Buna® EP
Ethylene Propylene Rubber

The Versatile Elastomer

Edition 2007-05
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(1) Buna is a registered trademark in many countries of the world

Front cover: Artist’s impression of the TianJin Olympic Center Stadium where Buna® EP will be used as a roofing sealant.
Preface

LANXESS is a major global supplier of Ethylene-Propylene Rubbers with over 30 years of production, sales, technical, research & development, and marketing experience.

We know the requirements of our customers to be:
- continuous supply
- expert technical support
- broad product portfolio for various markets
- 24x7 online ordering and information retrieval
- global production and sales presence
- orders ranging anywhere from skid to truckload volumes
- state-of-the-art global quality laboratory equipment
- continuous new product development
- standard industry bale sizes
- modern logistics IT infrastructure
and strive to deliver accordingly.

For further or more detailed information, please contact our local experts. You find their addresses at the end of this brochure.

For information on food contact applications, please contact the Health, Safety, Environment and Quality Department of LANXESS Germany or, for business in the USA, the LANXESS Product Safety and Regulatory Affairs Department in Pittsburgh, PA at 1-800-LANXESS.

Please note:
The information contained in this publication is current as of May, 2007. Please contact LANXESS Deutschland GmbH or LANXESS Corporation to determine if this publication has been revised.

We wish you, as our current or potential Buna® EP customer, continuous success in your business and hope this brochure to be of value to you as a useful reference.
Overall product description

The general term ethylene-propylene rubber refers to two different kinds of polymers:

- EPM represents a copolymer from ethylene and propylene monomers; EPM is entirely saturated and therefore requires vulcanization by radiation or products that release free radicals, such as organic peroxides.

- EPDM denotes a terpolymer based on three monomers: ethylene, propylene and a non-conjugated diene; EPDM grades have a residual unsaturation in the side chains and can therefore be cured with sulfur and accelerators. Its heat resistance is distinctly better than Natural Rubber, SBR and Butadiene Rubber.

The molecules of both EPM and EPDM have a completely saturated hydrocarbon backbone, through which excellent ozone resistance and very good resistance to heat and oxidation are achieved.

Key properties of ethylene-propylene elastomers are as follows:

- They have the lowest density (0.86 g/cm³) of all the commercially available rubbers.
- Can be molded, extruded, or calendared.
- Fast and efficient mixing with additives.
- Ability to accept higher filler loadings than other elastomers.
- Very good resistance to heat and oxidation.
- Very good resistance to ozone and weathering.
- Good chemical resistance.
- Good low temperature flexibility (depending on ethylene content).
- Good electrical insulation properties.
- Good vulcanizate physical properties (stress-strain behavior, compression set).

Ethylene-propylene rubbers are designed according to the following criteria:

- Mooney viscosity
- Ethylene/propylene ratio
- Diene content
- Oil content and oil type.

The properties of the raw EP rubber and the corresponding vulcanizates are directly influenced by the EP rubber polymer structure:

- Molecular weight
- Molecular weight distribution
- Composition
- Crystallinity
- Distribution of monomer units within a chain
- The extent of long-chain branching.

These properties are directly related to the polymerization conditions and catalyst system used in the EP rubber manufacturing process. By varying the reaction parameters, one can obtain a wide range of properties, suitable for a large number of applications. The production of a broad range of high quality synthetic rubber grades of this type is made possible by a thorough understanding of the relationship between the process variables and the resulting product properties.

Artist's impression of the TianJin Olympic Center Stadium where Buna® EP will be used as a roofing sealant.
Polymer properties such as rate of cure and degree of crosslinking depend on the type and amount of diene. Grades with different amounts of the third monomer are offered to meet requirements in a wide range of applications.

**Chemistry of EPM copolymers**

Buna® EP copolymers are produced by copolymerization of ethylene and propylene using Ziegler-Natta catalysts which are formed in-situ by reaction of vanadium salts and aluminum alkyl halides.

Distribution of the comonomer propylene can vary from random to alternating. The function of propylene is to disrupt long sequences of ethylene and prevent them from crystallizing.

- At high propylene levels (above 50 weight percent), only short ethylene sequences exist in the polymer chain so crystallinity is absent.
- At low propylene levels (e.g., below 35 weight percent), a small amount of crystallinity is present which provides the EPM with green strength.

The copolymerization results in a saturated backbone. Sulfur vulcanization cannot be used to crosslink EPM since no unsaturation exists. Therefore, e.g. peroxide cure must be used.

Peroxide curing of EPM is more efficient at high ethylene compositions due to competing chain scission which occurs at the tertiary carbon atoms of the propylene units.

