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# Precision Molding with High Performance Vectra® LCP

TECH TIPS
Vectra® LCP

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**Celanese – the go-to technical experts with the world-class high performance polymers.**

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## Precision Molding with High Performance Vectra® LCP

*Vectra® liquid crystal polymer (LCP) is an advanced polymer that offers exceptional processing and performance. Although it runs on conventional equipment, molders need to be aware of its unique properties and what these mean for optimal processing. This brochure provides some basic part design, tooling and molding guidelines so those who use Vectra LCP can gain the most from this highperformance polymer. For more detail on the topics covered here, please see Celanese's Liquid Crystal Polymer brochure (VC-7).*

### Why Use Vectra

Vectra LCP has property and processing profiles that meet demanding injection molding and end-use requirements. Its properties make it possible to create thin-walled parts having close tolerances in fast cycles over long production runs. The comprehensive product offering for Vectra LCP is built around a number of base polymers which differ in their melting point, heat resistance, rigidity and flow characteristics. By compounding with a variety of fillers and reinforcing materials (glass and carbon fibers, mineral fillers, graphite, PTFE and combinations of these), the base polymers can be tailored to meet many different application requirements.

*Processing benefits:*

- Exceptionally low melt viscosity so it fills long, thin and complex flow paths
- Replicates fine mold detail precisely
- Minimal warpage
- Flash-free injection molding
- Wide processing window
- Very low heat of fusion, which yields extremely fast cycle times
- Excellent dimensional stability that provides for exacting tolerances

*End use benefits:*

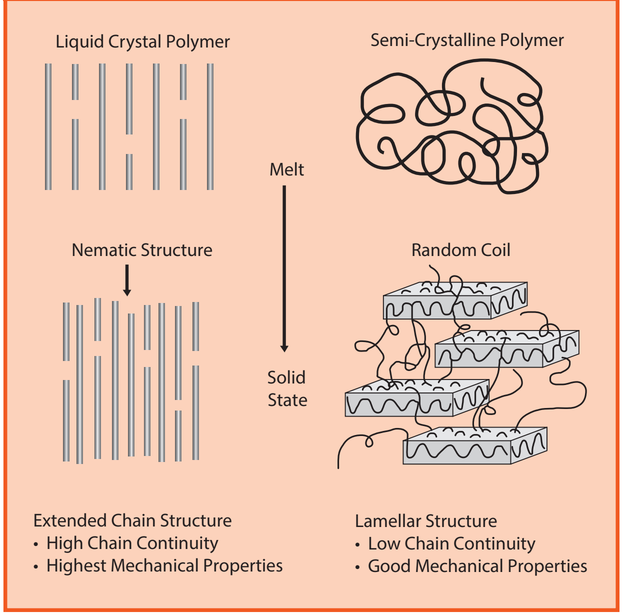
- Short-term temperature exposure up to 340°C (depending on grade)
- Operating temperatures up to 240°C (per UL Relative Thermal Index)
- High tensile strength and modulus in flow direction
- High strength-to-weight ratio
- Low coefficient of thermal expansion
- Inherently flame retardant (UL 94 V-0, 5 VA)
- Resists a broad range of aggressive chemicals
- Low moisture absorption

### What's Different about Processing Vectra

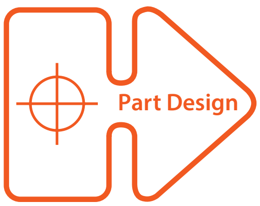
Unlike amorphous and semi-crystalline plastics, Vectra LCP forms an ordered melt containing rigid, rod-like molecules that allow it to flow extremely well. Although it can be processed in standard equipment, its structure gives it a number of novel molding characteristics, for example:

- It undergoes shear-thinning, so it flows best if it moves rapidly in narrow structures. As a result, runners should have a relatively small diameter and injection velocity should be high (typically two to four times that of other polymers).
- It thickens as flow slows, which affects the mold filling pattern and the design of thicker sections. It also keeps flash formation low.
- Its low heat of fusion means it cools from the melt phase to the solid phase quickly, shortening cycle time significantly.
- The ordered melt enhances properties in the flow direction, so dimensional and mechanical properties relate more to filling pattern than processing conditions. This allows for a wide processing window.
- Processors can use as much as 50% regrind with no major change in thermal or other properties. Most other resins are limited to 25%.

