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SOLAR COLLECTORS

Final Report

By
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June 1983

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Springborn Laboratories, Inc.
Enfield, Connecticut

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FINAL REPORT

SOLAR COLLECTORS

For

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June 1983

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SUMMARY

A broad information search was carried out in four areas: glazings, housing materials, acrylic coatings, etching processes and AR coatings.

An extensive list of all (known) U.S. transparent polymers was developed as well as tables of plastic, ceramic and metallic materials that could conceivably function as a housing. In addition, a compilation was made of commercially available solvent and water-base acrylic coatings for use as a UV protective coating for the glazing.

Twenty transparent polymers were chosen as possible glazings and twelve materials (plastic and wood) as possible housings and exposed in the Weather-Ometer. The glazing materials were also exposed outdoors at Hazardville, Connecticut, in the EMMAQUA in Arizona, and under the "Wet" RS-4 Sunlamp. Solar optical transmission and tensile properties were measured periodically. Several acrylic coatings containing UV absorbers were investigated as protective coatings for glazings and the coated glazings were exposed in the EMMAQUA. Tedlar 20 and Halar 500, with strong absorption in the UV, and two commercial films containing UV absorbers, Tedlar UT and Korad 201-R, were laminated by several different processes to four promising glazing materials and exposed in the Weather-Ometer. Antireflective coatings and surface etching processes were explored as a means of increasing transmission by reducing reflection.

CONCLUSION SUMMARY

The following materials - fluorocarbon polymers, polymethylmethacrylate, UV stabilized scrim reinforced crosslinked ethylene/vinyl acetate copolymer and acrylic/polyester laminate - are promising as glazings for solar collectors. Interpretation of the weathering data is based upon the need for high original transmission, as well as percent transmission and tensile properties retained.

The following potential housing materials have evidenced no significant change in properties after one year's exposure on the Weather-Ometer: Poly S-660, FRP, carbon black filled peroxide crosslinked HDPE, Melamine M-6024 and filled phenolic.

Several acrylic coating systems containing UV absorbers are promising as a means of protecting polymeric glazings against weathering degradation. Longer term aging is needed to find the best coating systems.

Methods of bonding UV screening polymer films to several polymer glazings have been developed. Tedlar 400XRB160SE (polyvinyl fluoride) film containing a UV absorber and Halar(ethylene/chlorotrifluoroethylene)film are promising as a means of protecting a less stable polymeric glazing substrate. The laminates prepared using these two films as top layers over peroxide crosslinked ethylene vinyl acetate copolymer shows little degradation after one year in the Weather-Ometer.

Magnesium fluoride antireflective coating increased the light transmission characteristics of several plastic sheets, but were not weather stable. Etching of the glazing sheets did not improve transmission.

DETAILED CONCLUSIONS AND FUTURE WORK

DETAILED CONCLUSIONS

Glazings

A wide variety of glazing materials were exposed in the Weather-Ometer, the RS-4 Sunlamp with water spray, outdoors in Connecticut and in the EMMAQUA(1) in Arizona. Samples were judged on the basis of loss of transmission, visual surface changes and loss of tensile and elongation.

The five best materials are shown in Tables A and B. Table B provides the chemical structure of each of these materials. There are two fluorocarbons, a thermoset polyester an acrylic homopolymer, a polyester/acrylic laminate and a crosslinked ethylene copolymer reinforced with glass scrim. The film or sheet thikcness is "as sold" by the manufacturer.

These materials were chosen on the basis of high original transmission and retention of optical and physical properties after aging, (Table A). Weathering was judged on the basis of exposure in the Weather-Ometer, in the RS-4 Sunlamp with water spray, outdoors at a 45° angle in Hazardville Connecticut and in the EMMAQUA in Arizona. Other properties - heat resistance, impact, abrasion resistance and cost are revealed in Table B.

Tedlar 100XRB160SE and PFA 9705 combine a high initial transmission with excellent property retention on aging. Both polymers have desirable heat resistance, impact strength and abrasion resistance. The principal disadvantage is the cost (Table C).

The thermoset polyester, Sunlite Premium II, is in a much lower price range but it has the lowest optical transmission of the six polymers selected. Although retention of transmission after aging is good, visually the surface is hazy. Heat resistance is good but impact strength and abrasion resistance are only fair.

Acrylics have long been recognized for their UV stability. Plexiglas V-811, polymethylmethacrylate, has high initial optical transmission and good property retention after UV aging. However, its heat and abrasion resistance are only fair and impact strength is low. Stagnation temperatures would cause a problem.

Flexigard, an acrylic/polyester laminate is similar to the acrylic homopolymer with slightly lower transmission and similar heat resistance but more desirable impact and abrasion resistance.

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(1) Natural sunlight concentrated by reflecting mirrors providing about an 8-fold acceleration. Water spray is used.

The final material selected, peroxide crosslinked, glass scrim reinforced ethylene/vinyl acetate copolymer has high initial transmission and reasonably good retention of transmission after aging. Data from another project for Jet Propulsion Laboratory indicates almost no loss of physicals after 20,000 hours of exposure under the dry RS-4 Sunlamp. Physical properties are fair. Its upper use temperature, as a polyolefin, is low but reinforced considerably with the glass scrim. The acrylic and the crosslinked ethylene/vinyl acetate copolymer (EVA) are the lowest price of the six polymers.

FUTURE WORK

A detailed study of the mechanism of degradation is needed to aid in the design of polymers with improved UV resistance. Simultaneously,selected polymer classes - fluorocarbon, acrylic, thermoplastic and thermoset polyester, ethylene/vinyl acetate etc. should be exposed under combined stress conditions e.g. UV, temperature cycling, moisture and atmospheric pollutants to fully understand the interaction of these stresses on material life.

It is essential that the UV stability of the polymers used as glazing be considerably improved. Stabilizers are incompatible with most polymers and will diffuse to the surface of the glazing and evaporate or be physically removed by rain.

Thus, we must develop UV stabilizer systems which are effective, and long lasting by:

a. Copolymerization or grafting of UV absorber with the polymer.

b. Use of higher molecular weight UV stabilizers

c. Simultaneous polymerization of the stabilizer with the polymer.

d. Blending compatibilization of the stabilizer with the polymer.

e. Study of synergistic systems

It is this latter approach, use of synergistic stabilizer systems, i.e. combinations of stabilizers which reinforce each others actions that offers significant promise. The mechanism of the interaction of blends of UV stabilizers, excited state quenchers, free radical stabilizing antioxidants, peroxide decomposing antioxidants and metal complexers should be investigated in depth.

Another approach to stable polymer glazings lies in the use of laminates, the outer layer of which is UV stable and the the inner layer satisfies price and/or physical property requirement. However, further work is needed on the outer protective films and methods of film lamination to prevent transmission loss.

Similar to laminates,coatings have also shown promise as a means of providing long term protection for lower cost glazings. More study is necessary to optimize both the coating acrylic vehicle as well as the UV absorber system dissolved in the coating.

Research is also needed to protect antireflective coatings against weathering degradation.

TABLE A

Properties of Selected Glazings After Exposure

	Original % Transmission(2)	Properties After Exposure			Thickness Mils
		Transmission	Tensile	Visual	
Tedlar 100XRB160SE	92	G	G	G	4
PFA 9705	94	G	G	G	2
Sunlite Premium II	87	G	G	F-G	40
Plexiglas V-811	90	G	G	G	40
Flexigard	88	G	G	G	7
X-ℓ EVA	91	F-G	G	G	18

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(1) G = Good
    F = Fair
    L = Low

(2) See Footnote 1, Table 6 for definition

TABLE B

Properties of Selected Glazings

	Heat Resistance(2)	Impact Strength	Abrasion Resistance	
Tedlar 100XRB160SE	G	G	G	Polyvinyl fluoride
PFA 9705	G	G	G	Perfluoroalkoxy
Sunlite Premium II	G	F	F-	Thermoset Polyester
Plexiglas V-811	F	L	F	Acrylic
Flexigard	F	G	G	Polyester/acrylic laminate
X-ℓ EVA/Scrim(1) Reinforced	F	F-G	F-	Crosslinked ethylene copolymer

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(1) Glass Scrim

(2) By heat resistance is meant upper use temperature, i.e. retention of physical properties at moderate to high temperature.

TABLE C

Costs

	Thickness Mils	Cost/¢ ft^2 at Thickness Shown	\$/lb	Cost ¢/Mil Per ft^2
Tedlar 100XRB160SE	4	20	-	5
PFA 9705	2	78	35	39
Sunlite Premium II	40	99	-	2.5
Plexiglas V-811	40	-	0.92	-
Flexigard	7	74	-	10.5
X-ℓ EVA/Scrim Reinforced	18	35	-	2

OBJECTIVES AND PROGRAM

The project goal is the evaluation of weather-resistant, low-cost, non-glass glazing and housing materials that will have a lifetime of up to twenty years under varying stress and high (300°F) temperature. To accomplish this, an information survey has been made and the materials selected. These polymers were then exposed to accelerated and natural weathering and loss of optical, tensile, and other physical properties measured. Critical mechanical, thermal and environmental resistance properties were examined on polymers having good weather resistance.

The state of development of surface etching processes and solar antireflective coatings to reduce surface reflectivity and to increase percent solar transmission of plastics was investigated. Methods were examined for applying antireflective coatings to plastics. Durable coatings and films for UV protection of plastic glazings were evaluated.

The overall program was divided into seven technical tasks:

Task 1 - Search the Literature and Contact Suppliers to Select Candidate Materials.

Task 2 - Expose Candidate Glazing and Housing Materials to Accelerated Weathering (UV) and Measure Changes in Optical and Tensile Properties vs Time.

Task 3 - Evaluate Critical Properties.

Task 4 - Expose Promising Materials to Accelerated Outdoor Aging on the EMMAQUA and Measure Changes in Optical and Tensile Properties.

Task 5 - Evaluate Durable Coatings or Films for UV Protection of Plastic Glazings.

Task 6 - Investigate Surface Etching Processes.

Task 7 - Evaluate Anti-Reflective Coatings for Reducing Reflectivity.

INTRODUCTION

A nonglass glazing (or housing) and surface coating must withstand many years of outdoor weathering in a terrestrial environment. As new structural materials, plastics offer attractive opportunities for outdoor use. Like most organic materials, however, they are reactive to atmospheric oxygen, moisture, and light. Thus, in extended outdoor use they gradually deteriorate by discoloration, loss of gloss, crazing, chalking, erosion, cracking, embrittlement, and loss of strength and extensibility.

The problems of weathering are complicated because of the multiplicity of conditions which may be imposed. Conditions of exposure, the nature of the plastic and its formulation, and the performance requirements are all interrelated and must be considered in choosing a material for an application.

Since an ultraviolet absorber in the interior of the polymer may still permit attack on the polymer, it is desirable to apply a surface coating containing a high concentration of ultraviolet absorber in a coating binder such as acrylic, which is relatively stable to weathering, to minimize attack on the polymer matrix and enhance long term stability.

An alternate approach to meet the proposed objectives of 20 year service life is the development of stable films containing UV absorbers capable of protecting the polymer substrate under adverse environmental conditions.

The plastic glazing must have minimum reflectivity to allow the maximum percentage of solar energy to pass through to the collector. One way of achieving this may be through use of an AR coating or by etching of the plastic surface.

1.0 MATERIALS SELECTION

There are two broad areas of technology requiring materials that have been considered in this program: (1) UV-resistant glazing and housing materials and (2) UV protective coatings.

A. Glazings

The polymeric glazing (and/or housing) must possess the following characteristics:

a. Rigidity to protect against heavy loads.

b. Clarity (for glazing) maintained over a wide range of exposure conditions.

c. Weather resistance as a combination of ultraviolet, SO_2, and moisture over a long time span without significant loss of clarity of physical properties.

d. Property retention over a wide use/temperature range, from -40 to 300°F.(1)(2)

e. Abrasion resistance (for glazing) to prevent opacification by wind-blown dust.

f. Impact strength against hail or other falling objects.

g. Resistance to hydrolyzing condition, such as high humidity and rain.

h. Ability to withstand stress fatigue arising from temperature cycling and varying physical stress.

i. Ease of maintenance.

j. Low cost.

There are two possible glazing components in the system being considered: (1) the Outer Glazing; and (2) the Inner Glazing. The outer glazing must withstand load stress and weathering plus moderate heat, and it must be abrasion resistant. The inner glazing must be stable to as high as 300°F; its UV resistance requirements are not as great as those for the outer glazing. It could be a thin film of higher use temperature.

A wide-ranging information search has been carried out to select non-glass materials for collector glazing and housings. Sources have included the literature, DOE contractor reports, JPL (photovoltaic) contractor reports, Springborn Laboratories, Inc. (SLI) work on the JPL solar cell encapsulation contract, and telephone calls to a variety of material manufacturers.

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(1) NSBIR 76-1187

(2) J.S. White, Polymer News, 3 , 239-245 (1977)

All commercially available transparent polymers(1) were surveyed and tabulated (Tables 1A-1D). The four survey tables were constructed according to price range, the ranges being: under $0.50 per pound (1A), $0.50 to $1.00 per pound (1B), $1.00 to $4.00 per pound (1C), and polymers costing in excess of $4.00 per pound (1D). The tables are set up to include in the first section a description of the polymer - i.e., its generic chemical type, at least one of its trade names, and the manufacturer. A given polymer is often available through many other producers, but for the sake of convenience only one has been listed.

The polymers surveyed encompassed a great variation in physical properties and chemistry and included such materials as the following: polyvinyl chloride, polystyrene, polyethylene, polyesters, ionomer, polyimides, cellulosics, urethanes, silicones, etc.

In the central portion of the table is a column showing the survival prognosis;this involves the survival span in years of unprotected materials. In the next column is shown an upgrading potential in years of completely protected polymers. By complete protection we imply a high level of an internal UV additive synergistic system and a film or coating containing a high level of UV absorber to screen out the impinging UV light. All of these figures are educated opinions, based on experience with related materials since this type of specific information is rarely available. The years predicted for the virgin polymer are given in ranges and those for the protected polymer as Fair (F) or Good (G) at 10 and 20 years of lifetime.

Among the 50 percent of the surveyed materials which fall within the cost range of $0.01 to $0.05 per square foot, no transparent material which could survive unprotected for 20 years outdoors has been identified. Currently existing weatherable fluorocarbon and silicone products are high-priced ($0.44 - 2.00/ft.^{2}), but acrylics are more moderately priced and are viable candidates.

B. Housings

Tables 2A, B, C, and D list respectively plastic, metal and ceramic materials that may be suitable for housings. Each table lists the manufacturer, the material, grade, physical form, flexural modulus, density, cost/lb., cost/ft^2 and volume cost.

As the tables indicate, the study was divided into sections according to the class of materials under investigation. For some composites, flexural modulus values could not be found since the value changes with variations in design.

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1. JPL 1978 Annual Report, Contract #954527

Plastic materials were the first considered - because of their fabrication versatility, relatively low cost, high availability, and the possibility of their being compounded with inexpensive fillers to further reduce the cost (Table 2A).

The cost effectiveness is basically a ratio of the stiffness (flex modulus) to the material cost. Fillers and fibers added to improve the rigidity also raise the density, however, and consequently many of the high-strength materials are less cost effective because of the increase in cost per unit volume.

Resin-reinforced structural laminates such as epoxy and polyester preimpregnated glass matt were much more expensive than a paper-based phenolic laminate. It was assumed that the stiffness-to-weight ratio of structural foam plastics would place them at an economic advantage, but actually costing found them to be competitively priced with many filled resins. The least expensive plastics in the table are filled polypropylenes.

A brief survey of some of the more widely used metal construction products (Table 2B) indicates that they may be competitive with plastics. The use of metals may also incur an additional fabrication cost if special design is required, as opposed to plastics that may be molded in a one-step operation.

Ceramic-based housings were also briefly considered (Table 2C), and costed out at lower prices than either plastics or metals. A drawback, however, is that the densities of these materials are so high, that they would undoubtedly require expensive support. Glass reinforced gypsum board would not endure outdoor weathering for long because of its high water sensitivity. The cost of upgrading would probably be high. Additionally, the elastic limit in this and other ceramic materials is very low. Small deflections in the panel would cause cracking and fatigue, leading to catastrophic failure.

Elasticized cement is a weatherable compound, however, and has a degree of flexibility not found in other mineral products. Latex-modified cement is estimated at $0.40 to $0.50 per square foot in 1/4 inch thicknesses. The load-bearing capacity is not presently known, and the cost also needs further investigation.

Table 2D lists some of the wood product housing materials investigated to date. This class represents the lowest cost structural materials at approximately three to four times less than the cost of the least expensive plastic compounds surveyed.

A disadvantage to plywood, however, is that it is manufactured in only certain standard thicknesses and would require retooling to produce special grades. This difficulty is overcome with the use of particle boards such as hardboard, chip board, and flake board - all of which are made by an extrusion and/or compression-molding type of process in which the thickness may be varied.

The lowest-cost particle board discovered so far is a 3/8-inch thick wood chip/phenolic binder composite (Roadman Company) which is marketed as having a flexural modulus of 500,000 psi and a cost of $0.16 per square foot. Unfortunately, this product is not weatherable in its commercial form.

As may be seen in Table 2D, the other types of fiber or particle board are similarly priced. The results of the wood products survey are highly encouraging.

Paper based materials are only just coming under investigation and three products of interest (not tabulated) have been identified. A structural paneling material known as "Homasote" is available in 0.5-inch thickness at $0.14 per square foot. This compound is prepared from waste paper and has a flexural modulus of 80,000 psi, which provides adequate deflection resistance for its thickness. Another interesting product is a weather-proofed pressed paper board panel manufactured by Mead Paperboard Products, Inc. under the trade name of "Pan-L-Board". This panel material has a modulus of 615,000 psi. Mead claims this panel board has endured 17 years of outdoor weathering in Wisconsin.

C. Coatings

One method of protecting a substrate against ultraviolet light degradation lies in the use of a thin coating containing relatively high concentrations of UV absorber. The weather resistance of the coating must be sufficient to protect the thick layer underneath. This can most likely be produced by compounding a high concentration of ultraviolet absorber into the thin coating, sufficient to stop ultraviolet energy before it enters the thick encapsulant underneath. In general, substituted o-hydroxy benzophenones and benzotriazoles are the best primary ultraviolet absorbers, and may often be synergized by organo-nickel and other additives.

In addition, it would be highly desirable that the thin coating be based on a polymer which is itself stable to ultraviolet, thus eliminating the need for stabilizing it, and avoiding the problem of surface degradation of the thin coating itself. These thin coatings might best be based on fluorocarbons, acrylics, or silicones. The acrylics are much more reasonable in price than silicones or flurocarbons, therefore, in this initial survey only acrylic coatings were considered.

Fortunately there exists an enormous number of acrylic products available in brushable and sprayable forms such as latex (water-emulsion based) and solution grades (solvent based) that may serve as UV screening vehicles. Rohm and Haas Company, a manufacturer of acrylics, has exposed coatings to more than twelve years of outdoor weathering without any visible evidence of deterioration(1). Experiments at Springborn Laboratories with acrylic coatings show equally successful performance.

Solvent-based acrylic coatings are polymers formulated especially for film-forming ability and solvent compatibility. Grades vary according to solvent composition, percent solids, surface hardness, and glass transition temperature. Table 3A shows the manufacturer, percent solids, type coating, curing agent (if applicable) and costs.

Since polymers with overly high molecular weights provide solutions of low solids content and unworkably high viscosities, an alternate solution is to introduce crosslinking to obtain improved properties. The advantages offered over thermoplastics in this approach are:

- Improved toughness and hardness
- Resistance to softening at higher temperatures
- Better resistance to solvents and moisture
- Lower solution viscosity and higher application solids
- Better compatibility with substrate materials

Solvent-based thermoset resins may be applied by conventional coating methods, dried, and cured through an oven cycle to produce the ultimate properties.

Latex-based coatings may be essential to avoid solvent attack on the organic glazing (Table 3B). A solvent coating solution may etch the glazing and reduce transmission.

Emulsion, or latex, polymers consist of discrete spherical particles of high molecular weight polymer dispersed in water (Table 3B). Since the polymer particles are separate from the continuous aqueous phase, the viscosity of the dispersion is relatively independent of the polymer's molecular weight. Consequently, molecular weight can be raised to high levels to take advantage of the resulting improvement in performance properties.

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(1) Rohm & Haas, "Thermoplastic Acrylics-Exposure Series 57YY" Memo 51-1243; May 14, 1969; Quoted by Permission from Dr. William Brendley.J

2.0 EXPERIMENTAL METHODS

A. Expose Samples to Accelerated UV Aging

In all cases compression molded sheets were used to prepare the specimens.

Microtensile specimens were exposed in the ASTM G23 Weather-Ometer which was used in accordance with recommended practice D1499 for operating carbon arc and water exposure of plastics. This device exposes a revolving rack of test specimens to the light of a three-filament carbon arc lamp and water spray simultaneously.

The Weather-Ometer is a widely used artificial accelerated aging technique. Natural outdoor weathering induces degradation through a complex pathway involving a combination of factors, however, and correlations between artificial and natural conditions are often difficult to establish. Because natural weather involves an infinite number of combinations of heat, humidity, light and dark cycles, rain, ultraviolet intensity, etc., that also vary with season and location, artificial "weather" cannot really be created. The Weather-Ometer has an immediate utility in that degradation stability of materials may be evaluated on a relative basis.

One possible problem with the Weather-Ometer is the presence of wavelengths below 290 nm. These wavelengths do not appear in the sun's spectrum. Since acrylics are adversely affected by wavelengths below 290 nm, the Weather-Ometer could give deceptive results. In our recent work we have installed quartz filters in both our Weather-Ometer and our RS-4 Sunlamps to screen out such wavelengths.

B. Test Specific Properties After Exposure

The following tests were run after each exposure time, whenever possible:

- Ultimate tensile strength
- Ultimate elongation
- Tensile modulus
- Qualitative color formation and other visual changes
- Total integrated solar transmittance

In addition, outdoor soil accumulation testing was conducted as follows: the tendency of a plastic to accumulate dust, soot, debris, etc., was assessed by molding a plaque and mounting it outdoors. Light transmission was measured at 120 and 360 days, before and after washing the surface at each set of readings.

C. Evaluate Critical Properties

Critical properties were evaluated on those polymers that are still promising after 240 days of accelerated UV exposure. The tests to be carried out are divided into general property areas of: clarity, toughness, heat resistance, mechanical properties, and environmental resistance. The following table lists the tests and the related ASTM numbers, where applicable.

Test	ASTM Number
Clarity:	
Total integrated solar optical transmittance (glazing only)	(1)
Abrasion (glazing only)	D673
Toughness:	
Tensile impact	D1822
Heat Resistance:	
Tensile properties measured at 250°F	D638
Tensile properties after exposure at 300°F for 120 and 240 days	D638
Mechanical Properties:	
Tensile strength, elongation, yield strength, and modulus	D1708
Environmental Resistance:	
H_2SO_3, HNO_3, ethylene glycol(2)	D543

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(1) See footnote (1) Table 6

(2) Run on housing only

D. Expose Promising Materials to Accelerated Outdoor Aging on the EMMAQUA and Measure Changes in Optical and Tensile Properties

The EMMAQUA is a follow-the-sun device having ten flat mirrors so positioned that the sun's rays strike them at about 90° all day and reflect onto the samples mounted in the target area. The mirrors are 6" x 72" sheets of electropolished aluminum treated by the Alzak^R process to prevent corrosion. The ultraviolet reflectance is in excess of 70 percent in the region 300- to 400-nm wavelength.

The EMMAQUA machines are operated only during periods of good sunshine, and two sun cells with balanced output maintain the machines in focus during operation. A shadow maker mounted above the cells shades them so that when one received more radiation than the other, the balance is disturbed and a signal is provided through an amplifier to a reversible motor that adjusts the machine back to proper focus. The machine's axis is oriented in the north/south direction.

A blower provides a cooling airstream (1460 cfm) that is directed over and under the samples by an adjustable deflector along one side of the target area. Should the airstream be reduced below a specified volume (1000 cfm) or cut off for any reason, an airflow switch releases a solenoid which permits a spring-loaded shutter to close between the target area and the mirrors. This airstream maintains surface temperatures of samples on EMMAQUA in the same general range as duplicates exposed at 45° south. The difference is that samples exposed on these devices reach maximum surface temperatures sooner and remain there longer; they rarely exceed 10°C higher than identical samples exposed on 45° south, and then only for certain types of black specimens.

The EMMAQUA machine has an effective target area of 5" x 55" and test samples cannot exceed the 5" dimension on one edge. The EMMAQUA device is similar to the EMMA with the exception that samples exposed on EMMAQUA are sprayed for 8 minutes out of each hour of operation with distilled water.

To determine the amount of solar energy striking the samples, it is first measured in langleys(1) on a follow-the-sun rack with an Eppley pyrheliometer. Then the total of langleys during the hours when the EMMA machines are operating (2) is multiplied by eight (the mirrors being 80 percent reflective). In this manner an exposure of, say, 50,000 langleys can be duplicated by timing the next series for the same number of langleys. This undoubtedly gives more reproducible results than timing exposures in days or months. It furnishes a careful record of the langleys received by every sample.

In Phoenix, where samples have been exposed, the daily average of langleys is recorded approximately as follows:

• At 45° south	500
• On follow-the-sun rack	625
• On EMMAQUA	5000

The most promising materials from the 240-day Weather-Ometer data of Task 2 were exposed on the EMMAQUA as circular disks for optical properties and as microtensile bars. Samples were withdrawn for testing at 120 and 240 days, for tensile and optical properties.

In addition, the most promising coatings and/or films were coated and/or bonded to substrates and exposed and tested as above on the EMMAQUA.

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(1) One langley equals 1 g-cal/cm^2, or 3.69 BTU/sq ft.

(2) Only for 8 or 9 hours per day.

3.0 UV EXPOSURE OF GLAZING MATERIALS

A. Weather-Ometer

The inner and outer glazing materials have different requirements. The inner glazing must withstand 300°F but does not have to withstand a load or be as resistant to UV, since it is screened by the outer glazing. The outer glazing must resist stress and weather and be abrasion resistant, but its temperature requirements are much lower. All materials must be capable of being mass-produced and must be low in cost.

A series of transparent plastics were chosen for study on the basis of weather resistance or wide outdoor industrial usage (solar or otherwise) keeping in mind the property requirements discussed above.

All films and sheets were used as received from the manufacturer except for Plexiglass V-811 which was compression molded into sheet in this laboratory.

These materials are divided into four classes (Table 4); fluorocarbons, thermoplastic polyester, thermoset polyester and a miscellaneous group (composed of polycarbonates, cellulose acetate butyrate, acrylic, polyvinyl chloride, crosslinked ethylene/vinyl acetate copolymer etc). The materials were chosen on the basis of our experience and the desire to include a wide variety of potentially useful polymer chemical classes.

Samples were under exposure for four, eight and twelve months on the Weather-Ometer, for four and eight months on the EMMAQUA, for six months on the Wet RS-4 Sunlamp and for twelve months outdoors at Hazardville, Connecticut. At the end of each time period the glazings were examined for integrated solar transmission, tensile strength, modulus and ultimate elongation. Loss of elongation is the most sensitive barometer of the effect of oxidative (UV or thermal) degradation. This was shown by Hirt (1) where individual polyethylene samples were exposed in Arizona each month of the year. As the intensity of the sun increases into summer the degree of oxidation, as measured both by infrared carbonyl and loss of elongation, increases.

