



Tedlar®

polyvinyl fluoride film

Adhesive and Lamination Guide for *Tedlar*® PVF Film

General

This guide is intended to assist the manufacturer in the selection of adhesives for laminating *Tedlar*® polyvinyl fluoride (PVF) film to a variety of substrates. Lamination and quality control guidelines are also included for laminating *Tedlar*® PVF film to:

Aluminum	Vinyl fabric
Cellulosic substrates	Thermoplastic sheet
Galvanized steel	Vinyl wall covering

Guidelines are also given for thermoforming *Tedlar*® PVF film and installation in solar collectors.

This information is believed to be the best currently available and is offered for what help it might be in your own experimentation and evaluations. This information will be revised as additional experience and information are developed.

Film and Adhesive Storage

Tedlar® must be used within one year of receipt by the laminator. Protect these materials from temperature and humidity extremes. The film should be kept in cool, dry storage in a kraft wrapper. If adhesives are exposed to temperatures below 4°C (40°F), they must be brought to room temperature, 22°C (70°F), and thoroughly mixed as separate units. Additional mixing is required when blending the compounds.

Adhesives, thinned to a desired viscosity with toluene, can be applied to the film using a variety of coating methods. The coated film is normally passed through an oven where the solvent is evaporated to obtain a nonblocking adhesive coating. Thorough drying is essential as residual solvent may cause blocking in the roll. Drying temperatures of 77–104°C (170–220°F) coordinated with proper film web speed and tension are presently being used with success. Excessive machine direction (MD) film stretching and transverse direction (TD) film shrinkage can result from

improperly controlled oven temperature and film web tension. Adhesive coated film should be used within six months of the coating date.

Flexible Product Adhesives

Over the last 25 years DuPont has developed a family of adhesives used for laminating *Tedlar*® PVF film to a wide range of substrates. These adhesives are characterized by excellent resistance to moisture and UV radiation.

DuPont flexible product adhesives are versatile acrylic adhesives developed specifically for laminating *Tedlar*® PVF film to a variety of substrates. With these adhesives, high-quality, long-lasting bonds can be achieved to meet demanding quality control specifications of manufacturers.

Acrylic adhesive 68040 is thermoplastic, but can be cured with epoxy resin to give thermoset properties. It has been used to bond *Tedlar*® PVF film to vinyl, aluminum foil, Nomex® aramid fiber, nylon, paper, and wood products. As an extrusion primer, 68040 has been applied to polypropylenes, aluminum foil, and PVDC-coated films—followed by extrusion of polyolefins, such as Surlyn® ionomer resin, EVA polyethylene, and polyethylene.

Resin solution 68065 and acrylic adhesive 68070 have been used to bond *Tedlar*® PVF film to aluminum and galvanized steel in various gauges. 68065 is a dispersion of corrosion-inhibiting pigment and epoxide polymer in toluene. It is formulated to be used in conjunction with 68070 at a ratio of one gallon of 68065 to fifteen gallons of 68070. 68065 is soft settling and the dispersion must be shaken just prior to use.

Acrylic adhesive 68080 is a liquid that can be preapplied to *Tedlar*® PVF film to facilitate lamination of products for interiors, such as vinyl wall coverings, and for exteriors, such as architectural siding, awnings, flexible sign faces, and fabric structures.

Adhesive Characteristics

DuPont flexible product adhesives have varying degrees of activation temperature, amine reactivity, and hardness. Key characteristics of these adhesives are shown below:

	68080	68040	68070
Composition	Polymethyl methacrylate	Methacrylate copolymer	Methacrylate copolymer
Increasing hardness	< -----<<<<		
Increasing amine reactivity	>>>> ----->		
Increasing activation temperature	< -----<<<<		
Lamination temperature	177–204°C (350–400°F)	149–204°C (300–400°F)	135–204°C (275–400°F)

Solvent Composition

	68080	68040	68070
Toluene, %	45	11	70
Isopropanol, %	55	67	30
Xylene, %	—	22	—

Product Advantages

These flexible product adhesives have superior durability that resists light and moisture degradation and discoloration. DuPont has accumulated extensive data in accelerated weatherometer testing and outdoor Florida exposure. In some applications the bond is warranted for 25 years. These adhesives are used in a wide variety of substrates and broad range of conditions.

