K·RESIN®

Styrene-Butadiene Copolymers

THE CLEAR CHOICE ™

TIB 200

Properties and Processing

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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 1970's. Since that time, they have grown steadily in the marketplace as more and more applications have been developed utilizing the 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 general purpose 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 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 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, 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 label film 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 its low density. K-Resin SBC have a 20 – 30% yield advantage over non-styrenic clear resins.

K-Resin SBC meet the requirements of FDA regulation 21 CFR 177.1640 for food contact and 90/128/EEC directive and all its amendments. Limitations on K-Resin SBC for the storage and packaging of foods, are addressed in detail in *TSM 288 Packageability of K-Resin SBC*. These copolymers also participate heavily in the medical market, qualifying as USP VI-50 materials and sterilizable 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 of K-Resin SBC.*

K-Resin SBC Grades

K-Resin SBC is available in two commercial types, KR01 and KR03.

KR01 is used almost exclusively for injection molding applications. Although it is not as tough as KR03, KR01 exhibits significantly higher impact than crystal polystyrene. It provides the advantages of warpage resistance, stiffness and surface hardness compared to KR03.

KR03, KR05, KR10: In this series of resins, all the copolymers are chemically equivalent. The different grades reflect the decreasing gel/fisheye content of the resin.

Nominal Physical Properties of K-Resin® SBC

Property	ASTM	Unit	KR01	KR03
Density	D1505	g/cc	1.01	1.01
Flow Rate, 200°C/5 kg	D1238	g/10 min	8.0	7.5
Tensile Yield Strength 2" per min	D638	psi (MPa)	4400 (30)	3700 (26)
Elongation	D638	%	20	160
Flexural Modulus	D790	psi (MPa)	215,000 (1482)	205,000 (1413)
Flexural Yield Strength	D790	psi (MPa)	6400 (44)	4900 (34)
Heat Deflection Temperature 264 psi	D648	°F (°C)	170 (77)	163 (73)
Izod Impact Strength 1/8" specimen, Notched	D252	ft•lbf/in (J/m)	0.4 (22)	0.75 (41)
Shore D Hardness	D2740	–	75	65
Vicat Softening Point	D1525	°F (°C)	200 (93)	188 (87)
Light Transmission		%	90	90

- KR03 is used in injection molding and sheet extrusion, where gels are not visible in the finished part.
- KR05 is used for blowing molding, neat sheet extrusion and profile extrusion.
- KR10 is selected for film extrusion and is segregated as the lowest gel level.

The KR03, KR05, and KR10 contain a microcrystalline wax which acts as an antiblock. While the wax provides processing benefits, it does make K-Resin SBC difficult to decorate. KR03NW and KR05NW are grades of K-Resin SBC available without wax. KR10 is not available in a no-wax form.

Optical Quality

The visual perception of clarity is dependent upon two factors: the intensity and distortion of light as it passes through a part. ASTM Standard D1003, Haze and Luminous Transmittance of Transparent Plastics, describes an optical method for measuring both the intentisy of a light beam and the amount it scatters as it passes through the test specimen.

Since K-Resin SBC are amorphous, they disrupt light less than many dense, crystalline polymers and thus exhibit very low haze values (1 – 3%) and excellent light transmission (89 – 91%).

To enhance clarity, the designer may take advantage of the polymers' excellent replication of mold detail and surface finish. For example, very smooth mold surface adds visible sparkle, while heavily textured surfaces can mask undesirable product details and emphasize clear areas. In short, the designer can control mold detail to refine various aesthetic effects.

Chemical Resistance

K-Resin SBC exhibit the styrenic characteristic of poor chemical resistance, the specifics of which are detailed in other literature. Basically, however, organic compounds such as alcohols, ketones, esters, and aromatics will soften or even dissolve K-Resin. Oils, and to a lesser degree, dilute acids and alkaline solutions will attack these, 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 part.

Stress Crack Resistance

Containers made of K-Resin SBC can stress crack, especially in polystyrene blends, when the container is subjected to a stress crack medium such as oil or fat. Factors that contribute to the speed at which failure may occur include molded-in stresses, part design, part loading, the stress crack medium and storage conditions. Again, the actual product should be compatibility-tested with the container.

Printing and Decorating

KR01 and KR03NW can be successfully treated by conventional processes using inks designed for styrenes. Their 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.

KR03 type resins are more difficult to print since they contain 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. When treating K-Resin SBC, the treatment should increase the surface energy to greater than 40 dynes. None of these treatments are permanent since the wax will bloom back to the surface of the part, but K-Resin parts can be retreated. The rate of migration is dependent on storage conditions.

Bonding

Bonding of K-Resin SBC to other materials or to themselves is possible by any number of techniques. Solvent bonding can be achieved with a broad range of solvents including toluene, 1,2-dichloroethylene, ethyl acetate and methylene chloride.