**Chemistry of EPDM terpolymers**

To produce a sulfur-curable rubber, a non-conjugated diene is introduced as the third monomer during polymerization. Appropriate third monomers contain one double bond which takes part in the polymerization and one which does not. This results in pendant unsaturation which serves as crosslinking sites without affecting the saturated main chain. Buna® EP terpolymers from LANXESS use ethylidene norbornene (ENB) as the third monomer.
Production technologies

LANXESS produces EP rubber on two continents, using two different production technologies. We are the only manufacturer worldwide that currently offers both solution and suspension (slurry) technology.

The combination of two different processes enables LANXESS to produce a very wide range of EP rubber products from very high molecular weight and high ethylene grades produced in suspension to amorphous, moderate molecular weight grades. Both processes offer distinct advantages.

In the LANXESS EP rubber solution process,
- a catalyst is used to produce EPM or EPDM in a hydrocarbon solvent in which the polymer dissolves as it is formed
- the viscous solution is short-stopped, washed and antioxidant is added; in the case of oil-extended grades, extender oil is added.
- the rubber solution is coagulated and residual hydrocarbons are stripped from the rubber using steam
- the wet rubber crumb is then dewatered and dried in the finishing segment of the process
- the dried rubber is finally baled and packaged

Fig. 3: Production flow sheet for Buna® EP G Marl

Fig. 2: Production via solution polymerization is carried out at our plant in Marl, Germany
In the LANXESS suspension (slurry) process, 
- a soluble catalyst is used to produce EPM or EPDM in a diluent in which the polymer is insoluble 
- subsequently, small rubber particles are formed as a suspension in the reaction medium; since the viscosity of the reaction medium is low, higher molecular weight rubber can be produced at high solid levels 
- following polymerization, water, antioxidants and extender oils (for oil-extended EPDM grades) are added and residual hydrocarbons are stripped from the suspension 
- the resulting crumb is then dewatered, dried and finished in a fashion similar to the solution process

Fig. 4: Production via suspension polymerization takes place at our plant in Orange, Texas, USA

Fig. 5: Production flow sheet for Buna® EP T Orange
Quality assurance

Quality is a core value of LANXESS, founded on the global principles of quality management, product stewardship, and sustainable development.

All of our EP manufacturing sites worldwide, customer service operations, and supply chain operations maintain quality systems registered to ISO 9001:2000.

To be certified to the ISO 9001 standard, LANXESS implemented a quality management system embracing all of the company's activities, including:

- employee training
- customer interaction
- meeting customer requirements
- product design and development
- purchasing materials and services
- delivering products
- fostering an environment for continual improvement

LANXESS operations in Europe, Latin America, Middle East, Africa, and Asia-Pacific are certified according to the international environmental standard ISO 14001. You can find further information on the LANXESS website: www.lanxess.com/lcs/en/portrait/certificates/performance_rubber

In North America, LANXESS Corporation is RC 14001 certified, which is a combined certification of both ISO 14001 and the American Chemical Council's RCMS standards. To be certified to the RC 14001 standard, LANXESS implemented an environmental management system (EMS) embracing all of the company's activities, including environmental impacts, product design and development, purchasing materials and services, and delivering products, while fostering an environment for continual improvement.

LANXESS utilizes root cause analysis and corrective action planning to prevent reoccurrence of non-conformities. For customers registered for LANXESS e-commerce, this process can be initiated using our online transaction system LANXESSOne, or in North America LANXESSDirect. Alternatively, our LANXESS sales representative can be contacted.

LANXESS is committed to maintain a leadership position in Buna® EP product quality and reliability.

Characteristic properties of the raw polymer

The Buna® EP nomenclature is as follows:

