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Materials Bonding - Ethylene Propylene Rubber

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FINAL REPORT

ON

MATERIALS BONDING

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13. ABSTRACT

Polyethylene, polypropylene, and neoprene are commonly used insulating materials on wire and cable for underwater service, as are stainless steel and beryllium copper for connector hardware. Ethylene Propylene Diene Rubber (EPDM), a synthetic rubber having chemical building blocks in common with polyethylene and polypropylene and physical properties similar to neoprene, has been investigated as a potential tie material between these insulations.

An EPDM formulation has been developed, utilizing a peroxide cure system, that will develop satisfactory physical properties over a cure temperature range compatible with polyethylene, polypropylene, and neoprene. This formulation has been molded and cured against samples of these materials as well as stainless steel, and beryllium copper, with various surface treatments, and the adhesion bonding obtained measured quantitatively. Test results indicate that, dependent on surface treatment and cure parameters, a reasonable degree of bonding can be achieved between the EPDM formulation and each of the other materials. Work, beyond the scope of this study, remains to be done to optimize the adhesion obtained; to investigate EPDM bonding to other materials; and to correlate the results with service testing of dual or multicomponent systems.

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1. Ethylene Propylene Rubber						
2. Underwater cable insulation						
3. Cable splice encapsulation						

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INTRODUCTION

The reliability of an underwater cable system for the gathering and/or transmission of data depends on the reliability of both its electronic components, and its electrical network of cable, splices, and connectors. The integrity of this network against the effects of sea water and hydrostatic pressure is maintained by insulation, using a suitable, dielectric material. Ideally, the same insulating material would be used throughout the system-restored at joints, splices, and connectors to maintain continuity of coverage. However, under certain conditions, it may not be possible or desirable to use the same insulation throughout a system. The electrical or mechanical requirements for part of a system may dictate the use of a different insulating material, or it may be necessary to incorporate standard or stock components available only with different insulation. In these instances, the re-insulation of joints between different materials becomes both a technical and a reliability problem.

Polyethylene, polypropylene, and neoprene are commonly used insulating materials on wire and cable for underwater service, as are stainless steel and beryllium copper for connector hardware. Ethylene Propylene Diene Rubber (EPDM), a synthetic rubber having chemical building blocks in common with polyethylene and polypropylene and physical properties similar to neoprene, has been investigated as a potential tie material between these insulations.

An EPDM formulation has been developed, utilizing a peroxide cure system, that will develop satisfactory physical properties over a cure temperature range compatible with polyethylene, polypropylene and neoprene. This formulation has been molded and cured against samples of these materials as well as stainless steel, and beryllium copper, with various surface treatments, and the adhesion bonding obtained measured quantitatively. Test results indicate that, dependent on surface treatment and cure parameters, a reasonable degree of bonding can be achieved between the EPDM formulation and each of the other materials. Work, beyond the scope of this study, remains to be done to optimize the adhesion obtained; to investigate EPDM bonding to other materials; and to correlate the results with service testing of dual or multicomponent systems.

SCOPE OF WORK

The evaluation of EPR as a possible tie material for bonding between polyethylene, polypropylene, neoprene, stainless steel, and beryllium copper required a two-stage program. In Phase I, desirable properties for an EP rubber formulation were specified, and a formulation developed and tested for conformance to those properties. In Phase II, the formulation selected was molded against treated samples of the five materials under study and the bond strength measured.

PHASE I

EP Rubber Properties

The following properties and/or characteristics were used as he basis for the development of an EP Rubber compound (formulation) for use in the study. In each case, a goal was set and ingredients selected for trial to reach the goal.

1. Reactivity

   Ethylene-Propylene Rubbers are available either as copolymers of ethylene and propylene with no unsaturation (Vistalon 404, Enjay Chemical) or as terpolymers of ethylene, propylene and diene where the diene adds a reactive double bond to the mixture. The copolymer is curable with peroxides only, while the terpolymers can be cured with either peroxide or sulfur systems. The double bond in the terpolymer appeared to offer a plus factor as far as reactivity in a potential chemical bond was concerned, and for this reason, terpolymers (EPDM) were used as the starting point for trial formulations. In an attempt to get additional reactivity, several formulations were tried with polyacrylate crosslinking agents (ref: Sartomer Resins' letter, appended). These materials had the added advantage of lowering uncured formulation viscosity, and the possibility of being added to the interface prior to molding.

2. Uncured Viscosity

   A compound for use as a tie material would have to be molded around a splice or connector, and frequently forced between several insulated wires eliminating voids and acting as an insulator. Low viscosity in the uncured state thus becomes a requirement for any such formulation to avoid bending wires or damaging existing insulation as the material is forced into a cavity (mold) under pressure. Nordel 1320, an EPDM from DuPont, had the lowest viscosity (Mooney ML-4 @ 250° of 18) of any of the commercial rubbers used in our formulations, and therefore was a prime candidate.

3. Cure System

Although the terpolymers (EPDM) can be cured with either sulfur or peroxide catalyst systems, peroxide cures were used exclusively for this program. This was done to eliminate the possibility of sulfur reactions with electrical components in future work, and also in the hope that peroxides in the rubber might give some crosslinking with other polymers during cure.

4. Cure Temperatures

One of the major problems in the formulation of a suitable rubber formulation, was the range of temperatures required by the various materials to which we wished to bond. The normal range of rubber cure temperatures is 300° - 350° F, and most compounds and cure systems are tailored to this range as are most primer systems for rubber to metal adhesion. The two metals, therefore, were no problem; neoprene as used in this study was already cured; polypropylene (cable grade SE-023) has a sharp melting point of about 330°F; but polyethylene (DFD 0160 Melt Index .3) has a crystallization temperature in the 230° - 250° F range and a softening point somewhat below that - with the result that a 300°F cure temperature would cause severe damage to polyethylene insulation.

At first we felt that two formulations with different temperature cure systems would be required, and tried several compounds with benzoyl peroxide or t-butyl peroctoate as low temperature systems, and dicumyl peroxide (Di-cup) as a high temperature system. These low temperature peroxides gave problems of decomposition on the rolls during mixing, and would have made formulations with low shelf life under normal storage conditions. In the search for more stable alternates to benzoyl peroxide, we tested Luperco 230XL - later replaced with D-231XL. The latter compound, a peroxyketal - data given in the appended bulletin, appeared to give satisfactory results both at 240°F, the maximum temperature picked for polyethylene, and 315°F, selected for polypropylene and the other materials. The availability of a wide range catalyst eliminated the need for more than one formulation.

TABLE I

Thermal Decomposition Data for Peroxides

	85°C	100°C	115°C
Benzoyl Peroxide	2.1 hrs.	0.4 hrs.	0.1 hrs.
t-Butyl Peroctoate	2.2 hrs.	0.4 hrs.	0.1 hrs.
D-231 & D-231XL	27.0 hrs.	3.8 hrs.	0.71 hrs.
Di-cup	132.0 hrs.	46.0 hrs.	9.2 hrs.

5. Physical Properties

A compound for use as a tie material or as encapsulation for cable connections and splices should have adequate physical properties to resist damage during handling and storage. It should also be as flexible as the material to which it is to be bonded to eliminate stress concentrations at the interface. With this end use in mind, the following targets were chosen for tensile strength, elongation, and hardness.