Product Limitations

These flexible solvent based adhesives have a one year shelf life.

68070 has been observed to interact with some components in a flame-retardant vinyl causing yellowing.

68070/68065 mixtures only have an 8-hour pot life.

68080 is incompatible with 68040 and 68070. Very small amounts of 68040 in 68070 drastically impair adhesion.

Ketone solvents should be avoided in diluting the adhesives as yellow discoloration will result.

Caution: In most cases DuPont does not warrant the “lamination.” DuPont warrants the film and adhesive separately as advertised in our technical bulletins. The performance of the “system” is the

sole responsibility of the applicator. DuPont will provide consultation and our best information in assisting the customer to achieve satisfactory lamination.

Other Additives

68065—Corrosion inhibiting, cure-promoting epoxide additive in toluene.

68011—Cure-promoting epoxide additive in carbon black. Dispersion of Shell Epon 828 and carbon black in toluene. This product is custom manufactured and available directly from CDI Dispersions, Inc.

Phenolic accelerator (Dimethyl aminoethyl phenol, formerly DuPont 68060). Available as CMP-10 from Rohm & Haas.

Safety Precautions

These products are **FLAMMABLE AND CONTAIN HARMFUL VAPORS**. Keep away from heat, sparks, and open flame. Use only with adequate ventilation. Avoid breathing vapor or spray mist. Avoid contact with eyes and skin. Keep container closed when not in use.

In case of skin contact, flush with plenty of water: for eyes, immediately flush with plenty of water for 15 minutes and get medical attention.

In case of fire, use water spray, foam, dry chemical, or CO₂. In case of spill, absorb and dispose of in accordance with local regulations.

Laminate Adhesive Selection Guide

Cellulosic Substrate	68070/CMP-10/Epoxy
Metals	68070/68065
Thermoplastics	
Polycarbonate	68040, 68080
Polystyrene	68040
PMMA	68040
ABS	68080
PVC Film	68070/Epoxy, 68080
Vinyl Siding	68080
Vinyl Wall Covering	68080

Flexible Adhesive Application

Heat the adhesive to room temperature and mix according to instructions. Dilute with toluene to desired viscosity. Apply adhesive using spray gun, brush, dipping, extrusion, rollers, doctor blade/wire

Adhesives Useful with *Tedlar*[®] PVF Film

Type	Manufacturer	Application	Advantage	Limitation
Modified acrylic	68080, 68070, 68040 (DuPont)	General use	Durability experience	Solvent based
Polyester/isocyanate	46960/RC-803 (Whitaker) 56065/RC-803 (Whitaker)	Polyester films		
Epoxy	Most 1- and 2-part epoxies	General use	Room temperature	
Urethane	Most 1- and 2-part urethane	General use	Room temperature	
Silicone RTV	Most 1- and 2-part silicones	Solar, laminate seams	Room temperature UV stable	Expensive
Phenolic	Most phenolic adhesives and embossing resins	Aircraft		
Rubber	Many rubber adhesives Nitrile—1099 (3M) Neoprene—1300, 1357 (3M)	Gasketing		
Acrylic pressure sensitive	Solvent: Gelva 1159, 1753 (Monsanto) Latex: Hycar 2600x-205, 146 (Goodrich)	Solar	Room temperature	
Silicone pressure sensitive	Silgrip SR-6573, 6574 (GE) 280A (Dow Corning)	Solar		

Note: Adhesives, especially non-DuPont, must be tested for the specific application. Some epoxies may not bond well to the *Tedlar*[®] PVF film. Trial laminations should be made to test adhesive suitability. The harder polyester adhesives do not bond well to *Tedlar*[®] PVF film. Isocyanate curing agents generally enhance adhesion. Some phenolic materials or curing agents may cause staining of the *Tedlar*[®] PVF film. Silgrip SR-6573 gives a credible bond with untreated *Tedlar*[®] PVF film.

wound rod, reverse roller coater, roller coater or gravure coating. Lamination can proceed as soon as the adhesive is dry.