- T = Texas
- G = Germany
- wt % ENB
- wt % Ethylene

```
Buna® EP T 5459 CL
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<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mooney Viscosity</td>
<td>ML (1+4) at 125 °C</td>
</tr>
<tr>
<td></td>
<td>5 = 50 – 59</td>
</tr>
<tr>
<td>phr paraffinic oil</td>
<td>9 = 90 – 100</td>
</tr>
<tr>
<td>Oil Color</td>
<td></td>
</tr>
</tbody>
</table>

Texas/Germany refers to the respective LANXESS production site where the Buna® EP grade is manufactured.

Buna® EP grade names containing the string 'VP' are experimental grades (VP stands for "Versuchsprodukt" = experimental grade in German).

Product range

Our customers have the choice of six different Buna® EP grade categories:

- EPM (copolymers)
- EPDM (terpolymers) in groups of increasing diene content: low, medium, high, very high.
- Maleic anhydride-grafted EP rubber.

Relevant safety data and references as well as the possibly necessary warning labels are to be found on the material safety data sheet (MSDS). They can be sent to you upon request.

- Our specific product data sheets are online at: www.techcenter.lanxess.com/trp
  Please choose the world region you are located in.

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2) “Responsible Care Management System” is an American standard which ensures that manufacturers have systems in place to ensure the health and safety of LANXESS employees, customers and surrounding communities.
1) unmassed (DIN 53 523; ASTM D 1646)

2) correction formula: \( C_2 \text{ corr.} = C_2 \text{ uncorr.} \times \left( \frac{100-\text{ENB\%}}{100} \right) \)

Density 0.86 g/cm³; for oil-extended grades 0.87 g/cm³

More detailed information concerning Buna® EP packaging and shipping can be obtained on pages 22 and 23.

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### Table 1: LANXESS EPM and EPDM product ranges

<table>
<thead>
<tr>
<th>Buna® EP</th>
<th>Mooney viscosity(^{(1)})</th>
<th>ENB content</th>
<th>Ethylene content (%) corr.(^{(2)})</th>
<th>Standard packaging bale weight (bares per pallet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ML (1+4) 125 °C / ML (1+8)(^{(1)})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Copolymers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T 2070</td>
<td>22 / 35 (100 °C) 0.0</td>
<td>68</td>
<td>34 kg (24) pellets on request</td>
<td></td>
</tr>
<tr>
<td>T 4040 (KA 8931)</td>
<td>40 / -</td>
<td>0.0</td>
<td>25 kg (30)</td>
<td></td>
</tr>
<tr>
<td><strong>Terpolymers – low unsaturation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G 6170</td>
<td>59 / -</td>
<td>1.5</td>
<td>20 kg (30), crumbs in 320 kg boxes</td>
<td></td>
</tr>
<tr>
<td>T 6250</td>
<td>55 / -</td>
<td>2.2</td>
<td>25 kg (36)</td>
<td></td>
</tr>
<tr>
<td><strong>Terpolymers – medium unsaturation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G 2440</td>
<td>24 / -</td>
<td>4.3</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>T 2450</td>
<td>22 / 35 (100 °C) 0.0</td>
<td>4.0</td>
<td>25 kg (30)</td>
<td></td>
</tr>
<tr>
<td>T 2460</td>
<td>21 / 33 (100 °C) 0.0</td>
<td>4.0</td>
<td>25 kg (30)</td>
<td></td>
</tr>
<tr>
<td>G 2470</td>
<td>24 / -</td>
<td>4.2</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>G 2470 LM</td>
<td>22 / -</td>
<td>4.2</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>G 3440</td>
<td>28 / -</td>
<td>4.1</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>G 3473 (30 phr paraffinic oil)</td>
<td>34 / -</td>
<td>4.6</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>G 3569 LF (100 phr paraffinic oil)</td>
<td>30 / -</td>
<td>5.1</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>G 5450</td>
<td>46 / -</td>
<td>4.3</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>G 5455 (50 phr paraffinic oil)</td>
<td>46 / -</td>
<td>4.3</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>T 5459 CL (100 phr paraffinic oil)</td>
<td>54 / 38 (150 °C) 4.0</td>
<td>5.1</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>T 6465 (50 phr paraffinic oil)</td>
<td>53 / 37 (150 °C) 4.0</td>
<td>5.1</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>T 6470</td>
<td>57 / 55 (125 °C) 4.5</td>
<td>6.5</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>G 6470</td>
<td>59 / -</td>
<td>4.7</td>
<td>20 kg (30)</td>
<td></td>
</tr>
<tr>
<td>G 8450</td>
<td>76 / -</td>
<td>4.3</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>G 8460</td>
<td>81 / -</td>
<td>4.5</td>
<td>20 kg (30)</td>
<td></td>
</tr>
<tr>
<td>G 5567 (75 phr paraffinic oil)</td>
<td>46 / -</td>
<td>5.1</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td><strong>Terpolymers – high unsaturation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T 6650</td>
<td>63 / 62 (125 °C) 6.5</td>
<td>53</td>
<td>25 kg (36)</td>
<td></td>
</tr>
<tr>
<td>T 9650</td>
<td>94 / 60 (150 °C) 6.5</td>
<td>53</td>
<td>25 kg (36)</td>
<td></td>
</tr>
<tr>
<td><strong>Terpolymers – very high unsaturation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G 3850</td>
<td>28 / -</td>
<td>7.8</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>G 3963 (30 phr paraffinic oil)</td>
<td>34 / -</td>
<td>9.0</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>G 5962 (25 phr paraffinic oil)</td>
<td>51 / -</td>
<td>9.0</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>G 6850</td>
<td>60 / -</td>
<td>7.7</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>G 8850</td>
<td>80 / -</td>
<td>7.7</td>
<td>25 kg (35)</td>
<td></td>
</tr>
<tr>
<td>T 6861 (15 phr paraffinic oil)</td>
<td>60 / -</td>
<td>8.0</td>
<td>25 kg (36)</td>
<td></td>
</tr>
<tr>
<td>T 4969 (100 phr paraffinic oil)</td>
<td>43 / 30 (150 °C) 10.0</td>
<td>62</td>