Tensile	-	500 psi minimum
Elongation	-	300% minimum
Hardness	-	40 (Shore D) minimum

With most of the rubbers tested, the attainment of these targets required the addition of carbon black as reinforcement with quantities kept as low as possible to avoid loss of electrical properties. The carbon black has the added advantage of increasing UV light and weathering resistance - a potential storage problem.

Rubber Formulations

During this first stage of the program, rubber formulations were selected for test with the foregoing considerations and properties in mind. In each case the ingredients were mixed on a 6" x 12" laboratory mill roll at the minimum temperature required to sheet, and the resulting compound molded and tested per ASTM D412-68. The following tables give the formulations tried and the results obtained:

TABLE 2

Formulations (phr)
(parts per hundred, rubber)

Compound	Rubber		Carbon Black	Zinc Oxide	Benzoyl	t-Butyl Peroctoate	Di-cup 40C	Luperco 230XL	Luperco D-231XL	Other
1	Nordel 1320	100					5			
2	Nordel 1320	100					10			
3	Nordel 1320	100					15			
4	Nordel 1320	100			1					
5	Nordel 1320	100			2					
6	Nordel 1320	100			2					
7	Nordel 1320	100			3					
8	Royalene 521	100					10			
9	Royalene 521	100			2					
10	Royalene 611	100					10			
11	Royalene 611	100			2					
12	Epsyn 55	100					10			
13	Nordel 1320	100	40				10			
14	Nordel 1320	100	40		2					
15	Nordel 1320	100	10		3					
16	Nordel 1320	100						5		
17	Nordel 1320	100	10					5		
18	Nordel 1320	100	10					7.5		
19	Royalene 611	100	2		3					
20	Royalene 611	100	2					5		
21	Nordel 1320	100	10			3				
22	Nordel 1320	100	10			3				10 Butyl LM
23	Nordel 1320	100	10		3					20 Butyl LM
24	Nordel 1320	100	10					5		10 Butyl LM
25	Nordel 1320	100	10		3	3				
26	Nordel 1320	100	10		6*					

* 50% paste Luperco ATC

Table 2 - continued

Compound	Rubber		Carbon Black	Zinc Oxide	Benzoyl	t-Butyl Peroctoate	Di-cup 40C	Luperco 230XL	Luperco D-231XL	Other
27	Nordel 1320	100	10		6*					
28	Vistalon 404	100	10		6*					10 Butyl LM
29	Vistalon 2504	100	10		6*					
30	Royalene 521	100	10		8*					10 Butyl LM
31	Royalene 521	100	10		8*					20 Butyl LM
32	Vistalon 3708	100	10		6*					
33	Vistalon 404	100	10		6*					
34	Nordel 1320	100							5	
35	Nordel 1320	100							6	
36	Nordel 1320	100							7	
37	Nordel 1320	100	20						6	
38	Nordel 1320	100	20						7	
39	Nordel 1320	100	20	5					6	
40	Nordel 1320	100	20	10					6	
41	Nordel 1320	100	20	5					6	10 SR 350
42	Nordel 1320	100	20	5					6	15 Saret 500
43	Nordel 1320	100	20	5					6	20 Saret 515
44	Nordel 1320	100	20	5					7	10 SR 297
45	Nordel 1320	100	20	5					7	10 SR 350
46	Nordel 1320	100	20	5					8	10 SR 350
47	Nordel 1320	100	20	5					7	15 Saret 500
48	Nordel 1320	100	20	5					7	15 Saret 515
49	Nordel 1320	100	20	5					7	
50	Nordel 1320	100	20	10					7	
51	Nordel 1320	100	20	5					10	10 SR 350
52	Commercial Cable splicing compound									

* 50% paste Luperco ATC

Table 2 - continued

Ingredients

Nordel 1320	EPDM	E. I. DuPont	Mooney Visc. 18
Royalene 521	EPDM	Uniroyal Chem.	Mooney Visc. 45
Royalene 611	EPDM	Uniroyal Chem.	Mooney Visc. 40
Epsyn 55	EPDM	Copolymer Rubber & Chem.	Mooney Visc. 55
Vistalon 404	EPR	Enjay Chemical	Mooney Visc. 40
Vistalon 2504	EPDM	Enjay Chemical	Mooney Visc. 40
Vistalon 3708	DPDM	Enjay Chemical	Mooney Visc. 50
Carbon Black	Vulcan 3	(HAF) Cabot Corp.	
Zinc Oxide	Grade 20-21	St. Joseph Lead Co.	
Benzoyl Peroxide		Lucidol Division	
t-Butyl Peroctoate		Lucidol Div. Wallace & Tiernan	
Di-cup 40-C		Hercules	
Luperco 230XL		Lucidol Div.	
Luperco D-231XL		Lucidol Div.	
Butyl LM-430		Enjay Chemical	
SR-350	Trimethylol propane trimethacrylate	Sartomer Resins Inc.	
SR-297	1,3 Butyl glycol dimethacrylate	Sartomer Resins Inc.	
Saret 500	(Proprietary)	Sartomer Resins Inc.	
Saret 515	(Proprietary)	Sartomer Resins Inc.	
Commercial cable splicing compound		Hotsplicer Corp. #111 EPR	

TABLE 3

Cure Conditions and Physical Properties
per ASTM D412-68

Compound No.	Mold Temperature °F	Cure Time min.	Tensile, psi	Elongation, %	Hardness, Shore D	
1A	325	30	190	170	47/46	
1B	315	30	170	170	48/47	
2A	325	30	180	80	55/54	
2B	315	30	180	80	54/53	
3	315	30	180	60	56/56	
4	240	45	>250	>1300	39/33	Not fully cured
5A	240	45	290	370	42/40	
5B	240	90	400	470	44/41	
5C	210	60	430	1100	39/34	Not fully cured
5D	210	120	450	620	43/39	
6	240	45	270	240	44/40	
7A	240	45	440	270	47/45	
7B	210	60	410	400	44/41	
7C	210	120	420	300	47/45	
8	315	30	240	140	53/52	
9	240	45	450	680	42/39	
10	315	30	1000	550	58/56	
11	240	45	2000	800	57/54	
12	315	30	220	60	61/60	
13	315	30	2300	240	70/68	
14	240	45	200	140	53/36	Peroxide decomposition on mill
15	210	60	Not cured			Peroxide decomposition on mill
16	315	30	200	230	47/46	
17	315	30	640	360	50/48	
18	315	30	550	260	52/52	

Table 3 - continued

Compound No.	Mold Temperature °F	Cure Time min.	Tensile, psi	Elongation, %	Hardness, Shore D	
19	210	60	Not cured			
20	315	30	2400	700	57/56	
21	240	45	Not cured			
22	240	45	Not cured			
23	240	45	Not cured			Peroxide decomposition on mill
24	315	30	640	440	47/45	
25	240	45	270	600	41/36	
26			Not Molded			Peroxide decomposition on mill
27	240	45	Not cured			
28	240	45	160	280	35/29	Pre-cure on mill during compounding
29			Not molded			Pre-cure on mill during compounding
30	240	45	1500	800	48/45	Pre-cure on mill during compounding
31			Not molded			
32			Not molded			
33			Not molded			
34			Not molded			
35			Not molded			
36			Not molded			
37	315	30	1600	510	53/51	
38A	240	85	1200	640	53/50	
38B	260	60	1600	440	55/53	
38C	315	30	1500	410	55/54	
39	240	60	Not cured			
40	240	90	380	850	51/44	
41A	240	60	590	330	60/54	
41B	315	30	1100	240	62/60	
42	240	60	410	450	59/51	
43	240	60	530	400	62/55	
44A	240	60	1200	510	57/53	
44B	315	30	1400	320	58/56	

