

VANOX[®] ZMTI
Antioxidant
VANOX MTI

**A synergistic antioxidant
for maximizing heat and flex resistance**

Manufactured by the R.T. Vanderbilt Company, Inc. in the USA

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09/2010

VANOX® ZMTI Antioxidant and VANOX MTI

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 R.T. Vanderbilt Company's 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.

VAROX® peroxide 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** or **AGERITE® SUPERFLEX® SOLID G** antioxidants. This synergistic combination of antioxidants also offers the best thermal stability and maximum flex fatigue resistance in conventional sulfur cure systems.

AGERITE STALITE® S is the preferred antioxidant for Neoprene. When used with **VANOX MTI** 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** 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** and **VANOX MTI** antioxidants, 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 AGERITE® SUPERLITE® SOLID Antioxidant 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.

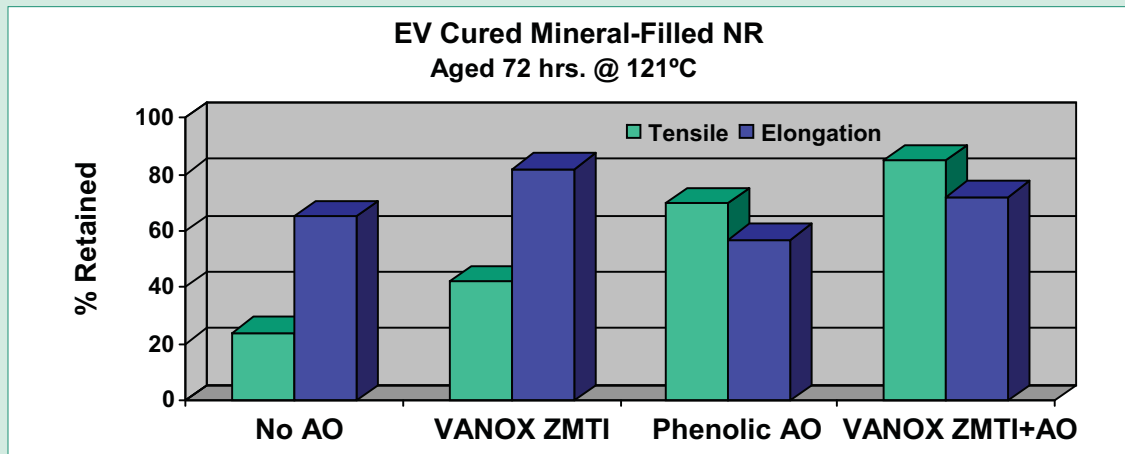


Figure 1: VANOX ZMTI Synergy with a Primary Antioxidant in NR

Ingredients (phr)	Control	VANOX ZMTI	AGERITE SUPERLITE SOLID	VANOX ZMTI + AO
Smoked Sheet NR	100.0	100.0	100.0	100.0
Stearic Acid	3.0	3.0	3.0	3.0
Zinc Oxide	5.0	5.0	5.0	5.0
VANPLAST® R	2.0	2.0	2.0	2.0
DIXIE CLAY®	50.0	50.0	50.0	50.0
Calcium Carbonate	50.0	50.0	50.0	50.0
Hi-Sil® 233	30.0	30.0	30.0	30.0
MORFAX®	1.5	1.5	1.5	1.5
ETHYL CADMATE®	1.5	1.5	1.5	1.5
VANOX ZMTI	---	3.0	---	2.0
AGERITE SUPERLITE S	---	---	3.0	1.0
Totals	243.0	246.0	246.0	246.0

PHYSICAL PROPERTIES

Press Cured 20 min. @ 143°C

300% Modulus, MPa	7.6	8.3	7.6	7.9
Tensile, MPa	13.9	15.6	15.6	15.9
Elongation, %	460	460	480	480
Hardness, Shore A	62	63	61	61

