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Composition Variables

Substrate and Capstock Selection

Once it has been established that the final part design will benefit from the surface characteristics of a Solarkote® acrylic surface product — weatherability, color/gloss control, chemical resistance or abrasion resistance — the decision must be made as to which thermoplastic is best suited to serve as the substrate. This decision is generally defined by the necessary physical properties for the finished part, OEM process/equipment and economics.

ABS

Acrylonitrile-Butadiene-Styrene (ABS) copolymer is characterized by its stiffness, high dimensional stability and impact resistance. Excluding its poor environmental resistance (weatherability), ABS is an outstanding material for most opaque, heavy-gauge, thermoformed products. The poor environmental stability is due to the compositional elements of ABS — a “hard phase” of SAN (Styrene-Acrylonitrile) and a “soft phase” that consists primarily of butadiene rubber. Neither of these components are as environmentally stable as PMMA or acrylic-based impact modifiers.

When ABS is protected by a Solarkote® capstock, the resulting composition is excellent for:
- Pool steps and slides
- Bath and shower furnishings
- Spa/hot tub shells
- RV components
- Marine components
- Lawn tractors
- Automotive components
- Window profiles
- Fence posts/rails

Solarkote® A is designed to be co-extruded over ABS to enhance its UV stability, scratch resistance, chemical resistance and cleanability.

HIPS

High-impact polystyrene (HIPS) has a robust process window where neither the resin nor sheet requires drying prior to extrusion or thermoforming. There are some new grades in the HIPS family that have impact performance approaching traditional ABS, but generally speaking, HIPS is a simpler polymer comprised of lower-cost raw materials that does not have the physical performance of ABS. Consequently, this lower-cost material generally is used in applications that are subject to fewer mechanical or thermal stresses. Historically, it was not possible to co-extrude PMMA over HIPS or general-purpose polystyrene. That limitation has been overcome with the introduction of the Solarkote® H capstock family of products.

Applications that are suitable for Solarkote® H/HIPS include:
- Tub and shower surrounds
- POP displays
- Store fixtures
- Refrigerator liners
- Window shutters
- Garage door panels

Solarkote® H capstock is designed to be co-extruded over HIPS to maximize the aesthetics and surface characteristics of a part that is subject to fewer thermal or mechanical stresses than those found in a Solarkote® A/ABS application.

PVC

Polyvinyl Chloride (PVC) is one of the most versatile of all thermoplastics. Often highly filled, impact-modified or plasticized, PVC has reinvented itself numerous times in its long history. Because of its versatility in compounding, and terrific natural balance of physical properties, PVC has been the material of choice for several challenging applications. Altuglas International offers two products to further enhance the available material systems that employ this substrate.

Solarkote® PB is an impact-modified acrylic powder that is designed to be blended with PVC powder at the compounding level to provide for an enhanced weathering cap with the best possible economics. This enhanced cap has allowed for penetration of PVC fence and siding into the challenging environment of the American Southwest, previously inaccessible to PVC-based products.

Applications suitable for Solarkote® PB are:
- Light-colored fence in challenging UV environments
- Light-colored siding in challenging UV environments

Solarkote® P is an all-acrylic, impact-modified capstock that is designed to be co-extruded over PVC or ABS. This resin can be processed on most existing process equipment and is available in high and low gloss.

Solarkote® P is suitable for:
- Dark-colored siding
- Dark-colored fence
- Applications requiring exceptional impact resistance
- Window profiles
Necessary Cap and Substrate Thickness Criteria

Capstock and substrate thicknesses are defined by the specific application being developed. The role of the capstock is to protect the substrate from exposure to environmental stresses that will degrade the substrate.

The capstock material serves the following roles:
- **Substrate protection from UV/visible light**
- **Color versatility**
- **Gloss control**
- **Long-term appearance retention**
- **Scratch resistance**
- **Chemical resistance**
- **System cost reduction by facilitating the use of lower-cost substrate materials**
- **Surface texture**

**CAP THICKNESS**

Solarkote® A and H clear acrylic formulations are designed to effectively screen out the high-energy UV wavelength (Figure 1) at a thickness of .006” (6 mils). Altuglas International recommends that a minimum thickness of .006” for these products be maintained after profile extrusion or sheet thermoforming to ensure proper UV screening. Solarkote® film is formulated to have comparable UV screening properties at .003” (3 mils) as that which is offered by Solarkote® capstock resins at .006”.

Please consider the drawdown ratio of a thermoforming process, and the process variability of the sheet production equipment, to establish the initial cap thickness and final cap thickness after forming.

**Example:** If a spa sheet starts at .300”, and after thermoforming has well cross-sectional thickness of .060”, then the application has a “5:1 draw-down”. This sheet would require an initial Solarkote® capstock of ~10%, so that after forming, a uniform cap thickness of at least 6 mils was maintained throughout the sheet.

Please see Appendix II: Determination of Capstock Layer Thickness on p. 20 for information on how to confirm that appropriate capstock thickness is maintained through the profile extrusion or thermoforming steps.

**Appearance Variables: Gloss and Color**

Solarkote® acrylic resin is available in its natural transparent clear form for blending with color concentrates, or as an Altuglas International prepared pre-color.

One of the primary functions of the capstock is to serve as a protective layer, shielding the substrate from certain environmental stresses that would otherwise lead to its degradation. This section will discuss the use of colorant systems (matting agents, pigments and dyes) that, when dispersed in Solarkote® or other capstock systems, help to protect the substrate from photo-initiated oxidation/degradation, and a methodology associated with the optimization of pigment systems to maximize the economics of color matching.

It is important to understand that while “colorless” Solarkote® acrylic resin and film is exceptionally UV opaque, it is nearly perfectly transparent to visible light. Visible light can degrade some pigment systems. If the decision is made to purchase field-produced color concentrates, be certain to request pigments that are stable with respect to visible light to ensure robust, long-term color retention.

**SOLARKOTE® COLORING GUIDELINES**

In the course of this section, the term “film” can be used in reference to commercially available Solkarkote® film that has been produced for inline lamination or in-mold decoration, or the term can be used to reference the resultant thin layer of Solarkote® that is produced in the co-extrusion process.
Solarkote® resins and films are weatherable capstocks with enhanced UV-screening properties to help prevent substrate degradation. It has good long-term outdoor performance with a high resistance to yellowing and ultraviolet degradation.

For the coloring of Solarkote® resins, it is important to choose colorants with good thermal stability that will have minimal adverse effect on the physical and optical properties of the resin. The color must remain serviceable for the duration of the application. Dyes at normal application concentrations have little or no effect on impact properties, but most pigments do. Pigments generally weather better than dyes.

Pigments must be well dispersed to minimize surface defects. Ideally, the pigments should be dispersed in Solarkote® resin for maximum retention of UV-screening and adhesion properties. Adding significant amounts of pigment to Solarkote® resins to produce a dispersion will typically reduce the melt flow. The resulting higher viscosity dispersion can be difficult to distribute uniformly if let down in a colorless Solarkote® matrix during processing. To increase the melt flow of the primary dispersion, a higher flow acrylic polymer may be added to the Solarkote® resin to compensate for the increase in viscosity effect of the pigment. Any time you dilute these high-UV absorber content, impact-modified products with diluting resin, you may decrease the UV screening protection and/or impact performance, surface quality or adhesion properties of the Solarkote® cap layer. Increasing the thickness of the cap layer so that it is equal to the dilution ratio of the flow-enhancing resin can compensate for the loss of UV-screening properties that are inherent in the Solarkote® resin.

Generally, it is advantageous to prepare these colorants in a primary dispersion for optimum pigment distribution. However, these primary dispersions may have to be reduced in total pigment content, with additional Solarkote® resin, in a subsequent step to tailor the letdown ratio of the color concentrate/masterbatch to your equipment capabilities.

A number of colorants have been shown to provide good weathering and retention of physical properties in acrylic resin systems. Major colorant suppliers are a good source for this information. During previous work to qualify colorant for the Plexiglas® Resin and Sheet Colorant Palette, Altuglas International has identified a number of colorants that either adversely affected impact, or failed weathering, or both. Because of the significant cost of testing, there are thousands of colorants that were not tested. Regulatory concerns, the cost of colorant testing, inventory control, and qualification of backup colorant and dispersion suppliers, make it desirable to keep the list of approved colorants to a minimum.

The general rules of good color matching practice apply to Solarkote® resins. Always choose a colorant of the proper hue to match the required color. For example, if a green match is required, start with a green pigment — never mix a yellow and a blue to produce a green. On exposure, one or the other of the components will fail first, causing a hue shift, the most objectionable type of failure. Normally, dyes and pigments would not be mixed, although it is permissible to mix a dye with a pigment of the same hue to improve saturation. In this situation, even if the dye should fade on exposure, the base color of the pigment would remain. Wherever possible, inorganic pigments should be used for pale pastel colors. The light-fastness obtained with most dyes tends to be too low, while organic pigments have inferior thermal stability and light-fastness.

The Colour Index (CI) is also a good reference source for information on colorants’ names and numbers of colorants found to be suitable for the coloring of acrylic resins. Also listed are some suppliers of these colorants. If alternate sources for previously approved colorants are considered, they should be tested before used as replacements in Solarkote® resin applications. Several words of caution are in order. CI numbers for inorganic pigments are not specific in some cases. For example, the same CI numbers cover all cadmium yellows, from primrose through golden hues. Also, all cadmium reds through maroons bear the same number. (Note: Some OEMs do not allow the use of cadmium nor other heavy metals in certain applications.) Even if you find a source offering the same hue for the same CI number, there is still danger. The texture of pigments differs from supplier to supplier. This difference in texture can affect dispersibility. Differences in dispersibility affect surface quality and impact strength, as do differences in particle size distribution. CI numbers for dyes are more specific — they define the molecular structure of the major component(s) — but differences in minor ingredients exist, as do differences in purity.

