ROYALENE® EPDM

An Industry Leader for over 40 Years.

COPOLYMER™

LION COPOLYMER, LLC

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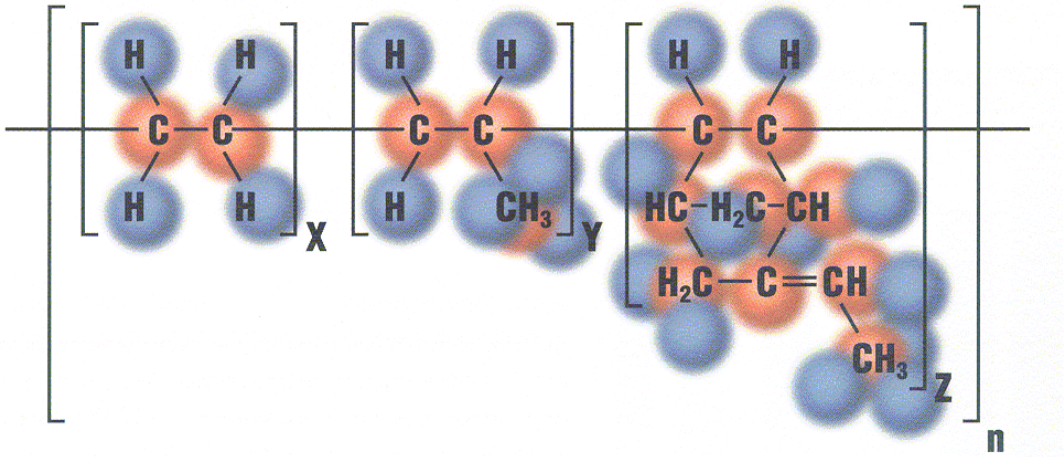


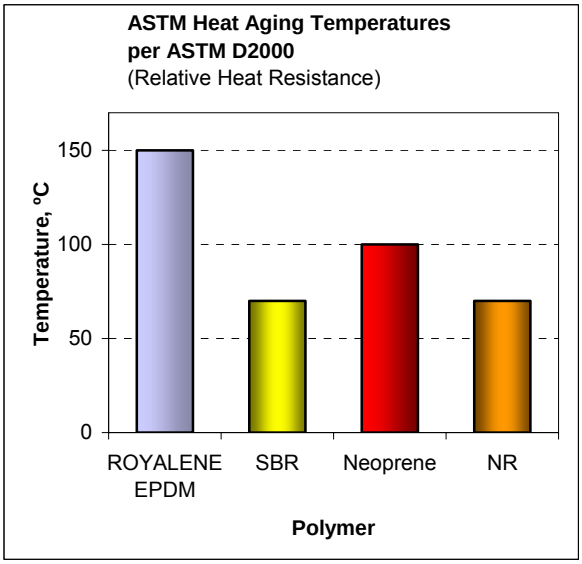
Royalene EPDM, a terpolymer of ethylene, propylene and a non-conjugated diene, is one of the most versatile specialty elastomers in commercial use today.

The main attributes of EPDM are its outstanding resistance to oxidation, ozone and the effects of weathering. It is also highly extendible, allowing high levels of fillers and plasticizers to be added while still maintaining good physical properties. Its low specific gravity combined with its high extendibility allow for inexpensive functional parts to be produced.

