DPR® Industries

Manufacturer of Liquid Natural Rubber • Division of Pacer Industries, Inc.

DPR®

Liquid Natural Rubber

Compounding Guide

General Information

Introduction

DPR Industries produces DPR for adhesives, sealants, and rubber compounds. DPR provides both specialty properties and improved processing in a wide range of applications.

DPR® Liquid Natural Rubber. Performance additive for rubber compounding. Reactive plasticizer processing aid for rubber compounding. Reactive wetting agent for highly filled rubber compounds. Binder for grinding wheels, brake pads and other highly-filled, wear-resistant products. Rheology modifier for lubricants, oils, and asphalt systems.

APPLICATIONS

DPR Liquid Natural Rubber

The DPR products are low molecular weight, liquid polymers of natural rubber. DPR liquid rubber offers processing flexibility and performance options for a wide range of applications. They contain no solvents or additives; and they are compatible with a broad range of solvents, plasticizers, resins and polymers. DPR liquid natural rubber is available in several grades that vary by molecular weight. The lower weight grades have lower viscosity.

Liquid natural rubber improves rubber and polymer compounding. It acts as a plasticizer to reduce cycle time and energy consumption. Since it cures by the same mechanism as natural rubber, it becomes part of the polymer matrix and remains non-fugitive.

Typical Applications

DPR liquid rubber provides all the performance properties of natural rubber in a convenient liquid. Liquid rubber performs many functions in a wide range of applications:

Binder for aggregates, grinding wheels, and friction products.
Rubber processing aid.
Rubber performance improvement.
Reactive vehicle for rubber additives.
Rheology modifier for lubricants.
Polymer base for molding and tooling systems.
Polymer base for electrical encapsulants.
Asphalt modifier.

DPR liquid rubber has excellent wetting characteristics. It binds synthetic fibers and other reinforcements into polymer matrices. DPR can bind more than ten times its weight in fillers and abrasives for grinding wheels and other friction products.

DPR reduces the viscosity of uncured rubber systems at levels of 5-to-20 parts of polymer. This reduces power requirements, improves blend consistency, and reduces the risk of scorching. It is also used with such polymers as polychloroprene, EPDM, polybutadiene, SBR and acrylonitrile-isoprene.

DPR liquid rubber improves the stability of heavy-duty lubricants by increasing the resistance to flow on vertical surfaces and by holding dry additives in a more stable suspension. It also improves asphalt formulations by reducing flow at high temperatures and improving properties at cold temperatures

PACKAGING, HANDLING AND PROCESSING

DPR

Is packaged in open-head drums. All grades may be charged directly from container to the appropriate mixing vessel .

DPR may be stored at elevated temperatures, which do not exceed 60°C. This pre-heating may be done for several days prior to use. Drums should always be vented during any exposure to elevated temperatures to avoid pressurizing that container.

Compounding DPR can usually be accomplished in comparatively lightweight mixers such as open churns. Efficient blending is usually possible with slow mixing. When a master batch technique is utilized, the initial addition of plasticizer is minimized. Dough mixers of the Hobart type are often used. If only a small amount of dry ingredients is to be incorporated, it should be mixed with part of the rubber to form a master batch. After an adequate dispersion is reached, the master batch can be let down gradually with the addition of the remaining liquids. When the dispersion must be optimized, a final processing step would be milling on a three-roll paint mill. More intense mixing, which would be required by extremely high consistency pastes, is possible using internal kneader-type equipment, manufactured by Bramley or Baker-Perkins.

TYPICAL PROPERTIES OF THE SPECIALTY ELASTOMERS

DPR® (Depolymerized Natural Rubber)

		GRADE			
PROPERTY	TEST METHOD	400	75	40	35
Viscosity, Poise @ 38°C	Brookfield	3,000-5,000	550-950	360-550	300-360
Molecular Weight, Mw	GPC/Isoprene Std	60,000	40,000	32,000	30,000
Unsaturated, Mol. %	Ozone Analysis	98	98	98	98
Specific Gravity @ 25°C	ASTM D1875	0.92	0.92	0.92	0.92
Flash Point, °C	COC	271	255	246	240
Volatiles, Weight %	Weight Loss After 2 hrs. @ 100°C	0.16	0.22	0.25	0.46
Ash, Weight %	ASTM D1416	0.5	0.5	0.5	0.5
Color	Visual	Dark Brown	Dark Brown	Dark Brown	Dark Brown

FORMULATIONS

ADHESIVES – PSA FORMULAS

DPR 400 GENERAL PURPOSE PRESSURE SENSITIVE ADHESIVE

SIR 20 Natural Rubber	100
Vanox 2246	2
SBR 1502	15
Zinc Oxide	25
DPR 400	10
SP 1056	15
Nevtac 115	75
Toluene	242

MIXING PROCEDURE

BASE	Mix Time
Charge Natural Rubber to Sigma blade type mixer and masticate -	10 min.
Add Cyanox 2246	2 min.
Slowly charge total of Zinc Oxide	3 min.
Incrementally add SBR 1502	6 min,
Add total of DPR 400	9 min.
Total Time	30 min.

Discharge batch and allow to cool before transferring to 2-roll mill. Add and mix SP 1056 on cool 2-roll mill. Sheet out mill stock and cut appropriately for addition to solvent churn charged with Toluene and Nevtac 115. Mix until adhesive solution is lump-free; correct solids and drain.

MIXING EQUIPMENT

Sigma blade type mixer, rubber mill and solvent churn.

ADHESIVE PROPERTIES

7 mil wet film applied from 50% solids base onto "crepe" substrate. Adhesive allowed to air dry 15 minutes, then cured 5 minutes @ 155°C.

