K•RESIN®

STYRENE-BUTADIENE COPOLYMERS

The Smart Choice™

TIB 203

Blow Molding

Introduction

K-Resin® styrene-butadiene copolymers (SBC) are a family of clear resins produced by Chevron Phillips Chemical Company LP. K-Resin® SBC were commercialized in the early 1970s. Since that time, they have grown steadily in the marketplace as more and more applications have been developed utilizing these polymers' unique blend of sparkling clarity and impact strength.

Applications range across the spectra of conventional processing techniques. K-Resin® SBC, alone or in blends with crystal polystyrene, can be extruded into sheet and thermoformed on conventional equipment at high output rates. The favorable economics of K-Resin® SBC, along with high productivity, have made possible tough clear disposable drinking cups, lids, and other packaging applications. These materials process equally well in injection molding, providing good cycle times and design flexibility. An example of an injection molded application is the clear living hinge box. The part is filled through the narrow hinge, yet still has enough toughness to provide good hinge life. In blow molding, K-Resin® SBC will process on most conventional equipment, allowing the molder to run a crystal clear bottle without expensive machine modifications, special molds, different screws, or dryers. K-Resin® SBC are blow molded in a broad range of sizes and shapes, from small pill bottles and medical drainage units, to very tall display bottles. They can also be injection blow molded into extremely high impact bottles with glass-like clarity. Produced as a film, K-Resin® SBC makes a clear, stiff, high gloss film suitable for applications such as candy twist wrap, shrink sleeves and overwrap. If extreme processing and regrinding conditions are avoided, the polymers can be reprocessed in multiple passes with minimal change in properties and processing.

A feature that makes K-Resin® SBC more economically attractive than other clear plastics is their low densities. K-Resin® SBC has a 20 - 30 percent yield advantage over non-styrenic clear resins.

All K-Resin® SBC grades as shipped by Chevron Phillips Chemical, meet the specifications of the United States FDA Food Packaging Regulation 21 CFR 177.1640 or the specifications of an effective United States FDA Food Contact Notification. By virtue of this compliance, K-Resin® SBC grades may be used as a component of articles for use in contact with food. Most K-Resin® SBC grades meet the food contact requirements for EEC Directive 2002/72/EEC and all its amendments. Limitations for the storage and packaging of foods in this polymer are addressed in detail in K-Resin® SBC TSM 288 "Food Packaging of K-Resin® SBC".

Most K-Resin® SBC grades have been tested and meet USP Class VI requirements and can be sterilized by ethylene oxide gas, gamma radiation or electron beam. More detailed information on the biocompatibility of K-Resin® SBC can also be obtained in TSM 292 "Medical Applications for K-Resin® SBC".

K-Resin SBC Grades

KR05 is the recommended grade for blow molding and injection blow molding. XK44 has been used as a coextruded outer gloss layer over polyethylene and other polyolefin blow molded bottles.

KR05 contains a microcrystalline wax which acts as an antiblock. While the wax provides processing benefits, it can make KR05 difficult to decorate. KR05NW is the no-wax form of KR05 to facilitate printing and decorating. KR05 may be surface treated to enhance printability (see Printing and Decorating section).

Equipment

Injection blow molding or extrusion blow molding equipment may be used for processing K-Resin® SBC. Extrusion blow molding can be either continuous or intermittent extrusion.

This copolymer is usually specified for parts that require both clarity and impact toughness. Though both properties are sensitive to thermal degradation of the resin, clarity is usually the limiting factor in blow molding. Even modest degradation of the resin will affect the clarity of parts blow molded from K-Resin® SBC. In blow molded parts, impact toughness is more dependent on suitable wall distribution and pinch-welds.

Blow molding equipment must be selected to minimize exposure to excessive temperatures and long residence times at even moderate temperatures. Special attention should be given to good temperature control of the extruder and streamlined design of the die and head.

Extruders and Screws

K-Resin® SBC can be processed on extrusion equipment normally used for high density polyethylene (HDPE).

Die Heads

The die head should be streamlined and capable of providing a uniform pattern and good temperature control. The die head should be highly polished, clean and free of surface imperfections.