The selection of a colorant, or pigment system requires a compromise between the parties associated with the product that is to be produced. Generally speaking, the more qualifying statements that are listed as restrictive agents in the development of a pigment system, the more challenging the program becomes:

- “No lead, cadmium, or other heavy metals”
- “Delta E not to exceed 2 after 2000 hours of Xenon Arc exposure (ex. ASTM G-155-00a, Cycle 2)”
- “Inbound lot-to-lot color variability in sheet not to exceed a Delta E of .3”
- “Minimum gloss of 88 and maximum gloss of 89 to be maintained before and after thermoforming”

Each of these, or similar, statements restricts the pool of available pigment systems from which the color technician can draw to meet customer expectations. Like everything else, pigment systems have a balance of properties, and restricting one component impacts others. Such restrictions have the tendency to increase the cost of the final pigment system.

Using an “opaque” cap gives the sheet producer the opportunity to “put their best foot forward” without the high cost of a “premier” color system being dispersed throughout the sheet. A “premier” color system can be dispersed in the cap to perfectly match the target color,
while using a more “utility,” or “field-of-color,” color system in the substrate. HIPS and ABS have a natural “straw” color whose lot-to-lot variability can affect the perceived color of production lots — even though the same pigment system is employed at the sheet production facility. Masking color variation, or imperfections in the substrate, also allows the sheet producer the opportunity to reclaim scrap or use virgin HIPS or ABS that may have more variability in the “natural” color than would be possible without a capstock.

Other restrictions on loading and processing temperatures may also exist. It is the responsibility of the user of this information to verify the suitability of these recommendations.

**OVERLOADING THE CAP OR SUBSTRATE**

Optimum pigment concentration in a formulation is dependent on end use, and needs to be determined for each specific application. One criterion is the desired opacity. In general, since pigments are usually the most expensive ($/color) ingredients in a capstock material, the most cost-effective formulation is one that gives exactly the opacity needed for the end use and no more. Other considerations enter into determining the minimum or maximum pigment loading in a capstock formulation. Pigments may be used to protect other components from degradation on exposure to visible and UV and IR radiation; or to help mask color changes from thermal degradation and stress whitening. Although pigment concentration can minimize visual color change, that may result when a thin sample is laminated over different substrate colors. Care is necessary to avoid undesirable changes in physical properties due to pigment overload.

Opacity can be defined either as transmission opacity or reflection opacity. Generally for transmission, the light source and observer are on the opposite sides of the object or film. The opacity is complete when no light is visible through the film. The light travels directly through the film once, and a high pigment concentration is needed to block the light completely. In reflection, the light source and the observer are on the same side of the object or film. If the film is not fully opaque, light travels through, strikes the substrate surface and, if not completely absorbed, returns through the film to the observer. Because of the longer path length of the light, less colorant is needed for full opacity.

Although opacity is generally an attribute used to describe **Visual Opacity**, it is also a metric that can be used for characterizing other wavelength regions. It is sometimes useful for capstock products to use **Ultra-Violet (UV) Opacity** as a measure of substrate protection, and **Near IR Opacity** to help design and optimize heat build formulations for colored products. The difference in IR, UV and Visible opacity leads to many interesting issues, which is a subject for another time.

**Visible Reflection Opacity** is usually measured by placing the film over a surface with a pattern of black and white areas (leneta cards). Visual determination of opacity is made by judging whether the operator can still detect the pattern behind the film. Instrumental determination is made by measuring the reflectance of the sample over a white and black background, then comparing them by some method. A very common instrumental measurement method is **Contrast Ratio (CR)**, the ratio of the reflectance, using the CIE tristimulus “Y” value of the sample over a black substrate, divided by that over a white substrate. Although this measurement is not fully indicative of the visual opacity, it is a useful guide to help minimize formulation overload. A somewhat more accurate measure is what Altuglas International refers to as the **Contrast Ratio Color Difference**, where the color difference of the film over a black substrate is compared to the same film over a white substrate. This color difference measurement helps to evaluate the effect of opacity changes, in terms of the more familiar color difference unit, that results when the substrate is changed from black to white. Designing formulation opacity for a white to black color change may seem extreme, but it is efficient, allowing a single formulation to be used with wide variations of substrate colors. A somewhat lower opacity can be employed if the film serves as a capstock over a material with the same or similar field of color. With contrast ratios in the range of 97 to 100, the CR color difference model will almost always show a near-zero color difference, although a reduction in the cap thickness below the tested CR thickness can cause a visual difference that may be objectionable with some color/substrate combinations.

ASTM D 2805 Method can be used as a reference method for Contrast Ratio. Although not specifically developed for Contrast Ratio, it is an appropriate test method to reference with suitable footnotes, i.e.:

**Note:**
1. **Contrast Ratio** as defined by ASTM D 2805, Using CIE 10 Degree Observer, Illuminant D65.
2. **Contrast Ratio color difference.** Using CIE 10 Degree Observer, Illuminant D65, CIELAB color difference over a black and white background.

**INSTRUMENTAL METHOD FOR CONTRAST RATIO**

Using a spectrophotometer, measure the CIE Yblack and Ywhite tristimulus values. The Contrast Ratio is then calculated CR = (Yb/Yw). The CR can be expressed as a decimal fraction or percent. It is recommended for the Solarkote® film/capstock procedure to use percent CR = (Yb/Yw x 100).

The Macbeth 7000 has a measurement mode which calculates the opacity directly. After selection of the desired instrument and data-reduction parameters, the procedure is the same. Two measurements, one with a black backing and one with a white backing, are made in the proper sequence. The software then calculates the Contrast Ratio. Since the procedure varies with instrument and software version, you should consult the Macbeth operation manual for specific instructions. Also, depending on which software
version is being used, you can either read the Contrast Ratio Color Difference directly using the same pair of measurements; or you may have to change to the color difference measurement mode, reselect your measurement parameters (CIE 10 Degree Observer, Illuminant D65, CIELAB Color Difference) and remeasure the sample.

**SOLARKOTE® PRE-COLORS**

One means of avoiding some of these concerns is by specifying that a Solarkote® pre-colored resin be used for the application being developed.

In the course of developing the Solarkote® acrylic capstock resin and film portfolio of products, Altuglas International has developed some novel technology that is available only as Solarkote® pre-colors. These Solarkote® pre-colors will have superior gloss after thermoforming than a comparable color match derived from field-produced color concentrates.

The Solarkote® line of pre-colors includes Metallics, GT colors, High-Gloss Technology for Dark colors, Soft colors that are a true Flat Matte and, of course, Grit White, Beige, Blue and Black colors.

Please contact your preferred sheet extruder, or reference the “Solarkote® Surface Products Solutions Provider Sample Kit” for sample plaques of each of these technologies.

---

**Weathering Performance**

"Weatherability" is a term that is used to describe how stable a polymer is with respect to changes in appearance or physical performance in an outdoor application subject to the standard environmental stresses of UV radiation, visible light, water contact/absorption, dirt accumulation, bacterial growth, etc.

Acrylics are categorically very stable with respect to these stresses. The Solarkote® acrylic capstock resin and film product lines have been engineered to impart these advantages to less environmentally stable polymers.

The Solarkote® acrylic capstock resin and film product lines are an extremely effective means of screening UV radiation (< 400 nm) light, while maintaining near-perfect optics for the visible spectrum (see Figure 1 on p.2). UV radiation is a very important contributor to the reduction of appearance or physical properties of any polymer that is exposed to the environment.

**It is critical to understand that Solarkote® acrylic capstock resin and film is UV opaque, but visible-light transparent.** If a pigment system or polymer is degraded by visible light, then the Solarkote® capstock may slow the degradation, but not stop it completely. Always use pigment systems that are stable with respect to UV and visible light. Contact your pigment/color concentrate house or substrate supplier to determine if the intended substrate is degraded by visible light (400 nm to 750 nm).

It is impossible to evaluate every combination of color system, capstock thickness and substrate polymer with respect to how things will perform under real time and accelerated weathering systems.

Altuglas International has invested significant resources building a catalog of weatherable pigment systems and modifying the Solarkote® polymer chemistry to offer the most environmentally stable surfacing systems to the heavy-gauge sheet and profile extrusion markets. Production part performance can be affected by non-Altuglas International color concentrates, extrusion conditions, sheet surface textures, polymer cross contamination and poor thermoforming process.

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The Extrusion Process

Extrusion Support

Historically, a multi-layer polymer system was comprised of either a decorative film being laminated on- or off-line to a polymer substrate, or two chemically different but compatible materials being co-extruded through a “feed-block” die.

While both of these systems were, and are still, very effective means of producing quality parts, the recent developments in multi-manifold die technology have introduced a heretofore-unprecedented combination of layers and layer thickness control that enables some very exciting opportunities for the heavy-gauge sheet extrusion/thermoforming and profile extrusion markets.

The Solarkote® acrylic capstock resin family of products are extremely process friendly and compatible with themselves and their intended substrates. These products are based on all-acrylic polymer technology, and consequently are extremely stable with respect to UV and visible light.

Please contact your preferred heavy-gauge sheet supplier or profile extruder for information on their multi-layer capabilities. For support in defining the appropriate structure for your application, please visit www.solarkote.com or contact the Surface Products Group at Altuglas International at 215-419-7982.

Note: See Appendix I: Extrusion Troubleshooting Guide on p. 19 for details on maximizing extrusion performance.