A series of glazing materials have now been exposed for 12 months in the carbon arc Weather-Ometer (Table 5). The fluorocarbon films (Tedlar, Halar, Kynar, PFA and FEP) are unchanged except for a slight cloudiness in the Tedlar. The polyester films (Mylar), as well as the polyesters impregnated with UV absorbers (Llumar, and the two from National Metallizing) are degraded. The three thermoset polyesters (Filon 558, Sunlite Premium II and Glasteel 500) are all in good condition although the Sunlite Premium II has yellowed slightly

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(1) R. C. Hirt and N. Z. Searle, Energy Characteristics of Exposure Sources, "Applied Polymer Symposia, No. 4", p. 66; M. R. Kamal, Editor, Interscience Publishers, N.Y. (1967).

and evidences some surface degradation. Lexan polycarbonate is yellowed and clouded whereas Tuffak, a UV stabilized (double walled) polycarbonate, although clouding, has not discolored. The PVC/scrim reinforced shows considerable yellowing but, as expected, the acrylic homopolymer (Plexiglas V-811) is completely clear and unaffected as is the peroxide crosslinked ethylene/vinyl acetate copolymer (EVA). The yellowing of Lexan and CAB (cellulose acetate butyrate) is the first sign of UV oxidation. The yellowing of the PVC/scrim material is due to chemical rearrangement of the UV stabilizer. According to Monsanto, yellowing of their material indicates in-situ change of their additive to an active UV absorber.

Thus, visually the fluorocarbons, acrylic homopolymer and crosslinked EVA are all essentially unchanged after one year exposure in the Weather-Ometer.

The effect of Weather-Ometer exposure for four, eight, and twelve months on the optical transmission of glazing materials is contained in Table 6. Integrated solar transmission is measured over the range 350 to 2100 nm per ASTM E424-71.

The glazing materials with the highest original transmission, the fluorocarbons (numbers 1-5), also have the highest transmission after exposure. Two of the polyesters, (numbers 6-9) Mylar and Nat. Met. 45-95-1 failed after eight months of Weather-Ometer exposure due to severe degradation, and Llumar has undergone an extremely large drop in transmission after twelve months. Nat. Met. 45-95-2 did, however, retain all of it's transmission except for the eight month sample, which lost only 2% from the original value of 85%. Ardel D-100 (#10) has no significant loss in percent transmission, but the original value is only 70%, which may eliminate it for consideration as a glazing material. All of the thermoset polyesters (number 11-13) have sustained losses with Sunlite Premium II having the largest drop. In the miscellaneous group, Lexan and PVC/Scrim show large losses in transmission. The lowest loss of transmission is seen in Plexiglas V-811 (acrylic), crosslinked EVA and Flexigard 7410, a polyester with a laminated top film of acrylic.

The Weather-Ometer, having wavelengths below 290 nm, which are not found in the sun's spectrum at the earth's surface, could cause premature degradation of some materials e.g., acrylics. On the other hand, materials that do well in the Weather-Ometer will most likely perform well under other types of aging.

To eliminate wave lengths below 290 nm glazings were exposed under the "Wet" RS-4 Sunlamp. The RS-4 Sunlamp is filtered to remove all wavelengths below 290 nm and has a water spray to simulate the Weather-Ometer exposure. Results are relatively similar to those on the Weather-Ometer.

B. "Wet" RS-4 Sunlamp Aging

Selected glazing materials were subjected to "Wet" RS-4 Sunlamp exposure for periods of four and eight months and transmission results are contained in Table 7. The largest decreases in transmission after four months were evidenced by Tedlar 400 x RB160SE, crosslinked EVA, FEP 105A, and PVC/scrim. After eight months of exposure, many of the glazings had sustained significant losses in transmission. Filon 558 had lost 11%, crosslinked EVA 8%, FEP-100A 7% and PVC/scrim 5%. All in all, 7 samples had shown additional losses in transmission from four month results. Only 4 samples retained all of their original transmission after eight months exposure, those being Tuffak CM-2, Glasteel 500, Nat. Met. 45-95-2, and Llumar. It is surprising that the polyesters, Llumar and Nat. Met. 45-95-2, faired so well, after observing how poorly they did as a group in the Weather-Ometer aging. After 12 months Llumar had dropped 5% transmission.

The fluorocarbons, Nat. Met. 45-95-2 Polyester, Plexiglas V-811 and Flexigard showed the highest transmission after 12 months with Plexiglas V-811 remaining unchanged.

C. Outdoor Exposure

Glazing materials were also exposed at a 45° angle on the roof at Hazardville, Connecticut for outdoor weathering for periods of four, eight, and twelve months, and the transmission values of unwashed samples are contained in Table 8. After four months exposure, only PVA/scrim showed a loss of more than 3% in transmission, Tenite CAB and PVC/scrim, losing 7% and 5% respectively, were the worst of the eight month samples. The twelve months results and analysis of the data as to solar transmission retained (Table 9) indicate that the only material to degrade significantly during this time period is the PVC/scrim reinforced.

The effective transmission of a glazing depends on having as high as possible original solar transmission and as low as possible loss during weathering. We have called the product of original solar transmission and solar transmission after aging the optical index.(1) Thus the optical index is a dimensionless number that takes into consideration both original transmission and loss of transmission during weathering. The higher the number, the better the material. In Table 10 all of the glazing materials are ranked by optical index after twelve months exposure outdoors at Hazardville, Connecticut.

As expected, the fluorocarbons are at the top of the list. Also near the top are the less costly polymers, e.g. Plexiglas V-811, crosslinked EVA, CAB and Flexigard. At the bottom are Ardel, PVC/scrim and Mylar.

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(1) This approach was used in our JPL program on photovoltaic encapsulation, contract No. 954527.

D. EMMAQUA Exposure

The thirteen best glazing materials as judged by previous aging results were exposed on the EMMAQUA in Arizona for four and eight months. The EMMAQUA consists of a series of mirrors which, with water spray, concentrates natural sunlight and accelerates normal (Arizona) outdoor exposure . C.R. Caryl from DSET(1) suggests an eight fold acceleration factor. Internal results as SL indicate five fold acceleration. Work by M. Berry agrees with 8 fold.(2)

Three of the fluorocarbons (Table 11), Tuffak CM-2, Plexiglas V-811 and Flexigard exhibited the least degradation in transmission with the acrylic (Plexiglas V-811) showing essentially no change.

The optical indices based on EMMAQUA data (Table 11 - last column) indicate that the fluorocarbons and Plexiglas V-811 are the optimum materials followed by Flexigard.

Table 12, is a "Summary Table" and compares the percent solar transmission retained after 12 months in the Weather-Ometer, outdoors at Hazardville, Connecticut and after 8 months under the EMMAQUA. The actual % transmission after each of these time periods is also shown. Polymers evidencing both the highest initial transmission and the least transmission loss under all conditions include the top four fluorocarbons, Tuffak CM-2 (abrasion resistant UV stabilized polycarbonate), Plexiglas V-811 (acrylic) and Flexigard (acrylic laminated to polyester). The most severe exposure condition is the EMMAQUA,and the least severe, one year outdoors at Hazardville, Connecticut. The EMMAQUA provides between 5 - 8 times the rate of degradation as does outdoor weathering. This is evidenced by the five materials, Kynar 450, FEP 100-A, Llumar, Sunlite Premium II and crosslinked EVA whose transmission is significantly less after 8 months in the EMMAQUA vs one year outdoors.

E. Effect of Washing

Glazing materials exposed for extended periods of time outdoors are subjected to accumulations of dirt which could lower transmission. In Tables 13 and 14, materials exposed for four and twelve months were washed using mild soapy water and cheesecloth and then rinsed with deionized water and allowed to air dry. Percent transmission was measured and compared to the original and aged, unwashed values.

In Table 13, washing of the samples did not create much of an improvement. One possibility could be the small difference in the values of the original and four month unwashed results. Another reason could be that all losses in transmission after four months may be due to UV degradation and not due to soil accumulation.

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(1) SPE - Journal, January 1967 p. 49.

(2) M. Berry & H. Dursch, Solar Energy Materials 3 , 247-261 (1980).

Table 14, however, presents a different picture. After washing, all samples, except for the thermoset polyesters (11-13) increased in transmission or stayed the same as the twelve month unwashed results, with many of the samples returning to their original transmission. The material showing the biggest difference between washed and unwashed was PVC/scrim which increased 5% after washing. The thermoset polyesters, the hardest of all the glazing materials, would most likely be least affected by dirt accumulation, with normal washing by rain being sufficient to remove most of the dirt. In turn, the softest samples, PVC/scrim and crosslinked EVA, would benefit most from washing.

F. Tensile Properties After UV Exposure

Tensile properties of glazings were measured after four (Table 15), eight (Table 16), and twelve (Table 17) months exposure in the Weather-Ometer. Table 19 presents the precent retention of elongation after 8 and 12 months exposure. Elongation retained is meaningless for those materials having high modulus and correspondingly low original elongation (thermoset polyesters).

A wide variety of glazing materials were placed under exposure on the Weather-Ometer. These include the following classes:

- fluorocarbons (1-5)
- thermoplastic polyesters (6-9)
- thermoset polyesters (11-13)
- polycarbonates (14 & 15)
- miscellaneous group (10,16,17,18,19, & 20)

All fluorocarbons showed a loss in tensile strength (Table 18) retained, with FEP 100A and Tedlar 400XRB160SE retaining only 38% of their tensile after 12 months exposure. PFA, Halar 500 and Kynar 450 retained over 50% of their tensile strength even after 12 months exposure. A significant loss in elongation, the most sensitive barometer of degradation, was evident in two (Tedlar 400XRB160SE and Kynar 450) of the fluorocarbons after eight months exposure. PFA and Halar 500 evidenced the best property retention of the fluorocarbon group.

The thermoplastic polyesters (6-9) have undergone severe degradation. Mylar failed after eight months exposure, and Llumar, Nat. Met 45-95-1, and Nat. Met. 45-95-2 showed extreme losses in both tensile and elongation. Nat. Met. 45-95-1 and Llumar failed after twelve months, and Nat. Met. 45-95-2 is close to failure, retaining only 38% of its tensile and 19% of its elongation, despite the impregnation of UV absorbers into the surface.

The thermoset polyesters present another picture. Not only is there no loss in tensile strength (10-12) but Glasteel is crosslinking as indicated by its large increases in tensile strength after both eight and twelve month exposure periods. Embrittlement could be a problem if this crosslinking, which is a "plus" initially, is carried too far. With the other two thermoset polyesters, Filon 558 has retained all of its tensile, while Sunlite Primium II has lost about 1/4 of its tensile.

In the miscellaneous group, both polycarbonates, Lexan and Tuffak CM-2, had small losses in tensile but retained only 21% and 44% of their elongation respectively after twelve months. Plexiglas V-811 acrylic retained 62% of its tensile after eight months and continued the downward trend to 32% after twelve months. It is known, however, that acrylics are affected by wavelengths below 290 nm not normally found in the sun's spectrum. Some of these shorter wavelengths are found in the carbon arc Weather-Ometer and this could account for Plexiglas V-811 low values. CAB (cellulose acetate butylate) has sustained large losses in both tensile and elongation, while PVC/scrim increased its tensile by 73% but lost over 90% of its elongation. PVC also failed by discoloration. Considerable losses in tensile were sustained by Flexigard and crosslinked EVA. Ardel D-100 shows negligible loss in tensile strength.

The glazings were also exposed in the EMMAQUA and tensile properties are shown after four (Table 20) and eight (Table 21) months exposure. Percent of tensile strength and percent of elongation retained are shown in Tables 22 and 23.

Tedlar 400XRB160SE, PFA, and Kynar 450 had increases in tensile strength after four months and eight months. Of these three only PFA retained its elongation. FEP 100-A and Halar 500 had losses in both tensile and elongation. At the end of eight months Halar 500 regained almost all of its elongation.

The thermoplastic polyesters, Nat. Met. 45-95-2 and Llumar both did as badly as they did in the Weather-Ometer exposure. Llumar embrittled in eight months; the Nat. Met. 45-95-2 sustained large losses in both tensile strength and elongation at the end of both four and eight month exposure periods. All other samples showed little or no loss in tensile strength or elongation except for Tuffak CM-2 which had an elongation drop of 67% after four months and 80% after eight months. There is very little difference between the results obtained at four and eight months.

Referring to percent elongation, (Table 23), four samples essentially retained their elongation - Halar 500, crosslinked EVA, Plexiglas V-811 and PFA.

Table 24 is a summary of the percent retention of tensile strength and ultimate elongation under both Weather-Ometer and EMMAQUA exposure. After eight months exposure the following comparison holds:

% Retention of Tensile Strength

	EMMAQUA	Weather-Ometer
Tedlar	107	55
PFA	158	80
Halar 500	67	47
Kynar 450	231	71
FEP 100A	57	37
Nat. Met 45-05-2	36	35
Llumar	Failed	22
Filon 558	141	112
Sunlit Premium II	90	75
Tuffak CM-2	79	83
Plexiglas V-811	158	62
Flexigard 7410	100	44
Crosslinked EVA	105	63 (4 months)

There is a consistently greater acceleration in the Weather-Ometer than under the EMMAQUA.

Elongation is not a useful barometer of degradation if the initial elongation is low, i.e. for a high modulus material. This eliminates four materials from a general comparison negating the use of elongation as a measure of degradation in this series of materials.

4.0 HOUSING MATERIALS

A wide variety of housing materials are also under exposure on the Weather-Ometer. These include the following classes:

- Wood composites
- Fiberglass reinforced polyester
- Peroxide crosslinked, filled HDPE
- Thermosets
- Glass or talc filled thermoplastics
- Thermoplastic foams
- PVC compounds

Details on the specific materials used follow:

Wood Composites

- Super Dorlux masonite particle board, 0.125"; Masonite Corporation
- Pan-L-Board, 0.100"; Mead Corporation

Fiberglass Reinforced Polyester

- FRP sheet (glass fiber reinforced polyester), 0.125"; Polyply, Inc.
- Polyester S660, 0.140"; Fiberite Corporation

Peroxide Crosslinked Filled High Density Polyethylene

- Carbon balck filled peroxide crosslinked high/density polyethylene; 0.125"; Springborn Laboratories formulation
- Burgess KE clay-filled, peroxide crosslinked high density polyethylene; 0.125"; Springborn Laboratories formulation

Filled Thermosets

- Melamine-M6024 (Melamine/formaldehyde copolymer), 0.125", Fiberite Corporation
- Filled Phenolic (phenol/formaldehyde copolymer FM 4005), 0.125"; Fiberite Corporation

Filled Thermoplastics

- Dylark 250 (styrene/maleic acid copolymer-glass filled), 0.125", Arco Chemical Company
- Forty percent talc-filled polypropylene; 0.125"; Hercules Corporation

Thermoplastic Foams

- Polypropylene structural foam - 30 percent fiberglass; 0.150"; Vantage Products Corporation
- Cellular polyvinyl chloride, 0.125"; B.F. Goodrich Co.

Polyvinyl Chloride Compounds

- Exterior grade PVC pipe compound 7084 (polyvinyl chloride); 0.125"; B.F. Goodrich Company
- IBID "11" but using 85857 compound (filled with silane-coated clay), 0.125": B.F. Goodrich Co.

The two PVC pipe compounds were compression molded from pellets. The peroxide-containing, carbon black and Burgess KE clay filled, compounds were compounded on our two-roll mill, and cured while compression molding into sheets. All other sheets were used as received.

The procedure and formulation used to prepare the peroxide cross-linked carbon black in clay formulations is:

Carbon Black Formulation

Cabot Sterling NSx76 Carbon Black	16.5%
Phillips-Marlex 5003 High Density Polyethylene (HDPE)	82.3%
Lupersol 101 Peroxide	1.2%

Clay Formulation

Burgess KE Vinyl Silane Coated Clay	16.5%
Marlex 5003 HDPE	82.3%
Lupersol 101	1.2%

The carbon black and clay were oven dried at 60°C overnight. The HDPE was fluxed on a two-roll mill and the black or clay milled in; finally, at the end of the milling cycle the peroxide is blended in. Compression mold curing was carried out at 325°F for 20 minutes.

Sheets of these materials were exposed in the Weather-Ometer and evaluated after four, eight and twelve months.

Visual changes in the housing materials after four months in the Weather-Ometer are revealed in Table 25. Both wood composites, the Super Dorlux Masonite and the Pan-L-Board, exhibit some delamination indicating the need for a protective coating as a moisture barrier. The filled phenolic has a friable (crumbly) surface as do the polypropylene structural foam and talc-filled polypropylene showing degradation. Incipient degradation of the cellular PVC and the polyester S-660 is revealed by discoloration.

After eight months exposure (Table 25) all materials have undergone some degree of change except for the carbon black filled crosslinked HDPE, which shows none except for a very slight loss in gloss. Three samples have failed completely. Super Dorlux and Pan-L-Board, both wood by-products, exhibited severe delamination and chalking. Crumbling and brittleness caused the failure of the 30% glass filled polypropylene structural foam. So of the original 14 samples only 11 remain.

Table 26 reveals the effect of 12 months exposure in the Weather-Ometer of a series of possible housing materials. Most materials are in good condition after one year exposure except for the following which have failed - the two wood composites (Super Dorlux and Pan-L-Board), glass and talc-filled polypropylene. The two polyesters are beginning to fail as shown by a rough surface. The three polyvinyl chloride samples evidence incipient surface chalking.

Changes in tensile strength, modulus and ultimate elongation are shown in Tables 27-29 and the percent tensile strength and elongation retained in Table 30. Elongation retained is meaningless for those materials having very high modulus and correspondingly low elongation (the thermosets and the fiberglass reinforced thermoplastics). Tensile data for the wood (Monsonite and Pan-L-Board) is not as significant as are the visual changes, e.g., swelling or delamination.

After four months Weather-Ometer (Table 27) exposure Monsonite Super Dorlux looses about half its tensile strength; the opposite is true of Pan-L-Board where the strength triples.

After four months exposure neither of the fiberglass reinforced polyesters nor the two thermosets (melamine and phenolic) evidence any loss of tensile strength. However, the glass reinforced Dylark 250 (styrene/maleic acid copolymer) has lost half of its tensile strength and elongation as may be anticipated from a styrenic polymer.

The two foams (polypropylene and PVC)show incipient degradation in their loss of elongation after four months.

Both polyvinyl chloride formulations are crosslinking as indicated by their increase in tensile strength; however, they all substantially decreased in elongation. Such crosslinking is a "plus" initially but could lead to embrittlement if carried too far.

The carbon black-filled crosslinked high-density polyethylene (HDPE) has lost some of its tensile strength and elongation even at four months exposure - a surprising result in view of the known UV stabilizing action of carbon black. The clay-filled peroxide crosslinked HDPE has lost almost all of its properties. The talc-filled polypropylene has degraded somewhat in elongation but its tensile is intact,(Table 27).

After eight months exposure the two wood composites, Pan-L-Board and Super Dorlux, failed (Table 28) due to severe delamination and chalking. There was one other failure after eight months of Weather-Ometer exposure, glass-filled polypropylene foam because of crumbling and brittleness.

FRP sheet and S-660 fiberglass reinforced polyesters exhibited no loss in tensile strength, nor did Melamine M-6024 after 12 months exposure. The other thermoset, filled Phenolic FM-4005, evidenced a small loss in tensile after eight months in the Weather-Ometer but no loss in tensile strength after 12 months exposure (Table 29).

Dylark 250 after eight months has lost 2/3 of its tensile as might be expected from a styrenic polymer. Losses of 21% and 27% in tensile after eight and twelve months were experienced by talc filled polypropylene, but more importantly these same samples lost over 60% of their elongation. It is obvious that polypropylene is inadequate for long term outdoor use (Table 29 and 30).

In summary the samples that changed the least in tensile properties were FRP sheet, S-660 polyester, Melamine M-6024 filled phenolic and carbon black-filled high density polyethylene (HDPE).

The chemical resistance of selected housing materials - Poly S-660, FRP, carbon black-filled peroxide crosslinked HDPE, Melamine M-6024 and filled phenolic - was analyzed by immersing these materials in dilute sulfuric and nitric acids and in ethylene glycol (50% in water) for one week (Table 31). Changes in weight and dimension were measured.

There were no significant changes in dimension. Nor did any of the materials lose weight in the presence of ethylene glycol. There were small losses in weight in the presence of the acids except for the carbon black filled HDPE.

The carbon black-filled crosslinked high density polyethylene has lost 20% of its tensile strength after one year's exposure in the Weather-Ometer and the FRP sheet and S-660 polyester have increased in modulus. These are indications of incipient degradation for the HDPE and of crosslinking for the FRP and S-660 polyesters. Assuming that one year in the Weather-Ometer equals 8-10 years outdoors(1) this gives a life expectancy of at least 10 years. Since there is no change in properties of the filled phenolic or of the Melamine M-6024, it would seem probable that these materials would have a life expectancy of at least 15 years outdoors.

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(1) EMMAQUA gives an 8X acceleration (page 10) and the Weather-Ometer is even more severe)page 13 and Table 24).

5.0 PROPERTY EVALUATION

The following properties were measured on selected glazing materials including five fluorocarbons, two thermoplastic polyesters, two thermoset polyesters, a polycarbonate, an acrylic, a polyester/acrylic laminate and crosslinked ethylene/vinyl acetate copolymer (Table 32).

	ASTM No.
Tensile properties at 250°F	D-638
Oven aging at 375°F	Visual
Tensile properties after four and eight months at 150°C	D-638
Tensile impact at room temperature and at 0°F	D-1822
Falling sand abrasion	D-673
Durometer hardness	D-2240
Optical transmittance	E-424-71

The materials selected for property evaluation are those which were still promising after initial UV exposure studies (Table 32).

Since an inner glazing in a double-glazed collector can reach a stagnation temperature of 250-350°F, it is essential that a material being considered as an inner glazing have reasonable tensile properties at these temperatures. Table 33 reveals the tensile properties (tensile strength, ultimate elongation and modulus), run at 250°F of 13 glazing materials. In Table 34 tensile properties at 250°F are compared to properties evaluated at room temperature.

Crosslinked EVA was too soft to measure tensile properties at 250°F. Almost all of the materials showed an increase in elongation and a loss in tensile strength. However, two of the fluorocarbons-Tedlar 400XRB160SE and FEP100A (neither of which is recommended as an inner glazing) lost about 2/3 and 90%, respectively, of their original tensile strength. As expected, the two thermoset polyester polymers, Filon 558 and Sunlite Premium II lost only 15-20% of their tensile. The acrylic, Plexiglass V-811, has lost over 70% of its tensile and would not be considered as an inner glazing unless reinforced.

To help determine which of the glazing materials would be suitable as an inner glazing, eleven of the best materials were subjected to heat aging in a 300°C air circulating oven for 120 and 240 days. Tensile properties were measured to see which materials are most resistant to high temperature for long periods of time.

Tensile properties measured after 4 months of oven aging are contained in Table 35. Five samples - Plexiglas V-811, crosslinked EVA, Kynar 450, Llumar, and Flexigard - all failed completely due to melting, shrinkage, or brittleness and could not be measured for tensile properties. Filon 558, a thermoset polyester, was the only material to show an increase in tensile strength indicating crosslinking. Sunlite Premium II, also a thermoset polyester, had a high retention of tensile strength, as did PFA, a fluorocarbon. On the whole, most glazings showed a drop in tensile strength and elongation.

After 8 months of oven aging at 300°F (Table 36) three additional samples, National Metalizing 45-95-2, Tedlar 400XRB160SE and Tuffak CM-2, failed. Llumar, which was to brittle to measure, retained only 1% of its original tensile strength and elongation and should be considered a failure. All materials showed a loss in tensile strength, with Filon 558 and PFA retaining the highest percentage of tensile strength.

When comparing the tensile property retention of the 4 and 8 month samples (Table 37), one can see that the difference between them was small except in the case of Filon 558. After 4 months of oven aging, Filon 558 had 123% of its original tensile strength, but the figure dropped to 90% after 8 months, a change of 33%. However, it still retained 100% of its original elongation.

Of all the materials that were heat aged only the fluorocarbons and thermoset polyesters were able to withstand the high temperature. The fluorocarbons may be somewhat better suited as an inner glazing material because of the higher percent transmission. For example PFA has a transmission of 94% versus 87% for Filon 558 and Sunlite Premium II. Also the two thermoset polyesters that were used in this test (Filon 558 and Sunlite Premium II) discolor and yellow when exposed to high temperatures for long periods of time.

In order to help determine which glazing material would be suitable as an inner glazing in a double glazed collector, 15 different glazing materials were mounted on 6" x 6" wooden frames and placed in an air circulating oven set at 275°F. The test was conducted for five days. Any changes that occurred, such as sagging, warping, yellowing, etc., were noted in Table 38.

Out of the 15 types of materials tried, only 7 made it through the oven aging with little or no change. Five materials, Plexiglas V-811, unreinforced and crosslinked EVA, Lexan, Tuffak CM-2 , and Flexigard could not withstand the heat physically. Plexiglas V-811 and crosslinked EVA sagged, and the heat also caused Lexan and Tuffak CM-2 to bow convexly, in addition to partially melting the Lexan. The acrylic top cover of Flexigard shrank about 1/2 inch on all sides after only 5 hours in the oven. Glasteel 500, Filon 558, and Sunlite Premium II, all thermoset polyesters, yellowed after exposure, enough to probably effect transmission and eliminate them from consideration as an inner glazing.

As a group, the fluorocarbons handled the heat aging the best, with the polyesters, Llumar and Nat. Met. 45-95-2, also performing well.

Table 39 shows the observations obtained from an experiment that tries to make Plexiglas V-811 and crosslinked EVA more heat stable so they could be used as inner glazings. Different types of glass scrim materials were compression molded in between layers of these materials. Samples were tacked to wood frames and placed in an air circulating oven set at 134°C.

The scrim materials worked very well in almost every case in preventing sagging of EVA and Plexiglas, but a new problem has developed. Samples using Craneglass scrim turned brown, and samples using Durolon S-50 yellowed. The browning of the Craneglass scrim is most likely due to the type of binder used. A new experimental type of glass scrim, one using an acrylic binder, was oven aged with no discoloration.

In a solar collector impact properties could be critical. The low temperature (0°F) and room temperature tensile impact was measured on the glazing materials shown in Table 40. The fluorocarbons, thermoplastic polyesters, polycarbonate and acrylic/polyester laminate have excellent impact strength at both room and low temperature. The impact strength of acrylic, although low, could be compensated for by suitable design.

Wind blown dust and sand may be abrasive to the glazing materials of solar collectors exposed outdoors over a number of years, enough so that it would affect transmission. In an effort to determine which material is more resistant to abrasion, a small sample of each material was mounted at a 45° angle beneath a 30 inch pipe. A hopper at the top of the pipe holds 1 pound of sand (sand used in standard sand 20-30 ASTM designation C-190), that when released with abrade the surface of the glazing. Transmission is measured before and after abrasion (Table 41).

The abrasion test had little effect on PFA, Nat. Met. 45-95-2, PEP100A, Kynar 450, Lexan, Flexigard, and Tuffak CM-2 which has an abrasion resistant coating on it's surface. The materials showing the greatest losses were Plexiglas V-811, Sunlite Premium II, and crosslinked EVA/scrim.

Hardness of glazings has been measured (Table 42) using Durometer D shore hardness (ASTM D-2240) for all materials except the softest, crosslinked ethylene/vinyl acetate copolymer (EVA) where Duometer A was used. The first column is an instantaneous reading and is the value usually quoted as "hardness". The second column, the 15 second shore reading gives an indication of plastic creep as the Durometer tip slowly penetrates.

As would be expected, the thermoset polyesters are the hardest, the miscellaneous high modulus group, mostly intermediate, the fluorocarbons somewhat softer and the softest materials are the PVC and EVA.

Hardness is a rough guide to stiffness: in general, modulus increases as hardness increases. Hardness may also be one of several factors involved in dirt resistance along with surface smoothness. hydrophobicity, oleophobicity, static charge and perhaps exudation of incompatible and/or low molecular weight materials.

