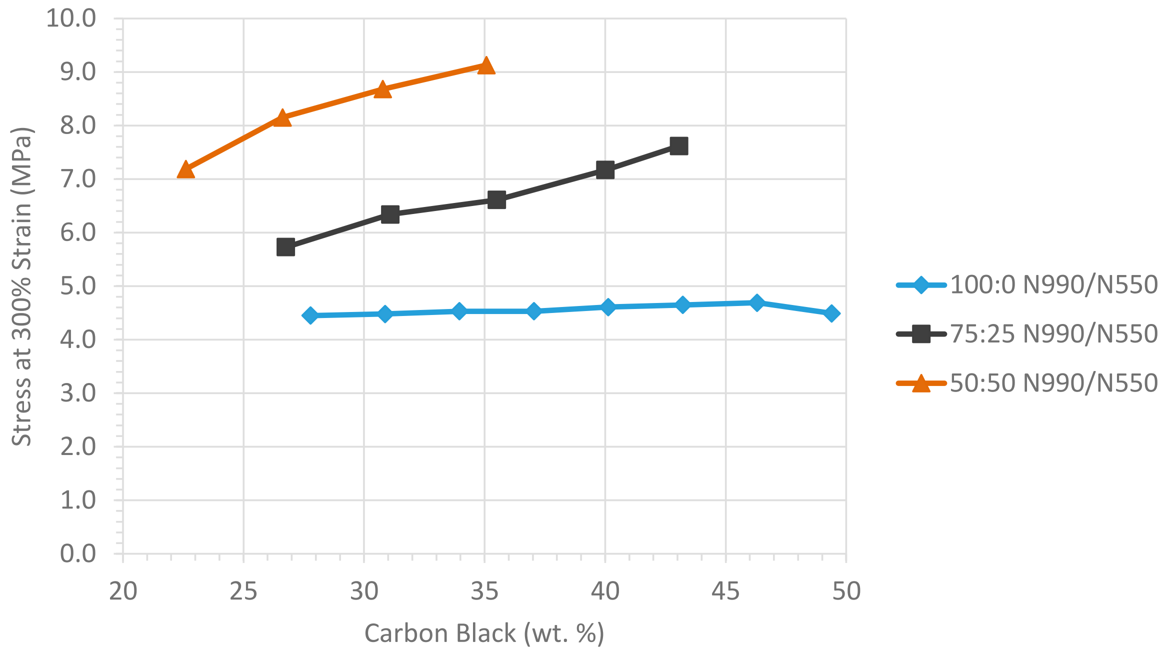

Figure 5. Stress at 300% strain versus carbon black content for the compounds. The 300% modulus tended to increase as carbon black content increased. At a given carbon black level, the 300% modulus was lower for compounds with higher N990 to N550 ratios.

