K·RESIN®

Styrene-Butadiene Copolymers

THE CLEAR CHOICE™

TIB 203

Blow Molding

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Introduction

K-Resin® styrene-butadiene copolymer (SBC) includes a family of clear resins made by Chevron Phillips Chemical Company LP. K-Resin SBC were brought to the marketplace in the early 1970s. Since that time, K-Resin SBC has grown steadily in the marketplace as more and more applications have been developed utilizing the copolymer's unique blend of sparkling clarity and impact strength.

Applications for K-Resin SBC range across the spectra of conventional processing techniques. Alone, or in blends with general purpose polystyrene, it can be extruded into sheet and thermoformed on conventional equipment at high output rates. The favorable economics of K-Resin SBC, along with its high productivity, has made possible tough clear drinking cups, lids, and other packaging applications. K-Resin SBC processes equally well in injection molding, providing good cycle times and design flexibility. An example of an injection molded application utilizing K-Resin SBC's properties is the clear living hinge box. K-Resin SBC allows the part to fill through the narrow hinge yet still have enough toughness to provide a 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 added dryers. K-Resin SBC can be blow molded in a broad range of sizes and shapes from small pill bottles and medical drainage units to very tall display bottles. K-Resin SBC can also be injection blow molded, without machine modification, 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 shrink wrap and overwrap. If extreme processing and regrinding conditions are avoided, this copolymer can be reprocessed in multiple passes with minimal change in properties and processing.

A feature that makes K-Resin SBC more economically attractive when compared to other clear materials is low density. K-Resin SBC has a 20 to 30 percent yield advantage over non-styrenic clear resins. K-Resin SBC meets the requirements of FDA regulation 21 CFR 177.1640 as well as EEC Directive 90/128/EEC and all its amendments for food packaging. Limitations for the storage and packaging of foods in this polymer are addressed in detail in K-Resin SBC TSM 288 “Food Packageability of K-Resin SBC”. K-Resin SBC participates heavily in the medical market, qualifies as a USP Class VI-50 material 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

K-Resin SBC is available in several grades. KR05 is the recommended grade for blow molding and injection blow molding. KR05 can also be used for neat sheet extrusion or profile extrusion.

KR05 contains a microcrystalline wax which acts as an antiblock. While the wax provides processing benefits, it does make KR05 difficult to decorate. KR05NW is the no-wax form of KR05 to facilitate printing and decorating.

K-Resin SBC can be processed on both injection blow and extrusion blow molding equipment. In the latter case, both intermittent (reciprocating and accumulator head) and continuous types are suitable. Regardless of the process, this copolymer is usually specified for a part due to the combination of 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 most cases, resin degradation serious enough to affect impact strength will probably preclude blowing the part altogether. 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

Streamlined die heads are desirable. Heads commonly used for HDPE or PVC are generally acceptable if capable of providing for a uniform flow pattern and good temperature control.

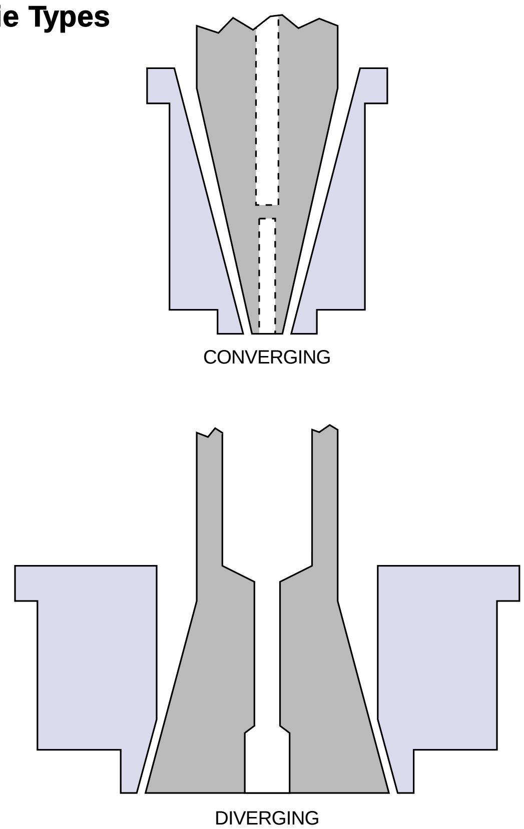
Die Tooling

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, adsorb 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 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. 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 is 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%. 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.

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 insulated 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.