**Representation of Structural Differences Between Liquid Crystal Polymers and Conventional Semi-Crystalline Polymers**



## Part Design, Tool Design and Molding Guidelines


**Part design** is important when molding with Vectra LCP. To avoid trapping air, design for uniform filling by the melt front. Take into account:

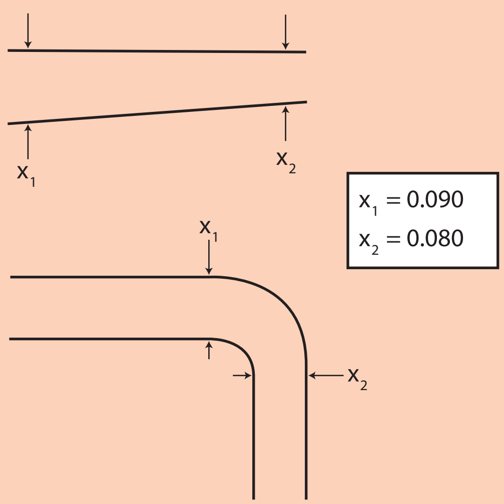
- Uniform wall thickness:
  - – In filling thin-to-thick, the polymer will jet or ribbon into the larger cavity, rolling up air which can cause blistering when exposed to high temperature.
  - – In filling thick-to-thin, the polymer will backfill into the thinner section. Backfilling can entrap air and gas, which can cause blistering, as well as poor weld lines, warpage and the formation of cold slugs that affect filling and part mechanical properties.
  - – Use generous and even transitions for ribs, corners and radii so melt flow is smooth. Also, avoid relatively wide fillets at a rib, which can cause flow leaders and problems associated with thick walls.
- Vectra LCP's mechanical properties are proportionally better in thinner wall sections than thick ones.


Proper tool design is critical when molding with Vectra LCP. Some key criteria for tool configuration include:

- Allow for high enough shear to keep viscosity low throughout the tool. Areas where the flow speed drops, such as sharp changes in runner direction, can allow cold slugs to form.
- Avoid the lead-lag effect that can occur when LCP fills a thick section before it fills the adjacent thin section. This effect causes portions of the flow to surge ahead and other portions to lag behind. The potential for differential filling can capture air which will blister later or change part properties and dimensions. This should be corrected in tool design, e.g., by proper gate location and runner sizing.
- Balance the sprue and runner system by, for example, using radii runners and avoiding 90° turns in runners and with no cold slug wells. The latter case can cause tumbling flow that captures air and gas and pulls them into the part. Also, avoid hot runners that often involve poor melt temperature control.
- Use generous venting throughout the tool, especially at weld lines and runner system to foster rapid filling.

- Core those features that thicken the walls to bring them in line with the rest of the part. Also use cores to minimize jetting. For example, have the flow from a gate that enters a large space impinge on a core pin to prevent the incorporation of air.
- Sprue size and runner size are determined by part: 3 to 5 times maximum wall thickness. Runner changes should be sized by .010 when sizes change.

**Example of sprue and runner size change**




Sprue at partline should be same size as runner

- Since Vectra LCP has very low shrinkage, polish vent lands in cavity, polish the runner and runner vents and allow adequate draft to aid mold release.
- Add abundant inserts so venting and wall thickness can be adjusted to balance flow without recutting the tool.
- Use trials to help locate vent size and depth, e.g., place vents where dark flow lines appear in the part. Also increase venting for runners until flash appears in the land area.