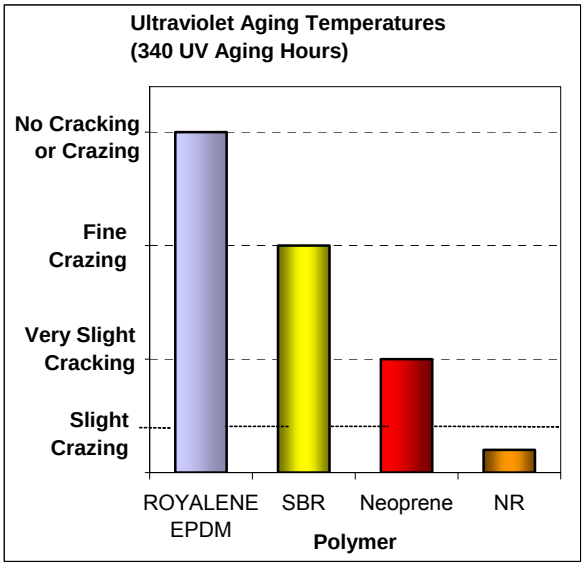
Royalene EPDM has found wide use in applications that take advantage of its excellent aging characteristics as well as its low temperature flexibility, chemical resistance and electrical properties. Examples of articles made from Royalene EPDM include: automotive weatherseal, hoses, tire sidewalls, single-ply roof membranes and wire and cable insulation.

There are a wide variety of types of Royalene EPDM available, varying in Mooney viscosity, molecular weight, ethylene/propylene ratio and cure rate. The different types are designated for optimum performance in specific applications, allowing compounders latitude in choosing the best polymer for their particular processing and product requirements.

Key Characteristics Royalene® EPDM



Heat resistance of ROYALENE EPDM compared to other general purpose polymers.



Outstanding ultraviolet aging of Royalene EPDM compared to other polymers (test is made on a WEATHER-OMETER® with 2.5 cm sample bent double on itself).

Heat Resistance

Royalene EPDM is noted for its oxidation resistance, which results in excellent heat aging characteristics. No special compounding is required for continuous service exposures up to 125 ºC. Service temperatures to 150 ºC and beyond can be achieved by proper compounding techniques and polymer selection.

Ozone Resistance

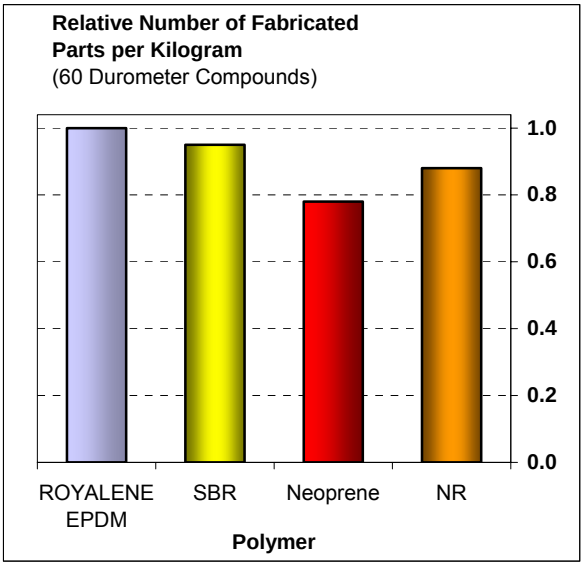
Because of its saturated polymer backbone, Royalene EPDM is inherently resistant to attack by ozone. Compounds are suitable for use in high ozone environments without the need for antiozonants, waxes or other additives.

Weather Resistance

Royalene EPDM compounds are superior to most other elastomeric compounds for weathering resistance and exposure to ultraviolet radiation.

Low Temperature Properties

Royalene EPDM polymers have inherently good low temperature properties. Vulcanizates remain flexible and serviceable down to temperatures as low as –55 ºC.



Relative number of parts per kilogram made with Royalene EPDM compared to other commonly used polymers.

Blends With Other Polymers
Royalene EPDM can be blended with many polymers to impart some of the beneficial characteristics of EPDM. For example, EPDM is often used in blends with diene polymers to improve their ozone resistance. EPDM is also commonly used in blends with butyl rubber in inner tubes to improve heat and ozone resistance as well as the tube's green strength.