Table 3 - continued

Compound No.	Mold Temperature °F	Cure Time min.	Tensile,psi	Elongation, %	Hardness, Shore D
45	240	60	750	290	61/57
46	240	60	1100	270	72/69
47	240	60	420	400	59/52
48	240	60	760	300	62/58
49	240	60	470	640	50/44
50	240	60	680	660	51/45
51	240	60	1000	190	71/69
52A	240	60	Not cured		
52B	315	30	560	940	52/47

Selection of Formulation

Based on the test results shown in Table 2, formulation #44 was selected as the standard rubber for bonding trials. While several others would have met the physical property targets, they were eliminated for other reasons. Those made with Royalene 611 as a base rubber showed outstanding tensile and elongation values (#5, 10, 11, and 20), but the presence of 40 phr paraffinic oil in the rubber would have meant introducing another variable. On the other hand #44 was chosen over #38 because #44 contained 10 phr SR297 an additional reactive component.

With the wide variety of ingredients available for rubber compounding, there is no doubt that #44 can be improved or replaced with another formulation. However, it met the criteria that we had set initially, and improvement did not appear necessary for Phase II of our study.

PHASE II BONDING TRIALS

Preparation of Samples

Samples for bond strength test were prepared as follows. A transfer mold (Figure 1,p 12A) was made with the following components: an electrically heated bottom plate; a 1/4" thick chase with a 2-1/4 x 5-1/4 rectangular cavity; an electrically heated top plate center gated; and a transfer pot and plunger also electrically heated. In operation, a 1/8" x 2-1/4" x 5-1/4" strip of a substrate material (polyethylene, polypropylene, neoprene, stainless steel, or beryllium copper) was placed in the chase against the bottom plate, the mold assembled with a charge of 32 gms of rubber in the transfer pot, and the assembly loaded into a Carver Laboratory press (Figure 2, p 12A). The mold was heated to 180°F - a temperature below the initiation of cure - and the rubber forced into the cavity over the substrate sheet under a pressure of 1000 psi. When the cavity was filled, the temperature of the mold was raised to the cure temperature selected and pressure maintained for the duration of the cure. At the end of the cure time, the mold was cooled slowly and the sample removed as a 1/4" x 2-1/4" x 5-1/4" "sandwich".

Test Procedure

The samples prepared as above were tested for bond between the molded rubber and the substrate as follows: Each "sandwich" was cut into 1/2" x 2-1/4" strips, or for the steel and beryllium specimens, the rubber cut

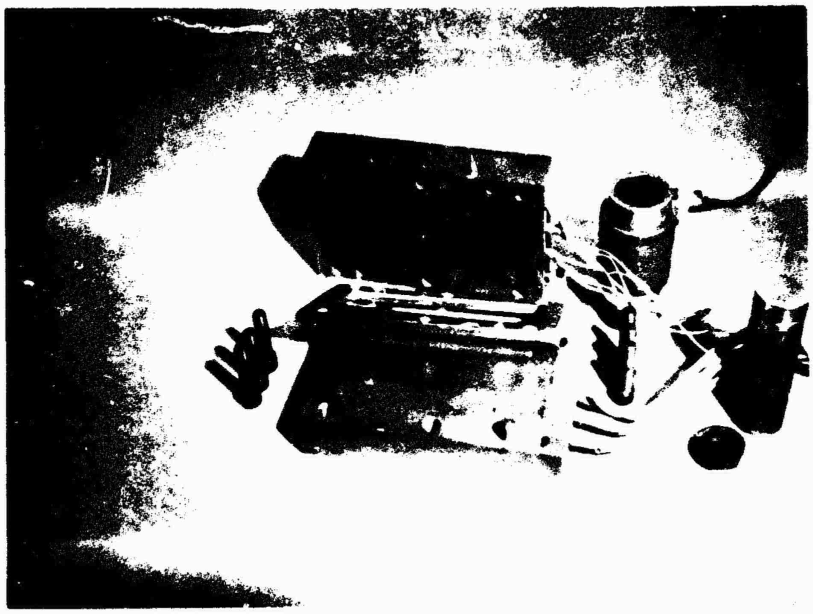


Figure 1. Transfer Mold for Sample Preparation

Figure 2. Molding Set-up for Sample Preparation

Figure 3. Instron Testing Machine Set-up

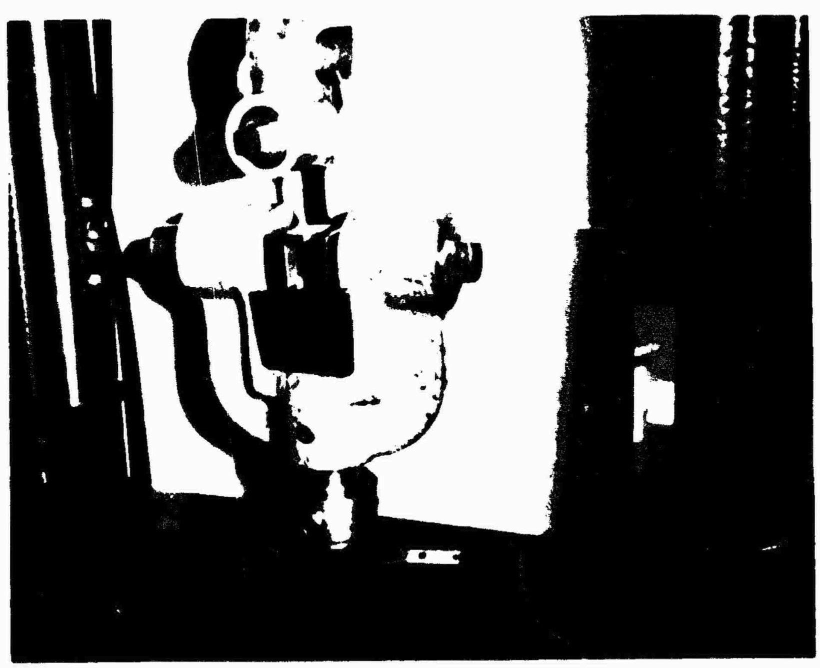


Figure 4. 90° Peel Test - 1/2" Sample Width

down to the metal surface in 1/2" wide strips. The substrate base of the sandwich was clamped horizontally, a length of rubber sufficient to clamp separated by cutting at the interface, and the rubber pulled from the substrate at 90° in an Instron testing machine Model TM. The 90° peel was used for all substrates except neoprene, which was too flexible to clamp in a vise, and was tested in 180° pull (T peeled). For all samples, cross head speed was set at 0.5-inch per minute, chart speed at 0.5-inch per minute and full load of 0-20 and 0-50 pounds. The test setup is shown in Figure 3, p 12B, and a sample clamped for 90° peel shown in Figure 4, p 12B.

Record of Trials

The following information is given for each sample prepared and tested.

