

VANOX[®] ZMTI & VANOX MTI Powder

Antioxidant

A synergistic antioxidant for maximizing heat and flex resistance



Vanderbilt Chemicals, LLC

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For sample requests, sales specifications, and Safety Data Sheets, please visit our website at www.vanderbiltchemicals.com

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VANOX[®] ZMTI Antioxidant and VANOX MTI Powder

Synergistic Antioxidants maximize a product's resistance to high temperature.

Rubber compounds are usually protected by just one antioxidant, but more severe service conditions require combinations of antioxidants.

VANOX ZMTI is an antioxidant that is manufactured at Vanderbilt Chemicals, LLC plant in Murray, KY. It works particularly well in combination with other antioxidants. Its synergistic effect has been demonstrated with various rubber formulations using polymers such as EPDM, Natural Rubber, Neoprene, NBR and SBR.

VANOX ZMTI provides excellent protection against heat and oxygen aging, especially when combined with amine or phenolic-type antioxidants, and is also beneficial where improved flex fatigue resistance is required. The synergistic effect of **VANOX ZMTI** with other antioxidants has been demonstrated in both mineral- and carbon black-filled compounds, as well as with conventional sulfur, low sulfur, sulfur-donors, or peroxide cure systems.

VANOX[®] Peroxide Accelerator cures provide vulcanizates with maximum thermal and oxidative stability, as well as superior resistance to compression set. Most antioxidants reduce peroxide efficiency, resulting in a loss of physical properties. **VANOX ZMTI** is fully compatible with peroxide cures and gives the best results in combination with amines such as **VANOX CDPA Solid** or **AGERITE[®] SUPERFLEX[®] SOLID G PDR** Antioxidant. This synergistic combination of antioxidants also offers the best thermal stability and maximum flex fatigue resistance in conventional sulfur cure systems.

AGERITE[®] ODPA PDR is the preferred antioxidant for Neoprene. When used with **VANOX MTI Powder** in Neoprene cure systems, the synergistic effect is evident in the improved heat resistance. This combination also improves flex fatigue resistance despite providing higher modulus and hardness.

In summary, **VANOX ZMTI** and **VANOX MTI Powder** exhibit the following features:

- Synergy with amines and phenol antioxidants
- Maximum high temperature resistance
- Flex fatigue resistance
- No interference with peroxide cures
- Nonvolatile
- Good color

Antioxidants in Natural Rubber

Antioxidants are materials that protect rubber against reaction with oxygen. Just a small percentage of oxygen chemically combined with rubber can seriously degrade the physical properties of a rubber part. Heat can significantly increase the rate at which oxygen reacts with rubber; the rate approximately doubles for each 10 degree Centigrade increase in temperature. Compared to room temperature, aging a vulcanizate in a 70°C oven provides about a 50-fold increase in reaction rate. Work in the Vanderbilt Rubber Laboratory shows that, in general, one day of oven aging at 70°C corresponds to one year of environmental or shelf aging for natural rubber.

The major types of antioxidants are phenols, amines, polymerized quinolines, peroxide decomposers and synergists.

- Phenols are most effective in non-black compounds and provide minimal discoloration.
- Amines cause moderate to severe discoloration and are typically used in black-filled compounds. Diphenylamine antioxidants are general-purpose antioxidants.
- Polymerized quinolines are relatively permanent in most polymers and cure systems.
- Peroxide decomposers are typically used in uncured applications as polymer stabilizers or to protect adhesives.
- Synergists, such as **VANOX® ZMTI** Antioxidant and **VANOX MTI Powder** Antioxidant, increase the performance of other antioxidants. The mechanism by which synergists work is not fully understood, but it may be that they are peroxide decomposers that can survive the vulcanization process.

In general, there is a trade-off between the discoloration caused by an antioxidant when exposed to light, and the oxidative protection it provides. While amines are progressively more discoloring than phosphites and phenols, the resistance to oxygen, heat, metal-catalyzed degradation and flex fatigue generally improve. For maximum effectiveness, the combination of a radical trap phenol or amine antioxidant with the synergist **VANOX ZMTI** will often be the best means to obtain a high standard of performance.

VANOX® ZMTI Antioxidant with VANOX MBPC POWDER in NR

The synergistic effect of **VANOX ZMTI** with a primary antioxidant in Natural Rubber is very evident in the retained elongation property after heat aging.