TEST TUBE AGED 72 HOURS @ 121°C

Tensile Retained, %	24	42	57	72
Elongation Retained, %	65	82	70	85

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®/CURE-RITE®18** accelerators and protected by **AGERITE® SUPERFLEX® SOLID G** 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
VANPLAST® R	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)	1.25	1.25	1.25	---	---	---
METHYL TUADS® (TMTD)	0.15	0.15	0.15	---	---	---
MORFAX	---	---	---	0.80	0.80	0.80
CURE-RITE 18	---	---	---	1.50	1.50	1.50
AGERITE SUPERFLEX SOLID G	---	2.00	2.00	---	2.00	2.00
6PPD	---	2.00	2.00	---	2.00	2.00
VANOX ZMTI	---	---	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

Press Cured 10 min. @ 153°C

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
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DEMATTIA FLEX

Kilocycles to 1.9 cm	<20	181	231	58	219	255
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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® STALITE® S** and **VANOX ZMTI** antioxidants provides excellent protection against copper deterioration, with minimal discoloration.

Ingredients (phr)	Control	AGERITE STALITE S	VANOX ZMTI + AGERITE STALITE S
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®	10.00	10.00	10.00
Titanium Dioxide	15.00	15.00	15.00
Ultramarine Blue	0.25	0.25	0.25
ALTAX® (MBTS)	1.00	1.00	1.00
METHYL TUADS® (TMTD)	2.50	2.50	2.50
Sulfur	0.25	0.25	0.25
Copper Oleate	0.10	0.10	0.10
AGERITE STALITE S	---	2.00	1.00
VANOX ZMTI	---	---	1.00
Totals	135.10	137.10	137.10

PHYSICAL PROPERTIES

Press Cured 20 min. @ 143°C

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 STALITE S	AGERITE RESIN D	VANOX NDBC	VANOX ZMTI
Vistalon™ 2504	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
VANPLAST® R	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)	1.5	1.5	1.5	1.5	1.5
METHYL TUADS® (TMTD)	1.5	1.5	1.5	1.5	1.5
Sulfur	1.5	1.5	1.5	1.5	1.5
AGERITE® STALITE® S	---	3.0	---	---	---
AGERITE RESIN D®	---	---	3.0	---	---
VANOX NDBC	---	---	---	3.0	---
VANOX ZMTI	---	---	---	---	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® RESIN D®** antioxidant is replaced with **VANOX ZMTI** in a peroxide-cured EPDM compound, the combination develops outstanding heat resistance at 150°C.

