cancarb

TECHNICAL BULLETIN

Wire & Cable Applications

Medium Thermal Black N990 nn Low Voltage Wire and Cable Insulation

Medium thermal carbon black (ASTM designation of N990) is used as a functional filler in low voltage wire and cable applications. While a variety of fillers are used in the wide range of cable applications, medium thermal carbon black is the most preferential filler in low voltage cable due to the functional benefits provided by this unique carbon black.

Cancarb Limited (Medicine Hat, Alberta, Canada) manufactures various grades of medium thermal carbon black which are sold under the tradename “Thermax®”. Pelletized, Powder, Ultra-Pure and Stainless grades of thermal black are available from Cancarb. Thermax® is produced by the thermal decomposition of natural gas, with the resultant carbon having a particle size range of 100 – 600 nm.

While most carbon blacks are semi-conductive, medium thermal carbon black has the highest volume resistivity of all carbon blacks. Three basic properties of carbon black are considered to affect the level of conductivity in rubber or plastic compounds. These are the particle size (or surface area), the degree of structure and the corresponding amount of void space between those particles, and finally porosity. Small particle furnace blacks, with their high degree of aggregation, and smaller void spaces between the particles, have higher levels of conductivity than thermal blacks. The greater amount of structure acts to reduce the distance between particles or aggregates, thereby allowing electrical flow to pass more easily along the molecular chains. The thermal blacks are characterized by large particles and more space between the particles due to the low degree of aggregation. Thus, an inverse relationship exists between both surface area and structure and the level of resistivity.

For reference, the following table provides a comparison of Thermax® to commercially available conductive blacks:

Carbon Black Type	Particle Diameter nm	Surface Area m^2/g	Structure DBP Adsorption cc/100 g
Thermax® N990	280	9.5	38
Conductex SC	20	220	115
Vulcan XC-72	30	254	178
Black Pearls 2000	15	1475	330
HI-Black 40B1	19	153	130
Ketjenblack EC	30	950	360
Acetylene Black	40	60	320

Other factors play a lesser role in determining conductivity, but not to the extent of the above noted properties. These are volatile type and content, moisture and extractable matters, all of which may act to inhibit or disrupt electron flow.

In addition to carbon blacks, other fillers may affect the inherent electrical properties of elastomers. Not all fillers, however, affect the electrical properties of an elastomer to the same degree. The following base formula for a natural rubber compound is used to show the effect of various fillers on volume resistivity.[1]

Pale Crepe NR	**100**
Stearic Acid	**2**
Zinc Oxide	**5**
Sulphur	**3**
Altax (accelerator)	**1**
Methyl zimate (accelerator)	**0.1**
	111.1

Press cures: 15 minutes at 143°C (290°F)

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[1] John D. Hogan, "Wire and Cable" in the Vanderbilt Rubber Handbook, 13th ed., 1990, p. 717

Effects of Fillers on Volume Resistivity (NR Compound) Ohm.cm

Loadings	Immersion Days at 70°C	Volume Resistivity
No Filler	0	4.4×10^{16}
	7	3.3×10^{16}
	14	1.4×10^{16}
Dixie Clay **50 phr**	0	3.6×10^{15}
	7	2.2×10^{14}
	14	1.7×10^{14}
Calcined Clay **50 phr**	0	4.3×10^{15}
	7	2.1×10^{14}
	14	2.1×10^{14}
Whiting (water ground) **50 phr**	0	8.4×10^{15}
	7	1.9×10^{15}
	14	1.4×10^{15}
Thermax® N990 **25 phr**	0	1.5×10^{16}
	7	1.9×10^{16}
	14	1.1×10^{16}
Thermax® N990 **50 phr**	0	2.5×10^{10}
	7	3.7×10^{12}
	14	4.1×10^{12}
SRF Black N765 **25 phr**	0	9.1×10^{10}
	7	3.6×10^{13}
	14	9.5×10^{13}

Thermax® has the lowest level of structure and one of the largest particle sizes of the carbon blacks. These properties combine to produce a carbon black which is in fact the least suited to conduct electricity in a polymer system. The fact that Thermax® is essentially individual spheres of carbon black will allow polymer chains to surround and electrically insulate the carbon. The inactive surface chemistry of thermal black greatly limits the amount of crosslinking possible between the thermal black particles and polymer chains, which eliminates the potential for electro-chemical pathways in the polymer system.

