Borecene™ Processing Guide
About Borealis

Borealis is a leading provider of innovative, value creating plastics solutions. With more than 40 years of experience in the polyethylene (PE) and polypropylene (PP) business, we focus on pipe systems, energy and communications cables, automotive and advanced packaging markets. We are strong in Europe and growing in the Middle East and Asia-Pacific through Borouge, our joint venture with the Abu Dhabi National Oil Company (ADNOC). Our technology shapes plastic products that make an essential contribution to the society in which we live. We are committed to lead the way in ‘Shaping the Future with Plastics’.

With EUR 5 billion revenue in sales and 4,500 employees, Borealis is headquartered in Vienna, Austria with innovation centres, customer service centres, and main production sites in Europe and the Middle East. Borealis has representative offices and operations in Asia, North and South America.

At its heart, the company’s four values of Responsible, Respect, Exceed and Nimblicity™, define its way of doing business. For Borealis, success is achieving value creation through innovation.

Borstar® is Borealis’ proprietary technology supporting differentiated PE and PP products. Borstar and is a registered trademark of Borealis AG.

Learn more about us at www.borealisgroup.com
Contents

02 Borecene: an advanced new polymer technology
03 Borecene processing
08 Cooling of Borecene
10 Grinding optimisation of Borecene
11 Colouring of Borecene
12 Other items of importance
13 Borecene: the latest catalyst technology
14 Simplified material handling
15 Significant materials savings
16 Solutions for rotational moulding applications

Courtesy of Valtra
The rotational moulding market is developing rapidly, both technically and in volume terms. Converters are looking for better and more competitive ways of production, and for improved material properties. To contribute to market advancement, Borealis has developed a new polymer technology, Borecene and Borecene Compact, the third generation of polyethylenes for the rotomoulding industry.

**History in the making**

The rotational moulding process was first developed commercially in the 1940s for use with PVC plastisols. Use of the process developed little in the early years, being regarded as a relatively slow method with limited material selection and product shape possibilities.

Rotational moulding differs from all other processing methods in that the heating, melting, shaping, and cooling stages all occur after the polymer is placed in the mould, and no external pressure is applied during forming. This brings a number of advantages; rotomoulded products are thought to be stress-free, there are no weld lines, large products can be produced very economically, mould costs are relatively low, and designers have extra freedom in regard to shape.

**Borecene advantages**

- Improved mechanical properties
  - Improved impact strength
  - Improved creep properties, particularly at higher temperatures
  - Weight reduction potential
  - Excellent ratio between mechanical properties and melt flow rate
  - Barrier properties
- Reduced cycle time
  - Easier flow of the polymer
  - Faster sintering
  - Earlier demoulding
  - Potential for productivity increase
- Broader processing window
  - White colour
  - Reaches optimum mechanical properties faster
  - Less susceptible to overcooking
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**Figure 1: Rotomoulding evolution**

- Borecene Compact
- Borecene - 3rd generation PE
- LLDPE - 2nd generation PE
- LDPE - 1st generation PE
- PVC plastisols


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Borecene processing

Phase 1: Heating, melting and material distribution

In figure 2 the Rotolog curve shows inner air temperature in the mould during the different process phases.

In phase 1 of the rotational moulding process, the mould and material temperature increase as a function of the oven temperature. This is illustrated on the Rotolog curve as a steep angle increase (figure 3, A-B).

The temperature rapidly increases in both the polymer powder and the surrounding air as long as no phase change occurs in the polymer.

According to thermodynamic principles, the consumption of energy is relatively low for a material remaining in the same phase while the temperature increases due to heating. Borecene and standard materials behave similarly in this early heating phase of the moulding process. However, while standard material starts to melt at approximately 75°C internal air temperature (figure 3, point B) measured using a Rotolog, the uniform Borecene material remains as a solid, free flowing powder.