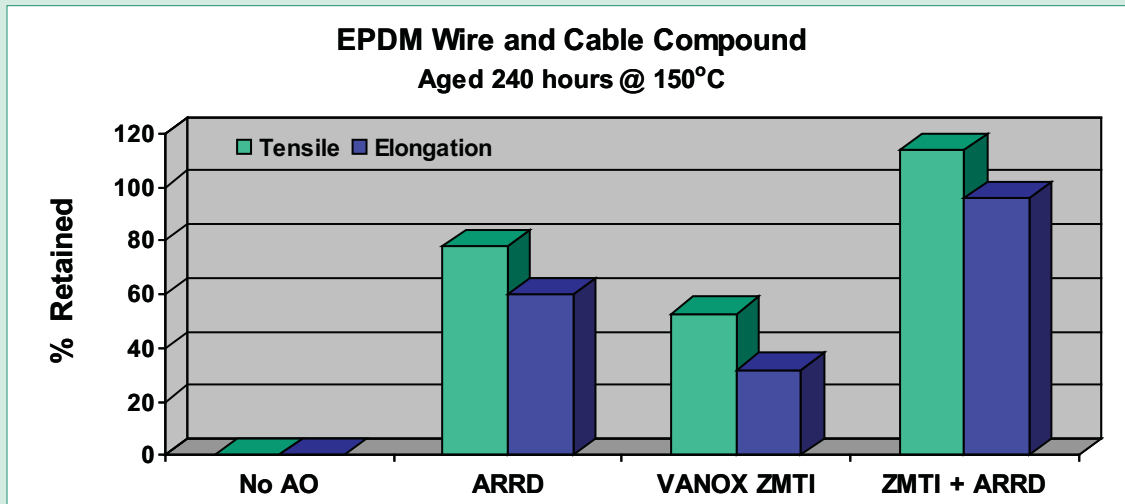


Figure 2: Antioxidants in Peroxide-Cured EPDM

Ingredients (phr)	No AO	AGERITE RESIN D	VANOX ZMTI	VANOX ZMTI + AGERITE RESIN D
Vistalon™ 2504	100.00	100.00	100.00	100.00
VANFRE® AP-2	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
VAROX® DCP-40KE	8.00	8.00	8.00	8.00
AGERITE RESIN D	---	1.50	---	0.75
VANOX ZMTI	---	---	1.50	0.75
Totals	256.50	258.00	258.00	258.00

MOONEY SCORCH @ 132°C

Minimum Viscosity, mu	26	28	27	26
t5, minutes	9	13	9	12

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® RESIN D®** or **VANOX CDPA** antioxidants to **VANOX ZMTI** provides the compounder with further high performance options.

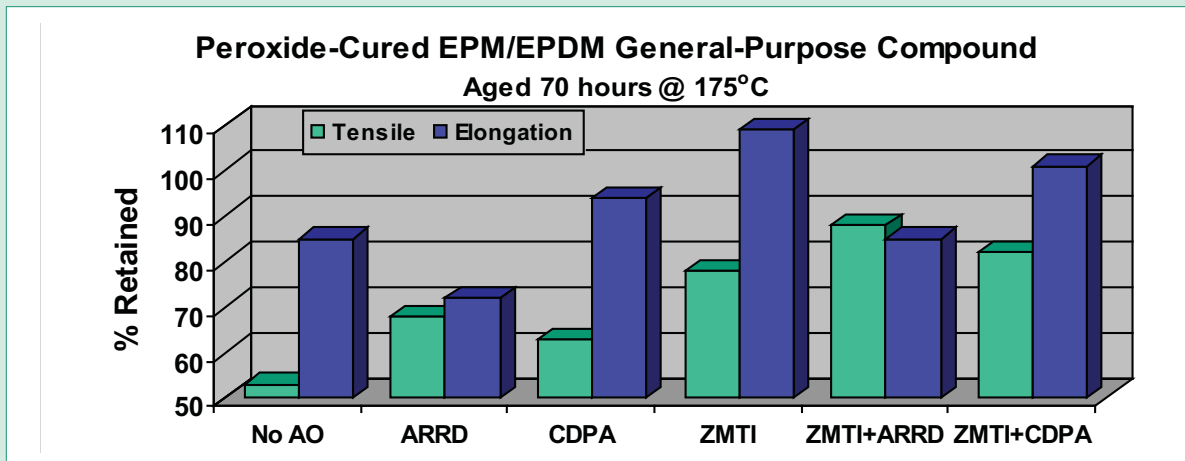


Figure 3: Antioxidant Performance of an EPDM Compound

R.T. Vanderbilt Company offers the following product options with regard to compounding requirements:

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

VANOX® ZMTI Antioxidant in an EPDM Compound

Ingredients (phr)	No AO	AGERITE RESIN D	VANOX CDPA	VANOX ZMTI	VANOX ZMTI + AGERITE RESIN D	VANOX ZMTI + VANOX CDPA
Vistalon™ 706	70.0	70.0	70.0	70.0	70.0	70.0
Vistalon 7500	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
VAROX® 802-40KE	6.0	6.0	6.0	6.0	6.0	6.0
VANAX® MBM	1.0	1.0	1.0	1.0	1.0	1.0
VANOX® ZMTI	---	---	---	2.0	2.0	2.0
VANOX CDPA	---	---	2.0	---	---	1.0
AGERITE® RESIN D®	---	2.0	---	---	1.0	---
Totals	262.0	264.0	264.0	264.0	265.0	265.0

PHYSICAL PROPERTIES

Press Cured t' 90 + 2 min. @ 177°C

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
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Antioxidants in Neoprene

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** antioxidant, when used in addition to the amine **AGERITE[®] STALITE[®] S** antioxidant, will improve the heat and flex resistance of both G and W types of Neoprene.