Drying Information

Drying required to avoid moisture-related defects. Assumes four hours drying at 180°F. N.B.: all Solarkote® resins thermally degrade by 390°F.
Initial Process Recommendations

<table>
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<tr>
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<th>Solarkote® A Acrylic Capstock:</th>
<th>Solarkote® H Acrylic Capstock:</th>
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<tbody>
<tr>
<td>Desiccant Predry</td>
<td>180°F (82°C), 4 Hours</td>
<td>170°F (82°C), 4 Hours</td>
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<tr>
<td>Melt-Flow Rate &quot;I&quot;</td>
<td>1.7 g/10 min.</td>
<td>5.0 g/10 min.</td>
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<tr>
<td>Uphill Barrel Temps</td>
<td>440-500°F (230-260°C)</td>
<td>390-420°F (200-215°C)</td>
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<tr>
<td>Typical Die Temps</td>
<td>420-480°F (215-250°C)</td>
<td>400-420°F (205-215°C)</td>
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<tr>
<td>Coex Dies</td>
<td>Feedblock or Multi-manifold</td>
<td>Feedblock or Multi-manifold</td>
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For Single Screw Process:
1- or 2-Stage Vented 80-100 RPM
Min. L/D 20:1
Compression Ratio 1.8-3.2:1
2-Stage Pump Ratio 1.5 min.

For Twin Screw Process:
Lower Melts Possible
Conical or Parallel

For additional process support, please contact the Altuglas International PTC (Process Technology Center) at 800-217-3258.

Protective Thermoformable Masking

To reduce surface scratching and improve manufacturing yields, Altuglas International recommends the use of protective formable masking.

Following is a list of protective film providers with products potentially suitable for Solarkote® capped substrates. They can suggest their preferred masking films and do some preliminary masking application testing. There are many factors affecting masking adhesion and appearance that makes masking a custom development application from extruder to extruder.

Europac Inc. (distributor for Silp in US)
3411 Silverside Road
Concord Plaza
205 Rodney Building
Wilmington, DE 19810
Contact: Richard Hyde
T 302.478.1795
F 302.478.2513

Market Quest (distributor for Bishop and Klein in US)
2 Anderson Street
Monmouth Beach, NJ 07750
Contact: Bill Pearson
T 732.229.8127
C 732.310.3066
F 732.229.8128
Marketquest@comcast.net

Atlantis Plastics Inc.
Atlantis Plastics
2111 Third Avenue
Mankato, MN 56001
Contact: Judd Collier, Market Manager
T 717.779.0066
C 770.335.3715
F 717.779.0077
Customer Service:
T 507.625.3011
F 507.388.2087
www.atlantisplastics.com
The Thermoforming Process

Heating

The objective during the heating process is to raise the composite sheet surface and core to the correct thermoforming temperature without burning or blistering the sheet surfaces. Because plastics are good thermal insulators, the key to good thermoforming is to make sure that the cross section of the sheet is sufficiently heated to allow the entire sheet — surface and core — the ability to elongate during the forming process.

Conduction of heat from the sheet surface to the core by a slow heat soak controls the heating time required. The time required for heat to soak into the core (center) of the sheet increases with the square of the sheet thickness. The heat capacity and thermal conductivity for the materials involved will influence the rate of conduction in multi-layer, multi-material sheets.

Either one-sided or two-sided heating can be used to thermoform Solarkote® capped sheet. Two-sided heating is recommended for any heavy-gauge application to maximize control and minimize time necessary to elevate the core to proper forming temperatures.

Radiant heating is the best heat source:

- Heating source of 500°F – 1700°F
- Ceramic heaters radiate heat energy more efficiently than quartz or cal rod heat sources
- ABS may absorb greater amounts of radiant energy than acrylic; thus, surface temperatures may increase more rapidly
- Care should be taken to maintain the surface temperature at 325°F – 360°F to avoid blistering, burning, color/gloss shift of the Solarkote® cap

IMPORTANT: Forming temperature is affected by:

- Sheet thickness; this is the primary limit
- Heat capacity and thermal conductivity of the plastic sheet; the type of ABS and level of regrind will affect forming temperature
- Intensity of heat source and efficiency and absorption characteristics of the sheet (minor limits)
- Forming too cold adversely affects material distribution and dramatically increases the level of residual stress from the forming cycle

For heavy-gauge (thicker than .225”) sheet, Altuglas International recommends only two-sided heating to prevent long cycles, cold forming and possible overheating of the sheet surface.

CAP TO CORE TEMPERATURE DELTA

The longer the heater percentage timers are turned on, the greater the temperature difference between the surfaces and the core (Diagram 3). This cap-to-core temperature delta can result in stress in the finished part. Stress in the finished part can compromise field performance with respect to reduced chemical resistance.

Figure 3 indicates how the required time to heat the sheet varies with thickness. The time to heat the core of a thermoplastic sheet increases with the square of the thickness; i.e., two times the thickness will require four times the heating.

The key to minimizing stress in thermoforming is to have the interior of the sheet at the correct temperature, not just the top and bottom surfaces! As the sheet thickness increases, the conduction of heat through the plastic becomes the limiting factor.

The process of heating the core can be speeded up by moving from a single-sided oven to two-sided heating (see Diagrams 4 and 5), but not by increasing the amount of time the heaters are on (see Diagram 3). Thermal conductivity from the sheet substrate to the sheet core controls the core heating time.

While one-sided ovens should be avoided, the following recommendations will help produce the best part from a single-sided oven:

- Preheat sheet for 2 to 3 hours in a hot air-circulating oven at 160°F – 180°F to begin crucial heat soak. Dehumidified heating air is beneficial.
  - Helps prevent overheating of sheet surface.
  - Prevents surface defects related to volatiles being driven off rapidly (bubbling).
  - Minimizes the likelihood of cold forming.
- Convection heating must be used in combination with single-sided radiant heat sources. However, the heating process should begin with the preheat cycle described above. In addition to the sheet preheating step, a 15-minute (minimum) oven heating cycle must be completed prior to forming.
- Heat transfer from air to sheet is improved by increasing the air velocity in an enclosed oven. Remember, this only raises the surface temperature. Do not overheat the surface! Allow the time required for the heat to soak into the core.
- Steps should be taken to shield oven from drafts to prevent thermal shock of the sheet during the heating and forming steps.
Cooling

All things being equal, thin sections cool faster than thick sections. The side of the sheet that is exposed to the air cools by convection. The side in contact with the thermoforming tool cools by heat conduction through the tool material. The tool material will influence the rate of conduction. Tools made of insulating materials, like wood, will have a lower conduction rate than thermally conductive materials, like aluminum.

Differential cooling rates produce stresses in the thermoformed part. These residual stresses will result in reduced performance of the final part. The aim is to minimize this effect by standardizing the cooling rates.

- **Molds should be heated/temperature controlled for even cooling of the formed shell**
- **Thermal stress results from plastic sheet coming in contact with a cold mold**
- **Cold mold + uneven cooling = risk of poor part performance**
- **Optimum mold temperature for Solarkote® A capped ABS** is approximately 150°F
- **Top cooling via fans or blowers can be used when the molds are made of insulating materials**

- **Prevent quick cooling of thin sections by insulating the thin sections and limiting differential cooling**
- **Check the mold and part surface temperature with a pyrometer or hand-held infrared heat gun**
- **The forming vacuum should be released when the material “freezes”; this will prevent the ABS sheet substrate from contracting in the mold, which can result in an increase in internal stresses in certain areas**
- **Remove the part from the tool after sufficient cooling**

While the part may be in its finished form at this point, there still may exist a thermal gradient through the sheet. Large parts that are formed from thick sheet can continue to cool for up to 30 minutes after ejection from the forming tool. To reduce the chance of part warp or excessive internal stresses, but maintain good cycle time, these parts can be placed in a separate “cooling fixture” that supports the part, but allows for convection cooling on both sides of the formed part.

*See Appendix III: Thermoforming Troubleshooting Guide on p. 21 for additional information.*
For drilling, there are some sensitivities to conditions and procedures:

- **When drilling co-extruded sheet/profile with an acrylic-modified drill bit, be sure to exit from the Solarkote® side**
- **When drilling co-extruded sheet/profile with a standard bit, be sure to have the bit exit from the substrate side**
- **For accuracy and safety, Solarkote® capped sheet should be clamped during drilling**

For further detail on drill-bit modification and drilling techniques, please see Altuglas International PLA-21d.

The following information on cutting, routing and trimming has been provided by Onsrud Cutter. For this exercise, samples of the indicated sheet structures were provided to Onsrud Cutter, and the optimal process conditions were defined as the combination of bit and router settings that produced the highest quality edge finish.

For cutting/trimming fiberglass-reinforced Solarkote® multi-layer sheet with CNC or air routers, a standard solid carbide FGR (fiberglass router – diamond-cut) tool can be used. Routing parts in a CNC environment is best done with chip-breaker-type, solid carbide tools. Routing fiberglass by hand is best done with straight-flute, carbide-tipped tools (for added cutter body strength).

Please contact Onsrud Cutter at 800-234-1560 or www.plasticrouting.com for further information regarding problems that may be specific to your application/problem.

### Post-Forming Operations

#### Drilling, Cutting, Routing and Trimming

For drilling, there are some sensitivities to conditions and procedures:

- **When drilling co-extruded sheet/profile with an acrylic-modified drill bit, be sure to exit from the Solarkote® side**
- **When drilling co-extruded sheet/profile with a standard bit, be sure to have the bit exit from the substrate side**
- **For accuracy and safety, Solarkote® capped sheet should be clamped during drilling**

For further detail on drill-bit modification and drilling techniques, please see [Altuglas International PLA-21d](#).

The following information on cutting, routing and trimming has been provided by Onsrud Cutter. For this exercise, samples of the indicated sheet structures were provided to Onsrud Cutter, and the optimal process conditions were defined as the combination of bit and router settings that produced the highest quality edge finish.

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Please contact Onsrud Cutter at 800-234-1560 or [www.plasticrouting.com](http://www.plasticrouting.com) for further information regarding problems that may be specific to your application/problem.

