ARCEL™
ADVANCED FOAM RESIN

# Expansion and Molding Guide

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NOVA Chemicals

# INTRODUCTION

NOVA Chemicals manufactures ARCEL resins at its North American facility located in Beaver Valley (Monaca), Pennsylvania and also in Ningbo, China, near Shanghai, which is operated under a long-term manufacturing agreement with Loyal Chemical Industrial Corporation. The Beaver Valley and Ningbo sites are certified under the International Organization for Standardization (ISO) 9001 quality standard. The Beaver Valley site is also certified under the ISO 14001 environmental standard. Supporting the manufacturing and sales of our products is our technology center at Beaver Valley, which also hosts a pilot demonstration plant. NOVA Chemicals has sales offices located throughout the world.

NOVA Chemicals' ARCEL resin consists of small spherical beads (primarily polystyrene and ethylene vinyl acetate copolymer) typically 0.03 - 0.08 inches (0.8 - 2.0 mm) in unexpanded diameter. ARCEL resin contains 5% - 12% by weight of isopentane; a volatile, flammable blowing agent. The pentane concentration may vary for developmental products, new products, and off-spec materials.

As a Responsible Care® company, NOVA Chemicals works to ensure the safest possible management of chemical products throughout their life cycle from the planning of new products through their manufacture, distribution, use and ultimate disposal. In support of our Responsible Care commitment, NOVA Chemicals has compiled this document as a general guide to help our customers safely handle, store and process our ARCEL resin. The information provided in this Guide is believed to be accurate as of the publication date of this Guide. NOVA Chemicals does not warrant or represent the information given to be accurate or complete, and expressly disclaims all implied warranties and conditions including those of merchantability and fitness of product(s) for a particular purpose. The information contained herein is subject to change without notice and NOVA Chemicals disclaims any obligation to update the information contained herein. Responsibility for use, transportation, storage, processing, handling and disposal of the products described herein is that of the purchaser or end user.

This Guide is intended for use in conjunction with NOVA Chemicals' Material Safety Data Sheet (MSDS) for ARCEL resin. Essential information relating to the safe handling, transporting, storing and use of ARCEL resin is detailed in the MSDS. It is important to note that government legislation/regulations and industry standards/codes for building, fire protection/prevention, environment, health and safety, processing, use and transporting of products such as ARCEL resin must always be observed. Certain information prescribed by government regulations is summarized on the MSDS. For an up-to-date MSDS, please contact NOVA Chemicals at 1-412-490-4063 or via e-mail at msdsemail@novachem.com . This document is intended as a general guide to processing ARCEL resins.

## Single Pass Continuous Expansion

Single pass continuous expansion can be performed with expanders ranging in size from 55 to 300 gallons (200 to 1100 L). Properly ground all equipment and make sure the expansion area is well ventilated (see Hazards section in NOVA Chemicals' ARCEL resin *Storage and Handling Safety Guide*). To ensure a continuous flow of ARCEL resin raw bead to the expander, inspect the hopper loader and inlet feed systems for restrictions that would impede raw bead flow. This step is important since ARCEL resin raw beads are large and somewhat wet.

To insure the expandability, remove from refrigerated storage only the amount of unexpanded ARCEL resin that will be expanded within several hours. Prolonged exposure of the unexpanded ARCEL resin to temperatures above 40°F (4°C) will adversely affect expandability as a result of loss of the isopentane blowing agent.

Pre-heat the expander for several minutes before starting the feed system. In most cases, the target density is the lowest attainable density. The following table details anticipated densities for various operating conditions. Use the values only as a guide because conditions vary from plant to plant.

| **55 to 300 GALLON EXPANDER (200 to 1100 L)** | **ARCEL 730 Resin** | **ARCEL 730LV Resin** |
|---|---|---|
| **FEEDRATE** | | |
| lb/hr | 400 to 1000 | 300 to 700 |
| kg/hr | 180 to 450 | 135 to 320 |
| **MINIMUM FRESH DENSITY** | | |
| pcf | 1.3 to 1.5 | 2.00 to 2.20 |
| g/l | 21 to 24 | 32 to 35 |
| **MINIMUM AGED DENSITY** | | |
| pcf | 1.4 to 1.6 | 2.10 to 2.20 |
| g/l | 22 to 26 | 34 to 35 |
| **STEAM TEMPERATURE** | 212°F (100°C) | 212°F (100°C) |

Note: Minimum indicated densities assume that freshly expanded ARCEL resin particles are not subjected to excessive thermal or mechanical shock.