## Molding

Guidelines to follow when molding parts made of Vectra LCP include:

- Follow Celanese's recommended drying procedures set for the grade being used.
- Mold each Vectra LCP grade within its temperature range specified to avoid poor filling at too low a temperature or polymer degradation at too high a temperature.
- Adjust equipment to maintain uniform screw retraction time and cushion.
- Be sure machine settings allow for smooth, uniform filling at a high injection velocity.
- Minimize back pressure to avoid polymer degradation and glass attrition.
- Avoid the use of decompression that can suck air and moisture into the melt. Instead, avoid drool at the nozzle by balancing sprue size and nozzle temperature.
- Do not overpack the material as it is injected into the mold.

# Troubleshooting Blister Formation in High Performance LCPs

*This section illustrates some of the design, tooling and molding guidelines given in the previous sections by looking at how they affect a single issue – blistering. Here we offer a systematic approach to identifying common blistering problems and provide troubleshooting tips for developing appropriate remedial actions.*

Celanese is the global leader in LCP. We are also the global technical experts in high performance polymers, committed to helping our customers get the most from our world-class products. Our global reach, extensive product portfolio, and engineering, research and science capabilities enable us to meet your design and engineering challenges, and exceed your expectations of customer support.

Celanese also understands molding. You can rely on our technical expertise for your material-related molding issues. Here we're offering a systematic approach to help you identify common blistering problems and provide troubleshooting tips to help you develop appropriate remedial actions.

## Typical Phenomenon of Blistering

**Blistering caused by gas**

Blistering occurs randomly on every part

**Blistering caused by delamination and gas**

Blistering occurs along the flow path from the gate


## Procedure to Troubleshoot Blistering Root Causes

**1 Confirm blistering situations including:**
- Material dried according to Celanese recommendations
- Molding conditions
- Frequency
- Specific appearance characteristics
- Location

**2 Investigate changes to molding conditions:**
- Confirm the short shot pattern
- Evaluate the tendency to blister under various barrel temperatures and injection speeds

**3 Identify root cause and take appropriate action:**
- Addition of vent
- Nozzle modification
- Gate relocation
- Improve sprue and runner design
- Adjust processing parameters

**4 Document results for future reference.**

# What Causes Blistering?

### Examples of Blister

Normal surface of molded parts

Blister

Cross section of blistering sample (connector housing)

### Blistering Caused by Gas

- Random location
- Usually occurs at high temperatures

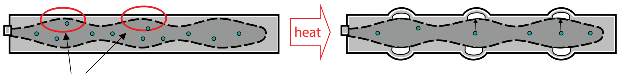
### Blistering Caused by Delamination from Weak Interface Between Skin and Core

- Occurs at same location in steppingstone pattern
- Can occur at low temperatures