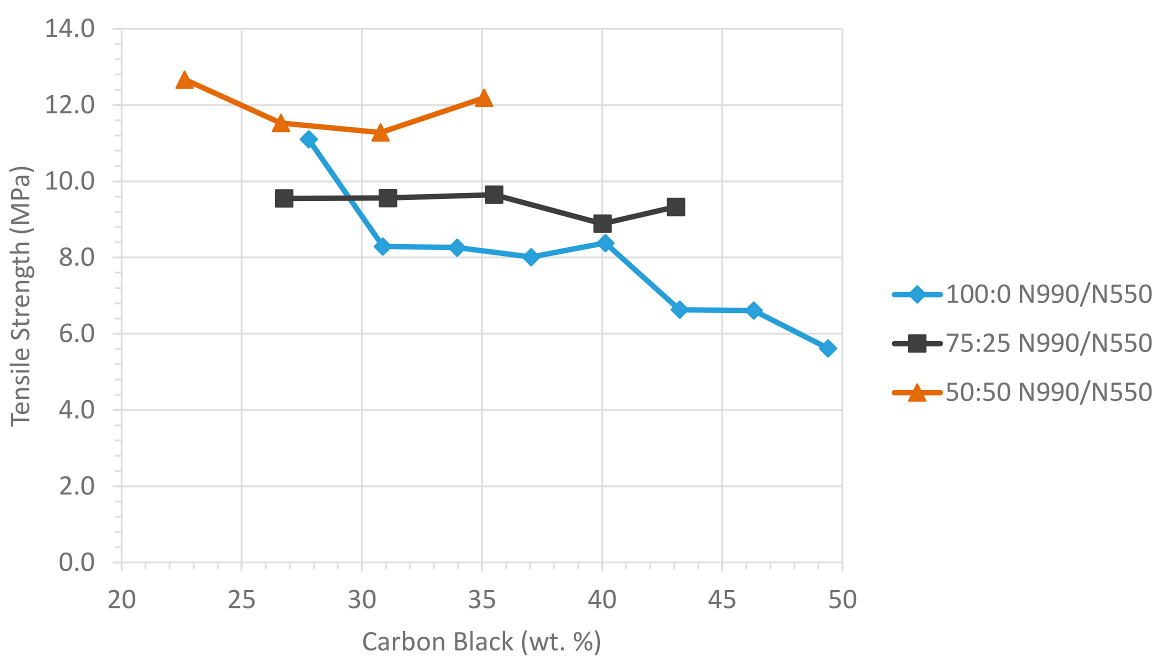

Figure 6. Tensile strength versus carbon black content for the compounds. At a given carbon black level, the tensile strength was generally lower for compounds with higher N990 to N550 ratios.

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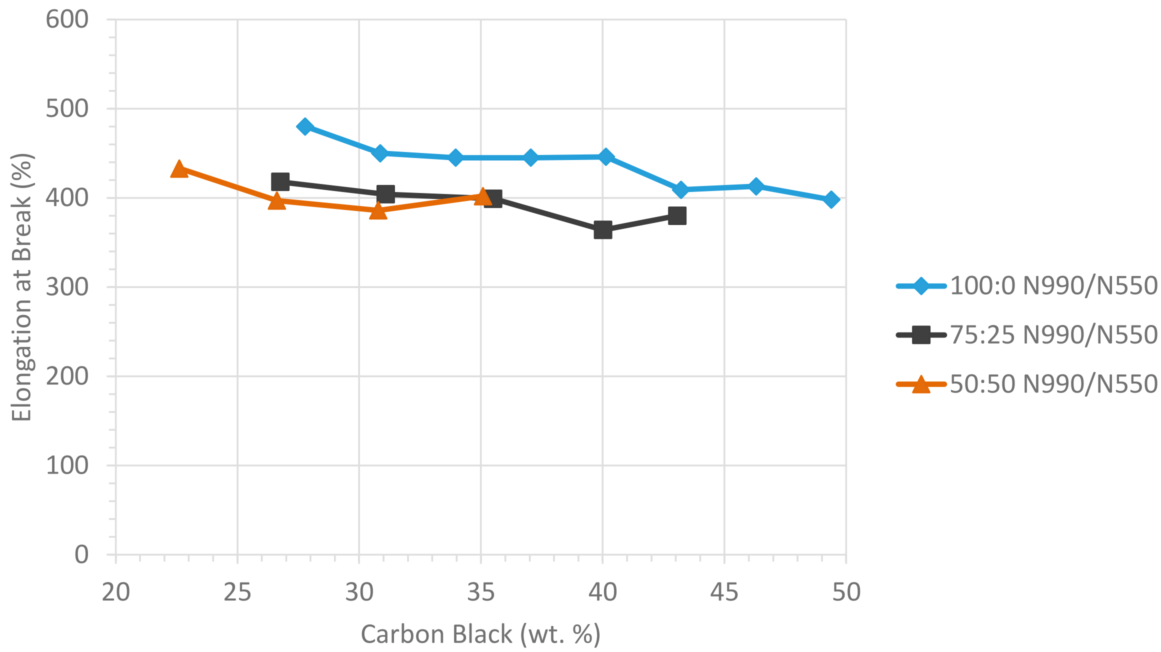

Figure 7. Elongation at break versus carbon black content for the compounds. Elongation tended to decrease slightly as carbon black content increased. At a given carbon black level, the elongation was higher for compounds with higher N990 to N550 ratios.