<td>25 kg (30)</td>
<td></td>
</tr>
<tr>
<td>T 3950</td>
<td>33 / 54 (100 °C) 11.5</td>
<td>56</td>
<td>34 kg (24)</td>
<td></td>
</tr>
</tbody>
</table>

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More detailed information concerning Buna® EP packaging and shipping can be obtained on pages 22 and 23.
Buna® EP - The Versatile Elastomer

Packaging and storage

Buna® EP rubbers are shipped in packaging on pallets or in crates made with treated wood and cardboard.

The product is normally packaged in individually wrapped bales, but certain grades such as Buna® EP T 2070 P, Buna® EP T 6470 P and Buna® EP T VP KA 8944* are supplied in pellet form.

The shelf life of EPM/EPDM is 2 years – except of Buna® EP T 2070 P: one year – and exposure to light should be strictly avoided (storage < 30°C).

More detailed information concerning Buna® EP packaging and shipping can be obtained on pages 22 and 23 and via our website: http://techcenter.lanxess.com/trp

Please choose the world region you are located in.

Polymer and vulcanizate properties

The ethylene/propylene ratio, the diene content, the molecular weight and the oil content are the principal factors influencing the properties of Buna® EP.

The Buna® EP product range comprises three main groups:

- Amorphous EPM/EPDM polymers containing approximately equal amounts of ethylene and propylene; the monomer units are randomly distributed along the polymer chains
- EPM/EPDM block polymers with an increased proportion of ethylene; some of the ethylene forms small blocks within the polymer chain; consequently, these polymers have a partially crystalline structure
- Oil-extended grades include both of the aforementioned groups; paraffinic oils are used

Within these three groups, the polymers have different diene contents and molecular weights.

All LANXESS EPM/EPDM grades contain a non-staining stabilizer.

Molecular structure

Ethylene and propylene can be polymerized to form either copolymers (EPM) or terpolymers (EPDM) when a non-conjugated diene is added. The polymer backbone is saturated. The remaining double bond of the diene is part of the side group. The saturated backbone results in the high resistance of EPDM to thermo-oxidative degradation as well as a variety of chemicals.

Influence of molecular weight and Mooney viscosity

Mooney viscosity of EPDM gives an indication of the polymer molecular weight. The Mooney viscosity can be varied within a relatively wide range during the polymerization.

In general, higher molecular weight provides the following properties:

- higher green strength at elevated temperatures
- higher capacity for filler/oil loading
- lower compression set
- better tear resistance

Polymer molecular weight has a substantial influence on the collapse resistance of extrudates at elevated temperatures. This is a property of special importance for the continuous production of extruded products.
Influence of the diene

The range of Buna® EP grades comprises both copolymers and terpolymers. Copolymers can only be crosslinked with peroxides or radiation. Terpolymers can be crosslinked both with peroxides and with sulfur. The cure rate and the crosslink density increase with increasing diene content. Terpolymers with high levels of ENB are particularly suitable for the production of profiles by pressure-less continuous vulcanization, or for co-vulcanization with diene rubbers.

Influence of the ethylene / propylene ratio

If the ethylene and propylene contents are approximately equal, both monomers within the polymer molecule are evenly distributed, meaning the rubber is amorphous.

If the ethylene content is over roughly 65 weight %, ethylene sequences form in increasing number and length. These sequences are able to form crystallites.

In the vulcanizate, the crystallinity of the polymer results in improved tensile strength and increased hardness, but also with a higher compression set at low temperatures.

Other effects of increasing ethylene content include:
- improved cold green strength
- good extrudability
- high filler and plasticizer loading capacity.

General polymer properties

General features of Buna® EP compounds which are dependent on the level and type of ingredients added to the polymer are provided in the following table as an initial guide.

<table>
<thead>
<tr>
<th>Table 2: Buna® EP basic physical data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>Density g/cm³</td>
</tr>
<tr>
<td>Specific heat kJ/kg • K</td>
</tr>
<tr>
<td>Thermal conductivity W/m • K</td>
</tr>
<tr>
<td>Thermal diffusivity cm²/s</td>
</tr>
<tr>
<td>Electrical properties</td>
</tr>
<tr>
<td>Electrical resistivity Ohm • cm</td>
</tr>
<tr>
<td>Dielectric constant r</td>
</tr>
<tr>
<td>Dissipation factor tan</td>
</tr>
<tr>
<td>Corona discharge resistance</td>
</tr>
<tr>
<td>Gas permeability</td>
</tr>
<tr>
<td>Air 10⁸ cm²/s • bar</td>
</tr>
<tr>
<td>Hydrogen 10⁸ cm²/s • bar</td>
</tr>
<tr>
<td>Nitrogen 10⁸ cm²/s • bar</td>
</tr>
<tr>
<td>Helium 10⁸ cm²/s • bar</td>
</tr>
<tr>
<td>Gas permeability rating</td>
</tr>
</tbody>
</table>
Chemical resistance

One of the most important features of properly formulated compounds based on Buna® EP is its exceptional resistance to aging and weathering i.e., to:
- oxygen
- ozone
- water
- elevated temperatures
- UV radiation to a certain degree

This, as already mentioned, is attributable to the saturated main chain of the polymer. Being a pure hydrocarbon rubber, Buna® EP is also inert to many chemicals.

Its resistance to solvents depends on their polarity. The nonpolar and inert nature of the EP(D)M grades make the vulcanizates substantially resistant to many polar media or substances containing oxygen in the molecule, such as alcohols, ketones, esters and glycols, and also to water, typical coolants and brake fluids.

