K-RESIN®
Styrene-Butadiene Copolymers
THE CLEAR CHOICE™

K-Resin® SBC Injection Blow Molding

Introduction

K-Resin styrene-butadiene copolymers (SBC) are a family of clear, economical resins used in such applications as medical containers, food packaging, toys, and retail display units. K-Resin SBC are easily processed in most common types of polymer processing equipment. This Technical Service Memorandum discusses the use of K-Resin SBC in injection blow molding equipment.

Equipment

K-Resin SBC can be run successfully on injection blow molding machines with either vertical or horizontal extruder systems. The machines must be designed to minimize exposure of K-Resin SBC to excessive temperatures as well as long residence times at even moderate temperatures. Special attention should be given to good temperature control of the extruder and streamlined design of the resins flow path through the machine. Since even modest degradation of K-Resin copolymers will negatively affect the clarity of injection blow molded parts, thermal degradation of the resin must be avoided.

Injection Unit

Although K-Resin SBC may be processed at melt temperatures ranging from 350 to 500°F (177 to 260°C), it is recommended that an extruder profile be used that supplies molten resin to the injection manifold in the range of 380 to 450°F (193 to 232°C). A straight ramp extruder temperature profile from 360°F (182°C) at the feed section to 440°F (227°C) at the manifold section is common.

Care should be taken to limit the copolymer's exposure to high melt temperatures or to extended residence time in the molding machine's extruder or mold runner system. As the resin is exposed to high shear, high temperatures or long residence time, degradation will induce yellowing, reducing part clarity, and will eventually char the resin. In molded parts, thermally degraded resin appears as haziness, milkiness, smoky or silvery streaks, yellowness, or black specks. To minimize thermal degradation, the resin should be uniformly plasticized using minimal heat.

Screw Design

K-Resin SBC generally process well on general purpose single stage screws with medium compression ratios. Mixing tips are discouraged because of the potential to overshear the resin and cause gels. In some cases poor mixing has been experienced with general purpose screws where high levels of tints are needed in the final product. Replacement of the general purpose screw with a screw designed with barrier flights has proven successful in improving mixing without overshearing the resin.

Shot Capacity

Since thermal degradation is dependent on residence time as well as melt temperature, K-Resin SBC should be molded in a machine having the smallest practical shot capacity. For example, with parts requiring a 55 gram shot a machine with a 400 gram capacity retains a cushion of six shots in the machine. In such cases, the extended residence time can produce thermal degradation even at moderate temperatures.

Recommended Processing Conditions

K-Resin SBC can be processed using a wide range of molding temperatures and pressures. When compared to many clear resins, they are less sensitive to moisture and can be molded at lower temperatures and with faster cycle times.

Injection Stage Melt Temperature

The single most important processing variable of K-Resin copolymers is melt temperature. As melt temperatures are increased up to 500°F (260°C), the flow of the material increases (Figure 1). Above 500°F (260°C) material flow becomes erratic. As noted above, excessive melt temperature or extended residence time at even a moderate temperature can degrade the resin, yielding poor part appearance and performance. Therefore, melt temperature should always be kept at the minimum, usually between 380 to 450°F (193 to 232°C), necessary to permit preform mold filling.

It is common to see melt temperatures 10 or 20°F (5 or 10°C) above the heater temperature settings due to shear heating of the polymer as it is transported through the extruder die tip and the molds runner system.

Injection Pressure

K-Resin copolymer's response to injection pressure is much like other polymers. The flow length of the resin increases as injection pressure increases (Figure 2).