Toluene and/or methyl ethyl ketone (for cleanup only) may be used to clean up equipment.

Laminating *Tedlar*[®] PVF Film to Aluminum

Lamination is accomplished by cleaning the metal, depositing a controlled conversion coating on the metal, coating the metal with a solvent-based adhesive, evaporating the solvent, heating the metal to 195–205°C (383–401°F) to activate the adhesive, combining with *Tedlar*[®] PVF film in nip rolls and quenching the laminate.

Materials

Film—*Tedlar*[®] PVF film type TWH15BL3 and colors

Adhesive—DuPont adhesives 68070, 68065

Metal—Aluminum

Adhesive Mixing and Application

The adhesive is prepared by the following formula:

Adhesive 68070	15 gal
Adhesive 68065	1 gal

Shake the 68065 on a paint shaker for 3 to 5 minutes to disperse the pigment. While stirring the 68070, slowly add the well mixed 68065. Blend the mixture for approximately 5 minutes with a suitable mechanical mixer. Adjust adhesive coater to lay down 37–50 μm (1.5 to 2.0 mil) wet adhesive equivalent to 6–7.5 μm (0.23 to 0.30 mil) of dry adhesive. Adjust viscosity by diluting with toluene.

During normal operation, the rate of solvent evaporation is slight enough to have no effect on the percent solids. If prolonged halts in coating occur, the viscosity must be checked and adjusted with toluene to the original value. Pot life of the mixed adhesive is 24 hours.

The solvent is removed and adhesive activated in an oven of such length that the metal is in the oven from 30 to 90 seconds. The metal temperature must be 195–205°C (383–401°F) at the end of the oven followed by immediate lamination.

Lamination

The laminating equipment consists of a pair of combining or “nip” rolls that are unaffected by the operating temperature of 175°C (347°F). A nip pressure of 87–175 N/cm (50–100 lb/in) of width must be used. A film wrap of at least 90° on the upper nip roll must be used to prevent wrinkling.

Quality Control—On Line

Formability Test

Test the formability of the laminate by pressing a 25 mm (1”) diameter steel ball into the metal forming a dimple 6 mm (1/4”) high. Make two parallel cuts in the film 2 mm (1/16”) apart across the apex of the dimple and attempt to peel the film from the metal. Any peeling of the film greater than one-half the distance from the apex to the bottom of the dimple requires that the coil be placed on “hold.”

Boiling Test

Immerse flat laminates in boiling water for 5 minutes, cool them, and make two parallel cuts 3 mm (1/8”) apart in the laminate. Try to peel the wet film from between the two parallel cuts. If more than 3 mm (1/8”) film peels from the laminate, place the coil from which the sample is taken on “hold.”

If the sample passes the 5-minute boiling water test, make another test after one hour boiling. As before, if more than 3 mm (1/8”) film peels from the laminate, place the coil from which the laminate is taken on “hold.”

Any coils placed on “hold” should be retested after 24 hours. If the samples pass, the coils may be released. If not, the coils should be rejected.

Laminating *Tedlar*[®] PVF Film to Cellulosic Substrates

Laminating *Tedlar*[®] PVF film to boards requires removing all dust, dirt, and loose material from the board, applying adhesive, evaporating the solvent from the adhesive, heating the adhesive to the required temperature, and laminating the board and *Tedlar*[®] PVF film with nip rolls.

Board Preparation

Remove loose material on the board surface prior to lamination. A revolving brush with vacuum, or an air knife, is suitable. Board edges to be wrapped with film must be smooth and free from nicks and loose particles.