### OPTIMAL PROCESS CONDITIONS FOR HIGHEST QUALITY EDGE FINISH

<table>
<thead>
<tr>
<th>Multi-layer Sheet Construction</th>
<th>Dia.</th>
<th>Cel</th>
<th>Onsrud Cutter Router Bit</th>
<th>Tool Description</th>
<th>Ranking</th>
<th>Finish</th>
<th>Feed</th>
<th>RPM</th>
<th>ADOC</th>
<th>RDOC</th>
<th>Cut</th>
</tr>
</thead>
<tbody>
<tr>
<td>.013” Solarkote® A201-56098</td>
<td>0.250</td>
<td>0.750</td>
<td>64-025</td>
<td>Super O Downcut</td>
<td>1st Spiral</td>
<td>27</td>
<td>190</td>
<td>18,000</td>
<td>0.125</td>
<td>0.250</td>
<td>Conventional</td>
</tr>
<tr>
<td>.112” Natural ABS</td>
<td>0.375</td>
<td>0.750</td>
<td>64-031</td>
<td>Super O Downcut</td>
<td>1st Spiral</td>
<td>29</td>
<td>230</td>
<td>18,000</td>
<td>0.125</td>
<td>0.375</td>
<td>Conventional</td>
</tr>
<tr>
<td>Total Sheet Thickness = .125”</td>
<td>0.375</td>
<td>0.875</td>
<td>61-122</td>
<td>Plastic O-flute Straight</td>
<td>1st Straight</td>
<td>25</td>
<td>190</td>
<td>18,000</td>
<td>0.125</td>
<td>0.250</td>
<td>Conventional</td>
</tr>
<tr>
<td>.003” Solarkote® 3100-103 Film</td>
<td>0.250</td>
<td>0.750</td>
<td>62-775</td>
<td>Plastic Spiral O-flute Downcut</td>
<td>1st Spiral</td>
<td>28</td>
<td>210</td>
<td>18,000</td>
<td>0.125</td>
<td>0.250</td>
<td>Conventional</td>
</tr>
<tr>
<td>.122” Natural ABS</td>
<td>0.375</td>
<td>0.750</td>
<td>64-031</td>
<td>Super O Downcut</td>
<td>1st Spiral</td>
<td>26</td>
<td>230</td>
<td>18,000</td>
<td>0.125</td>
<td>0.375</td>
<td>Conventional</td>
</tr>
<tr>
<td>Total Sheet Thickness = .125”</td>
<td>0.375</td>
<td>0.875</td>
<td>56-624</td>
<td>Plastic O-flute Straight</td>
<td>1st Straight</td>
<td>28</td>
<td>300</td>
<td>18,000</td>
<td>0.125</td>
<td>0.250</td>
<td>Conventional</td>
</tr>
<tr>
<td>.003” Solarkote® 3100-53003 Film</td>
<td>0.250</td>
<td>0.750</td>
<td>64-025</td>
<td>Super O Downcut</td>
<td>1st Spiral</td>
<td>29</td>
<td>230</td>
<td>18,000</td>
<td>0.125</td>
<td>0.375</td>
<td>Conventional</td>
</tr>
<tr>
<td>.122” Natural ABS</td>
<td>0.375</td>
<td>0.750</td>
<td>64-031</td>
<td>Super O Downcut</td>
<td>1st Spiral</td>
<td>26</td>
<td>230</td>
<td>18,000</td>
<td>0.125</td>
<td>0.375</td>
<td>Conventional</td>
</tr>
<tr>
<td>Total Sheet Thickness = .125”</td>
<td>0.375</td>
<td>0.875</td>
<td>61-082</td>
<td>Plastic O-flute Straight</td>
<td>1st Straight</td>
<td>25</td>
<td>190</td>
<td>18,000</td>
<td>0.125</td>
<td>0.250</td>
<td>Conventional</td>
</tr>
<tr>
<td>.003” Solarkote® 3100-43000 Film</td>
<td>0.250</td>
<td>0.750</td>
<td>64-025</td>
<td>Super O Downcut</td>
<td>1st Spiral</td>
<td>28</td>
<td>210</td>
<td>18,000</td>
<td>0.125</td>
<td>0.250</td>
<td>Conventional</td>
</tr>
<tr>
<td>.122” Natural ABS</td>
<td>0.375</td>
<td>0.750</td>
<td>64-031</td>
<td>Super O Downcut</td>
<td>1st Spiral</td>
<td>27</td>
<td>230</td>
<td>18,000</td>
<td>0.125</td>
<td>0.375</td>
<td>Conventional</td>
</tr>
<tr>
<td>Total Sheet Thickness = .125”</td>
<td>0.375</td>
<td>0.875</td>
<td>56-624</td>
<td>Plastic O-flute Straight</td>
<td>1st Straight</td>
<td>30</td>
<td>300</td>
<td>18,000</td>
<td>0.125</td>
<td>0.375</td>
<td>Conventional</td>
</tr>
<tr>
<td>3 Layer Structure</td>
<td>0.200</td>
<td>0.375</td>
<td>56-122</td>
<td>Plastic V-flute Straight</td>
<td>1st Straight</td>
<td>27</td>
<td>190</td>
<td>18,000</td>
<td>0.125</td>
<td>0.250</td>
<td>Conventional</td>
</tr>
<tr>
<td>.005” Solarkote® Top Coat</td>
<td>0.250</td>
<td>0.750</td>
<td>64-025</td>
<td>Super O Downcut</td>
<td>1st Spiral</td>
<td>30</td>
<td>150</td>
<td>18,000</td>
<td>0.125</td>
<td>0.250</td>
<td>Conventional</td>
</tr>
<tr>
<td>.013” Solarkote® A201-56098</td>
<td>0.250</td>
<td>0.750</td>
<td>64-031</td>
<td>Super O Downcut</td>
<td>1st Spiral</td>
<td>31</td>
<td>230</td>
<td>18,000</td>
<td>0.125</td>
<td>0.375</td>
<td>Conventional</td>
</tr>
<tr>
<td>Total Sheet Thickness = .013”</td>
<td>0.375</td>
<td>0.870</td>
<td>56-624</td>
<td>Plastic O-flute Straight</td>
<td>1st Straight</td>
<td>29</td>
<td>210</td>
<td>18,000</td>
<td>0.125</td>
<td>0.250</td>
<td>Conventional</td>
</tr>
</tbody>
</table>

DIA = Test Tool Cutting Diameter.
CEL = Test Tool Cutting Edge Length.
RANKING = Only the best test (“1st Spiral” and “1st Straight”) is typically recorded for each tool type. If there are similar results for additional tools, they will be listed as “2nd” or “Acceptable.”
FINISH = Surface Finish (measured in micrometers). The lower the value, the better the finish.
ADOC = Axial Depth of Cut (depth per Pass).
RDOC = Radial Depth of Cut (cut width or Stepover).

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Assembly Tools, Fasteners and Bonding

Pieces fabricated from Solarkote® capped ABS sheet may be joined using mechanical methods such as bolts, screws or clamps, or chemical methods such as cementing. In the interest of space, only cementing will be discussed in this particular section.

Cements, and particularly polymerizable cements, are an excellent method of affixing Solarkote® capped ABS sheet to a variety of different materials. Cement PS-30 and Weld-On 40 are polymerizable cements of this type. At room temperature, the cements harden (polymerize) in the container in about 45 minutes after mixing the components. They will harden more rapidly at higher temperatures. The cement joints are usually strong enough for handling 1 to 2 hours after assembly, depending upon part configuration. The joints may be machined four hours after assembly, but it is better to wait 24 hours.

Joints treated with Cement PS-30 and Weld-On 40 retain excellent appearance and color stability after outdoor exposure. These cements produce clear, transparent joints and should be used when the clarity and appearance of the joints are important.

PS-30 and Weld-On 40 should be used at temperatures no lower than 65°F. If cementing is done in a room cooler than 65°F, it will require a longer time to harden and the joint strength will be reduced. The cement should be prepared with the correct proportions of components (preferably fresh) as given in the suppliers’ instructions, and thoroughly mixed, making sure neither the mixing container nor mixing paddle adds color or affects the hardening of the cement. Clean glass or polyethylene mixing containers are preferred.

Please see Table 3, “Bonding to Solarkote® Capped Sheet,” for a summary of different combinations of materials, cements and comments.

### BONDING TO SOLARKOTE® CAPPED SHEET

<table>
<thead>
<tr>
<th>Solarkote® Capped Sheet joined to</th>
<th>Cement or Adhesive</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal (1)</td>
<td>Contact cements, Polysulfide cements</td>
<td>Joint life is limited. Max. bonding size is 2 ft. by 2 ft.; not suitable for outdoor use; joint is transparent; joint strength is low.</td>
</tr>
<tr>
<td>Rubber</td>
<td>Weld-On 40, PS-30</td>
<td>Before Solarkote® sheet may be joined to rubber with cements that do not attack its surface, it is necessary to treat the rubber with sulfuric acid until the surface face hardens. The rubber is then washed and flexed, breaking the surface into cracks that provide the means for mechanical adhesion of the cement to the rubber.</td>
</tr>
<tr>
<td>Wood</td>
<td>Weld-On 40, PS-30</td>
<td>Suitable for outdoor use; joint is transparent.</td>
</tr>
<tr>
<td>Vinyl (2)</td>
<td>Weld-On 40, PS-30 Cyclohexanone</td>
<td>Suitable for outdoor use; joint is transparent.</td>
</tr>
<tr>
<td>ABS (4)</td>
<td>Weld-On 40, PS-30, Solvent</td>
<td>Joint is transparent.</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>Weld-On 40, PS-30</td>
<td>Joint is transparent.</td>
</tr>
<tr>
<td>Polystyrene, Impact Styrene (4)</td>
<td>Solvent</td>
<td>Joint is transparent.</td>
</tr>
<tr>
<td>Styrene Acrylonitrile (SAN) (4)</td>
<td>Weld-On 40, PS-30, Solvent</td>
<td>Joint is transparent.</td>
</tr>
<tr>
<td>Cellulose Acetate Butyrate (CAB) (4)</td>
<td>Weld-On 40, PS-30, Solvent</td>
<td>Joint is transparent.</td>
</tr>
<tr>
<td>Phenolics</td>
<td>Weld-On 40, PS-30</td>
<td></td>
</tr>
</tbody>
</table>
CLEANING

To clean Solarkote® sheet, wash with plenty of mild soap or detergent and lukewarm water using the bare hand to feel and dislodge any caked dirt or mud. A soft cloth, sponge or chamois may be used, but only as a means of carrying water to the plastic. Rinse well.