Figure 1

Spiral Flow as Function of Melt Temperature

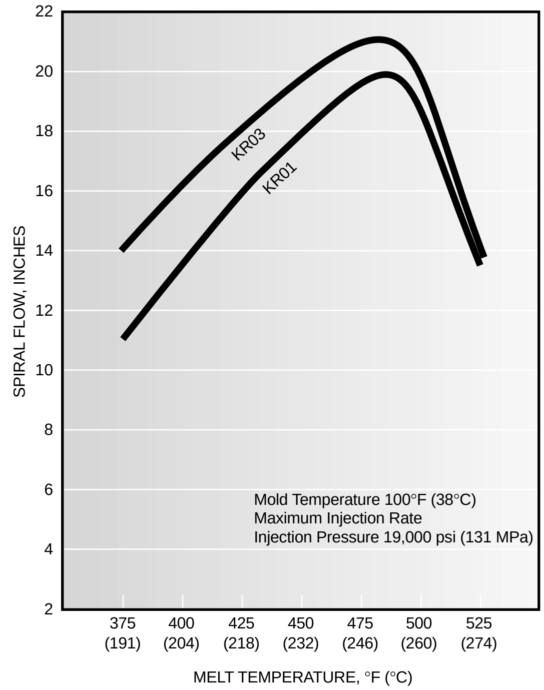
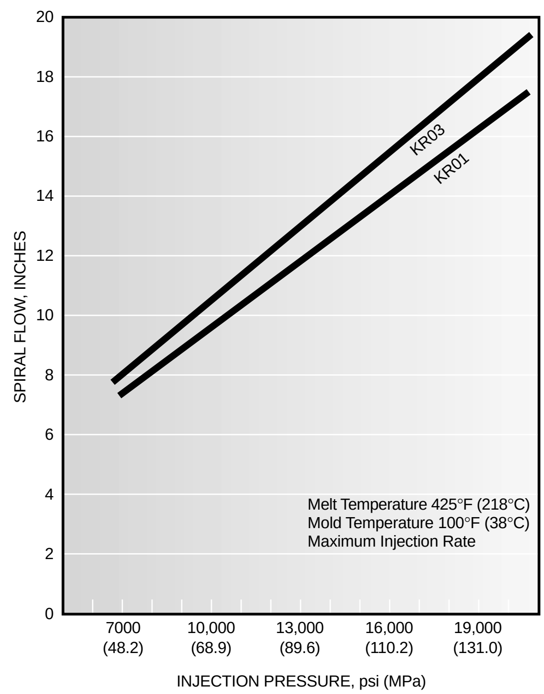


Figure 2

Spiral Flow as Function of Injection Pressure



Preforms made with K-Resin SBC tend to stick in the injection station mold when overpacked, so the injection pressure should not exceed the minimum required to fill the cavity. Minimum injection pressure depends on the ease of the resin flow into the cavity. Higher injection pressures will prove necessary to overcome flow restrictions caused by small gating, thin preform walls and melt flow patterns. To prevent overpacking, second stage injection pressure, if used, should be low and maintained only for the shortest practical injection hold time.

Since underpacking can result in a preform having “wavy” lines or surface ripples that will transfer to the blown part, a balance between underpacking and overpacking must be achieved if quality parts are to be produced.

Injection Rate

K-Resin SBC are sensitive to the injection rates. Flow lines can occur when the gates are too small. When flow marks are visible, and particularly when jetting occurs, a slower injection rate can eliminate the problem.

Injection Mold Temperature

The purpose of mold cooling in the injection station is to cool the preform sufficiently for transport to the blow station. Many imperfections seen in the blown parts can be attributed to incorrect preform temperatures at the time of transport. When processing K-Resin copolymers on a machine that transports the preform on core rods, a common injection mold temperature would be between 110 to 120°F (43 to 49°C). For a machine that transports the preform without the support of a core rod, the recommended injection mold temperature is 90 to 100°F (32 to 38°C).

Blow Station Melt Temperature

Maintaining proper melt temperature is extremely important to obtaining optimum clarity and gloss. K-Resin SBC should be blown with a melt temperature in the range of 360 to 405°F (182 to 207°C). Note that this temperature range is lower than the recommended range for the injection portion of the machine. Typically, K-Resin SBC have greater part impact strength when processed at the lower end of this range. Clarity is good over the entire range.