Adhesive Mixing and Application

The components of the adhesives are to be mixed thoroughly in the following proportions:

DuPont No.	Parts by Volume	Parts by Weight
68070	7 (7 gal)	20
68011	1 (1 gal)	3.1
CMP-10	0.016 (2 fl oz)	0.05

Shake component 68011 for at least 5 minutes on a paint shaker before mixing it with the other components.

On the average, this mix weighs 7.7 lb/gal and contains 36% solids by weight and 30% by volume. The mixed adhesive should have a pot life of at least 12 hours. Dilute and maintain an optimum application viscosity with nitration grade toluene (1°F cut).

Care must be taken that mixing, measuring, and coating equipment are cleaned of all possible contaminants to avoid “poisoning” of the adhesive.

The adhesive may be applied by roll coating or spraying. Exact adhesive thickness will depend on porosity of the board being used. (See Approximate Adhesive Requirements on page 5.)

Method A: Simultaneous application of adhesive to both board and film.

Method B: Application of adhesive to board only.

When the board is to be edge wrapped, either Method A or B may be used to apply adhesive to the edges of the board. If B is used, adhesive must also be applied to the back of the board.

After application of the adhesive, the solvent must be evaporated in an air oven or ovens.

Heating the Adhesive

After applying the adhesive and evaporating the solvent, heat the board so that it reaches 68–85°C (155–185°F) at the moment of lamination. Take precautions so that the adhesive on the board is not overheated. Heating may be accomplished by the same oven used for solvent removal or additional heaters may be used between the oven and nip roll station.

Infrared heaters will heat the adhesive on the board more rapidly than forced hot air and not add as much heat to the hardboard.

Heating elements should be positioned so the last element is as close to the nip station as possible. Overheating followed by subsequent cooling before the adhesive coated board enters the nip rolls should be avoided.

Lamination

Combine the adhesive coated board and the film (or coated film) in the nip rolls. Depending upon the laminating speed, it is essential that the temperature of the top nip roll be between 93–149°C (200–300°F).

The top nip roll should be made of rubber unaffected by temperatures of 149°C (300°F). Sufficient contact for a bonding is produced by a nip force of 30 to 60 lb/in.

To determine whether there is sufficient and uniform contact, place a 51 mm (2") cellophane tape lightly on a stationary board and lower the nip rolls. A 19–25 mm (3/4–1") uniform flat impression should be left on the tape across the width of the roll.

Flatten the film as it is unwound from the roll by uniformly applying heat across the film while using a small amount of tension. Reduce brake pressure as the film roll diameter decreases to maintain uniform tension. Film temperature should not exceed 121°C (250°F). The film entering the nip rolls should be under as low a tension as possible (the tension needed for flattening should be isolated). A film wrap of 90° around the nip is required.

If the laminate is edge wrapped, it is essential that the temperature of the adhesive on the edges and back of the board be maintained at 68–85°C (155–185°F). The rolls that nip the film to the edges and back of the board should be heated to 91–110°C (195–230°F).

Upon leaving the laminator and edge-wrapper, the laminate will have sufficient bond to allow normal handling in end-sealing and packaging operations.

Quality Control

Initial Peel Test

On-line quality control is based on appearance and initial peel on laminate. Test initial peels as soon as the laminate is made. A sample should be checked every 2 hours.

Determine initial peel by cutting a 13 mm (1/2") strip, 203–254 mm (8–10") long, across the surface of laminate and attempt to peel the strip by pulling it perpendicular to the board.

If the film peels, the plane of failure should occur in the hardboard or adhesive. Reject laminates if the plane of failure occurs between the film and adhesive.

Water Soak Test

Prior to shipment, samples should be tested before and after immersion in room temperature water for 24 hours. These tests may be started after the laminates have cured 2 days at 24°C (75°F) or 4 hours at 60°C (140°F).

Prepare 51 mm × 102 mm (2" × 4") samples for testing by making several parallel slits 3 mm (1/8") apart in the 51 mm (2") direction of each sample. Check the bond by attempting to peel a 13 mm (1/2") strip of film by first prying it up and then pulling it perpendicular to the board.