Dry by blotting with a clean damp cloth or chamois. Rubbing a dirty surface with a dry cloth will scratch the material. In addition, rubbing builds up an electrostatic charge on the Solarkote® sheet so that it attracts dust particles from the air. Wiping with a damp chamois will remove this charge as well as the dust.

DO NOT use window-cleaning fluids, scouring compounds, leaded or ethyl gasolines, benzene, acetone, carbon tetrachloride, fire extinguisher or de-icing fluid, lacquer thinners, or other strong solvents. To remove tar, grease, paint, etc., use a good grade of VM&P naphtha, kerosene or other aliphatic hydrocarbon compound.

CHEMICAL RESISTANCE

Solarkote® acrylic capstock resins and films have good resistance to a variety of common cleaners and application environments. The chemical resistance of Solarkote® acrylic capstock resins will vary with the stress level, temperature, reagent, duration of exposure and resin grade. Altuglas International recommends that parts made from Solarkote® capped sheet be tested with all reagents under appropriate conditions for the end-use application.

Stress being equal, the chemical resistance of the Solarkote® acrylic capstock family can be described as follows: Solarkote® Film < Solarkote® H300 < Solarkote® A200/201 < Solarkote® A210.

With consideration for the aforementioned caution about abrasive cleaners, in general the following chemicals may be safely used with parts made from Solarkote® capped product under moderate stress at ambient temperature conditions:

- **Calgon® Bath Oil**
- **Clorox® Bleach**¹
- **Fantastic® Cleaner**²
- **Formula 409® Cleaner**³
- **Freon TF Cleaner**
- **Glass Plus® Cleaner**⁴
- **Liquid Comet® Cleaner**⁵
- **Mineral Oil**
- **Mr. Clean™ Cleaner**⁶
- **Propylene Glycol**
- **Sodium Hydroxide**
- **Sodium Hypchlorite**
- **Soft Scrub® Cleanser**⁷
- **Spic & Span® Powder**⁸
- **Soap and Water**

The following chemicals may be used with caution in low-stress and/or short-duration exposure at ambient conditions:

- **Ammonia**
- **Brake Fluid**
- **Chlorine (10%)**
- **Dow® Disinfectant**⁹
- **Ethyl Alcohol (<40%)**
- **Gasoline**
- **Isopropyl Alcohol (<50%)**
- **Kerosene**
- **Lestoil® Cleaner**¹⁰
- **Lyso 1® Basin, Tub**¹¹
- **Pinesol® Cleaner**
- **VM&P Naphtha Bathroom & Tile Cleaner**

The following chemicals may cause crazing, cracking, discoloration or dissolving of acrylic articles and are generally not recommended:

- **Acetic Acid**
- **Acetone**
- **Aromatic Solvents**
- **Benzene**
- **Butyl Alcohol**
- **Chlorinated Solvents**
- **Lacquer Thinner**
- **Lyso 1® Spray Disinfectant**
- **Sulfuric Acid**
- **Toluene**
- **Turpentine**
- **White Cap® Cleaner**
- **Xylene**
Painting and Decorating

Generally speaking, one of the advantages to the Solarkote® system is that painting is unnecessary. Solarkote® resin and film is available in clear or Altuglas International prepared pre-colors. Solarkote® resin can be colored at the extrusion stage with field-prepared color concentrates. Please follow the recommendations on p. 2, under the subheading “Solarkote® Coloring Guidelines,” for recommendations for adding color to clear Solarkote®.

If it has been determined that a Solarkote® capped part is to be decorated with trim paint, or a part needs to be painted for some other reason, Solarkote® capstocks can be painted easily to create an almost unlimited variety of decorative and functional products. Solarkote® capstocks contain no plasticizers or additives to interfere with paint adhesion or affect the durability of paint film, and is no more difficult to paint than common non-plastics such as wood or metal. As with any material, however, proper techniques and paint suited to the application are necessary to successfully paint Solarkote® capstocks.

It is important that the paint selected for use on Solarkote® capstocks be designed expressly for use on acrylic plastics. Ordinary house paints and traditional water-based paints have poor adhesion to Solarkote® capstocks. Some paints contain organic solvents which may craze or swell Solarkote® capstocks.

For assurance that a specific formulation is suitable for use on Solarkote® capstocks in the intended application, consult the paint manufacturer. In the course of developing paint formulations for acrylics, the manufacturers have accumulated much valuable experience and should be able to make specific recommendations for their products.

The outstanding durability of Solarkote® capstocks on prolonged outdoor exposure requires paints that will give equally good service outdoors. This is especially important for the sign industry, which makes extensive use of painted copy to achieve great flexibility in design and decoration of outdoor acrylic signs.

Unlike the decoration of Plexiglas® sheet for the sign industry, where sign makers have the flexibility of decorating the “first” or “second” surfaces of the transparent Plexiglas® sheet, Solarkote® capstocks will always be painted on the “first surface.” The effects of weathering on first-surface paint films are more severe than they are on second-surface films. First-surface films eventually show surface dulling, chalking and erosion to the degree that repainting is often needed to restore appearance.

This surface deterioration is a function of the quality of the paint system employed and cannot be controlled by the Solarkote® capstock substrate. If opting to paint a Solarkote® capstock, be sure to choose an appropriate paint system that has been engineered to maximize the weatherability of the paint system.

HEALTH AND SAFETY

Before attempting to do any painting of Solarkote® capped product, or before using any solvent or commercially prepared products for cleaning, paint removal or masking removal, the user should become familiar with the properties of the materials used and the precautions necessary for their safe usage. Material Safety Data Sheets can be obtained from the manufacturer for this purpose.

The American Conference of Governmental Industrial Hygienists (ACGIH) recommends the following Time Weighted Averages (TWA) for airborne concentrations: cyclohexanone – 25 ppm; VM&P naphtha – 300 ppm; isopropyl alcohol – 400 ppm (skin). ACGIH has not recommended a TWA for Solvesso 199, but Exxon proposes a value of 50 ppm.

It is always good practice to provide local exhaust ventilation as close to the point of possible generation of vapors as practical. Suggestions for the design of exhaust ventilations systems are provided in Industrial Ventilation Manual of Recommended Practice, published by the American Conference of Governmental Industrial Hygienists (1988), and the American National Standards Institute’s Fundamentals Governing the Design and Operations of Local Exhaust Systems, 29.2-1979.

CLEANING SOLARKOTE® CAPSTOCKS BEFORE PAINTING

The surface of Solarkote® capstocks to be painted must be clean. Surface contamination, even though invisible, can cause paint failure. Solvents for dirt and grease must be carefully chosen to avoid those that are harmful to Solarkote® capstocks. Harmful solvents include chlorinated hydrocarbons, acetone, toluene, xylene, lacquer thinners and some paint thinners. All of these can craze or swell Solarkote® capstocks. Even though the crazing may not be apparent immediately, Solarkote® capstock surfaces that have been treated with these solvents become sensitized to crazing and may craze once in service. Table 4, on the following page, lists the most common contaminants and cleaning methods for the Solarkote® capstock.

MASKING PAPER ADHESIVE

When masking is removed from Solarkote® capped sheet, particles of masking adhesive sometimes remain on the surface and must be removed before painting. Dabbing the sheet with the gummed surface or the masking paper may remove the particles. If this fails, a solvent such as VM&P naphtha or 99% isopropyl alcohol can be used to clean the surface. Isopropyl alcohol may craze or whiten the surface of the Solarkote® capstock on continued contact and
should be rinsed off promptly. The solvent should be applied with a soft clean cloth. The Solarkote® capped sheet should be wiped gently, then the surface should be washed with a dilute solution of non-abrasive detergent in water. This should be followed with a clean-water rinse.

If the masking paper has not left any residue and the sheet has not been handled, it may be painted without any special cleaning.

**WATER AND OIL SOLUBLE CONTAMINANTS**

Both water-soluble and oil-soluble contaminants are present on Solarkote® capped sheet that has been handled without gloves after unmasking, or that has been exposed to the shop atmosphere for any period of time. Water-soluble contaminants can be removed by washing with a detergent-water solution, and then rinsing with fresh water. Oil-soluble contaminants can be removed from Solarkote® capped sheet only with aliphatic hydrocarbon solvents. Good-quality VM&P naphtha, kerosene or mixed spirits are not harmful to Solarkote® capstocks, and they evaporate rapidly without leaving a residue. The surface of the Solarkote® capstock should then be washed with a fresh detergent-water solution and rinsed with clean water. Make sure that the surface is dry before decorating.

**FINGERPRINTS**

Remove fingerprints with a soft, clean, cotton flannel cloth and 99% isopropyl alcohol. The surface of the Solarkote® capstock should then be washed with a fresh detergent-water solutions and rinsed with clean water.

**SPRAY-MASKING COMPOUNDS**

Spray-masking compounds may leave an invisible film on clear areas after stripping. Unless removed, this will affect the long-term durability of the paint coating. The film can be removed by wiping the area with a slightly damp synthetic sponge. The surface of the Solarkote® capstock should then be wiped with VM&P naphtha or isopropyl alcohol before painting.

**GREASE**

Grease remaining on the Solarkote® capstock can be removed by washing with kerosene or mineral spirits. This should be followed by washing with a detergent-water solution and then rinsing with clean water. The Solarkote® capstock must be thoroughly dry when it is painted, because moisture will reduce the effective service-life of the coating.