Blow Pressure

For K-Resin SBC, blow pressures of 40 to 100 psig (0.28 to 0.70 MPa) are common. Blow pressures in the lower end of this range may produce clearer parts but will require longer cooling times.

Blow Mold Temperature

Mold temperatures of 40 to 80°F (4 to 27°C) are typically used when molding K-Resin SBC. Running the mold temperature below the dew point can cause moisture to condense in the mold cavity and thus cause moisture marks on the finished parts. Maximum clarity and gloss are obtained at a mold temperature near 75°F (24°C).

Blowup Ratio

K-Resin SBC have a maximum blowup ratio of 3 to 1. Stretching the preform radially or longitudinally beyond this ratio will cause the part to rupture during inflation.

Part Shrinkage

K-Resin SBC are amorphous rather than crystalline and thus exhibit relatively low shrinkage rates. KR01 shrinks less than KR03, KR05, and KR10. K-Resin SBC blown containers usually shrink less than 0.015 inch per inch when molded under recommended machine conditions. The most important processing variable affecting warpage is part temperature at machine take out. The copolymer shrinks less if cooled in the blow mold longer and shrinks more if removed from the mold sooner. Table 1 contains the approximate shrinkage values of various part wall thickness using common molding parameters.

Table 1

Shrinkage, in/in

Part Wall Thickness	KR01	KR03
0.0156 in (0.040 cm)	0.002	0.003
0.0312 in (0.079 cm)	0.002	0.003
0.0469 in (0.119 cm)	0.003	0.004
0.0625 in (0.159 cm)	0.004	0.005
0.0938 in (0.238 cm)	0.005	0.006
0.1250 in (0.318 cm)	0.006	0.007
0.1875 in (0.476 cm)	0.007	0.008
0.2500 in (0.635 cm)	0.008	0.010

Purging

It is extremely important to start with clean equipment. If possible, the equipment should be disassembled and cleaned before any K-Resin SBC is introduced. Any residual contamination could produce part defects. Purging with a low melt flow polystyrene resin before the introduction of a K-Resin SBC into the machine, has been used with some success. After a production run, K-Resin SBC can be removed from the machine by purging with another low melt flow resin.

Drying

Since K-Resin SBC do not absorb moisture, drying is not usually required. They can, however, adsorb moisture onto the surface of the pellets if stored under humid conditions. Should surface moisture be a problem, the polymer can be dried for approximately one hour at 140°F (60°C). Excessive drying times and temperatures should not be allowed. Even if the resin does not degrade, pellets may soften enough to become tacky and stick to each other, thus interrupting resin feed to the injection unit.

Regrind

When regrinding K-Resin SBC, a chopper with sharp, properly aligned blades and good ventilation should be used to avoid heat buildup. Excessive temperatures in the chopper or storage container can degrade the resin. If extreme processing and regrinding conditions are avoided, K-Resin SBC can easily withstand multiple molding passes. For most production purposes, a maximum level of 50% regrind is recommended. The cleanliness of the regrind cannot be overemphasized. Any foreign contaminant will mar the appearance of a finished part.

Machine Shutdown

To avoid resin degradation, K-Resin SBC should not be allowed to heat soak at even moderate temperatures for extended periods of time. If the machine is going to be idle for any period of time, such as the end of a run, it is a good idea to “cool” the machine down. This will result in less maintenance down time and fewer lost parts due to burnt resin. Shutting down with crystal polystyrene in the extruder and runners is helpful in preventing degradation.

Mold Design

Injection Mold Finish

For optimum appearance of K-Resin SBC parts, the mold and core surfaces should be polished to at least an SPI A-2 finish. Imperfections on the preforms will be seen on the finished parts.

Blow Mold Finish

With K-Resin SBC, the mold surface pattern transfers exactly to the parts. For best clarity and gloss, an SPI A-1 or SPI A-2 finish is recommended. Air entrapment may occur for some part designs with these finishes. Grit blast finishes allow air to escape from between the molten polymer and the mold wall but the parts will appear hazy and have little gloss. Mold surfaces treated with a glass beading process can be a good finish compromise. Parts will have good clarity and gloss but trapped air will be allowed to escape when the parts are blown.