The laminates should peel film less than 3 mm (1/8"). Laminates may peel greater than 3 mm (1/8") if the plane of failure is in the substrate.

Approximate Adhesive Requirements

	Thickness of Adhesive
Sealed Hardboards	30.5–40.6 dry μm (1.2–1.6 dry mil)
Unsealed Hardboards	40.6–55.9 dry μm (1.6–2.2 dry mil)

Laminating Tedlar® PVF Film to Galvanized Steel

Lamination is accomplished by cleaning the metal, depositing a controlled conversion coating on the metal, coating the metal with a solvent-based adhesive, evaporating the solvent, heating the metal to activate the adhesive, combining with Tedlar® PVF film in nip rolls and quenching the laminate.

Materials

Film—Tedlar® PVF film type TWH15BL3 and colors.

Adhesive—DuPont adhesives 68070, 68065.

Metal—Hot dipped galvanized steel, generally G-90, is used. The steel must have good forming quality and preferably minimum spangle, temper rolled, lock forming quality or extra smooth spangle.

The metal being used must have a light oil (Tectyle 447—Ashland Oil Company or equivalent) applied at the mill after galvanizing and must not be chemically treated or stabilized. The metal must be free of white rust to enable proper surface treatment and adhesion. Prior to lamination the metal being used must have all mill oils removed; note that anything but light mill oils such as T447 may require aggressive removal techniques.

The optimum thickness metal to be laminated is 18 gauge (0.0516”).

Laminates on metal, 22 gauge (0.0366”) or lighter, may be made on any standard type of galvanized, including commercial quality, regular spangle. Better forming quality is preferred.

Metals heavier than 22 (0.0366”) gauge must be minimum spangle or spangle-free surface. Commercial quality, regular spangle steel is not acceptable in gauges heavier than 22 gauge (0.0366”). Care should be taken when laminating metal heavier than 22 gauge (0.0366”) and formed to a radius of less than 3 mm (1/8”) to prevent splitting.

Adhesive Mixing and Application

The adhesive is prepared by the following formula:

Adhesive 68070	15 gal
Adhesive 68065	1 gal

Shake the 68065 on a paint shaker for 3 to 5 minutes to disperse the pigment. While stirring the 68070, slowly add the well-mixed 68065. Blend the mixture for approximately 5 minutes with a suitable mechanical mixer. Adjust the coater to lay down 37–50 μm (1.5–2.0 mil) wet adhesive equivalent to 6–7.5 μm (0.23–0.30 mil) of dry adhesive.

During normal operation, the rate of solvent evaporation is slight enough to have no effect on the percent solids. If prolonged halts in coating occur, the viscosity must be checked and adjusted with toluene to the original value. The pot life of the mixed adhesive is 24 hours.

The solvent is removed and adhesive melted in an oven of such length that the metal is in the oven from 30 to 90 seconds. The metal temperature must be 195–205°C (383–401°F) at the end of the oven followed by immediate lamination.

Lamination

The lamination equipment consists of a pair of combining or “nip” rolls that are unaffected by the operating temperature of 175°C (347°F). A nip pressure of 10–20 kg/cm (50–100 lb/in) of width must be used. A film wrap of at least 90° on the upper nip roll must be used to prevent wrinkling.

Quality Control—On Line

Formability

To test the formability of the laminate, a 25 mm (1”) diameter steel ball is pressed into the metal forming a dimple 6 mm (1/4”) high. Two parallel cuts are made in the film 2 mm (1/16”) apart across the apex of the dimple and an attempt made to peel the film from the metal. Any peeling of the film greater than one-half the distance from the apex to the bottom of the dimple shall require that the coil be placed on “hold.”

Boiling Test

The boiling test consists of bending laminates 90° around a 3.18 mm (0.125”) mandrel. Bends are made with the *Tedlar*® PVF film both inside and outside. Test after 5 minutes boiling by cutting the *Tedlar*® PVF film and adhesive in the center of the bend parallel to the crest or valley and peeling parallel to the cut. Measure the width of the perpendicular peel.

