

MOISTURE ABSORPTION AND BLISTERING OF INDURO™ SHEET PRODUCTS

INTRODUCTION

A study of moisture absorption and its effect on the blister temperature of InDURO™ sheet products was performed by Aristech Surfaces. The purpose of this study was to become more knowledgeable of the phenomenon and to generate useful data for our customers to assist them in producing top quality finished products.

InDURO™ is manufactured and packaged under controlled conditions. This assures the delivery to the customer of the highest quality product.

Each individual sheet is protected by polyethylene masking. The material is protected top and bottom by wrapping in a six (6) mil poly/foil envelope. This is placed on a heavy-duty wood pallet. The pallet can be the horizontal type or a slanted type. The slanted type is only used for very large sheets shipped LTL in closed vans.

When InDURO™ products are produced, they are dry and can withstand surface temperatures up to 420° F (216° C) on the acrylic side and 380° F (193° C) on the ABS side without blistering. Any blistering occurring in new sheet at or above these temperatures is likely a result of overheating.

As InDURO™ sheets age, if stored improperly or in high humidity environments, the bottom layer of the sheets absorb moisture. As the amount of moisture absorbed by the bottom layer increases, the blister temperature decreases. The blister temperature is the lowest temperature at which small bubbles become visible in a

sheet subjected to a specific heating procedure in a thermoforming unit or in an oven. If the moisture content is high enough, the heat will vaporize the moisture in the bottom layer and bubbles are formed. The bubbles close to the surface may rupture or not and "blisters" appear in the surface. The blisters are typically scattered throughout the layer. As more moisture is absorbed, the blisters generated are larger and more numerous. Moisture, coupled with excessive thermoforming temperatures and/or heat soaking times, can cause delamination within the InDURO™ Sheet, particularly in the radii of the formed parts.

Moisture absorption is common among many plastic families. Although continued use with the above precautionary steps will prevent significant problems. The reader is invited to contact the Acrylic Technology Department of Aristech Surfaces, Telephone 1-800-354-9858.

The amount of moisture absorbed over a given period of time and the sheet's susceptibility to blistering are dependent on several factors. These factors must be controlled by the customer/user so that optimum finished product quality is obtained.

The influencing factors are: 1) Improper storage and handling methods; 2) High relative humidity in the storage area; 3) Excessive heating time and temperature/thermoforming equipment.

STORAGE AND HANDLING

How InDURO™ sheet products are stored and handled is most important in preventing moisture absorption into the sheets. When InDURO™ sheets are produced, they are palletized and wrapped with a layer of 6 mil poly/foil film. It is imperative that the wrapping remains undamaged and is re-sealed after sheets are removed from the pallet. Our tests show that, even on a perfectly wrapped pallet stored in a warehouse type environment where the ambient temperature ranged from 68 to 87°F (20 to 31°C)



and the relative humidity ranged from 25 to 80 %, .275" (7 mm) sheets in the center of the stack absorbed as much as .037 % moisture by weight in about 2 months. At 3.5 months they had absorbed .054 %. The sheets on the top and bottom of the stack, which have more surface area to absorb moisture, absorbed more than twice that absorbed by sheets from the middle of the stack. In about 2 months, the absorption was .076 % and at 3.5 months they had absorbed .147 %. Even these minor levels caused very light blistering (the generation of very small voids) at the acrylic/ABS interface when heated in a forced air circulating oven at 380°F (193°C). When the sheets were new, they could be heated in the same manner to a temperature of 440°F (227°C) before blistering of comparable severity occurred.

NOTE: Although blistering was present at these moisture levels and temperatures, they were extremely light and most likely would not be detected in most thermoformed applications. However, the potential for producing reject parts is present.

Under no circumstances should InDURO™ sheets be stored free standing without Aristech Surfaces supplied 6 mil protective wrapping or be left unwrapped on pallets while not being used. Our tests on .275" (7 mm) composite sheet samples stored free standing without 6 mil protective wrapping in the same environment as described previously, show a very rapid moisture absorption rate. After 2 months, the samples absorbed an average of .196 % moisture. At 2.5 months they averaged .302 % absorption and remained around that level through 3.5 months. At these levels of moisture, the blister temperature is reduced significantly. To better simulate typical thermoforming conditions, a lab thermoformer with quartz tube upper and lower heaters was used to determine blister temperatures of these samples. Light to moderate blistering was present in samples with .196 % moisture at surface temperatures of 360°F (182°C) on the acrylic side and 330°F (166°C) on the ABS side. At the .302 % moisture level, the blistering was slightly heavier at temperatures of 360°F (182°C) on the

top acrylic surface and 310°F (154°C) on the back of the surface. Forming temperatures 20°F (11°C) higher caused heavy blistering and separation of the material from the acrylic in the radii. At forming temperatures lower than the blister temperature, [360/310°F (182/154°C)] most thermoformed applications would be rejected due to insufficient detail, or radii sharpness.

When handling sheets at the thermoforming operation, remove one sheet at a time from the original package and strip the film from the acrylic surface. If not removed prior to thermoforming, any imperfections in the film masking, such as wrinkles and/or air bubbles, may result in unwanted surface mark off on the finished formed part. Do not stand a sheet vertically or lean it against something, with the back side exposed to the air, but leave it stacked on its pallet.

Antistatic air guns or blowers are usually all that are needed to clean a sheet of any airborne contaminants just prior to thermoforming. If the acrylic surface of a sheet must be cleaned, use a damp cloth or tack rag to wipe off simple dust or dirt, or use isopropyl alcohol or VM&P Naphtha to remove stubborn fingerprints, grease-pencil or other oily deposits.