Rolling Ball Tack (PSTC-6) cm (in.)	2.54(1.0)
180° Peel Adhesion (PSTC-1) N/cm(ppi)	4.45(2.5)
180° Shear (PSTC-7) 1000 gm. wt., hours	72.0

RUBBER COMPOUNDING

FILLED EBONITE CURED COMPOUND

DPR 75	100
White Fonoline	8
Sulfur	33
Calsol 8240	10
Accelerator 808	3
Hard Rubber Dust	200

MIXING PROCEDURE

Order of addition as above. While mixer is off, charge total of DPR and White Fonoline, then mix until thoroughly blended, approximately 5 minutes. Turn mixer off and begin adding sulfur by thirds. Mix between charges of sulfur (approximately 5 minutes). Continue mixing until sulfur is completely incorporated (approximately 15 minutes). With mixer on slowest speed, carefully and slowly add Hard Rubber Dust. Mix batch until Rubber Dust is thoroughly wet-out (approximately 35 minutes).

Total mix time is about 60 minutes.

MIXING EQUIPMENT

Dough or Sigma Blade type mixer.

CURE CYCLE

Press cured 20 minutes @ 170°C.

CURED PHYSICAL PROPERTIES

Tensile Strength, MPa/psi	27.56/4000
Elongation, %	1.6
Hardness, Shore D	80

CASTABLE HARD RUBBER COMPOUND

DPR 75	100.00
Bardol	5.00
Vertical Quicklime	10.00
DOTG	0.88
Sulfur	40.00
King Prince	74.00

MIXING PROCEDURE

Order of addition as above. Charge total of DPR and Bardol. Mix until thoroughly blended, approximately 5 minutes. Add total of calcium oxide, DOTG and ¼ of sulfur. Mix approximately 5 minutes. Continue to add sulfur in quarterly increments allowing approximately 5 minutes of mixing between sulfur additions. After total of sulfur is charged and blended into batch, begin adding King Prince carefully and slowly to batch. Mix batch until it is homogeneous (approximately 35 minutes). Total mixing time is about 60 minutes.

MIXING EQUIPMENT

Hobart, Day or Sigma blade type.

CURE SCHEDULE

Press cure 6 hours @ 149°C

CURED PHYSICAL PROPERTIES

Tensile Strength, MPa/psi	17.23/2500
Hardness, Shore D	90
Impact Resistance, Falling Ball, M-Kg/ft. lbs	0.55/4.0

GENERAL PURPOSE LOW-DUROMETER BINDER

DPR 400	50.00
SIR 20 Natural Rubber	50.00
HiSil 233	20.00
ZnO	15.00
Stearic Acid	2.00
Antioxidant 2246	1.00
CBS	0.50
TMTD	0.50
Sulfur	0.75

MIXING PROCEDURE

Charge total of SIR 20 to internal mixer. Charge DPR 400 incrementally with HiSil. When addition is complete, add balance of ingredients. Stock must be kept cool. After the stock has been thoroughly blended, it may be sheeted for later processing.

Other fillers such as abrasives, may be added during a post mixing stage using an internal mixer. This mixer should be dedicated to mixing abrasive materials.

MIXING EQUIPMENT

Internal mixer.

CURE CYCLE

Press cure 35 minutes @ 141°C.

MOONEY VISCOSITY

@ 100°C, ML 1+4	13.0

CURED PHYSICAL PROPERTIES

Tensile Strength, MPa/psi	>300
Modulus @ 100%, Elongation, MPa/psi	44
Modulus @ 300%, Elongation, MPa/psi	89
Elongation, %	>600
Hardness, Shore A	16
Compression Set, ASTM B, 22 hrs @ 70°C	9.0

LOW TEMPERATURE EXTRUDABLE RETREAD MASTIC

SIR 20 Natural Rubber	80.00
DPR 40	20.00
HiSil 233	40.00
MT Black	3.00
Zinc Oxide	5.00
Stearic Acid	1.00
Agerite Stalite ST	0.50
Vanox ZMTI	0.50
Sulfur	2.75
Altax	0.50
Methyl Tuads	0.50
Calsol 8240	2.00

MIXING PROCEDURE

Combine Sulfur, Altax and Methyl Tuads with Calsol 8240 to form paste and predisperse on paint mill.

Charge jacketed internal mixer with total of SIR 20 and allow to mass before charging MT Black, ZnO, Stearic Acid, Agerite Stalite ST and Vanox ZMTI. Mix approximately 10 minutes. Add HiSil in 4 equal increments allowing each increment to be accepted before charging the next. Complete charge time for filler is about 40 minutes.

Let batch cool or bring temperature below 60°C before adding predispersed rubber chemicals. Mix batch for about 10 minutes. Total mix time is approximately 60 minutes.

MIXING EQUIPMENT

Day mixer, paint mill and jacketd internal mixer.

CURE SCHEDULE

45 minutes @ 110°C.

CURED PHYSICAL PROPERTIES

Tensile Strength, MPa/psi	>1,734
Modulus @ 100% Elongation, MPa/psi	140
Elongation, %	>600
Hardness, Shore A	38

THE SPECIALTY POLYMERS AS PROCESSING AIDS

The advantages of blending the liquid polymers with their conventional counterparts are:

Lower Mooney plasticities and better mold flow.

Easier processing without sacrificing heat-aging properties.

Non-volatility and resistance to extraction.

Improved "green tack."

KALAR may be used as a processing aid and "green strength" enhancer for extruding and calendaring operations by helping to control shrinkage, die swell and splicing.

DPR PROCESSING AID CONTROL RECIPE

1RSS	100.0
Camelwite	50.0
ZnO	5.0
Cyanox 2246	1.0
Stearic Acid	0.5
Sulfur	3.0
Altax	1.0
Methyl Zimate	0.3

Stock was mixed on two-roll mill. Samples were press-cured for 5 minutes @ 150°C.

EFFECT OF DPR 400 INCREMENTS ON CURED PHYSICAL PROPERTIES

Level of DPR	Elong. %	Shore A
0	580	58
5	595	55
12.5	600	54

Level of DPR	Tensile MPa/psi	Modulus @ 200° Elong. MPa/psi
0	17.91/2600	2.68/390
5	16.81/2440	2.41/350
12.5	17.02/2470	2.31/335

EFFECT OF DPR 400 INCREMENTS ON MOONEY PLASTICITY @ 100°C, AFTER 4 MINUTES DWELL TIME

Level of DPR	Mooney Units
0	50
5	40
12.5	32

Comparable effects are noted with stocks based on SBR, EPDM, Nitrile and Neoprene.