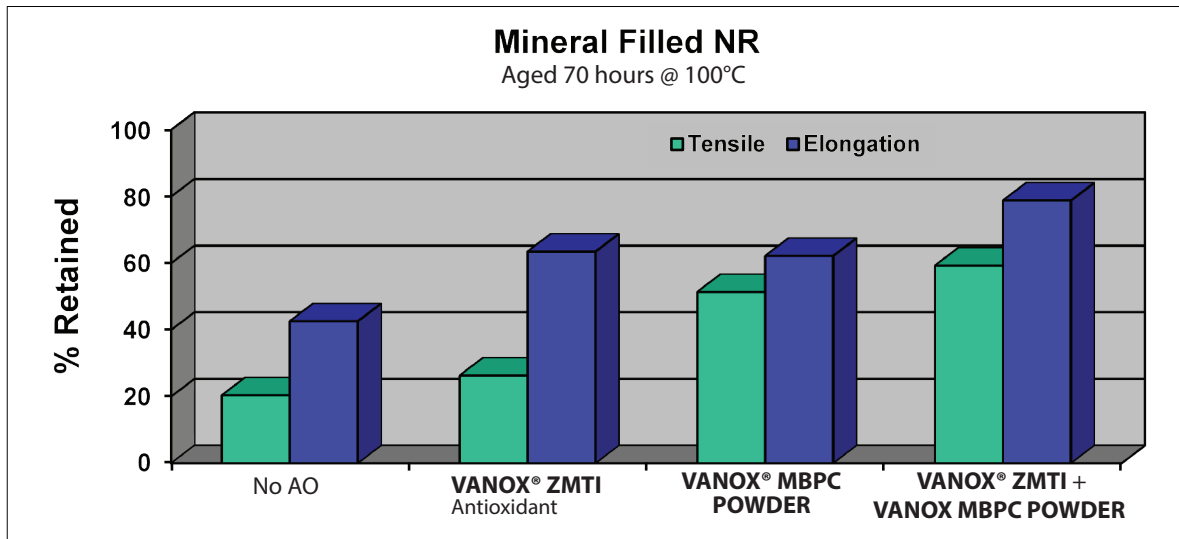


Figure 1: VANOX® ZMTI Synergy with a Primary Antioxidant in NR

Ingredients (phr)	Control	VANOX ZMTI	VANOX MBPC POWDER	VANOX ZMTI + VANOX MBPC POWDER
SMR-L NR	100.0	100.0	100.0	100.0
Stearic Acid	2.0	2.0	2.0	2.0
Zinc Oxide	5.0	5.0	5.0	5.0
VANFRE® AP-2 Processing Aid	2.0	2.0	2.0	2.0
DIXIE CLAY® Filler	50.0	50.0	50.0	50.0
Calcium Carbonate	50.0	50.0	50.0	50.0
Sulfur	2.75	2.75	2.75	2.75
ALTAX® MBTS DFP Accelerator	1.0	1.0	1.0	1.0
METHYL TUADS® TMTD Accelerator	0.1	0.1	0.1	0.1
VANOX® ZMTI Antioxidant	—	2.0	—	1.0
VANOX MBPC POWDER	—	—	2.0	1.0
Totals	212.85	214.85	214.85	214.85
PHYSICAL PROPERTIES				
<i>Press Cured t'90 + 2 min. @ 153°C</i>				
200% Modulus, MPa	4.0	4.1	3.6	3.8
Tensile, MPa	21.2	19.9	21.5	20.5
Elongation, %	618	542	616	581
Hardness, Shore A	53.5	52	51.5	51
OVEN AGED 70 HOURS @ 100°C				
Tensile Retained, %	20	26	51	59
Elongation Retained, %	43	64	62	79

VANOX[®] ZMTI Antioxidant in Sulfur and Low Sulfur Cures of NR

In sulfur-cured natural rubber compounds, the addition of 1 phr of **VANOX ZMTI** greatly improves flex resistance while also showing an increase in heat stability. A low sulfur-cured natural rubber compound, accelerated by the combination of **MORFAX[®] POWDER** Accelerator and **VANAX[®] OTOS POWDER** Accelerator and protected by **AGERITE[®] SUPERFLEX[®] SOLID G PDR** Antioxidant and 6PPD, develops outstanding flex resistance and heat stability. In both conventional and low sulfur-cured compounds, the addition of **VANOX ZMTI** to the antioxidant system greatly improves flex resistance while also showing an improvement in heat stability.

Ingredients:	Compounds (phr)					
	1	2	3	4	5	6
SMR-5 Natural Rubber	100.00	100.00	100.00	100.00	100.00	100.00
Stearic Acid	2.00	2.00	2.00	2.00	2.00	2.00
Zinc Oxide	5.00	5.00	5.00	5.00	5.00	5.00
Plasticizer	5.00	5.00	5.00	5.00	5.00	5.00
N330 Carbon Black	50.00	50.00	50.00	50.00	50.00	50.00
Sulfur	2.50	2.50	2.50	0.60	0.60	0.60
ALTAX[®] MBTS DFP Accelerator	1.25	1.25	1.25	—	—	—
METHYL TUADS[®] TMTD Accelerator	0.15	0.15	0.15	—	—	—
MORFAX[®] POWDER Accelerator	—	—	—	0.80	0.80	0.80
VANAX[®] OTOS POWDER Accelerator	—	—	—	1.50	1.50	1.50
AGERITE[®] SUPERFLEX[®] SOLID G PDR Antioxidant	—	2.00	2.00	—	2.00	2.00
6PPD	—	2.00	2.00	—	2.00	2.00
VANOX[®] ZMTI Antioxidant	—	—	1.00	—	—	1.00
Totals	165.90	169.90	170.90	164.90	168.90	169.90
MOONEY SCORCH @ 121°C						
Minimum Viscosity, mu	31	38	39	42	37	40
t5, minutes	11	10	11	23	19	16
PHYSICAL PROPERTIES <i>Press Cured 10 min. @ 153°C</i>						
300% Modulus, MPa	16.8	14.3	12.7	13.5	13.2	11.4
Tensile Strength, MPa	26.6	29.1	27.4	28.2	29.7	27.7
Elongation at Break, %	475	520	540	550	560	550
Tear, Die C, kN/m	88	93	110	122	133	132
Hardness, Shore A	65	65	64	60	60	62
TEST TUBE AGED 96 HOURS @ 100°C						
Tensile Retained, %	57	60	65	74	81	85
Elongation Retained, %	32	44	48	58	79	78
COMPRESSION SET – METHOD B – 22 HOURS @ 70°C						
Set, %	19.0	21.0	20.0	15.0	15.0	17.0
DEMATTIA FLEX						
Kilocycles to 1.9 cm	<20	181	231	58	219	255

VANOX® ZMTI Antioxidant as a Copper Inhibitor in Natural Rubber

Some antioxidants provide protection to natural rubber when copper contamination is present. The combination of **AGERITE® ODPA PDR** Antioxidant and **VANOX ZMTI** Antioxidant provides excellent protection against copper deterioration, with minimal discoloration.