Optimising of processing conditions for Borecene is very dependent on type of rotomoulding machine used, machine settings, mould, mould material etc. Therefore only these general guidelines are given. If more detailed advice is required, please contact your Borealis Technical Service representative.

Guidelines for phase 1
- Increase oven temperature
- Increase rotation speed
- Optimise rotation ratio

Borecene
- Heating (A to B)
- Melting and material distribution (B to D)
- Peak inner air temperature (E)
- Sintering (D to F)
- Cooling (E to G)
Melting of standard material

When the inside of the mould wall reaches the temperature at which the polymer powder first starts to melt and become sticky, the smallest particles will begin to adhere to the mould surface. A thin layer of molten polymer builds up, which immediately increases the energy consumption (illustrated by the Rotolog curve flattening out, figure 4, B-C). When a layer of partly molten powder is sticking to the mould surface, the heat transfer to this thin layer increases and the powder continues to melt.

This initial molten polymer layer insulates the remaining powder from direct contact with the mould wall, but as this initial layer becomes completely molten the remaining powder will start to stick to this polymer layer. The main bulk of the powder in the mould has still not reached its main melting temperature and therefore the temperature measured by Rotolog increases more slowly than for Borecene (figure 4, B-C).

Once the powder reaches the main melting temperature, the bulk of the powder melts. Most of the heat is used for melting and the internal air temperature increases more slowly (figure 5, C-D). At this point the process proceeds more quickly. The amount of powder sticking to the wet polymer surface accelerates every time the powder pool is exposed to a new part of the mould. Energy consumption is now at its maximum and there is almost no temperature increase in the mould or melt. All the energy transferred to the mould/melt is used for melting the polymer. When all the powder has melted, the internal air temperature starts to increase rapidly again. This is the onset of the sintering phase (figure 5, point D).
Melting of Borecene

The Rotolog curve in figure 2 shows that while the powder remains solid at the beginning of the heating phase, the internal air temperature increases at the same rate for Borecene as for standard material. However, Borecene powder does not start to become sticky until about 90°C. This is shown in the Rotolog curve as the temperature continues to rise faster than with conventional materials up to approximately 90°C (figure 2, point C). The temperature does not flatten out at 75°C, as with standard material. When Borecene powder becomes sticky at about 90°C, the internal air temperature is then so high that a large proportion of the uniform Borecene powder will quickly melt. Consequently the build-up of polymer on the mould surface occurs rapidly.

Due to its uniform molecular structure Borecene starts to melt at a higher temperature and after onset, melting is quicker than for conventional materials.

Optimisation for Borecene

In order to achieve the desired even wall thickness in the finished article, the rapid melting of Borecene compared to standard material should be taken into account.

Increase the rotation speed and optimise the rotation ratio

To minimise the residence time of the powder pool in critical areas an increased rotation speed will also assist even distribution of material in the mould.

With insufficient rotation speeds and an unoptimised rotation ratio, uneven material distribution can occur. If the residence time is too long in a given part of the mould, especially where the mould wall is thick, material build-up will occur faster for Borecene. This is because the powder temperature is higher before Borecene begins to melt, and the energy conserved in the thick part of the mould will then sustain the melting process more easily for Borecene than for standard material. The unwanted result can then be a thicker wall in these areas of the moulded product.

Figure 6: Influence of rotation ratio and speed on material distribution

Compared to standard materials
Borecene shows:
• A narrower melting range
• Onset of polymer melting at a higher temperature

This influences the melting behaviour of the polymer in the rotational moulding process.
Phase 2: Sintering

Sintering begins as soon as the powder particles have melted completely. At this point the internal air temperature has reached approximately 130°C (figure 7, point D). However, the most effective part of sintering occurs at higher temperature, because the molten polymer then flows more easily. For Borecene effective sintering begins at a lower air temperature because the viscosity of the molten polymer is lower, thereby facilitating the flow of Borecene compared to standard materials. This is illustrated in figure 8.