OTHER SEALANTS

TWO PART, SULFUR CURED SEALANT

BASE

DPR 400	50.0
Captax	4.1
Methyl Zimate	4.1
TI-PURE	1.5
ZnO	9.1
Britol 7T	8.3
Butyl 8	5.0

CURATIVE

DPR 400	50.0
Agerite HP-S	1.5
Sulfur	3.0
ZnO	10.0
Red Iron Oxide	5.0
DEA	5.0
Britol 7T	7.5

MIXING PROCEDURE

The base and curative components are mixed independently using the same technique which follows.

Charge Sigma blade type mixer with the total of rubber and all the powders. Mix for 30 minutes then finish the batch with the slow addition of the liquids which continuing to mix. Total mix time is approximately 60 minutes.

An alternate procedure would be to first form a master batch using ¼ of the rubber and all the other ingredients. After the master batch is thoroughly blended pass it through a paint mill. The predispersed master batch may be charged directly to a Day mixer for blending with the remaining rubber.

MIXING EQUIPMENT

Sigma blade type mixer or a three roll paint mill and Day mixer.

MIX RATIO

1:1 by weight or volume,

CURE SCHEDULE

Pot Life @ 25°C	18-24 hours
Cure Time @ 25C	30 days

CURED PHYSICAL PROPERTIES

Tensile Strength, MPa/psi	6.20/900
Modulus @ 100%, Elongation, MPa/psi	.55/80
Elongation, %	530
Hardness, Shore A	40

ONE COMPONENT CABLE SEALANT

DPR 75	100
Camelwite	75
ZnO	10
DOP	15
Austin Black 325	3
PAB 8342	9

MIXING PROCEDURE

Charge total of rubber, Austin Black 325, ZnO and PAB 8342 to Day mixer and blend 15 minutes. Then alternately add 1/3 increments of DOP and Camelwite while continuing to mix. Total mix time is about 60 minutes.

MIXING EQUIPMENT

Day mixer.

CURE SCHEDULE

2 hours @ 121°C.

CURED PHYSICAL PROPERTIES

Tensile Strength, MPa/psi	.51/75
Elongation, %	250
Hardness, Shore A	13

ONE PART SEMI-CONDUCTIVE SEALANT

DPR 400	100.00
Conductex 975	30.00
Bardol	5.00
Zinc Oxide	3.00
Methyl Tuads	4.85
Methyl Zimate	0.90
Captax	0.90
Sulfur	0.78
RPO	3.90

MIXING PROCEDURE

Charge jacketed Baker-Perkins or other suitable internal mixer with total of DPR. While cold water is on, charge total of Bardol and blend 5 minutes. Incrementally add Conductex; mixer should be off while additions are being made. After the balance of Conductex has been charged, mixing should be continued for 35 minutes. All remaining ingredients mat be added after the Conductex is well dispersed. The batch should be further blended for at least 20 minutes. The sealant's conductivity may be maximized by further processing on a three-roll mill.

MIXING EQUIPMENT

Jacketed internal mixer and three-roll mill.

SEALANT CONSISTENCY

@ 23°C	Heavy Paste

CURE CYCLE

Press-cure @ 121°C for 30 minutes.

CURED PHYSICAL PROPERTIES

Surface Conductivity – ohms resistance measured with 1/8" diameter probes @ 23°C, probe interval 1"	7000
Tensile Strength, MPa/psi	1.79/260
Modulus @ 100% Elongation, MPa/psi	0.41/60
Elongation, %	375
Hardness, Shore A	30

DPR/PVC EXPANDABLE SEALANT

ELASTOMER BASE

DPR 400	100.00
Paroil 57-61	100.00
Stearic Acid	2.00
Zinc Oxide	5.00
Agerite Stalite ST	0.75
Vanox ZMTI	0.75
Sulfur	3.00
Captax	1.00
Methyl Tuads	1.00
Methyl Zimate	0.75
Twinkling Star Antimony Oxide	30.00
Dechlorane 515	40.00
Hydral 710	100.00

PVC BASE

Geon 136	215.0
DOP	140.0
Stabilizer 75-001	6.5
Celogen OT	21.5

MIXING PROCEDURE

The above formulation is best prepared in two steps. The elastomer base and PVC base are mixed separately and combined later to form the finished expandable sealant.

(ELASTOMER BASE)

All ingredients except the Dechlorane and Hydral are charged to a charge-can-type mixer. The charged ingredients are blended approximately 15 minutes, then transferred to a paint mill to optimize the dispersion of the active rubber chemicals and Twinkling Star Antimony Oxide. The milled compound is returned to the original mixing vessel, where the balance of ingredients is added. The mixing time of this final step is approximately 15 minutes.

(PVC BASE)

Charge Day mixer with 1/3 of DOP; add total of stabilizer and Celogen OT. With mixer on slow speed, incrementally add total of Resin 7401. After resin is completely wetted out, slowly add balance of DOP. Total mixing time is approximately 15 minutes.

The bases, when blended, result in a soft thixotropic paste. This combination offers a sealant with properties of both polymers to produce low-density, flame-retardant sealant which remains in a thixotropic state during the vulcanization/fusing process. Physical properties of this type of compound may be varied by adjusting the proportion of the PVC base to the elastomer base.

MIXING EQUIPMENT

Day mixer and paint mill.

CURE SCHEDULE

8 minutes @ 149°C.

CURED PHYSICAL PROPERTIES

Tensile Strength, Mpa/psi	1.02/150
Elongation, %	100
Hardness, Shore A	50
Calculated Density, lbs./cu. ft.	66

In accordance with ASTM 635-68, compound is self-extinguishing.

FILLED HOT MELT SEALANT WITH DPR

	I	II
Kraton Polymer D1102	9.6	9.3
Zonarez 7085	38.5	37.0
Red Iron Oxide	51.9	50.0
DPR 400	- - - -	3.7
Irganox 1010	0.1	0.1

MIXING PROCEDURE

Charge hot melt kettle with total of resin and Irganox following the preceding procedure. When the resin is completely melted, raise the temperature to 149°C-176°C and begin the addition of Iron Oxide. When addition of Iron Oxide is complete, add Kraton. The DPR should be added last while mixing is continued until a homogeneous blend is reached.