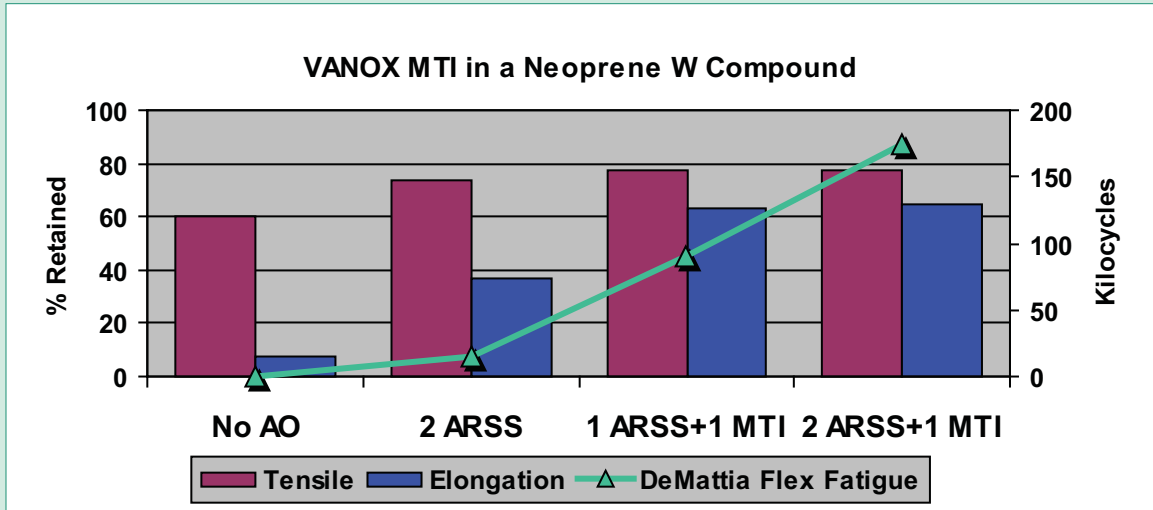


Figure 4: VANOX MTI Antioxidant in Neoprene W

Ingredients (phr)	No AO	AGERITE STALITE S	1 AGERITE STALITE S + 1 VANOX MTI	2 AGERITE STALITE S + 1 VANOX MTI
Neoprene W	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
VANPLAST [®] PL	5.0	5.0	5.0	5.0
Zinc Oxide	5.0	5.0	5.0	5.0
VANAX [®] CPA	1.5	1.5	1.5	1.5
AGERITE STALITE S	---	2.0	1.0	2.0
VANOX MTI	---	---	1.0	1.0
Totals	181.0	183.0	183.0	184.0

VANOX® MTI Antioxidant in a Neoprene W Compound

Compounds	No AO	AGERITE® STALITE® S	1 AGERITE STALITE S + 1 VANOX MTI	2 AGERITE STALITE S + 1 VANOX MTI
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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 _{s1} , minutes	1.56	2.31	1.10	1.02
t' 90, minutes	26.32	26.19	20.14	19.63

PHYSICAL PROPERTIES

Press Cured t' 90 + 2 min. @ 160°C

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
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DEMATTIA FLEX

Kilocycles to 1.9 cm	0.5	15	90	175
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VANOX® MTI Antioxidant in a Neoprene GW Compound