Applications and Advantages of Thermax®

Thermax® is used in a wide range of low voltage XLPE, Neoprene, PVC, EPDM, SBR, CSM and natural rubber compounds. Applications include insulation, insulation jackets, flexible cord jackets, UL Class 25 heavy duty jackets and others. The most common application is crosslinked resin insulation, such as PE, EVA or EEA. The advantages of Thermax® include:

a) High Volume Resistivity

The properties of thermal black are such that it can be loaded into polymer systems without degrading the inherent high volume resistivity of the polymer system. As resistivity may be affected by trace amounts of metallic and other elemental impurities, Thermax® is preferred due to its high purity and low sieve residue.

b) Flame Retardancy

Safety regulations require a minimum amount of filler in the compound to act as a flame retardant. Thermal black increases the flame temperature of the compound, eliminating the need for expensive flame retardants. It has been reported by Woodell that an insulation jacket containing 16% of a medium thermal carbon black in an ethylene vinyl silane copolymer compound provides sufficient flame resistance to meet UL 44 horizontal burn requirements.[1]

c) Ultra-Violet Protection

UV rays have enough energy to break bonds in XLPE, which destroys the compound. Thermal black, at sufficiently high loading levels, provides UV protection because carbon particles absorb UV rays and emit the energy in the form of heat.

d) Compound Processing

Thermal black moderates the nerve of the polymer which improves mixing and processing characteristics. The viscosity of the polymer does not greatly increase with the addition of medium thermal black. The low structure, large particle thermal black disperses readily with low heat build-up and provides good extrusion characteristics.

e) Cross-Linking

The non-acidic surface chemistry of thermal black does not interfere with the free radical formation of the peroxide, necessary for cross-linking. Thermal blacks also have a very low moisture content compared to other carbon blacks, which inhibits premature crosslinking.

f) Cost-Effectiveness

The relatively high loading of thermal black (25% - 30%) in low voltage cable compounds provides some degree of compound extension and eliminates or reduces the need for expensive flame retardants. Low temperature cured EPDM jacket compounds are known to contain 50 phr of Thermax® N990 and up to 100 phr of furnace blacks. [1]

g) Surface Appearance

Thermax® has very small amounts of sieve residue (specification of 15 ppm on 325 mesh for Thermax® FloForm N990). The relative absence of sieve residue helps to improve surface appearance by eliminating blemishes and other surface imperfections.

h) Reinforcement

Although generally non-reinforcing in most elastomers, Thermax® will provide some degree of reinforcement at sufficiently high loadings. Thermax® is used in XLPE underground residential distribution (URD) systems at varying levels for reinforcement purposes.

Generally, 20 to 50 parts of medium thermal carbon black can be loaded per one hundred parts of polymer. At low loadings, the mechanical properties of the compound will essentially be the same as those without thermal black. According to Queen, polyethylene which has been cross-linked by radiation or peroxide (such as dicumyl peroxide) can often be loaded with excessive amounts of medium thermal black, upwards of 75%, without destroying the polymer's physical properties.[2]

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[1] John D. Hogan, "Wire and Cable" in the Vanderbilt Rubber Handbook, 13th ed., 1990, p. 717

[2] Queen, E.J., "Carbon Black", Handbook of Fillers and Reinforcements for Plastics, H.S. Katz and J.S. Milewski, eds., Van Nostrand Reinhold Company, 1978, p. 288

Appendix I – Typical Cross-Linked Polyethylene Low Voltage (600-1500 Volt) Insulation Jacket Formulation