6.0 LAMINATES

Polymers that are weather-resistant are high in price (Table 43). Thus, a route to a lower cost glazing could be a composite comprising a low-cost substrate and a UV protective top laminated film or coating. There are four routes to UV stabilization of glazings:

1. Film with UV absorbers:
   Base on UV stable polymer

2. Commercial films containing UV absorbers:
   Tedlar 100BG30UT (polyvinyl fluoride)
   Korad 201R (acrylic)

3. Coating with UV absorbers:
   Base on UV stable polymer

4. Stabilize the substrate

Tedlar 20 (Tedlar 400SG20TR) , DuPont's polyvinyl fluoride, and Halar 500 (ethylene chlorotrifluoroethylene, Allied Chemical) were chosen as films which absorb strongly in the UV and are UV stable (Table 44). In addition, three commercial films containing UV absorbers, two fluorocarbon types, (Tedlar 400XRB16SE and 100BG30UT from DuPont) and an acrylic (Korad 201R, from XCEL Corporation) were investigated (Table 45). All of these films were laminated by a variety of techniques to the following four glazing substrates:

- Tedlar 400XRB160SE (polyvinyl fluoride)
- Plexiglas V-811 (acrylic homopolymer)
- Crosslinked ethylene/vinyl acetate copolymer
- Llumar (thermoplastic polyester)

These substrates were selected because these materials are used in solar applications.

Tedlar 100BG300UT is a one mil film designed as a UV protective film to be laminated to a substrate. Tedlar 400XRB160SE is a four mil film primarily intended for use as an unsupported glazing for solar collectors. The UT has a sharper cut off below 400nm than does the 160SE.

Bonding techniques included heat, Lupersol 101 peroxide [2,5-Dimethyl-2, 5-di (t-butyl peroxy) hexane from Lucidol], and other potential bonding agents ,(Table 46), interspersed between the films. The laminations made are indicated in Table 47. Efficiency of adhesion is rated in Table 48 for each of these systems on a scale of F (failure), M (moderate adhesion) and S (strong adhesion). Tables 49A and 49B also show the laminations and their bond strengths. The top box in each section of Table 49A is lamination by heat alone; the bottom section is with peroxide. In Table 49B, the adhesives used are GE SS-4179 and Dow Corning 90% Z6030/10% Z6020.

Two new protective cover films manufactured by 3M were laminated to crosslinked EVA using heat, heat + Lupersol 101, and heat + Silane A11861-1. One of the films, an AR polyester, had a moderate bond, but failed after immersion in water for 4 days. X-22417 PMMA acrylic film failed for a number of reasons. The bond strength was poor and the acrylic film shrank and became brittle.

The laminates to be exposed in the Weather-Ometer were those whose bonds were intact after one week water immersion (Table 50).

After four months exposure in the Weather-Ometer (Table 51) bond strengths of the laminations were tested and compared to the originals. Also examined were any visual changes that might have occurred. All the results are contained in Table 52.

Of the 11 laminations that were placed in the Weather-Ometer, 4 have failed. Three, Llumar/Korad, X-ℓ EVA / Korad, and Tedlar 400XRB160SE/ Korad failed because of Korad (a UV stabilized acrylic) degradation, characterized by cloudiness, brittleness, and cracking. Acrylics are activated by the shorter wavelengths (below 290 nm), some of which are found in the carbon arc Weather-Ometer but not in the sun's spectrum. This could cause premature degradation of Korad that may not occur under normal outdoor exposure.

In the Llumar/Halar 500 lamination, the Halar failed to protect the Llumar substrate, which became brittle and cracked when bent. Strong bonds are evident on all the remaining laminations, and only a slight cloudiness is apparent in a few of the samples.

Date on qualitatively assessed bond strengths and visual changes are presented in Tables 53 and 54 for eight and twelve months exposure respectively.

After eight months, (Table 53) the three Llumar composites and all Korad systems have failed.

After 12 months exposure, (Table 54) two additional composites have failed - X-ℓ EVA (crosslinked ethylene vinyl acetate copolymer)/ Tedlar 100BG30UT with DuPont 68070 adhesive and X-ℓ EVA/Halar 500. Three composites are still in excellent condition: X-ℓ EVA/Tedlar 400, Plexiglas V-811/Tedlar 100 and X-ℓ EVA/Tedlar 400. Thus, 4 mil Tedlar protects the crosslinked EVA effectively while the Tedlar 100 (1 mil Tedlar)is not quite so effective. Perhaps Tedlar 200 (2 mil Tedlar) ,not yet available commercially, may be a better combination of cost and UV protection.

The effect of Weather-Ometer exposure for 4, 8 and 12 months and EMMAQUA exposure for 8 months on the percent transmission of the laminates is revealed in Table 56.

After 12 months in the Weather-Ometer, (Table 56) it is obvious that only the polyvinyl fluoride cover films, Tedlar 100BG30UT and Tedlar 400XRB160SE offered protection to the underlying substrate. There is insufficient data to assess whether the adhesive on the films themselves are causing the loss of transmission. The same general conclusion is reached on examining the EMMAQUA data.

7.0 PROTECTIVE COATINGS

In addition to protective films another method of protecting a substrate against ultraviolet light degradation lies in the use of a thin coating containing relatively high concentrations of UV absorber. The weather screening of the coatings must be sufficient to protect the thick layer underneath. This can most likely be produced by compounding a high concentration of ultraviolet absorber into the thin coating, sufficient to stop ultraviolet energy before it enters the thick encapsulant underneath. In general, substituted o-hydroxy benzophenones and benzotriazoles are the best primary ultraviolet absorbers, and may often be synergized by organo-nickel and other additives.

It would also be highly desirable that the thin coating be based on a polymer which is itself stable to ultraviolet, thus requiring minimum stabilization, and avoiding the problem of surface degradation of the thin coating itself. These thin coatings might best be based on fluorocarbons, acrylics, or silicones. The acrylics are much more reasonable in price than silicones or fluorocarbons; therefore, in this initial survey only acrylic coatings were considered.

The following companies were contacted for acrylic coatings:

Service Coatings
Red Spot
Valspar
Rohm & Haas
Conchem Company
Goodrich
Ashland
MR Plastics
Monsanto

BASF
Union Carbide
Polyvinyl Chemicals
Johnson Wax
Celanese
National Starch
Staley Chemical
Spencer Kellogg
Air Products

Fortunately there exists an enormous number of acrylic products available in brushable and sprayable forms such as latex (water-emulsion based) and solution grades (solvent based) that may serve as UV screening vehicles. Rohm & Haas Company, a manufacturer of acrylics, has exposed acrylic coatings to more than twelve years of outdoor weathering without any visible evidence of deterioration. Experiments at Springborn Laboratories with acrylic coatings show promising performance.

Both latex acrylic and solvent-based coatings were examined (Tables 57 and 58). Since polymers with overly high molecular weights provide solutions of low solids content and unworkably high viscosities, an alternate solution is to introduce crosslinking to obtain improved properties. The advantages offered over thermoplastics in this approach are:

- Improved toughness and hardness
- Resistance to softening at higher temperatures
- Better resistance to solvents and moisture
- Lower solution viscosity and higher application solids
- Better compatibility with substrate materials

The purpose of all of these coating studies is to select carriers for UV stabilizer systems to protect glazings against weathering degradation. In order to choose the best systems, a series of acrylics were coated on the top surface of glass slides and these coated slides were dried at 100°C for one hour. The slides were then exposed in both a 100°C circulating air oven and under the "wet" RS-4 Sunlamp. The condition of these coated slides after three weeks exposure is shown in Table 61. Gloss and pencil hardness were measured on the exposed slides. Gloss reading (60°C)are given on Table 60 and scratch "hardness" in Table 59. Scratch hardness is measured by scratching the coated glass slide with a series of pencils of varying hardness. Loss of gloss and hardness are a means of judging the effect of aging (heat or accelerated RS-4 UV) on the coating.

Table 62 summarizes all of the data on acrylic glass coatings. With pencil hardness,the higher the number and the higher the letter the harder the coating. The higher the gloss and gloss stability, i.e. no change, the more desirable. Finally, the highest transmission is obviously the most desirable.

The next step was to develop coating systems for each of the three substrates. Peroxide crosslinked EVA (ethylene/vinyl acetate copolymer)was chosen as a substrate because of its excellent performance as a laminating resin for solar cells in our project for Jet Propulsion Laboratories. Plexiglas V-811 (polymethylmethacrylate) was selected because of its well-deserved reputation for UV stability. Lexan, polycarbonate, was used as the third substrate, since its known tendency to yellow under UV would make it a visual barometer for efficiency of the protective coating.

The initial coating study on EVA involved coating EVA by a dipping procedure and drying the coated crosslinked EVA at room temperature and at 100°C. However, bond strengths were poor.

An additional coating series was undertaken to improve bond strength of the acrylic coatings to EVA. Uncrosslinked EVA was coated with acrylics. After drying the sheet was cured in a Preco Press at 302°F for 20 minutes at 20 tons pressure. The coated crosslinked sheet dried at 170°F for 20 minutes is the control.

Bonds strength of an acrylic coated on EVA before cure is much stronger than the same coating put on after cure. However, coating quality was poor.

In another attempt to improve coating quality and bond strength of acrylic coatings on EVA the coating solids were cut in half. Sheets of crosslinked EVA were dipped into the reduced solids coating solution and dried in a 100°F oven. Coated EVA sheets were stretched to see if coating will crack and peel. Bond strength was measured by prying with a knife and rated as strong (S), medium (M) and fair(F).

As shown in Table 63, there is a significant improvement in bond strength when coating solids are reduced by half.

A wide variety of other coatings were also applied to crosslinked EVA (Tables 64, 65 and 66). The ultimate test was immersion of the coated EVA in water for one week. Quality after water immersion was judged by:

- Clarity
- Bond strength
- Flexibility - judged by bending the coated EVA around a glass rod to see if the coating will crack.
- Stretchability - the coated EVA is stretched to see if the coating will crack and flake off.

The effect of these bonding studies (Tables 59-69) reveals four coatings that are promising: EB-9391, EB-2813, Neocryl A-601 and Neocryl A-620.

By reducing the solid content of acrylic coatings by half several coatings have been found useful with crosslinked EVA (ethylene/vinyl acetate copolymer). Since crosslinked EVA softens excessively at 250°F (stagnation temperature), it will be reinforced with glass mat.(1)

The best coatings were now applied (at reduced solids) to crosslinked EVA reinforced with glass mat. The reinforcement was necessary to permit higher use temperatures for the EVA . All of the bonds of this group of coatings were strong before and after water immersion(Table 67).

A wide variety of coatings were now applied to Plexiglas V-811 (Tables 68 & 69) (polymethylmethacrylate) and Lexan (polycarbonate) (Table 70).

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(1) Craneglas , Crane & Co. Inc., Dalton, MA

From all of these coating studies the optimum coatings for EVA, Plexiglas and Lexan are shown in Table 71. They were chosen based not only upon coating quality, color and bond strengths before and after water immersion, but also on the desire for a diversity of coating types. Plexiglas and Lexan have both thermoset and thermoplastic solvent base coatings. EVA utilizes water-base (latex) thermoplastic and thermoset coatings.

Of the three substrates chosen acrylic is well known for its UV stability and protective coatings merely ensure even longer life. Lexan will yellow when exposed to UV and thus is an excellent guide to the effectiveness of the acrylic-UV coating systems. The scrim reinforced, peroxide crosslinked EVA is a new material which shows promise as a pottant to protect photovoltaic cells.

The UV absorbers used in these coatings are described below:

Stabilizer	Function	Chemical Nature
Tinuvin 328	UV Absorber	Benzothiazole
Cyasorb 5411	"	Higher Molecular Weight Benzotriazole
Cyasorb 2126	"	Higher Molecular Weight Benzophenone
Cyasorb UV 531	"	Benzophenone
Sanduvor VSU	"	Oxalic-anilide
Permyl B-100	"	Benzophenone
DSTDP	Antioxidant Synergist	Distearylthiodipropionate
Irganox 1010	Antioxidant	Hindered Phenolic Antioxidant
Goodrite 3114	Antioxidant	Isocyanurate
Naugard P	Antioxidant Synergist	Phosphite

Specific details as to the exact coating formulations used on each substrate are shown in Tables 72 and 73.

Effectiveness of a UV absorber can be estimated from its UV spectrum. An efficient absorber for solar glazing should screen out the UV with minimal effect on visible and infrared transmission spectrum. It would be appropriate to point out that there would be approximately a 5% loss in the solar spectrum by screening out the energy below 400 nm. Table 74 presents the UV transmission of the systems discussed in Table 73. What is desired is "0" percent transmission up to near 400 nm and then high transmission thereafter.

To measure UV transmission the solution acrylic coating-UV absorber systems were cast on cellulose gum (on glass). This was immersed in water and the coating lifted off as a film. Latex coatings were cast on Teflon and removed for measurement.

Most of the UV absorbers were dissolved in the acrylic coating solution. Those absorbers that didn't dissolve were emulsified using the following formulation mixed in a high speed blender.

. 10 phr (1)	UV absorber
. 10 phr	surfactant (Pluronic L72 Polyol)
. 40 phr	water
. 40 phr	Toluene

Systems 1 through 18 are UV transmissions of the coating-UV absorber films. Systems 3, 10, 11 and 16 should provide excellent protection since they screen out the UV almost up to 380 nm. The UV absorbers which appear to be best (based on transmission) are Cyasorb UV 5411 and Tinuvin 328, both benzothiazoles.

A wide variety of coated glazings were sent to DSET for EMMAQUA exposure in Arizona (Tables 75 & 76). EMMAQUA is a water spray device using reflecting mirrors to concentrate the sun; it accelerates natural sunlight degradation about five to eight fold. Six month exposure results are shown in Table 76.

According to Table 74 the coatings containing UV absorbers having the least UV transmission are runs 10, 11, 13, 16 and 17 and coatings on substrates numbers 23 (Lexan), 35 (acrylic V-811) and 38-45 (crosslinked, scrim reinforced EVA). If UV cut off were the principal factor in preventing degradation, these coated samples should have the best UV resistance. However, six months of EMMAQUA exposure in Arizona indicate that there is no necessary relationship of cut-off (at 280 nm and below) and sample stability. The causes of degradation are complex. However, the exposure times have not been long enough to reach a definitive conclusion.

On scrim reinforced crosslinked EVA the acrylic coating, Valspar EB9389 - a thermoplastic latex, gave the highest initial transmission. The best systems after six months, i.e. the least loss in transmission, were numbers 3, 5, 6 and 7.

The Valspar EB9389 acrylic coating with only 0.05% Permyl B-100, benzophenone UV absorber is quite interesting. Visually the control has yellowed while all other specimens are somewhat hazy.

On Lexan polycarbonate initial transmission is high for all coatings. The best protective UV absorber was Tinuvin 328. However, a control, experiment number 13 without UV absorber in the acrylic coating, also provided UV protection. Thus, six months exposure is insufficient to differentiate these systems.

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(1) phr = parts of additive per hundred parts of resin

Visually most of the Lexan samples yellowed. The only exceptions were the following coatings:

- Lexan/Rohm & Haas B84 acrylic/2% Tinuvin 328
- Lexan/Rohm & Haas B84 acrylic/2% Cyasorb 5411
- Lexan/Arolon 557D acrylic/5% Tinuvin 328

These results agree with the UV transmission data previously discussed.

On Plexiglas V-811 acrylic initial transmission is high for most coatings, but six months exposure is not sufficient time to decide which UV absorber system provides optimum protection against sunlight degradation. All coated specimens were clear.

8.0 ANTIREFLECTIVE (AR) COATINGS

Anti-reflective coatings have had a long history of use on glass and are now being applied to plastics to decrease reflectance losses. The ideal condition is the maximization of solar transmittance while retaining infrared reflection characteristics. A wide variety of materials have been used as anti-reflective coatings - including magnesium fluoride, cerium oxide, silicon monoxide, zinc sulfide, tin oxide, etc. These coatings are capable of reducing the approximate 4 percent reflectance at each surface to as low as 1/2 percent, on glass.

The coatings are applied to glass by vacuum evaporation over one to two hours at 300°C. Under these conditions a tough coating is formed. By necessity these coatings must be applied to plastics at a much lower temperature, producing a coating which may be less durable.

The anti-reflective coating must have a refractive index between that of air and the plastic, i.e. between 1.0 and approximately 1.5. Magnesium fluoride was the only AR coating successfully applied to the glazings.

Sheets of the following glazings were coated with a single layer of magnesium fluoride and a multiple layer coating, both at 45° and 90° angles.

.	5 mil	Llumar (thermoplastic polyester)
.	35 mil	crosslinked ethylene/vinyl acetate copolymer
.	4 mil	Tedlar 400XRB160SE (polyvinyl fluoride)
.	40 mil	Plexiglas V-811 (acrylic)

Table 77 presents the direct transmission at 550 nm, and Table 78 the direct transmission over the range of 400 nm to 700 nm. The same results are shown by both sets of data. In all cases, except one, multilayer crosslinked EVA, there was an increase in percent transmission on the magnesium fluoride coated sheets.

The magnesium fluoride single and double layer AR coated glazings were exposed in the Weather-Ometer. However, weather stability was poor, since after three months exposure the coatings were cloudy and in poor condition.

9.0 ETCHING

The usual technique to decrease reflectance on silicon or glass surfaces is the use of antireflective (AR) coatings. An alternate method for glass has been etching with hydrofluoric acid.

To allow the maximum percentage of solar energy to pass through to the collector, the plastic glazing must have minimum reflectivity. One way of achieving this may be through etching of the plastic surface.

The following represents some of the plastic surface etching methods that have been explored in the past to improve adhesion:

- Sulfuric acid/dichromate[1]
- Argon ions[2]
- Aqueous KOH[3]
- Sodium dodecylbenzenesulfonate/trisodium phosphate/ sodium hypochlorite [4]
- Sodium hydroxide/organic solvent/wetting agent [5]
- Sodium in liquid ammonia or naphthalene-THF [6]
- Glow discharge [7]
- Aqueous hydrazine[8]
- Pyridine/dimethyl sulfoxide/tetraethyl-ammonium hydroxide [9]
- N,N-dialkylamide or pyridine [10]
- Naphthalene-sodium-tetrahydrofuran complex [11]
- Hydrazine compounds/alkyl hydroxy compounds/polar solvents[12]

Honeywell, Inc.[13] examined the use of sodium-naphthalene-tetrahydrofuran, acetophenone and cyclohexanone to etch Tedlar to improve transmission. The Tedlar was to be used as a collector glazing. Only acetophenone improved transmission, by 2-3%, of a few of the seven Tedlar sheets examined.

In our work a wide variety of potential chemical etchants have been examined on four transparent plastics: peroxide crosslinked ethylene/vinyl acetate copolymer (Elvax 150 from DuPont) (Table 79), polymethylmethacrylate (Rohm & Haas' Plexiglas V-811) (Table 80), thermoplastic polyester (Llumar - a UV absorber impregnated material from Martin Processing, Inc., Martinsville, VA) (Table 81), and polyvinyl fluoride (Tedlar XRB160SE from DuPont) (Table 82). These four were chosen because they are four widely varying chemical structures - polyolefin, acrylic, thermoplastic polyester and a fluorocarbon - with potential as glazings.

The polymer sheets were treated, as shown in Tables 79-82 , and 75° gloss (as a guide to reflectance), was measured on a gloss meter (Gardner portable 75° Glossmeter, Gardner Labs, Bethesda, Md.). In many experiments gloss was reduced. However, to check the significance of these gloss readings, reflectance and transmission were run on specific cases.

Table 83 compares the results of gloss, reflectance and transmission measurements on Llumar polyester, EVA and V-811 acrylic. With EVA, gloss was reduced considerably by room temperature immersion in toluene, reflectance remained unchanged, but transmission was decreased somewhat. The acrylic treatment (29% sodium hydroxide) also decreased gloss and reflectance, but transmission remained unchanged. With Llumar the alkaline treatment had no effect.

Two conclusions are apparent:

1. Gloss is not a valid method of measurement.
2. None of the treatments so far examined are effective.

Other etching conditions were examined using solvents to etch Plexiglas V-811, Llumar and Tedlar (Table 84); however, transmission after etching was decreased (Table 85).

Thus, none of these etching techniques are promising.

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TABLE 1A

TRANSPARENT PLASTICS SURVEY
MATERIALS UNDER 50 CENTS/POUND

Date From JPL 1977 Annual Report, Contract No. 954527

Generic Type	Trade Name	Manufacturer	Survival[a,b] Prognosis: Max. Span of Years to Failure	Upgrading[a,c] Potential in Years	
				10	20
Hydrocarbon polymers	Polyvol G100	Velsicol	< 1	F	P
Hydrocarbon polymers	X 125, 685	Neville	< 1	F	P
Polyvinyl chloride (PVC)	Geon 103	Goodrich	1-5	G	F
Polystyrene	Cosden 500	Cosden Oil	1-5	F-G	P-F
Polypropylene	Profax 6523	Hercules	< 1	F-G	P-F
Poly-α-methyl styrene	Resin 18	AMOCO	1-5	F	P
High-density polyethylene	Dow 75731	Dow	1-5	G	F
Low-density polyethylene	DYNH	UCC	1-5	G	F
Ethylene/vinyl acetate	EVA 3185	Du Pont	1-5	G	F
Plasticized PVC copolymer	Numerous		1-5	G	F
Ethylene/ethyl acrylate	DPD 6169	UCC	1-5	G	F
Isophthalic polyester	Aropol	Ashland	1-5	G	F
Styrene/acrylonitrile	Lustran	Monsanto	1-5	F	P
Styrene/butadiene	Kraton	Shell	< 1	F	P
Propylene/ethylene	Polyallomer 5021E	Eastman	< 1	F	P
Neopentyl glycol polyest.	Cargill 5446	Cargill	1-5	G	F
Ethylene propylene rubber	Nordel	Du Pont	1-5	G	F
Chlorinated polyethylene	CPE	Dow	1-5	F-G	P-F
Polybutylene	Witron	Witco	< 1	F	P
PVC Plastisol copolymer	Numerous		1-5	G	F

(a) Springborn Laboratories educated opinion

(b) No UV absorber

(c) Protected with an internal UV absorber and an external coating or sheet containing a UV absorber.

Code: G = Good; F = Fair; P = Poor

(d) Data from JPL 197 Annual Report, 1978 Contract No. 954527

TABLE 1B

TRANSPARENT PLASTICS SURVEY

MATERIALS COSTING 50 CENTS TO $1.00/POUND

Generic Type	Trade Name	Manufacturer	Survival(a,b) Prognosis: Max. Span of Years to Failure	Upgrading(a,c) Potential in Years	
				10	20
Unfilled cast phenolic	Gen-El	G.E.	< 1	P	P
Modified polyethylene terephthalate	Kodar PETG	Eastman	1-5	G	F
Clear acrylonitrile/butadiene/styrene (AMBS)	Cycolac CIT	Marbon	1-5	F-G	P-F
Ethylene/acrylic acid	EAA 435	Dow	1-5	F-G	F-P
Acrylic multipolymer	XT 250	Am.Cyanamid	1-5	F	P
Polybutadiene	Poly BD	ARCO	< 1	P	P
Ionomer	Surlyn 1707	Du Pont	< 1	F-G	F-P
Acrylonitrile/rubber/multipolymer	Barex	SOHIO	1-5	F	P
Melamine formaldehyde (d)	Cymel	Am.Cyanamid	5-10	G	F-G
Polybutadiene telomer	-	Lithium Corp.	< 1	P	P
Polyvinyl alcohol	Gelvatol	Monsanto	1-5	F	P
Cellulose propionate	Tenite	Eastman	1-5	G	F
Cellulose acetate buryrate	Tenite 479	Eastman	4-5	G	F
Cellulose acetate	Tenite	Eastman	1-5	G	F
Chlorosulfonated polyethylene	Hypalon	Du Pont	1-5	G	F
Thermoplastic polyester	Vitel	Goodyear	1-5	G	F
Vinyl chloride/vinyl acetate	VYHH	UCC	1-5	F	P

(a) Springborn Laboratories educated opinion

(b) No UV absorber

(c) Protected with an internal UV absorber and an external coating or sheet containing a UV absorber

(d) Not sold unfilled; data are on cellulose-filled product.

...Continued

TABLE 1B (Continued - 2)

Generic Type	Trade Name	Manufacturer	Survival Prognosis: Max. Span of Years to Failure	Upgrading Potential in Years	
				10	20
Linear epoxy	Phenoxy	UCC	1	F-G	F
• Hot Melts					
Ethylene/vinyl acetate	Bostik 4364	Bostik (USM)	1-5	G	F
Polyamide	Versalon 1112 Milvex 1000	General Mills	1	F	P
Acrylic (solid materials)	329-002 68-42	Daubert Williamson	8-10 8-10	G G	G G
• Acrylics					
Copolymer Homopolymer	Plexiglas DR100 Plexiglas V811	Rohm & Haas Rohm & Haas	5-10 16-20	G G	G G
MMA*/styrene (60% MMA) MMA /styrene (85% MMA)	P205 P301	Richardson Richardson	5-10 8-10	G G	G G

* MMA = Methyl methacrylate

TABLE 1C

TRANSPARENT PLASTICS SURVEY
MATERIALS COSTING $1.00 to $4.00/POUND

Generic Type	Trade Name	Manufacturer	Survival (a,b) Prognosis: Max. Span of Years to Failure	Upgrading (a,c) Potential in Years	
				10	20
Epoxy urethane	Isochem UE5	Isochem	1	F	P
Castable urethane	System 30	Castor	1	F	P
Nylon copolymer	Versalon	General Mills	1	F	P
Poly(4-methyl pentene)	TPX RT18	ICI	1	F	P
Polyvinyl butyral	Butvar	Monsanto	1-5	G	F
Polycarbonate (stabilized)	Lexan 123-111	G.E.	10-20	G	G
Polycarbonate (hydrogenated)	C-4	UCC	4-5	G	F
MMA casting resin	Tame 500	B.F. Goodrich	8-10	G	G
Nylon 6/12	Capron	Allied Chem.	1-5	F	P
Polyaryl sulfone	Udel 1700	UCC	1-5	F	P
Polyglycol epoxy	DER 732	Dow	1-5	F	P
Epoxy casting resin	Eccogel 1265 Stycast 1264	Emerson & Cummings	1-5	F	P
Polysulfone	Radel P Natural	UCC	1	F	P
Diethylene glycol diallyl carbonate	CR-39	PPG	5	G	F

(a) Springborn Laboratories educated opinion

(b) No UV absorber

(c) Protected with an internal UV absorber and an external coating or sheet containing a UV absorber

TABLE 1D

TRANSPARENT PLASTICS SURVEY
MATERIALS COSTING MORE THAN $4.00/POUND

Generic Type	Trade Name	Manufacturer	Survival Prognosis: Max. Span of Years to Failure (a,b)	Upgrading Potential in Years (a,c)	
				10	20
Silicone gel	63-6527	Dow	8-10	G	G
Cycloaliphatic epoxy	ERL 4221	UCC	4-5	G	F
Polyvinylidene fluoride	Kynar 460	Pennwalt	>20	G	G
Perfluoroethylene propylene	FEP 100	Du Pont	>20	G	G
Ethylene/chlorotrifluoroethylene	Halar 500	Allied Chem.	>20	G	G
Ethylene/tetrafluoroethylene	Tefzel 280	Du Pont	16-20	G	G
Hexafluoropropylene vinylidene fluoride	Viton AHV	Du Pont	4-5	G	F
Silicone	Sylgard 184	Dow	10-20	G	G
Silicone	RTV 615	G.E.	10-20	G	G
Perfluoroalkoxy	PFA 9705	Du Pont	> 20	G	G
Silicone "glass resin"	Resin 650	Owens-Illinois	16-20	G	G
Chlorotrifluoroethylene	Resin 81	3M	> 20	G	G
Chlorotrifluoroethylene/ vinylidene fluoride	Kel-F 800	3M	1-5	G	F
Polyvinyl fluoride film	Tedlar 20	Du Pont	10-20	G	G

(a) Springborn Laboratories educated opinion

(b) No UV absorber

(c) Protected with an internal UV absorber and an external coating or sheet containing a UV absorber.

