

# **Thermoforming Guide**

# Introduction

This guide is intended to provide technical information to thermoformers of general-purpose extrusion grade ABS sheet clad with *Tedlar*<sup>®</sup> SP polyvinyl fluoride (PVF) film. While thermoforming ABS sheet clad with *Tedlar*<sup>®</sup> SP does not require a great deal of processing changes or equipment modifications, the basic information included in this guide will assist in forming a successful part. *Tedlar*<sup>®</sup> SP films have also been used successfully with a range of other thermoplastic substrates, including polycarbonate, acrylic, PVC, PETG, and PEKK.

*Tedlar*<sup>®</sup> SP film is a fluorocarbon-based material that is designed to give exceptional conformability to substrates while maintaining the superb cleanability, durability, color stability, and chemical resistance expected of PVF film. In contrast to traditional *Tedlar*<sup>®</sup> PVF film that is made by a biaxial orientation process, *Tedlar*<sup>®</sup> SP film is cast onto a carrier web so that negligible stretching occurs. This lack of orientation makes the film much more formable and compliant than oriented film. Room temperature elongation at break is commonly greater than 150% for 1.5-mil thick pigmented films, and increases to 400% or greater

at 50°C (122°F). In actual use, such films will generally withstand 200% to 300% elongation without losing integrity. These high elongations are what makes *Tedlar*<sup>®</sup> SP film appropriate for applications requiring a great deal of stretching during processing.

In addition to its fluoropolymer properties and excellent conformability characteristics, *Tedlar*<sup>®</sup> SP film offers several other distinct advantages over conventional materials (e.g., refinish paints and gel coats):

- The film is a "dry coating," and emits no volatile organic compounds (VOCs) to the atmosphere during application—a big plus environmentally.
- The film is preapplied by the sheet manufacturer; therefore, once the part is thermoformed it already has its decorative and protective coating in place. For companies that typically send parts off-site to be painted, this one-step process can translate into a reduced cost of manufacturing. Three additional steps are eliminated: shipping to and from the paint shop, and the actual application of paint. Reduced handling lowers the risk of damage to parts, as well.

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 The film has enhanced color, distinctness of image (DOI), and gloss retention when tested in a xenon arc accelerated weathering environment versus a number of finishing materials on the market (refer to the DuPont bulletin "Properties and Maintenance of High-Gloss Tedlar<sup>®</sup> SP Film in Laminate Applications").

Tedlar<sup>®</sup> SP film has proven to be suitable for manufacturing thermoformed parts for a variety of markets, including:

- Aircraft interiors
- Mass transit (buses)
- Automotive trim and fascia
- Sportscraft
- Industrial equipment

#### Safety

*Tedlar*<sup>®</sup> SP film is not hazardous as shipped. Laboratory studies by DuPont and experience by DuPont and processors have shown that *Tedlar*<sup>®</sup> SP film, itself, presents no health hazards. At temperatures above 204°C (400°F) or upon prolonged heating, film discoloration and evolution of small amounts of hydrogen fluoride (HF) vapor may occur. The time-weighted average concentration of HF should not exceed 3 ppm vapor in air by volume, as prescribed by OSHA regulations (29 CFR 1910.1000). Furthur safety information can be found in the DuPont bulletin "Materials and Processing Information Safety Considerations" for *Tedlar*<sup>®</sup> SP film.

# **Processing Thermoformed Parts**

There are no exact rules that can be given to a thermoformer processing ABS sheet capped with *Tedlar*<sup>®</sup> SP film, just as there are no exact rules for forming bare sheet. Many variables will affect the final part appearance and performance; forming a new part design may require some degree of trial and error. General guidelines are discussed in this section, as well as outlined in the following section titled "Troubleshooting Guide—Thermoforming ABS Sheet Clad with *Tedlar*<sup>®</sup> SP Film."