1. Sample Number
2. Substrate Material
3. Substrate pre-treatment (prior to molding)
4. Cure temperature (°F) and cure time (minutes)
5. Peel strength - reported as pounds per 1/2 inch width. average estimated from chart
6. Appearance of substrate surface after peel or type of failure.

#1 Substrate: SE-023 Polypropylene copolymer - Hercules
Treatment: A. Trichloroethane wash
B. Chromic acid for 30 min. @ 210°F
Cure: 315° 30 min.
Peel: 48 hours 5.9 lbs.
6 months 7.1 lbs.
Appearance: Some discoloration and spots of rubber left on surface

#2 Substrate: SE-023
Treatment: A. Trichloroethane wash
Cure: 240° 60 min.
Peel: 48 hours 2.1 lbs.
6 months 4.3 lbs.
Appearance: Clean peel

#3	Substrate:	SE-023
	Treatment:	A. Trichloroethane wash
	Cure:	280^{o} 45 min.
	Peel:	48 hours 4.2 lbs.
		6 months 4.6 lbs.
	Appearance:	Clean peel
#4	Substrate:	SE-023
	Treatment:	A. Trichloroethane wash
	Cure:	320^{o} 30 min.
	Peel:	48 hours 8.4 lbs.
		6 months 9.3 lbs.
	Appearance:	Clean except for stop-start lines transverse to peel direction. Rubber shows on these lines.
#5	Substrate:	SE-023
	Treatment:	A. Trichloroethane wash
		B. Soak 10 min. @ 140^{o} in the following solution
		Tetrachloroethylene 100 parts
		Sartomer SR 298 10 parts
		D-221 (liquid) 5 parts
		C. Dry 5 min. @ 140^{o}F
	Cure:	320^{o} 30 min.
	Peel:	48 hours 8.6 lbs.
		6 months 8.3 lbs.
	Appearance:	Clean peel.
#6	Substrate:	SE-023
	Treatment:	A. Trichloroethane wash
		B. Soak 10 min. @ 140^{o}F in the following solution
		Tetrachloroethylene 100 parts
		Sartomer SR 350 10 parts
		D-231 (liquid) 5 parts
		C. Dry 5 min. @ 140^{o}F
	Cure:	320^{o} 30 min.
	Peel	48 hours 7.6 lbs.
		6 months 7.2 lbs.
	Appearance:	Clean peel

#7 Substrate: SE-023

Treatment: A. Trichloroethane wash

B. Soak 10 min. @ 140°F in the following solution

Tetrachloroethylene	100 parts
Sartomer Saret 515	10 parts
D-231 (liquid)	5 parts

C. Dry 5 min. @ 140°F

Cure: 320° 30 min.

Peel: 48 hours 7.1 lbs.
6 months 6.8 lbs.

#8 Substrate: Polyethylene - Union Carbide DFD 0160

Treatment: A. Trichloroethane wash

Cure: 240° 60 min.

Peel: 48 hours 7.7 lbs.
5 months 7.9 lbs.

Appearance: Thin rubber left on approximately 90% of surface

#9 Substrate: Polyethylene - Union Carbide DFD 0160

Treatment: A. Soak 15 min. @ 140°F in the following solution

Toluene	100 parts
SR-297	10 parts
Lucidol D-231	5 parts

B. Dry 5 min. @ 140°F

Cure: 240° 60 min.

Peel: 48 hours 8.0 lbs.
5 months 9.6 lbs.

Appearance: Thin rubber left on approximately 80% of surface

#10 Substrate: Polyethylene - Union Carbide DFD 0160

Treatment: A. Soak 15 min. @ 140°F in the following solution

Toluene	100 parts
SR-350	10 parts
D-231	5 parts

B. Dry 5 min. @ 140°F

Cure: 240° 60 min.

Peel: 48 hours 6.7 lbs.
5 months 8.2 lbs.

Appearance: Thin rubber left on approximately 40% of surface

#11	Substrate:	SE-023
	Treatment:	A. Abrade surface with 150 grit emery paper
		B. Soak 15 min. @176°F in the following solution
		Trichloroethane 100 parts
		SR-297 10 parts
		D-231 5 parts
		C. Dry 5 min. @ 176°F
	Cure:	320° 30 min.
	Peel:	48 hours 8.6 lbs.
		5 months 9.8 lbs.
	Appearance:	Thin rubber left on surface - primarily in the scratch lines from Treatment A.
#12	Substrate:	SE-023
	Treatment:	A. Abrade surface with 150 grit emery paper
		B. Soak 15 min. 2 176°F in the following solution
		Trichloroethane 100 parts
		SR-350 10 parts
		D-231 5 parts
		C. Dry 5 min. @ 176°F
	Cure:	320° 30 min.
	Peel:	48 hours 11.6 lbs.
		5 months 12.9 lbs.
	Appearance:	Similar to #11
#13	Substrate:	SE-023
	Treatment:	A. Abrade surface with 150 grit emery paper
		B. Soak 15 min. @ 176°F in the following solution
		Trichloroethane 100 parts
		SR-515 10 parts
		D-231 5 parts
		C. Dry 5 min. @ 176°F
	Cure:	320° 30 min.
	Peel:	48 hours 10.7 lbs.
		5 months 10.7 lbs.
	Appearance:	Similar to #11

#14 Substrate: Stainless Steel - Type 316
Treatment:
A. Vapor degrease in perchloroethylene
B. Grit blast with 80 mesh Aluminum Oxide
C. Vapor degrease in perchloroethylene
D. Prime with two coats Thixon D 12809 (.001 in.) and 1 coat Thixon AP 1434 (.001)

Cure: 320^{o} 30 min.
Peel: 48 hours 25.1 lbs.
5 months 30.3 lbs.
Appearance: No peel. Rubber tab broke.

#15 Substrate: Beryllium Copper
Treatment:
A. Vapor degrease in perchloroethylene
B. Grit blast with 80 mesh Aluminum Oxide
C. Vapor degrease in perchloroethylene
D. Prime with two coats Thixon D 12809 (.001 in.) and 1 coat Thixon AP 1434 (.001)

Cure: 320^{o} 30 min.
Peel: 48 hours 17.2 lbs.
5 months 20.4 lbs.
Appearance: Peeled at rubber - AP 1435 interface - one of four tabs broke during test

#16 Substrate: SE-023 Polypropylene
Treatment:
A. Abrade surface with 150 grit emery paper
B. Trichloroethane wash

Cure: 320^{o} 30 min.
Peel: 48 hours 8.8 lbs.
5 months 9.6 lbs.
Appearance: Thin rubber left in surface scratches.

#17 Substrate: SE-023 Polypropylene
Treatment: Oxidizing Flame
Cure: 320^{o} 30 min.
Peel: 48 hours 4.0 lbs.
5 months 4.1 lbs.
Appearance: Clean peel.