MIXING EQUIPMENT

Hot melt kettle.

TYPICAL PROPERTIES

	I	II
Melt Viscosity @ 149°C, cps	50,000	18,000
Peel Strength, untreated steel, N/cm (pli)	8.9(5)	44.5(25)
Bond Failure	Adhesive	Adhesive

ISOLENE or DPR can be used in hot melt sealants as plasticizer/oil substitutes to afford sealants which are easily applied at moderately elevated temperatures.

The addition of these polymers often augments the sealant's adhesive qualities.

DPR 40 PEROXIDE CURED SEALANT

DPR 40	100.00
$CaCO_3$	50.00
Zinc Oxide	7.00
Stearic Acid	1.00
t-Butyl perbenzoate	7.70
Sartomer 633	30.00
Maglite D	2.00

MIXING PROCEDURE

Charge Sigma blade type mixer with total amount of DPR 40. Add all dry ingredients in three or four increments; permit each addition to be complete dispersed before adding the next. After the mixed compound is completely homogeneous, allow the batch to cool below 50 °C before adding the t-Butyl perbenzoate.

MIXING EQUIPMENT

Sigma blade type mixer.

CURE SCHEDULE

Cure time @160 °C	25 min.

CURED PROPERTIES

Adhesion:

Lap Shear CRS/CRS,(MPa/psi)	4.55/660
Aged 2wks@ 130 °C	4.79/700

Physicals:

Tensile Strength, (MPa/psi)	4.20/613
Elongation,%	
Durometer, Shore A	90

POTTING AND ELECTRICAL COMPOUNDS

DPR POTTING COMPOUND FOR MODERATE TEMPERATURE APPLICATIONS

BASE

DPR 400	100.00
QDO	3.75
ISOTARV	150.00
Camelwite	500.00

CURATIVE

PbO_2	20.0
Camelwite	20.0
DOP	20.0

MIXING PROCEDURE

BASE: Charge Day mixer with total of DPR, QDO and 1/10 of Mentor; blend approximately 10 minutes. Add Camelwite in quarterly increments while using an additional 1/10 of Mentor to prevent an overly stiff mix. After the final charge of filler is complete, continue to mix batch for at least 30 minutes. Follow with the balance of Mentor and blend for 20 minutes.

CURATIVE: Blend all ingredients in a Day mixer; then transfer to a paint mill. Grind to a smooth, flowable paste.

MIXING EQUIPMENT

Day mixer and paint mill.

MIX RATIO

100 parts Base to 8 parts Curative by weight

MIXED VISCOSITY

@ 25°C, cps	~30,000
GEL TIME @ 25°C	1 hour
CURE SCHEDULE @ 25°C	24 hours

CURED PHYSICAL PROPERTIES
from sheets press cured 1 hour @ 66°C

Tensile Strength, MPa/psi	1.1/160
Modulus @ 100% Elongation, MPa/psi	.55/80
Elongation, %	200
Hardness, Shore A	28

ELECTRICAL PROPERTIES @ 25°C

Dielectric Constant @ 1 kHz	4.1
Dissipation Factor @ 1 kHz	0.0052
Dielectric Strength, 40 mil pad, 500V/min rise, volts/mil	517.0
Volume Resistivity, ohms-cm	1.3×10^{13}

DPR GENERAL PURPOSE POTTING COMPOUND

BASE

DPR 400	100.00
QDO	3.75
Camelwite	200.00
DOP	100.00

CURATIVE

PbO_2	20.00
Camelwite	20.00
DOP	20.00

MIXING PROCEDURE

BASE: Charge Day mixer with total of DPR, QDO and 1/10 of DOP; blend approximately 10 minutes. Add Camelwite in quarterly increments while using an additional 1/10 of DOP to prevent an overly stiff mix. After all the filler has been charged, continue to mix the batch for at least 30 minutes. Complete the batch with the balance of DOP and mix for 20 minutes.

CURATIVE: Blend all ingredients in a Day mixer; then transfer to a paint mill. Grind to a smooth, flowable paste.

MIXING EQUIPMENT

Day mixer and paint mill.

MIX RATIO

100 parts Base to 16 parts CURATIVE by weight.

MIXED VISCOSITY

@ 25°C, cps	~100,000
GEL TIME @ 25°C	1 hour
CURE SCHEDULE @ 25°C	24 hours

CURED PHYSICAL PROPERTIES
from sheets press cured 1 hour @ 66°C

Tensile Strength, MPa/psi	1.1/160
Modulus @ 100% Elongation, MPa/psi	.31/45
Elongation, %	500
Hardness, Shore A	35
Thermal Conductivity, cal/sec/sq.cm./cm/°C	3.175×10^{-4}
WVTR, g./100 sq. in./24 hrs @ 38°C and 90% RH diff.	1.7

ELECTRICAL PROPERTIES @ 25°C

Dielectric Constant @ 1 kHz	5.47
Dissipation Factor @ 1 kHz	0.0133
Dielectric Strength, 40 mil pad, 500V/min rise, volts/mil	634
Breakdown Voltage, KV	24.1

MISC. APPLICATIONS

BASIC GRINDING WHEEL FORMULATION

DPR 75	100.0
Sulfur	50.0
Durite Resin AD5043	12.5
Abrasive, e.g. Al_2O_3	1000.0

MIXING PROCEDURE

Order of addition as above. DPR may be warmed to facilitate handling and blending. All dry ingredients including resin AD5043 must be thoroughly wet-out before abrasive is added.

MIXING EQUIPMENT

Hobart or change-can type mixer.

CURE CYCLE

Stock is molded under pressure at 2500 psi. The stock is then cured 16 hours @ 160°C.

THE LIQUID POLYMERS AS VEHICLES AND RHEOLOGY MODIFIERS

DPR is employed as a liquid vehicles for a wide variety of powdered materials, including pigments and lubricants, such as graphite and molybdenum disulfide. These dispersed powdered concentrated offer less critical proportioning and dust free addition. Dispersions based on the liquid polymers are more readily incorporated into the final compound. Since the liquid polymers are reactive, they become non-fugitive once vulcanization is complete.

