K-RESIN®

STYRENE-BUTADIENE COPOLYMERS

The Smart Choice™

TIB 200

Properties and Processing

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 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 density. K-Resin® SBC have 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 FDA 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 on K-Resin® SBC for the storage and packaging of foods are addressed in detail in TSM 288 Packaging of K-Resin® SBC.

Most K-Resin® SBC grades have been tested and meet the requirements of a USP XXIII Class VI type polymer. Even so, Chevron Phillips Chemical does not recommend using any K-Resin® SBC grade in medical applications that involve permanent or temporary implantation in the human body. Detailed information on the biocompatibility and sterilization methods of K- Resin® SBC can be obtained in TSM 292 *Medical Applications of K-Resin® SBC*.

K-Resin SBC Grades

Injection Molding Grades

Several K-Resin® SBC grades (KR01, KR03, KR03NW and BK10) are available for injection molding.

K-Resin® SBC grade KR01 is used almost exclusively for injection molding applications and exhibits significantly higher impact resistance than crystal polystyrene. KR01 provides advantages of higher warpage resistance, stiffness, and surface hardness when compared to grade KR03. K-Resin® SBC grade KR03 is used in injection molding applications as well as sheet extrusion applications and exhibits improved toughness and breakage resistance compared to KR01. KR03 contains a microcrystalline wax that acts as an anti-block in extrusion. While the wax provides processing benefits, it can make KR03 difficult to decorate. KR03 is available in a no-wax form, KR03NW, to facilitate printing and decorating. BK10 provides higher melt flow for improved mold filling performance and decreased cycle times compared to KR03.

Sheet & Thermoforming Grades

Several K-Resin® SBC grades (KR05, KK38, XK40, XK41 and XK44) have been developed for sheet extrusion and thermoforming processes. These grades are typically blended with crystal polystyrene for use in single service and rigid packaging markets.

KR05, KK38, XK40 and XK41 were developed for the single service markets (cups, lids, deli items). KR05 blends with crystal polystyrene have exceptional clarity and good toughness. KK38 and XK40 blends with crystal polystyrene have improved toughness and slightly higher haze properties (using lower SBC content in the blend, which improves economics) compared to the KR05 blends. XK41 blends with crystal polystyrene provide a middle ground for both optical and toughness properties when compared to the KR05, KK38 and XK40 blends mentioned above.

XK44 was developed specifically for rigid packaging markets (medical trays, clam shells, secure packaging, etc). XK44 in blends with crystal polystyrene or styrene acrylate copolymers provide parts with exceptional clarity and toughness.

These grades contain a microcrystalline wax which acts as an anti-block. While the wax provides processing benefits, it does make these copolymers difficult to decorate. KR05NW is the no-wax form of KR05 to facilitate printing and decorating.

These grades can also be used in profile extrusion.

Film Grades

K-Resin® SBC grades specifically designed for blown film extrusion are DK11 and KR53. DK11 has high stiffness, excellent clarity, and good permeability. KR53 is not as stiff, has greater elongation and improved tear resistance. Both DK11 & KR53 contain a wax, and therefore will require surface treatment (such as corona discharge) before printing.

KR52 is designed for use in the uniaxial oriented film process for shrink sleeves.

Blow Molding 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 in blow molding processes.

KR05 contains a microcrystalline wax which acts as an anti-block. 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.

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 intensity of a light beam and the amount it scatters as it passes through the test specimen.

Since K-Resin® SBC are amorphous, the disruption of light is 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, organic compounds such as alcohols, ketones, esters, and aromatics will soften or even dissolve K-Resin® SBC. 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. It is the ultimate responsibility of the end

user to determine the safety and suitability of their product in which a K-Resin® SB Copolymer is a component.

Stress Crack Resistance

Containers made of K-Resin® SBC can stress crack, especially when used 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, stress crack medium and storage conditions. Again, it is the ultimate responsibility of the end user to determine the safety and suitability of their product in which a K-Resin® copolymer is a component.

Printing and Decorating

KR01 and no wax grades (KR03NW & KR05NW) can be successfully treated by conventional processes using inks designed for polystyrenes. Their surface tension is adequate to accept the inks used in silk screening, dry offset and flexographic printing, as well as label transfer processes.