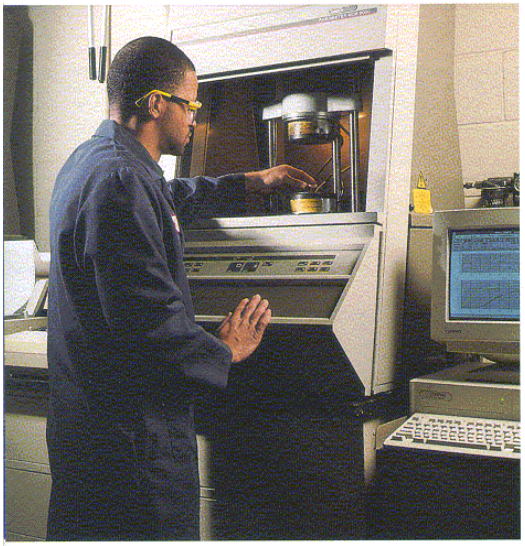
Low Specific Gravity
Royalene EPDM has the lowest specific gravity of any commercial polymer. This results in a higher yield of fabricated parts per kilogram of mixed compound.

High Extendibility
The ability of Royalene EPDM to be highly extended with inexpensive oils and fillers while maintaining good physical properties results in finished parts with low costs.

Chemical Resistance
Vulcanized articles of Royalene EPDM have good resistance to many chemical agents such as alcohols, esters, acids, alkalis, ketones, hydraulic fluids and antifreeze fluids. This makes it well-suited for heating/cooling and brake system components.

Royalene EPDM generally has poor resistance to hydrocarbon solvents and oils, comparable to that of natural rubber, SBR and butyl.

Compounding Royalene® EPDM



Lion Copolymer's laboratories are equipped for extensive polymer and compound testing.

Polymer Selection

Lion Copolymer manufactures a wide range of Royalene EPDM polymers based upon ENB (ethylidene norbornene) or DCPD (dicyclopentadiene) termonomers. These polymers can vary in termonomer content, molecular weight (frequently measured by Mooney viscosity), molecular weight distribution, ethylene/propylene ratio and – in some types – the amount of extender oil.

These characteristics affect the physical properties, processing behavior and the cure rate of the finished compound.

Vulcanization Systems

Royalene EPDM polymers, in general, have slower cure rates than the more commonly used diene rubbers such as NR and SBR. To overcome this difference and achieve comparably fast cure rates, higher levels of curatives or faster accelerators must be used.

Most commonly used rubber curatives are utilized for vulcanizing compounds made from Royalene EPDM. Sulfur or sulfur donor cure systems and peroxide cure systems can be used for curing Royalene EPDM. Peroxide cure systems are used where the optimum in heat and compression set resistance is required.

Activators

Typically, 3 to 5 parts of zinc oxide and 0.5 to 1.0 part of stearic acid are used as activators for sulfur cure systems. Zinc stearate when used at a 50% higher level than stearic acid can replace the stearic acid and also function as a processing aid.

Processing Aids

Although Royalene EPDM compounds normally have good processing characteristics, small amounts of processing aids are sometimes desirable. Stearic acid, zinc stearate, low-melt polyethylene, waxes and proprietary processing aids have some benefit in improving mold flow, release characteristics and processing in general. Tackifiers, when used at a 5 to 20 part level, improve building tack in fabricated parts.

Protective Agents

Antioxidants are not typically used in Royalene EPDM except in the case of critical temperature conditions. For severe high temperature applications, a peroxide cure is normally used in combination with an antioxidant package.

Lion Copolymer employs the latest technology and state-of-the-art equipment for physical testing.

Fillers

Royalene EPDM is essentially an amorphous polymer and needs reinforcing fillers to obtain satisfactory physical properties. Carbon blacks are the most effective and widely used fillers. Small particle size blacks generally give higher physical properties than large particle size blacks, but may be more difficult to mix and achieve good dispersion in a compound. Higher structure blacks tend to give better extrusion and mixing characteristics than lower structure blacks.

Non-black fillers can also be used to extend EPDM compounds. Silicas or silicates are the most reinforcing of the non-black fillers, with clays and calcium carbonates being moderate-to-low in reinforcement but also lower in cost.

Plasticizers

Mineral oils are widely used as plasticizers in Royalene EPDM because of their high compatibility. Naphthenic or paraffinic oils are the normal choices.