Injection Mold Venting

Since K-Resin SBC are sensitive to thermal degradation, it is imperative that the injection mold be generously vented to prevent gas entrapment, subsequent overheating and a resultant burning of the resin. The well-designed mold can incorporate vents from 1 to 3 mils (0.03 to 0.08 mm) thick around the cavity. Adequate venting is critical for maximum weld line strength, if weld lines cannot be avoided.

Blow Mold Venting

To obtain good surface appearance with K-Resin SBC, a well-vented mold is necessary. Poor venting allows air to be trapped in pockets between the expanding parison and the cavity wall. The entrapped air prevents intimate contact with the mold which precludes good replication of detail and surface polish. Moreover, the entrapped air insulates the part from the mold resulting in non-uniform cooling and surface appearance. Non-uniform cooling promotes varying degrees of shrinkage, molded-in stresses and warpage.

Injection Mold Nozzle Balancing

An important part of any multi-cavity mold design is a properly balanced manifold and nozzle set. The manifold and nozzles affect the flow rate of the K-Resin copolymer as it is injected into the mold cavities. It is necessary for all molds to fill and pack at the same time to ensure uniform preform temperature conditioning. If any of the preforms are not filled out at exactly the same time as the rest, their temperature(s) will be different from the ones filled first. Preform temperatures have a major effect on neck size and uniformity as well as body wall distribution and molded-in stresses.

Mold Release

K-Resin copolymers tend to stick to the surfaces of the injection molds and preform parts are often deformed when removed. This sticking problem can be alleviated by dry blending with zinc stearate according to the following procedure:

Step 1 Add 0.1% (50 grams per 100 lbs. [45.5 kg] of material) regular mineral oil to the resin and drum tumble for 5–10 minutes. This wetting agent will help the zinc stearate adhere to the pellets.

Step 2 Add 0.1% (50 grams per 100 lbs. [45.5 kg] of material) zinc stearate powder to the pre-treated resin and drum tumble for another 5–10 minutes. This step will ensure a uniform coating on the resin pellets.

Dry blending of resin pellets and zinc stearate may later allow the stearate to separate, clump together and then process through the machine in a high concentration. Levels of 0.3% stearate or higher will cause haziness or cloudiness in the parts.

Problems	Possible Causes	Suggested Solutions
Short shot of preform	Low melt temperature	Increase extruder and /or manifold temperature zone settings. Check extruder and manifold heater bands. Check extruder speed.
	Low injection pressure	Confirm proper pressure.
	Low hold pressure	Check for proper hold pressure.
	Injection time too short	Lengthen low pressure preform time.
	Nozzle size restriction	Check nozzle for contamination. Check orifice size.
	Extruder out of plastic	Check hopper for material. Check hopper for restrictions.
Flashing of preform	Melt temperature too high	Check extruder and manifold temperature zones for correct settings. Check extruder speed. Check for excessive shear heating at the nozzle. Check for excessive injection speed.
	Preform mold temperature too high	Lower preform mold zone temperatures.
	Injection pressure too high	Lower injection pressure.
	Hold pressure too high	Lower hold pressure.