Ingredients (phr)	Control	AGERITE ODPA PDR	VANOX ZMTI + AGERITE ODPA PDR
SMR-5	100.00	100.00	100.00
Stearic Acid	1.00	1.00	1.00
Zinc Oxide	5.00	5.00	5.00
DIXIE CLAY® Filler	10.00	10.00	10.00
Titanium Dioxide	15.00	15.00	15.00
Ultramarine Blue	0.25	0.25	0.25
ALTAX® MBTS DFP Accelerator	1.00	1.00	1.00
METHYL TUADS® TMTD Accelerator	2.50	2.50	2.50
Sulfur	0.25	0.25	0.25
Copper Oleate	0.10	0.10	0.10
AGERITE® ODPA PDR Antioxidant	—	2.00	1.00
VANOX® ZMTI Antioxidant	—	—	1.00
Totals	135.10	137.10	137.10
PHYSICAL PROPERTIES <i>Press Cured 20 min. @ 143°C</i>			
500% Modulus, MPa	12.4	12.4	12.8
Tensile, MPa	28.3	26.6	25.2
Elongation, %	650	610	600
Hardness, Shore A	52	48	46
TEST TUBE AGED 168 HOURS @ 121°C			
Tensile Retained, %	melted	31	44
Elongation Retained, %	melted	72	82
Hardness, Pts. Change	melted	-8	-6
OXYGEN BOMB AGED 168 HOURS @ 80°C			
Tensile Retained, %	70	98	100
Elongation Retained, %	89	95	97
Hardness, Pts. Change	-11	-4	-1
GE BRIGHTNESS			
Original	61	62	63
48 hrs. exposure to UV light	32	24	31

Antioxidants in EPDM

In sulfur-cured EPDM, it is often sufficient to use only primary antioxidants. However, peroxide curing does require that attention be paid to antioxidant selection because many types of antioxidants can interfere with peroxide crosslinking. Primary antioxidants can donate hydrogen atoms, which compete with the polymer for peroxide radicals and lessen the state of cure **VANOX® ZMTI** Antioxidant is recommended for use in combination with primary antioxidants in peroxide curing because it exhibits minimal interference with the crosslinking mechanism.

VANOX® ZMTI Antioxidant in Sulfur-Cured EPDM

Ingredients (phr)	No AO	AGERITE ODPA PDR	AGERITE TMQ	VANOX NDBC	VANOX ZMTI
Vistalon™ 2504 Ethylene Propylene Diene	100.0	100.0	100.0	100.0	100.0
Stearic Acid	1.0	1.0	1.0	1.0	1.0
Zinc Oxide	5.0	5.0	5.0	5.0	5.0
Plasticizer	5.0	5.0	5.0	5.0	5.0
N990 Carbon Black	75.0	75.0	75.0	75.0	75.0
N550 Carbon Black	75.0	75.0	75.0	75.0	75.0
Paraffinic Oil	70.0	70.0	70.0	70.0	70.0
CAPTAX® (MBT) Accelerator	1.5	1.5	1.5	1.5	1.5
METHYL TUADS® TMTD Accelerator	1.5	1.5	1.5	1.5	1.5
Sulfur	1.5	1.5	1.5	1.5	1.5
AGERITE® ODPA PDR Antioxidant	—	3.0	—	—	—
AGERITE® TMQ Antioxidant	—	—	3.0	—	—
VANOX® NDBC Antioxidant	—	—	—	3.0	—
VANOX ZMTI Antioxidant	—	—	—	—	3.0
Totals	335.5	338.5	338.5	338.5	338.5

PHYSICAL PROPERTIES

Press Cured 10 min. @ 171°C

300% Modulus, MPa	6.7	6.0	5.7	5.7	5.4
Tensile, MPa	8.9	8.3	8.0	7.6	7.8
Elongation, %	430	450	460	420	490
Hardness, Shore A	63	64	66	64	68

TEST TUBE AGED 72 HOURS @ 150°C

Tensile Retained, %	112	130	131	132	113
Elongation Retained, %	35	44	37	50	45
Hardness, Pts. Change	+8	+8	+9	+7	+6

TEST TUBE AGED 168 HOURS @ 150°C

Tensile Retained, %	117	126	137	135	127
Elongation Retained, %	28	35	30	43	35
Hardness, Pts. Change	+13	+8	+10	+8	+9

TEST TUBE AGED 240 HOURS @ 150°C

Tensile Retained, %	109	123	133	145	132
Elongation Retained, %	26	31	24	43	31
Hardness, Pts. Change	+16	+12	+15	+11	+11

VANOX® ZMTI Antioxidant in a Peroxide-Cured EPDM Wire & Cable Compound

When half of **AGERITE® TMQ** Antioxidant is replaced with **VANOX ZMTI** in a peroxide-cured EPDM compound, the combination develops outstanding heat resistance at 150°C.