### Blistering Caused by Gas


Random Locations

### Blistering Caused by Delamination from Heterogeneous Layer Structure

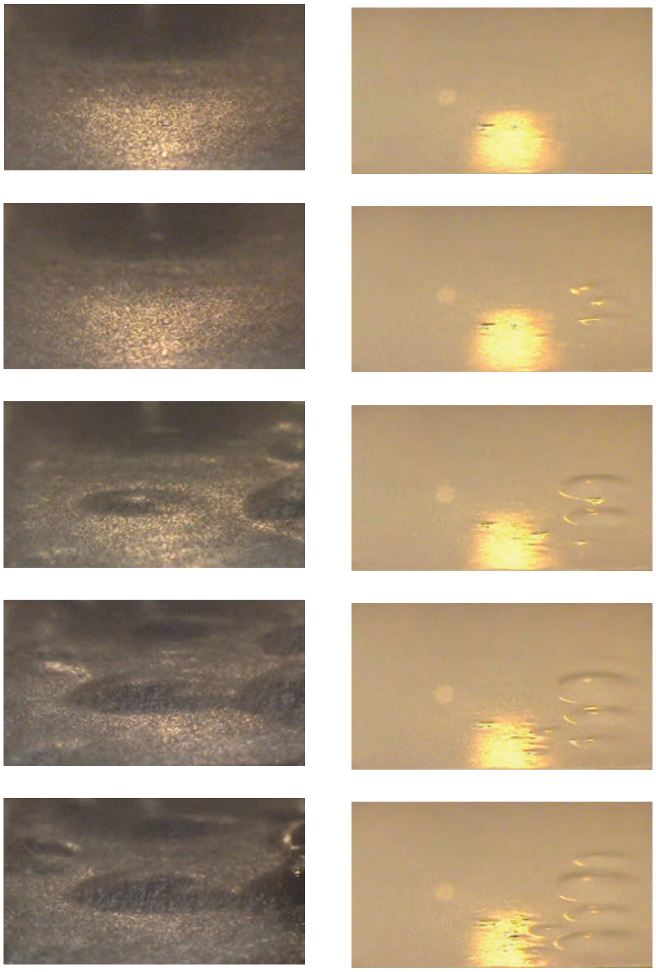



Weak interface between skin and core

Specific Pattern

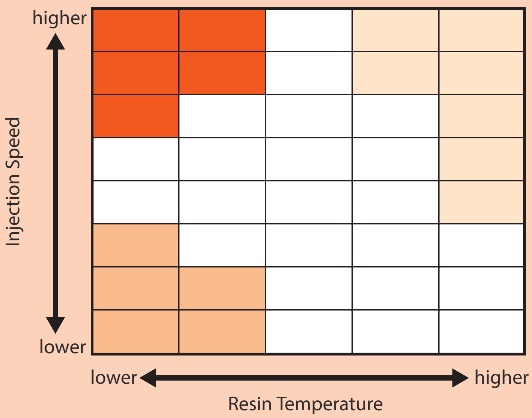
- Blistering occurs at weak interface between skin and core layer

**Image sequence shown over time.**



### Typical Molding Conditions and Blistering

**Relationship between molding conditions and type of blistering**




- Mainly in gas and air
- Mainly in delamination from weak skin and core interface
- Mainly in heterogeneous layer structure