If more than 3 mm (1/8”) film peels from the laminate, the coil from which the sample is taken must be placed on “hold.” If the sample passes the 5-minute boiling water test, test again after one hour boiling. As before, if more than 3 mm (1/8”) film peels from the laminate, the coil from which the laminate is taken must be placed on “hold.”

Any coils placed on “hold” shall be retested after 24 hours. If the samples pass, the coils may be released. If not, the coils should be rejected.

Slitting of Laminate

High speed slitting of the galvanized laminate must be done with the knives positioned so that the ones in contact with *Tedlar*® PVF film are on the section of laminate that is to be retained.

Laminating *Tedlar*® PVF Film to PVC for Outdoor Applications

Since there are many formulations of PVC, optimum laminating conditions may vary with the PVC formulation. The following is given as a suggested starting point for lamination studies and has given good results with a number of PVC films.

Materials

For transparent *Tedlar*® PVF film/PVC laminates for outdoor use, the *Tedlar*® PVF film overlay should be UV screening, usually TUT10BG3, with adhesive 68070/Epon 828 in a ratio of about 30/1 by volume (24/1 by weight). This is somewhat lighter in epoxy than normal usage of this adhesive combination, but it appears to be the best place to start in balancing the possible light discoloration

tendency of epoxy against the added resistance to moisture, which it gives the bond.

For opaque laminates, pigmented *Tedlar*[®] PVF film, such as TWH15BL3 white film, can be used. Under the pigmented films, a higher proportion of epoxy can be used, and a 68070/Epon 828 ratio of 18/1 by volume (14/1 by weight) can be used.

Adhesive Application

Apply 7.5–12.7 μm (0.3 to 0.5 mil) (measured on dry resin) of adhesive to the *Tedlar*[®] PVF film or PVC. Dry the adhesive at 66–71°C (150–160°F), film temperature. After drying, the adhesive will appear practically dry to touch and only slightly tacky. If the PVC is coated, note that the adhesive solvent contains toluene, which attacks vinyl, but under the above conditions it will probably be flashed off so fast that this will not cause trouble. Note also that ketones should not be used for dilution as they can cause yellowing of the 68070 adhesive.

Lamination

Combine the *Tedlar*[®] PVF film and PVC in a nip roll, with a glue line temperature of at least 79°C (175°F) but preferably not over 121°C (250°F). Some people have accomplished such laminations with roll temperatures of about 121°C (250°F).

Satisfactory laminations will give strong initial bonds, but these should be tested slightly warm. When cold they may be “zippy” initially but should cure within 4 to 24 hours to eliminate this defect.

Laminating *Tedlar*[®] PVF Film to Thermoplastic Sheet

Materials

Film	Any <i>Tedlar</i> [®] PVF Film
Adhesive	DuPont 68040, 68070, or 68080
Plastic	Polystyrene, Polymethacrylate, Polycarbonate, Acrylonitrile-butadiene-styrene (ABS)

Adhesive Application

Adhesive	% Solids	ft ² /mil/gal	Recommended Thickness
68040	25	300	6–7.5 dry μm (0.2–0.3 dry mil)
68070	34	460	6–7.5 dry μm (0.2–0.3 dry mil)
68080	30	370	6–7.5 dry μm (0.2–0.3 dry mil)

Apply the adhesive, thinned with toluene to a desired viscosity, to the film using adhesive coating equipment. Pass the coated film through an oven evaporating the solvent obtaining a nonblocking adhesive coating. Thorough drying is essential as residual solvent may cause blocking in the roll. Drying temperatures of 77–104°C (170–220°F) coordinated with proper film web speed and tension are presently being used with success. Excessive MD film stretching and TD film shrinkage can result from improperly controlled oven temperature and film web tension.