During the first part of the sintering phase the heating continues and both the internal air temperature and the temperature of the polymer melt continue to rise. Because of the lower viscosity and easier flow of molten Borecene, an even distribution of polymer in the mould will be achieved at a lower temperature, allowing the heating to be stopped earlier for Borecene than for standard materials. This results in excellent sintering at lower air peak temperatures, thereby saving energy as well as shortening the overall heating time in the oven.

For Borecene MFR6 material it is possible to stop the heating at a temperature of about 165°C, while for standard materials heating normally needs to be continued to a temperature of 185°C (figure 7, point E).

The sintering will continue through the first part of the cooling cycle until crystallisation starts (figure 7, point F).
Phase 3: Cooling and demoulding

**Guidelines for phase 3**
- Slow cooling, especially after crystallisation of the material has started
- Even cooling
- Slow and even release from mould
- Internal cooling to achieve even cooling

Cooling has a very important effect both on cycle times and product quality. Modern rotational moulding machines are therefore equipped with combinations of water jets, spray mists and compressed air to cool the mould. For Borecene, where crystallisation is faster than for standard material, controlled cooling is essential.
Even cooling is very important in order to avoid internal differences in degree of crystallisation in the final product. Even wall thickness of the moulding is an important feature which will help to achieve even cooling.

Avoid water cooling during the crystallisation phase. Most shrinkage occurs when the polymer crystallises or freezes in the mould. If cooling is rapid at this point (figure 11, point F - G), the potential for encountering warpage is high.
Internal cooling

Use of internal cooling is beneficial for maintaining even cooling and even crystallisation through the whole mould wall.

Demoulding of Borecene

Borecene materials become stiff and reach dimensional tolerances at a higher temperature than conventional materials. Demoulding therefore can take place earlier and substantial reductions in cycle time can be realised. After the end product has been removed, cooling by ambient air should be as even as possible. Placing the end product on a cold surface, immediately after demoulding is discouraged.

After cooling

When the product is taken out of the mould, attention should be given to how the product should be further cooled.

The outside temperature of the product should be between 90 and 100°C when demoulding. However in rotational moulding the products usually have a large wall thickness, in which case the internal temperature of the product will be much higher (for 12 - 14 mm walls sometimes still close to the melt phase!). In the after-cooling stage it is important with Borecene that an equilibrium is achieved in the cooling speed.

The product is cooled only on the outside when still in the mould in the cooling chamber of the machine. So the inside needs to be cooled more during the after-cooling stage to balance the cooling.

Controlled air flow through the inside of the product helps to achieve this balance in cooling. Attention should be given to making the after-cooling as constant as possible during production. Blowing up the product and jigging do not help to balance cooling.

Only large flat surfaces which tend to sag under their own weight need to be supported with a slight internal pressure, but even in this case a slight air flow is still necessary.
Grinding optimisation of Borecene

Feeding
The feeding of the grinder is the main influencer of output. High feeding gives high output, but it should be noted that high feeding may lead to high frictional heat and blocking of the knives.

Knives
The knives are normally composed of one static and one rotating plate that are conical in form and facing each other. The pellets, which are fed from the centre, are “thrown” onto the plates, whose distance apart becomes increasingly narrow.

Typical distances between the knives are 0.45 – 0.55 mm. The temperature should be approx. 80°C ± 10°C, depending on the point of measurement. If the temperature is measured close to the outlet, then it should be a little higher.

Sieves
The powder is blown from the mill into the sieves, which differ in number depending on the grinder. The two largest screens are approx. 0.55 and 0.6 mm. Particles that are too large are returned to the mill or to a secondary mill.

Troubleshooting

Improper dry flow
The usual cause is hairy particles, which easily stick to each other and block the funnel. Borecene is a little harder to grind so the knives must be very sharp. The temperature can also be increased to make the particles less hairy.

Too much fines
Increase the distance between the knives.