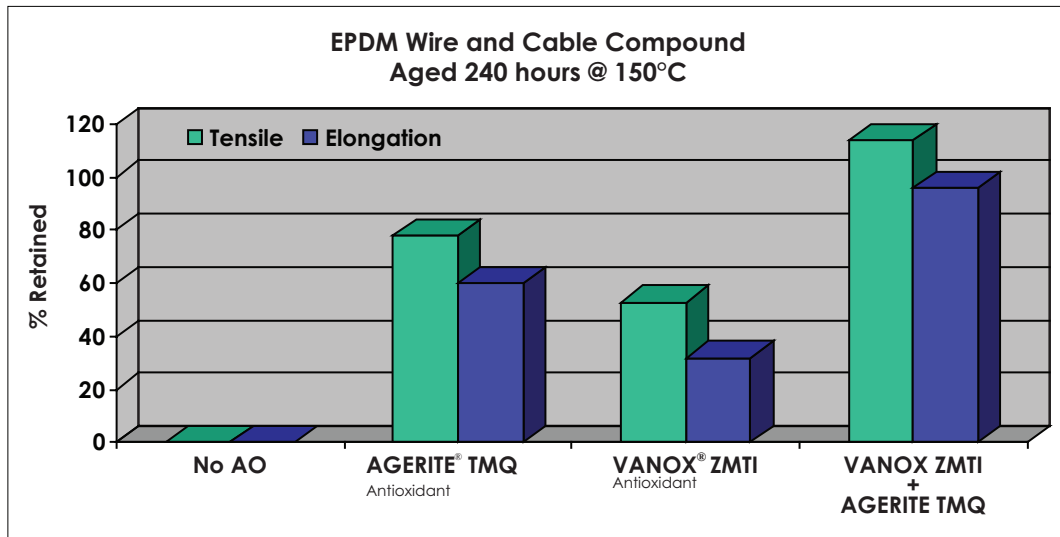


Figure 2: Antioxidants in Peroxide-Cured EPDM

Ingredients (phr)	No AO	AGERITE TMQ	VANOX ZMTI	VANOX ZMTI + AGERITE TMQ
Vistalon™ 2504 Ethylene Propylene Diene	100.00	100.00	100.00	100.00
VANFRE® AP-2 Processing Aid	2.50	2.50	2.50	2.50
Zinc Oxide	5.00	5.00	5.00	5.00
N990 Carbon Black	10.00	10.00	10.00	10.00
Translink® 37	110.00	110.00	110.00	110.00
Paraffinic Oil	15.00	15.00	15.00	15.00
Silane A-172	1.00	1.00	1.00	1.00
Red Lead	5.00	5.00	5.00	5.00
Dicumyl 40% on Kaolin Peroxide Accelerator	8.00	8.00	8.00	8.00
AGERITE® TMQ Antioxidant	—	1.50	—	0.75
VANOX® ZMTI Antioxidant	—	—	1.50	0.75
Totals	256.50	258.00	258.00	258.00
MOONEY SCORCH @ 132°C				
Minimum Viscosity, mu	26	28	27	27
t5, minutes	9	13	9	9
PHYSICAL PROPERTIES Press Cured 10 min. @ 171°C				
300% Modulus, MPa	4.3	3.3	4.6	3.7
Tensile, MPa	6.2	7.1	5.6	6.2
Elongation, %	500	680	470	570
Hardness, Shore A	62	62	65	63
TEST TUBE AGED 240 HOURS @ 150°C				
Tensile Retained, %	Brittle	78	53	114
Elongation Retained, %	Brittle	60	32	96
Hardness, Pts. Change	Brittle	+6	+3	+2

VANOX® ZMTI Antioxidant in an EPDM Compound

The selection of an antioxidant system that optimizes the physical properties of the finished product is extremely important in rubber compounding. The effectiveness of several antioxidants was compared in peroxide-cured EPDM. **VANOX ZMTI** works synergistically with other antioxidants to greatly improve the retention of physical properties. **VANOX ZMTI** by itself was found to be the best performing antioxidant, having the highest heat aged retention and lowest compression set. The addition of **AGERITE® TMQ** Antioxidant or **VANOX CDPA Solid** to **VANOX ZMTI** provides the compounder with further high performance options.

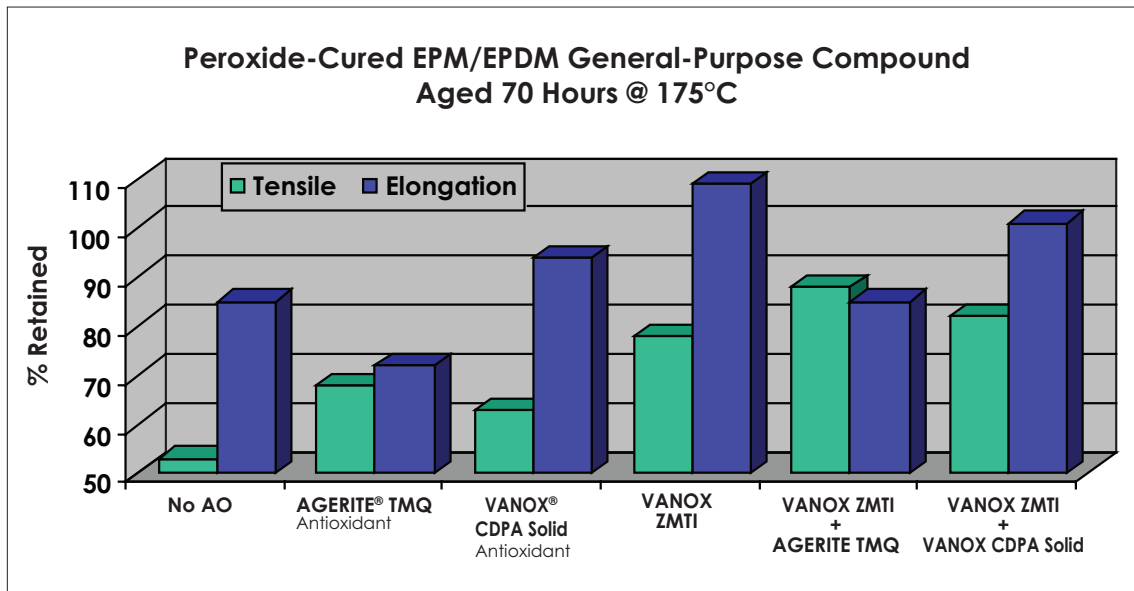


Figure 3: Antioxidant Performance of an EPDM Compound

Vanderbilt Chemicals, LLC offers the following product options with regard to compounding requirements:

- **VANOX ZMTI** alone has the best elongation retention and compression set resistance.
- **AGERITE TMQ** alone is a good cost-effective option.
- **VANOX CDPA Solid** alone has good overall results.
- **VANOX ZMTI** and **AGERITE TMQ** together provide the best tensile retention.
- **VANOX ZMTI** and **VANOX CDPA Solid** together provide the best overall results.

VANOX® ZMTI Antioxidant in an EPDM Compound

Ingredients (phr)	No AO	AGERITE TMQ	VANOX CDPA Solid	VANOX ZMTI	VANOX ZMTI + AGERITE TMQ	VANOX ZMTI + VANOX CDPA Solid
Vistalon™ 706 Ethylene Propylene Diene	70.0	7 0.0	70.0	70.0	70.0	70.0
Vistalon™ 7500 Ethylene Propylene Diene	30.0	30.0	30.0	30.0	30.0	30.0
N550 Carbon Black	110.0	110.0	110.0	110.0	110.0	110.0
Paraffinic Oil	45.0	45.0	45.0	45.0	45.0	45.0
Di-(2-tert-butyl peroxyisopropyl)Benzene 40% on Kaolin Peroxide Accelerator	6.0	6.0	6.0	6.0	6.0	6.0
VANAX® MBM Accelerator	1.0	1.0	1.0	1.0	1.0	1.0
VANOX® ZMTI Antioxidant	—	—	—	2.0	2.0	2.0
VANOX CDPA Solid Antioxidant	—	—	2.0	—	—	1.0
AGERITE® TMQ Antioxidant	—	2.0	—	—	1.0	—
Totals	262.0	264.0	264.0	264.0	265.0	265.0
PHYSICAL PROPERTIES						
<i>Press Cured t'90 + 2 min. @ 177°C</i>						
100% Modulus, MPa	3.9	4.4	3.6	4.3	4.0	3.6
Tensile Strength, MPa	14.0	14.0	12.9	13.3	13.4	12.4
Elongation, %	287	304	306	272	302	283
Hardness, Shore A	68	69	65	70	69	68
OVEN AGED 70 HOURS @ 175°C						
Tensile Retained, %	53	68	63	78	88	82
Elongation Retained, %	85	72	94	109	85	101
OVEN AGED 168 HOURS @ 150°C						
Tensile Retained, %	73	83	78	97	96	93
Elongation Retained, %	91	80	96	111	98	107
COMPRESSION SET – METHOD B - 70 HOURS @ 150°C						
Set, %	30	26	32	27	31	32