Lamination

Laminating adhesive-coated *Tedlar*[®] PVF film to thermoplastic sheet is easily accomplished at the extruder. The operation consists of combining the film with the hot sheet at the first nip of the take-off stack. Stock temperatures of 149°C (300°F) or higher are necessary to heat activate the adhesive and adequately bond the film. The unwind roll of *Tedlar*[®] PVF film should be positioned so that the film wraps the top roll 30° or more and tension across the sheet is uniform. Press Operations: 1-1/2 minutes, 135–149°C (275–300°F), 100–150 psi; cool to 38°C (100°F) before removing from press.

Quality Control

Peel Test

Test samples for adhesion by making two parallel cuts in the film 3 mm (1/8”) apart. Using a razor knife, attempts to pry or peel the film from the substrate between these parallel cuts. A satisfactory bond will exhibit no peel when tested in this manner. The usual cause of poor adhesion is a lack of heat and/or pressure during lamination.

Laminating *Tedlar*[®] PVF Film to Vinyl Wall Covering

Wall covering having excellent stain resistance and cleanability is possible with *Tedlar*[®] SP PVF film. Lamination is accomplished by combining adhesive-coated *Tedlar*[®] SP PVF film with preheated vinyl in heated nip rolls. The finished product is recommended for interior applications only.

Film Types

Tedlar[®] type TTRWCAM9, TTR5JAM9, or TTR10AM9 coated with 6–7.5 μm (0.2–0.3 mil) dry 68080 acrylic adhesive from DuPont.

Vinyl Wall Covering

As described in Federal Specification CCC-W-408D and CFFA-W-101A furnished in various weights, textures, and designs. Plasticizer content should not exceed 50 parts per 100 parts of resin.

Laminating

Laminating adhesive-coated *Tedlar*[®] PVF film to vinyl has been successfully demonstrated on various types of equipment familiar to the wall covering industry. The operation consists of combining the film with the vinyl in hot nip rolls, heating the composite to 149–177°C (300–350°F) and embossing. The unwind roll of *Tedlar* PVF film should be positioned so that the film wraps the top nip roll at least 90° and tension across the sheet is uniform.

Quality Control

Vinyl-based wall coverings clad with *Tedlar*[®] SP PVF film should be evaluated using the following tests.

Water Soak Test

Soak samples from the beginning and end of each laminating run in 50°C (122°F) water for 24 hours. Test laminates by making two parallel cuts in the film 3 mm (1/8") apart. Using a razor knife, attempt to pry or peel the film from the vinyl between these parallel cuts. A satisfactory bond will exhibit no peel when tested in this manner. The usual cause of poor adhesion is a lack of heat during lamination.

Shrinkage Test

Laminate shrinkage should conform with CFFA Specification W-101-A. Soak three 254 mm × 254 mm (10" × 10") specimens in distilled water at room temperature 30 minutes and dry in a circulating air oven at 93°C (200°F) for 30 minutes. Condition the specimens as described in ASTM D-751 for 8 hours prior to remeasuring. Calculate percent shrinkage using the original and final dimensions. Maximum shrinkage in machine direction is 2% and 1% in the transverse direction.

Film Integrity Test

Soak samples in a solvent such as acetone until the *Tedlar*[®] SP PVF film can be separated from the vinyl. Check the free film under a microscope for damage that can result from severe embossing. Good quality laminates will exhibit no film splitting or "pinholing" when examined in this manner.

Thermoforming *Tedlar*[®] PVF Film

Tedlar[®] PVF film is readily thermoformed if conditions are adjusted to suit its characteristics. Some of the important points are summarized below.

Type of Forming Machine

The narrow forming temperature range and the low heat capacity of thin films make it necessary for the heat source to be brought over the work; that is, a skin packaging setup.

Clamping

At the forming temperature, *Tedlar*[®] PVF film becomes taut and exerts considerable pull on the clamping device. It is necessary to have a clamp that can restrain the relatively thin film without slippage.

Heat Input

Best results are achieved with rapid rate of heating with the film reaching forming temperatures in less than 15 seconds. In the case of printed laminates, minimum heat-up time is important to reduce the possibility of ink discoloration.