Small additions of DPR impart significant rheology changes to many oils. Advantages are increased flow resistance on vertical surfaces and an improvement in the oil's ability to hold dry additives in suspension.

SPECIALTY ELASTOMER ASPHALT BLENDS

The addition of DPR to asphalt will improve cold temperature properties and reduce the flow of asphalt at elevated temperatures.

Non-Reacted DPR/Asphalt Blends

	Control
Asphalt (60/70)	100

MIXING PROCEDURE

Pre-weighed asphalt is heated to 176°C then charged to a suitable low shear mixer. DPR, pre-heated to 127°C is charges to mixer. Blend until DPR is well dispersed.

MIXING EQUIPMENT

Low shear mixer capable of being heated to flux temperature of Asphalt.

TYPICAL PROPERTIES

	Control
Flow after 24 hrs. @ 38°C, in. 1½" x 1/8" x1" specimen @ 45° incline	8.25
Softening Point (R&B)	51.00
Elongation @ 25°C, %	700.00

REACTED DPR/MODIFIED ASPHALT

	Control	I
Asphalt	100.0	95.0
DPR 35	- - - -	5.0
Sulfur	- - - -	0.4

MIXING PROCEDURE

Pre-weighed asphalt is heated to 176°C and charges to a suitable low shear mixer. The proper proportion of DPR is charged to the mixer and thoroughly dispersed. Sulfur is added while the temperature is maintained at 176°C. Mixing is continued for at least 15 minutes.

MIXING EQUIPMENT

Jacketed low shear mixer.

COMPARISON OF TYPICAL PROPERTIES

	Control	I
Flow after 24 hrs. @ 82°C, in.	1.44	0.81
Softening Point (R&B), °C	82	88
Ductility @ 25°C, cm.	3.4	4.3
Toughness @ 25°C, In.-lb.	35.4	49.5
Viscosity @ 176°C, cps	230	345
Impact @ 2°C, Ft.-lb.	0.95	1.37

APPENDIX A

TABLE I

TYPICAL SOLUBILITY DATA

Viscosity (cps) determined @ 25°C with Brookfield Model RVT

% DPR 40	TOLUENE	MIBK	VM&P	HEXANE	MINERAL SPIRITS
10	13	9	11	1	7
50	176	150	150	76	280
90	14,000	17,700	24,200	12,700	26,200
% DPR 400					
10	16	8	10	8	13
50	600	640	480	260	820
90	114,000	99,000	90,000	93,000	119,000

APPENDIX B

TABLE I
QDO/PbO_2 CURED DPR SYSTEMS

	A	B	C	D	E
DPR 400	100	- - - -	- - - -	100	100
DPR 75	- - - -	100	- - - -	- - - -	- - - -
DPR 40	- - - -	- - - -	100	- - - -	- - - -
QDO	3	3	3	2.7	3.3
CA 517	60	60	60	60	60
PHYSICAL PROPERTIES					
Tensile Strength, MPa/psi	1.10/160	0.89/130	0.83/120	1.03/150	1.13/165
100% Modulus, MPa/psi	0.41/60	0.38/56	0.33/48	0.41/60	0.44/65
Elongation, %	300	300	300	300	300
Hardness, Shore A	30	24	24	30	30
Compression Set, ASTM B, 22 hrs., @ 70°C, %	13.6	15	15	17	13.1

Test samples were prepared at ~ 85% solids in toluene and press cured 1 hour at 66°C, then post cured at 66°C.

APPENDIX B

TABLE II
QDO/ PbO_2 CURED DPR SYSTEMS

	G	H	I	J	K	L	M	N
DPR 400	100	100	100	100	100	100	100	100
QDO	3	3	3	3	3	3	3	3
Camelwite	50	----	----	----	----	----	----	----
Hydral 710	----	50	----	----	----	----	----	----
TI-PURE	----	----	50	----	----	----	----	----
HiSil 233	----	----	----	50	----	----	----	----
Elftex 8 (N-330)	----	----	----	----	50	----	----	----
Sterling R (N-774)	----	----	----	----	----	50	25	----
Elftex 12	----	----	----	----	----	----	----	50
CA 517	60	60	60	60	60	60	60	60
PHYSICAL PROPERTIES								
Tensile Strength, MPa/psi	1.55/225	2.32/336	2.03/295	4.48/650	6.82/990	5.06/735	2.55/370	6.24/905
100% Modulus, MPa/psi	0.58/85	0.57/84	0.67/98	2.77/403	2.07/300	1.67/242	0.79/115	1.89/274
Elongation, %	450	500	350	200	250	250	300	250
Hardness, Shore A	39	35	40	70	60	56	38	60
Compression Set, ASTM B, 22 hrs., @ 70°C, %	13	15.8	14.1	10	9.1	12.1	13	10

Test samples were prepared at ~ 85% solids in toluene and press cured 1 hour @ 66°C, then post cured at 66°C.

APPENDIX B

TABLE III

QDO/ PbO_2 CURED DPR SYSTEMS

	O	P	Q	R	S
DPR 400	100	100	100	100	100
QDO	3	3	3	3	3
TI-PURE	100	100	100	100	100
Kenplast G	50	----	----	----	----
DOP	----	50	----	----	----
Britol 7T	----	----	50	75	100
CA 517	60	60	60	60	60
PHYSICAL PROPERTIES					
Tensile Strength, MPa/psi	1.18/171	1.21/176	1.24/180	0.85/123	0.63/91
100% Modulus, MPa/psi	0.41/60	0.38/55	0.40/59	0.27/40	0.23/33
Elongation, %	300	275	275	250	250
Hardness, Shore A	25	28	30	22	22
Compression Set, ASTM B, 22 hrs., @ 70°C, %	13.2	13	13.5	13	16

Test samples were prepared at ~ 85% solids in toluene and press cured 1 hour @ 66°C, then post cured at 66°C.