Naphthenic oils have the greatest degree of compatibility and are widely used in compounds extended with high levels of fillers and oils. Paraffinic oils should be used with peroxide cures because of their minimal effect on cure. For the best long-term and/or high temperature aging, a low volatility paraffinic oil should be chosen.

Foaming Agents

Royalene EPDM may be compounded to produce a variety of cellular products. Most sponge formulations are based upon Celogen® AZ (azodicarbonamide) or its activated forms. The density of the finished products may vary from about 80 to over 640 kg/m^3 (5 to over 40 lb/ft^3). When a very fine cell size is desired, Celogen OT (OBSH) is used as an activator for Celogen AZ to help provide a broader temperature range of gas evolution.

Comparative Properties Royalene® EPDM

Common Name – Base Polymer		Royalene® EPDM	Natural Rubber	SBR	Butyl	Butadiene	Neoprene
Chemical Name		**Ethylene Propylene**	Polyisoprene	Styrene Butadiene	Isobutylene Isoprene	Polybutadiene	Polychloroprene
Material Designation, ASTM D2000		**BA, CA, DA**	AA	AA	AA	AA	BC, BE
ASTM D1418 Designation		**EPDM**	NR	SBR	IIR	BR	CR
Tensile Strength, MPa	Pure Gum	**Below 7**	Over 20	Below 7	Over 10	Below 7	Over 14
Black Loaded Stocks		**Over 17**	Over 20	Over 14	Over 14	Over 17	Over 14
Hardness Range, Durometer A		**25-95**	30-90	40-90	40-75	40-80	15-95
Specific Gravity, Base Material		**0.86**	0.93	0.94	0.92	0.94	1.23
Adhesion to Metals		**Good**	Excellent	Excellent	Good	Excellent	Excellent
Adhesion to Fabrics		**Good**	Excellent	Good	Good	Good	Excellent
Tear Resistance		**Good**	Very Good	Fair	Good	Good	Good
Abrasion Resistance		**Good to Excellent**	Excellent	Good to Excellent	Good	Excellent	Very Good
Compression Set		**Very Good**	Excellent	Good	Fair	Very Good	Good
Resilience:	Cold	**Good**	Excellent	Good	Poor	Outstanding	Good
	Hot	**Very Good**	Excellent	Good	Very Good	Excellent	Very Good
Dielectric Strength		**Outstanding**	Excellent	Good	Good	Good	Good
Electrical Insulation		**Outstanding**	Good to Excellent	Good	Good	Good to Excellent	Fair to Good
Impermeability to Gases		**Good**	Good	Fair	Outstanding	Good	Good
Acid Resistance:	Dilute	**Excellent**	Fair to Good	Fair to Good	Excellent	Fair to Good	Good
	Concentrated	**Good**	Fair to Good	Fair to Good	Good	Fair to Good	Fair
Solvent Resistance:	Aliphatic Hydrocarbons	**Poor**	Poor	Poor	Poor	Poor	Fair to Good
	Aromatic Hydrocarbons	**Poor**	Poor	Poor	Poor	Poor	Fair
	Oxygenated (Ketones, etc.)	**Excellent**	Poor	Poor	Good	Poor	Poor to Fair
	Lacquer Solvents	**Fair to Good**	Poor	Poor	Fair to Good	Poor	Poor
Resistance To:	Swelling in Lubricating Oil	**Poor**	Poor	Poor	Poor	Poor	Good
	Oil and Gasoline	**Poor**	Poor	Poor	Poor	Poor	Good
	Animal Oils	**Fair**	Poor	Poor	Fair	Poor	Fair
	Water Absorption	**Excellent**	Very Good	Very Good	Very Good	Very Good	Good
	Oxidation	**Excellent**	Good	Fair	Excellent	Good	Good
	Ozone	**Outstanding**	Poor	Poor	Excellent	Poor	Fair
	Sunlight Aging	**Outstanding**	Poor	Poor	Very Good	Poor	Very Good
	Heat Aging	**Excellent**	Fair	Good	Very Good	Fair	Good
	Low Temperature	**Excellent**	Very Good	Very Good	Poor	Very Good	Good
	Flame	**Poor**	Poor	Poor	Poor	Poor	Good
	Vegetable Oils	**Fair**	Poor	Poor	Fair	Poor	Good
	Chlorinated Hydrocarbons	**Poor**	Poor	Poor	Poor	Poor	Poor