Adhesive bonding is readily achieved with KR01 using contact adhesives, urethane adhesives, pressure sensitive adhesives, epoxies and rubber based cements. After surface treatment, KR03 may also be bonded using these adhesives. For both KR01 and KR03, cyanoacrylate adhesives are also effective.

K-Resin SBC can also be ultrasonically welded to themselves, KR01 welding better than the KR03.

Polymer Blends

K-Resin SBC can be blended with many other polymers. The most widespread blend application is with crystal styrene in sheet extrusion. This combination of polymers results in an economically favorable sheet with good clarity, stiffness and toughness. Crystal styrene can also be blended with K-Resin SBC in injection molding. However, unless excellent mixing is obtained, the parts are likely to be hazy, with a bluish cast. Other materials have been successfully blended with K-Resin SBC in injection molding; K-Resin SBC imparts gloss to HIPS, economics to ABS, pearlescence with PP and improved impact to SAN and SMMA. More detailed information on blends is available in other literature.

Processing

One of the most attractive facets of K-Resin SBC is its ease of processing. They can be formed on a wide variety of conventional equipment with a relatively broad range or “window” of process parameters. As with most polymers, optimum part appearance and performance can only be achieved if the part and mold are designed to meet certain

processing requirements specific to the resin selected. Both processing parameters and their effects on mold and part design are detailed in separate bulletins for each processing technique. The major points are summarized here to compare the capabilities and limitations of various forming techniques.

General Processing Considerations

Conventional processing equipment is suitable for K-Resin SBC. Unlike many clear plastics there is generally no need to dry K-Resin SBC prior to processing. It is important that the temperature controllers of the heater zone be well maintained and accurately calibrated and the melt temperature be maintained below the recommended maximum level for each process. (If processed at too high a temperature, performance or appearance could be impaired.) To minimize residence time at processing temperature, an extruder with a relatively low length to diameter (L/D) ratio should be used. Preferably, the L/D ratio should be less than 36:1. To limit polymer shear, the extruder screw should have a low to medium compression ratio with no high shear mixing sections or barrier flights. Startup and shutdown procedures should avoid excessive temperatures or soaking time. Similarly, the melt flow path should be streamlined to eliminate areas where melt could stagnate or hang up long enough to degrade the polymer.

Injection Molding

K-Resin SBC may be molded on either plunger or reciprocating-screw type machines. Screw type machines are preferred for consistent melt temperature and homogeneity. Plunger type machines are generally reserved for specific effects such as tortoise shell patterns requiring non-homogeneous melt.

For most parts, melt temperature, injection pressure and injection rate should be the minimum required to fill the mold. Gate size and mold venting should be generous enough to

accommodate both the higher pressures needed to adjust packing and the faster rates necessary to improve weldline strength.

K-Resin SBC can be molded utilizing all types of gate and runner systems as long as they are sized and streamlined to minimize shear and residence time. Heaters must be accurately controlled. Depending on part size, barrel size and cycle time, recommended processing temperatures should be between 350 – 450°F (177 – 232°C). Mold temperature can range from 50 – 120°F (10 – 49°C). Lower mold temperatures improve impact resistance and cycle time, while high mold temperatures maximize surface gloss and reproduction of mold detail.

The mold surface duplicates so well with K-Resin copolymers that parts can tend to stick in highly polished molds, especially on deep cores or when overpacked. To facilitate ejection, a draft angle of 3° with no undercuts is recommended. Stripper plates or rings are preferred to distribute stripping force. Air may be used to break the natural vacuum created between the part and the mold.

Since K-Resin SBC is amorphous rather than crystalline, its shrinkage rate is relatively low, about 0.003 to 0.010 in./in. The cooling system should be designed to balance shrinkage throughout the part and thus minimize warpage.

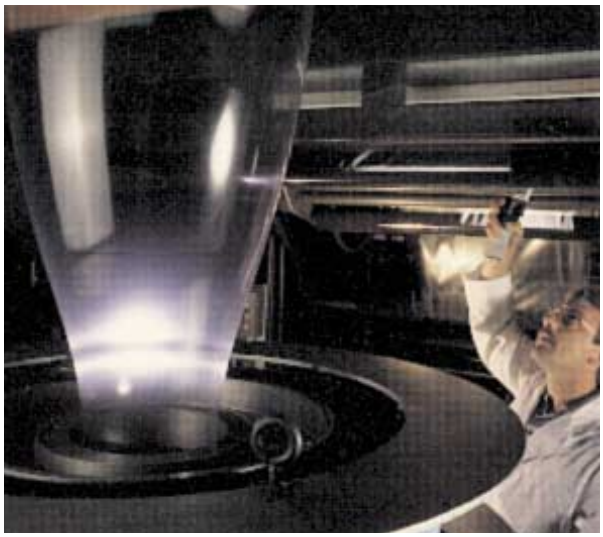
Blow Molding

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. Regardless of the process, the die head should be streamlined and capable of providing a uniform flow pattern and good temperature control. Either converging or diverging dies are acceptable, but they should be highly polished, clean and free of surface imperfections. Highly polished, well vented molds will yield optimum clarity and gloss. If these equipment requirements are satisfied, part appearance then depends primarily on certain processing parameters: 360 – 380°F (182 – 193°C) melt temperature, 60 – 100 psi (0.4 – 0.7 MPa) blow pressure, and mold temperature around 75°F (24°C).