TABLE 2A

PLASTIC BASED SUBSTRATE MATERIALS [b]

(Data From JPL 1978 Annual Report, Contract 954527)

Manufacturer	Material	Grade	Form	Flexural Modulus (psi x 10^5)		Density (g/cc)	Price		Avg. Cost/ Volume ($/in^3)
				Lengthwise	Crosswise		$/Lb	$/Ft^2	
LNP	HDPE Fiberglass reinforced								
	20% Fiberglass	FF-1004	Pellet	6.0		1.10	0.61	-	0.0242
	40% Fiberglass	FF-1008	Pellet	11.0		1.28	0.69	-	0.0318
LNP	HDPE Glass bead filled								
	20% Glass	FB-1004	Pellet	3.4		1.10	0.61	-	0.0242
	40% Glass	FB-1008	Pellet	3.9		1.28	0.69	-	0.0318
Primex	Acrylic Honeycomb	Prime-Cor-X-Lucite	4mm Sheet	(a)		0.28 lb/ft^3	-	0.60	0.0265
Voltek	Polyethylene foam	R300	1" Sheet	(a)		2.4-4.0 lb/ft^3	-	1.50	0.0104
Norfield	Polycarbonate Honeycomb	NorCore	1" Sheet	(a)			-	0.85	0.0059
Norfield	Impact Styrene Honeycomb	NorCore	1" Sheet	(a)			-	0.55	0.0038
Rohm & Haas	Acrylic	V-811	Pellet	3.0		1.2	1.42	-	0.0391
General Electric	Polycarbonate	Lexan 123	Pellet	3.2		1.2	1.84	-	0.077
Monsanto	Polystyrene	Lustran	Pellet	2.1		1.08	0.38	-	0.0142

(a) These are structural materials that demonstrate only apparent modulus.

(b) Data from JPL 197 Annual Report, 1978, Contract No. 954527

TABLE 2A (Continued - 2)

Manufacturer	Material	Grade	Form	Flexural Modulus (psi x 10^5)		Density (g/cc)	Price		Avg.Cost/ Volume ($/in^3)
				Length-wise	Cross-wise		$/Lb	$/Ft^2	
Numerous	Polyurethane foam, rigid	-	Foam	0.5		0.32	0.77	-	0.0089
Rohm & Haas	Polycarbonate Honeycomb	Tuffak		3.2(a)		0.16	4.40	-	0.0252
Synthane Taylor	Paper-based phenolic laminate	X, 1/16"	Sheet	18.0	13.0	1.36	1.00	0.46	0.0490
Synthane Taylor	Fabric-based phenolic laminate	C, 1/16"	Sheet	10.0	9.0	1.36	2.07	0.94	0.1016
Synthane Taylor	Glass-reinforced melamine laminate	G-9	Sheet	25.0	20.0	1.90	2.90	-	0.1988
Synthane Taylor	Glass-reinforced epoxy laminate	G-10	Sheet	27.0	22.0	1.80	3.07	-	0.1994
Synthane Taylor	Glass-reinforced epoxy laminate	FB-400	Sheet	27.0	22.0	1.80	2.10	-	0.1364
Kalwal	Polyester Fiberglas laminate	1.16" 1/8"	Sheet	10.0		1.45	- -	0.52 0.85	0.0472
Arco Polymer	Glass-reinforced styrene-maleic copolymer	Dylark 238 F20	Compound	7.2	4.1	1.22	0.46	-	0.0202
Arco Polymer	Styrene-maleic copolymer	Dylark 238	Compound	4.6		1.08	0.35	-	0.0136

TABLE 2A (Continued - 3)

Manufacturer	Material	Grade	Form	Flexural Modulus (psi x 10^5)		Density (g/cc)	Price		Avg. Cost/ Volume ($/in^3)
				Lengthwise	Crosswise		$/Lb	$/Ft^2	
Arco Polymer	Structural foam, by Carbide Process	Dylark 238 F20, 1/4"	Sheet	5.3		0.8	-	0.64	0.0177
Fiberite	BMC (Bulk Molding Compound)	S-660B	Compound	15.0		1.8	0.65	-	0.0422
Fiberite	B-stage dry polyester molding compound	S-6414	Compound	15.0		1.8	1.30	-	0.0844
Fiberite	Short glass fiber reinforced phenolic molding compound	FM-4007	Compound	25.0		1.75	0.85	-	0.0536
ICC Primex	High-impact polystyrene		Sheet	2.7		1.04	0.45	-	0.0168
American Hoechst	Rigid vinyl		Sheet	4.7		1.4	2.00	-	0.1010
Hercules	Polypropylene homopolymer with 40% talc	65F4-4	Compound	5.5		1.22	0.32	-	0.0140
Hercules	Polypropylene homopolymer with 40% $CaCO_3$	65F5-4	Compound	4.0		1.22	0.31	-	0.0136
Hercules	Polypropylene copolymer with 40% talc	75F4-4	Compound	5.0		1.22	0.33	-	0.0145
Hercules	Polypropylene copolymer with 40% $CaCO_3$	75F5-4	Compound	4.0		1.22	0.34	-	0.0149

TABLE 2A (Continued - 4)

Manufacturer	Material	Grade	Form	Flexural Modulus (psi x 10^5)		Density (g/cc)	Price		Avg. Cost/Volume ($\$/\text{in}^3$)
				Length-wise	Cross-wise		$/Lb	$\$/\text{Ft}^2$	
Hercules	Polypropylene structural foam	Med. impact copolymer 1/4"	Sheet	1.07		0.67	0.65	-	0.0157
Hercules	Polypropylene structural foam - 30% coupled Fiberglas	PC-072	1/4" Sheet	4.33		0.75	0.80	-	0.0216
Goodrich	Rigid PVC pipe compound	85781	Compound	Tensile Modulus 4.2		1.40	0.31	-	0.0156
Goodrich	Rigid PVC pipe compound	85707	Compound	Tensile Modulus 4.6		1.40	0.30	-	0.0151
Goodrich	PVC pipe compound	3007	Compound	4.26		1.55	0.79	-	0.0441
Premix	Polyester sheet molding compound	1222	Compound	15.0		1.85	0.61	-	0.0407
Ferro	Epoxy prepreg	E-293	10-mil Sheet	33.0		1.80	-	0.34	0.2361
Mastic (Valley Building Products)	Vinyl siding, 0.046" thick, for home exteriors		Sheet	4.0		1.46	-	0.45	0.0679

TABLE 2B

METALS

Manufacturer	Material	Grade	Form	Flexural Modulus (psi x 10^5)		Density (g/cc)	Price		Avg. Cost/ Volume ($/in^3)
				Lengthwise	Crosswise		$/Lb	$/Ft^2	
Armco	Galvanized steel	Roofing stock, 80-gage	Coil: 25-mil 50-mil 150-mil	300		7.8	- - -	0.21 0.42 1.26	0.058
Republic	Aluminum-coated steel	26-gage 1.5-mil coat	Sheet: 25-mil 40-mil	300 300		7.8 7.8	- -	0.25 0.60	0.104
Republic	Painted steel	26-gage	40-mil Sheet	300		7.8	-	0.60	0.104
Republic	PVC-coated steel	26-gage	40-mil Sheet	300		7.8	-	0.80	0.138
Alcan	Aluminum	5052H32; H34	25-mil Sheet	100		2.6	0.84	-	0.079
Hamden	Aluminum	11H14; 5052H14	20-mil Sheet	100		2.6	0.85	-	0.079
Alcan	Anodized aluminum	Anodized film: 1-mil 1.5-mil	Coil: 25-mil 25-mil	100		2.6	0.95 1.05	-	0.094
Numerous	Stainless steel	316	Sheet	300		7.8	1.13	-	0.323
Numerous	Mild steel, hot-rolled		Sheet	300		7.8	0.15	-	0.043
Ferro	Porcelainized Steel	4-mil ground coat	Sheet	300		(b)		(a)	0.06

(a) Cost of 4-mil ground coat, both sides, approximately $0.24

(b) Enamel density alone, 2.7

TABLE 2C

CERAMIC MATERIALS

Manufacturer	Material	Grade	Form	Flexural Modulus (psi x 10^5)		Density (g/cc)	Price		Avg. Cost/ Volume ($/in^3)
				Length-wise	Cross-wise		$/Lb	$/Ft^2	
American Colloid	Bentonite/Paper	-	1/2" Sheet	(a)			-	0.35	0.0048
Resin Coated Sand Company	Foundry sand/phenolic	Casting powder	Powder	(a)		2.8	0.03	-	0.0030
Umaco	Acrylic latex modified Portland cement on plywood base.	Stone Panels	1" Sheet	> 5	(b)	2.5	-	2.00	0.0140
Silibond	Same - 13% Latex	Floor leveling compound	Powder	> 5	(b)	2.5	0.19	-	0.0170
Crossfield	Neoprene-latex elasticized aluminum cement	Floor leveling compound	Powder	> 5	(b)	2.5	-		
Volary	Glass-reinforced gypsum (coated)	1" thick panel	Panel	10 Equivalent		1.7		0.30	0.0021
U.S. Gypsum	Glass-reinforced gypsum (uncoated)	Fabricated, 0.1" thick	Sheet	10 Equivalent		1.7		0.12	0.0083
PPG	Soda-lime glass	Float	Sheet	100		2.24	0.23	-	0.0208

(a) Very low elastic limit; unusably brittle (b) Estimated (c) Water-soluble; unusable

TABLE 2D

WOOD PRODUCTS

Manufacturer	Material	Grade	Form	Flexural Modulus (psi x 10^5)		Density	Price		Avg. Cost/ Volume ($/in^3)
				Lengthwise	Crosswise		$/Lb	$/Ft^2	
Champion	Plywood	1/4" AC [a] 3/8" AC	4' x 8' Sheet	10			- -	0.25 0.34	0.0063
Potlatch	Plywood	1/2" Sheeting [b] 1/2" Sanded	4' x 8' Sheet	10			- -	0.22 0.30	0.0042
Plywood Association	Fiberglass/plastic-covered plywood	1/4", with 3/16"FRP 3/8", with 3/16"FRP	Sheet	30			- -	0.50 0.70	Avg. 0.0082
Plywood Association	Kraft paper covered plywood	High-density overlay plywood, 1/4" thick Same, 3/8" thick	Sheet				- -	0.33 0.46	
Roadman	Particle board, Phenolic binder	3/4" thick 3/8" thick	4' x 8' Panel	5		62 lb/ft^3	- -	0.33 0.16	0.0030 0.0029
Roadman	Regular; urea resin binder	3/8" thick	4' x 8' Panel	5		62 lb/ft^3	-	0.19	0.0035
Blandin	Particle Board Segments 1"-1-1/2" large; phenolic binder.	1/4" thick 3/4" thick	4' x 8' Panel 8' x 28' Panel	5			- -	0.13 0.40	0.0036 0.0637
Potlatch	Oriented flakeboard; phenolic binder.		Sheet	5					
Masonite	Masonite, Fiber board	No. 1 Siding	7/16" Sheet	3.5		1.5 lb/ft^2	-	0.27	0.0043

(a) A-face with C-backing (suggested for outdoor use).

(b) C-face with D-backing (not weatherable).

TABLE 3-A

SOLVENT-BASED ACRYLIC COATINGS

Manufacturer	Coating	Percent Solids	Specific Gravity of Film (Dry)	T_g, °C	Thermoset; Curing Agent	$/Lb	$/Ft^2/Mil
Rohm & Haas	Acryloid:						
	AT-400	80	1.10		Yes; Melamine	0.26	0.00186
	A-101	40	1.10		No; -	0.49	0.00700
	A-10	30	1.10		No; -	0.65	0.01239
	A-21	30	1.10		No; -	0.42	0.00800
	A-21LV	30	1.10		No; -	0.44	0.00838
	B-44	40	1.10		No; -	0.43	0.00607
	B-48N	45	1.10		No; -	0.54	0.00680
	B-50	45	1.10		No; -	0.48	0.00610
	B-66	50	1.09		No; -	0.49	0.00950
	B-78	45	1.05		No; -	0.60	0.00728
	B-67MT	45	1.05		No; -	0.60	0.00728
	B-72	50	1.15		No; -	0.61	0.00729
	B-82	50	1.16		No; -	0.46	0.00555
	B-84	45	1.10		No; -	0.60	0.00762
	B-99	50	1.10		No; -	0.56	0.00640
	C-10LV	40	1.10		No; -	0.76	0.01086
	F-10	40	1.10		No; -	0.51	0.00729
	NAD-10	40	1.10		No; -	0.68	0.00965
	AT-50	50	1.10		Yes; Self-cure	0.66	0.00755
	AT-51	50	1.10		Yes; Self-cure	0.53	0.00606
	AT-56	50	1.10		Yes; Amine	0.50	0.00572
	AT-70	50	1.10		Yes; Epoxy	0.56	0.00635

...Continued

TABLE 3-A (Continued - 2)

Manufacturer	Coating	Percent Solids	Specific Gravity of Film (Dry)	T_g, °C	Thermoset; Curing Agent	$/Lb	$/Ft^2/Mil
Rohm & Haas	Acryloid:						
	AT-71	50	1.10		Yes; Epoxy	0.51	0.00583
	AT-75	50	1.10		Yes; Epoxy	0.56	0.00635
	AT-63	50	1.10		Yes; -	0.50	0.00572
	AT-64	50	1.10		Yes; -	0.51	0.00583
	Au-608	60	1.10		No; -	0.74	0.00705
	B-7	20	1.10		No; -	0.68	0.01943
	C-10	20	1.10		No; -	0.99	0.02830
	CS-1	83	1.10		No; -	0.93	0.00640
	F-89	60	1.10		No; -	0.65	0.00615
	OL-42	80	1.10		No; -	0.91	0.00650
	RAS-75	86	1.10		No; -	1.06	0.00726
	WR-97	70	1.10		No; -	0.69	0.00564
Conchemco	Acrylic Resin:						
	311-104		1.12				
	311-405		1.12				
	311-121		1.12				
	311-120		1.12				
Goodrich	Carboset:						
	514A	70	1.12			1.04	0.00865
	XL-11	30		55	Yes; Epoxy amine	Experimental	
	XL-19	40		26		Experimental	

...Continued

TABLE 3-A (Continued - 3)

Manufacturer	Coating	Percent Solids	Specific Gravity of Film (Dry)	T_g, °C	Thermoset; Curing Agent	$\$/\mathrm{Lb}$	$\$/\mathrm{Ft}^2/\mathrm{Mil}$
Ashland Chemical	Aeroset:						
	41-10X60	60	1.13		Yes; Melamine	0.51	0.00494
	41-20-XB50	50	1.14		Yes; Melamine	0.52	0.00610
MR Plastics and Coatings	Mistacote:						
	127-F (a)	20			No; -		
	125-F	19			No; -		

(a) Good adhesion to aluminum

TABLE 3-B

ACRYLIC LATEX COATINGS

Manufacturer	Material	Latex Type	Percent Solids	Specific Gravity (Dry)	T_g (^oC)	Thermoset; Curing Agent	$/Lb	$/Ft^2/Mil
B. F. Goodrich	Hycar:							
	2600X83	Anionic	52	1.13	-15	Yes; Self-Cure	0.51	0.00576
	2600X84	Anionic	50	1.14	8	Yes; Self-Cure	0.54	0.00634
	2600X91	Anionic	50	1.13	20		0.54	0.00634
	2600X92	Anionic	50	1.12	-12	Yes; Self-Cure	0.54	0.00623
	2600X94	Anionic	50	1.13			0.56	0.00652
	2600X104	Anionic	50	1.12	-15	Yes; Self-Cure	0.52	0.00605
	2600X106	Anionic	50	1.10	29	Yes; Self-Cure	0.54	0.00617
	2600X112	Anionic	50	1.13	29	Yes; Self-Cure	0.55	0.00646
	2600X120[a]		50	1.14	-11	Yes; Self-Cure	0.53	0.00622
	260X138	Anionic	50	1.14	25		0.56	0.00658
	2671	Anionic	52	1.13	-11	Yes; Self-Cure	0.58	0.00649
	2679	Anionic	48	1.12	-3	Yes; Self-Cure	0.53	0.00643
	2679X6	Anionic	48	1.10	-3	Yes; Self-Cure	0.58	0.00690
	2600X137		50	1.13	-18	Yes; Self-Cure	0.56	0.00658
	2600X146	Anionic	50	1.13	-55	Yes; Self-Cure	0.99	0.01163
	2600X171	Anionic	48	1.06	45	Yes; Self-Cure	0.56	0.00643
	2600X172	Anionic	50	1.10	33	Yes; Self-Cure	0.57	0.00651
	2600X178		51	1.13			0.58	0.00662
	2600X189	Anionic	51	1.11	-32	Yes; Self-Cure	0.60	0.00679
	2600X205		49	1.13	-43	Yes; Self-Cure	0.68	0.00851
	2600X207		50	1.13	-39		0.68	0.00799
	2600X208		50	1.13			0.56	0.00652

(a) Special

...Continued

TABLE 3-B (Continued - 2)

Manufacturer	Material	Latex Type	Percent Solids	Specific Gravity (Dry)	T_g (°C)	Thermoset; Curing Agent	$/Lb	$/Ft^2/Mil
B. F. Goodrich	Hycar:							
	2600X210[(a)]		50	1.14	-20	Yes; Self-Cure	0.56	0.00664
	2600X222	Anionic	49	1.13	-50		0.99	0.01186
	2600X223		50	1.13	-20		0.66	0.00775
	2600X237		50	1.21	76		0.62	0.00780
	2600X238		50	1.13			0.66	0.00775
	2600X255		50	1.13			0.54	0.00628
	2600X256	Anionic	50	1.20	45		0.62	0.00773
Rohm & Haas	Rhoplex:							
	AC-22	Nonionic	44.5	1.15	-27	No; -	0.24	0.00322
	AC-33	Nonionic	46.5	1.15	-27	No; -	0.26	0.00334
	AC-73	Nonionic	46.5	1.15	2	No; -	0.33	0.00479
	B-60A	Nonionic	46.5	1.15	-27	No; -	0.27	0.00344
	AC-234	Nonionic	46.5	1.15	-23	No; -	0.28	0.00353
	AC-61	Anionic	46.5	1.15	-17	No; -	0.31	0.00395
	N-580	Anionic	55	1.15	-85	No; -	0.42	0.00455
	N-619	Anionic	57	1.15	-75	No; -	0.48	0.00503
	HA-4	Nonionic	45	1.15	-62	Yes; -	0.33	0.00438
	B-5	Nonionic	46	1.15	-59	Yes; -	0.54	0.00702
	B-10	Nonionic	46	1.15	-52	Yes; -	0.38	0.00491
	B-15	Nonionic	46	1.15	-49	Yes; -	0.27	0.00354
	LC-40	Anionic	55	1.15	-49	Yes; -	0.37	0.00397
	N-495	Anionic	57	1.15	-48	Yes; -	0.42	0.00440
	K-14	Nonionic	46	1.15	-92	Yes; Self-Cure	0.35	0.00458

(a) Special

...Continued

TABLE 3-B (Continued - 3)

Manufacturer	Material	Latex Type	Percent Solids	Specific Gravity (Dry)	T_g (°C)	Thermoset; Curing Agent	$/Lb	$/Ft^2/Mil
Rohm & Haas	Rhoplex:							
	K-3	Nonionic	46	1.15	-77	Yes; Self-Cure	0.29	0.00380
	K-87	Nonionic	46	1.15	-63	Yes; Self-Cure	0.35	0.00448
	HA-8	Nonionic	46	1.15	-59	Yes; Self-Cure	0.27	0.00354
	HA-24	Anionic	44.5	1.15	-52	Yes; Self-Cure	0.27	0.00366
	E-32	Nonionic	46	1.15	-47	Yes; Self-Cure	0.27	0.00344
	E-358	Nonionic	60	1.15	-45	Yes; Self-Cure	0.38	0.00376
	E-269	Anionic	46	1.15	-38	Yes; Self-Cure	0.30	0.00393
	RA-90	Nonionic	46	1.15	-33	Yes; Self-Cure	0.30	0.00387
	HA-12	Nonionic	45	1.15	-28	Yes; Self-Cure	0.26	0.00342
	HA-20	Anionic	45.5	1.15	-16	Yes; Self-Cure	0.39	0.00506
	HA-16	Nonionic	46	1.15	-12	Yes; Self-Cure	0.27	0.00354
	TR-520	Nonionic	50	1.15	-53	Yes; Self-Cure	0.30	0.00361
	LC-45	Anionic	65	1.15	-10	Yes; -	0.47	0.00432
	TR-440	Nonionic	46.5	1.15	-59	Yes; Self-Cure	0.35	0.00447
	TR-485	Nonionic/ Anionic	50	1.15	-91	Yes; Self-Cure	0.41	0.00487
	MV-1	Anionic	46	1.15		No; -	0.36	0.00461
	MV-2		46	1.15			0.34	0.00448
	MV-9		45.5	1.15			0.38	0.00499
	MV-17		45	1.15			0.37	0.00485
	N-560		57	1.15			0.45	0.00467
	P-50		43	1.15			0.34	0.00476
	P-64		45.5	1.15			0.30	0.00392
	P-376		50	1.15			0.33	0.00389
	P-491		46	1.15			0.28	0.00364

...Continued

TABLE 3-B (Continued - 4)

Manufacturer	Material	Latex Type	Percent Solids	Specific Gravity (Dry)	T_g (°C)	Thermoset; Curing Agent	$/Lb	$/Ft^2/Mil
Rohm & Haas	Rhoplex:							
	PR-26		30.5	1.15			0.54	0.01048
	R-47		40	1.15			0.27	0.00403
	TR-96		44.5	1.15			0.37	0.00493
	TR-653		35	1.15			0.26	0.00446
	TR-908		50.5	1.15			0.32	0.00382
	TR-914		50	1.15			0.29	0.00341
	TR-934		44.5	1.15			0.28	0.00369
	WN-80		40	1.15			0.35	0.00527
	B-85	Anionic	38	1.15	55	No; -	0.29	0.00507
	AR-74	Anionic	45	1.15	-4	No; -	0.23	0.00345
	SS-521	Nonionic	50	1.15	10	No; -	0.41	0.00554
	WL-91		41.5	1.15		No; -		
	AC-19		44.5	1.15			0.23	0.00309
	AC-25		46.5	1.15			0.28	0.00353
	AC-64		60.5	1.15			0.35	0.00341
	AC-172		45	1.15			0.37	0.00491
	AC-201	Nonionic	45.6	1.15		Yes; Self-Cure	0.44	0.00570
	AC-235		46.5	1.15			0.29	0.00369
	AC-388		50	1.15			0.29	0.00350
	AC-490	Nonionic	46	1.15		No; -	0.27	0.00351
	AC-507		47	1.15		No; -	0.30	0.00375
	AC-604		46	1.15			0.42	0.00546
	AC-634		46.5	1.15			0.29	0.00366
	AC-635		46.5	1.15			0.30	0.00382
	AC-658		47	1.15			0.39	0.00496

...Continued

TABLE 3-B (Continued - 5)

Manufacturer	Material	Latex Type	Percent Solids	Specific Gravity (Dry)	T_g (°C)	Thermoset; Curing Agent	$/Lb	$/Ft^2/Mil
Rohm & Haas	Rhoplex:							
	AC-707		65	1.15			0.37	0.00340
	AC-1084		50	1.15			0.37	0.00442
	B-58		32	1.15			0.54	0.01004
	B-74		38	1.15			0.32	0.00503
	B-88		42.5	1.15			0.30	0.00472
	B-89A	Nonionic	35	1.15		Yes; Self-Cure	0.35	0.00602
	B-413		39	1.15			0.34	0.00535
	B-505	Anionic	40	1.15		Crosslinked	0.31	0.00456
	B-654		40	1.15			0.34	0.00508
	B-832		40	1.15			0.30	0.00441
	B-924		38	1.15			0.23	0.00362
	CA-12		53.5	1.15			0.41	0.00452
	E-330		47	1.15			0.31	0.00394
	LC-67		65	1.15			0.49	0.00451
	MC-76		47	1.15			0.31	0.00394
	Acrysol:							
	WS-12		~30	1.15	~37	Yes; Amines	0.32	0.00628
	WS-24		36	1.15	39	Yes; Amines	0.36	0.00589
	Experimental Emulsion E-15	Anionic	54	1.15	-49	Yes; -		
B. F. Goodrich	Hycar:							
	2600X257		50	1.13			0.55	0.00640
	2671X 20		50	1.13			0.55	0.00646

...Continued

TABLE 3- B (Continued - 6)

Manufacturer	Material	Latex Type	Percent Solids	Specific Gravity (Dry)	T_g (°C)	Thermoset; Curing Agent	$/Lb	$/Ft^2/Mil
B. F. Goodrich	Hycar:							
	2671X22		50	1.13			0.53	0.00623
	2671X23		50	1.13			0.54	0.00634
	2679X22		62	1.13			0.56	0.00530
Staley Chemical Co.	Ubatol:							
	U-3045			1.15				
	U-3050			1.15				
	U-3054		40	1.15	23.5		0.25	0.00037
	U-3101	Anionic	40	1.15			0.26	0.00381
	U-3400	Anionic	40	1.15				
	U-3406		40	1.15			0.20	0.00296
	U-3500			1.15				
	U-3215	Anionic	40	1.15			0.28	0.00411
National Starch	X-Link:							
	2802	Anionic	45	1.19	29	Yes; Self-Cure	0.23	0.00316
	2813	Anionic	45	1.16	-2	Yes; Self-Cure	0.30	0.00402
	2833	Anionic	45	1.13	-29	Yes; Self-Cure	0.28	0.00362
	2873	Anionic	45	1.16	-36	Yes; Self-Cure	0.29	0.00389
Celanese	CL-300	Nonionic	46	1.15				
Johnson Wax	Joncryl:							
	74		49	1.14			0.43	0.00520
	M73 (b)		50				–	–

(b) Custom formulation (not commercial)

...Continued

TABLE 3-B (Continued - 7)

Manufacturer	Material	Latex Type	Percent Solids	Specific Gravity (Dry)	T_g (°C)	Thermoset; Curing Agent	$/Lb	$/Ft^2/Mil
Polyvinyl Chemical	Neocryl:							
	A601		32	1.12		Yes; Amine	0.39	0.00700
	A604		32	1.12		Yes; Amine	0.44	0.00800
	A620		40	1.12		Yes; Amine	0.36	0.00517
	A621		40	1.15		Yes; Amine	0.36	0.00530
Union Carbide	Ucar:							
	130	Nonionic	58	1.2	43	No; -		
	131	Nonionic	60	1.15	26	No; -		
	150	Nonionic	58	1.2	37	No; -		
	151	Nonionic	60	1.12	24	No; -		
	152	Anionic	58	1.12	-7	Yes; -		
	153	Anionic	55	1.12	-2	Yes; -		
	154	Anionic	60	1.14	0	Yes; -		
	163	Anionic	58	1.12	-5	No; -		
	167	Anionic	63	1.15	23	No; -		
	380	Nonionic	48	1.14	17	No; -		
	865	Anionic	55	1.14	5	No; -		
	872		58	1.12	-7	No; -		
	874		60	1.14	-1	No; -		
	878		61	1.14	10	No; -		
	1248		50					
	4312	Anionic	45	1.1	23	No; -		
	4358	Anionic	45		25	No; -		
	4510	Anionic	43	1.13	44	Yes; -		
	4550	Anionic	45	1.13	39	Yes; -		
	508		53		20			
	4341	Anionic	45.5	1.04	10	No; -		

. . . Continued

TABLE 3-B (Continued - 8)

Manufacturer	Material	Latex Type	Percent Solids	Specific Gravity (Dry)	T_g (°C)	Thermoset; Curing Agent	$/Lb	$/Ft²/Mil
Union Carbide	Ucar:							
↓	165	Anionic/ Nonionic	55	1.15	28	No; -		
	166	↓	55	1.15	22	No; -		
	360		55	1.16	27	No; -		
	365		55	1.15	28	No;		
	366		55	1.15	23	No;		
	366HS		64	1.15	23	No;		
	4150		55	1.15	28	No; -		
	4362		48	1.12	16	No; -		
	5000		55	1.15	5	No; -		

TABLE 4

GLAZING MATERIALS

	Chemical Structure	Manufacturer	Sample Thickness Mils
Fluorocarbons			
1. Tedlar 400XRB160SE	Polyvinyl Fluoride	DuPont	4
2. PFA 9705	Perfluoro Alkoxy	DuPont	2
3. Halar 500	Ethylene/Chlorotrifluoroethylene	Allied	2
4. Kynar 450	Polyvinylidene Fluoride	Pennwalt	5
5. FEP 100A	Perfluorethylene Propylene	DuPont	1
Thermoplastic Polyesters			
6. Mylar	Polyethylene Terephthalate	DuPont	5
7. N.M. 45-95-1	Experimental Polyester	Nat. Metallizing	2
8. N.M. 45-95-2		Nat. Metallizing	2
9. Llumar	Polyethylene Terephthalate	Martin Processing	5
10. Ardel 100	Polyarylate	Union Carbide	100
Thermoset Polyesters			
11. Filon 558	Tedlar - Coated over Acrylic Modified FRP	Filon	40
12. Sunlite Premium II	Modified Thermoset Polyester	Kalwall	40
13. Glasteel 500	Neopentyl Glycol Thermoset Polyester	Glasteel	11
Miscellaneous			
14. Lexan	Polycarbonate	G.E.	40
15. Tuffak CM-2	Abrasion Resistant Polycarbonate (Twin Wall)	Rohm & Haas	40
16. Tenite 479	Cellulose Acetate Butyrate (CAB)	Tennessee Eastman	35
17. Plexiglas V811	Polymethyl Methyacrylate	Rohm & Haas	40
18. Geon 103EP, Scrim Reinforced	Polyvinyl Chloride	Monsanto	20
19. EVA 150 /1/	Peroxide Crosslinked Ethylene/Vinyl Acetate Copolymer	Uncrosslinked EVA 150 is from DuPont	20
20. Flexigard 7410	Polyester/Acrylic Laminate	3M	8

/1/ Also called crosslinked EVA (or X-ℓ EVA).