CPE	Nitrile	Urethane	Chlorosulfonated Polyethyene	Epichlorohydrin	Acrylic	Silicone	Fluorosilicone	Fluorocarbon
Chlorinated Polyethylene	Acrylonitrile Butadiene	Polyester / Polyether Urethane	Chlorosulfonated Polyethylene	Polyethylene Oxide	Polyacrylate	Polysiloxane	Fluoroalkyl Polysiloxane	Fluorinated Hydrocarbon
BC, BE, CE	BF to BK, CH	BG	CE	CH	DF, DH	FC, FE, GE	FK	HK
CM	NBR	AU, EU	CSM	CO/ECO	ACM/ANM	Q	FVMQ	FKM
Over 10	Below 7	20-35	Over 10	Below 7	Below 7	Below 8	Below 10	8
Over 17	Over 20	20-35	Over 17	14	15	Over 8	Over 10	3.5-20
60-90	25-95	30-70D	40-90	40-90	40-90	20-85	60-90	60-90
1.16-1.32	0.96-1.02	1.02-1.20	1.12	1.27-1.36	1.10	1.14-2.05	1.30-2.20	1.80
Fair to Good	Excellent	Excellent	Excellent	Fair to Good	Very Good	Excellent	Excellent	Fair to Good
Fair	Good	Very Good	Good	Fair to Good	Very Good	Excellent	Excellent	Good
Fair	Fair	Excellent	Fair	Fair to Good	Fair	Poor	Poor to Fair	Fair to Good
Good	Good	Outstanding	Very Good	Fair to Good	Fair	Poor	Poor	Good
Good	Good	Good	Fair	Poor	Good	Very Good	Good	Very Good
Fair	Fair	Good	Fair	Fair	Poor	Excellent	Excellent	Fair
Good	Fair	Good	Good	Fair	Poor	Excellent	Excellent	Good
Excellent	Poor	Excellent	Very Good	Good	Fair	Good	Good	Very Good
Good	Poor	Good	Good	Good	Fair	Excellent	Excellent	Good
Excellent	Excellent	Good	Excellent	Excellent	Good	Fair	Good	Excellent
Excellent	Good	Fair	Excellent	Fair to Good	Fair	Excellent	Excellent	Good to Excellent
Good	Good	Poor	Good	Fair	Poor	Fair	Fair	Excellent
Good	Excellent	Good	Fair to Good	Excellent	Excellent	Poor	Excellent	Excellent
Fair	Good	Fair	Fair	Good	Fair to Poor	Poor	Excellent	Excellent
Fair	Poor	Poor	Poor to Fair	Poor	Poor	Poor	Poor	Poor
Fair	Fair	Poor	Poor	Fair	Poor	Poor	Poor	Poor to Fair
Good	Very Good	Good	Good	Excellent	Excellent	Fair	Excellent	Excellent
Good	Excellent	Good	Good	Excellent	Fair	Fair	Excellent	Excellent
Fair	Excellent	Fair	Fair	Excellent	Excellent	Fair	Excellent	Excellent
Very Good	Good	Poor to Good	Good	Good	Good	Excellent	Excellent	Very Good
Excellent	Good	Very Good	Very Good	Good	Excellent	Excellent	Excellent	Outstanding
Excellent	Poor	Excellent	Outstanding	Excellent	Excellent	Excellent	Excellent	Outstanding
Outstanding	Poor	Very Good	Outstanding	Good	Good	Excellent	Excellent	Outstanding
Very Good	Very Good	Good	Very Good	Very Good	Excellent	Outstanding	Outstanding	Outstanding
Good	Fair to Good	Fair to Excellent	Good	Good to Very Good	Poor	Outstanding	Outstanding	Fair to Good
Good	Poor	Poor	Good	Poor to Fair	Poor	Fair	Excellent	Excellent
Fair	Excellent	Fair	Poor	Excellent	Good	Good	Excellent	Excellent
Poor	Fair	Fair to Good	Poor to Fair	Good to Excellent	Poor	Poor to Good	Good to Excellent	Good to Excellent

Processing ROYALENE® EPDM

Cooling water on full.