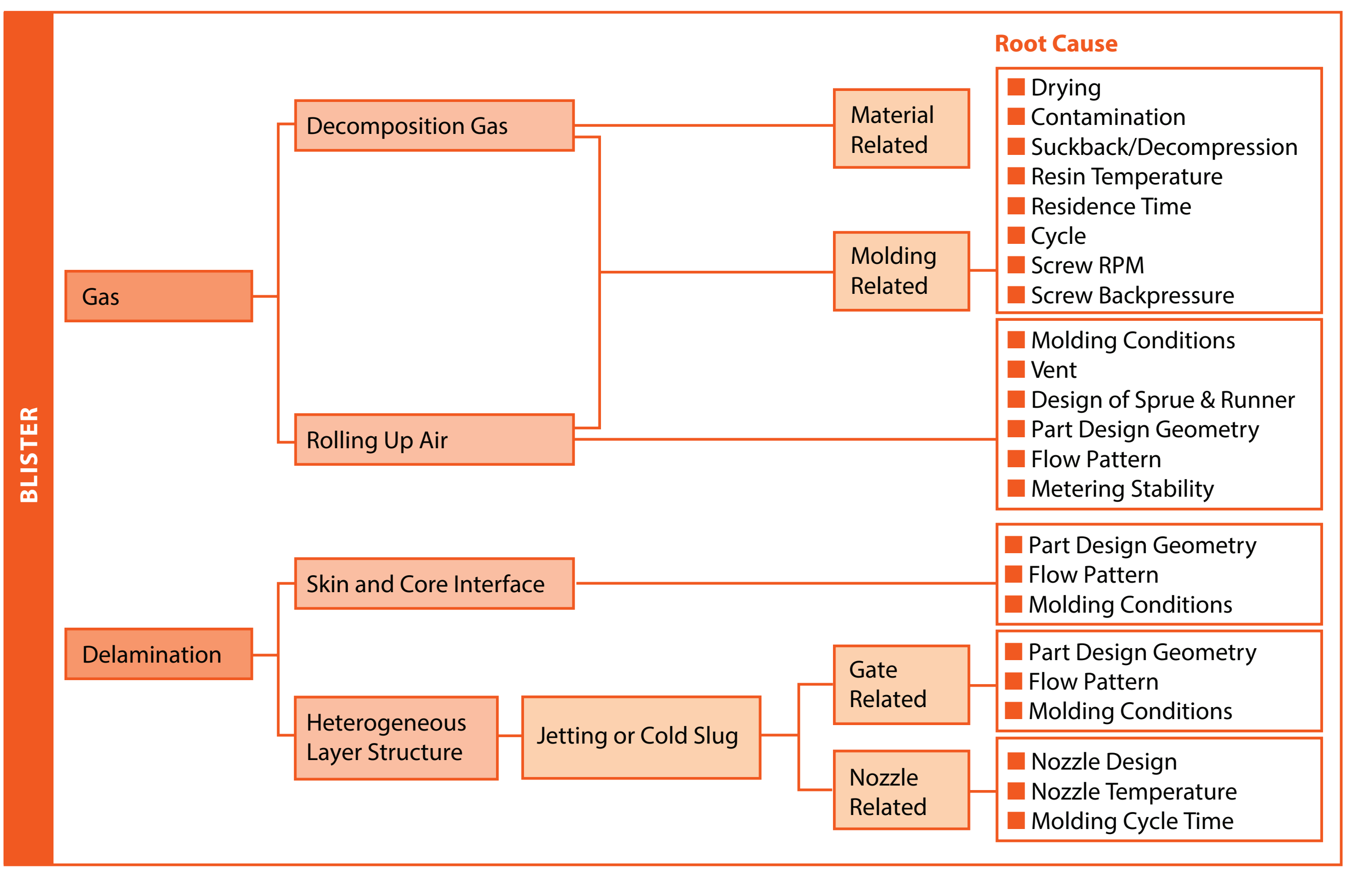
# Root Cause of Blistering

The major root causes for common blistering problems include: abusing the polymer, rolling up gas and air, and delamination – either from a weak interface between skin and core or heterogeneous layer structure.

### Causes for Common Blistering

| Factor/Appearance | Cause | Action |
|---|---|---|
| **1. Rolling up gas & air** | | |
| ■ Small size<br>■ End of flow or near the weld line<br>■ Blister was observed before heat treatment<br>■ Enlarge or disappear with heat treatment (IR-reflow) | ■ High resin temperature and/or longer residence time<br>■ Low density of molten resin due to poor metering stability | ■ Decrease gas generation<br>■ Improve metering stability<br>■ Improve vent |
| **2. Delamination from weak skin and core interface** | | |
| ■ Comparatively big size<br>■ Near the gate<br>■ Blister was observed after heat treatment | ■ Low injection speed<br>■ Low resin temperature | ■ Increase melt flow |
| **3. Delamination from heterogeneous layer structure** | | |
| ■ Comparatively big size<br>■ Blister was observed like a "stepping stone" along the flow pattern<br>■ Blister was observed after heat treatment | ■ High injection speed<br>■ Low nozzle temperature | ■ Prevent jetting<br>■ Prevent nozzle plugging<br>■ Prevent cold slug |