#18 Substrate: Polyethylene - Union Carbide DFD 0160
Treatment: Oxidizing Flame
Cure: 240° 60 min.
Peel: 48 hours 6.3 lbs.
5 months 6.2 lbs.
Appearance: Thin rubber left on approximately 20% of surface

#19 Substrate: SE-023 Polypropylene
Treatment: A. Abrade surface with 150 grit emery paper
B. Trichloroethane wash

Rubber Formulation: (phr)

Nordel 1320	100
SE-023 polypropylene	20
Zinc Oxide	5
Carbon Black	20
SR-297	12
D-231XL	8.4

Cure: 320° 30 min.
Peel: 48 hours 6.2 lbs.
5 months 7.0 lbs.
Appearance: Clean peel except for scratches

#20 Substrate: Polyethylene - Union Carbide DFD 0160
Treatment: A. Abrade surface with 150 grit emery paper
B. Trichloroethane wash

Rubber Formulation: (phr)

Nordel 1320	100
DFD 0160 polyethylene	10
Zinc Oxide	5
Carbon Black	20
SR-298	11
D-231XL	7.7

Cure: 240° 60 min.
Peel: 48 hours 10.9 lbs.
5 months 11.6 lbs.
Appearance: Thin rubber coating on interface 90%.

#21	Substrate:	SE-023 Polypropylene	
	Treatment:	A. Abrade with 150 grit emery paper	
		B. Trichloroethane wash	
	Rubber Formulation: (phr)	Nordel 1320	100
		SE-023 polypropylene	10
		Zinc Oxide	5
		Carbon Black	20
		SR-297	11
		D-231XL	7.7
	Cure:	320° 60 min.	
	Peel:	48 hours 6.0 lbs.	
		5 months 6.4 lbs.	
	Appearance:	Clean peel except for scratches	
#22	Substrate:	Stainless Steel Type 316	
	Treatment:	A. Vapor degrease in perchloroethylene	
		B. Grit blast with 80 mesh Aluminum Oxide	
		C. Vapor degrease in perchloroethylene	
		D. Prime with 2 coats Chemloc 205 (.0006) and 2 coats Chemloc 236 (.0028)	
	Cure:	320° 30 min.	
	Peel:	Rubber blistered @ bond interface - not tested	
#23	Substrate:	Beryllium Copper	
	Treatment:	A. Vapor degrease in perchloroethylene	
		B. Grit blast with 80 mesh Aluminum Oxide	
		C. Vapor degrease in perchloroethylene	
		D. Prime with 2 coats Chemloc 205 (.0005) and 2 coats Chemloc 236 (.0028)	
	Cure:	320° 30 min.	
	Peel:	Rubber blistered @ bond interface - not tested	
#24	Substrate:	Stainless Steel Type 316	
	Treatment:	A. Vapor degrease in perchloroethylene	
		B. Grit blast with 80 mesh Aluminum Oxide	
		C. Vapor degrease in perchloroethylene	
		D. Prime with 2 coats Thixon D-12809 (.0005) and 1 coat Thixon AP 1435 (.0028)	
	Cure:	320° 30 min.	
	Peel:	48 hours 27.7 lbs.	
		3 months 27.1 lbs.	
	Appearance:	40% failure at interface (RC-40)	
		All four tabs tested broke.	

#25	Substrate:	Beryllium Copper
	Treatment:	A. Vapor degrease in perchloroethylene
		B. Grit blast with 80 mesh Aluminum Oxide
		C. Vapor degrease in perchloroethylene
		D. Prime with one coat Thixon D 12809 (.0005) and 2 coats Thixon AP 1435 (.0026)
	Cure:	240° 60 min.
	Peel:	48 hours 3.5 lbs.
		3 months 7.6 lbs.
	Appearance:	Interface failure 40% (RC-40) Rubber failure 60% (R-60) Rubber at interface not fully cured.
#26	Substrate:	Neoprene Shore D 60
	Treatment:	A. Trichloroethane wash
		B. Prime with Chemloc 236 (.003)
	Cure:	240° 60 min.
	Peel:	48 hours 0.7 lbs.
		3 months 0.8 lbs.
	Appearance:	Smooth Interface
#27	Substrate:	Neoprene Shore D 60
	Treatment	A. Trichloroethane wash
		B. Prime with Chemloc 236 (.003)
	Cure:	320° 30 min.
	Peel:	48 hours 1.1 lbs.
		3 months 1.5 lbs.
	Appearance:	Dull surface
#28	Substrate:	Beryllium Copper
	Treatment:	A. Vapor degrease in perchloroethylene
		B. Grit blast with 80 mesh Aluminum Oxide
		C. Vapor degrease in perchloroethylene
		D. Prime with 2 coats Chemloc 205 (.0007) and 2 coats Chemloc 236 (.0017)
	Cure	240° 60 min.
	Peel:	48 hours 9.5 lbs.
		3 months 10.0 lbs.
	Appearance:	Interface failure 70% (RC-70) Rubber failure 30% (R-30)

#30	Substrate:	Neoprene Shore D 60
	Treatment:	A. Trichloroethane wash
		B. Prime with Chemloc 234
	Cure:	320° 30 min.
	Peel:	48 hours 4.6 lbs.
		3 months 6.3 lbs.
	Appearance:	Dull, rough surface. More evidence of adhesion than #27.
#33	Substrate:	Neoprene Shore D 60
	Treatment:	A. Trichloroethane wash
		B. Prime with Chemloc 220
	Cure:	320° 30 min.
	Peel:	48 hours >14.0 lbs.
		3 months >14.7 lbs.
	Appearance:	Tabs broke
#34	Substrate:	Neoprene Shore D 60
	Treatment:	A. Abrade surface with 150 grit emery paper
		B. Trichloroethane wash
		C. Prime with Chemloc 220
	Cure:	320° 30 min.
	Peel:	48 hours 9.5 lbs.
		3 months 11.8 lbs.
	Appearance:	Surface of molded rubber very rough - Tab broke.
#35	Substrate:	Stainless Steel Type 316
	Treatment:	A. Vapor degrease in perchloroethylene
		B. Grit blast with 80 mesh Aluminum oxide
		C. Vapor degrease in perchloroethylene
		D. Prime with two coats Thixon and 1 coat Thixon AP 1435.
	Cure:	240° 60 min.
	Peel:	48 hours 3.8 lbs.
		3 months 3.3 lbs.
	Appearance:	Interface failure 90%

#36	Substrate:	Stainless Steel Type 316
	Treatment:	A. Vapor degrease in perchloroethylene
		B. Grit blast with 80 mesh Aluminum Oxide
		C. Vapor degrease in perchloroethylene
	Cure:	320° 30 min.
	Peel:	48 hours 2.5 lbs.
		3 months 2.7 lbs.
	Appearance:	Clean peel

#37	Substrate	Beryllium Copper
	Treatment:	A. Vapor degrease in perchloroethylene
		B. Grit blast with 80 mesh Aluminum Oxide
		C. Vapor degrease in perchloroethylene
	Cure:	320° 30 min.
	Peel:	48 hours 2.7 lbs.
	Appearance:	Clean peel

#38	Substrate:	SE-023 Polypropylene		
	Treatment:	Trichloroethane wash		
	Rubber Evaluation:	(phr)	Nordel 1320	100
			Polyethylene OFD 0160	10
			Zinc Oxide	5
			Carbon Black	20
			SR-297	11
			D-231XL	7.7
	Cure:	320° 30 min.		
	Peel:	48 hours 8.1 lbs.		
		3 months 7.3 lbs.		
	Appearance:	Clean peel - dull finish		

Sources of Primers used:

"Chemloc"	Hughson Chemical Co. Division of Lord Corp. Erie, Pennsylvania 16512
"Thixon"	Dayton Chemical Products Division Whittaker Corp. West Alexandria, Ohio 45381