Ingredients (phr)	No AO	AGERITE STALITE S	AGERITE STALITE S + VANOX MTI
Neoprene GW	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
VANPLAST® PL	5.0	5.0	5.0
Zinc Oxide	5.0	5.0	5.0
AGERITE® STALITE® S	---	2.0	1.0
VANOX MTI	---	---	2.0
Totals	179.5	181.5	182.5

MOONEY SCORCH @ 121.1°C

Minimum Viscosity, mu	30	26	31
t5, 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 _{s1} , minutes	1.16	1.07	0.71
t' 90, minutes	7.62	14.86	24.85

PHYSICAL PROPERTIES

Press Cured t' 90 + 2 min. @ 160°C

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
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DEMATIA FLEX

Kilocycles to 1.9 cm	300	700	966
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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® RESIN D®**, **AGERITE STALITE® S** or **VANOX CDPA** antioxidants.

VANOX ZMTI Antioxidant in Peroxide-Cured Nitrile

Ingredients (phr)	AGERITE RESIN D	AGERITE STALITE S	METHYL NICLATE®	VANOX ZMTI
Chemigum® N689	100.0	100.0	100.0	100.0
Paraplex® G25	10.0	10.0	10.0	10.0
N990 Carbon Black	65.0	65.0	65.0	65.0
N550 Carbon Black	35.0	35.0	35.0	35.0
VANOX® DCP-40KE	4.0	4.0	4.0	4.0
AGERITE RESIN D	1.5	---	---	---
AGERITE STALITE S	---	1.5	---	---
METHYL NICLATE Dustless	---	---	1.5	---
VANOX ZMTI	---	---	---	1.5
Totals	215.5	215.5	215.5	215.5

MOONEY SCORCH @ 121°C

Minimum Viscosity, mu	80	72	73	72
t5, minutes	7	7	6	7

PHYSICAL PROPERTIES

Press Cured 20 min. @ 160°C

100% Modulus, MPa	2.9	3.1	3.4	3.2
Tensile, MPa	13.6	13.8	13.7	13.9
Elongation, %	350	310	310	320
Hardness, Shore A	68	66	67	67

TEST TUBE AGED 70 HOURS @ 121°C

Tensile Retained, %	49	71	64	122
Elongation Retained, %	97	93	94	97
Hardness, Pts. Change	+6	+6	+6	+8

COMPRESSION SET – METHOD B - 70 HOURS @ 121°C

Set, %	31	34	34	36
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VANOX® ZMTI Antioxidant Synergy in Peroxide-Cured Nitrile

Ingredients (phr)	AGERITE RESIN D + VANOX ZMTI	AGERITE STALITE S + VANOX ZMTI	METHYL NICLATE + VANOX ZMTI
Chemigum® N689	100.00	100.00	100.00
Paraplex® G25	10.00	10.00	10.00
N990 Carbon Black	65.00	65.00	65.00
N550 Carbon Black	35.00	35.00	35.00
VANOX® DCP-40KE	4.00	4.00	4.00
AGERITE® RESIN D®	0.75	---	---
AGERITE STALITE® S	---	0.75	---
METHYL NICLATE® Dustless	---	---	0.75
VANOX ZMTI	0.75	0.75	0.75
Totals	215.50	215.50	215.50

MOONEY SCORCH @ 121°C

Minimum Viscosity, mu	72	68	71
t5, minutes	7	8	6

PHYSICAL PROPERTIES

Press Cured 20 min. @160°C

100% Modulus, MPa	2.9	3.0	2.9
Tensile, MPa	13.4	13.3	13.6
Elongation, %	350	320	340
Hardness, Shore A	67	68	68

TEST TUBE AGED 72 HOURS @121°C

Tensile Retained, %	107	123	93
Elongation Retained, %	97	97	94
Hardness, Pts. Change	+8	+5	+5

COMPRESSION SET – METHOD B - 70 HOURS @ 121°C

Set, %	37	36	41
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VANOX[®] ZMTI Antioxidant in Efficient Vulcanization (EV)-Cured NBR