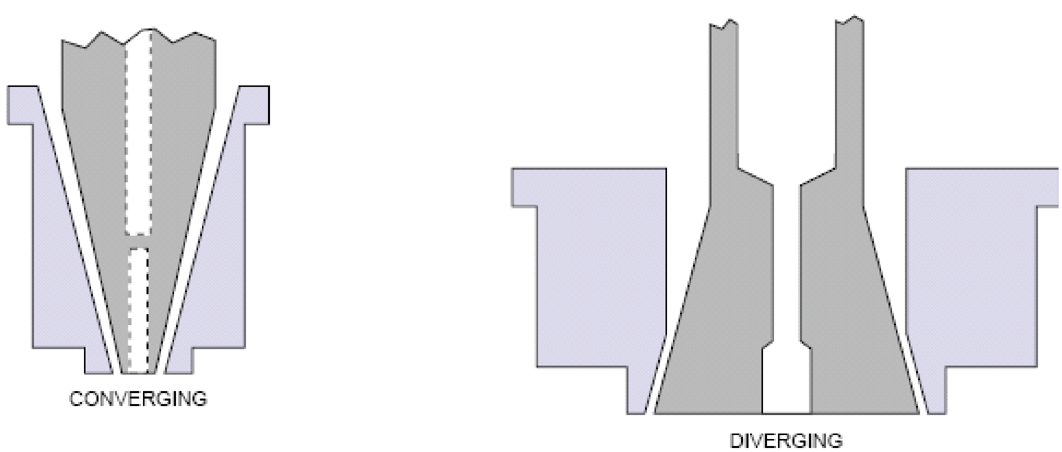
Die Tooling

Depending upon the particular application, either converging or diverging dies (Figure 1) can be used. For optimum part clarity, dies must be clean and polished. Non-stick coatings aid processing and delay the buildup of deposits which may cause die lines.

Parison diameter swell is affected by the type of extrusion equipment used. Continuous extrusion gives a parison swell of -15 to -5%. Intermittent extrusion provides a swell of -8 to +10%. In both extrusion methods, a blowup ratio of 3:1 should be considered as a maximum when selecting appropriate tooling size.

Figure 1

Die Types



Recommended Processing Conditions

Purging

It is extremely important to start with clean equipment. If possible, the equipment, including the screw and head, should be disassembled and cleaned before any K-Resin® SBC is introduced. Any residual contaminant could produce die and weld-line defects. Purging with a blend of a low melt flow polystyrene and K-Resin® SBC has been used with some success. After a production run using K-Resin® SBC, low melt flow polymers such as HDPE can be used for purging.

Drying

Since K-Resin® SBC does not absorb moisture, drying is not usually required. It can, however, collect surface moisture if stored under humid conditions. Should surface moisture be a problem, the polymer can be dried for approximately one to two hours at a temperature no greater than 140°F (60°C). Higher temperatures or longer times can cause sticking problems or resin degradation.

Melt Temperature

Maintaining proper melt temperature is extremely important in obtaining optimum clarity and gloss. Melt temperatures in the range of 360 – 390°F (182 – 199°C) are suitable. However, greater part impact strength is typically achieved when it is processed at the lower temperatures in this range. A general temperature profile is shown in Table 1.

Table 1

Typical Processing Conditions

Feed, °F (°C)	290–320 (143–160)
Transition, °F (°C)	330–350 (166–177)
Metering, °F (°C)	330–360 (166–182)
Head, °F (°C)	340–360 (171–182)
Melt Temperature, °F (°C)	360–390 (182–199)
Blow Pressure, psi (MPa)	40–80 (0.28–0.56)
Mold Temperature, °F (°C)	60–80 (16–27)

Blow Pressure

Lower blow pressures produce clearer parts. Although blow air pressure is highly dependent on part configuration, the typical range is 60 –100 psig (0.42 – 0.70 MPa).

Molds

To obtain maximum clarity and gloss, molds should be maintained at warm temperatures (75°F [24°C]). For continued optimum appearance of K-Resin® SBC parts, the mold surface should be cleaned and polished with a jeweler's rouge such as Simichrome.