Antioxidants in Neoprene Polychloroprene

An amine antioxidant is standard in most formulations of both G and W types of Neoprene. The Neoprene G types have inherently good strength and flex fatigue resistance, while the Neoprene W types offer improved heat and compression set resistance. **VANOX® MTI Powder** Antioxidant, when used in addition to the amine **AGERITE® ODPA PDR** Antioxidant, will improve the heat and flex resistance of both G and W types of Neoprene.

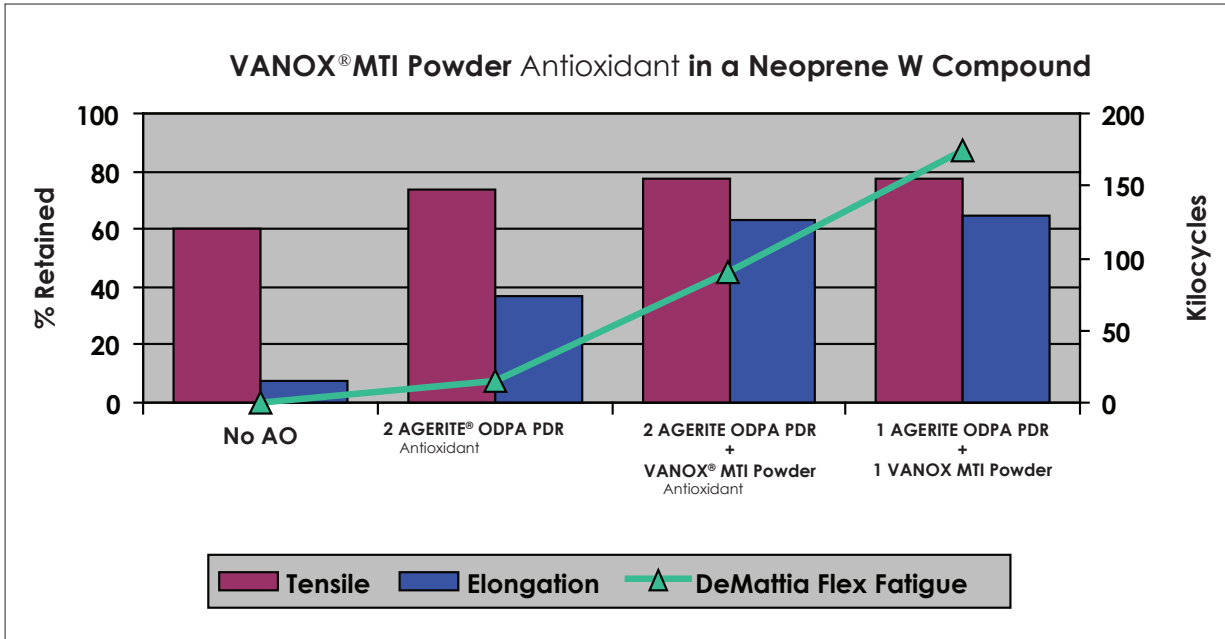


Figure 4: VANOX® MTI Powder Antioxidant in Neoprene W

Ingredients (phr)	No AO	AGERITE ODPA PDR	1 AGERITE OPDA PDR + 1 VANOX MTI Powder	2 AGERITE OPDA PDR + 1 VANOX MTI Powder
Neoprene W Polychloroprene	100.0	100.0	100.0	100.0
Stearic Acid	0.5	0.5	0.5	0.5
Magnesium Oxide	4.0	4.0	4.0	4.0
N774 Carbon Black	60.0	60.0	60.0	60.0
Naphthenic Oil	5.0	5.0	5.0	5.0
Plasticizer	5.0	5.0	5.0	5.0
Zinc Oxide	5.0	5.0	5.0	5.0
VANAX® CPA Accelerator *discontinued	1.5	1.5	1.5	1.5
AGERITE® ODPA PDR Antioxidant	—	2.0	1.0	2.0
VANOX® MTI Powder Antioxidant	—	—	1.0	1.0
Totals	181.0	183.0	183.0	184.0

*Vanderbilt Chemicals recommends 1 phr of **THIATE® EF-2** Accelerator as a replacement.

VANOX® MTI Powder Antioxidant in a Neoprene W Compound

Compounds	No AO	AGERITE® ODPA PDR Antioxidant	1 AGERITE ODPA PDR + 1 VANOX® MTI Powder Antioxidant	2 AGERITE ODPA PDR + 1 VANOX MTI Powder
MOONEY SCORCH @ 121.1°C				
Minimum Viscosity, μ	53	34	35	34
t ₅ , minutes	14	18	8	8
MDR @ 160°C, 0.5° Arc				
Min. Torque, M _L , dN·m	1.83	1.14	1.12	1.07
Max. Torque, M _H , dN·m	20.73	18.61	17.72	16.37
t ₅ 1, minutes	1.56	2.31	1.10	1.02
t ₉₀ , minutes	26.32	26.19	20.14	19.63
PHYSICAL PROPERTIES <i>Press Cured t₉₀ + 2 min. @ 160°C</i>				
200% Modulus, MPa	14.7	10.2	11.7	11.9
Tensile Strength, MPa	17.3	18.2	18.5	19.0
Elongation, %	235	327	310	338
Hardness, Shore A	67	6	69	68
OVEN AGED 168 HOURS @ 121°C				
Tensile Retained, %	60	73	78	78
Elongation Retained, %	7	37	63	65
Hardness, Pts. Change	+23	+18	+12	+13
COMPRESSION SET – METHOD B - 70 HOURS @ 121°C				
Set, %	35	32	41	42
DEMATTIA FLEX				
Kilocycles to 1.9 cm	0.5	15	90	175