The polymers are also resistant to acids and bases. EP(D)M has generally poor resistance to oils based on hydrocarbons and to fuels. However, medium oil resistance can be obtained with the oil-extended grades of very high molecular weight. High termonomer contents improve the oil resistance by permitting higher crosslink densities.

The following overviews emerge when comparing the properties of EPDM with SBR, NR, CR and NBR rubbers:

Table 3: Comparing physical properties of Buna® EP with SBR and NR

<table>
<thead>
<tr>
<th>Physical properties</th>
<th>Buna® EP</th>
<th>SBR</th>
<th>NR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity (g•cm⁻³)</td>
<td>0.86</td>
<td>0.94</td>
<td>0.93</td>
</tr>
<tr>
<td>Suitability for coloring</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Tensile strength (MPa)</td>
<td>7 – 24</td>
<td>7 – 24</td>
<td>7 – 28</td>
</tr>
<tr>
<td>Hardness (Shore A)</td>
<td>20 – 100</td>
<td>40 – 100</td>
<td>20 – 100</td>
</tr>
<tr>
<td>Tear strength</td>
<td>Good</td>
<td>Good</td>
<td>Very good</td>
</tr>
<tr>
<td>Abrasion resistance</td>
<td>Good</td>
<td>Good</td>
<td>Very good</td>
</tr>
<tr>
<td>Rebound resilience at room temperature</td>
<td>Good</td>
<td>Good</td>
<td>Very good</td>
</tr>
<tr>
<td>Rebound resilience at elevated temperature</td>
<td>Good</td>
<td>Good</td>
<td>Very good</td>
</tr>
<tr>
<td>Electrical insulation properties</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>Resistance to weathering, sunlight</td>
<td>Very good</td>
<td>Fair</td>
<td>Fair</td>
</tr>
<tr>
<td>Resistance to ozone</td>
<td>Very good</td>
<td>Fair to poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Heat resistance</td>
<td>Very good</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td>Resistance to fluids</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Mineral oils</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Polar substances: alcohols, ketones, glycols, phosphoric acid esters</td>
<td>Good to very good</td>
<td>Fair to poor</td>
<td>Fair to poor</td>
</tr>
<tr>
<td>Animal and vegetable oils</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Acids</td>
<td>Good</td>
<td>Fair to good</td>
<td>Fair to good</td>
</tr>
<tr>
<td>Swelling in Water</td>
<td>Very good</td>
<td>Good</td>
<td>Good</td>
</tr>
</tbody>
</table>
Compounding

Selection of a suitable Buna® EP Grade:
The choice is determined by the Mooney viscosity, ethylene content, and termonomer content of the polymer.

With increasing Mooney or molecular weight, the typical properties of a rubber, such as resilience, compression set and tensile strength, are improved.

On the other hand, molecular weight has a tremendous influence on the flowability of the uncured compound, so that the choice is primarily driven by processing requirements. Since the flowability decreases with increasing molecular weight, the following rule of thumb applies:

- Low viscosity EPDM grades for compounds with low plasticizer content
- High viscosity grades for compounds with high plasticizer content

In continuous curing processes, a high molecular weight grade is preferred to ensure good collapse resistance and shape retention in the uncured state, but a compromise has to be found in terms of extrudability.

The grades with high ethylene content behave more like a thermoplastic and can be more easily mixed, extruded and calendared. They give higher tensile strength values and therefore tolerate correspondingly higher filler and plasticizer loadings. Additionally, they impart higher hardness and elongation.

The content of non-conjugated diene (termonomer) influences especially the rate of cure (scorch time, cure time), compression set and the stress-strain behavior.

In continuous vulcanization processes (UHF, LCM, hot air, Ballotini) where sulfur is used as a curative, highly unsaturated EPDM grades are chosen to obtain as fast a cure rate as possible in order to provide high quality end products at high output rates.

In discontinuous processes, on the other hand, medium unsaturated grades are generally used, because here cure times can be reduced more effectively by increasing the cure temperature (autoclave, compression molding) or the processing temperature / injection rate (in injection molding).

Vulcanization chemicals

Peroxide cure:
Both EPM and EPDM can be vulcanized with organic peroxides. The choice of peroxide and coagent is important in achieving the optimum rate of cure for the processing conditions. The amount of peroxide has little influence on the rate of cure but will influence the final crosslink density. This allows the compounder to optimize such properties as:

- rebound resilience
- compression set
- modulus
- elongation at break

Peroxides give the most heat-stable crosslinks. A fairly high ratio of ethylene/propylene in the polymer contributes to the crosslinking efficiency. When the free radicals formed by the peroxide attack a propylene unit, there is a much greater tendency to break the chain than to form crosslinks. Therefore more crosslinks per mole of peroxide are formed in an EPDM with high ethylene content than in an EPDM with low ethylene content.

Sulfur-cure:
For sulfur-curing, the amount of termonomer in the EPDM polymer (unsaturation in the side chain) determines the rate of crosslinking. However even at high termonomer levels, EPDM has a lower reactivity in comparison to Natural Rubber or Butadiene Rubber, and therefore accelerators must be used to achieve cure times that are acceptable in practice. Care must be taken in designing the accelerator package, as many have limited solubility in EPDM which can result in surface blooming.