Blowup Ratio

A maximum blowup ratio of 3:1 is recommended for best wall thickness uniformity.

Regrind

For production purposes, a maximum of 50% regrind is recommended. The cleanliness of regrind cannot be overemphasized. Any foreign contaminant will mar the appearance of a blow molded part. When reprocessing K-Resin® SBC, use a chopper with sharp blades, proper clearances, and adequate ventilation 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 withstand multiple molding passes. K-Resin® SBC has been reprocessed through a reciprocating screw blow molder for seven passes with minimal effect on physical, rheological, and optical properties.

Shutting Down the Machine

To avoid resin degradation, K-Resin® SBC should not be allowed to heat soak even at 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. This will result in less maintenance down time and fewer lost parts due to burned resin. Shutting down with crystal polystyrene in the extruder and head is helpful in preventing degradation.

Trimming

Standard fly wheel cutters can provide a good neck finish, but knife cutters with fixtures have proven more successful. In any case, during trimming, K-Resin® SBC parts are much less likely than general purpose polystyrene parts to shatter but are more likely than polyolefin parts to sustain damage.

Part and Mold Designs

Part design recommendations for K-Resin® SBC are similar to those for most other materials. Sharp corners should be avoided and generous radii allowed. Abrupt variations in wall thickness should also be avoided as they tend to concentrate stress and promote warpage due to differential shrinkage.

The ideal part design should be as symmetrical as possible. This allows the parison to blow out a uniform distance before contacting the mold walls, resulting in uniform part thickness. However, the ideal part design is often impractical because of functional design considerations or aesthetic requirements. As a result, many parts produced are necessarily of non-uniform thickness and geometry.

Shrinkage

Although K-Resin® SBC exhibits relatively low shrinkage, the mold cavity size must, in addition to wall thickness, allow for shrinkage. Overall, blown containers shrink less than 1.5 percent. Specific shrinkage measurements for several typical parts are shown in Table 2. For parts other than those shown, shrinkage may be approximated using the percentages noted.

Table 2

Nominal Shrinkage of Typical Containers Blow Molded in K-Resin® SBC

Part	Neck Size, in (cm)	Waist in (cm)	Height, in (cm)	Avg. Neck Thickness in (cm)	% Shrinkage Neck	% Shrinkage Waist	% Shrinkage Height
6 oz. Boston Round	0.83 (2.11)	1.80 (4.57)	3.68 (9.35)	0.68 (0.172)	1.19	0.77	0.57
8 oz. Shampoo	0.84 (2.13)	2.88 (7.32)	5.76 (14.63)	0.055 (0.140)	1.07	0.81	0.50
16 oz. Wide Mouth	1.95 (4.95)	3.12 (7.92)	4.98 (12.65)	0.050 (0.127)	1.03	0.82	0.40

Mold Venting

To obtain good surface appearance, 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 mold 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.

Mold Cooling

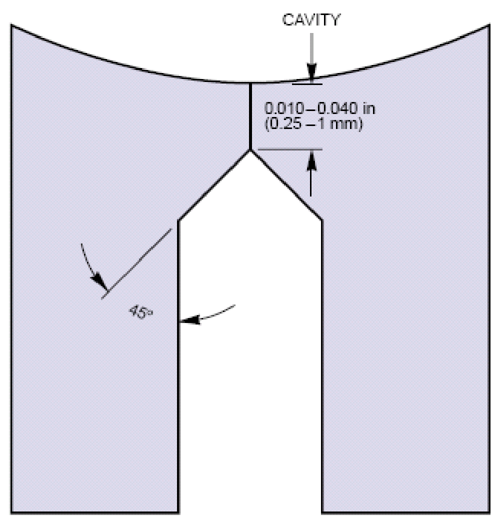
To minimize warpage, as with most thermoplastics, mold cooling should be of adequate capacity to maintain recommended mold temperatures. As with blow molds for other materials, thick sections in the neck and pinch-off require additional cooling to balance shrinkage rates throughout the part.