Prior to thermoforming ABS sheet clad with Tedlar<sup>®</sup> SP film, it is important to work with the laminate supplier to obtain a *quality laminate*; this helps to ensure the best possible finished part. It is generally recommended that the Tedlar® SP films intended for lamination to ABS substrate be coated with DuPont 68080 acrylic adhesive. This system has shown excellent adhesion durability in extended water soak tests. The sheet resin must be free of contamination so that defects such as bumps and color markings are not present in the finished part. To avoid color changes in deeply formed parts, it is advised that extreme color differences between the sheet resin and the film be avoided. The sheet extruder must avoid applying excessive tension to the Tedlar<sup>®</sup> film during lamination, as this may reduce the film's thickness below the required tolerance, or introduce curl into very thin laminates. For further details, refer to the "Laminating Guide" for Tedlar® SP film. It is also recommended that the extrusion laminator interleave the laminates with a nonabrasive paper or film to avoid scratching or marring the film surface during stacking and shipping of the sheet. This interleaf material should be removed from the sheet prior to forming.

The standard product line for thermoforming is a nominal 1.5-mil thick *Tedlar*<sup>®</sup> SP film; however, there are situations that warrant using a thicker film—primarily those applications involving a deep draw or complex shape. Using film that is too thin can result in film splits and/or a change in film aesthetics (color, DOI, and gloss).

The *forming temperature* of the sheet is one of the most critical processing parameters, and can be influenced greatly by the type of thermoforming equipment used. For example, heater efficiency, distance of sheet from the heaters, and uniformity of heat distribution can impact how the part forms. The length of time the part is heated and the thickness of the laminate also affect the sheet temperature. Tedlar® SP film by itself is formable over a fairly wide temperature range (approximately 130–205°C [265–400°F]). Experience has shown that forming temperatures in the range of 165 to 195°C (330 to 380°F) work best for ABS sheet laminated with this film. Irreversible temperature-sensitive tape is a useful tool for determining the maximum temperature that the sheet reaches during the heating cycling. This tape is also helpful when troubleshooting (i.e., when looking for temperature gradients).

Forming temperatures that are too high can lead to a number of part defects, including film splits, excessive thinning of the sheet, and compromise of aesthetic properties. Forming temperatures that are too low can result in film splits, poor definition of part details, and lightening of the film color from stretching beyond its yield point. In general, it is best to form parts (with or without *Tedlar*<sup>®</sup> SP film) at a minimum *vacuum gauge level* of 25 in of Hg (a perfect vacuum occurs at 29.92 in of Hg). The vacuum should be pulled rapidly to ensure efficient, uniform cooling, thereby minimizing internal stresses and obtaining optimal part detail.

The *mold* material of construction and cooling design also have an effect on the finished part. These parameters do not typically change when *Tedlar*<sup>®</sup> SP film is used instead of bare sheet. However, it is critical that the mold surface be free of irregularities when attempting to achieve a class A finish, as markings such as scratches and dimples will create a nonuniform surface on the film side, even when a male mold is used. Conversely, *Tedlar*<sup>®</sup> SP film will readily accept and retain an embossed pattern when formed using a textured mold.

Just as it is important to handle the sheet carefully prior to thermoforming, it is also crucial to avoid abrading the film in subsequent *handling* steps after forming the part, just as you would a painted part. This is especially true while the part is still warm and susceptible to scuff marks. When *packaging* thermoformed parts clad with *Tedlar*<sup>®</sup> SP film, it is beneficial to wrap each part individually and stack them tightly so there is as little slippage and movement between parts as possible during shipping.

# Troubleshooting — Thermoforming ABS Sheet Clad with *Tedlar*<sup>®</sup> SP Film

**Table 1** addresses conditions that cause defects on the *Tedlar*<sup>®</sup> SP film surface of the part. It is not intended as a complete guide to resolving all thermoforming issues.