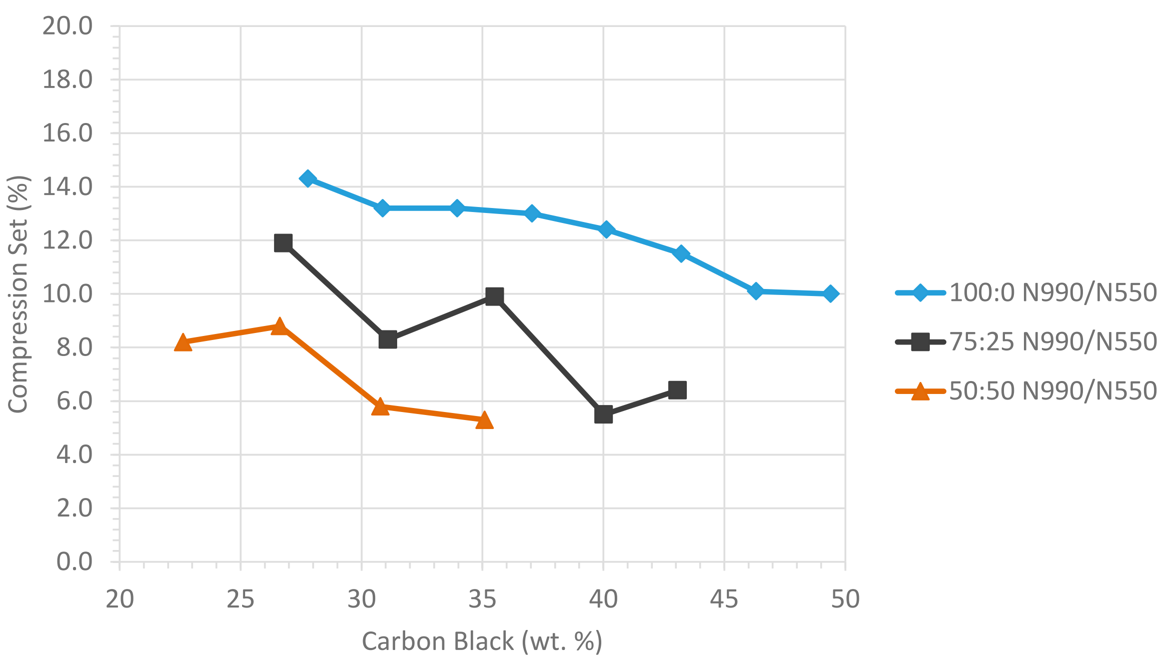

Figure 8. Compression set versus carbon black content for the compounds measured after 22 hours at 70°C. Compression set tended to decrease as carbon black content increased. At a given carbon black level, compression set was higher for compounds with higher N990 to N550 ratios. This was likely due to the higher clay content and higher total filler loading of the higher N990 to N550 ratio compound.