Some processors may choose to leave the polyethylene masking film on the acrylic surface during thermoforming. Aristech Surfaces does not recommend nor condemn the use of this procedure; however, some manufacturers use this procedure very successfully. Leaving the film on during thermoforming can cause problems if not done properly. For example; if the surface is overheated, the film may bond so tight that it is virtually impossible to remove it. Also, film left on a finished part will gradually bond tighter and tighter as time goes by. Film left on for more than one (1) year probably cannot be removed.



TEMPERATURE AND HUMIDITY OF THE STORAGE AREA

Environmental conditions of the storage area are also influencing factors that should be considered. Ideally, the sheets should be stored in a temperature and humidity-controlled area. In the absence of such a storage area, the sheets should be stored indoors on the original pallet with the original wrapping. The pallets should be stored away from doors or openings such as dock areas and exits. Under no circumstances should the sheets be stored outside where they are exposed to the elements. It should be noted that Aristech Surfaces customers located in very high humidity areas experience no problems with moisture related blistering of composite sheets when precautionary recommendations are followed. If the sheet is suspected to contain moisture, the user **MUST** dry the sheet prior to thermoforming. Proper drying procedures are outlined later in this bulletin.

HEATING TIME AND SURFACE TEMPERATURE/THERMOFORMING EQUIPMENT

Heating time and surface temperature, as well as thermoforming equipment and methods are key influencing factors in the sense that they can be altered or controlled to lessen the possibility of blistering of sheets containing moisture. Ideally, composite sheets should be heated with equipment providing two-sided heat with adjustable output. However, some manufacturers may not have this capability and must heat one surface only. Other manufacturers may even use forced air circulating ovens rather than the traditional shuttle or rotary type machines. Our tests on .275" (7 mm) composite sheets showed that when heated in a forced air circulating oven for a length of time needed to obtain a specific surface temperature (typically 20 minutes), samples containing moisture exhibited more severe blistering than samples of the same material heated to equivalent surface temperatures in 10 minutes in the lab thermoformer with two side quartz tube heaters. Ten minutes is the typical

time required for this sheet thickness in this thermoformer. This indicates that thermoformers who use forced air circulating ovens are more likely to experience blistering of the sheets as a result of moisture absorption. One sided heating will likely generate hotter core temperatures as well since the heat cycle will generally be longer than when two-sided heating is used. The heating process of the thermoforming cycle can do one of two things. It will either dry the sheet by forcing the moisture to migrate out or vaporize the moisture creating voids. Blistering occurs simply because the core of the sheet becomes too hot.

AGE OF SHEETS

As a final precaution, Aristech Surfaces suggests that the user's inventories be rotated when new shipments are received so that older sheets are processed first. Keeping a log of the pallet tag numbers with the dates they are received is a simple method to keep track of the age of the inventory. If this is not practical, simply labeling the pallets with the dates they are received may suffice. In either case, it is important that older sheets are processed first to reduce the possibility of blistering occurring as a result of moisture absorption over longer periods of time.

DRYING

If InDURO™ absorbs moisture and must be dried prior to thermoforming, the following procedures should be followed:

- 1) If the moisture absorption is slight to moderate, one-sided infrared heating from the acrylic side only can be used. This procedure is slow, and precise surface temperatures must be observed. Heat the acrylic side no hotter than 350° F (177°C) and monitor the temperature of the back side. The exposed back side should not exceed 290° F (143°C). It will take about 45 minutes "soak" time at these conditions before the sheet can be thermoformed successfully.



- 2) Place a stack of the sheets spaced by dry wood slats [1" x 2" (2.5 x 5 cm)] in an enclosed convection oven overnight (16 hours minimum) at 170°-180°F (77°-82°C). If the material is extremely wet, more time may be required (48 hours drying time will usually cover all situations).

Sheets containing excessive moisture can be thermoformed successfully without blistering if they are dried properly. Increasing the temperature and decreasing the time is not advisable as this can cause the generation of small blisters as described earlier in this technical bulletin, which subsequently become larger during the heating and forming process. Drying temperatures above 180°F (82°C) can cause the sheet to distort and warp which could cause problems later for the user during thermoforming.

After the drying process is completed, the sheets must be allowed to cool to ambient temperature before thermoforming. Any un-used sheets which have been dried must be re-packaged in a manner like the original packaging to protect them from absorbing moisture again.

These drying procedures are also required for users who thermoform the sheet at relatively high forming temperatures, run relatively long heat soaking times and/or require a high degree of detail on the finished formed part.

FINAL OBSERVATIONS/SUMMARY

When an InDURO™ sheet that is exposed to high humidity/moisture laden ambient air or moisture of any kind is heated, the bubbles/blisters in the back side layer will be most visible. If the heating conditions are appropriate and enough time is allowed, no bubbles will be formed. The moisture will have the time to migrate out from the back side before its concentration and vapor pressure will increase enough to form bubbles.

In addition:

- › For users who have one sided heat thermoformers, where all the heating energy for the InDURO™ sheet comes from the top side, the top layer becomes too hot too quickly and much hotter than the back layer.
- › For users who have two sided heat thermoformers, the forming temperature of the top is higher than that of the back; therefore the center where the two materials fuse will always be hotter and more likely to vaporize the moisture into small voids.

When ABS is heated above the recommended temperatures, the polymer chains begin to break apart. The first indication of overheating is given by a color change of the back side, which becomes more yellowish-brown, and blisters may appear.



Note: for cautions and information on exposure to any Aristech Surfaces' product, please see the applicable material safety data sheet.

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