Problem	Causes	Solutions
Film splits	Sheet temperature too high or too low	Recommend forming film side of sheet in the range of ~165–195°C (~330–380°F). Resin side of sheet may be able to tolerate slightly higher temperatures depending on thickness and grade of laminate. Decrease laminate dwell time if sheet temperature is too high; increase laminate dwell time if sheet temperature is too low.
	Sheet not heated uniformly	Ensure heaters are clean and all are functioning. Use screens to redistribute heat. Minimize air currents through area that may cool select areas of the sheet.
	Draw ratio too great for selected film thickness	Modify mold design. Select an alternate thermo- forming thickness technique, such as prestretch- ing by inflation, evacuation, or plug-assist. Purchase thicker film if available.
	Scratches/holes in film side of sheet before forming	Request laminate supplier to ship sheet with a protective interleaving paper or film. Do not drag top sheet across sheet beneath when removing from pallet to place in thermoformer.
Film delamination	Adhesive does not reach activation temperature during lamination	Consult with laminate supplier.
	Inadequate film treatment or adhesive application	Consult with a DuPont representative for <i>Tedlar</i> <sup>®</sup> SP film.
Surface bump/pits	Nonhomogeneous sheet resin	Consult with laminate supplier (often these defects will disappear upon thermoforming).
	Poor mold surface quality	Refinish mold.
Bubbles/blisters	Moisture in sheet	Dry sheet prior to forming at approximately 15° below the resin's heat distortion temperature. Drying time will be dependent on sheet thickness.
	Poor quality sheet	Consult with laminate supplier. Reduce regrind content.

Table 1			
Troubleshooting—Thermoforming ABS Sheet Clad with	Tedlar®	SP	Film

Problem	Causes	Solutions
DOI/gloss loss	Draw ratio too great for selected film thickness	Modify mold design. Purchase thicker film if available.
	Sheet temperature too high	Decrease heater output on film side of laminate. Decrease length of heating cycle.
	Nonhomogeneous sheet resin	Counsult with laminate supplier.
Color change	Draw ratio too great for selected film thickness	Modify mold design. Select sheet color that is close to film color. Purchase thicker film if available.
	Sheet temperature too hot	Decrease heater output on film side of laminate. Decrease length of heating cycle.
	Sheet temperature too cold (film stretching beyond its yield point)	Increase heater output. Increase length of heating cycle.
Color marks/ streaks	Nonhomogeneous sheet resin	Consult with laminate supplier.
	Nonhomogeneous film	Consult with a DuPont representative for <i>Tedlar</i> ® SP film.
Scratches/scuff marks	Improper handling of part	Use care when removing hot part from thermoformer—the film is most susceptible to marring at this point.
	Poor packaging of parts	Package parts with protective covering around each one. Pack together tightly so that parts do not shift and rub during shipping.

#### Troubleshooting—Thermoforming ABS Sheet Clad with Tedlar® SP Film (continued)

### Recyling ABS Sheet Clad with *Tedlar*<sup>®</sup> SP Film

Initial recycle testing of *Tedlar*<sup>®</sup> SP film laminated to ABS sheet indicates that the material can be recycled at reasonable regrind levels with little change in tensile properties and impact strength. It is generally advised that the regrind first be repelletized on an extruder using a screen pack

that is changed out at regular intervals. It is also recommended that a thin layer of neat ABS be coextruded to the sheet containing regrind to enhance the thermoformed part aesthetics (primarily DOI). The neat ABS layer should be at least 10% of the final laminate thickness. For optimum formed part aesthetics it is recommended that the overall regrind level be kept below 50%.

## For more information on *Tedlar*<sup>®</sup> SP PVF Films:

# (800) 255-8386

FAX: (716) 879-4545

DuPont *Tedlar*® P.O. Box 88 Sheridan Drive and River Road Buffalo, NY 14207-0088

#### Europe

DuPont de Nemours Int'l SA 2, chemin du Pavillon P.O. Box 50 CH-1218 Le Grand-Saconnex Geneva, Switzerland (022) 7175111

# Asia Pacific

DuPont Asia Pacific Ltd. TST P.O. Box 98851 1122 New World Office Bldg. (East Wing) Salisbury Road, TST Kowloon, Hong Kong (011) 852-3-734-5345

#### Canada

DuPont Canada, Inc. P.O. Box 2200, Streetsville 7070 Mississauga Road Mississauga, Ontario, Canada L5M 2H3 (800) 263-2742

DuPont Singapore PTE Ltd. 1 Maritime Square #07-01 World Trade Center Singapore 099253 65-273-2244

#### Japan

DuPont Kabushiki Kaisha *Tedlar®* PVF Film 4th Floor Chiyoda Honsha Bldg. 5-18, Sarugaku-cho 1-chome Chiyoda-Ku, Tokyo 101 Japan (011) 81-3-5281-3428

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