Problems	Possible Causes	Suggested Solutions
Flashing of preform *(continued)*	Excessive shot size	Decrease high pressure preform time.
	Molds opening under pressure	Increase clamp pressure. Check mold's projected area.
	Mold halves do not mate	Repair or replace molds. Check mold surfaces for obstructions.
Preform sticking to preform mold	Insufficient lubricant in melt	Contact resin supplier for suggested lubricant specification.
	Melt temperature too high	Lower extruder and /or manifold temperature settings. Decrease extruder speed. Decrease injection speed. Increase nozzle size.
	Preform mold temperatures too high	Decrease preform mold zone temperatures.
	Hold pressure too low	Increase hold pressure.
	Hold time too short	Increase hold time.
Preform sticking to core rod	Insufficient lubricant in melt	Contact resin supplier for suggested lubricant specification.
	Core rods too hot	Increase core rod cooling (internal and/or external).
	Preform mold temperatures too high	Decrease preform mold temperatures.
	Melt temperature too high	Lower extruder and/or manifold temperature settings. Decrease extruder speed. Decrease injection speed. Increase nozzle size.
	Hold pressure too high	Decrease hold pressure.
	Hold time too short	Increase hold time.
	Hold pressure too low	Increase hold pressure.
Thin bottom gate area	Too much decompression time	Decrease decompression time.
	Too much reverse screw rotation	Decrease reverse screw rotation rpm.
	Nozzle temperature zone too hot	Decrease nozzle and/or manifold temperature.
	Core rod tip too hot	Increase core external cooling.
	Hold pressure too low	Increase hold pressure.
	Packing time too short	Increase low pressure preform timer.
	Cure time too short	Increase cure timer.
Tails at gate bottom	Extruder not decompressing	Increase decompression time. Check system for reverse screw rotation failure. Increase reverse screw rotation speed.
	Preform mold bottom zone too cool	Increase preform mold bottom temperature zone setting.
	Nozzle and/or manifold too cool	Increase nozzle and/or manifold temperature.
Bulging bottle bottom	Melt temperature too high	Decrease extruder temperature settings. Decrease extruder speed. Increase nozzle orifice size.
	Molding cycle too fast	Increase blow time.
	Air trapped in blow mold	Clean contamination from vent channels and ports.

Problems	Possible Causes	Suggested Solutions
Bulging bottle bottom *(continued)*	Poor cooling of blown bottle	Decrease temperature of blow mold bottom temperature zone. Check coolant lines for proper coolant flow. Increase blow air pressure.
Poor bottle surface	Rough blow mold surface	Have blow mold surface polished to an SPI A-2 finish.
	Poor blow mold venting	Clean contamination from vent channels and ports. Have vent channels and ports re-machined.
	Condensation on blow mold	Wipe mold dry. Decrease humidity levels in molding room.
	Preform temperature too cold	Decrease low pressure preform timer.
	Melt temperature too cold	Increase extruder temperature. Increase preform mold zone temperatures.
	Blow air pressure too low	Increase blow air pressure. Check blow air line for restriction.
	Blow time too short	Decrease blow delay timer setting and increase blow timer setting.
Warped bottle walls	Cycle time too short	Increase overall cycle time to allow longer blow time.
	Blow time too short	Decrease blow delay timer setting and increase blow timer setting.
	Blow air pressure too low	Increase blow pressure. Check blow air line for restriction.
	Preform temperature too cold	Decrease low pressure preform timer.
	Melt temperature too cold	Increase extruder temperature. Increase preform mold zone temperatures.
	Poor blow mold venting	Clean contamination from vent channels and ports. Have vent channels and ports re-machined.
Unfilled neck threads	Preform neck zone too cold	Increase temperature setting on neck zone. Check oil lines for proper flow to preform mold.
	Low injection pressure	Confirm proper pressure.
	Hold pressure too low	Increase hold pressure.
	Hold time too short	Increase hold time.
	Air trapped in preform mold	Clean contamination from vent channels and ports. Have vent channels and ports re-machined.
	Melt temperature too cold	Increase extruder temperature. Increase preform mold zone temperatures.
Neck folds	Preform neck zone too cold	Increase temperature setting on neck zone. Check oil lines for proper flow to preform mold.
	Melt temperature too cold	Increase extruder temperature. Increase preform mold zone temperatures.
	Cure time too long	Decrease cure time.
	Hold time too long	Decrease hold time.
	Hold pressure too high	Decrease hold pressure.
	Injection pressure too high	Decrease injection pressure.
	Core rod temperature too cold	Decrease internal cooling on core rod. Decrease external cooling on core rod.

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