### Root Cause Analysis of Blistering



# Blister Examples and Recommended Actions

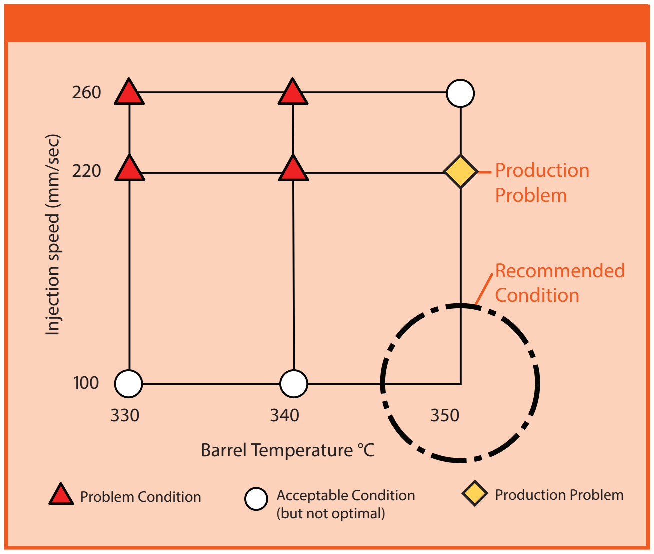
## Board to Board Connector Example

- Frequency: less than 1%
- Blister appeared after IR re-flow

| Influence of Molding Conditions on Blistering | | | | | | |
|---|---|---|---|---|---|---|
| Exp. No. | Barrel Temp. °C | Nozzle Temp. °C | Injection Speed mm/sec | No. of parts tested | No. of blistered parts | Ratio % |
| 1 | 350 | 330-340 | 220 | 103 | 0 | 0.0 |
| 2 | 350 | 330-340 | 100 | 102 | 0 | 0.0 |
| 3 | 350 | 330-340 | 260 | 101 | 0 | 0.0 |
| **4** | **330** | **330-340** | **260** | **105** | **12** | **11.4** |
| **5** | **340** | **330-340** | **260** | **165** | **16** | **9.7** |
| **6** | **340** | **330-340** | **220** | **96** | **10** | **10.4** |
| 7 | 340 | 330-340 | 100 | 102 | 0 | 0.0 |
| 8 | 330 | 330-340 | 100 | 110 | 0 | 0.0 |
| **9** | **330** | **330-340** | **220** | **118** | **10** | **8.5** |
| 1 | 350 | 330-340 | 220 | 140 | 0 | 0.0 |
| **10** | **350** | **310-330** | **220** | **111** | **2** | **1.8** |

**Conclusion:**

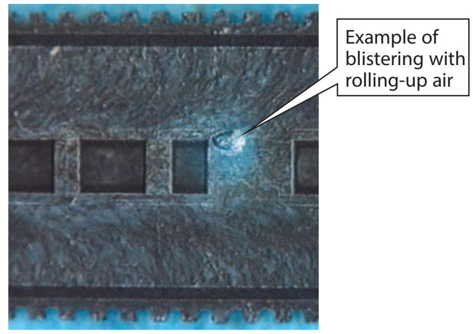
- Blistering tends to occur at lower barrel temperature and higher speed
- Lower nozzle temperature showed increased tendency to blister (see Exp. No. 1 and 10)




**Action:**

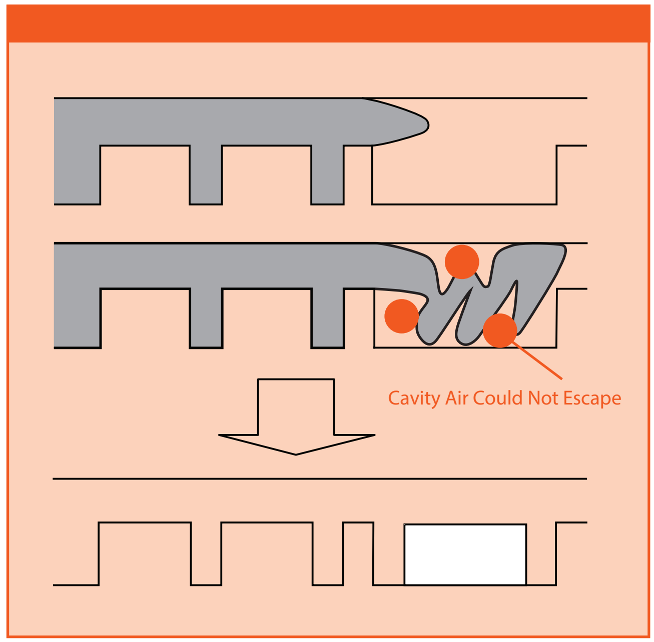
- Change molding condition to a higher barrel temperature and lowering injection speed as first step
- Modify the nozzle and sprue design