TABLE 5

VISUAL CHANGES ON GLAZINGS AFTER 12 MONTHS EXPOSURE IN THE WEATHER-OMETER

Glazing Material	Original Color	Changes After 12 Months
Tedlar 400XRB160SE	Clear	Slightly cloudy, sample has curled
Halar 500	Clear	Clear
Kynar 450	Clear	Clear, covered by white substance
PFA	Clear	Clear
FEP 100-A	Clear	Clear
Mylar	Cloudy	Very severe clouding, failed. Very brittle, sample crumbles when handled
National Met. 45-95-1	Clear	Failed, brittle
National Met. 45-95-2	Clear	Severe clouding
Llumar	Clear	Severe clouding, brittle
Ardel	Amber to gold tint	Color the same, water spots
Filon 558	Cloudy, fibers are visible	Fibers more visible
Sunlite Premium II	Cloudy, fibers are visible	Yellowed slightly, some surface degradation
Glasteel 500	Cloudy, fibers are visible	Fibers more visible
Lexan	Clear	Yellowed and clouded
Tuffak CM-2	Clear	Clouding over
Cellullose Acetate Butyrate	Clear	Chalking & clouding
Plexiglas V-811	Clear	Clear
PVC/Scrim	Clear, with view distortion	Yellowed, covered by white substance
Flexigard 7410	Clear	Clouding around edges, clear in middle, water spots
X-ℓ EVA	Clear	Clear, slight water spoting

TABLE 6

EFFECT OF FOUR, EIGHT,AND TWELVE MONTHS EXPOSURE OF GLAZING MATERIALS IN THE WEATHER-OMETER (3)

		Original %(1)	% Transmission After		
	Material	Transmission	4 Months	8 Months	12 Months
1.	Tedlar 400XRB160SE	92	89	85	87
2.	PFA	94	95	89	87
3.	Halar 500	93	93	92	89
4.	Kynar 450	93	92	80	87
5.	FEP 100A	96	95	90	89
6.	Mylar	84	75	(2)	(2)
7.	N.M. 45-95-1	88	86	(2)	(2)
8.	N.M. 45-95-2	85	85	83	83
9.	Llumar	86	86	80	78
10.	Ardel D-100	70	69	68	67
11.	Filon 558	87	83	80	78
12.	Sunlite Premium II	87	85	78	76
13.	Glasteel 500	83	85	81	77
14.	Lexan	86	84	77	68
15.	Tuffak CM-2	85	84	76	78
16.	CAB Tenite	91	88	80	77
17.	Plexiglas V-811	90	90	86	86
18.	PVC/Scrim	88	81	64	56
19.	Crosslinked EVA	91	87	85	84
20.	Flexigard 7410	88	88	84	80

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(1) Integrated solar transmission is measured from 350 to 2100 nm using ASTM E424-71, normal hemispherical, air mass 2.
Equipment: Varian 635 with integrating sphere for 350-800 nm and a Beckman DK-2A, tungsten source, lead sulfite detector for 800-2100 nm.

(2) Failed due to degradation - crumbling and brittleness.

(3) Carbon Arc

TABLE 7

EFFECT OF "WET" RS-4 EXPOSURE ON TRANSMISSION OF GLAZING MATERIAL

Material	Original % Transmission	% Transmission After		
		4 Months	8 Months	12 Months
1. Tedlar 400XRB160SE	92	87	89	86
2. PFA	94	91	91	90
3. Halar 500	93	91	90	89
4. Kynar 450	93	91	90	88
5. FEP 100A	96	91	89	87
6. Nat. Met. 45-95-2	85	85	88	85
7. Llumar	86	86	86	80
8. Filon 558	87	84	76	74
9. Sunlite Premium II	87	85	83	81
10. Glasteel 500	83	82	85	81
11. Lexan	86	82	84	81
12. Tuffak CM-2	85	85	85	83
13. Plexiglas V-811	90	89	89	89
14. PVC/Scrim	88	83	83	76
15. Crosslinked EVA	91	86	83	82
16. Flexigard	88	85	86	84

TABLE 8

EFFECT OF FOUR, EIGHT, AND TWELVE MONTHS EXPOSURE OF GLAZING MATERIALS OUTDOORS AT HAZARDVILLE, CT(1)(3)

	Material	Original % Transmission(2)	% Transmission After 4 Months	8 Months	12 Months
1.	Tedlar 400XRB160SE	92	89	90	88
2.	PFA	94	95	91	93
3.	Halar 500	93	92	90	89
4.	Kynar 450	93	91	89	90
5.	FEP 100A	96	95	92	91
6.	Mylar	84	84	84	81
7.	Nat. Met. 45-95-1	88	85	83	85
8.	Nat. Met. 45-95-2	85	86	83	85
9.	Llumar	86	86	85	84
10.	Ardel D-100	70	71	71	72
11.	Filon 558	87	85	85	84
12.	Sunlite Premium II	87	86	81	82
13.	Glasteel 500	83	84	83	84
14.	Lexan	86	86	84	82
15.	Tuffak CM-2	85	86	84	84
16.	CAB Tenite	91	88	84	86
17.	Plexiglas V811	90	90	90	89
18.	PVC/Scrim	88	82	83	77
19.	Flexigard	88	89	85	86
20.	Crosslinked EVA	91	89	87	86

(1) Exposed at 45°

(2) Integrated solar optical transmission; 350-2100 nm. (see Footnote 1 Table 6)

(3) The samples are unwashed

TABLE 9

INTEGRATED SOLAR OPTICAL TRANSMISSION RETAINED AFTER 12 MONTHS EXTERIOR EXPOSURE AT HAZARDVILLE, CT

Glazing Material	Solar Transmission Original	% Solar Transmission Retained After 12 Mos.
Fluorocarbons		
Tedlar 400XRB160SE	92	96
P.F.A.	94	99
Halar 500	93	96
Kynar 450	93	97
F.E.P. 100A	96	95
Thermoplastic Polyesters		
Mylar	84	96
Nat. Metallizing 45-95-1	88	97
Nat. Metallizing 45-95-2	85	100
Llumar	86	98
Ardel	70	100
Thermoset Polyesters		
Filon 558	87	97
Sunlite Premium II	87	94
Glasteel 500	83	100
Miscellaneous		
Lexan	86	95
Tuffak CM-2	85	99
Tenite CAB	91	95
Plexiglas V-811	90	99
PVC Scrim	88	88
Flexigard	88	98
Crosslinked EVA	89	94

(1) Integrated from 350 - 2100 nm.(see Footnote 1, Table 6)

TABLE 10

RANKING OF GLAZING SAMPLES BY OPTICAL INDEX(1) AFTER TWELVE MONTHS OUTDOOR EXPOSURE AT HAZARDVILLE, CT

1.	FEP	Fluorocarbon	87
2.	PFA	Fluorocarbon	87
3.	Kynar 450	Fluorocarbon	84
4.	Halar 500	Fluorocarbon	83
5.	Tedlar 4000XRB160SE	Fluorocarbon (UV Stabilized)	81
6.	Plexiglas V-811	Acrylic	80
7.	Crosslinked EVA	Theylene Copolymer	78
8.	CAB	Cellulose Ester	78
9.	Flexigard	Polyester/Acrylic Laminate	76
10.	Nat. Metalizing 45-95-1	Thermoplastic Polyester (UV Stabilized)	75
11.	Filon 558	Tedlar Coated FRP	73
12.	Nat. Metallizing 45-95-2	Thermopolastic Polyester (UV Stabilized)	72
13.	Llumar	Thermoplastic Polyester (UV Stabilized)	72
14.	Tuffak CM-2	Polycarbonate	71
15.	Lexan	Polycarbonate	71
16.	Sunlite Premium II	Thermoset Polyester	71
17.	Glasteel 500	Thermoset Polyester	70
18.	Mylar	Thermoplastic Polyester	68
19.	PVC Scrim Reinforced	Polyvinyl (Polyester scrim) Chloride (UV Stabilized)	68
20.	Ardel	Polyether	50

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(1) Product of % transmission after elapsed time and original transmission; e.g. Plexiglas is 89% x 90% = 80%.

TABLE 11

EFFECT OF FOUR AND EIGHT MONTHS EMMAQUA EXPOSURE ON TRANSMISSION (1) OF GLAZING MATERIALS

Material	Original % Transmission	% Transmission After(3)		Optical Index
		4 Months	8 Months	
Tedlar 400XRB160SE	92	89	89	82
PFA	94	92	92	86
Halar 500	93	88	91	85
Kynar 450	93	88	87	81
FEP 100A	96	89	83	80
Nat. Met. 45-95-2	85	82	(2)	-
Llumar	86	77	78	67
Filon 558	87	84	73	64
Sunlite Premium II	87	79	81	70
Tuffak CM-2	85	88	84	71
Plexiglas V-811	90	88	89	80
Crosslinked EVA	91	74	69	63
Flexigard	88	86	86	76

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(1) Solar optical transmission integrated over 350 to 2100 nm. (See Footnote 1, Table 6).

(2) Sample degraded

(3) Samples not cleaned after exposure.

(4) The thirteen best uncoated glazing materials as judged by accelerated (Weather-Ometer) exposure were sent for EMMAQUA exposure.

TABLE 12

PERCENT SOLAR OPTICAL TRANSMISSION(1) RETAINED AFTER EXPOSURE IN THE WEATHER-OMETER, EMMAQUA AND OUTDOORS AT HAZARDVILLE, CT

		Solar Transmission After					
		12 Mths. Weather-Ometer		8 Mths EMMAQUA		12 Mths Outdoors	
Material	Original	%T	% Retained	%T	% Retained	% T	% Retained
Fluorocarbons							
Tedlar 400XRB160SE	92	87	95	88	96	88	96
PFA	94	87	93	92	98	93	99
Halar 500	93	89	96	90	97	89	96
Kynar 450	93	87	94	85	91	90	97
FEP 100-A	96	89	93	78	81	91	95
Thermoplastic Polyesters							
Mylar	84	(2)	(2)	(3)	-	81	89
Nat. Met. 45-95-1	88	(2)	(2)	(3)	-	85	97
Nat. Met. 45-95-1	85	83	98	(2)	-	85	100
Llumar	86	68	79	78	91	84	98
Ardel	70	67	96	(3)	-	72	100
Thermoset Polyesters							
Filon 558	87	78	90	73	84	84	97
Sunlite Premium II	87	76	87	81	93	82	94
Glasteel 500	83	77	93	(3)	-	84	100
Miscellaneous							
Lexan	86	68	79	(3)	-	82	95
Tuffak CM-2	85	78	92	84	99	84	99
CAB	91	77	85	(3)	-	86	95
Plexiglas V-811	90	86	96	89	99	89	99
Polyester Scrim Reinforced PVC	88	56	64	(3)	-	77	88
Flexigard 7410	88	84	95	86	98	86	98
Crosslinked EVA	91	80	88	69	76	86	94

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(1) Integrated over the range 350 nm to 2100 nm
(2) Sample is degraded
(3) Material not put under exposure , (see Footnote 4, Table 11.)

TABLE 13

EFFECT OF WASHING ON PERCENT TRANSMISSION AFTER FOUR MONTHS OUTDOOR EXPOSURE AT HAZARDVILLE, CT

	Material	Original % Transmission	% Transmission After 4 Month Exterior	% Transmission After 4 Month Exterior Washed
1.	Tedlar 400XRB160SE	92	89	90
2.	PFA	94	95	97
3.	Halar 500	93	92	93
4.	Kynar 450	93	91	92
5.	FEP 100A	96	95	95
6.	Mylar	84	84	85
7.	Nat. Met. 45-95-1	88	85	86
8.	Nat. Met. 45-95-2	85	86	84
9.	Llumar	86	86	86
10.	Ardel D-100	70	71	71
11.	Filon 558	87	85	87
12.	Sunlite Premium II	87	86	86
13.	Glasteel 500	83	84	83
14.	Lexan	86	86	85
15.	Tuffak CM-2	85	86	85
16.	CAB Tenite 479	91	88	88
17.	Plexiglas V-811	90	90	90
18.	PVC/Scrim	88	82	81
19.	Crosslinked EVA	91	89	89
20.	Flexigard 7410	88	89	90

TABLE 14

EFFECT OF WASHING ON PERCENT TRANSMISSION AFTER TWELVE MONTHS OUTDOOR EXPOSURE AT HAZARDVILLE, CT

	Material	Original % Transmission	% Transmission After 12 Month Exterior	 12 Month Exterior Washed
1.	Tedlar 400XRB160SE	92	88	92
2.	PFA	94	93	96
3.	Halar 500	93	89	92
4.	Kynar 450	93	90	93
5.	FEP 100A	96	91	95
6.	Mylar	84	81	84
7.	Nat. Met. 45-95-1	88	85	85
8.	Nat. Met. 45-95-2	85	85	85
9.	Llumar	86	84	86
10.	Ardel D-100	70	72	73
11.	Filon 558	87	84	83
12.	Sunlite Premium II	87	82	81
13.	Glasteel 500	83	84	83
14.	Lexan	86	82	86
15.	Tuffak CM-2	85	84	85
16.	CAB Tenite 479	91	86	89
17.	Plexiglas V-811	90	89	91
18.	PVC/Scrim	88	77	82
19.	Crosslinked EVA	91	86	89
20.	Flexigard 7410	88	86	87

TABLE 15

TENSILE PROPERTIES OF GLAZINGS AFTER FOUR MONTHS EXPOSURE IN THE WEATHER-OMETER

	Tensile Strength psi		Modulus psi x 10^5		Ult. Elongation %	
Material	Original	After 4 Months	Original	After 4 Months	Original	After 4 Months
Fluorocarbons						
- Tedlar 400XRB160SE	14,271	11,506	2.28	2.37	214	219
- PFA	4,090	4,083	0.48	0.50	251	289
- Halar 500	10,500	7,966	1.68	1.18	115	114
- Kynar 450	7,197	5,589	1.10	1.07	337	218
- FEP 100A	7,072	7,360	0.79	2.51	177	264
Thermoplastic Polyesters						
- Mylar	19,481	6,718	3.44	4.28	86	7.8
- Nat. Met. 45-95-1	28,750	22,001	6.38	3.93	51	29
- Nat. Met. 45-95-2	39,306	28,735	3.34	5.83	48	37
- Lumar	29,936	22,927	5.02	3.48	53	32
- Ardel 100	8,580	7,890	4.01	4.10	< 1	< 1
Thermoset Polyesters						
- Filon 558	8,390	10,975	4.23	3.57	2.8	2.8
- Sunlite II	10,483	8,305	3.47	3.23	3.9	2.2
- Glasteel	6,630	9,149	5.10	4.22	1.0	4.5
Miscellaneous						
- Lexan	7,401	7,064	1.66	2.07	42	13
-Tuffak CM-2	7,810	7,430	1.78	2.94	70	20
-CAB	5,190	3,375	0.92	0.89		
-Plexiglas V-811	5,127	3,923	2.43	2.38	3.3	1.7
-Scrim Reinforced Vinyl	2,930	2,643	0.20	0.24	316	276
-Flexigard 7410 (UV Stab. Acrylic top layer)	10,600	7,240	4.19	4.62	< 1	< 1
- EVA 150(Crosslinked)	1,900	1,597	-	-	510	699

TABLE 16

TENSILE PROPERTIES OF GLAZING MATERIALS AFTER 8 MONTHS WEATHER-OMETER EXPOSURE

Glazing Material	Tensile Strength(psi) Original	Tensile Strength(psi) After 8 Months	Modulus(psi x 10^{-5}) Original	Modulus(psi x 10^{-5}) After 8 Months	Ultimate Elongation (%) Original	Ultimate Elongation (%) After 8 Months
1. Tedlar 400XRB160SE	14271	7850	2.28	2.95	214	100
2. PFA	4090	3270	0.48	0.53	251	290
3. Halar 500	10500	4950	1.68	1.55	115	130
4. Kynar 450	7197	5080	1.1	20	337	80
5. FED 100-A	7072	2640	0.79	0.38	177	150
6. Mylar	19481	(1)	3.44	-	86	-
7. Nat. Met. 45-95-1	28750	8720	6.38	3.81	51	1
8. Nat. Met. 45-95-2	39360	13600	3.43	7.02	48	7
9. Llumar	29936	6490	5.02	5.51	53	2
10. Ardel	8580	7460	4.01	4.25	<1	1
11. Filon 558	8390	9420	4.23	3.21	2.8	5
12. Sunlite Premium II	10483	7810	3.47	3.29	3.9	4
13. Glasteel	6630	10900	5.1	4.2	1.0	3
14. Lexan	7401	6940	1.66	2.63	42	9
15. Tuffak CM-2	7810	6490	1.78	4.81	70	19.7
16. CAB	5190	3460	0.92	1.25	29	10
17. Plexiglas V-811	5127	3180	2.43	2.48	3.3	2
18. PVC/Scrim	2930	5070	0.20	0.61	316	20
19. Flexigard 7410	10600	4620	4.19	5.78	<1	1

(1) Sample broken

TABLE 17

TENSILE PROPERTIES OF GLAZING MATERIALS AFTER 12 MONTHS WEATHER-OMETER EXPOSURE

Glazing Material	Tensile Strength(psi)		Modulus(psi x 10^{-5})		Ultimate Elongation (%)	
	Original	After 12 Months	Original	After 12 Months	Original	After 12 Months
Tedlar 400XRB160SE	14271	5470	2.28	2.68	214	50
PFA	4090	2940	0.48	0.64	251	260
Halar 500	10500	6510	1.68	1.49	115	140
Kynar 450	7197	4030	1.10	1.5	337	80
FEP 100A	7072	2680	0.79	0.59	177	220
Mylar	19481	(1)	3.44	-	86	-
Nat. Met. 45-95-1	28750	(1)	6.38	-	51	-
Nat. Met. 45-95-2	39306	15100	3.43	6.72	48	9
Llumar	29936	(1)	5.02	-	53	-
Ardel 100	8580	8330	4.01	4.01	<1	22
Filon 558	8390	8100	4.23	3.65	2.8	3
Sunlite Premium II	10483	8220	3.47	3.62	3.9	5
Glasteel	6630	12500	5.1	3.81	1.0	5
Lexan	7401	7220	1.66	2.09	42	9
Tuffak CM-2	7810	6580	1.78	4.69	70	31
CAB	5190	2930	0.92	1.14	29	<1
Plexiglas V-811	5127	1630	2.43	2.23	3.3	2
PVC/Scrim	2930	5070	0.20	0.48	316	30
Flexigard 7410	10600	2900	4.19	4.52	<1	3
Crosslinked EVA	1900	1446	-	-	510	450

(1) Samples broken

TABLE 18

TENSILE STRENGTH RETENTION OF GLAZING MATERIALS AFTER WEATHER-OMETER EXPOSURE FOR 8 AND 12 MONTHS

Material	Original Tensile Strength (psi)	After 8 Month Weather-Ometer Exposure	After 12 Month Weather-Ometer Exposure
		% Retained	% Retained
1. TEDLAR 400XRB160SE	14271	55	38
2. PFA	4090	80	72
3. HALAR 500	10500	47	62
4. KYNAR 450	7197	71	56
5. FEP 100 A	7072	37	38
6. MYLAR	19481	0	0
7. Nat. Met. 45-95-1	28750	30	0
8. Nat. Met. 45-95-2	39360	35	38
9. LLUMAR	29936	22	0
10. ARDEL D-100	8580	87	97
11. FILON 558	8390	112	97
12. SUNLITE PREMIUM II	10483	75	78
13. GLASTEEL	6630	164	189
14. LEXAN	7401	94	98
15. TUFFAK CM-2	7810	83	84
16. C. A. B.	5190	67	56
17. PLEXIGLAS V-811	5127	62	32
18. PVC/SCRIM	2930	173	173
19. FLEXIGARD 7410	10600	44	27
20. X-ℓ EVA (1)	1900	-	78

(1) X-ℓ = Crosslinked

TABLE 19

RETENTION OF ULTIMATE ELONGATION AFTER EXPOSURE IN WEATHER-OMETER FOR 8 AND 12 MONTHS

Material	Original Ultimate Elongation (%)	After 8 Month Weather-Ometer Exposure	After 12 Month Weather-Ometer Exposure
		% Retained	% Retained
1. TEDLAR 400XRB160SE	214	47	23
2. PFA	251	116	104
3. HALAR 500	115	113	122
4. KYNAR 450	337	24	24
5. FEP 100 A	177	85	124
6. MYLAR	86	0	0
7. Nat. Met. 45-95-1	51	2	0
8. Nat. Met. 45-95-2	48	15	19
9. LLUMAR	53	4	0
10. ARDEL D-100	1	(1)	(1)
11. FILON 558	2.8	(1)	(1)
12. SUNLITE PREMIUM II	3.9	(1)	(1)
13. GLASTEEL	1	(1)	(1)
14. LEXAN	42	21	21
15. TUFFAK CM-2	70	29	44
16. C. A. B.	29	34	3
17. PLEXIGLAS V-811	3.3	(1)	(1)
18. PVC/SCRIM	316	6	9
19. FLEXIGARD 7410	1	(1)	(1)
20. X-ℓ EVA	510	-	88

(1) Original percent elongation of these materials too low to be useful.

TABLE 20

TENSILE PROPERTIES OF GLAZING MATERIALS AFTER FOUR MONTHS EMMAQUA EXPOSURE

Glazing Material	Tensile Strength(psi)		Modulus(psi x 10^{-5})		Ultimate Elongation (%)	
	Original	After 4 Months EMMAQUA	Original	After 4 Months EMMAQUA	Original	After 4 Months EMMAQUA
Tedlar 400XRB160SE	14271	16200	2.28	3.61	214	160
PFA	4090	7090	0.48	1.21	251	270
Halar 500	10500	5460	1.68	2.06	115	60
Kynar 450	7197	16900	1.10	2.51	337	110
FEP 100-A	7072	2510	0.79	4.03	177	140
Nat. Met. 45-95-2	39306	14200	3.43	5.89	48	7
Llumar	29936	7650	5.02	6.40	53	10
Filon 558	8390	10200	4.23	4.13	2.8	3
Sunlite Premium II	10483	8220	3.47	2.59	3.9	5
Tuffak CM-2	7810	6390	1.78	4.88	70	23
Plexiglas V-811	5127	8380	2.43	2.45	3.3	5
Flexigard 7410	10600	8610	4.19	4.83	< 1	2
Crosslinked EVA	1900	1800	-	—	510	450

TABLE 21

TENSILE PROPERTIES OF GLAZING MATERIALS AFTER 8 MONTHS EMMAQUA EXPOSURE

Glazing Material	Tensile Strength(psi)		Modulus(psi x 10^{-5})		Ultimate Elongation (%)	
	Original	After 8 Months EMMAQUA	Original	After 8 Months EMMAQUA	Original	After 8 Months EMMAQUA
Tedlar 400XRB160SE	14271	15200	2.28	3.5	214	150
PFA	4090	6480	0.48	1.07	251	270
Halar 500	10500	7060	1.68	2.04	115	100
Kynar 450	7197	16600	1.10	2.59	337	120
FEP 100-A	7072	4030	0.79	9.28	177	80
Nat. Met. 45-95-2	39306	14200	3.43	5.89	48	7
Llumar	29936	(1)	5.02	(1)	53	(2)
Filon 558	8390	11800	4.23	3.67	2.8	2
Sunlite Premium II	10483	9440	3.47	4.23	3.9	4
Tuffak CM-2	7810	6180	1.78	4.84	70	14
Plexiglas V-811	5127	8090	2.43	2.58	3.3	4
Flexigard 7410	10600	10600	4.19	5.33	< 1	6
Crosslinked EVA	1900	1990	–	–	510	480

(1) See Footnote 4, Table 11)

(2) Embrittled

TABLE 22

PERCENT OF TENSILE STRENGTH RETAINED OF GLAZING MATERIALS AFTER EMMAQUA EXPOSURE FOR EIGHT MONTHS

Material	Original Tensile Strength (psi)	After 8 Months % Retained
Tedlar 400XRB160SE	14271	107
PFA	4090	158
Halar 500	10500	67
Kynar 450	7197	231
FEP 100-A	7072	57
Nat. Met. 45-95-2	39306	36
Llumar	29936	0
Filon 558	8390	141
Sunlite Premium II	10483	90
Tuffak CM-2	7810	79
Plexiglas V-811	5127	158
Flexigard 7410	10600	100
Crosslinked EVA	1900	105

TABLE 23

PERCENTAGE OF ULTIMATE ELONGATION OF GLAZINGS RETAINED AFTER EMMAQUA EXPOSURE

Material	Elongation(%)	After 4 Months EMMAQUA Exposed % Retained	After 8 Months EMMAQUA Exposed % Retained
Tedlar 400XRB160SE	214	75	70
PFA	251	108	108
Halar 500	115	52	87
Kynar 450	337	33	36
FEP 100A	177	79	45
Nat. Met. 45-95-2	48	15	15
Llumar	53	20	(1)
Filon 558	2.8	(2)	(2)
Sunlite Premium II	3.9	(2)	(2)
Tuffak CM-2	70	33	20
Plexiglas V-811	3.3	151	121
Flexigard 7410	< 1	(2)	(2)
X-ℓ EVA (3)	510	88	94

(1) Samples broke after 8 months exposure.