Antidegradants:
Since EPDM has a fully saturated backbone, antidegradants are not usually required for oxidative stability. However, some improvement can be obtained with LANXESS’ Vulkanox® HS (TMQ) in peroxide- or sulfur-cured vulcanizates. LANXESS’ Vulkanox® MB or MB 2 often increases the retention of elongation at break after aging. This may be important for the fulfillment of certain aging requirements.

Fillers:
EPDM rubbers, in comparison to general purpose or specialty rubbers, have an excellent capacity for high loadings of filler/oil. The rubber content in compounds is frequently as low as 25-30 %. Carbon black is the most commonly used filler for EPDM because the reinforcing effect and processing behavior are combined in a particularly advantageous manner, but EPDM can also accept high levels of light colored fillers.

The polymer grade and, above all, the molecular weight determine the filler loading that can be easily incorporated. Oil-extended grades have the highest molecular weights and are able to accept the highest filler loadings.
With the same molecular weight, polymers of higher ethylene content permit the use of higher filler loadings than do those of lower ethylene content.

**Processing and vulcanization**

**Mixing**

Internal mixer:
For mixing EPDM, the internal mixer is most suitable due to the high loading levels. The batch size is critical for optimization of the mixing cycle. The recommended fill factor is 80-85 %, which is slightly larger than for most rubbers, but may vary depending on the degree of loading and the hardness of the compound.

For grades with higher molecular weights, the preferred speed is 25-35 rpm in reference to a medium sized production mixer. This gives optimum dispersion of the filler, especially in highly loaded compounds.

An upside-down cycle is recommended as the standard technique. Here the carbon black and oil are added first, followed by the polymer. Single stage mixing, with a maximum temperature at dumping of about 110 °C, is usual. If this temperature is exceeded, the vulcanization chemical must be added in a second mixing stage or on the open mixing mill.

**Mill Mixing:**

The oil-extended grades are best suited for mill mixing because band formation occurs immediately. Here, too, EPDM grades with higher molecular weight and those with higher ethylene content easily accept large quantities of fillers and are therefore easy to handle. Further, part of the appropriate filler masterbatch (10-15 %) can be added at the beginning of the mixing cycle. If the batch changes over to the faster back roll, it can be brought back onto the front roll, if necessary, by lowering the temperature.

**Processing of compounds**

**Extrusion:**

The majority of EPDM extrusion compounds are continuously cured. High molecular weight polymers yield compounds which have superior dimensional stability.

The following comments can be made concerning compound design and the selection of polymer grades for extrusion compounds:

a) For compounds of 25-55 Shore A:
- high Mooney viscosity (oil-extended polymers)
- high oil loading
- medium to high ethylene content
- high ENB content
b) For compounds of 55-70 Shore A:
- high Mooney viscosity
- medium ethylene content
- medium to high ENB content

Plasticizers:
In EPDM, processing oils are used to adjust the hardness and modulus of the vulcanizate and to improve the flow behavior and extrusion properties. Normally paraffinic mineral oils and also, if necessary, naphthenic mineral oils are used to plasticize EPDM compounds. Phosphoric acid esters and chlorinated hydrocarbons are occasionally incorporated to improve the flame resistance. Low quantities (below 10 phr) are used.

For optimum heat resistance, process oils with relatively high paraffinic contents are used. Other additives, such as paraffin waxes of low molecular weight, polyethylene and polybutene, can also be used as process aids. As with fillers, the EPDM grades of higher molecular weight tolerate higher plasticizer loadings. This is particularly important in the formulation of compounds of low hardness where a high compound viscosity is required to prevent porosity. High viscosity oils are preferable here.
c) For compounds of 70-95 Shore A:
- low Mooney viscosity
- highest ethylene content
- medium degree of unsaturation

EPDM compounds can be cured continuously in
- microwave / hot air units,
- steam,
- fluidized beds, or
- salt baths

Calendering:
EPDM compounds calender easily, resulting in smooth and attractive surfaces and good dimensional stability. An essential condition is a medium to high roll temperature. Control of the compound viscosity and temperature is very important for maintenance of the thickness of the sheet.
In general, the following should be watched out for:
- Excessive heat loss must be avoided when the viscosity is low
- Heat build-up must be avoided when the viscosity is high

Molding:
EPDM compounds of low viscosity have good flow behavior and therefore can be molded to complicated shapes by
- compression molding
- transfer molding
- injection molding

The feed strips for injection molding must have good green strength to ensure good feed behavior. Additionally, a relatively high ethylene content improves the flow behavior and remolding properties. The reversion resistance of the material permits high cure temperatures and therefore short cure cycles.

Bonding of EPDM to other materials:
Some applications require rubber to metal bonding. EPDM has no polar groups or groups with high electron density and therefore can be difficult to bond to metals or other substrates. To overcome this problem, LANXESS has developed maleic anhydride-grafted EPDM grades. These Buna® EP XT grades have maleic anhydride groups grafted to the polymer backbone. When blended into an EPDM compound at low levels (e.g., 10 phr), the XT grades afford improved adhesion to metals, minerals, and polymers such as nylon and polyester.
Versatility in Various Markets - Typical Applications of Buna® EP
Applications

Markets using the Buna® EP range, are as follows:
- Aerospace
- Appliances
- Automotive
- Construction
- Consumer Goods
- Electronics
- Food Applications
- Footwear
- Industrial Applications
- Oil
- Packaging
- Plastics
- Sporting Goods
- Wire & Cable
- Others

Plastics modification

Typical Buna® EP-modified plastics applications are bumpers, bottles, boxes, toys and films. EPM/EPDM polymers are increasingly used as impact modifiers for plastics such as polyolefins. These thermoplastic olefins (TPO) exhibit superior flexibility and impact strength.

The rubber fraction in the blend is usually kept to a minimum - at most 40% - to maintain the plastic’s other physical properties and processing characteristics.

In plastic-modified rubber, thermoplastic elastomers (TPE) or thermoplastic vulcanizates (TPV), EPM/EPDM is the main component and is responsible for the required physical properties of the end product.

The elastomer component should provide:
- Maximum elastic properties improvement per unit volume
- Efficient vulcanization
- Contribute to a uniform dispersion of small, highly cross-linked particles
- Allow the compound designer full freedom in color selection

TPEs provide functional performance and properties similar to conventional thermoset rubber products, but can be processed with the speed, efficiency and economy of thermoplastics.

The plastic phase imparts stiffness to the blends, enables plastic-like processing and recyclability, and eliminates the need for vulcanization. Buna® EP / polyolefin blends are finding growing applications in areas such as automotive parts, consumer products, wire and cable, building construction and mechanical goods. The automotive sector is currently the largest market for these materials. Examples include soft exterior parts, such as fascia covers, air dams, body side moldings, window and body seals.
Buna® EP - The Versatile Elastomer

Automotive industry

This is by far the largest application segment, ranging from solid and sponge automotive body sealing to "under the hood" applications like coolant hoses and tubes.

The majority of the extruded profiles are made by pressure-less continuous cure. For these products the emphasis is on requirements such as low compression set and good retention of heat-aged physical properties. Based on the need for higher end product reliability and extended service life, there is a growing demand for better surface finish.

The product should be free from porosity, fast curing, and should adhere well to textile flock and metal. High modulus is required for optimum sealing force, to prevent leakage through window surrounds and to minimize wind noise from window seals.

The growing demand for nitrosamine-free compounding prompted the need for faster curing EPDM types that should allow the formulation of cure systems which are free from bloom and iridescence.

Building industry

Since the 1980s, EPDM has shown a spectacular growth pattern in the field of single ply roofing sheets, particularly in the USA. The use of a thin flexible membrane to replace traditional asphalt materials represents a considerable technological advance, and improves long term performance. Membrane technology has been directed towards developing a single grade suitable for general use in different climates and roofing constructions. The basis is a low modulus, high molecular weight EPDM compound, with excellent tear resistance to accommodate service stresses.

Due to their superior water, ozone and weathering resistance, such membranes have proven longevity, and are endorsed by a track record over 25 years.

Since vulcanization takes place in pressure-less continuous curing machines, high molecular weight EPDM provides good collapse or distortion resistance during the curing step. Glazing gaskets and building profiles must retain high elastic sealing forces over a wide temperature range. To withstand strong wind forces, low compression set requirements need to be met.

Other typical applications include expansion joints, solar panel tubing, sound insulation wall panels, bridge bearing pads and rubber tiles for playgrounds.
Technical goods

Due to the great application versatility of Buna® EP, a broad spectrum of diverse requirements can be met. The below mentions only a few technical goods applications:

- washing machine gaskets
- potable water seals
- valve and tank linings
- roll coverings
- hoses and tubes
- conveyors
- floor tiles

Electrical industry

Buna® EP can be especially used in the following wire & cable industry applications:

- low and medium voltage cables and
transmission and distribution:
  - connectors
  - arrestors
  - relays
Buna® EP – The Versatile Elastomer

About LANXESS

LANXESS is one the world's leading manufacturers of performance and fine chemicals, synthetic rubber, and plastics.

Our core functions include the development, production, and marketing of chemicals, rubbers, and plastics. LANXESS serves a broad range of markets including: Automotive, Construction, Housing, Electronic, Wood and Furniture, Medical Engineering, Footwear, Sports and Leisure, Textiles and Clothing, Packaging, and more.