Mold Pinch-Offs

Mold pinch-offs and pinch pocket depths normally associated with HDPE are suitable for K-Resin® SBC. In some large part applications the use of a pre-pinch system will be needed. A typical pinch-off section is shown in Figure 2. Pinch land lengths of 0.010 – 0.040 inches (0.25 –1 mm) with a 45° angle taper on the bottom side to the pinch pocket should be of a depth which slightly compresses and cools the flash.

Figure 2

Typical Pinch-off Section



Mold Surface

For optimum clarity and gloss, molds should be highly polished at least to a SPI-SPE mold finish #2. Molds should have all tool marks polished out, followed by vapor honing with a very small glass bead size (#13) or lightly sanding toward the vents with 320 grit sandpaper (radial wipe).

Part Performance

Part Impact Strength

Impact resistance of blow molded bottles may be characterized by drop impact testing containers filled with water from various heights (ASTM D2463). The number of failures at those heights is evaluated statistically to determine a critical height related to 50% probability of failure. Though the resultant F50 value should not be used for predicting performance of production containers, it is valuable in comparing the performance of one material to another (Table 3).

Table 3

Nominal Drop Impact Strength of Typical Containers Blow Molded in K-Resin® SBC

Bottle Type	Bottle Weight, g	Impact, F_{50}, ft (m)
16 oz. Cylindrical	38	12 (4)
1 gal. Boston with handle	90	3 (1)
1 gal. with handle	110	6 (2)

Chemical Resistance

K-Resin® SBC exhibit the styrenic characteristic of poor chemical resistance, the specifics of which are detailed in PTC 353 "Chemical Resistance of K-Resin® SB Copolymers." Basically, organic hydrocarbons such as alcohols, ketones, esters, and aromatics will soften or even dissolve these polymers. Oils and to a lesser degree dilute acids and alkaline solutions will attack them, but the rate and severity of attack is dependent upon part design and storage conditions. It is the ultimate responsibility of the end user to determine the safety and suitability of their product in which a K-Resin® SBC is a component.

Barrier Properties

K-Resin® SBC does not possess the high barrier characteristics necessary for many long-term stable shelf packaging applications. It is, however, adequate for packaging many dry goods and aqueous products.

Printing and Decorating

KR05NW can be successfully treated by conventional processes using inks designed for styrenics. The surface tension is adequate to accept the inks used in silk screening, dry offset, and flexographic printing, as well as label transfer processes. KR05 is more difficult to print since it contains a microcrystalline wax which blooms to the surface. The wax can be removed from the surface by washing with isopropyl or methyl alcohol before decoration. An alternative method for thick walled parts is flame treating. None of these treatments are permanent, as the wax will bloom back to the surface of the part. While the rate of migration is dependent on storage conditions, it is best to decorate the part within 48 hours of surface treatment.

Bonding

K-Resin® SBC can be bonded by any number of techniques to itself or other materials. Solvent bonding can be achieved with a broad range of solvents, including toluene, MEK (methyl ethyl ketone, ethyl acetate and THF (tetrahydrofuran). Adhesive bonding can be readily achieved with KR05NW using contact adhesive, urethane adhesives, pressure sensitive adhesives, epoxies, and rubber based cements. After surface treatment, KR05 may also be bonded using these adhesives. Cyanoacrylate adhesives are also effective for all grades. K-Resin® copolymer can also be ultrasonically welded to itself with the no-wax grades welding better than KR05.

Troubleshooting Guide

K-Resin SBC processes well in all types of molding machines when the proper conditions are maintained. Some problems that can occur are listed below with the most likely solutions.