(2) Original elongation on these materials too low to be useful.

(3) Crosslinked ethylene/vinyl acetate copolymer.

TABLE 24

COMPARISON OF RETENTION OF TENSILE PROPERTIES: EMMAQUA AND WEATHER-OMETER EXPOSURE OF GLAZING MATERIALS

Material	Retention of Tensile Strength %					Retention of Ultimate Elongation				
	EMMAQUA Exposure		Weather-Ometer Exposure			EMMAQUA Exposure		Weather-Ometer Exposure		
	4 Months	8 Months	4 Months	8 Months	12 Months	4 Months	8 Months	4 Months	8 Months	12 Months
Tedlar 100XRB160SE	114	107	81	55	38	75	70	102	47	23
PFA	173	158	100	80	72	108	108	115	116	104
Halar 500	52	67	76	47	62	52	87	100	113	122
Kynar 450	235	231	78	71	56	33	36	65	24	24
FEP 100A	35	57	104	37	38	79	45	149	85	124
Nat. Met. 45-95-2	36	36	73	35	38	15	15	77	15	19
Llumar	26	(1)	77	22	(2)	20	(1)	60	4	(2)
Filon 558	122	141	131	112	97	(3)	(3)	(3)	(3)	(3)
Sunlite Premium II	78	90	79	75	78	(3)	(3)	(3)	(3)	(3)
Tuffak CM-2	82	79	89	83	84	33	20	81	29	44
Plexiglas V-811	163	158	77	62	32	(3)	(3)	(3)	(3)	(3)
Flexigard 7410	81	100	66	44	27	(3)	(3)	(3)	(3)	(3)
Crosslinked EVA	95	105	63	-	23	88	94	137	-	88

(1) Sample failed after 8 months EMMAQUA exposure
(2) Sample failed after 12 months Weather-Ometer exposure
(3) Original percent elongation of these materials is to low to measure change

TABLE 25

QUALITATIVE VISUAL ANALYSIS OF HOUSING MATERIALS AFTER WEATHER-OMETER EXPOSURE

Housing Material	Original Color	Visual Changes After 4 months (1)	Visual Changes After 8 months (2)
Super Dorlux	Brown	Chalky white, slight delamination	Failed, severe delamination and chalking
Pan-L-board	Brown	Completely white, moderate delamination	White, Failed-severe delamination
FRP sheet(glass fibre reinfacid polyester)	Shiny black	Dark gray	Dark gray
Carbon black filled X-ℓ HDPE	Black	None	None
Burgees KE Clay-filled X-ℓ HDPE	White	White,slight chalking	White, chalking with craze lines
Melamine M 6024	Shiny black	Dull black	Dull black
Filled Phenolic FM 4005	Shiny black	Dull black with patches of gray	Grayish-black, rough surface
Dylark 250	Yellow	Dark yellow→tan	dark yellow →tan
Polypropylene structural foam 30% glass filled	Gray	Grayish-green-bubbles on edges, crumbles easily	Grayish with white patches Failed - crumbles very easily
40% Talc-filled Polypropylene	Light gray	White, slight chalking	White-moderate chalking
Geon 7084	White	Light tan in some areas	Light tan in some areas
Geon 85857	White	Light tan in some areas	Light tan in some areas
Cellular PVC	White	Dark brown smooth surface	Light tan, rough chalky surface
Polyester S-660	Shiny black	Dull black	Grayish black

(1) 4 months exposure equals 2880 hours.
(2) 8 months exposure equals 5760 hours.

TABLE 26

Qualitative Visual Analysis of Housing
Materials After Weather-Ometer Exposure
for 12 Months

Housing Material	Original Color	Changes After 12 Months
Super Dorlux	Brown	Failed after 8 months due to severe delamination and chalking
Pan-L-Board	Brown	Failed after 8 months due to severe delamination
FRP Sheet (glass fibre reinforced polyester)	Shiny black	Dull black-light chalking - moderate chalking - rough surface
Carbon Black filled X-ℓ(1) HDPE	Shiny black	Black - no crazing or chalking - good shape
Burgess KE clay-filled X-ℓ HDPE	White	Dull white with craze lines
Melamine M6024	Shiny black	Dull black with some small patches of gray - rough surface - light chalking
Filled Phenolic FM4005	Shiny black	Grayish-black with patches of light gray that can be scraped off exposing the grayish-black surface
Dylark 250	Yellow	Dark yellow-tan
Polypropylene structural foam 30% glass filled	Gray	Failed after 8 months due to crumbling and brittleness
Geon 7084	White	Mostly white with tan patches throughout - very light chalking
Geon 85857	White	White with patches of light brown sometimes covering almost entire surface - light chalking
Cellular PVC	White	Yellow to light tan - rough surface, chalking
Polyester S-660	Shiny black	Grayish black - rough surface - light chalking
40% Talc filled Polypropylene	Light gray	White with craze lines - severe chalking - rough surface

(1) X-ℓ means crosslinked

TABLE 27

TENSILE PROPERTIES OF HOUSING MATERIALS AFTER FOUR MONTHS EXPOSURE IN THE WEATHER-OMETER

Material	Tensile Strength psi		Modulus psi x 10^5		Ult. Elongation %	
	Original	After 4 Months	Original	After 4 Months	Original	After 4 Months
Super Dorlux	4150	1910	9.1	3.71	< 1	0.9
Pan-L-Board	1570	4670	1.3	5.64	5.5	1.7
FRP Sheet	10260	11550	14.1	21.0	2.0	1.8
Carbon-Filled Crosslinked HDPE	3525	2410	1.5	2.6	259	227
Clay-Filled Crosslinked HDPE	2520	275	1.5	2.1	248	17
Melamine M6024	3560	4050	14.9	15.3	< 1	0.4
Filled Phenolic	6050	6590	18.9	21.2	< 1	0.4
Dylark 250	4110	2080	3.2	3.63	< 1	0.7
Glass-Filled Polypropylene Foam	1440	1200	1.0	0.93	7.5	2.0
Talc-Filled Polypropylene	4090	3975	7.6	7.18	8.0	3.0
Geon 7084 PVC	4800	6820	4.6	5.22	46.5	8.0
Geon 85857 PVC	4770	6430	4.0	3.94	5.5	2.0
Cellular PVC	1680	1990	1.1	1.21	46.0	20.0
S-660 Polyester	3710	4010	18.9	30.7	< 1	0.1

TABLE 28

TENSILE PROPERTIES OF HOUSING MATERIALS AFTER 8 MONTHS WEATHER-OMETER EXPOSURE

Material	Tensile Strength(psi)		Modulus(psi x 10^{-5})		Ultimate Elongation(%)	
	Original	After 8 Months	Original	After 8 Months	Original	After 8 Months
Super Dorlux	4150	(1)	9.1	-	1	-
Pan-L-Board	1570	(1)	1.3	-	5.5	-
FRP Sheet	10260	10900	14.1	16.9	2	2.7
660 Polyester	3710	4340	18.9	19.5	< 1(3)	<1
Carbon Black Filled Crosslinked HDPE	3525	2650	1.5	1.7	259	250
Clay Filled Crosslinked HDPE	2520	810	1.5	1.1	248	13.6
Melamine M6024	3560	4620	14.9	17	< 1(3)	<1
Filled Phenolic	6050	4620	18.9	17	<1(3)	<1
Dylark 250	4110	1450	3.2	3.0	<1(3)	<1
Talc Filled Polypropylene	4090	3230	7.6	6.3	8	3
Glass Filled Polyproplyene Foam	1440	(2)	1.0	-	7.5	-
Cellular PVC	1680	1650	1.1	1.3	46	7
Geon 7084 PVC	4800	6920	4.6	4.9	46.5	4
Geon 85857 PVC	4770	5820	4.0	3.9	5.5	2

(1) Failed after 8 months Weather-Ometer exposure due to delamination and chalking.
(2) Failed after 8 months Weather-Ometer exposure due to crumbling and brittleness.
(3) Elongation too low to be useful for measurement.

TABLE 29

TENSILE PROPERTIES OF HOUSING MATERIALS AFTER 12 MONTHS WEATHER-OMETER EXPOSURE

Glazing Material	Tensile Strength(psi)		Modulus(psi x 10^{-5})		Ultimate Elongation(%)	
	Original	After 12 Months	Original	After 12 Months	Origianl	After 12 Months
Super Dorlux	4150	(1)	9.1	-	<1	-
Pan-L-Board	1570	(1)	1.3	-	5.5	-
FRP Sheet	10260	11040	14.1	17.8	2	1.7
S-660 Polyester	3710	3980	18.9	20.9	<1	<1
Carbon Black Crosslinked HDPE	3525	2870	1.52	1.38	259	287
Clay Filled Crosslinked HDPE	2520	600	1.51	1.34	248	7.8
Melamine M6024	3560	3510	14.9	13.8	<1	<1
Filled Phenolic	6050	6490	18.9	18	<1	<1
Dylark 250	4110	1450	3.2	3.12	<1	1
Talc Filled Polypropylene	4090	2970	7.6	5.83	8	2.7
Glass Filled Polypropylene Foam	1440	(2)	1.0	-	7.5	-
Cellular PVC	1680	1690	1.1	1.06	46	6
Geon 7084 PVC	4800	6220	4.6	4.89	46.5	4.7
Geon 85857 PVC	4770	6050	4.0	3.93	5.5	2.7

(1) Failed after 8 months Weather-Ometer exposure due to severe delamination and chalking.

(2) Failed after 8 months Weather-Ometer exposure due to brittleness and crumbling.

TABLE 30

TENSILE PROPERTY RETENTION OF HOUSING MATERIALS AFTER FOUR, EIGHT, AND TWELVE MONTHS AGING IN THE WEATHER-OMETER

	% Tensile Strength Retained			% Ultimate Elongation Retained		
Material	4 Months	8 Months	12 Months	4 Months	8 Months	12 Months
Super Dorlux	46	(2)	(2)	90	(2)	(2)
Pan-L-Board	297	(2)	(2)	31	(2)	(2)
FRP Sheet	113	106	108	(1)	(1)	(1)
S-660 Polyester	108	117	107	(1)	(1)	(1)
Carbon-filled Crosslinked HDPE	68	75	81	88	97	111
Clay-filled Crosslinked HDPE	11	32	24	7	6	3
Melamine M6024	114	97	99	(1)	(1)	(1)
Filled Phenolic FM 4005	109	76	107	(1)	(1)	(1)
Dylark 250	51	35	35	(1)	(1)	(1)
Talc Filled Polypropylene	97	79	73	38	38	34
30% Glass-filled Polypropylene Foam	83	(3)	(3)	27	(3)	(3)
Geon PVC Cellular Sheet	118	98	101	43	15	13
Geon 7084 PVS	142	144	130	17	9	10
Geon 85857 PVC	135	122	127	35	36	49

(1) The percent elongation of these materials are too low to be useful for measurement.
(2) Failed after 8 months of Weather-Ometer exposure due to severe delamination and chalking.
(3) Failed after 8 months of Weather-Ometer exposure due to crumbling and brittleness.

TABLE 31

CHEMICAL RESISTANCE OF HOUSING MATERIALS

Housing	Solution	Weight			Thickness			Width			Length		
		Original	Immersed	Change	Original	Immersed	Change	Original	Immersed	Change	Original	Immersed	Change
Poly. S-660	H_2SO_4 (1)	13.1360	13.0925	-0.0435	0.141	0.141	0	1.035	1.034	-0.001	3.001	3.001	0
"	"	13.0282	12.9695	-0.0587	0.140	0.140	0	1.031	1.030	-0.001	3.006	3.006	0
"	"	12.6245	12.5740	-0.0505	0.140	0.140	0	1.028	1.026	-0.002	2.865	2.865	0
Average				-0.0509			0			-0.001			0
Poly. S-660	HNO_3 (2)	13.2571	13.2765	+0.0194	0.141	0.141	0	1.033	1.034	+0.001	3.004	3.011	+0.007
"	"	13.0900	13.1070	+0.0170	0.140	0.140	0	1.030	1.034	+0.004	3.007	3.008	+0.001
"	"	12.3173	12.3290	+0.0117	0.137	0.137	0	1.034	1.034	+0.002	2.873	2.875	+0.002
Average				+0.0160			0			+0.002			+0.003
Poly. S-660	Ethylene Glycol (3)	12.9318	12.9360	+0.0042	0.137	0.137	0	1.030	1.030	0	3.010	3.010	0
"	"	13.1838	13.1887	+0.0049	0.141	0.141	0	1.031	1.031	0	3.003	3.003	0
"	"	12.8066	12.8117	+0.0051	0.137	0.137	0	1.025	1.025	0	3.010	3.010	0
Average				+0.0047			0			0			0
Polyply. FRP	H_2SO_4	5.3496	5.3110	-0.0386	0.141	0.141	0	0.756	0.756	0	1.666	1.665	-0.001
"	"	5.3313	5.2870	-0.0443	0.141	0.141	0	0.756	0.756	0	1.669	1.669	0
"	"	5.2525	5.1975	-0.0550	0.139	0.139	0	0.758	0.758	0	1.662	1.661	-0.001
Average				-0.0460			0			0			-0.001
Polyply. FRP	HNO_3	5.2792	4.9030	-0.3762	0.140	0.140	0	0.752	0.752	0	1.665	1.665	0
"	"	5.2206	4.8525	-0.3681	0.139	0.139	0	0.754	0.754	0	1.664	1.664	0
"	"	5.2880	4.9220	-0.3580	0.140	0.140	0	0.759	0.759	0	1.665	1.665	0
Average				-0.3722			0			0			0
Polyply.FRP	Ethylene Glycol	5.2930	5.2938	+0.0008	0.140	0.140	0	0.754	0.754	0	1.667	1.667	0
"	"	5.2875	5.2878	+0.0003	0.139	0.139	0	0.756	0.756	0	1.672	1.672	0
"	"	5.2655	5.2664	+0.0009	0.140	0.140	0	0.756	0.756	0	1.665	1.665	0
Average				+0.0007			0			0			0

TABLE 31 - Continued

CHEMICAL RESISTANCE OF HOUSING MATERIALS

Housing	Solution	Weight			Thickness			Width			Length		
		Original	Immersed	Change	Original	Immersed	Change	Original	Immersed	Change	Original	Immersed	Change
Carbon Blk/ HDPE	H_2SO_4	3.3646	3.3658	+0.0012	0.123	0.123	0	1.037	1.037	0	1.669	1.680	+0.011
"	"	3.5869	3.5876	+0.0007	0.131	0.131	0	1.030	1.030	0	1.671	1.675	+0.004
"	"	3.5027	3.5036	+0.0009	0.127	0.127	0	1.033	1.034	+0.001	1.671	1.673	+0.002
Average				+0.0009			0			0			+0.006
Carbon Blk/HDPE	HNO_3	3.5335	3.5335	0	0.132	0.132	0	1.030	1.030	0	1.647	1.647	0
"	"	3.4174	3.4175	+0.0001	0.124	0.124	0	1.026	1.026	0	1.638	1.638	0
"	"	3.4035	3.4035	0	0.125	0.125	0	1.035	1.035	0	1.637	1.637	0
Average				0			0			0			0
Carbon Blk/HDPE	Ethylene Glycol	3.2259	3.2268	+0.0009	0.119	0.120	+0.001	1.014	1.014	0	1.672	1.675	+0.003
"	"	3.2719	3.2723	+0.0004	0.120	0.120	0	1.036	1.036	0	1.671	1.671	0
"	"	3.6172	3.6172	0	0.135	0.135	0	1.031	1.031	0	1.665	1.665	0
Average				+0.0004			0			0			+0.001
Melamine M6024	H_2SO_4	13.1709	13.2835	+0.1126	0.143	0.147	+0.004	1.029	1.032	+0.003	3.006	3.012	+0.006
"	"	12.0873	12.1969	+0.1096	0.139	0.145	+0.006	1.033	1.035	+0.002	2.830	2.843	+0.013
"	"	13.1829	13.2765	+0.0936	0.145	0.148	+0.003	1.031	1.036	+0.005	3.004	3.008	+0.004
Average				+0.1053			+0.004			+0.003			+0.008
Melamine M6024	HNO_3	13.8598	13.2485	-0.6113	0.153	0.149	-0.004	1.040	1.035	-0.005	3.005	3.007	+0.002
"	"	13.8154	13.2875	-0.5279	0.153	0.149	-0.004	1.040	1.039	-0.001	3.009	3.006	-0.003
"	"	13.6004	13.3535	-0.2469	0.152	0.149	-0.003	1.030	1.041	+0.001	3.010	3.016	+0.006
Average				-0.4620			-0.004			+0.002			+0.002

TABLE 31- Continued

CHEMICAL RESISTANCE OF HOUSING MATERIALS

Housing	Solution	Weight			Thickness			Width			Length		
		Original	Immersed	Change	Original	Immersed	Change	Original	Immersed	Change	Original	Immersed	Change
Melamine M6024	Ethylene Glycol	13.1991	13.2278	+0.0287	0.143	0.143	0	1.033	1.035	+0.002	3.006	3.010	+0.004
"	"	13.1998	13.2274	+0.0276	0.144	0.144	0	1.028	1.031	+0.003	3.002	3.002	0
"	"	12.0922	12.1181	+0.0259	0.139	0.139	0	1.024	1.024	0	2.852	2.855	+0.003
Average				+0.0274			0			+0.002			+0.002
Filled Phenolic FM4005	H_2SO_4	13.7530	13.8605	+0.1075	0.153	0.155	+0.002	1.040	1.045	+0.005	3.009	3.010	+0.001
"	"	13.5172	13.6300	+0.1128	0.150	0.153	+0.003	1.040	1.040	0	3.009	3.012	+0.003
"	"	12.7801	13.8715	+1.0914	0.151	0.153	+0.002	1.023	1.023	0	2.848	2.850	+0.002
Average				+0.4372			+0.002			+0.002			+0.002
Filled Phenolic FM4005	HNO_3	13.1310	14.0295	+0.8985	0.143	0.156	+0.013	1.028	1.045	+0.017	3.002	3.007	+0.005
"	"	13.1554	13.9705	+0.8151	0.144	0.156	+0.012	1.033	1.041	+0.008	2.999	3.010	+0.010
"	"	13.2471	13.7735	+0.5264	0.144	0.156	+0.012	1.028	1.030	+0.002	3.006	3.014	+0.008
Average				+0.7467			+0.012			+0.009			+0.008
Filled Pehnolic FM4005	Ethylene Glycol	13.4218	13.4261	+0.0043	0.149	0.149	0	1.039	1.040	+0.001	3.010	3.010	0
"	"	13.4246	13.4308	+0.0062	0.150	0.150	0	1.037	1.037	0	3.009	3.011	+0.002
"	"	13.6779	13.6814	+0.0035	0.153	0.153	0	1.034	1.034	0	2.996	2.999	+0.003
Average				+0.0047			0			0			+0.002

(1) H_2SO_4 (3 %) - added 16.6 mls. of H_2SO_4 to 988 mls. H_2O

(2) HNO_3 (10%) - added 108 mls. of HNO_3 to 901 mils. H_2O

(3) Ethylene glycol- prepared a 50/50 solution in distilled water

TABLE 32

MATERIALS SELECTED FOR CRITICAL PROPERTY EVALUATION

Material	Composition
Tedlar 400XRB160SE	Fluorocarbon
PFA	Fluorocarbon
Halar 500	Fluorocarbon
Kynar 450	Fluorocarbon
FEP 100-A	Fluorocarbon
National Metallizing 45-95-2	Thermoplastic Polyester
Llumar	Thermoplastic Polyester
Filon 558	Thermoset Polyester
Sunlite Premium II	Thermoset Polyester
Tuffak CM-2	Polycarbonate
Plexiglas V-811	Acrylic
Flexigard	Polyester/Acrylic Laminate
X-ℓ EVA	Crosslinked Ethylene/Vinyl Acetate Copolymer

TABLE 33.

TENSILE PROPERTIES AT 250°F

Material	Break Strength PSI	Modulus 10^5 PSI	Ultimate % Elongation
Kynar 450	10,380	1.32	150%
PFA	2,660	0.87	336%
Tedlar 400XRB160SE	4,780	0.15	303%
Halar 500	3,780	1.26	357%
FEP 100-A	689	0.086	161%
Nat. Metallizing 45-95-2	16,145	8.47	73%
Llumar	13,300	8.76	72%
Flexigard	8,010	7.6	140%
Filon 558	6,880	20.2	5%
Sunlite Premium II	8,260	28.5	5%
Tuffak CM-2	5,490	18.0	124%
Plexiglas V-811	1,450	3.18	160%
X-ℓ EVA (2)	(1)	-	-

(1) EVA became too soft in jaw at 250°F to get a reading.

(2) Crosslinked ethylene/vinyl acetate copolymer

TABLE 34

TENSILE PROPERTIES AT 250°F AND AT ROOM TEMPERATURE

Glazing Material	Tensile Strength (PSI) Original	Tensile Strength (PSI) @ 250°F	Loss	Ultimate % Elongation Original	Ultimate % Elongation @ 250°F	% Change
Kynar 450	7,197	10,380	--	337	150	-55
P.F.A.	4,090	2,660	65	251	336	+34
Tedlar 400XRB160SE	14,271	4,780	67	214	303	+42
Halar 500	10,500	3,780	64	115	357	+310
FEP 100-A	7,072	689	90	177	161	- 9
Llumar	29,936	13,300	56	53	72	+36
Flexigard 7410	10,600	8,010	24	< 1	14	+1400
Filon 558	8,390	6,880	18	2.8	5	+79
Sunlite Premium II	10,483	8,260	21	3.9	5	+28
Tuffak CM-2	7,810	5,490	30	70	124	+60
Plexiglas V-811	5,127	1,450	72	3.3	16	+484
X-ℓ EVA 150	(1)	--	--	--	--	--
Nat. Metallizing 45-95-2	39,306	16,145	59	48	73	+52

(1) EVA became too soft in jaw @ 250°F @ 0-4 lbs to get a reading.

TABLE 35

TENSILE PROPERTIES AFTER 4 MONTHS @ 150°C

Glazing Material	Tensile Strength (PSI)		% Retained	Modulus PSI X10^5		% Retained	Ultimate % Elongation		% Retained
	Original	4 Months @ 150 °F		Original	4 Months @ 150 °F		Original	4 Months @150 °F	
Tedlar 400XRB160SE	14,271	6,630	46	2.28	2.47	108	214	5.25	2
PFA	4,090	3,430	84	0.48	0.56	117	251	2.64	1
Halar 500	10,500	6,600	63	1.68	1.37	82	115	112	97
FEP 100-A	7,072	1,870	26	0.79	0.65	82	177	242	136
Nat.Met.45-95-2	39,306	2,570	7	3.43	3.54	103	48	1.1	2
Llumar	29,936	(1)	-	5.02	-	-	53	-	-
Filon 558	8,390	10,320	123	4.23	4.07	96	2.8	3.07	109
Sunlite Premium II	10,483	8,490	81	3.47	4.74	137	3.9	2.1	54
Tuffak CM-2	7,810	5,650	72	1.78	1.3	73	70	7.1	10
Plexiglas V-811	5,127	(2)	-	2.43	-	-	3.3	-	-
X-ℓ EVA	1,900	(3)	-	-	-	-	510	-	-
Kynar 450	7,197	(4)	-	1.10	-	-	337	-	-
Flexigard	10,600	(5)	-	4.19	-	-	< 1	-	-

(1) Tab failures-cracked and brittle
(2) Samples melted and bubbled
(3) Samples shrank and melted together
(4) Samples shrank to 1/2 size after one hour @ 150°F
(5) Flexigard is a polyester/acryalic laminate, the acrylic shrank to about 1/4 normal size.

TABLE 36

TENSILE PROPERTIES
AFTER 8 MONTHS AGING IN A 150°C OVEN

Material	Tensile Strength psi			Modulus psi x 10^5			Ultimate Elongation %		
	Original	Oven Aging	% Retained	Original	Oven Aging	% Retained	Original	Oven Aging	% Retained
Tedlar 400XRB16SE	14,271	(1)	-	2.28	-	-	214	-	-
PFA	4,090	3,600	88	.48	0.56	116	251	280	106
Halar 500	10,500	6,530	62	1.68	1.57	93	115	128	111
FEP 100-A	7,072	1,740	25	0.79	0.53	67	177	95	53
Kynar 450	7,197	(1)	-	1.10	-	-	337	-	-
Nat. Met. 45-95-2	39,306	(1)	-	3.43	-	-	48	-	-
Llumar	29,936	(1)	-	5.02	-	-	53	-	-
Filon 558	8,390	7,580	90	4.23	3,35	79	3	3	100
Sunlite Premium II	10,483	8,020	77	3.47	4.37	126	4	2	50
Plexiglas V-811	5,127	(2)	-	2.43	-	-	3	-	-

(1) Samples embrittled

(2) Samples melted

(3) Sample shrank

TABLE 37

PERCENT TENSILE PROPERTIES RETAINED AFTER OVEN AGING AT 150°C

Material	Tensile Strength Original (psi)	% Retained		Modulus psi X 10^5 Original	% Retained		Ultimate Elongation % Original	% Retained	
		After 4 Months	After 8 Months		After 4 Months	After 8 Months		After 4 Months	After 8 Months
Tedlar 400XRB160SE	14,271	46	(1)	2.28	108	-	214	2	-
PFA	4,090	84	88	0.48	116	116	251	105	106
Halar 500	10,500	63	62	1.68	82	93	115	97	111
FEP 100-A	7,072	26	25	0.79	82	67	177	136	53
Kynar 450	7,197	(3)	(3)	1.10	-	-	337	-	-
Nat. Met. 45-95-2	39,306	7	(1)	3.43	103	-	48	2	-
Llumar	29,936	(1)	(1)	5.02	-	-	53	-	-
Filon 558	8,390	123	90	4.23	96	79	3	100	100
Sunlite Premium II	10,483	81	77	3.47	137	126	4	50	50
Plexiglas V-811	5,127	(2)	(2)	2.43	-	-	3	-	-

(1) Embrittled
(2) Samples melted
(3) Samples shrank

TABLE 38

EFFECT OF OVEN(1) AGING ON GLAZING MATERIALS

Sample	Visual Changes After 5 hrs.	After 2 days	After 5 days
Flexigard	Acrylic top cover is shrinking	Same	Acrylic shrank about 1/2" on all sides
Lexan	Bowing convexly	Feels tacky, bowing upward	Very tacky, bowing upward
Tuffak CM-2	Bowing convexly	Same	Same
Glasteel 500	Yellowing	Yellowing	Yellowing
Sunlite Premium II	No Change	No Change	Slight to moderate yellowing
Filon 558	Yellowing	Yellowing	Moderate yellowing
Tedlar 400 X RB160SE	No Change	No Change	No Change
PFA	No Change	No Change	No Change
Llumar	No Change	No Change	No Change
Kynar 450	No Change	No Change	No Change
Halar 500	Slight shrinkage	Same	Same
Nat. Met. 45-95-2	No Change	No Change	No Change
FEP 100-A	No Change	No Change	No Change
Plexiglas V-811	Sagging	A lot of sagging after 6 hours	Sagging
X-ℓ EVA	Sagging	Sagging, holes	Sagging

(1) Air circulating oven set at 134°C (375°F).