Time	
0’	Load Royalene EPDM and ⅓ fillers.
1’	Add ⅓ fillers and ½ oil.
2’	Add zinc oxide and remaining ingredients except curing agents.
3-5’	Add curing agents.
4-8’	Discharge at 110ºC (230ºF)

A typical ROYALENE EPDM mixing procedure is shown above.

Mill Mixing

When mill mixing a Royalene EPDM-based compound, reinforcing fillers and zinc oxide are generally added early in the mix to insure good dispersion. Plasticizers and non-reinforcing fillers are then added, followed by the remaining ingredients. Curatives are generally added late in a mill mix, to reduce the likelihood of premature cure.

As a general rule, low Mooney viscosity Royalene EPDM grades are the fastest mill banding and easiest mixing. A similar rule applies to ethylene/propylene ratio. Low ethylene Royalene EPDM grades are typically easier to mill mix than high ethylene types.

Internal Mixing

Procedures for Banbury® mixing Royalene E EPDM compounds can be extremely varied. Highly extended stocks may require higher discharge temperatures, an upside down mix or two pass mixing. Exceptionally fast curing stocks may require curative addition on the mill, or in a second Banbury pass.

Calendering

Royalene EPDM compounds can be designed to provide the optimum combination of processing characteristics and physical properties necessary for the manufacture of high quality calendered goods. As a general rule, broader molecular weight distribution EPDM grades provide better calendering behavior than very narrow types.

Extrusion

Royalene EPDM-based compounds can be readily extruded on hot or cold feed extruders. As a general rule, high ethylene, high Mooney viscosity grades provide the best combination of green strength, shape retention and cured properties necessary for the manufacture of high quality extruded profiles.

Microwave Cures

Microwave continuous curing is typically used for the production of dense rubber or sponge extruded profiles. Royalene EPDM-based compounds can be designed to be receptive to microwave energy by utilizing various compounding ingredients such as carbon black or zinc oxide, or blending with polar polymers such as nitrile rubber.

Steam Cures

Steam cures can be either batch or continuous in operation. Open steam is used in autoclaves to cure batches of molded, extruded or calendered goods.

Continuous vulcanization (CV tube) steam cures are typically used by wire and cable manufacturers to cure insulations at very high production rates. CV tubes typically operate at considerably higher temperatures and pressures than autoclaves.

Lion copolymer's technical service laboratory has extrusion and vulcanization capabilities for factory-scale evaluations.

Molding

Royalene EPDM can be compounded to meet the varied processing requirements of compression, transfer or injection molding applications. Compound viscosity and cure rate are extremely important considerations in the design of a Royalene EPDM compound for molding.

Dry Heat Cures

Dry heat cures (hot air vulcanizing) are also used for batch curing, calendered, extruded or molded products. These cures may be at atmospheric or elevated pressure.