APPENDIX C

SILANE Y4310 PRIMER ADHESION

TEST COMPOUND 1			TEST COMPOUND 2		
DPR 400	28.3	- - - -	DPR 400	13.0	- - - -
QDO	1.0	- - - -	QDO	0.5	- - - -
Univolt 60	28.3	- - - -	ISOTARV	20.0	- - - -
TI-PURE	42.4	- - - -	Camelwite	66.5	- - - -
33% PbO_2 Paste	- - - -	17	33% PbO_2 Paste	- - - -	8

ADHESION DATA
COMPOUND 1

SUBSTRATE	Glass	Wood	Aluminum	Steel
Control, MPa (psi)	.41 (60)	.13 (20)	.20 (30)	.41 (60)
Primed, MPa (psi)	> .82 (>120)	.41 (60)	1.10 (160)	1.92 (280)
Type of Failure	A	A	C	C

ADHESION DATA
COMPOUND 2

SUBSTRATE	Glass	Wood	Aluminum	Steel
Control, MPa (psi)	.13 (20)	.06 (10)	.20 (30)	.41 (60)
Primed, MPa (psi)	.55 (80)	.41 (60)	.79 (115)	.82 (120)
Type of Failure	A	A	C	C

Notes:

1. C denotes cohesive failure; A denotes adhesive failure.
2. Substrates were clean and free to contaminates; special treatments were avoided.
3. Primer Y4310 was applied neat and allowed to air dry 20 minutes prior to casting mixed compounds.
4. Test samples were aged 1 week at 25°C before adhesion values were determined.

APPENDIX D

TABLE I

ACCELERATORS FOR DPR SYSTEMS

	Control	1	2	3	4
DPR 400	100	100	100	100	100
QDO	3.75	3.75	3.75	3.75	3.75
TI-PURE	150	150	150	150	150
Univolt 60	100	100	100	100	100
Diethanolamine	- - - -	1.0	- - - -	2.0	- - - -
Neoheptanoic Acid	- - - -	- - - -	1.0	- - - -	2.0
GEL TIME @ 25°C, Minutes	50	13	18	10	15
PHYSICAL PROPERTIES					
Tensile Strength, MPa/psi	.83/120	.93/135	7.23/105	.96/140	.69/100
Modulus @ 100% Elongation, MPa/psi	.38/55	.41/60	.34/50	.41/60	.27/40
Elongation, %	200	240	220	265	255
Hardness, Shore A	25	25	25	25	25

DPR compounds cured with a 33% PbO_2 Paste at a weight ratio of 100 parts base compound to 17 parts PbO_2 Paste. Cured DPR physical properties were determined after a 24 hour cure @ 25°C.

Raw material Suppliers

Trade Name or Designation	Chemical Name/Description	Supplier	Phone
1RSS	#1 ribbed smoked sheet rubber	AlcanRubber & Chemical, New York, NY	(212) 952-9230
65% DPR 40 (dry form)		Natrochem Inc., Savannah, GA	(912) 236-4464
Accelerator 808	butyraldehyde-anine condensation product	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
Agerite HP-T	antioxidant	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
Agerite Resin D	polymerized 1,2-dihydro-2,2,4-trimethylquinoline	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
Agerite Stalite ST	sym. Dibetanophthyl-p-phenylenediamine	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
Altax (MBTS)	benzothiazyl disulfide	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
Amax	n'oxydiethelene benzothiazole-2-sulfanamide	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 234-6064
ASTM N539		Harwick Standard Distribution Co., Akron, OH	(330) 798-9300
Austin Black 325	carbon black	Harwick Standard Distribution Co., Akron, OH	(800) 899-4412
Bardol		Honeywell, Morristown, NJ	(800) 421-2133
Britol 7T	mineral oil	R.E. Carroll Inc., Trenton, NJ	(800) 257-9365
Butyl 365	polyisobutylene polyisoprene copolymer	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
Butyl 8	activated dithiocarbamate	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
Butyl Tuads	tetrabutylthiuram disulfide	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 234-6064
C-33	hydrated alumina	Alcoa Industrial Chemicals, Bauxite, AR 72011	(800) 860-3290
Cab-O-Sil M5	fumed colloidal silica	Cabot Corp., Tuscola, IL	(800) 222-6745
CaCO3	calcium carbonate	H.M. Royal, Trenton, NJ	(609) 396-9176
Calcene TM	calcium carbonate coated stearic acid		
Calcium Stearate		Witco Performance Chemical, Louisiana, KY	(877) 948-2662
Calsol 8240	napthenic oil	R.E. Carroll Inc., Trenton, NJ	(800) 257-9365
Camel Carb	calcium carbonate	H.M. Royal, Trenton, NJ	(609) 396-9176
Camelwite	calcium carbonate	H.M. Royal, Trenton, NJ	(609) 396-9176
Captax (MBT)	2-mercaptobenzothiazole	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
Celogen OT	benzenesulfonyl hydrazide	Uniroyal Chemicals, Middlebury CT	(800) 243-3024
Conductex 975	conductive black	Columbian Chemicals, Marietta, GA	(800) 822-7266
Cumar LX 509	coumarone - indene resin	Neville Chemical, Pittsburgh, PA	(412) 331-4200
Cyanox 2246	2,2'-methylene-bis (4-methyl-6-t-butyl-phenol)	Cytec Industries, West Paterson, NJ	(973) 357-3100
DBP	dibutylphthalate	C.P. Hall Co., Chicago, Illinois (Mfg. by Denza in Czech Repub.)	(708) 594-5923
DEA	diethanolamine	C.P. Hall Co., Chicago, Illinois	(708) 594-5923
DEAP	2,2 diethoxy-acetophenone	First Chemical, Pascagoula, MS	(800) 828-7940