TABLE 39

EFFECTIVENESS OF SCRIM MATERIALS IN PREVENTING SAGGING OF PLEXIGLAS AND EVA WEHN HEATED IN AN AIR OVEN (1)

Material	1 Hour	3 Hours	6 Hours	1 Day	2 Days	3 Days
EVA with Craneglas Scrim	Tacky slight sagging	Same	Same	Slight brown tint. Slight sagging.	Same; brown tint getting worse	Brown tint, only some slight sagging
EVA with 2 pcs of Craneglas Scrim	No Change	Slightly tacky, very slight sagging	Same	Slight brown tint	Same; brown tint getting worse	Brown tint is quite bad but sagging has been held in check
Plain EVA	Tacky, sagging	Same	Same	Failure-sagging badly, holes are developing	--	--
Plexiglas V-811 with Craneglas Scrim	No Change	Slight Sagging	Same	Same with light brown tint	Brown tint becoming worse sagging is also worse	Failed-brown tint, sagging is quite bad
Plexiglas V-811 with Durolon S-50 Scrim	No Change	No Change	No Change	No Change	Yellowing, slight pulling away at nail holes	Same
Plexiglas V-811	Sagging about 1/4"	Sagging about 1/2" in center	Sagging about 1" in center-failure	No Change	Slight yellowing	Slight yellowing

Note: Scrim materials are compression molded between two pieces of glazing material.

(1) Oven set at 134°C.

TABLE 40

TENSILE IMPACT OF GLAZING MATERIALS

Chemical Nature	Material	Tensile Impact Strength(1)	
		Room Temp.	0°F
Fluorocarbon	PFA9705	159	232
Flurocarbon	Halar 500	301	274
Fluorocarbon	Tedlar 400XRB160SE	194	240
Fluorocarbon	Kynar 450	339	353
Fluorocarbon	FEP 100-A	499	412
Thermoplastic Polyester	Nat. Metallizing 45-95-2	121	141
Thermoplastic Polyester	Llumar	201	176
Thermoset Polyester	Filon 558	35	21
Thermoset Polyester	Sunlite II Premium	25	20
Polycarbonate	Tuffak CM-2	116	106
Acrylic	Plexiglas V-811	15	2
Acrylic/polyester Laminate	Flexigard 7410	116	88
Crosslinked Polyolefin	X-1 EVA Scrim	(2)	(2)

(1) Units are (ft lbs/in^2)

(2) Too soft to measure

TABLE 41

EFFECT OF FALLING SAND ABRASION TEST ON TRANSMISSION OF GLAZING MATERIALS

	Material	Original % Transmission(1)	% Transmission After Abrasion(2)
1.	Tedlar 400XRB160SE	92	89
2.	PFA	94	94
3.	Halar 500	93	88
4.	Kynar 450	93	91
5.	FEP 100A	96	94
6.	Nat. Met. 45-95-2	85	84
7.	Llumar	86	82
8.	Filon 558	87	84
9.	Sunlite Premium II	87	77
10.	Lexan	86	84
11.	Tuffak CM-2	85	85
12.	Plexiglas V-811	90	85
13.	Crosslinked EVA/Scrim	91	83
14.	Flexigard 7410	88	86

(1) See Table 6 for definition of % transmission

(2) One pound of sand (standard sand 20-30 ASTM designation C-190) falling thru a 30 inch pipe abrading surface of sample which is mounted at a 45° angle.

TABLE 42

DUROMETER HARDNESS

Material	Durometer	Shore After One Second	Hardness (1) After 15 Seconds
Fluorocarbons			
Tedlar 400XRB160SE	D	75	72
P.F.A.	D	57	55
Halar 500	D	73	70
Kynar 450	D	85	82
F.E.P. 100-A	D	57	55
Thermoplastic Polyesters			
Mylar	D	86	85
Nat. Metallizing 45-95-1	D	(2)	(2)
Nat. Metallizing 45-95-2	D	(2)	(2)
Llumar	D	89	88
Ardel	D	88	85
Thermoset Polyesters			
Filon 558	D	92	91
Sunlite Premium II	D	91	90
Gasteel 500	D	91	90
Miscellaneous			
Lexan	D	85	84
Tuffak CM-2	D	85	84
Tenite 479 CAB	D	82	79
Plexiglas V-811	D	87	86
PVC Polyester Scrim Reinforced	D	43	35
Flexigard 7410	D	86	85
Crosslinked EVA	A	78	74

(1) All are durometer D except EVA which is Durometer A.

TABLE 43

UV STABLE POLYMERS

Polymer	Problems
Fluorocarbons	High cost
Silicones	High cost, too soft
Acrylics	Possible stagnant temperature resistance

TABLE 44

UV ABSORBING FILMS[3]

	Tedlar[1] 20	Halar[2] 500
% Transmission before aging	13	36
% Elongation retained after 120 days in Weather-Ometer	100	135
% Elongation retained after 120 days under the RS-4 Sunlamp	141	131

---

(1) Polyvinyl fluoride
(2) Ethylene/chlorotrifluoroethylene
(3) Neither contain a UV absorber

TABLE 45

UV PROTECTIVE FILMS

Manufacturer	Film	Nature	Contains UV Absorbers	Thickness (in.)	% Optical Transmission			
					UV 290-350 nm			Visible 350-900 nm(1)
					Ave.	Range		
						290	350	
E. I. DuPont	Tedlar 100BG30UT	Polyvinylfluoride	Yes	.001	0	0	0	83
E. I. DuPont	Tedlar 400XRB160SE	Polyvinylfluoride	Yes	.004	2.5	0	5	79
Xcel Corp.	Korad 201R	Acrylic	Yes	.003	2.5	0	5	88

(1) Specular transmission - normalized to solar energy wavelengths.

TABLE 46

BONDING AGENTS SCREENED

Dow Corning Z-6029 N-(2-aminoethyl)-3-aminophropyltrimethoxy Silane

Dow Corning Z-6030 γ-Methacryloxypropyltrimethoxy Silane

Dow Corning Z-6032 Vinylbenzylamine Functional Silane

Dow Corning Z-6062 Mercaptropropyltrimethoxy Silane

General Electric SS-4179 Silane (GE)

DuPont Tyzor AA Organic Titanate

DuPont Tyzor TE Organic Titanate

Pierce Surfasil Silane

DuPont 68070 Acrylic Adhesive (DP)

Dow Corning 90% Z6030/10% Z6020 (DC)

TABLE 47

GLAZING LAMINATIONS

Sample No.	Substrate	Top Film	Adhesive	Observations or Problems
A9309-1	Plex. V-811⁽¹⁾	Tedlar SE⁽²⁾	DuPont⁽³⁾	Transparent
A13596-2	EVA⁽⁴⁾	Halar⁽⁵⁾	Lupersol⁽⁶⁾	Transparent
A13593-1	Tedlar SE⁽²⁾	Korad⁽⁷⁾	Lupersol⁽⁶⁾	Transparent and slightly yellowed
A13594-2	Plex. V-811⁽¹⁾	Korad⁽⁷⁾	Heat Only	Surface irregularities but transparent
A9311-3	Plex. V-811⁽¹⁾	Tedlar UT⁽⁸⁾	DuPont⁽³⁾	Transparent
A9312-1	EVA⁽⁴⁾	Korad⁽⁷⁾	DuPont⁽³⁾	Transparent
A9312-3	EVA⁽⁴⁾	Tedlar UT⁽⁸⁾	DuPont⁽³⁾	Transparent
A9307-2	EVA⁽⁴⁾	Tedlar SE⁽²⁾	Heat Only	Transparent and slightly yellowed
A9310-1	Llumar⁽⁹⁾	Korad⁽⁷⁾	DuPont⁽³⁾	Yellowed Sample. Transparent
A9310-2	Llumar⁽⁹⁾	Halar⁽⁵⁾	DuPont⁽³⁾	Yellowed Sample. Surface irregularities but transparent
A9310-3	Llumar⁽⁹⁾	Tedlar UT⁽⁸⁾	DuPont⁽³⁾	Yellowed transparent sample. Small adhesive layer bubbles.

(1) Plexiglas V-811 - Methyl Methacrylate Homopolymer
(2) Tedlar 400XRB160SE - Polyvinyl Fluoride
(3) DuPont 68070 - F&F Adhesive
(4) Crosslinked Ethylene/Vinyl Acetate
(5) Halar 500 - Ethylene/Chlorotrifluoroethylene
(6) Lupersol 101 - 2,5-Dimethyl-2,5-Di(t-butylperoxy) Hexane
(7) Korad 201R - Multistage Acrylic Copolymer
(8) Tedlar 100BG30UT - Polyvinyl Fluoride
(9) Llumar - Polyester

TABLE 48

BONDING(1) OF LAMINATES

Substrates	Korad 201R (2)	Tedlar (2) 100BG30UT	Halar 500 (2)	Tedlar 400SG20TR (2)
Tedlar 400XRB160SE	Heat N	N	N	N
	Peroxide S	N	F	N
	GE (3) F	N	F	N
	DC F	N	F	N
	DP S	S	F	N
Plexiglas Acrylic V-811	Heat S	N	N	N
	Peroxide S	S	F	S
	GE S	M	F	S
	DC S	F	F	F
	DP S	S	M	M
Crosslinked EVA	Heat F	M	N	F
	Peroxide S	M	M	M
	GE S	S	F	F
	DC S	S	F	F
	DP S	S	F	S
Llumar Polyester	Heat N	N	N	N
	Peroxide S	F	F	F
	GE F	F	F	F
	DC M	F	F	F
	DP S	S	S	F

(1) F - Failure

M - Moderate

S - Strong Adhesion

N - Not Attempted

(2) Protective top cover.

(3) See Table 46 for adhesive explanation

TABLE 49A(1)

LAMINATION CHART

	Korad 201R	Halar 500	Tedlar 400SG20TR	Tedlar 100BG30UT
Tedlar 400XRB160SE	N S	N F	N N	N N
Plexiglas V-811	S S	N F	N S	N S
Crosslinked EVA	F S	M M	F M	M M
Llumar Polyester	N S	N F	N F	N F

S = Strong Adhesion
M = Moderate Adhesion
F = Failure
N = Not Attempted

(1) The top box in each section of the table uses lamination by heat alone; the bottom half of each box uses peroxide.

TABLE 49B(1)

LAMINATION CHART

		Korad 201R	Halar 500	Tedlar 400SG20TR	Tedlar 100BG30UT
Tedlar 400XRB160SE	GE	F	F	N	N
	Dow Corning	F	F	N	N
Plexiglas V-811	GE	S	F	S	M
	Dow Corning	S	F	F	F
Crosslinked EVA	GE	S	F	F	S
	Dow Corning	S	F	F	S
Llumar	GE	F	F	F	F
	Dow Corning	M	F	F	F

S = Strong Adhesion

M - Moderate Adhesion

F = Failure

N = Not Attempted

(1) Adhesives used are GESS-4179 and Dow Corning 90% Z6030/ 10% Z6020.

TABLE 50

LAMINATE BOND(1) STRENGTH AFTER ONE WEEK WATER IMMERSION

Substrate	Top Film	Adhesive	Original Adhesive Strength	Adhesion(1) After Water Immersion
Llumar(6)	Korad 201R(7)	DP(14)	S	M
Llumar	Korad 201R	Lupersol 101(13)	M	M (Hazy)
Llumar	Halar 500(8)	DP	S	M
Llumar	Tedlar UT(10)	DP	S	M
EVA(5)	Korad 201R	DC(12)	M	M
EVA	Korad 201R	DP	S	Film Brittle
EVA	Tedlar UT	DP	S	(2)
EVA	Tedlar UT	GE (11)	M	M
EVA	Tedlar UT	DC	M	M
EVA	Tedlar 160SE(3)	DP	S	S
EVA	Tedlar 160SE	DC	S	S
EVA	Tedlar SE	Heat Only	S	S
EVA	Korad 201R	Heat Only	F	F
EVA	Korad 201R	GE	M	F
EVA	Korad 201R	Lupersol 101	S	M (Hazy)
EVA	Tedlar 20(9)	Lupersol 101	S	M
Plexiglas V-811(4)	Tedlar 20	Lupersol 101	M	F (Hazy)
Plexiglas V-811	Tedlar UT	Lupersol 101	M	M
Plexiglas V-811	Tedlar UT	DP	S	S
Plexiglas V-811	Korad 201R	Lupersol 101	S	S
Plexiglas V-811	Korad 201R	Heat Only	S	S
Plexiglas V-811	Korad 201R	DC	S	S
Plexiglas V-811	Korad 201R	DP	S	S
Plexiglas V-811	Korad 201R	GE	S	S
Tedlar 160SE	Korad 201R	DP	S	S (Opaque)
Tedlar 160SE	Korad 201R	Peroxide	S	(2)

(1) S = Strong Adhesion. Attempts to delaminate will deform, bend, tear, and/or break off film/substrate. Only composites with an "S" rating dry were chosen for water immersion.

M = Moderate adhesion, delamination occurs with moderate, not strong, manual effort: without deforming, (etc...), materials.

F = Adhesive failure. Very little effort is necessary to cause delamination.

(2) Film breaks and chips during delamination attempts.
(3) Tedlar 400XRB160SE (4 mil, UV stabilized).
(4) Polymethyl methacrylate.
(5) Crosslinked EVA.
(6) Llumar-Polyester.
(7) UV stabilized acrylic film.
(8) Ethylene/chlorotrifluoroethylene.
(9) Tedlar 400SG20TR.
(10) Tedlar 100BG30UT.
(11) GE SS4179 Silicone Adhesive for Plastics.
(12) Dow Corning Z6030; -Methacryloxypropyl Trimethoxy Silane
(13) Lupersol 101, 2,5-Dimethyl-2,5-Di(t-Butylperoxy)Hexane; by Lucidol.
(14) Dupont 68070 adhesive.

TABLE 51

GLAZING LAMINATES ON EXPOSURE IN THE WEATHER-OMETER

Top Film	Substrate	Adhesive
Korad(7)	Tedlar SE(2)	Lupersol(6)
Korad	Plex. V-811(1)	Heat Only
Korad	EVA(4)	DuPont(3)
Korad	Llumar(9)	DuPont
Halar(5)	EVA	Lupersol
Halar	Llumar	DuPont
Tedlar UT(8)	Plex. V-811	DuPont
Tedlar UT	EVA	DuPont
Tedlar UT	Llumar	DuPont
Tedlar SE(2)	Plex. V-811	DuPont
Tedlar SE	EVA	Heat Only

(1) Plexiglas V-811 - Methyl Methacrylate Homopolymer.
(2) Tedlar 400XRB160SE - Polyvinyl Fluoride (4 Mil UV stabilized).
(3) duPont 68070 - Adhesive.
(4) Crosslinked Ethylene/Vinyl Acetate.
(5) Halar 500 - Ethylene/Chlorotrifluoroethylene.
(6) Lupersol 101 - 2,5-Dimethyl-2,5-Di(t-butylperoxy) Hexane.
(7) Korad 201R - Multistage Acrylic Copolymer.
(8) Tedlar 100BG30UT - Polyvinyl Fluoride (1 Mil, adhesive bondable, UV stabilized).
(9) Llumar - Polyester.

TABLE 52

COMPOSITE BOND(1) STRENGTHS AND QUALITATIVE COLOR CHANGES AFTER 4 MONTH WEATHER-OMETER EXPOSURE

Substrate	Cover Film	Adhesive	Bond Strength Before	Bond Strength After	Color Before	Color After	Comments
Llumar	Korad 201R	DuPont 68070	S	F	Clear	Cloudy	Failed-All samples are delaminating
Llumar	Halar 500	DuPont 68070	S	S	Clear	Slight Clouding	Failed-Llumar cracks when bent toward substrate side
Llumar	Tedlar 100BG30UT	DuPont 68070	S	S	Clear	Slight Clouding	--
X-ℓ(2) EVA	Tedlar 400XRB160SE	Lupersol 101	S	S	Clear	Clear	--
X-ℓ EVA	Tedlar 100BG30UT	DuPont 68070	S	S	Clear	Slight Clouding	--
X-ℓ EVA	Korad 201R	DuPont 68070	S	F	Clear	Clear	Failed-Korad crumbles off when EVA is bent
X-ℓ EVA	Halar 500 2 mils	Lupersol 101	S	S	Clear	Clear	Very clear
Plexiglas V-811	Korad 201R	Heat	S	S	Clear	Slight Clouding	--
Plexiglas V-811	Tedlar 100BG30UT	DuPont 68070	S	S	Clear	Slight Clouding	--
Plexiglas V-811	Tedlar 400 X RB160SE	DuPont 68070	S	S	Clear	Clear	--
Tedlar 400XRB160SE	Korad 201R	Lupersol 101	S	S	Clear	Clear	Failed-Korad crumbles

(1) F-Failure, M-Moderate, S-Strong Adhesion

(2) Peroxide crosslinked ethylene/vinyl acetate copolymer

TABLE 53

COMPOSITE BOND(1) STRENGTHS AND QUALITATIVE COLOR CHANGES AFTER 8 MONTH WEATHER-OMETER EXPOSURE

Substrate	Cover Film	Adhesive	Bond Strength		Color		Comments
			Before	After	Before	After	
Llumar	Korad 201R	DuPont 68070	S	F	Clear	Cloudy	Failed-All samples are delaminating
Llumar	Halar 500	DuPont 68070	S	S	Clear	Slight Clouding	Failed at 4 mo. -Llumar cracks when ben toward substrate side
Llumar	Tedlar 100B G30UT	DuPont 68070	S	M	Clear	Slight Clouding	Tedlar peels off and tears with moderate pull
X-1(2) EVA	Tedlar 400XRB160SE	Lupersol 101	S	S	Clear	Clear	--
X-1 EVA	Tedlar 100B G30UT	DuPont 68070	S	S	Clear	Slight Clouding	--
X-1 EVA	Korad 201R	DuPont 68070	S	F	Clear	Clear	Failed at 4 months - Korad crumbles off when EVA is bent
X-1 EVA	Halar 500	Lupersol 101	S	S	Clear	Clear	Very clear
Plexiglas V-811	Korad 201R	Heat	S	(3)	Clear	Mod. Clouding	Chalking, Korad tab has disintegrated; Failure
Plexiglas V-811	Tedlar 100B G30UT	DuPont 68070	S	S	Clear	Slight Clouding	--
Plexiglas V-811	Tedlar 400 X RB160SE	DuPont 68070	S	S	Clear	Clear	--
Tedlar 400XRB160SE	Korad 201R	Lupersol 101	S	S	Clear	Clear	Failed at 4 months-Korad crumbles

(1) F-Failure, M-Moderate, S-Strong Adhesion

(2) Peroxide crosslinked ethylene/vinyl acetate copolymer

(3) Tab has disintegrated, should be considered a failure

TABLE 54

COMPOSITE BOND(1) STRENGTHS AND QUALITATIVE COLOR CHANGES AFTER 12 MONTH WEATHER-OMETER EXPOSURE

Substrate	Cover Film	Adhesive	Bond Strength		Color		Comments
			Before	After	Before	After	
Llumar	Korad 201R	DuPont 68070	S	F	Clear	Cloudy	Failed at 4 Months- all samples are delaminating
Llumar	Halar 500	DuPont 68070	S	S	Clear	Slight Clouding	Failed at 4 Months-Llumar cracks when bent toward substrate side
Llumar	Tedlar 100BG30UT	DuPont 68070	S	F	Clear	Slight Clouding	Failed - Tedlar pulls off easily
X-ℓ(2) EVA	Tedlar 400XRB160SE	Lupersol 101	S	S	Clear	Clear	- -
X-ℓ EVA	Tedlar 100BG30UT	DuPont 68070	S	S	Clear	Slight Clouding	If EVA is bent sharply, the Tedlar cracks
X-ℓ EVA	Korad 201R	DuPont 68070	S	F	Clear	Clear	Failed at 4 months-Korad crumbles off when EVA is bent
X-ℓ EVA	Halar 500	Lupersol 101	S	M	Clear	Clear	Halar 500 pulls off with moderate effort
Plexiglas V-811	Korad 201R	Heat	S	F	Clear	Clouding	Failed at 8 mo.- chalking, Korad Tab has disintegrated
Plexiglas V-811	Tedlar 100BG30UT	DuPont 68070	S	S	Clear	Slight Clouding	--
Plexiglas V-811	Tedlar 400 X RB160SE	DuPont 68070	S	S	Clear	Clear	--
Tedlar 400XRB160SE	Korad 201R	Lupersol 101	S	S	Clear	Clear	Failed at 4 months Korad crumbles

(1) F-Failure, M-Moderate, S-Strong Adhesion

(2) Peroxide crosslinked ethylene/vinyl acetate copolymer

TABLE 55

INTEGRATED SOLAR TRANSMISSION FOR LAMINATES

Top Film		Substrate			
Type	% Solar Trans. (1)	Type	% Solar Trans.	Adhesive	% Solar Trans. of Laminate
Korad 201R	91	Tedlar 400XRB160SE	92	Lupersol 101	89
Korad 201R	91	Plexiglas V-811	90	Heat	87
Korad 201R	91	X-ℓ EVA	91	DuPont 68070	87
Korad 201R	91	Llumar	86	DuPont 68070	86
Halar 500	93	X-ℓ EVA	91	Lupersol 101	89
Halar 500	93	Llumar	86	DuPont 68070	85
Tedlar 100BG30UT	92	Plexiglas V-811	90	DuPont 68070	88
Tedlar 100BG30UT	92	X-ℓ EVA	91	DuPont 68070	87
Tedlar 100BG30UT	92	Llumar	86	DuPont 68070	86
Tedlar 400XRB 160SE	92	Plexiglas V-811	90	DuPont 68070	88
Tedlar 400XRB 160SE	92	X-ℓ EVA	91	Lupersol 101	88

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(1) See Table 6 for definition of % transmission.

TABLE 56

EFFECT OF EXPOSURE OF FILM LAMINATES IN THE WEATHER-OMETER ON PERCENT TRANSMISSION

Substrate	Cover Film	Adhesive	Original	Weather-Ometer Exposure			EMMAQUA Exposure
				% Transmission			% Transmission
				4 Mo.	8 Mo.	12 Mo.	8 Mo.
Llumar	Tedlar 100BG30UT	DuPont 68070	86	85	85	83	76
Llumar	Halar 500	DuPont 68070	85	85	(1)	-	(1)
Llumar	Korad 201R	DuPont 68070	86	(1)	-	-	(2)
X-ℓ EVA	Halar 500	Lupersol 101	89	87	80	72	62
X-ℓ EVA	Tedlar 100BG30UT	DuPont 68070	87	86	84	82	76
X-ℓ EVA	Tedlar 400XRB160SE	Lupersol 101	88	84	81	79	78
X-ℓ EVA	Korad 201R	DuPont 68070	87	86(2)	-	-	(2)
Plexiglas V811	Korad 201R	Heat	87	78	(1)	-	(1)
Plexiglas V811	Tedlar 100BG30UT	DuPont 68070	88	86	84	83	82
Plexiglas V811	Tedlar 400XRB160SE	DuPont 68070	88	85	81	80	81
Tedlar 400XRB160SE	Korad 201R	Lupersol 101	89	87	84	80	(1)

(1) Failed - Sample delaminating

(2) Failed - Korad crumbles when EVA is bent

TABLE 57

ACRYLIC LATEX COATINGS

Manufacturer	Coating	Latex Type	Percent Solids	T_g (°C)	Thermoset Curing Agent
B. F. Goodrich	Hycar 2600x84	Anionic	50	8	Yes: self-cure
B. F. Goodrich	Hycar 2600x91	Anionic	50	20	-
B. F. Goodrich	Hycar 2600x112	Anionic	50	29	Yes: self-cure
B. F. Goodrich	Hycar 2600x138	Anionic	50	25	-
B. F. Goodrich	Hycar 2600x171	Anionic	48	45	Yes: self-cure
B. F. Goodrich	Hycar 2600x172	Anionic	48	45	Yes: self-cure
B. F. Goodrich	Hycar 2600x256	Anionic	50	45	-
B. F. Goodrich	Hycar 2671	Anionic	52	-11	Yes: self-cure
B. F. Goodrich	Hycar 2679	Anionic	48	-3	Yes: self-cure
Rohm & Haas	Rhoplex AC-73	Nonionic	46.5	2	No: -
Rohm & Haas	Rhoplex B-60A	Nonionic	46.5	-27	No: -
Rohm & Haas	Rhoplex B-413	-	39	-	-
Rohm & Haas	Rhoplex B-924	-	38	-	-
Rohm & Haas	Rhoplex CA-12	-	53.5	-	-
Rohm & Haas	Rhoplex MV-1	Anionic	46	-	No: -
Rohm & Haas	Rhoplex WL-91	-	41.5	-	No: -
Staley Chem. Co.	Ubatol 3054	Anionic	40	23.5	-
Staley Chem. Co.	Ubatol 3215	Anionic	40	-	-
National Starch	X-Link 2813	Anionic	45	-2	Yes: self-cure
National Starch	X-Link 3730	Anionic	50	18	Yes: self-cure
National Starch	X-Link 4280	Anionic	51	-4	Yes: self-cure
Polyvinyl Chem.	Neocryl A601	Anionic	32	-	Yes: amine
Polyvinyl Chem.	Neocryl A620	Anionic	40	-	Yes: amine
Polyvinyl Chem.	Neocryl A621	Anionic	40	-	Yes: amine
Polyvinyl Chem.	Neocryl A622	Anionic	32	-	Yes: amine

TABLE 58

SOLVENT-BASED ACRYLIC COATINGS (1)

Manufacturer	Coating	% Solids	Thermoset: Curing Agent	T_g (°C)
Rohm & Haas	Acryloid AT-70	50	Yes: Epoxy	-
"	Acryloid B-44	40	No: -	60
"	Acryloid B-48N	45	No: -	50
"	Acryloid B-50	45	No: -	50
"	Acryloid B-72	50	No: -	40
"	Acryloid B-84	45	No: -	50
"	Acryloid B-99	50	No: -	82
"	Acryloid C10LV	40	No: -	5
Johnson	Permacote 62	14	No: -	-
Celanese	ED 25164	55	Yes: self-cure	19
B.F. Goodrich	Carboset 514A	70	Yes: amine	-

(1) Acrylate-methacrylate copolymers

TABLE 59

PENCIL HARDNESS
ACRYLIC COATINGS AFTER AGING

Coating	Manufacturer	Hardness Readings					
		Control		100°C Oven		RS-4	
		Gauge	Scratch	Gauge	Scratch	Gauge	Scratch
Acrysol WS-12	Rohm & Haas	4H	2H	2H	H	2H	H
Acrysol WS-32	Rohm & Haas	H	B	5B	6B	HB	B
Acryloid B-84	Rohm & Haas	5H	3H	7H	5H	7H	5H
Rhoplex CA-12	Rohm & Haas	B	6B	B	<6B	<6B	< 6B
Rhoplex AC-73	Rohm & Haas	2H	HB	4H	H	5H	H
Rhoplex HA-12	Rohm & Haas	4H	2H	3H	B	4H	B
Acryloid B-99	Rohm & Haas	3H	2H	5H	2H	3H	2H
Joncryl M-50	Johnson Wax	4H	H	3H	H	5H	2H
347-63-5S	Service Coatings	7H	5H	7H	5H	7H	5H
A-601	Polyvinyl Chemicals	3H	H	4H	H	5H	2H
A-620	Polyvinyl Chemicals	3H	HB	2H	HB	5H(1)	2H
A-622	Polyvinyl Chemicals	5H	HB	5H	H	5H	H
X-link 2813	National Starch	5H	H	3H	HB	5H	H
Resyn 2345	National Starch	2H	B	H	HB	H	HB
Arolon 557-D-70	Spencer Kellogg	4H	3H	5H	3H	2H	H
EB 9389	Valspar Corp.	5H	HB	5H	2H	5H	3H
EB 9391	Valspar Corp.	HB	F	HB	F	HB	F
514A	B.F. Goodrich	3H	HB	4H	HB	4H	H
Hycar 2600x172	B.F. Goodrich	2H	HB	5H	4H	4H	HB
ED 25164	Celanese	4H	2H	3H	H	5H	2H

(1) Delaminated from glass - so accuracy of hardness is suspect.