**SILICONE CONTAMINANTS**

Silicone-based oils and greases should not be used anywhere in the fabrication area, because it is virtually impossible to remove these contaminants from the Solarkote® surface. Paint adhesion on Solarkote® capstocks contaminated with silicones is very poor.

**NEUTRALIZATION OF STATIC ELECTRICITY**

Charges of static electricity accumulate on the surfaces of Solarkote® capstocks during processing and cause uneven paint deposition and paint crawling. These static charges are most common under dry, winter atmospheric conditions of low, relative humidity. Conditions of high relative humidity, conversely, reduce the problems of static charges. At 70% relative humidity, for example, there is no problem in painting except for the possibility of moisture condensation on the surface of the Solarkote® capstock. Anti-static solutions affect paint adhesion and cannot be used on a Solarkote® capstock that will be painted.

There are a number of ways to eliminate static charges on the Solarkote® capstock surface.

The surface to be painted can be wiped with a mixture of 10 parts isopropyl alcohol in 90 parts water. This solution should be applied with a well-wrung-out, clean chamois to minimize water spotting after drying. After wiping down the surface, the moisture must be removed from that surface by blowing with a dry-air gun. Care must be taken, however, since excessive blowing will generate a new static charge.

A metal window screen placed near the surface not to be painted also will reduce the static charge. For best results, the screen should be grounded.
Silk-screen tables can be covered with grounded conductive rubber sheeting or wire glass. The screen frame also can be grounded by strips of copper. After the plastic sheet is placed on the conductive material, a tinsel bar passed across the upper surface, but not in contact with it, will dissipate the charge.

Wiping the surface to be painted with a clean flannel cloth dampened with 99% isopropyl alcohol (IPA) also may remove the static charge. IPA is a potential crazing agent. It should be noted that IPA should not be used on a thermoformed part where residual stress may significantly reduce the chemical resistance of the Solarkote® acrylic capstock. Strong atmospheric ionization also will remove static charges from Solarkote® acrylic capstock. Low-voltage induction equipment and ionizing air guns are available from a number of sources. The manufacturer of the equipment will give specific recommendations for static elimination.

Caution: The air guns contain radioactive materials that emit alpha particles. Under no circumstances should they be disassembled. The guns should be returned directly to the manufacturer for servicing.

MIXING THE PAINT

Paint must be thoroughly stirred to obtain uniform pigment distribution. When pressure-feed tanks are used, they should be equipped with continuous air-operated stirrers to prevent pigment settling, which can cause high pigment volume concentration in the paint film and lead to failure of the paint. It is important to use the proper type and amount of thinner. Too much thinner can reduce the durability of the paint. The paint supplier’s instructions for mixing should be followed.

For spray application, the viscosity of the paint should be controlled on each batch of paint after mixing and before spraying. Manufacturers’ recommendations may vary slightly, but are usually based on measurement with a No. 4 Ford viscosity cup. Viscosity cups are available from most chemical supply houses. Viscosity is affected by temperature and should be adjusted for a standard temperature of 73°F. Acrylic-based paints are usually sprayed at a viscosity of 15 to 17 seconds as measured by a No. 4 Ford cup. Other viscosity cups may be used, but the time will be different. The corresponding time on a No. 2 Zahn cup, for example, is 22 seconds.

The colorfastness of the paint film depends on the quality of the paint. In some cases, however, poor color stability will result from mixing or reducing two normally stable colors. Before making production parts, therefore, consult the paint manufacturer for an opinion on the color stability of specific mixtures of paints.

APPLYING THE PAINT

Solarkote® capstocks may be painted by spraying, screening or brushing. Each paint manufacturer makes grades of paint matched to each type of application.

COLOR COAT

The color coat should be at least one mil thick for best durability. When painted Solarkote® capstocks are thermoformed at high-forming temperatures, some colors may bleed. This can be overcome by forming at lower temperatures, where the surface temp does not exceed 320°F.

PAINTED TOPCOATS

It is often advantageous to apply a clear topcoat over the color coat to protect the paint from mild abrasion during cleaning and handling. The topcoat does not add significant life to the paint system.

REMOVING PAINT FROM SOLARKOTE® CAPPED PRODUCTS

Paint may be removed from Solarkote® capped products with solvents, trialene soap or by sandblasting.

SOLVENTS

Solvents used for removing the paint from Solarkote® capstocks must be chosen carefully, because most solvents tend to cause crazing or swelling, particularly on deeply drawn, formed parts. The best solvent for paint removal is cyclohexanone. The Solarkote® capstock should be wiped with a solvent-soaked rag. The complete part -- capstock and substrate -- should not be soaked in the cyclohexanone. Solvesso 100 may also be used. The painted Solarkote® capstock may be immersed in the solvent for a period of 10 minutes or less. After soaking, the paint may be removed by wiping the surface with a cloth. When solvent is used to remove paint from Solarkote® capstocks, the stripped part should be annealed to remove the residual solvent which may cause crazing. While the initial solvent treatment may not craze the Solarkote® capped surface, subsequent contact with other solvents may cause crazing unless the Solarkote® capped product is properly annealed. See the Plexiglas® Acrylic Sheet Fabricating Manual, PLA-21, in the Annealing section for more details.

TRIALENE SOAP

Trialene soap is particularly useful for paint removal when the paint has not been on the Solarkote® capstock for a long time. Once the paint has been removed, the Trialene soap must be thoroughly cleaned from the Solarkote® surface by rinsing with fresh water. The Solarkote® surface must be dried before repainting.

Caustic soda and trisodium phosphate also may be used for removing paint from the sheet.
Caution: Trialene soap, caustic soda and trisodium phosphate attack human skin very quickly. The operators’ hands should be protected by rubber gloves. Safety goggles should be worn while using these compounds.

SANDBLASTING
Sandblasting will also remove paint from Solarkote® capstocks, but this method is generally more expensive and damaging to the Solarkote® surface than other methods. The surface finish of the Solarkote® capstock will have a “frosted” appearance after sandblasting. This method of paint removal should only be employed if the intent is to repaint the part. Only a fine grade of sand should be used. Appropriate safety concerns should always be followed, including face shields, gloves and proper ventilation.

Repairing a Damaged Part

REFINISHING SOLARKOTE® SURFACE WITH MINOR ABRASION DEFECTS
Solarkote® capped sheet should be handled carefully to avoid scratching its surface. It is easier to avoid scratches than to remove them. Information on protective sheet masking film suppliers can be found on p. 7 of this manual. Scratched surfaces can be restored to a good finish by a process of polishing and/or sanding. Sawed edges and machined surfaces can also be polished to a high gloss. Where power-operated polishing equipment is not available, it is possible to hand-polish minor scratches from the surface of the sheet. Rubbing with soft flannel and a good grade of automotive paste wax can polish minor scratches.

Before sanding, buffing or polishing, clean the Solarkote® surface carefully. The buffing wheels and compounds should also be free from dirt and grit. Separate buffs should be dedicated to acrylic surfaces. Running the buffing wheel against a hard metal edge to remove hardened tallow, grease or other binders should clean the buffs.

The friction of buffing, sanding or polishing too long or too vigorously in any one spot can generate enough heat to soften or "burn" the Solarkote® surface, resulting in visual distortion and possibly discoloration. This is especially true in the situation of a clear Solarkote® cap. To avoid this, keep the Solarkote® surface constantly in motion relative to the wheel, use light pressure and change the direction of buffing often. Air-cooling buffing wheels are often used to help reduce heat from friction.

Polishing techniques vary with the equipment available and the size or shape of the acrylic parts polished.

Sanding and buffing can cause thickness variation in the scratched area of the Solarkote® surface. If skillfully done, these operations cause only minor optical distortions that should not be objectionable for most applications. On occasion, critical sections, even though scratched, should not be sanded or buffed. They should simply be washed and waxed.

SCRATCHES
A clear Solarkote® topcoat offers the thermoformer/fabricator/end user the opportunity to restore a slightly abraded surface to an “as-good-as-new condition” if the proper protocol is used. The following protocol has been defined using materials from 3M®. If executed properly, this process will restore a slightly scuffed Solarkote® surface to a lustrous, very high gloss.

Recommended procedure for the repair and polishing of Solarkote® acrylic capped surfaces with 3M™ products:

1. Sand using 3M™ Trizact™ abrasive (PN 02075) with the DA pad (PN 05251) and the 3M™ Soft Interface Pad (PN 05274) on a DA sander. Use the 3M™ Trizact™ abrasive damp and sand until you see the “white foam.”

2. Use 3M™ Perfect-It™ Foam Compound Pad (PN 05737) with 3M™ Perfect-It™ 3000 Spot Finishing Material (PN 06070) on a back-up pad (PN 05717) with an adaptor (PN 05710). Set the polisher at 1500 rpm.

Note: When sanding with P3000 3M™ Trizact™ abrasive, use a spray bottle to apply enough water to dampen the Trizact™ abrasive. Sand until all scratches are removed.

3. Use 3M™ Perfect-It™ Foam Polishing Pad (PN 05738) with 3M™ Perfect-It™ 3000 Swirl Mark Remover (PN 06064) on a back-up pad (PN 05717). Set polisher at 1500 rpm; use medium pressure on the buffer.

Apply 3M™ Perfect-It™ Durable Glaze, PN 38112 by hand as a final step. Wipe clean with 3M™ Perfect-It™ Detailing Cloth, PN 06016.

If there is a deeper scratch in a Solarkote® surface, it should not be sanded unless the surface imperfections are too deep to be removed by light buffing. This process will result in some optical distortion, and should only be attempted if the final part can tolerate a “less than ‘class A’ surface.” The way to tell if sanding is necessary is to rub a fingernail over the scratch. If it can be felt, then sanding is required. For situations that must be sanded, sand by hand, NOT BY POWER TOOL. Progressively finer grit
sandpaper/polishing compound should be used up to grits of 12,000. These grits are available as cushioned abrasive cloth. Use the finest sandpaper that will remove the imperfections. Coarse paper can cause scratches deeper than the original imperfection, and additional finishing operations will be needed.