Freshly expanded ARCEL resin exhibits a higher degree of prepuff shrinkage than EPS resins. As a result, it is very easy to over-expand ARCEL resin. Shrinkage is controllable to some extent. Expander conditions (feedrate, inlet steam pressure and expander temperature) should be adjusted to yield the lowest possible density with the least amount of prepuff shrinkage. Typically, this can be accomplished by targeting a freshly expanded ARCEL resin density no lower than 0.2 to 0.3 pcf (3 to 5 g/l) below desired aged density.

Do not be deceived by the capability of ARCEL resin to expand to very low fresh densities. In most cases, expansion of ARCEL resin to very low fresh densities will result in aged densities well above those that are expected because of increased prepuff shrinkage and densification. If lower density is required, double pass expansion should be considered. Double pass expansion is detailed in another section of this *Expansion and Molding Guide*.

Post expansion, prepuff shrinkage is density related. As the aged target density increases, post expansion shrinkage decreases. When the target density approaches 2.5 pcf (40 g/l) and above, very little post expansion shrinkage occurs. The fresh density target should be adjusted to account for this difference.

Freshly expanded ARCEL resin is not only sensitive to the over expansion possible during pre-expansion, but also the thermal and mechanical shock that may be encountered in air conveying systems. Air conveying freshly expanded low density ARCEL resin can increase density as much as 0.2 to 0.6 pcf (5 to 10 gms/l) depending on fresh density, conveyor length and complexity and operating conditions.

If minimum density is desired, minimize mechanical shock through proper air conveyor design, use of heated air or double pass expansion of the resin. In many cases, depending on density, ARCEL 730 resin will tolerate immediate air conveyance with only a minor increase in density. Freshly expanded ARCEL resin particles should be collected in open containers or vented storage bags and allowed to cool at least several hours. Once conditioned, the tough particles are no longer sensitive to the mechanical forces encountered in traditional conveying equipment. ARCEL resin can be immediately air conveyed if the conveying system uses heated air. Contact your technical service representative for details concerning the design and operation of such a system.

## Double Pass Expansion

Although ARCEL advanced foam resin can be single pass or batch expanded to relatively low densities, there are instances and applications where even lower densities are desired.

The following table lists the densities that can be attained with ARCEL resin under ideal conditions, illustrating the benefits of double-pass expansion:

| DENSITIES | ARCEL 730 Resin | ARCEL 730LV Resin |
|---|---|---|
| **SINGLE PASS FRESH** | | |
| pcf | 1.3 to 1.5 | 2.00 to 2.20 |
| g/l | 21 to 24 | 32 to 35 |
| **SINGLE PASS AGED** | | |
| pcf | 1.4 to 1.6 | 2.10 to 2.20 |
| g/l | 22 to 26 | 34 to 35 |
| **DOUBLE PASS FRESH** | | |
| pcf | 1.00 – 1.10 | 1.70 – 1.80 |
| g/l | 16 – 18 | 27 – 29 |
| **DOUBLE PASS AGED** | | |
| pcf | 1.10 – 1.20 | 1.80 – 1.90 |
| g/l | 18 - 19 | 29 - 30 |

Attaining the above densities assumes that the freshly expanded ARCEL resin particles are not subjected to severe thermal or mechanical shock. A processing benefit of double pass expansion is the reduced sensitivity of freshly expanded particles to the rigors of air conveying. A benefit associated with processing ARCEL 730LV resin is the lower isopentane level, which translates into easier processing at higher densities, lower emissions and improved yield. The density benefits associated with double pass expansion of ARCEL moldable foam resins can be very attractive, and the capital needed to install such a system can often be economically justified.