Forming Temperature

The best indication of readiness for forming is the appearance of the film. During the heat-up period, the film first sags due to thermal expansion, then pulls up into loose wrinkles due to unbalanced shrinkage. As the temperature increases further, the wrinkles suddenly smooth out. At this instant, the film has entered the forming range. Paper thermometer measurements indicate around 193°C (380°F) on the lower surface. Drape should take place within 1–2 seconds of "smooth out."

Sequence

Timing of vacuum application after drape is critical for the production of well-detailed pieces. Vacuum must be applied at the earliest instant before the thin film can cool below the forming range.

Handling

Care should be taken that the surface of the film is not scratched or abraded in handling as this could lead to splitting during forming.

Solar Collector Assembly with Tedlar® PVF Film

Several methods of assembly have been used for solar collector covers glazed with *Tedlar*® PVF film. Presently we prefer attaching the film to a frame with adhesives and subsequently heating the assembly slightly to shrink the film, pulling it taut.

Adhesives and Mounting

Epoxy

Two-component epoxy adhesives give strong durable bonds and are readily available. In paste form, these should be satisfactory for initial experimental work, but might present difficulties in handling for production. Liquid epoxies are available but have not been studied extensively because of low initial tack.

A liquid, modified epoxy formulation having reasonable green tack has been used in our laboratory with satisfactory results. The formulation is:

	Parts by Weight
DuPont Adhesive 68070	10
Shell Epon 828	2

Apply the adhesive to one side of the frame in a uniform thickness of about 76.2–127 μm (3–5 mil) wet and air dry for 15–30 minutes to remove solvent. Gentle heat can shorten drying time. Turn the frame adhesive side down and press on a slightly oversized sheet of film that has been spread on a table, adhering the film to the frame. Turn the frame film side up and roll the bond to ensure good contact. Insufficient adhesive tack suggests that the adhesive layer is too thin or has been dried too long. After standing overnight at room temperature, the adhesive cures sufficiently to permit shrinking the film at temperatures up to 163°C (325°F). The appearance of bubbles under the film after shrinking suggests insufficient drying of the adhesive.

Acrylic

Some liquid acrylic adhesives, such as Monsanto's Gelva RA-1753, are also easy to use. It gives a pressure-sensitive mass, which has sufficient creep resistance to permit the film to be shrunk at temperatures as high as 163°C (325°F). The taut film will support considerable weight with no apparent

creep of the adhesive. However, there have been indications of creep on exposure in several of a group of collector covers; this may have been due to insufficient removal of solvent. It is suggested that anyone evaluating liquid acrylic adhesives watch for this possible problem.

Silicone

Silicone adhesives generally give good bonds with *Tedlar*® PVF film, are durable, and have been used with *Tedlar*® PVF film for other uses. They are being used in solar collectors, but our experience with them in this application is limited.

Film and Shrinkage

Tedlar® PVF film types TSE30BG2 and TUT20BG3 can be used directly with a variety of adhesives for glazing applications. All adhesive should be shielded from direct exposure to the sun when the collector is in use.

After the film is attached to the glazing frame, shrink it slightly, pulling it taut for appearance and preventing wind flutter, noise, and film fatigue. Exact shrinkage conditions should be checked as they will depend to some extent on how the film has been mounted.

When *Tedlar*® PVF film is heated, two opposite effects take place: the film shrinks and simultaneously undergoes thermal expansion. (The coefficient of thermal expansion of *Tedlar*® PVF film is roughly twice that of aluminum.) Because of the thermal expansion, the shrinkage may not be apparent until the collector cover is cooled. However, as the film cools and contracts thermally, the shrinkage that has occurred will be obvious. Excessive shrinkage can warp light frames during cooling because of the film's strength. On repeated heating cycles, no further shrinkage will occur unless the film temperature exceeds that reached in a previous heating cycle.

Film on frames can be shrunk by heating in an oven at 135–163°C (275–325°F). Shrink tunnels have also been used, and heating by hot air may be preferred to radiation because of the film's transparency. Reasonably taut spans of a single glazing have been shrunk satisfactorily on the collector by exposing it under stagnant conditions for a few hours.

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