**SANDING**

First try using 600-grit sandpaper wrapped around a rubber-padded sanding block. Sand over the scratch using increasingly larger areas of sanding. If this does not readily remove the scratch, step down to 400-grit sandpaper. The sanding should be done in directions mutually 30° apart to produce a diamond pattern. After sanding and stepping back up to 600-grit sandpaper, polish the sheet as described below.

Do not use disc or belt sanders when dry. The greater danger of heat generation with mechanical sanders makes the use of water or oil coolants doubly desirable. Wet sanders are preferred, but dry orbital sanders can be used with care. Open-coat sandpaper should be used, since it does not become clogged as fast as closed-coat sandpaper.

**MACHINE BUFFING**

The Solarkote® surface should be clean and dry at the start of each buffing operation. Some polishing compounds leave the surface clean after buffing. If these polishing compounds are not used, washing the surface should follow the last step in polishing.

If the part has previously been sanded or is deeply scratched, an abrasive-coated wheel is used first. The abrasive is a standard polishing compound composed of very fine alumina or similar abrasive and tallow.

When most of the scratches have been reduced on the first wheel, the Solarkote® surface is buffed on the second wheel charged only with tallow. These first two wheels should be air-ventilated, cotton muslin rag wheels and should operate at 3,000 to 4,500 surface feet per minute (SFPM). To calculate: SFPM equals 1/4 the diameter of buffing wheel in inches multiplied by the spindle speed in rpm.

The Solarkote® surface is next brought to a high polish by a soft, loose buff in which no abrasive or tallow is used. These cleaning buffs should be very loose and made of imitation chamois or cotton flannel. The wheels should be 10 to 12 inches in diameter and run at 3,000 to 4,500 SFPM. A hand-applied coat of wax may be used in place of buffing on the finish wheel, if desired.

**POLISHING EDGES OF SOLARKOTE® CAPPED SHEET**

Solarkote® capped sheet edges should be free of chips and major irregularities to avoid a notching effect. Notches can become sites for cracks to start, and notched areas are more susceptible to chemical attack than notch-free areas. Sometimes good machine-finished edges are used as a decorative element in the design of a part made of sheet. Well-polished edges, however, may be required for decorative applications.

Saw marks can be removed from the edges of Solarkote® capped sheet by scraping with a hard steel or Carboloy scraper, square-ground to a straight, smooth edge. After scraping, the edges should be sanded on a wet belt sander with 320-grit then 400-grit sandpaper.

A fast method to polish sheet edges is to make buffs of layers of medium density 100 percent wool felt about 3/16 to 1/4 inch thick. The felt should have a specific gravity of about 0.27. The wheels should be 10 to 12 inches in diameter and should be held between hard faceplates about three inches smaller in diameter than the buff. The wheels should be run at a speed of 3,000 to 4,500 SFPM.

The edges are buffed on a felt wheel that is charged with abrasive and tallow. The final polish is given to the edges with a soft cotton buff. Felt wheels should not be used on large flat areas, since there is a tendency to burn and distort the sheet.

Whenever possible, a number of sheet or formed parts should be locked together in a jig leaving only the edges exposed, so that the edges may be planed, sanded and polished simultaneously. This technique is faster and gives better results without rounding the edges. Lapidary wheels surfaced with high-density felt also may be used for polishing flat surfaces.

To prevent heat buildup, the sheet may be buffed with a paste or liquid wax with an abrasive.

**SOURCES OF SUPPLY MATERIALS FOR SOLARKOTE® SURFACE CLEANERS AND POLISHING COMPOUNDS**

3M Automotive Aftermarket Division
www.MMM.com

BTI Chemical Co., Inc. - Plexus® Plastic Cleaner
638 Lindero Canyon Road, # 371
Oak Park, CA 91377
T 818.879.1493
F 818.879.0697
www.plexusplasticcleaner.com

Meguiar's Inc. for Mirror Glaze
17991 Mitchell South
Irvine, CA 92714
T 800.854.8073
F 714.752.5784
CRACKS, HOLES AND DEEP GOUGES

Depending on the size of the crack or hole, and the cost of replacing the part, the repair strategy for damage of this severity is slightly different.

For a low-cost part with significant damage, the best strategy is to simply purchase a replacement part.

For more expensive parts — such as boat hulls, bathtub liners or hot tubs — or less challenging repair projects, you might consider having the damaged part repaired by a professional or attempting a DIY repair job. Before attempting to repair the part yourself, honestly evaluate your skill level for such activity to avoid doing more harm than good. Acrylic surfaces have exceptional beauty, and a bad repair job might look worse than the original problem.

For the “DIYer” who is committed to attempting this, follow these steps:

1. Order the appropriate repair kit for your application. For help in determining the appropriate repair kit, visit our website, or contact the OEM for the part in question.
2. Clean the surface.
3. Grind the area, scratch or hole to create an even perimeter that will be filled by the repair compound. **CAUTION:** The use of a high-speed sanding tool might generate excessive heat and end up melting, rather than grinding, the area to be repaired. This action will result in a more difficult repair job. Use a low-speed, high-grit abrasion device for this step.
4. If possible, slightly undercut the perimeter of the defect area.
5. Mix components from repair kit to form the filler paste.
6. Build up the filler in the defect area, being careful to fully pack out the edges with the filler compound.
7. Build a very slight “mound” of repair compound above the surface of the sheet. This mound will either be textured to match the surrounding surface texture, or sanded to a smooth finish. Similar to the mudding of drywall joints, this is definitely a case where less is more.
8. If the original part has a surface texture, use the appropriate texturizing pad in the repair kit.
9. Apply the texturizing pad while the filling paste still has a “putty-like” consistency.
10. If the original part has a smooth surface, sand down the mound of the repair area to be flush with the surrounding sheet.
11. Follow the procedure for buffing out scratches detailed in "Post-Forming Operations: Repairing a Damaged Part", pp. 16-17.

One of the most challenging elements of this process is achieving a reasonably good color match to the original sheet. Please visit www.solarkote.com, or contact the OEM for the appropriate repair kit.

COMPANIES INVOLVED IN THE REPAIR, MATERIALS OR TRAINING FOR THE REPAIR OF DAMAGED ACRYLIC PLASTIC

Arkema Inc.
Altuglas International
2000 Market Street
Philadelphia, PA 19103
T 800.523.1532
Contact: Customer Service

- If the application in question was designed with a Solarkote® pre-color package, then a Burst Pack™ repair kit by Burst Pack, LLC can be used to achieve a near perfect match to the original sheet.
- Information required includes the application being repaired, OEM and Solarkote® color number.
- If the application in question was designed using field-produced color systems, Altuglas International may have a color match that is close. Please visit www.solarkote.com to view our pallet of pre-color options.

Northern Acrylics & Supply
4765 N. Brown Road
Manton, MI 49663-9327
T 231.824.3888
Contact: Bob Fuller
- Distributor of the Burst Pack™ acrylic repair system

Julians Porcelain & Fiberglass
10732 Sepulveda Boulevard
Mission Hills, CA 91345
T 818.890.0740
Contact: Adriana Ruvalcava
- Company repairs damaged acrylic surfaces in house

Multi-Tech Products
41519 Cherry Street
Murrieta, CA 92562
T 800.218.2066
www.multitechproducts.com
- Manufactures a professional and DIY repair kit formulated for Solarkote® acrylic capstocks
# Appendix I

## Extrusion Troubleshooting Guide

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<td>Poor Wall or Diameter</td>
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<td>Cutting and Trimming</td>
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<td>Polished Marks</td>
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<td>Flow Marks</td>
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<td>Melt Fracture Regions</td>
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<td>Embossed Reproduction</td>
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<td>Bubbles</td>
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<td>Flow Marks</td>
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<td>Melt Fracture Pattern</td>
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<td>Poor Embossed Reproduction</td>
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<td>Excessive Orientation</td>
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<tr>
<td>Suggested Remedy</td>
<td></td>
</tr>
<tr>
<td>Check mounting and location of line equipment</td>
<td>X</td>
</tr>
<tr>
<td>Check polishing drive system</td>
<td></td>
</tr>
<tr>
<td>Polish die to remove nicks</td>
<td>X X</td>
</tr>
<tr>
<td>Reduce die temperature</td>
<td></td>
</tr>
<tr>
<td>Increase die temperature</td>
<td>X</td>
</tr>
<tr>
<td>Purge or clean die or extruder</td>
<td></td>
</tr>
<tr>
<td>Be sure temperature controllers are functioning properly</td>
<td>X</td>
</tr>
<tr>
<td>Reduce output rate</td>
<td>X X X X X</td>
</tr>
<tr>
<td>Dry material more effectively</td>
<td></td>
</tr>
<tr>
<td>Use a vented extruder</td>
<td>X</td>
</tr>
<tr>
<td>Adjust feed-zone temperature</td>
<td></td>
</tr>
<tr>
<td>Increase barrel temperature in transition zone</td>
<td>X</td>
</tr>
<tr>
<td>Use proper screw design</td>
<td>X X X X</td>
</tr>
<tr>
<td>Adjust die flow</td>
<td></td>
</tr>
<tr>
<td>Increase take-off speed</td>
<td>X</td>
</tr>
<tr>
<td>Reduce pressure of polishing roll</td>
<td></td>
</tr>
<tr>
<td>Increase polishing or embossing roll temperature</td>
<td>X</td>
</tr>
<tr>
<td>Reduce polishing or embossing roll temperature</td>
<td>X</td>
</tr>
<tr>
<td>Increase pressure of polishing or embossing roll</td>
<td>X</td>
</tr>
<tr>
<td>Regulate speed ratio between embosser and pull rolls</td>
<td>X X</td>
</tr>
<tr>
<td>Increase stock temperature</td>
<td>X</td>
</tr>
<tr>
<td>Eliminate contamination</td>
<td></td>
</tr>
<tr>
<td>Adjust temperature differential between rolls</td>
<td>X</td>
</tr>
<tr>
<td>Adjust bead at polishing rolls</td>
<td>X</td>
</tr>
<tr>
<td>Reduce stock temperature</td>
<td></td>
</tr>
<tr>
<td>Use highly polished rolls</td>
<td></td>
</tr>
<tr>
<td>Reduce drawdown</td>
<td></td>
</tr>
<tr>
<td>Repair worn screw or barrel</td>
<td></td>
</tr>
</tbody>
</table>
Appendix II

Determination of Capstock Thickness

INTRODUCTION
Performance sheet manufactured from Solarkote® capstock resin is determined by the thickness of the protective capstock layer. Accurate determination of the capstock thickness after thermoforming or profile extrusion is critical for end-use performance. Likewise, accurate determination of the protective capstock layer during sheet or profile co-extrusion is required in order to predict the thickness of the capstock on the final product. The techniques outlined below serve as a guideline for determining Solarkote® capstock thickness.