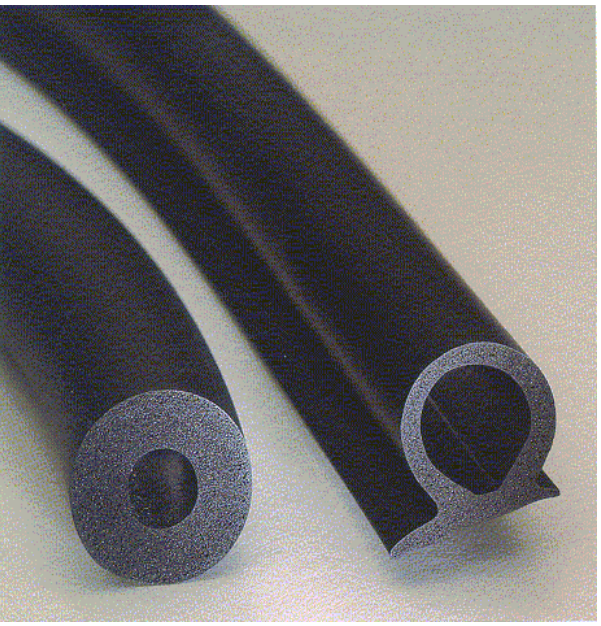
LCM Cures

Liquid curing media (LCM) requires special compounding techniques. In the LCM process, extruded profiles are cured in baths of molten salts or metal alloys, at temperatures in excess of 200 ºC (400 ºF).

Applications ROYALENE® EPDM

Hose

Outstanding resistance to temperature extremes, water absorption antifreeze and acid and alkali attack make Royalene EPDM perfectly suited to meet the demanding requirements of a variety of high quality hose applications for use in automotive, appliance and industrial markets.



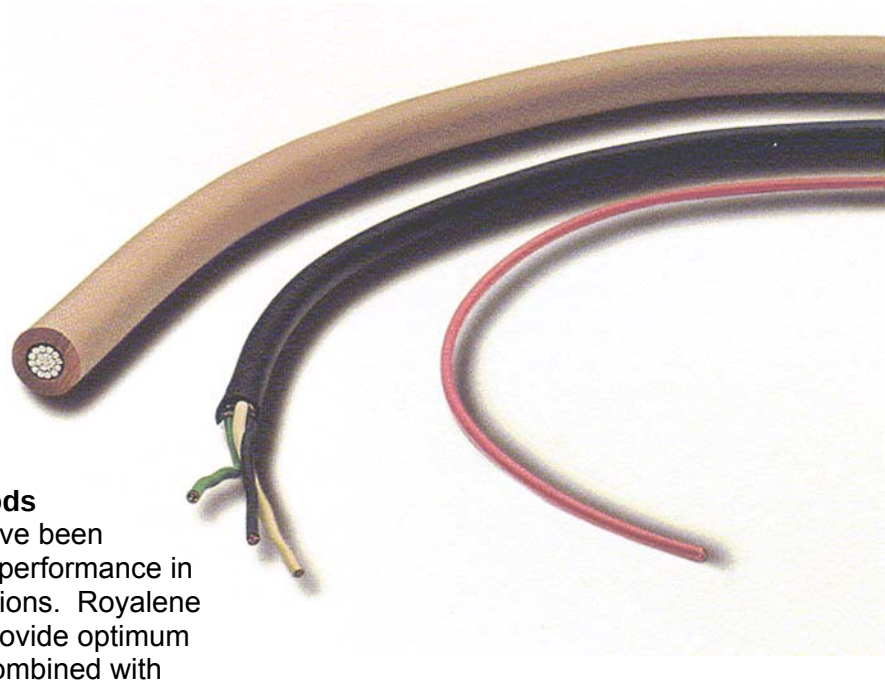
Weatherseals and Cellular Products

Royalene EPDM is recognized worldwide for outstanding performance in Weatherseals and cellular (sponge) products. A wide selection of Royalene polymers have been specially developed to provide optimum physical properties and superior surface finish for EPDM weatherseal and cellular goods applications, including automotive single and dual durometer Weatherseals, construction (building) weather-seals, appliance seals, sheet sponge, protective tubings, drum seals and other uses.

Thermoplastics

Blends of Royalene EPDM and thermoplastic polyolefin resins function as thermoplastic elastomers, which combine many of the properties of vulcanized rubber with the processing advantages of true thermoplastics. Polyolefin thermoplastic elastomers are widely used in a variety of automotive applications including exterior rub strips, claddings and sight shields.

Royalene EPDM is also an effective modifier of thermoplastic polyolefin resins. The addition of EPDM to polypropylene or polyethylene imparts low temperature properties, as well as superior flexibility, resilience, impact and stress crack resistance.