TABLE 4

Summary by Substrate

Substrate	Sample #	Cure	Peel Short Term	Peel Long Term	Avg.
Polyethylene	8	240° 60 min.	7.7	7.9	7.8
	9	240° 60 min.	8.0	9.6	8.8
	10	240° 60 min.	6.7	8.2	7.5
	18	240° 60 min.	6.3	6.2	6.2
	20	240° 60 min.	10.9	11.6	11.3
Polypropylene	1	315° 30 min.	5.9	7.1	6.5
	2	240° 60 min.	2.1	4.3	3.2
	3	280° 45 min.	4.2	4.6	4.4
	4	320° 30 min.	8.4	9.3	8.8
	5	320° 30 min.	8.6	8.3	8.4
	6	320° 30 min.	7.6	7.2	7.4
	7	320° 30 min.	7.1	6.8	6.9
	11	320° 30 min.	8.6	9.8	9.2
	12	320° 30 min.	11.6	12.9	12.2
	13	320° 30 min.	10.7	10.7	10.7
	16	320° 30 min.	8.8	9.6	9.2
	17	320° 30 min.	4.0	4.1	4.0
	19	320° 30 min.	6.2	7.0	6.6
	21	320° 60 min.	6.0	6.4	6.2
Neoprene	26	240° 60 min.	0.7	0.8	0.7
	27	320° 30 min.	1.1	1.5	1.3
	30	320° 30 min.	4.6	6.3	5.4
	33	320° 30 min.	>14.0	>14.7	>14.0
	34	320° 30 min.	> 9.5	>11.8	>10.0
Stainless Steel	14	320° 30 min.	25.1	30.3	27.7
	24	320° 30 min.	27.7	27.1	27.4
	35	240° 60 min.	3.8	3.3	3.6
	36	320° 30 min.	2.5	2.7	2.6
Beryllium Copper	15	320° 30 min.	17.2	20.4	18.8
	25	240° 60 min.	3.5	7.6	5.5
	28	240° 60 min.	9.5	10.0	9.7
	37	320° 30 min.	2.7	-	2.7

CONCLUSIONS

1. The EPDM formulation (#44) as used for this study shows a fair degree of adhesion to polyethylene when molded and cured in contact at 240° F for 60 minutes - even with no surface treatment of the polyethylene except solvent wash (ref. #8). The best treatment found increased the force required to peel by 13% (ref. #9 SR-297 and D-231 in toluene). If we assume that 20 lbs. is required to break tabs in 90° peel, the best reading on polyethylene would rate 44% of break.

   The addition of polyethylene to the EPDM formulation (ref. #20) gives a definite improvement in adhesion and would rate at 57% of break.

2. The EPDM formulation (#44) when molded aginst polypropylene at 240° for 60 minutes has very low adhesion (ref. #2). As the temperature is raised to 320° the adhesion (untreated) approaches that of polyethylene (ref. #4). Surface treatment appears to be more effective with polypropylene, with the best treatment found (ref. #12 SR-350 and D-231 in toluene) giving a 39% improvement over no treatment and a rating of 61% of break.

3. The EPDM formulation (#44) has very little adhesion when molded and cured against untreated neoprene. A commercial primer system is available (ref. #33) which will give sufficient adhesion to cause tab failure in 180° peel.

4. The EPDM formulation (#44) molded against clean mechanically roughened surfaces of either stainless steel or beryllium copper shows very little adhesion (ref. #'s 36 & 37). In both cases, however, commercial primer systems are available which will give sufficient adhesion when properly used to cause tab failure in 90° peel. (ref. #'s 14 & 15).

RECOMMENDATIONS

Although a degree of bonding has been achieved between Ethylene Propylene Rubber and the substrate materials used in this study, there is no correlation between the peel strengths measured and its performance as a "tie" material between the different components of an underwater system. We would, therefore, recommend that the performance of bonds between components and EPR be evaluated under simulated or actual service conditions, and the results correlated with the peel strength values obtained.

SBK/jcv
April 1973
Attachments

N00014-72-C-0209

LUCIDOL

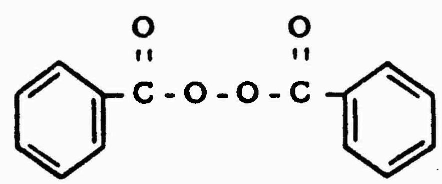
LUCIDOL® Benzoyl Peroxide

Product Bulletin 1.100

LUCIDOL Benzoyl Peroxide is a mild organic oxidizing agent and a convenient source of free radicals for polymerization of numerous unsaturated monomers and polyesters.

Formula

Molecular Weight 242.22



SPECIFICATIONS

Benzoyl Peroxide	98.5% + 1%
Active Oxygen	6.5% ± 0.07%

PROPERTIES

Melting Point (Decomposes)	103°-105°C (216°-222°F)
Form	Fine granules
Color	White
Solubility @ 20°C (Weight Percent)	
Insoluble (<1%)	Water, ethylene glycol, petroleum ether, mineral oil
Slightly Soluble (1-5%)	Carbon tetrachloride, cyclohexane, alcohols, esters
Moderately Soluble (5-15%) . . .	Ethyl acetate, styrene, toluene, trichloroethylene
Soluble (15-50%)	Acetone, benzene, chloroform, methyl ethyl ketone, dioxane (More data in Bulletin 20.11)

THERMAL DECOMPOSITION DATA

Half-life in dilute solutions.

Temperature °C	Temperature °F	Benzene	Cyclohexanone	Acetone
70	158	13.0 hr.	11.7 hr.	7.3 hr.
85	185	2.15 hr.	1.9 hr.	1.4 hr.
100	212	0.4 hr.	0.38 hr.	0.33 hr.

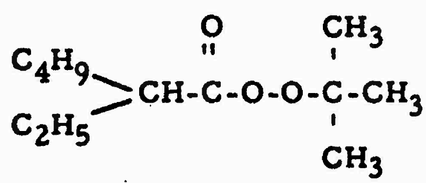
LUCIDOL

t-BUTYL PEROCTOATE

Product Bulletin 6.701

t-Butyl Peroctoate* is an efficient medium temperature initiator exhibiting catalytic activity in the same range as that of benzoyl peroxide. Because this new perester is a liquid, it dissolves much more easily in monomers and resins and can be metered or pumped like any liquid catalyst.

Formula



Molecular Weight 216.3

SPECIFICATIONS

t-Butyl Peroxy (2-ethyl hexanoate)	97.0% minimum
Active Oxygen	7.18% minimum

PROPERTIES

Form	Liquid
Color	Colorless
Odor	Faint
Freezing Point	Below -30°C
Specific Gravity @ 25°C/25°C	0.895 minimum
Refractive Index @ 25°C	1.426 minimum
Viscosity @ 20°C (68°F)	3.8 centipoises
@ 30°C (86°F)	2.8 centipoises
@ 40°C (104°F)	2.1 centipoises
Flash Point	Above 88°C (190°F)
Solubility	Miscible with esters, ketones, alcohols, hydrocarbons; practically insoluble in water.

The following table shows that t-Butyl Peroctoate has approximately the same half-life as benzoyl peroxide. This means that t-Butyl Peroctoate will also perform over the wide temperature range which has made benzoyl peroxide useful in so many applications.