**Procedure, Equipment and Installation**

Successful double pass expansion of ARCEL resin begins with successful single pass expansion. ARCEL resin should be single pass expanded close to its minimum density. To avoid densification, freshly expanded material ideally should not be air conveyed long distances or with equipment that imparts significant thermal or mechanical shock to the prepuff. Some flexibility exists depending on desired final density and processing equipment. Tests can easily be conducted to determine the effect of the air conveyor system. Store freshly expanded prepuff for 4 to 8 hours before the next expansion.

Double pass expansion typically requires a large expander (188 to 300 gallons, 700 to 1100 liters) to accommodate the increased volume and maintain a reasonable feedrate. Fit the expander with double pass equipment, including:

- 4, 6, 8 inch (10, 15, 20 cm) feed auger, depending on expander size
- Variable speed drive
- 6 inch (15 cm) aluminum feed tube with slide gate
- Intermediate feed hopper (small storage bag)
- Appropriate prepuff storage

Install the double pass auger upstream of the steam source to allow agitation to carry the material toward the steam source. Height placement should approximate the existing feed inlet.

Second pass expansion operating conditions vary by plant, but a starting point is to duplicate first pass conditions. As with freshly expanded single pass material, care should be taken to avoid any unusually severe thermal and mechanical shock that may be encountered in air conveyors. Naturally, some flexibility exists depending on desired density.

Actual experience with ARCEL 730 resin in several plants has demonstrated that a prepuff density of 1.0 pcf (16 gms/l) can be achieved with double pass expansion, even when air conveying freshly expanded single and double pass material. Once the expanded particles have cooled and re-inflated, they are no longer sensitive to any thermal or mechanical forces that may be encountered in traditional conveying equipment.

Expanded ARCEL resin has an indefinite shelf life, although the small amount of residual isopentane in 8 to 24 hour old prepuff can be an asset to molding particularly complex shapes. Molding of low density ARCEL resin pre-puff is naturally more sensitive to molding conditions than is higher density prepuff. Cell walls are thinner, and since essentially no blowing agent is present during fusion, care must be taken to avoid over-steaming, very cold cooling water (<70°F or 21°C) and high eject pressures. One or all of these conditions can cause molded part shrinkage or distortion. As part thickness increases, these precautions become more important.

## Batch Expansion

Batch expansion is typically performed with custom molding sized expanders, using typical EPS settings. Properly ground all equipment and make sure the expansion area is well ventilated (see ARCEL Safety Precautions section in NOVA Chemicals' ARCEL resin *Storage and Handling Safety Guide*). To insure a continuous flow of ARCEL raw resin to the expander, inspect the hopper loader, inlet feed system and weigh cell areas for restrictions that would impede raw bead flow. This step is important since ARCEL raw resin beads are large and somewhat wet. Ensure that the particle screener at the expander discharge is capable of handling the larger prepuff particle.

To ensure the expandability, remove from refrigerated storage only the amount of unexpanded ARCEL resin that will be expanded within several hours. Prolonged exposure of the unexpanded ARCEL resin to temperatures above 40°F (4°C) will adversely affect expandability as a result of loss of the isopentane blowing agent.

Pre-heat the expander for several minutes before starting the feed system. In most cases, the target density is the lowest attainable density. The following table details anticipated densities for various operating conditions. Use the values only as a guide since conditions vary from plant to plant.

| 300 GALLON (1100 L) BATCH EXPANDER | ARCEL 730 Resin | ARCEL 730LV Resin |
|---|---|---|
| **FEEDRATE** | | |
| lb/hr | 400 to 1000 | 300 to 700 |
| kg/hr | 180 to 450 | 135 to 320 |
| **MINIMUM FRESH DENSITY** | | |
| pcf | 1.1 to 1.3 | 1.75 to 1.85 |
| g/l | 18 to 21 | 28 to 30 |
| **MINIMUM AGED DENSITY** | | |
| pcf | 1.2 to 1.3 | 1.8 to 2.1 |
| g/l | 19 to 21 | 29 to 34 |
| **STEAM TEMPERATURE** | 212°F (100°C) | 212°F (100°C) |

Note: Minimum indicated densities assume that freshly expanded ARCEL resin particles are not subjected to excessive thermal or mechanical shock.