## Rolling-Up Air Example




**Conclusion:**

- In certain filling patterns such as thin walls filling thick, the melt front can capture air which could blister when exposed to high temperature




**Action:**

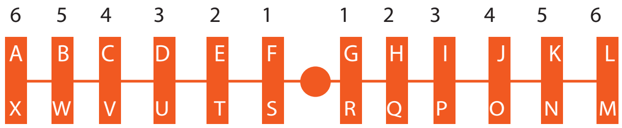
- Blistering was solved by coring out the thicker wall section and improving the venting

# Blister Examples and Recommended Actions (continued...)

**Buzzer Part Example**

- Number of cavities: 24
- Blistering Frequency: 1-2%
- Blister appeared during the adhesive curing process (160°C)


Configuration of Cavities

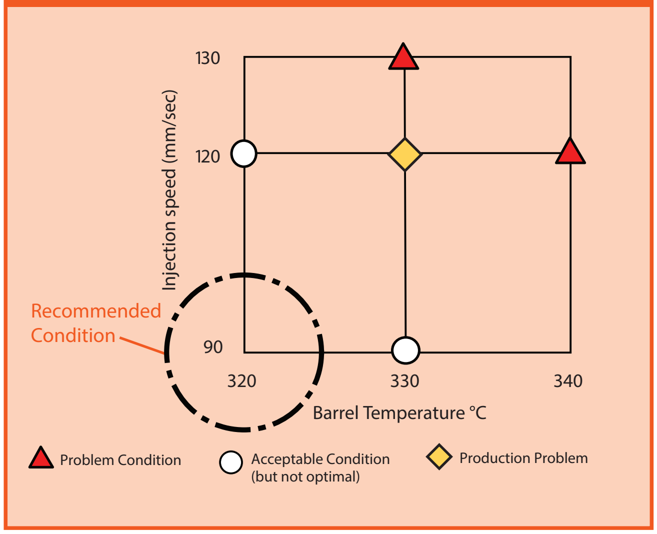



| Influence of Molding Conditions on Blistering | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Exp. No. | Barrel Temp. °C | Inj. Speed mm/sec | Nozzle | CAVITY 1 | 2 | 3 | 4 | 5 | 6 | Total |
| 1 | 320 | 120 | | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0% |
| 2 | 330 | 120 | | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0% |
| 3 | 340 | 120 | | **50.0%** | **5.0%** | 0.0% | 0.0% | 0.0% | 0.0% | 55% |
| 4 | 330 | 90 | | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | | 0% |
| 5 | 330 | 120 | | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0% |
| 6 | 330 | 130 | | **20.0%** | **2.5%** | **5.0%** | **5.0%** | **2.5%** | 0.0% | 35% |
| 7 | 330 | 120 | +10°C | 2.5 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 3% |

Blister test condition: Dip into 280°C oil-bath.

**Conclusion:**

- Blistering tends to occur at higher barrel temperatures and higher injection speeds
- Blistering increases in cavities 1 and 2




**Action:**

- Optimize molding conditions as a first step
- Improve venting
- Modify flow pattern to balance the runner

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# ENGINEERED MATERIALS

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## Engineered Materials

- Celanex® thermoplastic polyester (PBT)
- Hostaform® and Celcon® acetal copolymer (POM)
- Celstran®, Compel® and Factor® long fiber reinforced thermoplastic (LFRT)
- Celstran® continuous fiber reinforced thermoplastic (CFR-TP)
- Fortron® polyphenylene sulfide (PPS)
- GUR® ultra-high molecular weight polyethylene (UHMW-PE)
- Impet® thermoplastic polyester (PET)
- Riteflex® thermoplastic polyester elastomer (TPC-ET)
- Thermx® polycyclohexylene-dimethylene terephthalate (PCT)
- Vandar® thermoplastic polyester alloy (PBT)
- Vectra® and Zenite® liquid crystal polymer (LCP)

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