* U. S. Patent 2,567,615

WALLACE & TIERNAN INC. / LUCIDOL DIVISION / 1740 MILITARY ROAD • BUFFALO, N.Y. 14240

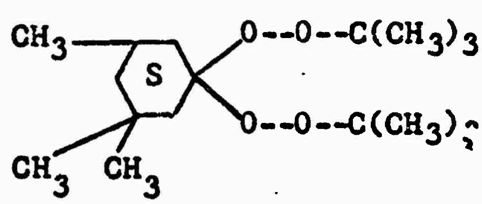
PENNWALT
LUCIDOL
CHEMICALS

Development Peroxides: D-231
D-231XL

Organic Peroxide Bulletin
July 1972

D-231, a new peroxyketal, is especially designed for vulcanization of elastomers such as SBR, NBR, EPDM, EPR, Urethane and Silicones. The material is also suited for polyester molding at temperatures slightly above the benzoyl peroxide temperatures. D-231XL is a free flowing powder in which the peroxide has been blended with inert fillers.

Chemical Structure:



Empirical Formula $C_{17}H_{34}O_4$

Molecular Weight 302.5

Change E, Kcal 33

SPECIFICATIONS	D-231	D-231XL
1,1-Bis(t-butylperoxy)3,3,5-trimethyl-cyclohexane	92% min.	40% min.
Active Oxygen	9.73 min.	4.23 min.

PROPERTIES		
Form	Liquid	Powder
Color	Colorless	White
Freezing Point	-40°C.	-
Specific Gravity	0.9039-0.9088	-
Flash Point (micro open cup)	155°F.	-
Solubility	Soluble in common organic solvents	

THERMAL DECOMPOSITION DATA

	85°C.	100°C.	115°C.	10 Hour Half Life
Benzoyl peroxide	2.1 hrs.	.4 hrs.	.1 hrs.	72°C.
D-231	27 hrs.	3.8 hrs.	.71 hrs.	92°C.
t-Butylperoxy isopropyl carbonate	57 hrs.	8.3 hrs.	1.42 hrs.	99°C.
t-Butyl perbenzoate	115 hrs.	12 hrs.	6.2 hrs.	105°C.
Dicumyl peroxide	132 hrs.	46 hrs.	9.2 hrs.	114°C

COMMERCIAL DEVELOPMENT DEPARTMENT

LUCIDOL DIVISION, PENNWALT CORPORATION / 1740 MILITARY ROAD / BUFFALO, NEW YORK 14240 / 716-877-1740

SARTOMER RESINS, INC.
MANUFACTURERS OF CUSTOM MONOMERS AND POLYMERS
P.O. BOX 56, ESSINGTON, PA., 19029 U.S.A. • 215-521-3800 • CABLE SARTOMER, ESSINGTON, PA.

REC'D APR 14 1972

April 5, 1972

Mr. George Patterson
DeBell & Richardson Company
Water Street
Enfield, Connecticut 06092

Dear Mr. Patterson:

Thank you for your interest in Sartomer monomers. I have forwarded to you, under separate cover, one pound samples of -

SR-297, 1,3 Butylene glycol dimethacrylate
SR-350, Trimethylol propane trimethacrylate
SARET™ 500 Crosslinking Agent*
SARET™ 515 Crosslinking Agent*

These are samples and, of course, there is no charge.

Enclosed are three booklets on the use of our monomers in elastomers. As I pointed out on the telephone, we prefer to recommend SR-297, SR-350, and the SARET™ Crosslinking Agents* rather than SR-206, Ethylene glycol dimethacrylate, for use in elastomers.

The biggest problem in using methacrylate monomers in elastomers is usually scorch. For this reason, Sartomer Industries introduced the SARET™ Crosslinking Agents*. These are polyfunctional methacrylate type systems, but are scorch retardant, and give excellent processing properties, along with excellent physical properties.

If I may be of any further use to you whatsoever, please do not hesitate to give me a call.

Very sincerely yours,

Barrie Hands

Barrie Hands
Technical Sales Representative

BH:ne
Enc.

*Patent applied for on composition.

Research Bulletin

from

SARTOMER RESINS, INC.
MANUFACTURERS OF CUSTOM MONOMERS AND POLYMERS
P.O. BOX 56, ESSINGTON, PA., 19029 U.S.A. • 215-521-3800 • CABLE SARTOMER, ESSINGTON, PA.

SARET™ Crosslinking Agents*

A new development, SARET™ Crosslinking Agents* offer maximum scorch and processing safety when used with the peroxide cure of elastomers while maintaining the property improvements typical of acrylic coagents. These new coagents are tailor-made for injection and transfer, as well as compression molding.

Typical Properties	SARET 500	SARET 515
Appearance	Dark liquid	Dark liquid
Color, APHA	>1000	>1000
Odor	Mild	Mild
Boiling point	>200°C @ 1 mm	>200°C @ 1 mm
Refractive index @ 25°C	1.473-1.475	1.473-1.475
Weight/gallon @ 25°C	9.0 lbs.	9.0 lbs.
Viscosity @ 25°C	85-92	85-92
Specific gravity @ 25°C	1.078	1.078
Moisture	0.3% max.	0.3% max.
Flash point, Cleveland Open Cup	326°F	326°F
Solubility	These crosslinking esters are compatible with alcohols, ethers, ketones, esters, and aromatic hydrocarbons.	

Storage and Handling

SARET™ 500 and SARET™ 515 Crosslinking Agents* are stable over an extended period of time if stored at room temperature away from direct sunlight. The use of amber bottles is recommended if stored in glass.

Toxicity

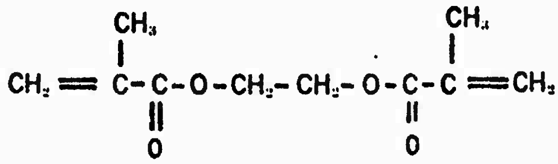
Complete toxicity data of SARET™ 500 and SARET™ 515 Crosslinking Agents* is not available. However, preliminary testing has not shown general skin sensitivity. Caution should be exercised when handling to prevent contact with skin, eyes or injestion. Copious washing with warm soapy water should be used immediately if spilled on the skin.

*Patent applied for on composition.