Dechlorane 515	chlorinated paraffin	OxyChem, Dallas, TX	(800) 752-5151
Dechlorane Plus 515	chlorinated paraffin	OxyChem, Dallas, TX	(800) 752-5151
DLTDP	dilauryl thiodiopropionate	Witco Polymer Chemicals, Louisiana, KY	(877) 948-2662
DMSO	dimethyl sulfoxide	Monomer-Polymer & Dajac Labs Inc., Feastervile, PA	(215) 364-1155
DOP (Plasthall DOP)	dioctyl phthalate	C.P. Hall Co., Chicago, Illinois	(708) 594-5923
DOTG	diorthotolyl guanidine	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
DPG	diphenly guanidine	Solutia, St. Louis, MO	(800) 321-3416
DPR® 35	Liquid Natural Rubber	DPR Industries	(484) 784-5667
DPR® 40	Liquid Natural Rubber	DPR Industries	(484) 784-5667
DPR® 400	Liquid Natural Rubber	DPR Industries	(484) 784-5667
DPR® 75	Liquid Natural Rubber	DPR Industries	(484) 784-5667
Drikalite	natural ground calcium carbonates	Imerys, Rosewell, GA	(888) 277-9636
Durite Resin AD5043	phenolic resin	Borden Chemicals & Plastics	(800) 451-1037
Escorez 2101	aromatic/aliphatic hydrocarbon resin	ExxonMobil Chemical Company, Houston, TX	(800) 231-6633
Escorez 5300	cycloaliphatic hydrocarbon resin	ExxonMobil Chemical Company, Houston, TX	(800) 231-6633
Elvax 750	ethylene vinyl/acetate copolymer	DuPont, Delaware	(800) 438-7225
Flexon 765	process oil	Exxon Lubricants and Petroleum Division Corp., Houston, TX	(888) 228-4437
Flexon 845	process oil, hydrogenated paraffinic	Exxon Lubricants and Petroleum Division Corp., Houston, TX	(888) 228-4437
Foral 105	penterythritol ester of fully gydrogenated wood resin	Hercules Inc., Wilmington, DE	(800) 247-4372
Foral 85	glycerin ester of fully hydrogenated wood resin	Hercules Inc., Wilmington, DE	(800) 247-4372
Geon 136	4% vinyl ester/vinyl chloride copolymer	GEON Company, Avon Lake, OH	(800) 438-4366
Hard Rubber Dust	cured and reground rubber	H.M. Royal, Trenton, NJ	(609) 396-9176
Heptanoic Acid		Celanese, Dallas, TX	(800) 235-2637
Hercolyn D	methyl ester of fully hydrogenated wood resin	Hercules Inc., Wilmington, DE	(800) 247-4372
HiSil 233	hydrated silica	PPG Industries Inc., Pittsburgh, PA	(800) 243-6745
HiSil 243B	hydrated silica	PPG Industries Inc., Pittsburgh, PA	(800) 243-6745
HiSil 422		PPG discontinued (try BASF 800-798-1235)	
Hydral 710	aluminum trihydrate	Alcoa Industrial Chemicals, Bauxite, AR 72011	(800) 860-3290
Indopol H100	polybutene	B.P. Amoco Chemicals Corp., Naperville, PA	(877) 701-2726
Indopol H1900	polybutene	B.P. Amoco Chemicals Corp., Naperville, PA	(877) 701-2726
Irganox 1010		Ciba Specialty Chemicals, Tarrytown, NY	(800) 431-2360
ISOLENE® 40	Liquid Synthetic Rubber	Royal Elastomers	(888) 442-7362
ISOLENE® 400	Liquid Synthetic Rubber	Royal Elastomers	(888) 442-7362
ISOLENE® 400S	Liquid Synthetic Rubber	Royal Elastomers	(888) 442-7362

ISOLENE® 40S	Liquid Synthetic Rubber	Royal Elastomers	(888) 442-7362
ISOTARV	oil	Exxon Lubricants and Petroleum Division Corp., Houston, TX	(888) 228-4437
IT 3X Talc	magnesium calcium silicate	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
KALAR® 5210	Cross-linked Butyl Rubber	Royal Elastomers	(888) 442-7362
KALAR® 5215	Cross-linked Butyl Rubber	Royal Elastomers	(888) 442-7362
KALAR® 5246	Cross-linked Butyl Rubber	Royal Elastomers	(888) 442-7362
KALAR® 5263	Cross-linked Butyl Rubber	Royal Elastomers	(888) 442-7362
KALAR® 5275	Cross-linked Butyl Rubber	Royal Elastomers	(888) 442-7362
KALENE® 1300	Liquid Butyl Rubber	Royal Elastomers	(888) 442-7362
KALENE® 800	Liquid Butyl Rubber	Royal Elastomers	(888) 442-7362
King Prince	dixie clay (hydrated aluminum silicate	H.M. Royal, Trenton, NJ	(609) 396-9176
Kraton Polymer D1102	SBS block copolymer	Shell Chemical Co., Houston, TX	(800) 457-2866
Kraton Polymer D1107		Shell Chemical Co., Houston, TX	(800) 457-2866
Levapren 500HV	ethylene-vinyl acetate copolymer	Bayer Corporation, Akron OH	(330) 836-0451
LIO85 (powdered reagent)	red lead oxide	Spectrum Laboratory Products, Gardena, CA	(800) 772-8786
Maglite K	magnesium oxide	C.P. Hall Co., Chicago, Illinois	(708) 594-5923
Marble Dust		Imerys, Rosewell, GA	(888) 277-9636
MBT (Captax)	2-mercaptobenzothiazole	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
MBTS (Altax)	benzothiazyl disulfide	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
Methyl Tuads	tetramethylthiuram disulfide	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
Methyl Zimate	zinc dimethyldithiocarbamate	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
MicroCel E	calcium silicate	World Minerals, Lompoc, CA	(800) 342-8667
Mineral Spirits	petroleum distillates	Ashland Chemical, Columbus, OH	(888) 274-2436
Mistron Vapor Talc (MVT)	magnesium silicate	H.M. Royal, Trenton, NJ	(609) 396-9176
MnO2*	manganese dioxide	Eagle-Picher Indus., Cincinnati. Ohio	(417) 623-8000
Molecular Seive 4A		UOP, Mt. Laurel, NJ	(877) 867-7487
MVT (Mistron Vapor Talc)	magnesium silicate	H.M. Royal, Trenton, NJ	(609) 396-9176
N-347 Carbon		Columbian Chemicals, Marietta, GA	(800) 822-7266
Neo-heptanoic Acid		Exxon Chemical Corp., Houston, TX	(800) 231-6633
Norsorex (100%)	pure polymer	Zeon Chemicals, Louisville, KY	(800) 735-3388
Octoate Z		R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
Oleic Acid		Aldrich Chemical Co., Inc., St. Louis, MO	(800) 771-6737
OMYA BLH	treated calcium carbonate	Omya Inc., Proctor, VT	(800) 459-4468
PAB 8342		Flow Polymers	(800) 445-4924