Freshly expanded ARCEL resin exhibits a higher degree of prepuff shrinkage than EPS resins. As a result, it is very easy to over-expand ARCEL resin. Shrinkage is controllable to some extent. Expander conditions (feedrate, inlet steam pressure and expander temperature) should be adjusted to yield the lowest possible density with the least amount of prepuff shrinkage. Typically, this is accomplished by targeting a freshly expanded ARCEL resin density no lower than 0.2 to 0.3 pcf (3 to 5 gms/l) below desired aged density.

Do not be deceived by the capability of ARCEL resin to expand to very low fresh densities. In most cases, expansion of ARCEL resin to very low fresh densities will result in aged densities well above those that are expected because of increased prepuff shrinkage and densification. If lower density is required, double pass expansion should be considered. Double pass expansion is detailed in another section of this *Expansion and Molding Guide.* Post expansion prepuff shrinkage is density related. As the aged target density increases, post expansion shrinkage decreases. When the target density approaches 2.0 pcf (32 g/l) and above, very little post expansion shrinkage occurs. The fresh density target should be adjusted to account for this difference.

Freshly expanded ARCEL resin is not only sensitive to the over expansion possible during pre-expansion, but also to the thermal and mechanical shock that may be encountered in air conveying systems. Air conveying freshly expanded low-density ARCEL resin can increase density as much as 0.3 to 0.6 pcf (5 to 10 g/l) depending on fresh density, conveyor length and complexity and operating conditions.

If minimum density is desired, minimize mechanical shock through proper air conveyor design, use of heated air or double pass expansion of the resin. In many cases, depending on density, ARCEL 730 resin will tolerate immediate air conveyance with only a minor increase in density. Freshly expanded ARCEL resin should be collected in open containers or vented storage bags and allowed to cool at least several hours. Once conditioned, the tough particles are no longer sensitive to the mechanical forces encountered in traditional conveying equipment.

ARCEL resin can be immediately air conveyed if the conveying system uses heated air. Contact your technical service representative for details concerning the design and operation of such a system.

## Block Molding

With minor adjustments, ARCEL 730 resin can be successfully block molded on typical EPS equipment. Several molders in North America have demonstrated this.

Successful processing at low densities (1.0 - 1.1 pcf, 16 - 18 g/l) requires double pass expansion of the resin. Besides the fact that unexpanded ARCEL resin needs to be refrigerated to avoid accelerated loss of the isopentane blowing agent, its expansion is very similar to EPS. Review *Single Pass, Continuous Expansion* and *Double Pass Expansion* sections of this Guide for additional processing details.

Large block molding expanders easily expand ARCEL 730 resin to 1.25 pcf (20 g/l) at feed rates over 1,000 lbs/hr (450 kg/hr). Since block molding normally involves a second expansion, there is no need for any special prepuff handling to avoid densification. Fresh prepuff can be immediately air conveyed to storage. After a minimum of 4 hours of aging (or the following day), second pass expansion is conducted using a large auger (8 - 12 in, 20 - 30 cm) at a feedrate similar to that used during first pass expansion. The prepuff easily expands to final densities of 1.0 - 1.1 pcf (16 – 18 g/l), and can be handled in the same manner as EPS since very little secondary expansion is required to attain the density, the fresh prepuff is not sensitive to the thermal and mechanical shock of airveying. It can be treated the same as EPS.

After a minimum of 4 hours age, the low-density material can be block molded. Conventional block molds without the ability to compress the prepuff (crush fill) can be used at slightly higher steam pressures than EPS to produce acceptable molded blocks. When block molding ARCEL resin, the absence of crush fill can result in higher levels of block shrinkage than EPS (3 -7%), depending on mold tightness and steam penetration. Newer block molds have movable ends allowing the mold to be filled at one length and compressed to a shorter length for steaming, a feature that mimics the crush fill feature in shape molding. These newer block molds produce extremely well-fused, dimensionally stable blocks (same as EPS).