BASIC PROCEDURE
Measuring capstock thickness can be difficult when color-matched layers are incorporated into a co-extruded sheet. It may take a combination of the individual techniques to obtain an accurate reading. Briefly, you want to enhance the differences between the materials. Optical measurements of small pieces of co-extruded sheet are preferable. Examples of equipment include portable vernier-scale microscopes (e.g. Travers Tool Co.: Micro-Mike, precision pocket microscope).

OTHER CONSIDERATIONS
STAINING
Acrylic is less porous than its ABS substrate. Lightly draw a line across the cross section with a pencil or a water-soluble pen, and then wipe it off with your finger.

SURFACE
A saw cut is necessary for good measurement. Shear-cut or scored/snapped edges will deform the edge. The quality of the surface finish may help the measurement. Oftentimes, a rough saw cut will emphasize the interface. However, starting with a smooth edge and lightly abrading it may reveal the layers.
Example: Acrylic is harder than ABS. Slight abrasion of the cross-sectional surface with an eraser or very fine sandpaper will roughen the ABS and not the acrylic. The abraded surface may not be evident until low-angle lighting is directed at the surface.

LIGHTING
This is perhaps the most critical aspect of analyzing cap thickness. Generally, low angles of light will reveal the interface. In certain instances, the cap may be translucent enough to allow light to penetrate (side lighting), so the cap will act as a light pipe. Direct sunlight may reveal a difference in color or texture. A colored light source may also enhance the interface areas (yellow/amber, red or blue filters). Black lights are very effective in exaggerating the color differences that exist in color systems that have been engineered to match under white light.

MICROTOME
A thin cross-sectional slice placed in a measuring microscope with back lighting may be necessary.
A sharp utility knife will cut a thin piece.
Safety: Cut-resistant (Kynar®) gloves should be worn.

SUBSTRATE THICKNESS
The thickness of the substrate should be defined by the minimum thickness of the final part necessary for a robust service life for the application in question.
## Thermoforming Troubleshooting Guide

### Appendix III

## Thermoforming Troubleshooting Guide

### OVERALL

There are four major technical resources available for assistance. All of these should be used during manufacture and troubleshooting.

- Sheet extruder
- ABS resin manufacturer
- PUR/UPR/other reinforcement system supplier
- Arkema Inc. - Altuglas International 800-523-1532

### BLISTERING OR BUBBLING OF SHEET DURING THERMOFORMING

<table>
<thead>
<tr>
<th>Causes</th>
<th>Cures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive moisture</td>
<td>Minimize sheet storage time.</td>
</tr>
<tr>
<td></td>
<td>Install a dehumidifier in sheet storage area.</td>
</tr>
<tr>
<td></td>
<td>Keep a moisture barrier wrap on stored sheet.</td>
</tr>
<tr>
<td></td>
<td>Predry sheet.</td>
</tr>
<tr>
<td></td>
<td>Preheat sheet.</td>
</tr>
<tr>
<td>Heating sheet too rapidly</td>
<td>Slow down heating rate by using a longer heat cycle and lower temperatures.</td>
</tr>
<tr>
<td>Uneven heating</td>
<td>Use screening techniques, or zone temperature control if available.</td>
</tr>
<tr>
<td></td>
<td>Check heater operation.</td>
</tr>
<tr>
<td></td>
<td>Increase distance between heaters and sheet.</td>
</tr>
</tbody>
</table>

### BLISTERING OR BUBBLING OF SHEET AFTER THERMOFORMING – PUR FOAM REINFORCED

<table>
<thead>
<tr>
<th>Causes</th>
<th>Cures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uneven adhesion between the ABS and the polyurethane layers</td>
<td>Place a release layer between the ABS and PUR foam.</td>
</tr>
<tr>
<td></td>
<td>Review PUR procedures and types.</td>
</tr>
<tr>
<td>Residual PUR components vaporizing</td>
<td>Make sure the PUR components remain exactly in ratio while spraying, and are the correct temperature.</td>
</tr>
<tr>
<td></td>
<td>Consult polyurethane manufacturer or sheet resin manufacturer.</td>
</tr>
</tbody>
</table>

### CORNERS TOO THIN IN DEEP DRAWS

<table>
<thead>
<tr>
<th>Causes</th>
<th>Cures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor material distribution pattern</td>
<td>Check for controlled heating.</td>
</tr>
<tr>
<td></td>
<td>Reduce heater intensity.</td>
</tr>
<tr>
<td></td>
<td>Use screening.</td>
</tr>
<tr>
<td>Variation in mold temperature</td>
<td>Adjust mold temperature system.</td>
</tr>
</tbody>
</table>

### LOSS OF COLOR BY BLUSHING OR DEGRADATION (ABS), OR BLISTERING (SOLARKOTE® ACRYLIC CAPSTOCK)

<table>
<thead>
<tr>
<th>Causes</th>
<th>Cures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet surface overheated</td>
<td>Reduce heater intensity.</td>
</tr>
<tr>
<td></td>
<td>Reduce heater proportional timer.</td>
</tr>
</tbody>
</table>

### WHITENING OF ABS SURFACE

<table>
<thead>
<tr>
<th>Causes</th>
<th>Cures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet is too cold</td>
<td>Increase heating cycle time.</td>
</tr>
<tr>
<td></td>
<td>Increase heater proportional timer.</td>
</tr>
<tr>
<td>Insufficient radius in mold details</td>
<td>Modify mold to provide more generous radii.</td>
</tr>
</tbody>
</table>

### POOR WALL THICKNESS DISTRIBUTION / EXCESSIVE THINNING

<table>
<thead>
<tr>
<th>Causes</th>
<th>Cures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncontrolled sheet heating</td>
<td>Check heaters for operability.</td>
</tr>
<tr>
<td></td>
<td>Use screening techniques.</td>
</tr>
<tr>
<td></td>
<td>Check for drafts in heating stage.</td>
</tr>
<tr>
<td></td>
<td>Enclose heating and forming area.</td>
</tr>
</tbody>
</table>

### CRACKING OF PART IN USE

<table>
<thead>
<tr>
<th>Causes</th>
<th>Cures</th>
</tr>
</thead>
<tbody>
<tr>
<td>High residual stresses from thermoforming</td>
<td>Use a higher sheet temperature during forming — throughout the sheet, not just on the surface.</td>
</tr>
<tr>
<td></td>
<td>Use proper forming temperature, cycle time and cooling rate (i.e., heat longer at lower intensity).</td>
</tr>
<tr>
<td></td>
<td>Round any sharp corners in the mold surface.</td>
</tr>
<tr>
<td>Uncontrolled sheet heating</td>
<td>Use screening techniques to control heat distribution in thin sections.</td>
</tr>
<tr>
<td>Attachment to frame</td>
<td>During design, account for differences in thermal expansion between the PUR and frame material.</td>
</tr>
</tbody>
</table>

### "SPIDER WEB" CRAZING

<table>
<thead>
<tr>
<th>Causes</th>
<th>Cures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress-induced chemical crazing</td>
<td>Use a higher sheet temperature during forming — throughout the sheet, not just on the surface.</td>
</tr>
<tr>
<td></td>
<td>Use proper forming temperature, cycle time and cooling rate (i.e., heat longer at lower intensity).</td>
</tr>
<tr>
<td></td>
<td>If the part is fiberglass reinforced, improve control in the application of the fiberglass system.</td>
</tr>
<tr>
<td></td>
<td>Remove the chemical crazing agent.</td>
</tr>
<tr>
<td></td>
<td>Move to a more chemically resistant top coat (i.e., Solarkote® A210 acrylic capstock).</td>
</tr>
</tbody>
</table>

### OVERALL

There are four major technical resources available for assistance. All of these should be used during manufacture and troubleshooting.

- Sheet extruder
- ABS resin manufacturer
- PUR/UPR/other reinforcement system supplier
- Arkema Inc. - Altuglas International 800-523-1532
Contact Information

HEALTH AND SAFETY

Heating of Solarkote® capped sheet can result in the release of monomer vapors. Permissible exposure level at time weighted average is 100 ppm for MMA, and 10 ppm for EA.

Cutting Solarkote® substrate sheet or profile can result in the generation of nuisance dust. Permissible exposure at time weighted average is total 15 mg/cubic meter and respirable dust at 5 mg/cubic meter.

MSDS information for Solarkote® products can be secured by contacting customer service or by visiting www.solarkote.com.

CUSTOMER SERVICE

Arkema Inc.
Altuglas International
2000 Market Street
Philadelphia, PA 19103
T 800.523.1532
F 215.419.5511

TECHNICAL SUPPORT

Arkema Inc.
Altuglas International
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King of Prussia, PA 19406
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F 215.419.5511

SALES AND MARKETING

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Altuglas International
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Philadelphia, PA 19103
T 800.523.1532
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See MSDS for Health & Safety Considerations.

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