VANOX® MTI Powder Antioxidant in a Neoprene GW Compound

Ingredients (phr)	No AO	AGERITE ODPA PDR	AGERITE ODPA PDR + VANOX MTI Powder
Neoprene GW Polychloroprene	100.0	100.0	100.0
Stearic Acid	0.5	0.5	0.5
Magnesium Oxide	4.0	4.0	4.0
N774 Carbon Black	60.0	60.0	60.0
Naphthenic Oil	5.0	5.0	5.0
Plasticizer	5.0	5.0	5.0
Zinc Oxide	5.0	5.0	5.0
AGERITE® ODPA PDR Antioxidant	—	2.0	1.0
VANOX® MTI Powder Antioxidant	—	—	2.0
Totals	179.5	181.5	182.5
MOONEY SCORCH @ 121.1°C			
Minimum Viscosity, μ	30	26	31
t ₅ , minutes	16	15	6
MDR @ 160°C, 0.5° Arc			
Min Torque, M _L , dN·m	0.90	0.80	0.95
Max Torque, M _H , dN·m	20.83	18.82	19.72
t ₅ 1, minutes	1.16	1.07	0.71
t'90, minutes	7.62	14.86	24.85
PHYSICAL PROPERTIES <i>Press Cured t'90 + 2 min. @ 160°C</i>			
300% Modulus, MPa	13.9	14.1	14.7
Tensile Strength, MPa	17.4	18.2	18.0
Elongation, %	454	460	423
Hardness, Shore A	69	66	71
OVEN AGED 168 HOURS @ 121°C			
Tensile Retained, %	62	80	80
Elongation Retained, %	6	19	38
Hardness, Pts. Change	+22	+21	+14
COMPRESSION SET – METHOD B - 70 HOURS @ 121°C			
Set, %	82	78	73
DEMATIA FLEX			
Kilocycles to 1.9 cm	300	700	966

Antioxidants in NBR

Due to the unsaturation in their polymer backbone, nitrile compounds require antioxidants to combat the degradation caused by high temperatures. These antioxidants may also need extraction resistance since NBR compounds are often used in oils and solvents. **VANOX® ZMTI** Antioxidant is the recommended antioxidant for heat stability in nitrile rubber. It can be used with good results alone or in combination with **AGERITE® TMQ** Antioxidant, **AGERITE ODPA PDR** Antioxidant or **VANOX CDPA Solid** Antioxidant.

VANOX® ZMTI Antioxidant in Peroxide-Cured Nitrile

Ingredients (phr)	AGERITE TMQ	AGERITE ODPA PDR	VANOX ZMTI	AGERITE TMQ + VANOX ZMTI	AGERITE ODPA PDR + VANOX ZMTI
Chemigum® N689	100.0	100.0	100.0	100.00	100.00
Paraplex® G25	10.0	10.0	10.0	10.00	10.00
N990 Carbon Black	65.0	65.0	65.0	65.00	65.00
N550 Carbon Black	35.0	35.0	35.0	35.00	35.00
Dicumyl 40% Kaolin Peroxide Accelerator	4.0	4.0	4.0	4.00	4.00
AGERITE® TMQ Antioxidant	1.5	—	—	0.75	—
AGERITE ODPA PDR Antioxidant	—	1.5	—	—	0.75
VANOX® ZMTI Antioxidant	—	—	1.5	0.75	0.75
Totals	215.5	215.5	215.5	215.50	215.50
MOONEY SCORCH @ 121°C					
Minimum Viscosity, mu	80	72	72	72	68
t5, minutes	7	7	7	7	8
PHYSICAL PROPERTIES Press Cured 20 min. @ 160°C					
100% Modulus, MPa	2.9	3.1	3.2	2.9	3.0
Tensile, MPa	13.6	13.8	13.9	13.4	13.3
Elongation, %	350	310	320	350	320
Hardness, Shore A	68	66	67	67	68
TEST TUBE AGED 72 HOURS @ 121°C					
Tensile Retained, %	49	71	122	107	123
Elongation Retained, %	97	93	97	97	97
Hardness, Pts. Change	+6	+6	+8	+8	+5
COMPRESSION SET - METHOD B - 70 HOURS @ 121°C					
Set, %	31	34	36	37	36