Too many large particles
Decrease the gap between the knives or choose a smaller sieve. Sometimes the large particles are hairy particles. In this case increase the temperature or sharpen the knives.

Lumps
Decrease the temperature or increase cooling after mill outlet (if possible).

Insufficient output
This is the trickiest problem to solve but by fine-tuning feeding, temperature, knife distance and sieve size it is possible to increase output to an acceptable level.
As with standard material, a coloured Borecene product can be made either by using a coloured compound, or by dry blending with colour pigments or a masterbatch. The best quality is obtained with the former method, which not only gives the most homogeneous colour but also the best mechanical properties in the formed item.

However, good quality colouring can also be achieved through dry blending. As with standard materials, pigments which are stable in the rotational moulding process should be used. Their selection is also based on the need for adequate pigment dispersion throughout the formed item.

Borecene can generally use the same pigments as conventional PEs. However, it is recommended to initially monitor the performance of the coloured product in order to avoid unwanted negative effects between the pigment and the polymer.

Some pigments may have a strong involuntary coloured effect that could reduce mechanical strength of product. Details regarding pigments can be supplied by the pigment manufacturer.
**Other items of importance**

**Release agents**
Experience has shown that agents providing slow release operate the best. This is because the solid resin pulls away from the mould surface as late as possible, allowing more even cooling and less time for the item to warp. Situations where the solid resin is freed from the mould surface in some places while being held in others is thus avoided. Both water based agents and solvent based systems can be used. Teflon coating can also be utilised.

**Spider positioning**
As with the processing of conventional materials, the position of the mould on the arm, or spider, is critical for Borecene. If the mould is too close to the arm there is a tendency for hot spots to be generated. This can cause differences in polymer wall build-up. The way the mould is mounted is also critical. This should be done in a manner which ensures that all parts of the mould experience the same heating and cooling patterns. This allows the polymer to be laid down equally over all parts of the mould.

**Mould material**
Moulds can be manufactured from aluminium or steel. The mould surface is important: polished surfaces allowing early release can be sensitive.
**Borecene: the latest catalyst technology**

The key to Borecene’s long list of advantages is the new generation polyethylene catalyst – the metallocene catalyst. Borealis Borecene polymers are characterised by a very narrow molecular weight distribution, an even comonomer distribution and optimised rheological properties such as low zero shear viscosity. Single site/metallocene catalysts open up the possibility of controlling polymerisation in a more efficient and easier way.

**Metalocene PE polymers for rotomoulding were introduced by Borealis**

![Figure 16: Side chain incorporation is more uniform with Borecene compared to standard material, giving more uniform melting](image1)

**Improved mechanical properties**

**Higher impact strength**

Borecene has better impact performance, achieved after shorter curing times. It is still superior to standard PE even when optimal cure for the standard grades is used. Consequently Borecene is less critical to ‘over-cooking’. Furthermore, tests have shown that Borecene can tolerate some wall bubbles at low cure time yet retain its impact performance.

**Borecene: greater strength in shorter curing times**

![Figure 18: Better impact performance with Borecene](image2)
**Simplified material handling**

**Less resin complexity**

The combination of physical properties and improved flow properties avoids the traditional drop-off in properties – an MFR6 Borecene grade performs at least as well as standard PE MFR3 grades. The same resin can thus be used in a variety of different applications, simplifying materials handling requirements or inventory management.

**How an MFR6 Borecene grade compares**

![Bar chart comparing strength N/mm for Borecene MFR6, PE MFR3.6, PE MFR3.4, and C8 MFR4](image)

*Figure 19: High speed impact, -20°C on rotomoulded samples optimal cooking time (14 min)*

(Courtesy of Uponor)
**Lightweighting potential**

Borecene displays improved behaviour under constant load (creep). This, together with the general improvement in mechanical properties, provides the potential to significantly reduce wall thickness and so decrease the weight of most rotomoulded articles. An even wall thickness distribution due to the material’s flow properties further facilitates lightweighting potential. Tests have shown that wall thickness reductions of 10-20% have been possible in applications such as underground tanks. Such reductions clearly assist in reducing cycle times.

