TECHNICAL BULLETIN

NBR O-Ring Compounds

Thermax® N990 medium thermal black, manufactured by Cancarb Limited, is characterized by its large particle size and low structure. Thermax® is also known for its high purity and very low sieve residue. Cancarb manufactures Thermax® N990 to a specification of 15 ppm on 325 mesh. Thermax® is widely used in applications such as o-rings, gaskets and seals, where low sieve residue is crucial for surface quality. The large particle size and low structure provide superior compound properties including low viscosity and excellent mold flow, necessary for the intricate molds used in o-rings, seals and gaskets. The inert nature of Thermax®, the low surface activity and the high carbon purity provide superior heat and chemical resistance in sealing applications.

In this report, Thermax® N990 is compared to a new carbon black (Sterling 2320) in an NBR o-ring compound. Various new carbon blacks, such as Sterling 2320, are being marketed as a replacement for N990 thermal black. This report will demonstrate the superior nature of Thermax® N990 and its uniqueness in o-ring compounds.

Comparison of Physical Properties of Carbon Blacks

	Thermax® N990*	Sterling 2320
NSA m^2/g	9.7	18.4
DBP cc/100 g	38	48.8
pH	10	4.6
Ash Content %	0.1	0.37
325 Mesh Sieve Residue	8	61
Fines %	4	4.4
Pellet Crush +10 mesh	20	69

**Typical Properties*

A fast curing, oil and heat resistant NBR o-ring compound is used for this report. A low viscosity NBR was selected as the polymer for this compound in order to accommodate high carbon black loadings.

1702 Brier Park Crescent N.W., Medicine Hat, AB, Canada, T1C 1T9 Phone 1.403.527.1121 Fax 1.403.529.6093 customer_service@cancarb.com www.cancarb.com

Formulation (pts by weight)

	#1	#2	#3	#4
NBR, Krynac 34.35	100.0	100.0	100.0	100.0
Thermax® N990	65.0	90.0	-	-
Sterling 2320 Carbon Black	-	-	65.0	90.0
N550 FEF Carbon Black	25.0	25.0	25.0	25.0
Spider Sulphur	0.3	0.3	0.3	0.3
Naugard 445	2.0	2.0	2.0	2.0
Vulcanox MB-2	2.0	2.0	2.0	2.0
Stearic Acid	0.5	0.5	0.5	0.5
Zinc Oxide	15.0	15.0	15.0	15.0
Paraplex G/50 (Polyester)	10.0	10.0	10.0	10.0
Sulfasan R (Monsanto)	1.5	1.5	1.5	1.5
TMTD	4.0	4.0	4.0	4.0
CBS	3.0	3.0	3.0	3.0
Total	**228.3**	**253.3**	**228.3**	**249.3**

Naugard 445: Uniroyal Diphenylamine
Vulcanox MB-2: Bayer antioxidant, 4-5 – methyl-mercaptobenzimidazole
CBS: N-cyclohexyl-2-benzothiazyl sulphenamide

Compound Properties				
Compound Viscosity	40.5	48.5	49.0	64.7
(ML 1 + 4 @ 100°C)				
Mooney Scorch Time	7.2	6.7	7.4	6.6
(t5 @ 125°C)				
Monsanto Rheometer @ 166°C, 3° arc				
MH	133.94	143.58	133.83	149.96
ML	4.51	5.18	5.51	7.12
Delta torque	129.43	138.40	128.32	142.84
tc50	1.99	1.92	2.00	1.89
tc90	4.78	3.90	3.71	3.44
tc50 – tc10	0.40	0.39	0.40	0.39
ts1	1.14	1.09	1.15	1.07
ts2	1.25	1.19	1.26	1.16