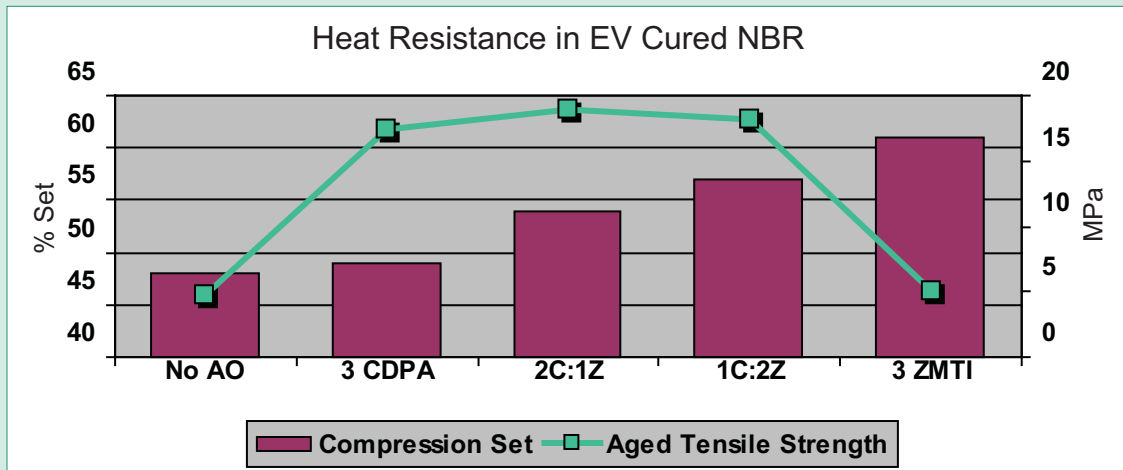


Figure 5: VANOX ZMTI Antioxidant in EV-Cured NBR

Ingredients (phr)	No AO	VANOX CDPA	VANOX CDPA + VANOX ZMTI (2:1)	VANOX ZMTI + VANOX CDPA (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)	3.0	3.0	3.0	3.0	3.0
VANOX CDPA	---	3.0	2.0	1.0	---
VANOX ZMTI	---	---	1.0	2.0	3.0
Totals	179.0	182.0	182.0	182.0	182.0

PHYSICAL PROPERTIES

Press Cured t' 90 + 2 min. @ 171°C

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
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VANOX® ZMTI Antioxidant in Peroxide-Cured NBR