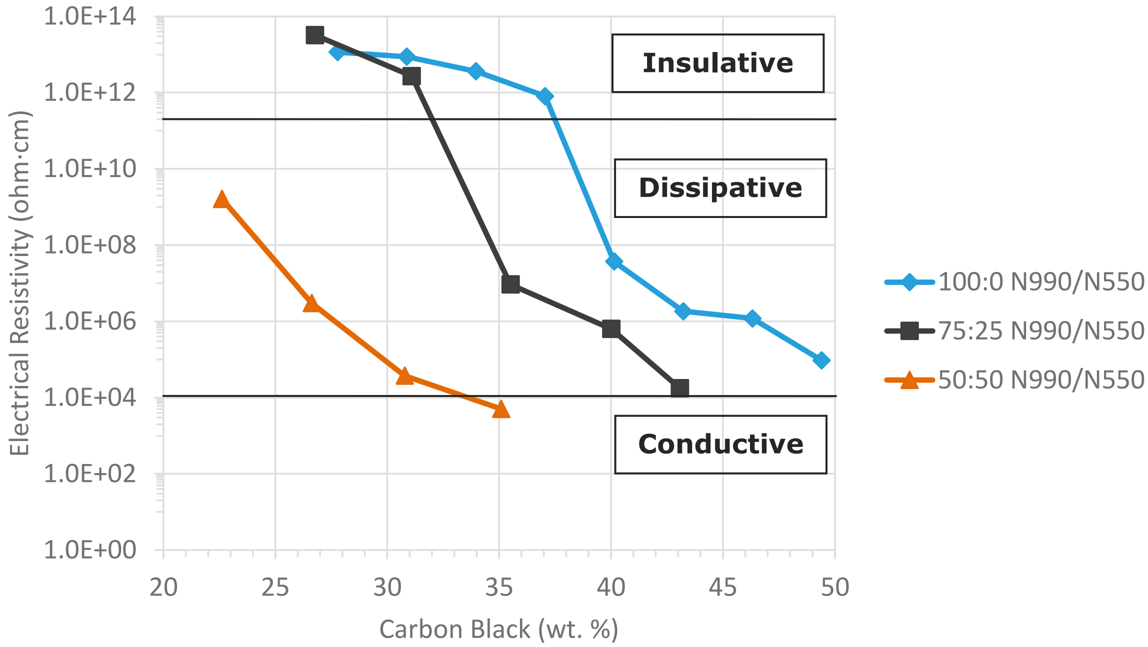

Figure 9. Electrical resistivity versus carbon black content for the compounds. Resistivity decreased as carbon black content increased. The percolation threshold increased for compounds with higher N990 to N550 ratios. Compounds with a 50:50 N990/N550 ratio were likely insulative up to 20 wt.% carbon black. Compounds with a 75:25 N990/N550 ratio were insulative up to 31 wt.% carbon black. Compounds with only N990 were insulative up to 37 wt.% carbon black.

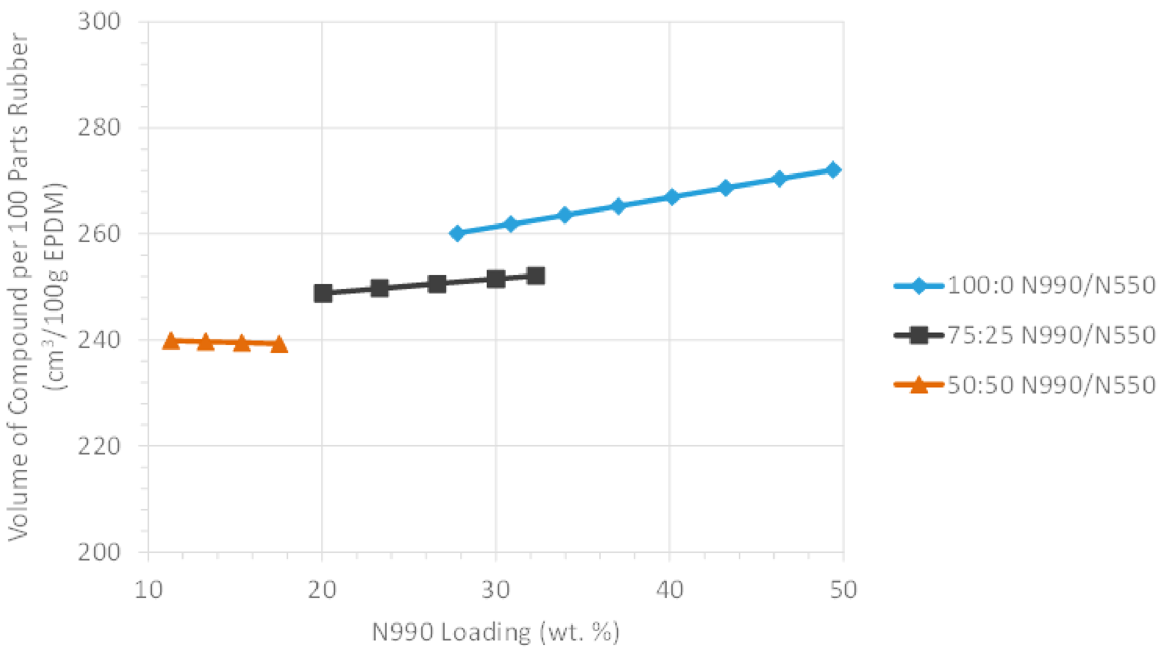

Figure 10. Volume of compound per 100 parts rubber versus N990 loading for the compounds. Replacing clay with N990 leads to a compound density reduction. Replacing N550 with N990 leads to higher total filler loading. In either case, the total volume of compound obtained per 100 parts rubber is increased.