VANOX® ZMTI Antioxidant in Efficient Vulcanization (EV)-Cured NBR

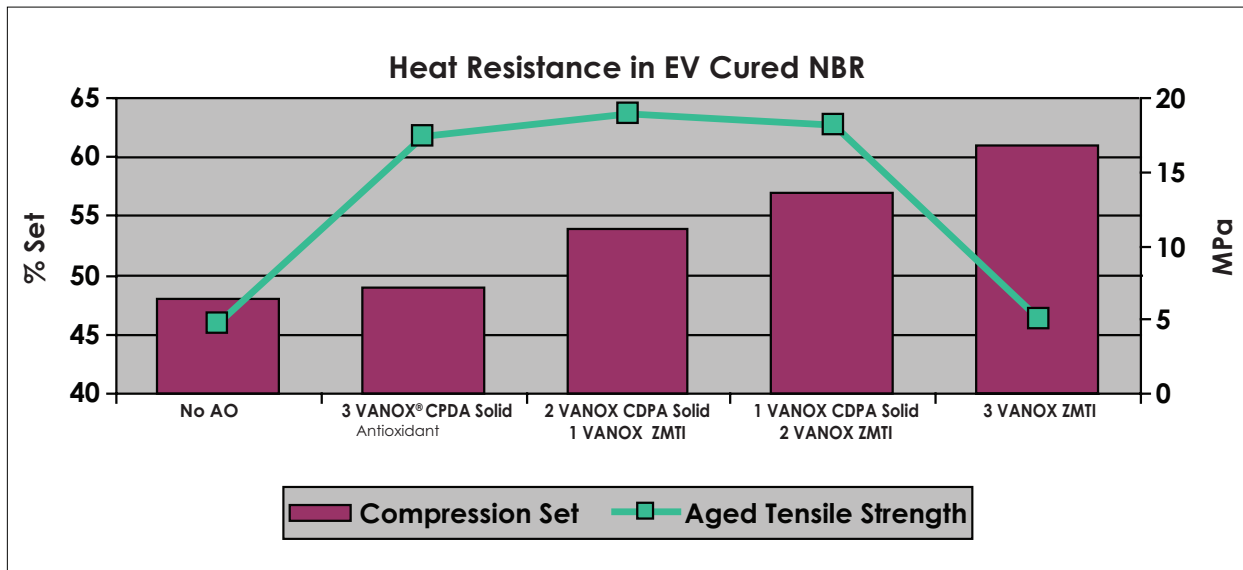


Figure 5: VANOX® ZMTI Antioxidant in EV-Cured NBR

Ingredients (phr)	No AO	VANOX CDPA Solid	VANOX CDPA Solid + VANOX ZMTI (2:1)	VANOX ZMTI + VANOX CDPA Solid (2:1)	VANOX ZMTI
Nipol® DN 3380	70.0	70.0	70.0	70.0	70.0
Nipol DN 3335	30.0	30.0	30.0	30.0	30.0
Zinc Oxide	5.0	5.0	5.0	5.0	5.0
Stearic Acid	1.0	1.0	1.0	1.0	1.0
N774 Carbon Black	65.0	65.0	65.0	65.0	65.0
DOP	5.0	5.0	5.0	5.0	5.0
METHYL TUADS® TMTD Accelerator	3.0	3.0	3.0	3.0	3.0
VANOX® CDPA Solid Antioxidant	—	3.0	2.0	1.0	—
VANOX ZMTI Antioxidant	—	—	1.0	2.0	3.0
Totals	179.0	182.0	182.0	182.0	182.0
PHYSICAL PROPERTIES <i>Press Cured t'90 + 2 min. @ 171°C</i>					
200% Modulus, MPa	5.5	5.1	4.4	4.1	4.5
Tensile Strength, MPa	16.1	16.0	16.2	15.7	16.5
Elongation, %	566	582	735	722	704
Hardness, Shore A	59	60	60	60	60
OVEN AGED 70 HOURS @ 150°C					
Aged Tensile Strength, MPa	4.8	17.4	18.9	18.2	5.1
Aged Elongation, %	Brittle	154	193	185	Brittle
Hardness, Pts. Change	+28	+17	+18	+17	+28
COMPRESSION SET – METHOD B - 70 HOURS @ 121°C					
Set, %	48	49	54	57	61

VANOX® ZMTI Antioxidant in Peroxide-Cured NBR

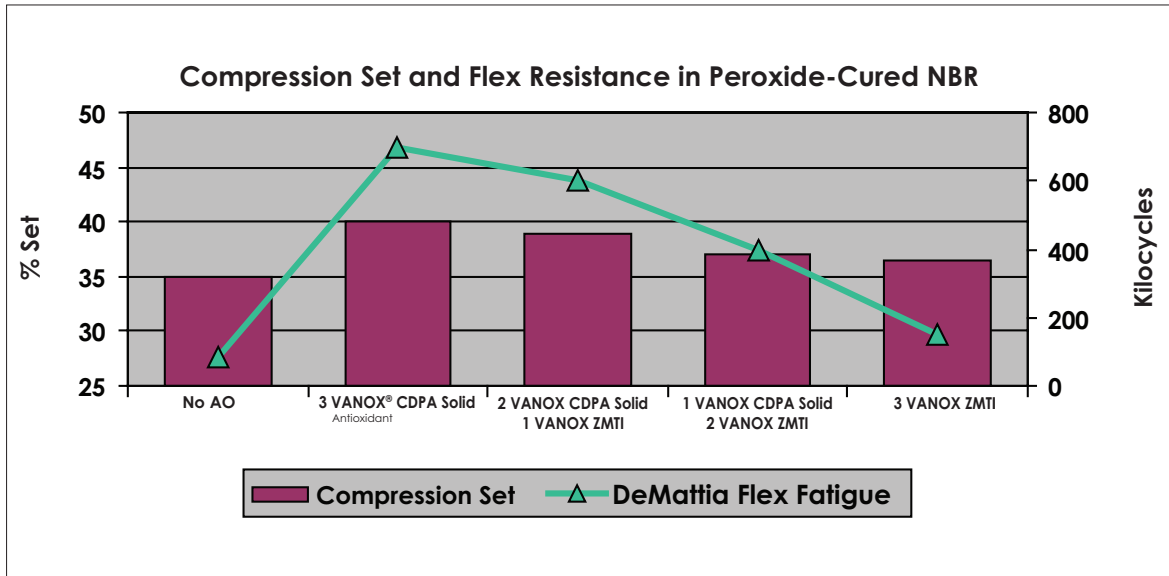


Figure 6: VANOX® ZMTI Antioxidant in a Peroxide-Cured NBR

Ingredients (phr)	No AO	VANOX CDPA Solid + VANOX ZMTI (2:1)		VANOX ZMTI + VANOX CDPA Solid (2:1)	
		VANOX CDPA Solid	VANOX ZMTI	VANOX CDPA Solid	VANOX ZMTI
Nipol® DN 4555	100.0	100.0	100.0	100.0	100.0
Zinc Oxide	5.0	5.0	5.0	5.0	5.0
Stearic Acid	1.0	1.0	1.0	1.0	1.0
N774 Carbon Black	90.0	90.0	90.0	90.0	90.0
DOP	15.0	15.0	15.0	15.0	15.0
Dicumyl 40% Kaolin Peroxide Accelerator	3.0	3.0	3.0	3.0	3.0
VANOX® CDPA Solid Antioxidant	—	3.0	2.0	1.0	—
VANOX ZMTI Antioxidant	—	—	1.0	2.0	3.0
Totals	214.0	217.0	217.0	217.0	217.0
PHYSICAL PROPERTIES Press Cured t'90 + 2 min. @ 171°C					
200% Modulus, MPa	14.8	12.5	11.8	13.4	14.3
Tensile Strength, MPa	17.3	16.3	16.2	16.6	17.2
Elongation, %	292	336	358	337	309
Hardness, Shore A	72	69	68	71	73
COMPRESSION SET – METHOD B - 70 HOURS @ 121°C					
Set, %	35	40	39	37	37
DEMATTIA FLEX					
Kilocycles to 1.9 cm	85	700	600	400	150

Antioxidants in HNBR

HNBR rubber is nitrile rubber which has been hydrogenated to reduce the number of carbon-carbon double bonds. The saturation improves the heat and ozone resistance of nitrile in HNBR. All HNBR rubber can be peroxide-cured to provide the most heat resistant cure system.