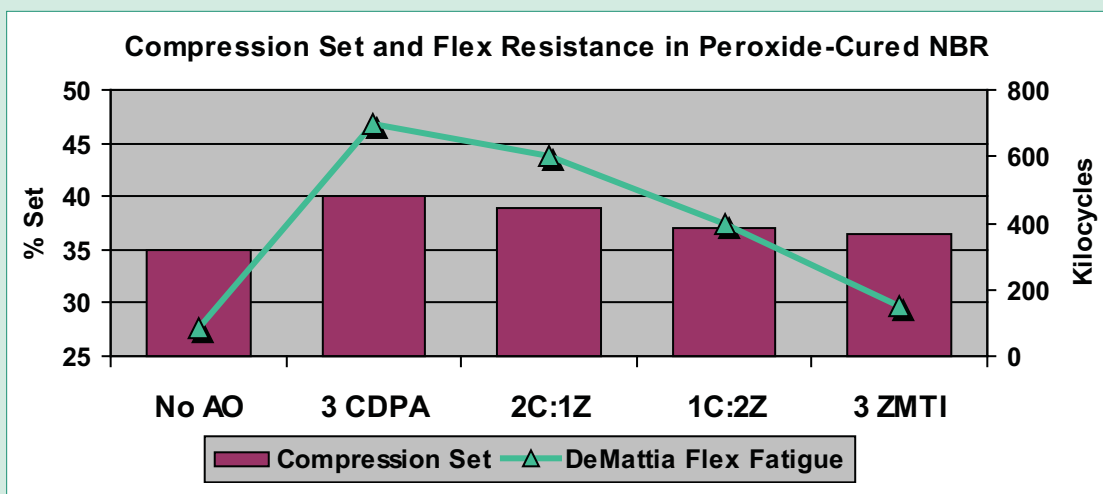


Figure 6: VANOX ZMTI Antioxidant in a Peroxide-Cured NBR

Ingredients (phr)	No AO	VANOX CDPA	VANOX CDPA + VANOX ZMTI (2:1)	VANOX ZMTI + VANOX CDPA (2:1)	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
VANOX® DCP-40KE	3.0	3.0	3.0	3.0	3.0
VANOX CDPA	---	3.0	2.0	1.0	---
VANOX ZMTI	---	---	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
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DEMATIA FLEX

Kilocycles to 1.9 cm	85	700	600	400	150
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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	VANOX CDPA + 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	---	1.5	1.5
VANOX ZMTI	---	---	1.5
VAROX® DCP-40KE	8.0	8.0	8.0
Total	178.5	180.0	181.5

MOONEY SCORCH @ 121°C

Minimum Viscosity, mu	59	51	53
t5, minutes	18	23	28

PHYSICAL PROPERTIES

Press Cured t' 90 + 2 min. @ 171°C

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
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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** antioxidant, are known to inhibit gel formation in hot mixing, and are used in compounds to assure uniform extrusion and calendering. **VANOX® MTI** antioxidant or phenols like **SONGNOX® 3114** antioxidant are often used in non-black compounds.

VANOX MTI in Mineral-Filled SBR

Ingredients (phr)	No AO	VANOX MTI	SONGNOX 3114
SBR 1502	100.00	100.00	100.00
VANFRE® AP-2	2.00	2.00	2.00
Stearic Acid	2.00	2.00	2.00
Zinc Oxide	5.00	5.00	5.00
VANPLAST® R	2.00	2.00	2.00
DIXIE CLAY®	80.00	80.00	80.00
Sulfur	2.50	2.50	2.50
ALTAX® (MBTS)	1.50	1.50	1.50
METHYL TUADS® (TMTD)	0.50	0.50	0.50
VANOX MTI	---	2.00	---
SONGNOX 3114	---	---	2.00
Totals	195.50	197.50	197.50

PHYSICAL PROPERTIES

Press Cured 30 min. @ 153°C

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 Specifications

RTV Product Code: **53499**

Composition: Zinc 2-mercaptotolumidazole

Physical State: White to light tan 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

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.	

*Certified Property

Uses - A nondiscoloring, nonstaining antioxidant for NR and SR. Particularly effective in EPDM and Nitrile stock. Suggested as a synergist with **AGERITE® STALITE® S**, **AGERITE RESIN D®**, and **AGERITE SUPERFLEX® SOLID G** for aging at normal or elevated temperatures. Offers excellent flex resistance in NR.

VANOX® MTI Specifications

RTV Product Code: **53505**

Composition: 2-mercaptotolumidazole

Physical State: White to off-white powder

	Specification	Test Method
*Ash Content	0.5% maximum	T-4
*Assay	97% minimum	T-719
*Fineness, through 100 mesh	99.9% minimum	T-14
*Heat Loss, 2 hrs at 100-105°C	1.0% maximum	T-1A
*Melting Point, Initial	250°C minimum	T-3B

GENERAL INFORMATION

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

Density at 25°C	1.33 Mg/m ³
Solubility - Moderately soluble in acetone and alcohol. Insoluble in water.	

*Certified Property

Uses - A non-discoloring, non-staining antioxidant for natural and synthetic rubbers. Suggested as a synergist with **AGERITE® STALITE® S**, **AGERITE SUPERFLEX® SOLID G** and **AGERITE RESIN D®**.



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