LANXESS operations have a long history, rich with a tradition of research and discovery. The company's roots go back to 1863, the year Bayer was founded. In 2004, during its reorganization, Bayer AG combined most of its chemical activities and approximately one-third of its polymer activities into a new stand alone company named LANXESS.

We have roughly 18,000 employees at 50 international production sites and offices in all major regions to ensure we can offer our business partners the best possible service on the world’s markets.

For more information please visit the Internet at:

2005 Sales for LANXESS were approximately 7.1 Billion Euros.

Our global LANXESS Web site is: http://www.lanxess.com/lcs/en/

Our LANXESS Corporation (USA) Web site is:
http://us.lanxess.com/

LANXESS has a streamlined organizational structure to make it flexible and dynamic. Our structure and business activities are geared to market needs, ensuring that we have the speed and flexibility to continue offering customers top-quality products supported by excellent service.

For more information please visit:

The parent company of the conglomerate LANXESS is a publicly traded company listed on the Frankfurt Stock Exchange. For more information please visit:
Make use of our experience!

Talk to us! Whether it’s technical details or new product ideas you need, our experts will be at your side from development right through to full-scale production. From individual recipe recommendations to on-site advice. We think of ourselves not just as suppliers, but as an active partner to our customers. We’ve been providing this service throughout the world for over 90 years. Make use of all this experience in research and practical applications – get in touch today!

Please direct any questions on Buna® EP from LANXESS to one of the following addresses or contact your regional sales office at: www.sales-offices-trp.lanxess.com

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**Table 4: Buna® EP packaging units**

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Exceptions: in 20’-container: T 6470 = 6 pallets; T 6650, T 6861, T 9650 = 7 pallets; T 6470 P = 8 pallets
in 40’-container: T 6470, T 6650, T 6861, T 9650 = 14 pallets; T 6470 P = 18 pallets.

| G 2050 | 20                                     | 12.5                                      | 42                                     | 26.3                                      | 42                                | 26.3                                 | 24                                               |
| G 2440 | 10                                     | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 2470 | 10                                     | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 2470 LM | 10                                      | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 3440 | 10                                     | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 3440 F | 10                                      | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 3473 | 10                                     | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 3569 LF | 10                                      | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 3850 | 10                                     | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 3963 | 10                                     | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 5450 | 10                                     | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 5450 F | 10                                      | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 5455 | 10                                     | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 5567 | 10                                     | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 5962 | 10                                     | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 6170 | 10                                     | 6.0                                       | 21                                     | 12.6                                      | 21                                | 12.6                                 | 24                                               |
| G 6170 C | 10                                      | 3.2                                       | 21                                     | 6.7                                       | 21                                | 6.7                                   | 24                                               |
| G 6470 | 10                                     | 6.0                                       | 21                                     | 12.6                                      | 21                                | 12.6                                 | 24                                               |
| G 6850 | 10                                     | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 8450 | 10                                     | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |
| G 8460 | 10                                     | 6.0                                       | 21                                     | 12.6                                      | 21                                | 12.6                                 | 24                                               |
| G 8850 | 10                                     | 8.8                                       | 21                                     | 18.4                                      | 21                                | 18.4                                 | 24                                               |

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