VANOX® ZMTI Antioxidant in HNBR

Ingredients (phr)	No AO	VANOX CDPA Solid	VANOX CDPA Solid + VANOX ZMTI
Zetpol® 2020	100.0	100.0	100.0
Zinc Oxide	5.0	5.0	5.0
Stearic Acid	0.5	0.5	0.5
N330 Carbon Black	20.0	20.0	20.0
N990 Carbon Black	45.0	45.0	45.0
VANOX® CDPA Solid Antioxidant	—	1.5	1.5
VANOX ZMTI Antioxidant	—	—	1.5
Dicumyl 40% Kaolin Peroxide Accelerator	8.0	8.0	8.0
Totals	178.5	180.0	181.5
MOONEY SCORCH @ 121°C			
Minimum Viscosity, mu	59	51	53
t5, minutes	18	23	28
PHYSICAL PROPERTIES <i>Press Cured t'90 + 2 min. @ 171°C</i>			
200% Modulus, MPa	22.9	15.4	14.9
Tensile, MPa	24.0	23.2	23.0
Elongation, %	232	306	330
Hardness, Shore A	69	66	66
OVEN AGED 70 HOURS @ 175°C			
Tensile Retained, %	26	37	66
Elongation Retained, %	1	13	26
Hardness, Pts. Change	+18	+14	+14
OVEN AGED 168 HOURS @ 150°C			
Tensile Retained, %	57	106	106
Elongation Retained, %	25	55	58
Hardness, Pts. Change	+13	+11	+13
COMPRESSION SET – METHOD B - 70 HOURS @ 150°C			
Set, %	22	28	32

Antioxidants in SBR

While all SBR polymers contain some antioxidant, it is considered good compounding practice to include an antioxidant in each formula, particularly when compounding for heat resistance and heavy duty service.

Certain amines, like **AGERITE® SUPERFLEX® SOLID G PDR** Antioxidant, are known to inhibit gel formation in hot mixing, and are used in black compounds to assure uniform extrusion and calendaring. **VANOX® MTI Powder** Antioxidant or phenols like **SONGNOX® 3114 PW** Antioxidant are often used in non-black compounds.

VANOX® MTI Powder in Mineral-Filled SBR

Ingredients (phr)	No AO	VANOX MTI Powder	SONGNOX 3114 PW
SBR 1502	100.0	100.0	100.0
VANFRE® AP-2 Processing Aid	2.0	2.0	2.0
Stearic Acid	2.0	2.0	2.0
Zinc Oxide	5.0	5.0	5.0
Plasticizer	2.0	2.0	2.0
DIXIE CLAY® Filler	80.0	80.0	80.0
Sulfur	2.5	2.5	2.5
ALTAX® MBTS DFP Accelerator	1.5	1.5	1.5
METHYL TUADS® TMTD Accelerator	0.5	0.5	0.5
VANOX® MTI Powder Antioxidant	—	2.0	—
SONGNOX® 3114 PW Antioxidant	—	—	2.0
Totals	195.5	197.5	197.5
PHYSICAL PROPERTIES <i>Press Cured 30 min. @ 153°C</i>			
Tensile Strength, MPa	13.0	10.3	12.0
Elongation at Break, %	760	950	830
Hardness, Shore A	60	59	59
OVEN AGED 48 HOURS @ 100°C			
Tensile Retained, %	70	89	74
Elongation Retained, %	46	58	65
Hardness, Pts. Change	+10	+9	+7
GE BRIGHTNESS			
Original	20	19	20
24 hrs. exposure to UV light	12	12	10

VANOX® ZMTI Antioxidant Specifications

RTV Product Code: 53499

Composition: Zinc 2-mercaptotolumidazole
Physical State: Cream to light yellow powder

	Specification	Test Method
*Fineness, through 200 mesh	99.9% minimum	T-14D
*Heat Loss 2 hrs. @ 60-65°C	2.0% maximum	T-1A
*Zinc Content	17.2-19.3%	T-365, AA-103

*Certified Property

GENERAL INFORMATION

Typical values not routinely measured or reported on the Certificate of Analysis.

Anti-Dusting Agent Content	3-5%
Density at 25°C	1.54 Mg/m ³
Melting Point, Initial	300°C minimum
Solubility - Soluble in ethanol and methanol. Practically insoluble in other organic solvents and water.	

Uses - A non-discoloring, non-staining antioxidant for natural and synthetic rubbers. Suggested as a synergist with **AGERITE® ODP A PDR** Antioxidant, **AGERITE TMQ**, and **AGERITE SUPERFLEX® SOLID G PDR** for aging at normal or elevated temperatures. Offers excellent flex resistance in NR, SBR, NBR, and CR.

VANOX MTI Powder Antioxidant Specifications

RTV Product Code: 53503

Composition: 2-mercaptotoluimidazole
Physical State: White to beige powder

	Specification	Test Method
*Ash Content	0.50% maximum	QCD/TM/11
*Assay	97.0% minimum	QCD/TM/75
*Volatile Matter @ 70°C	1.0% maximum	T-1A

*Certified Property

GENERAL INFORMATION

Typical values not routinely measured or reported on the Certificate of Analysis.

Density at 25°C	1.3 g/m ³
Solubility - Moderately soluble in acetone and alcohol. Insoluble in water.	

Uses - A non-discoloring, non-staining antioxidant for natural and synthetic rubbers. Suggested as a synergist with **AGERITE ODP A PDR** Antioxidant, **AGERITE SUPERFLEX SOLID G PDR** and **AGERITE TMQ**.



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