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	#1	#2	#3	#4
Vulcanizate Properties				
Cure Time (min @ 166°C)	10	10	9	10
Hardness, Shore A2	71	78	75	80
Modulus @ 50% elong (MPa)	2.4	3.1	3.1	4.6
Modulus @ 100% elong (MPa)	4.9	6.7	7.2	10.7
Modulus @ 200% elong (MPa)	11.2	12.9	14.6	-
Tensile strength (MPa)	12.7	13.0	15.8	17.4
Ultimate elongation (%)	275	225	240	195
Tear strength, die C (kN/m)	23.6	25.9	26.2	31
Tear strength @ 100°C, die C	9.8	11.8	11.8	13.7
Compression set – Method B	15	15	15	15
(70 h @ 100°C – cured + 15 min)				
Aged Properties, aged in IRM 903 oil (70 h @ 150°C)				
Hardness	65	70	68	75
- pts change	-6	-8	-7	-5
Modulus @ 100% elong (MPa)	4.4	5.8	6.2	9.2
% change	-10	-13	-14	-14
Tensile strength (MPa)	15.0	15.0	17.3	17.6
% change	18	15	9	1
Ultimate elongation (%)	270	225	230	175
% change	-2	0	-4	-10
Volume change (%)	7.4	7.3	7.2	7.2
Aged Properties, aged in air (70 h @ 135°C)				
Hardness	80	84	83	87
- pts change	9	6	3	7
Modulus @ 100% elong (MPa)	9.0	12.1	14.4	18.1
% change	84	81	100	69
Tensile strength (MPa)	15.1	15.7	18.2	18.3
% change	19	21	15	5
Ultimate elongation (%)	170	150	125	100
% change	-38	-33	-48	-49
Dynamic Properties				
MER 11 (Static deformation 5%, dynamic deformation 2%)				
Tan delta @ 0°C	0.668	0.652	0.647	0.620
Tan delta @ 25°C	0.233	0.237	0.233	0.264
Tan delta @ 100°C	0.099	0.115	0.119	0.130

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Discussion

Compound Properties

Viscosity: The two compounds with N990 had substantially lower viscosity than the compounds with Sterling 2320. This would be of particular importance in injection and transfer molded compounds and if polymers of higher viscosity were used. The maximum amount of Sterling 2320 tolerable in a given compound would be less than that which could be safely incorporated using N990. If N990 was not used, lower loadings of carbon black would be necessary and this would increase the compound cost proportionately.

Curing Characteristics: Mooney scorch times remained about the same for all compounds although a minor trend to reduced safety was seen as compound viscosity increased.

The rheometer data indicated that Sterling 2320 develops higher torque, which is consistent with a move reinforcing material.

Vulcanizate Properties

Unaged Properties: The Sterling black provided higher hardness than Thermax® N990 in both cases of 65 phr and 90 phr, again consistent with a smaller particle black with higher structure. The Sterling 2320 provided higher modulus, which also increased more with loading than it did with the thermal black N990. As a consequence, ultimate elongation suffered with the Sterling 2320 compound. Higher tensile strength was provided by the compounds with Sterling 2320, as was the tear strength. Although Sterling 2320 provided higher levels of tear strength at both room and elevated temperatures, the differences were not remarkable. Compression set was equivalent at the two loading levels.

Aged Properties: **(Oil)** Apart from volume change in fluids, the two properties which are perhaps the most important from an aging resistance viewpoint are hardness and elongation change. Taking these two into consideration, the best performance overall after oil aging was given by Thermax® N990. For example, at 90 phr, the elongation of the Thermax® compound did not change while the Sterling 2320 compound changed – 10%.

(Air) After aging in air, elongation deteriorated more severely in the Sterling compounds. This was most evident at the loading of 90, where the Thermax® compound changed – 33% and the Sterling compound changed – 49%.

Dynamic Properties: Although the compound used in this work was not designed for service under dynamic conditions, the results of dynamic testing still give an indication of the suitability of the carbon blacks for such applications and because only a low level of N550 black was used, this is still suitable comparative test of the carbon blacks.

Elasticity is the key requirement for elastomeric sealing and is generally best at low filler loadings. Dynamically, it is predicted by low tan delta. In this work, the thermal black compounds demonstrated superiority in elasticity and low heat build-up because of their contribution of relatively low stiffness to the compounds. Sterling 2320 compounds, with their higher modulus, develop higher tan delta than those containing equivalent levels of thermal blacks and therefore, would be expected to show higher heat build-up.

Summary

1. Sterling 2320 provides higher levels of reinforcement and appears to be similar to an SRF grade of carbon black and therefore should not be considered as a replacement for N990.

2. The higher level of sieve residue in the Sterling 2320 may increase the potential for surface imperfections. This is highly undesirable in o-rings.

3. As would be expected of a more reinforcing carbon black, Sterling 2320 provides higher modulus, tensile and tear strength than the Thermax® N990. This has a damaging effect on dynamic properties causing higher heat build-up and lower elasticity as indicated by a tan delta. Increased stiffness would also lead to increased stress relaxation, especially at high carbon black loading, thus further detracting from Sterling 2320's use in seals as a replacement for N990.

4. Compound viscosity is higher when Sterling 2320 replaces Thermax® N990. This could lead to processing problems at high loadings and signifies that the optimum usable amounts would be less than those permitted with N990.

5. The resistance of Sterling 2320 to hot air aging is inferior to the thermal black. At the loadings tested, the change in elongation was higher than for the thermal blacks, leading to questionable service performance of the non-thermal black in applications that would require heat resistance.