Part toughness depends heavily on uniform wall distribution and proper pinch-welds. For most parts, wall distribution may be controlled most easily if the die tooling is sized to maintain blowup ratio below 3:1, allowing for a comparison diameter swell of -5 to + 10%. Mold pinch-offs and pinch pocket depths should be similar to those used for high density polyethylene (HDPE). As with other materials, thick sections in the pinch-off and the neck will require additional cooling to balance shrinkage rates throughout the part.

Blown Film

Clear, glossy K-Resin SBC film is well suited for vegetable wrap, over wrap, labels, candy twist, flexible medical and shrink wrap applications requiring good rigidity and impact strength. In general, blown film extrusion of K-Resin SBC is very similar to that of high density polyethylene. K-Resin film has 100% crease retention, so wrinkles cannot be pulled out of the film. Therefore, the processor should maintain bubble symmetry by accurate alignment of the die and film tower with a low collapsing frame. To maintain bubble stability, the air ring should be a single lip design with little or no chimney and



cooling air should be room temperature, low velocity and uniformly distributed. K- Resin copolymers may be produced on cast film equipment as well as blown film equipment. The cast film process is well suited to K-Resin film because of the low level of wrinkles and excellent gauge control of the process. Producing blown film is more challenging, but does offer improved film properties.

Sheet Extrusion

K-Resin SBC can be extruded into high quality sheet with equipment normally used for HDPE, polystyrene or the cellulosics. Regardless of equipment type, it should be clean and well maintained to eliminate surface imperfections caused by nicks and burrs. The die should be a flex-lip design with choke bar to facilitate line-out. Die temperature should be uniform across its width and not varied to adjust gauge because mechanical die adjustment provides more accurate and trouble-free gauge control.

For optimum performance, the die opening should be set 0 – 10% over the required sheet gauge. This minimizes single direction orientation and maximizes impact strength of the sheet and formed parts. The polishing roll nip height should be adjusted to minimize premature contact of extrudate with cooling rolls. The nip rolls should press firmly against the sheet, but line speed

should be adjusted to minimize the melt bank. Excess melt can produce surface imperfections and unacceptable stress levels in the sheet. The rolls should be chrome-plated and highly polished so the sheet will not reproduce any surface imperfections. Roll temperatures should also be adjusted to optimize clarity and gloss.

Thermoforming

K-Resin SBC and blends are excellent thermoforming materials because of their processing ease, excellent reproduction of part detail and good balance of optical quality and mechanical strength. As with other polymer materials, part performance and appearance depends on proper part and mold design, good thermoforming techniques and consistent quality of sheet stock. With the proper techniques, K-Resin SBC can be formed into a wide variety of items, including thick- or thin-walled and deep or shallow draw parts.

K-Resin sheet can be thermoformed using any of the common techniques, such as male or female drape (with or without plug assist) and prebillow or predraw. For durability and rapid heat transfer, aluminum is the preferred mold material. The mold should be well polished and vented.

For typical parts, sheet temperature should range from 275 – 300°F (135 – 149°C). A warmer sheet can improve uniformity of drawdown and reproduction of part detail. If sag bands are used, they must be positioned so that their surface marks do not show on the part. For small shallow parts, the mold temperature can be as low as 70°F (21°C). In deep draw items, especially when using a plug assist, a mold temperature as high as 125°F (52°C) will facilitate uniform wall distribution. The excellent replication of mold surface and detail achieved by K-Resin SBC can make part removal difficult, especially from deep draw plug assists and highly polished molds. To facilitate removal from the mold, the draft angle should be greater than 3° and the plug provided with a release coating. Air can be blown through the vent system to break the natural vacuum.

Conclusion

In addition to their toughness and sparkling clarity, K-Resin SBC are economical and easily processed by any of several techniques. Their design versatility is so broad that it cannot be easily addressed in one publication. This bulletin is intended to help in product conception and preliminary comparison of processing techniques. Guidelines for more complete product evaluation are detailed in separate literature titled by market segments such as packaging or medical applications. Processing techniques and their effects on part and mold design are detailed by processes such as injection molding, sheet extrusion and thermoforming, blow molding and blown or cast film.

When you select K-Resin SBC, you get more than the design freedom of the right polymer – you get experience, over 40 years of experience in innovative product and polymer development, with state-of-the-art processing expertise. Chevron Phillips Chemical Company LP is justifiably proud of its technical capabilities, and invites you to utilize the support available. K-Resin SBC has a long and successful history of helping turn challenges into opportunities.

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