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	Waist	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 Cooling

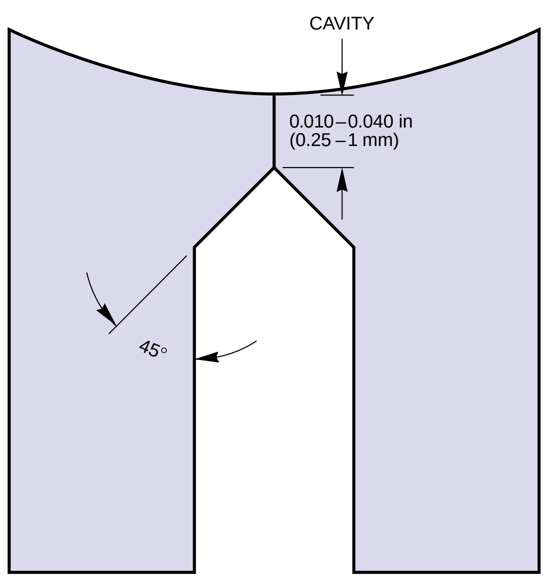
To minimize warpage, as with most thermoplastics, K-Resin SBC parts should be of adequate capacity to maintain recommended mold temperatures. As with blow molds for other materials, thick sections in the neck and pinch-off require additional cooling to balance shrinkage rates throughout the part.

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 prepinch 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 F_{50} 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 exhibits the styrenic characteristic of poor chemical resistance, the specifics, of which are detailed in PTC 353 “Chemical Resistance of K-Resin SB Copolymers”. Basically, however, 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. The actual product should, therefore, be tested for compatibility with the K-Resin SBC part prior to commercial production.

Barrier Properties

K-Resin SBC does not possess the high barrier characteristics necessary for many long-term stable shelf packaging. 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 styrenes. The surface tension (> 40 dynes) 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 is surface oxidation by corona discharge, plasma generation or flame treating. None of these treatments are permanent, however, as the wax will bloom back to the surface of the part. The rate of migration is dependent on storage conditions.

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, 1, 2-dichloroethylene, ethyl acetate, and methylene chloride.

Adhesive bonding can be readily achieved with KR01 or 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 head and screw 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 2. Mandrel too high 3. Die face dirty	1. Allow mandrel to reach equilibrium with rest of system. 2. Lower mandrel slightly. 3. Clean die.
Parison length variations	1. Cooling to extruder feed zone not turned on 2. Insufficient back pressure 3. Extruder operating erratically 4. Extruder slipping	1. Turn on air/water cooling to feed section. 2. Increase back pressure. 3. Repair extruder. 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 2. Needle stroke too short 3. Needle is blunt	1. Increase pressure to needle cylinder. 2. a. Lengthen stroke if possible. b. Install cylinder with longer stroke. 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 2. Air entrapment	1. Increase blow pressure. 2. Improve mold venting.
Poor weld at pinch-off	1. Mold temperature too high 2. Mold closing speed too fast 3. Pinch-off land too sharp	1. Reduce mold temperature to 75°F (24°C). 2. Increase mold “cushion” or decrease mold closing speed. 3. a. Widen pinch land. b. Dam up pinch-off relief to thicken pinch weld.
Warpage	1. Insufficient cooling 2. Non-uniform cooling due to air entrapment 3. Cooling differential in thick and thin areas	1. a. Provide good water flow in molded channels. b. Increase cooling time. 2. Increase good venting. 3. Improve wall distribution.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FOR FURTHER INFORMATION OR
TECHNICAL ASSISTANCE, CONTACT:

THE AMERICAS
(includes North, Central, South Americas and the Carribean Area)
CHEVRON PHILLIPS CHEMICAL COMPANY LP
P.O. BOX 3766
HOUSTON, TX 77253-3766
TEL: 800-231-1212
FAX: 800-231-3890

EUROPE/AFRICA
CHEVRON PHILLIPS CHEMICALS INTERNATIONAL N.V.
BRUSSELSESTEENWEG 355
B-3090 OVERIJSE, BELGIUM
TEL: 32-2-689-1211
FAX: 32-2-689-1472

NORTHERN ASIA
CHEVRON PHILLIPS CHEMICAL INTERNATIONAL LTD.
NIHONBASHI IT BUILDING 9F
3-9 NIHONBASHI-MUROMACHI 3-CHOME
CHUO-KU, TOKYO, JAPAN 103-0022
TEL: 81-3-5200-0511
FAX: 81-3-5200-0509

SOUTHERN ASIA
CHEVRON PHILLIPS CHEMICALS ASIA PTE. LTD.
5 TEMASEK BOULEVARD, #05-01
SUNTEC CITY TOWER
SINGAPORE 038985
TEL: 65-864-8401
FAX: 65-861-6770

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