Molded blocks can be dried at ambient conditions or heat aged along with EPS blocks. Hot wire cutting of ARCEL resin molded foam blocks is a bit slower than EPS but is carried out using the same equipment. Cut board surface will be dependent on moisture level, wire diameter, cutting speed and wire temperature. Generally speaking, the cut board surface is a bit rougher than EPS at equivalent density. ARCEL resin can also be saw cut, routed, knife cut and die cut.

## Shape Molding

With some consideration for handling the larger particle size, ARCEL resin can be successfully shape molded with conventional or vacuum-assisted EPS equipment using basic EPS molding techniques. As with EPS, ARCEL resin prepuff requires a stabilization period (age time) prior to molding. This period allows the many cells throughout each expanded particle to re-inflate with air. This re-inflation is necessary for good fusion and dimensional stability since much of the blowing agent escapes during the pre-expansion process. Molding ARCEL resin prepuff too soon after expansion will result in poorly fused and severely distorted parts. A minimum age of 4-6 hours is recommended. Some other key elements to consider for successfully shape molding ARCEL resin are described below:

**Filling** – This is the critical step in successfully shape molding ARCEL resin. Although the basic shape molding process is the same as for EPS, special attention must be paid to mold design and to the size, number and location of fill guns to ensure efficient and complete fill. Venturi fill guns with a ¾-inch (19 mm) internal diameter are recommended for handling the larger ARCEL resin prepuff particles. Larger guns may be beneficial at densities below 1.4 pcf (22 g/l).

While pressure fill systems may work, they are not the optimum method for filling most ARCEL resin molds unless they have been specifically designed to handle the larger particle. Use of crush fill (telescoping tools) is

recommended, especially for complex parts. Additional suggestions and recommendations for successfully filling ARCEL resin part molds are discussed in the NOVA Chemicals' ARCEL resin *Tooling* and *Part Design Guide*.

**Venting** – Maximum venting in tool design is desirable to aid filling and molding. A vent-to-molded surface area ratio of 2% is recommended. An example of this would be 3/8-inch (10 mm) diameter slotted core vents on 1-inch (25 mm) centers. Although pinhole type core vents are more cosmetically appealing, they do significantly restrict the flow of air and steam when compared with a comparably sized slotted core vent. Typically, slotted core vents provide ~50% more venting area than the same size pinhole vent.

The larger fill guns required to handle the larger ARCEL resin prepuff particles will use more air than in a typical EPS mold, thus requiring more vent area to facilitate proper fill. Venting is also very important to fusion of ARCEL resin prepuff. Since much of the blowing agent escapes during the pre-expansion and prepuff aging steps, expanding the air trapped in each cell becomes more important in attaining proper fusion. Increased venting allows more steam to enter the mold cavity.

**Fusion Cycles** – Compared with EPS of similar part thickness and density, ARCEL resin requires slightly higher molding steam back pressures and/or slightly longer fusion cycles. However, extremely high pressures or long fusion cycles may lead to molded part distortion problems, especially at very low densities.

**Cooling Cycles**– Because ARCEL resin does not contain fast-cool additives, cooling cycles are generally equivalent to an EPS with an average molding cycle. Like freshly expanded prepuff, the near-finished part is also sensitive to thermal and mechanical shock. Cooling water temperature below 75°F (24°C) and high eject air pressures can result in significant collapse and distortion of the molded part. These sensitivities are most obvious at very low densities (<1.25 pcf, <20 g/l) and naturally diminish as density increases. Generous use of cool dwell and water temperature of 85-100°F (29-38°C) is recommended.

**Utilities** – Sufficient air volume and pressure are needed for successful operation of the larger fill guns. Alterations to some air header systems may be required depending on the number of fill guns being used.

**Low Density Parts** – ARCEL resin becomes more delicate as the expanded particles increase in volume and cell walls become thinner. The following precautions are presented to help avoid excessive shrinkage and distortion at part densities below ~1.4 pcf (~22 g/l):

- Design for optimum mold fill (telescoping tools, fill gun locations, etc.).
- Avoid wide variations in part thickness.
- Maintain 85-100°F (29-38°C) cooling water and minimum eject air pressure.
- Avoid over-steaming.
- Do not expose newly ejected parts to cold or drafts.

Note – Molded ARCEL resin does not require any post treatment such as oven conditioning.