Most K-Resin® SBC grades are more difficult to print since they contain a wax which blooms to the surface. The wax can be removed from the surface of thin parts (sheet and film) by using corona discharge. Wax can be removed from thicker molded parts (bottles) using flame treatment or by wiping the surface with isopropyl or methyl alcohol. 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 re-bloom 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

Parts molded from K-Resin® SBC can be joined to themselves and to parts molded from other materials by adhesives and solvents. It requires a trial of adhesives or solvents in each application to find the one most suitable. More detailed information on bonding is available in other literature.

Polymer Blends

K-Resin® SBC can be blended with many other polymers. The most widespread blend

application is with crystal polystyrene in sheet extrusion. This combination of polymers results in an economically favorable sheet with good clarity, stiffness and toughness. Crystal polystyrene 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, 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 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

Most 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 processed on most conventional injection molding machines.

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 weld-line 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 stick in highly polished molds, especially on deep cores or when over-packed. 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. K-Resin® SBC Concentrate SKR18 contains a mold release and a slight blue tint, which added at 1.5 percent or less can aid in part ejection from the mold. Detailed information regarding alleviating part sticking can be found in the TIB 202: *K-Resin® SBC Injection Molding Processing Guide.*.

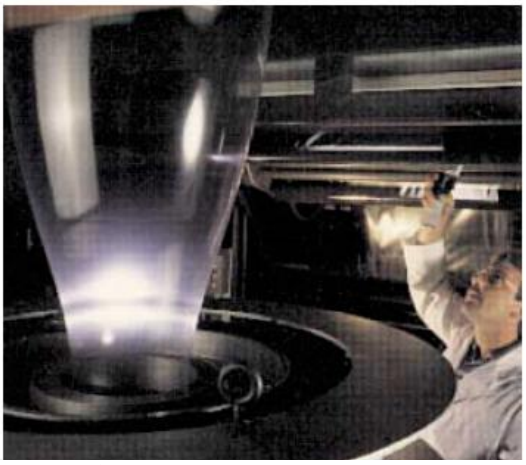
Since K-Resin® SBC are amorphous rather than crystalline, its shrinkage rates are relatively low, about 0.003 to 0.010 in/in. The cooling system should be designed to balance shrinkage throughout the part and thus minimize warpage.

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 parison diameter swell of -5 to + 10 percent. 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, candy twist, flexible medical and shrink sleeve 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 percent crease retention, so wrinkles cannot be pulled out of the film. Therefore, the processor should maintain bubble symmetry by accurate alignment of the die, film tower and 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. Monolayer or complex multilayer K-Resin® SBC films may be produced on cast film equipment as well as blown film equipment. The cast film process is well suited to K-Resin® SBC 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.

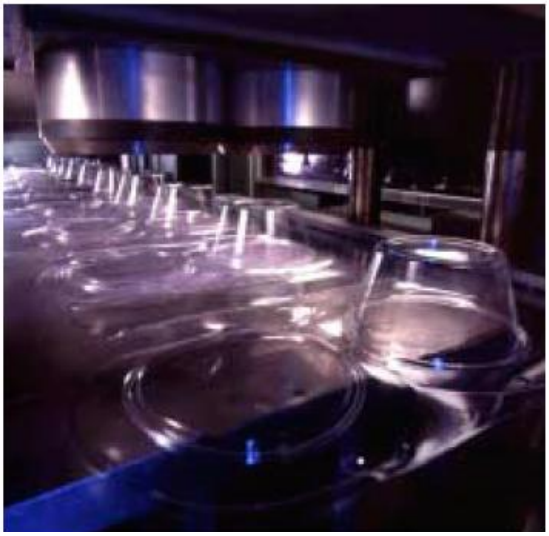
Sheet Extrusion

K-Resin® SBC and K-Resin® SBC blends with crystal polystyrene can be extruded into high quality sheet with equipment normally used for styrene base polymers. The equipment 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 5 – 10 percent 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. The melt bank 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® SBC sheet can be thermoformed using any of the common techniques, such as male or female drape (with or without plug assist) and pre-billow or pre-draw. 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 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 over 40 years of experience in innovative product and polymer development, with state-of-the-art processing expertise. Chevron Phillips Chemical 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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