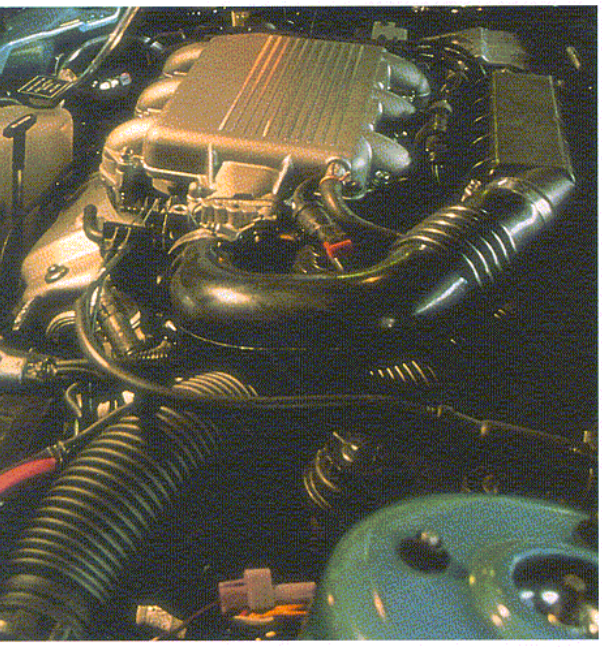
Wire & Cable and Molded Electrical Goods
A number of Royalene EPDM-polymers have been specifically developed to offer outstanding performance in wire and cable and other electrical applications. Royalene EPDM compounds can be formulated to provide optimum physical, electrical and aging properties, combined with excellent wet electricals, flame and treeing resistance.

Electrical applications for Royalene EPDM include wire and cable insulation and jackets for power distribution, residential, automotive and appliances, as well as molded plugs and connectors. Heat sunlight, ozone and chemical resistance make Royalene EPDM the polymer of choice for an ever increasing number of applications.

Mechanical Goods
Abrasion and chemical resistance, resilience and excellent heat aging characteristics make Royalene EPDM an outstanding choice for a vast number of mechanical goods applications that include diaphragms, insulations, seals and other high quality components requiring optimum dynamic properties.

Tire and Tubes
Royalene EPDM, in blends with high diene polymers such as NR and SBR, has demonstrated its usefulness in tire compounds to impart improved heat and ozone protection. EPDM is also a common component in white sidewall stocks due to its ability to function as a nonstaining antiozonant. The addition of Royalene EPDM to an inner tube stock increased green strength, as well as improved heat and ozone protection.

Primary Markets Royalene® EPDM



EPDM roof sheeting installation

Automotive

The inherent heat, ozone and weathering resistance of Royalene EPDM in combinations with its ability to withstand the detrimental effects of polar liquids such as water, antifreeze and brake fluid, makes it the perfect choice for an extensive array of automotive interior, exterior and underhood components, including:

- Radiator, heater and vacuum hoses
- Weatherseal for windshields and exterior lights
- Cellular weatherseal for doors and deck lids
- Brake cups and seals
- Ignition cable insulation
- Dust seals, boots and miscellaneous gaskets
- Exterior cladding, rub strips and sight shields
- Interior trim
- Tire sidewalls and inner tubes.

Building Products

Sunlight and the elements can drastically reduce the life span of most general purpose elastomers. The natural ability of Royalene EPDM to withstand harsh weather, water and temperature extremes makes it an outstanding choice for use in single-ply roof membranes, expansion joints, architectural gaskets, weatherseal and other exterior building product applications.

Industrial Products

Industrial product applications typically require the utmost in physical properties from a polymer. Royalene EPDM is commonly used for demanding industrial applications including conveyor belting, vibration mounts, hose, loading dock bumpers, O-rings and diaphragms.

Appliance

The ability to function over a wide temperature range and resist acid and alkali attack makes Royalene EPDM ideal for washing machine, refrigerator and other appliance part applications, including hoses, door gaskets, seals and wire insulation.