Ingredient	Description	%
Polyethylene (PE)	Ethylene vinyl acetate (EVA)	68 - 72
Ethylene copolymer	Containing 9-17% VA	
Thermax® FloForm N990	Pelletized medium thermal carbon black	26 - 30
Agerite Resin D	Hydroquinoline: antioxidant, stabilizer	Variable
Stearic Acid	Fatty acid: lubricant, processing aid	Variable
Peroxide	Cross-linking agent	Variable

Thermax® FloForm N990 acts as an economical compound extender. At the same time it reduces the nerve of the polymer, provides ultra-violet protection, flame retardance and allows the compound to maintain good dielectric properties.

Appendix II – Cross-Linked Polyethylene Insulation Jacket Formulation

Polyethylene (DYNH)	100	
Agerite MA	0.5	Antioxidant
Thermax® FloForm N990	60	Medium thermal carbon black
Varox DCP-40KE	7	Peroxide cross-linking agent
TOTAL	**167.5**	
Press Cured 20 minutes @ 171°C (340°F)		
100% Modulus, MPa	11.0	(1600 psi)
Tensile Strength, MPa	16.1	(2330 psi)
Elongation (%)	310	
After Aging 20 Hours in Air Bomb @ 127°C (216°F), 550 kPa Air (80 psi)		
Tensile Strength (% Retained)	97	
Elongation (% Retained)	94	
After Aging 168 hours in Oxygen Bomb @ 80°C (176°F), 2.1 MPa Oxygen (300 psi)		
Tensile Strength (% Retained)	97	
Elongation (% Retained)	80	

Source: The Vanderbilt Rubber Handbook, 13th ed., p. 720

Appendix III – Neoprene Cable Jacket Formulations

	Heat Resistant Cord	**Insulation**
Neoprene W	100	100
Vanplast R	2	5
Magnesium Oxide	4	4
Vanfre AP-2	3	3
Agerite Stalite S	2	2
Agerite White	0.5	-
Vanwax H Special	2	2
Whiting (water ground)	50	-
Thermax® FloForm N990	30	50
Oxidized Carbon Black (S315)	30	-
Dixie Clay	-	50
Zinc Oxide	5	5
Sulfads	1.5	1.5
Vanax DOTG	0.5	0.5
Vanax NP	1.0	1.4
TOTAL	**231.5**	**224.4**
Properties, Cured 45 seconds @ 198°C (388°F) in steam		
200% Modulus, MPa (psi)	4.6 (660)	5.1 (740)
Tensile Strength, MPa (psi)	13.7 (1990)	13.0 (1880)
Elongation (%)	420	600
Mooney @ 121°C (250°F)		
Scorch, t5, minutes	-	10
After 168 hours in Oxygen Bomb @ 70°C (158°F), 2.1 MPa (300 psi) Oxygen Pressure		
Tensile Strength, (% Retained)	91	89
Elongation (% Retained)	86	80
After 20 hours in Air Bomb @ 127°C (260°F), 550 kPa (80 psi) Air Pressure		
Tensile Strength (% Retained)	92	-
Elongation (% Retained)	84	-

Source: The Vanderbilt Rubber Handbook, 13th ed., p. 720

Appendix IV – EPDM Medium Voltage Insulation Formulation

Royalene EPDM 56/44	100.00
Thermax® N990	10.00
Clay	120.00
Vinyl Silane A-172-50	2.00
TMQ	1.50
Zinc Oxide	5.00
Paraffin wax	5.00
Paraffinic Oil	25.00
VC-60, 60% Peroxide	5.80
ODR @ 177°C, 3° arc	
MH, dN-m	61.0
ML, dN-m	10.6
ts2, minutes	1.4
100% Modulus, MPa	2.4
200% Modulus, MPa	4.1
Tensile Strength, MPa	6.7
Elongation at Break (%)	640
Hardness	66
Oven Aged, 7 days @ 136°C	
Tensile Strength (% Retained)	114
Elongation (% Retained)	78
Hardness, pts change	+1