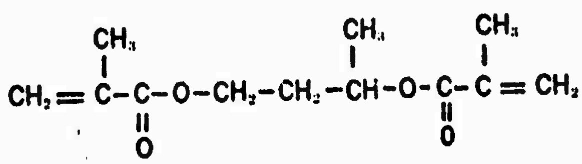
10/71

SARTOMER'S MONOMERS

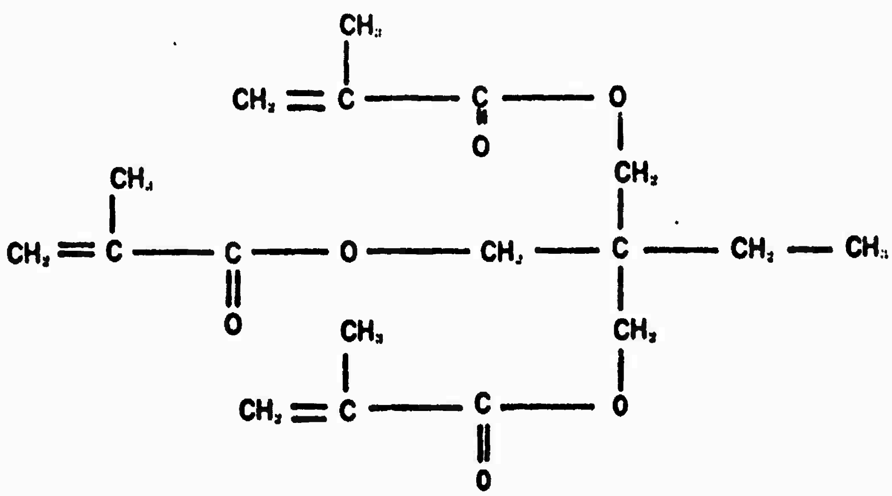
SR-206 ETHYLENE DIMETHACRYLATE



SR-297 1,3 - BUTYLENE GLYCOL DIMETHACRYLATE



SR-350 TRIMETHYLOL PROPANE TRIMETHACRYLATE



TECHNICAL BULLETIN

THIXON®

Whittaker Corporation
DAYTON CHEMICAL PRODUCTS DIVISION
WEST ALEXANDRIA, OHIO 45381

THIXON D-12809

FUNCTION:

1) A vulcanizing primer cement for bonding all elastomers to all metals when used with appropriate cover cement.

2) Especially formulated for coil coating applications.

3) May be used as a one-coat cement for nitrile and neoprene compounds.

TYPICAL PHYSICAL PROPERTIES:

Color	Gray
Wgt./Gal. (U.S.A.)	8.8 lbs.
Specific Gravity	1.06
Viscosity (#3 Zahn Cup)	22 sec.
Viscosity (#4 Ford Cup)	50 sec.
Non-Volatile Solids	36%
Shelf Life at 75° F.	6 mos. min.
Flash Point (Tag Closed Cup)	36° F.
Dry Film	0.5 mil
Theoretical Per Gal. Coverage	1000 sq. ft.
Bond Temp. Range (° F.)	300-450

ENVIRONMENTAL RESISTANCE: Oil, water. High temp. 300-350°F.

DIRECTIONS FOR USE:

May be applied by brushing, dipping, or spraying. Should be agitated thoroughly before use, preferably with a high speed propeller-type agitator. Stir while adding diluents.

For spraying or dipping, dilute to a viscosity of 22 seconds using a #2 Zahn Cup at 78° F.

Must be applied to clean metal surfaces, preferably to gritblasted (#40 or #50 Grit) and solvent degreased substrates. After application, dry the film for 20 to 30 minutes at room temperature before applying the cover cement. Stored parts should be kept free of contamination.

DILUENTS: Ketones and Aromatic Solvents.

TOXICITY: Non-toxic in ordinary handling, but ingestion or prolonged breathing of vapors may be harmful. Usual fire safety measures should be observed.

Whittaker CORPORATION

technical bulletin

DAYTON CHEMICAL PRODUCTS DIVISION
WEST ALEXANDRIA, OHIO 45381

THIXON AP-1435
RUBBER-TO-METAL BONDING ADHESIVE — September, 1968

Function: Vulcanizing secondary cement for bonding Ethylene-Propylene terpolymer (EPDM), Butyl (IIR), and Ethylene-Propylene Copolymer (EPM) rubber to primed metals.

Advantages:

1. Formulated to give good performance over a wide curing range.
2. Maintains excellent bond under high temperature service conditions when used over THIXON D-12809 primer.

Composition: Special rubber and chemical derivatives in volatile solvent.

Typical Physical Properties:

Color	Black
Odor	Hydrocarbon
Weight	6.9 lbs./gal.
Consistency	Brushing
Shelf Life	Approximately 1 year at 75°F. or less

Toxicity: Non-toxic in ordinary handling but usual personal and fire safety measures should be observed due to its inflammable characteristics.

Brushing: THIXON AP-1435 can be used as received for all brushing applications. It brushes out to a smooth film and provides excellent coverage.

Dipping: For dipping operations, suggest 2 parts THIXON AP-1435 to 1 part (by volume) of Heptane or similar solvent. High speed stirring is required before and adding diluent.

Spraying: When used in spraying equipment, suggest 2 parts THIXON AP-1435 to 1 part (by volume) of aliphatic solvent with a 30 to 40 Kauri Butanol Value and an initial boiling point in the range of 245° to 280°F. Example, Super Naphtholite. Stir vigorously before and after adding diluent.

Drying of Cement Film: If cement coated parts are subjected too quickly to above normal temperatures, blistering of the film may occur. Most of the solvent should be allowed to evaporate at normal or near normal room temperature before vulcanizing takes place.

hughson ELASTOMER BONDING GUIDE

▪ Chemlok® Adhesive Systems

This guide presents the one and two coat adhesive systems suggested for bonding the common elastomers *during vulcanization.* These systems are widely accepted throughout the rubber industry. Their reliability has been demonstrated under a broad range of conditions.

One Coat vs. Two

One coat systems are entirely satisfactory for many applications if your bonding involves:

1. Standard production compounds
2. Normal environmental resistance
3. Good substrate preparation

Two coat systems are suggested for:

1. Maximum environmental resistance
2. Severe after-bonding service requirements (deflashing or plating)
3. Wider processing tolerances with minimum surface preparation
4. Reduced scrap
5. Higher bonding temperatures – above 320°F (75 psi steam)
6. Elimination of adhesive changes between production runs

Alternate Adhesive Systems

The systems and dilutions listed here are our "best" suggestions. They will produce dependable, high-quality bonded assemblies for most applications. Thus, they are the logical ones to be tried first.

Other Hughson systems will also produce successful results and may be required for some compounds or special conditions. For suggestions on alternate systems or dilutions, contact your Hughson technical representative or Hughson Chemical Company, Erie, Pennsylvania 16512. Phone: 814-455-7581.

For bonding elastomers to metals and certain plastics (nylon, cured phenolic, epoxy, polycarbonate, Teflon*, Delrin*)

Elastomer	Chemlok 1-Coat System	Chemlok 2-Coat System	
		Primer	Cover Coat
Butyl	220	205	220 or 231 or 234
Chlorobutyl	(Requires 2-coat system)	205	231
EPM (EPR)	231 (Only to fabric, rubber or brass)	205	EX-B60-04
EPDM (EPT)	(Requires 2-coat system)	205	EX-B60-04
Fluoro Elastomers	607 (up to 200% dilution)	—	—
Hypalon*	231	205	231 or 234
Natural	220	205	220 or 231
Neoprene	217	205	220 or 231
Nitrile	205 or EX-B60-03	205	220 or 231
• Carboxy Modified	EX-B60-03	205	231 or EX-B60-03
• Vinyl Modified	EX-B60-03	205	231 or EX-B60-03
Polyacrylate	607 or 205	205	231
Polybutadiene	220	205	220 or 231 or 234
Polyisoprene	220	205	220 or 231 or 234
SBR	220	205	220 or 231
SBR – natural	220	205	220 or 231
Silicone.	607 (up to 500% dilution)	—	—
Urethane			
• Castable	218	218	218
• Millable	218 or 220	218	218
		or 205	or 220 or 231

For bonding elastomers to elastomers (any combination of vulcanized and unvulcanized)

Use Chemlok 234. Coat both surfaces.

*DuPont trademark