Blow Molding Troubleshooting Guide

Problems	Possible Causes	Suggested Solutions
Rough crystalline surface	1. Overheating of copolymer	1. a. Lower extruder temperature and increase barrel cooling if possible. Try to reduce melt temperature to below 400°F (204°C). b. Slow down extruder.
Great number of large gels	1. Overheating of copolymer in blow molder or grinder	1. The suggested solution is the same as above. 2. Reduce heat buildup in grinder.
Contamination from highly incompatible resins and other sources	1. K-Resin SBC will not purge out some polymers easily	1. a. The best plan is to disassemble the head and screw and thoroughly clean. b. If purging is the selected method of clean-out, purge for full time needed to complete clean-out.
	2. Contamination by foreign material	2. Inspect bags, hopper loader and grinder if used. Take indicated steps to eliminate foreign material.
	3. Contamination by decomposed particles	3. a. Clean die and extruder of any degraded material. b. Cool extruder before shutdown.
Pock marks, bubbles or streaks in part	1. Moisture	1. Dry resin at 140°F (60°C) for approximately one hour.
Cloudy or hazy part	1. Contamination	1. Same as contamination problem above.
	2. Melt temperature too high or too low	2. Correct melt temperature to 360– 390°F (182–199°C).
	3. Mold temperature too cool	3. Adjust mold temperature to approximately 75°F (24°C).
Part dull in appearance	1. Mold finish not polished (i.e., grit-blasted)	1. Polish mold.
	2. Mold finish dirty	2. Clean and polish with Simichrome polish.
	3. Improper mold temperature	3. Adjust mold temperature to 75°F (24°C).
Poor wall thickness distribution, top to bottom	1. Parison necking down	1. a. Program parison. b. Increase extrusion rate. c. Lower melt temperature.
	2. Larger part periphery at top	2. Invert mold, if possible.
Poor wall thickness circumferentially	1. Non-symmetrical part shape	1. a. Shape die to increase parison thickness in thin area. b. Preblow parison. c. Use larger parison diameter.
Parison rupture or part "blowout"	1. Too large a blowup ratio	1. Use larger die tooling.
	2. Mold separation	2. Increase clamp pressure or decrease blow pressure.
	3. Pinch-off too sharp	3. Provide wider pinch-off land.

Blow Molding Troubleshooting Guide

Problems	Possible Causes	Suggested Solutions
Die lines	1. Dirty or damaged die	1. a. Clean die land surfaces.
		b. Nicks or scratches in die or mandrel may need to be removed.
		c. Check for foreign material.
		d. Streamline flow to eliminate holdup in die.
Parison "doughnut" formation	1. Mandrel not up to temperature	1. Allow mandrel to reach equilibrium with rest of system.
	2. Mandrel too high	2. Lower mandrel slightly.
	3. Die face dirty	3. Clean die.
Parison length variations	1. Cooling to extruder feed zone not turned on	1. Turn on air/water cooling to feed section.
	2. Insufficient back pressure	2. Increase back pressure.
	3. Extruder operating erratically	3. Repair extruder.
	4. Extruder slipping	4. Repair extruder.
Low part weight	1. Wall thickness of parison too thin	1. a. Increase annular opening to make wall thicker.
		b. Make parison faster.
Part weight too heavy	1. Wall thickness of parison too heavy	1. Decrease annular opening to make wall thinner.
Part not fully inflated	1. Blow air pressure inadequate	1. a. Increase blow air pressure.
		b. Check for blocked air lines.
Blow needle not puncturing parison	1. Insertion rate too slow	1. Increase pressure to needle cylinder.
	2. Needle stroke too short	2. a. Lengthen stroke if possible.
		b. Install cylinder with longer stroke.
	3. Needle is blunt	3. Sharpen needle to ensure good puncture.
Parison collapses inside mold	1. Blow air incorrectly timed	1. Start blow air earlier in cycle.
Thinning or stretching at parting line	1. Low blow pressure	1. Increase blow pressure.
	2. Air entrapment	2. Improve mold venting.
Poor weld at pinch-off	1. Mold temperature too high	1. Reduce mold temperature to 75°F (24°C).
	2. Mold closing speed too fast	2. Increase mold "cushion" or decrease mold closing speed.
	3. Pinch-off land too sharp	3. a. Widen pinch land.
		b. Dam up pinch-off relief to thicken pinch weld.
Warpage	1. Insufficient cooling	1. a. Provide good water flow in mold channels.
	2. Non-uniform cooling due to air entrapment	b. Increase cooling time.
	3. Cooling differential in thick and thin areas	2. Increase good venting.
		3. Improve wall distribution.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