**Borecene: enables increased service temperature or reduced article weight**

![Figure 20: Performance at elevated temperatures](image)

- Borecene Density 940, MFR4
- Borecene Density 934, MFR6
- Std. Density 934, MFR3.6
Solutions for rotational moulding applications

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<th>Product name</th>
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<th>Density (kg/m³)</th>
<th>Tensile modulus (MPa)</th>
<th>Stress at Yield 2% (MPa)</th>
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<td>940</td>
<td>700</td>
<td>20</td>
<td>92</td>
<td>68</td>
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<td>86</td>
<td>58</td>
<td>Very good combination of properties. Versatile usage 4</td>
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<td>20</td>
<td>82</td>
<td>65</td>
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<td>Black versions of ME8185/ME8152. Very good combination of properties. Versatile usage 4</td>
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1. Base resin density
2. To maximize the application benefits Borecene products in Rotational Moulding, utilize the recommended processing conditions stated in the Borecene and Borecene Compact Processing Guide.
3. WRC/WRAS approved for contact with drinking water.
4. UV stabilisers and antioxidants

All Borecene grades for Rotational Moulding are UV stabilised. The black grades listed above are extra UV stabilised with Carbon Black. Borecene RM7402/RM7403 contains less than 1% Carbon Black. Borecene RM8342/RM8343 contains 1%. Carbon Black. RL7382 and RL7383 are extra UV stabilised and are to be considered as UV according to ISO 11803-2. Borecene knows that external factors like processing, pigmentation, article design, atmospheric conditions, etc. may influence mechanical performance and UV lifetime of articles made of polyethylene products. Borecene can therefore not guarantee the product lifetime of articles made of Borecene products, and the final lifetime must therefore be verified and guaranteed by the converter towards the end-user.

Ultrapolymers is a major European distributor in the field of commodities, engineering and specialty polymers. With sales offices and warehouses throughout Europe, Turkey and South Africa Ultrapolymers established a commercial network with local presence to serve its suppliers in the best possible way and to offer a full product portfolio to its customers and quickly deliver any quantity from 1 bag to a full truckload. Ultrapolymers has also become a leading, involved provider of plastics solutions with a long-term commitment to the rotomoulding market in Europe.
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Borealis Business Unit Moulding specialises in supplying advanced polyolefin plastics for injection, rotational moulding and blow moulding processing technologies. Through leading Borealis technologies such as Borstar®, and BNT (Borealis Nucleation Technology) and a product portfolio for a wide range of applications like bottles, thin wall packaging, caps and closures, transport packaging, houseware and healthcare, Borealis has over 40 years established a leading position on the moulding market across Europe.

Borealis believes that customer-driven innovation is the only way to achieve and sustain progress. In the moulding industry, Borealis has pioneered the development of several leading edge solutions. For example, low temperature impact, transparent polyolefins have opened up new opportunities in deep freeze display packaging. In the ISBM segment, biaxially oriented PP has reduced the weight and increased the transparency of bottles. Through foresight and focus on customer needs, Borealis continues to provide innovative solutions for the moulding industry that add real value throughout the value chain.

We know the high value that our customers in the moulding industry place on product consistency and processability. We pride ourselves on the performance of our products, and through ongoing investment in upgrades and new plant programmes, we continue to set new records for output efficiency and product reliability.

Borealis believes that responsiveness is the foundation of fruitful customer partnerships. Business Unit Moulding ensures this through the resources of strategically placed Borealis hubs across Europe: Borealis Scandinavia, Borealis Central Europe, Borealis Belgium and Borealis Finland, an innovation centre at Borealis Scandinavia in Bamble, Norway, and a strong sales force across Europe.

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