Paroil 57-61	chlorinated paraffin oil	Dover Chemical Corp.	(800) 321-8805
PbO2 (FC)*	lead peroxide (fast cure)	Eagle-Picher Indus., Cincinnati. Ohio	(417) 623-8000
PbO2 (MC)*	lead peroxide (medium cure)	Eagle-Picher Indus., Cincinnati. Ohio	(417) 623-8000
PbO2 (VFC)*	lead peroxide (very fast cure)	Eagle-Picher Indus., Cincinnati. Ohio	(417) 623-8000
PbO2*	lead peroxide	Eagle-Picher Indus., Cincinnati. Ohio	(417) 623-8000
Pliolite S6B	high styrene reinforcing resin	Goodyear Chemical., Akron, OH	(800) 633-3965
PVP K30	2-Pyrrolidone	ISP Van Dyke, Wayne, NJ	(877) 812-7501
Pyrax A	pyrophyllite	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
QDO	p-quinone dioxime	Lord Corp/Chemical Product Division, Erie, PA	(814) 868-3611
Raven 880 Ultra		Columbian Chemicals, Marietta, GA	(800) 822-7266
Red Iron Oxide		H.M. Royal, Trenton, NJ	(609) 693-9176
Santicizer 141	sanitizer	Solutia, St. Louis, MO	(800) 321-3416
Sartomer 633	metallic diacrylate	Sartomer Company, Inc., Exton, PA	(800) 727-8663
Sartomer SR-230	diethylene glycol diacrylate	Sartomer Company, Inc., Exton, PA	(800) 727-8663
Sartomer SR-350	trimethylolpropane trimethacrylate	Sartomer Company, Inc., Exton, PA	(800) 727-8663
Sartomer SR-351	trimethyloipropane triacrylate	Sartomer Company, Inc., Exton, PA	(800) 727-8663
Satromer SR-395	isodecyl acrylate	Sartomer Company, Inc., Exton, PA	(800) 727-8663
Sartomer SR-2000		Sartomer Company, Inc., Exton, PA	(800) 727-8663
Satin Tone		Englehard Specialty Pigments & Additives, Iselin, NJ	(732) 205-5000
Shellflex 371	process oil	Shell Chemical Co., Houston, TX	(800) 231-6950
Silane A-187	silane	OSI Specialties, Greenwich, CT	(800) 334-4674
Silverez 2T5100		Arizona Chemicals, Jacksonville, FL	(800) 733-1374
Silverez TR1135	turpene based resin	Arizona Chemicals, Jacksonville, FL	(800) 733-1374
SP 1055	synthetic resins	Schenectady Chemicals Inc., Schenectady, NY	(518) 370-4200
SP 1056	synthetic resins	Schenectady Chemicals Inc., Schenectady, NY	(518) 370-4200
SP 553	synthetic resins	Schenectady Chemicals Inc., Schenectady, NY	(518) 370-4200
Stabilizer 75-001		Ferro Corp., Walton Hills, Ohio	(800) 321-9946
Stearic Acid	triple pressed stearic acid	H.M. Royal, Trenton, NJ	(609) 396-9176
Struktol TR354		Struktol Company, Stow, OH	(800) 327-8649
Sulfur	sulfur	H.M. Royal, Trenton, NJ	(609) 396-9176
Sundex 790		Sun Oil Co., Philadelphia, PA	(800) 395-2786
Sunpar 2280		Sun Oil Co., Philadelphia, PA/RE Carroll	(800) 395-2786
Talc Nytal 300	hydrous magnesium calcium silicate	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
t-butyl perbenzoate	peroxide	Elfatochem NA Fine Chemicals Group, Phil. PA	(215) 419-7000
Tellurac (TDEDC)	ethyl tellurac	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064

Thermax N-990	thermal process carbon black	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
TI-PURE	titanium dioxide	DuPont, Wilmington, DE	(800) 441-7515
TI-PURE R-900	titanium dioxide	DuPont, Wilmington, DE	(800) 441-7515
TI-PURE RF-30	titanium dioxide	DuPont, Wilmington, DE	(800) 441-7515
Toluene	toluene	Solutia, St. Louis, MO	(800) 325-4330
Triethanolamine	TEA	Spectrum Laboratory Products, Gardena, CA	(800) 772-8786
Twinkling Star Antimony Oxide	silica treated with antimony trioxide	H.M. Royal, Trenton, NJ	(609) 396-9176
Tyzor TPL	titanate	DuPont, Wilmington, DE	(800) 441-7515
Univolt 60	transformer or insulation oil	Exxon Lubricants and Petroleum Division Corp., Houston, TX	(888) 228-4437
Ultrathene EVA	ethylene vinyl acetate copolymer	Equistar Chemicals, Houston, TX	(800) 615-8999
Vanox ZMTI	Dibetanophthyl-p-phenylenediamine	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
Varox DCP-40C	resin	R.T. Vanderbilt Co., Inc., Norwalk, CT	(800) 243-6064
Varsol 18	mineral oil	Exxon Lubricants and Petroleum Division Corp., Houston, TX	(888) 228-4437
Vertical Quicklime	calcium oxide	Mississippi Lime Company, Alton, IL	(800) 437-5463
Vistanex LMMS	polyisobutylene	Exxon Chemical Corp., Houston, TX	(800) 231-6633
Vulklor	tetrachloro-p-benzo quinone	Uniroyal Chemicals, Middlebury, CT	(800) 243-3024
White Fonoline	petrol atum	Crompton Corporation, Petrolia, PA	(877) 948-2688
Wingtack 95	aliphatic c-5 petroleum hydrocarbon resin	Goodyear Chemical., Akron, OH	(800) 633-3965
Zinc Oxide	zinc oxide	H.M. Royal, Trenton, NJ	(609) 396-9176
Zonarez 7085	polyterpene resins	Arizona Chemical Co., Jacksonville, FL	(800) 526-5294