Procedure:

ASTM D3363-74 is followed to a certain degree except for a few changes.

Coated glass slide is placed on a horizontal surface. The pencil is held firmly against the film; at a 45° angle (pointed away from operator) and pushed away from operator in a 1/4" stroke. The hardest pencil is used first and continued down the scale of hardness. A 531.6 g. wt. with a hole in the center is placed over the top of the pencil. Masking tape is used to keep the wt. approx. the same distance away from the tip of each pencil (about 3").

Following pencils are used:

9H-7H-5H-4H-3H-2H-H-HB-F-B-2B-3B-4B-5B-6B

Harder Softer

The two end points are as follows:

Gauge Hardness: The hardest pencil that will leave the film uncut or gouged for at least 1/8".

Scratch Hardness: The hardest pencil that will not rupture or scratch the surface.

TABLE 60

GLOSS ON OVEN AGED ACRYLIC COATED GLASS SLIDES

Coating	Manufacturer	Gloss Readings (°)		
		Original (Degrees)	100°C Oven (Degrees)	Water Wash RS-4 (Degrees)
Acrysol WS-12	Rohm & Haas	67	50	47
Acrysol WS-12	Rohm & Haas	82	57	48
Acryloid B-84	Rohm & Haas	78	75	72
Rhoplex CA-12	Rohm & Haas	63	45	40
Rhoplex AC-73	Rohm & Haas	52	57	50
Rhoplex HA-12	Rohm & Haas	90	59	45
Acryloid B-99	Rohm & Haas	84	82	87
Joncryl M-50	Johnson Wax	72	54	51
347-63-5S	Service Coatings	86	63	64
Neocryl A-601	Polyvinyl Chem.	72	68	64
Neocryl A-620	Polyvinyl Chem.	85	95	66
Neocryl A-622	Polyvinyl Chem.	94	78	86
X-link 2813	National Starch	69	67	70
Resyn 2345	National Starch	80	41	49
Arolon 557-D-70	Spencer Kellog	90	80	95
EB-9389	Valspar Corp.	89	85	81
EB-9391	Valspar Corp.	92	91	89
Carbonset 514A	B.F. Goodrich	94	54	85
Hycar 2600x172	B.F. Goodrich	58	22	12
ED-25164	Celenese	87	76	59

(1) Gardner 60° Glossmeter is used.

Operating Procedure

1. Place instrument over polished black gloss standard.
2. Pull switch on and keep "on" until all measurements are completed. (A 5 minute warm-up period is allowed).
3. Adjust rheostat knob until meter reads 90° gloss (standard value). The knob is then adjusted to read 50° gloss because the coatings have a gloss higher than 100°.
4. Glass shims are placed under the base of the glossmeter so that it is on same level as glass slide specimens.
5. Place glossmeter over specimen surface and determine gloss by reading values off the meter.

TABLE 61

APPEARANCE OF ACRYLIC COATINGS AFTER THREE WEEKS EXPOSURE

Coating	Physical Characteristics of Coatings		
	Original	100° Oven	RS-4
Acrysol WS-12	Clear	No Change	No Change
Acrysol WS-12	Clear-Slightly Tacky	Clear-Slightly Tacky	Clear-Still Tacky
Acryloid B-84	Clear-Few Bubbles	No Change	No Change
Rhoplex CA-12	Slightly Yellow Bubbles Along Edges	Yellow-Tacky	Yellow-Tacky
Rhoplex AC-73	Clear	No Change	No Change
Rhoplex HA-12	Clear	Slight Yellowing	No Change
Acryloid B-99	Clear-Few Bubbles	No Change	No Change
Joncryl M-50	Clear	No Change	No Change
347-63-5S	Clear	No Change	No Change
Neocryl A-601	Slight Brown Tint	Brownish Tint in Thicker Portions of Coatings	Clear
Neocryl A-620	Clear	No Change	No Change
Neocryl A-622	Clear	No Change	No Change
X-Link-2813	Clear	Slight Yellowing	Clear
Resyn 2345	Brownish Tint Few Bubbles	> Browish Tint Few Bubbles	Slight Yellow Tint
Arolon 557-D-70	Clear	No Change	No Change
EB 9389	Clear	No Change	No Change
EB 9391	Clear	No Change	No Change
Carboset 514A	Clear-Few Bubbles	No Change	No Change
Hycar 2600x172	Whitish-Few Lines	White-Few Lines	White-Delaminating
ED 25164	Clear	No Change	Yellowed

TABLE 62

PROPERTIES OF ACRYLIC COATINGS ON GLASS

Coating	Substrates Coating Adhered Strongly	Bond Strength Before & After One Week Immersion in Water		Pencil Hardness(2)						Gloss Readings(3) After Exposure in 100°C Oven & Wet RS-4 (Degrees)			% Transmission of Coated Glass Slides (1)
				Control		After Exposure 100° Oven		After Exposure RS-4					
		Before	After	Gouge	Scratch	Gouge	Scratch	Gouge	Scratch	Control	100°C Oven	Wet RS-4	
Acrysol WS-12	Lexan Plexiglas V-811	Strong	Strong	4H	2H	2H	H	2H	H	67	50	47	87.2
Acrysol WS-32	Lexan Plexiglas V-811	Strong	Strong	H	B	5B	6B	HB	B	82	57	48	86.1
Rhoplex CA-12	Lexan Plexiglas V-811	Strong	Strong	B	6B	B	< 6B	< 6B	< 6B	63	45	40	87.0
Rhoplex AC-73	Lexan Plexiglas V-811	Strong	Strong	2H	HB	4H	H	5H	H	52	57	50	50.3
Acryloid B-84	Lexan Plexiglas V-811	Strong	Strong	5H	3H	7H	5H	7H	5H	78	75	72	86.0
Acryloid B-99	Lexan Plexiglas V-811	Strong	Strong	3H	2H	5H	2H	3H	2H	84	82	87	86.5
Joncryl M-50	Plexiglas V-811	Strong	Strong	4H	H	3H	H	5H	2H	72	54	51	71.2
347-63-5S	Lexan Plexiglas V-811	Strong	Strong	7H	5H	7H	7H	5H	5H	86	63	64	85.3
Neocryl A-601	X-1 EVA/Scrim Plexiglas V-811	Strong	Strong	3H	H	4H	H	5H	2H	72	68	64	86.5
Neocryl A-620	X-1 EVA/Scrim-Lexan Plexiglas V-811	Strong	Strong	3H	HB	2H	HB	5H(1)	2H	85	95	66	85.1
Neocryl A-622	Lexan Plexiglas V-811	Strong	Strong	5H	HB	5H	H	5H	H	94	78	86	87.7
X-Link 2813	X-1 EVA/Scrim Plexiglas V-811	Strong	Strong	5H	H	3H	HB	5H	H	69	67	70	85.1
Resyn 2345	Lexan Plexiglas V-811	Strong	Strong	2H	B	H	HB	H	HB	80	41	49	84.0
Arolon 557-D-70	Lexan Plexiglas V-811	Strong	Strong	4H	3H	5H	3H	2H	H	90	80	95	87.5
EB-9389	X-1 EVA/Scrim Plexiglas V-811	Strong	Strong	5H	HB	5H	2H	5H	3H	89	85	81	83.3
EB-9391	X-1 EVA/Scrim Plexiglas V-811	Strong	Strong	HB	F	HB	F	HB	F	92	91	89	87.3
Carboset 514A	Lexan Plexiglas V-811	Strong	Strong	3H	HB	4H	HB	4H	H	94	54	85	87.1
Hycar 2600x172	Plexiglas V-811	Strong	Strong	2H	HB	5H	4H	4H	HB	58	22	12	73.4
ED 25164	Lexan Plexiglas V-811	Strong	Strong	4H	2H	3H	H	5H	2H	87	76	59	87.2
Rhoplex HA-12	Lexan Plexiglas V-811	Strong	Strong	4H	2H	3H	B	4H	B	90	59	45	85.4

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(1) Coating delaminated from glass so hardness reading is suspect.

(2) ASTM D3363-74

Following pencils were used:

9H - 7H - 5H - 4H - 3H - 2H - H - HB - F - B - 2B - 3B - 4B - 5B - 6B
Harder Softer

Two end points are as follows:

Gouge Hardness: The hardest pencil that will leave the film uncut or gouged for at least 1/8".

Scratch Hardness: The hardest pencil that will not rupture or scratch the surface.

(3) Instrument used is Gardner 60° Glossmeter.

(4) Direct transmission measured from 350 nm to 900 nm using spectrophotometer ,(see Footnote 4, Table 6). Uncoated glass has a value of 85.7%.

TABLE 63

REDUCED SOLIDS COATINGS ON CROSSLINKED EVA

Coating	Color		Bond Strength		Comments
	Before Reduction	After Reduction	Before Reduction	After Reduction	
EB9388	Clear	Clear	S	M	Problem with surface wetting.
EB9389	Clear	Clear	F(peeled)	S	Looks good
EB9391	Clear	Clear	F(peeled)	S	Looks good
Joncryl 74F	Clear	Clear	M	S	Very clear coating.
Joncryl M130	Yellowish	Clear	F	M	Coating cracks when bent around mandrel
Joncryl 101	Hazy	Clear	F	M	Coating cracks when bent aroung glass mandrel.
Joncryl M50	Clear	Clear	F	M	Coating cracks when bent around mandrel.
2345	Slight	Clear	F	S	EVA can be bent around mandrel without cracking coating.
Hycar 2600X91	Clear	Clear	M	S	Coating looks good.
Hycar 2600X138	Clear	Clear	S	S	Coating cracks when bent around mandrel.
2813	Clear	Clear	M	S	Coating looks good.
3730	Clear	Clear	F	F	Problem with surface wetting.
Permacote 62	Clear	Clear	F	F	Cracks and peels off when bent around mandrel -very clear.
Acryloid B-84	Clear	Clear	F	F	Cracks and peels off when bent around mandrel -very clear.
347-635S	Clear w/ bubbles	Clear	F	F	Cracks and peels off when bent aroung mandrel.
Rhoplex WL-81	Clear	Clear	F	S	Coating cracks into extremely tiny particles which do not come off.
(2) Rhoplex B-85	(1)	Clear	(1)	F	Problem with surface wetting.
(2) Rhoplex B-60A	(1)	Hazy	(1)	F	Problem with surface wetting.
(2) Rhoplex AC-172	(1)	Clear	(1)	M	Problem with Surface wetting.

(1) These coatings were never tried before on EVA.

(2) All coatings had a problem with surface wetting. It seems that the water based coatings have a greater problem with surface wetting than the solvent based ones. Rhoplex AC-172 did adhere somewhat to the EVA.

TABLE 64

ACRYLIC COATINGS ON CROSSLINKED EVA

Coating + Drying Temp.	Color	Bond Strength	Comments
AT 50 (Room Temp.)	Clear	Failed	Coating peels off when EVA is bent. Few bubbles.
AT 50 (100°C Dry)	Clear	Failed	Bubbled while drying. Coating peels off when EVA is bent.
AT 51 (Room Temp.)	Clear	Failed	Few bubbles, cracks when EVA is bent and can be peeled off.
AT 51 (100°C Dry)	Clear	Failed	Bubbles while drying, coating peels off when EVA is bent.
AT 56 (Room Temp.)	Clear	Failed	Few bubbles, coating can be peeled off.
AT 56 (100°C Dry)	Clear	Failed	Bubbles, coating can be peeled off when stretched.

TABLE 65

EFFECT OF WATER IMMERSION ON COATED CROSSLINKED EVA

Coatings (1)	Color		Bond Strength		Comments
	Before Reduction	After Reduction	Before Reduction	After Reduction	
Rhoplex B-413	–	Cloudy	–	M	Problem with surface wetting.
Rhoplex HA-8	–	Clear	–	M	
Rhoplex B-924	–	Cloudy	–	F	Problem with surface wetting.
Rhoplex HL-658	–	Spotty	–	F	Problem with surface wetting.
Neocryl A-601	–	Clear	–	S	Coating looks good.
Rhoplex HA-12	–	Clear	–	M	Problem with surface wetting.
Neocryl A-620	–	Clear	–	S	–
Rhoplex CA-12	–	Clear	–	M	Problem with surface wetting.
ED25164	Clear	Clear	F	F	Crumbles when bent.

(1) Acrylics

TABLE 66

EFFECT OF WATER IMMERSION ON BOND STRENGTH OF COATINGS ON EVA

Coating	Application Drying Temp (C°)	Color Before Submersion	Color While Still Wet	Color After Drying	Bond(1) Before Submersion	Bond While Still Wet	Bond After Drying
Joncryl 74F	Room Temp	Clear	White, few bubbles	Clear	M	F	F
Hylar 2600 x 91	100°C	Clear	White	Clear	M	F	M-F
	Room Temp	Clear	White	Clear	M	F	F
Hylar 2600 x 138	100°C	Clear	Clear	Clear	S	F	F
	Room Temp	Clear	Clear	Clear	S	F	F
EB938	100°C	Clear, few cracks	Clear, cracks, few bubbles	Clear, surface all crack	S	S	S
28139	100°C	Clear	Slightly cloudy	Clear	M	F	F
	Room Temp	Clear	Slightly cloudy	Clear	S	F	F

(1) F - Failure, M - Moderate, S - Strong Bonds.

TABLE 67

ACRYLIC COATINGS (1)
ON CROSSLINKED EVA REINFORCED WITH GLASS MAT

Coating	Color		Bond Strength	
	Before Immersion	After Immersion	Before Immersion	After One Week Water Immersion
Neocryl A-601 Latex	Clear	Clear	S (2)	S
Neocryl A-620 Latex	Clear	Clear	S	S
X-link 2813	Clear	Clear	S	S
EB 9391	Clear	Clear	S	S
EB9389	Clear	Clear	S	S

(1) 1" x3" pieces are dipped in acrylic at 50% dilution. Coated pieces are then placed in a 100°C oven for one hour to dry.

(2) Strong

TABLE 68

ACRYLIC COATINGS ON POLYMETHYLMETHACRYLATE(2)

Coating	Percent Solids	Color of Coating After Drying	Adhesion(1)
Rhoplex AC-172	45	Milky	M
Rhoplex WL-81	41.5	Clear	M
Acrysol WS-12	∼30	Clear	S
Rhoplex AC-658	47	Slightly Cloudy	M
Neocryl A-620	40	Clear	S
Neocryl A-601	32	Clear	S
Carboset 514H	70	Clear	S
Carboset XL-19	40	Clear	S
Carboset XL-11	30	Clear	S
Rhoplex CA-12	53.5	Clear	S
Rhoplex B-413	39	Clear	M
Rhoplex AR-74	45	Clear	S
Rhoplex HA-12	45	Clear	S
Rhoplex AC-73	46.5	Clear	S
Rhoplex HA-8	46	Clear	M
Acrysol WS-32	NA	Clear	S
Rhoplex B-60A	46.5	Clear	S
Rhoplex B-85	38	Clear	F

(1) F - Failure, M - Moderate, S - Strong

(2) Plexiglas V-811

TABLE 69

EFFECT OF WATER IMMERSION ON BOND STRENGTH OF COATINGS ON PLEXIGLAS V-811*

Coating	Application Drying Temp (C°)	Color Before Submersion	Color While Still Wet	Color After Drying	Bond Before Submersion	Bond While Still Wet	Bond After Drying
Arolon 557-D-70	Room Temp	Clear with bubbles	White	White	M	S	S
Joncryl 74F	100°C	Clear	White	Clear	S	M	M
	Room Temp	Clear	White	Clear, bubbles	S	M	M
M-50	100°C	Cloudy	White	Cloudy	S	S	S
	Room Temp	Cloudy	White	Cloudy	S	S	S
M-130	100°C	Clear	Slightly cloudy	Clear, bubbles	S	M	M
Permacote 62	100°C	Clear	Cl.w/wh.patches	Clear	S	F	M
	Room Temp	Clear	Cl.w/wh.patches	Clear	S	F	M
Hylar 2600 x 91	100°C	Clear	White	Clear	S	M	M
	Room Temp	Clear	White	Clear	M	F	M
Hylar 2600 x 138	100°C	Clear	Patches of Wh.	Clear	S	M	M
	Room Temp	Clear	Very slightly cloudy	Clear	S	F	M
Hylar 2600 x 172	100°C	Cloudy	Wh.few clear patches	Cl. slightly rippled surface	S	S	S
	Room Temp	Cloudy	Clear	Clear	M	M	M
Hylar 2600 x 256	100°C	Clear	White		S	F	M-F
Neocryl A-622	100°C	Clear	Slightly cloudy		S	M	M
	Room Temp	Clear	Cloudy		S	F	M
EB9389	100°C	Clear	Wh. w/bubbles	Cl. w/bubbles	S	S	S
	Room Temp	Clear	White	Clear	M	M-F	M
EB9391	100°C	Clear			S	M	S
	Room Temp	Clear			S	M	M
3730	100°C	Cl.few lines	Wh., few lines, some cl.patches	Cl.,few lines	M	M	M
2345	100°C	Brown Tint	White	Brownish Tint	S	M-S	M-S
2813	100°C	Cl.few lines	White	Cl., few lines	S	M	M
	Room Temp	Clear	White	Clear	S	M	M

*Polymethylmethacrylate

(Continued)

Table 69 -(Continued 2)

Coating	Application Drying Temp (C°)	Color Before Submersion	Color While Still Wet	Color After Drying	Bond Before Submersion	Bond While Still Wet	Bond After Drying
4280	100°C	Clear	Cl. w/one cloudy patch	Clear	M	M-F	M
	Room Temp	Clear	Cl. but tacky	Clear	M	M	M
Mistacote 600-F-900	100°C	Cloudy	White	Cloudy	M	F	F
	Room Temp	Cloudy	White	Cloudy	M	F	M-F
229549442	100°C	Black	Black	Black	S	S	S
	Room Temp	Black	Black	Black	S	S	S
549444	100°C	Black, Translucent	Black Translucent	Black, Translucent	M	M	M
347-63-55	100°C	Cloudy	Cloudy	Cloudy	S	S	S
	Room Temp	Cloudy	Cloudy	Cloudy	S	S	S
Acryloid B-84	100°C	Clear Bubbles	Wh., Bubbles	Slightly cloudy, Bubbles	S	S	S
	Room Temp	Clear	White	White	S	S	S
ED25164	100°C	Clear	White	Clear	S	S	S
	Room Temp	Clear with Bubbles	White with Bubbles	Clear with bubbles	M	M	M

F - Failure
M - Moderate
S - Strong Bonds

TABLE 70

ACRYLIC (2) COATINGS ON LEXAN

Coating	% Solids	Condition of Coating		Adhesion (1)	
		Original	After Water Immersion	Original	After Water Immersion
WL-81 Rhoplex	41.5	Clear	Clear	S	S
Acryysol WS-12	30	Clear	White	S	S
Neocryl A-620	40	Clear	Clear	S	S
Neocryl A-601	32	Clear	Clear	S	M
Carboset 514H	70	Clear	Sl. Cloudy	S	S
Carboset XL-19	40	Clear	White	S	M
Carboset XL-11	30	Clear	White	S	M
Rhoplex CA-12	53.5	Clear	Clear	S	M-S
Rhoplex B-413	39	Clear	Cloudy	S	M
Rhoplex AR-74	45	Clear	Clear	S	S
Rhoplex HA-12	45	Clear	Clear	S	S
Rhoplex AC-73	46.5	Clear	Clear	S	S
Acrylsol WS-32	NA	Clear	Cloudy	S	S
Acryloid B-99	46	Clear	White	S	S

(1) F - Failure, M - Moderate, S - Strong

(2) All coatings are lattices except Carbonset which is solvent-based.

TABLE 71

ACRYLIC COATINGS SELECTED FOR THE COLLECTOR GLAZINGS

Substrate	Coating	Latex	Solvent	Thermoset	Thermoplastic
Plexiglas	Acryloid B99	-	X	-	X
	Arolon 557-D	-	X	X	-
EVA	Neocryl A601	X	-	X	-
	EB9389	X	-	-	X
Lexan	Acryloid B99	-	X	-	X
	Arolon 557-D	-	X	X	-

TABLE 72

ACRYLIC COATINGS/UV ABSORBER SYSTEMS FOR COLLECTOR GLAZINGS

Substrate	Coating	% Solids	UV Absorber	% Concentration
Plexiglas	Acryloid B-99	25%	Cyasorb 5411	2%
	Acryloid B-99	25%	Tinuvin 328	2%
	Arolon 557-D-70	25%	Tinuvin 328	2%
	Arolon 557-D-70	25%	Cyasorb 2126	2%
	Acryloid B-99	25%	Sanduvor VSU	2%
X-ℓ EVA/ Scrim	Neocryl A-601	16%	Sanduvor USU(1)	2%
	Neocryl A-601	16%	Cyasorb UV-531(1)	2%
	Neocryl A-601	16%	Cyasorb 5411(1)	2%
	EB-9389	23%	Cyasorb 5411(1)	2%
	EB-9389	23%	Permyl B-100	.03%
Lexan	Acryloid B-99	25%	Cyasorb 5411	2%
	Acryloid B-99	25%	Tinuvin 328	2%
	Acryloid B-99	25%	Sanduvor VSU	2%
	Arolon 557-D-70	35%	Tinuvin 328	1%
	Arolon 557-D-70	35%	Tinuvin 328	2%
	Arolon 557-D-70	35%	Tinuvin 328	5%
	Arolon 557-D-70	35%	Cyasorb 2126	2%
	Arolon 557-D-70	35%	-- Tinuvin 328 DSTDP Irganox 1010	0.75% 0.25% 0.1%
	Arolon 557-D-70	35%	-- Tinuvin 328 Goodrite 3114 Naugard P	0.35% 0.35% 0.3 %

(1) For latex coatings, an emulsion is made using the following formula:

10 pph UV Absorber
40 pph Toluene
10 pph Pluronic L72 polyol surfactant
40 pph Water

Mix at high speed in high speed blender for 1 minute.

TABLE 73

ACRYLIC COATINGS - UV ABSORBER SYSTEMS

(Specific Coated Glazing Formulations)

Acrylic Coatings	UV Absorbers
1. Valspar EB9389(1)	No UV Absorber
2. Valspar EB9389	Permyl B-100(5) (0.05%)(15)
3. Valspar EB9389	Cyasorb UV 5411(6) (2%) Emulsion(16)
4. Neocryl A-601(2)	No UV Absorber
5. Neocryl A-601	Cyasorb UV 5411(2%) Emulsion
6. Neocryl A-601	Cyasorb UV 531(7) (2%) Emulsion
7. Neocryl A-601	Sanduvor VSU(8) (2%) Emulsion
8. Arolon 557-D-70(3)	No UV Absorber
9. Arolon 557-D-70	Tinuvin 328(9) (1%)
10. Arolon 557-D-70	Tinuvin 328 (2%)
11. Arolon 557-D-70	Tinuvin 328 (5%)
12. Arolon 557-D-70	Cyasorb UV 2126(10) (2%)
13. Arolon 557-D-70	Tinuvin 328 (0.75%), DSTDP(11) (0.25%), Irganox(12) 1010 (0.1%)
14. Arolon 557-D-70	Tinuvin 328 (0.35%), Goodrite 3114(13) (0.35%), Naugard P(0.3%)(14)
15. Acryloid B-84 (4)	No UV Absorber
16. Acryloid B-84	Tinuvin 328 (2%)
17. Acryloid B-84	Cyasorb UV 5411(2%)
18. Acryloid B-84	Sanduvor VSU (2%)

TABLE 73- Continued

ACRYLIC COATING-UV ABSORBER SYSTEMS

(Specific Coated Glazing Formulations)

Plastic Substrate	Acrylic Coating	UV Absorbers
19. Lexan	Uncoated Control	None
20. Lexan	Arolon 557-D-70	None
21. Lexan	Arolon 557-D-70	Tinuvin 328 (1%)
22. Lexan	Arolon 557-D-70	Tinuvin 328 (2%)
23. Lexan	Arolon 557-D-70	Tinuvin 328 (5%)
24. Lexan	Arolon 557-D-70	Tinuvin 328 (0.75%) DSTDP (0.25%), Irganox 1010
25. Lexan	Arolon 557-D-70	Tinuvin 328 (0.35%), Goodrite 3114 (0.35%), Naugard P (0.3%)
26. Lexan	Acryloid B-84	None
27. Lexan	Acryloid B-84	Tinuvin 328 (2%)
28. Lexan	Acryloid B-84	Cyasorb UV 5411 (2%)
29. Lexan	Acryloid B-84	Sanduvor VSU (2%)
30. Plexiglas V-811	Uncoated Control	None
31. Plexiglas V-811	Arolon 557-D-70	None
32. Plexiglas V-811	Arolon 557-D-70	Tinuvin 328 (2%)
33. Plexiglas V-811	Arolon 557-D-70	Cyasorb UV 2126 (2%)
34. Plexiglas V-811	Acryloid B-84	None
35. Plexiglas V-811	Acryloid B-84	Tinuvin 328 (2%)
36. Plexiglas V-811	Acryloid B-84	Cyasorb UV 5411 (2%)
37. Plexiglas V-811	Acryloid B-84	Sanduvor VSU (2%)

TABLE 73 - Continued

ACRYLIC COATING-UV ABSORBER SYSTEMS

(Specific Coated Glazing Formulations)

Plastic Substrate (17)	Acrylic Coating	UV Abosrbers
38. X-ℓ EVA/Scrim	Neocryl A-601	None
39. X-ℓ EVA/Scrim	Neocryl A-601	Cyasorb UV 5411 (2%)
40. X-ℓ EVA/Scrim	Neocryl A-601	Cyasorb UV 531 (2%)
41. X-ℓ EVA/Scrim	Neocryl A-601	Sanduvor VSU (2%)
42. X-ℓ EVA/Scrim	Uncoated Control	None
43. X-ℓ EVA/Scrim	Valspar EB9389	None
44. X-ℓ EVA/Scrim	Valspar EB9389	Permyl B-100 (0.05%)
45. X-ℓ EVA/Scrim	Valspar EB9389	Cyasorb UV 5411 (2%)

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(1) Acrylic latex, Valspar

(2) Thermoset acrylic latex Polyvinyl Chemicals

(3) Thermoset, solvent acrylic, Spencer Kellog

(4) Thermoplastic solvent acrylic , Rohm & Haas

(5) Benzophenone UV absorber, Ferro Corporation

(6) Benzotriazole UV absorber, American Cyanamid

(7) Benzophenone UV absorber, American Cyanamid

(8) An oxalic-anilide UV absorber, Sandoz

(9) Benzotriazole UV absorber, Ciba-Geigy

(10) Higher molecular weight benzophenone UV absorber, American Cyanamid

(11) Distearylthiodipropionate, Uniroyal (a secondary stabilizer)

(12) Hindered phenolic antioxidant, Ciba-Geigy

(13) Isocyanurate antioxidant - UV stabilizer, Goodrich

(14) Phosphite stabilizer, Uniroyal

(15) All percentages are concentrations of stabilizer in the acrylic coating

(16) Prepared as Emulsion

(17) Peroxide crosslinked ethylene/vinyl acetate copolymer

TABLE 74

UV TRANSMISSION SPECTRUM OF ACRYLIC/UV ABSORBER SYSTEMS

Acrylic Coating No.	Wavelength 290	300	320	340	360	380	400
1	25	31	44	51	57	67	33
2	35	42	51	57	67	76	80
3	0	0	0	0	0	8	31
4	59	63	67	73	76	77	81
5	2	4	5	6	35	67	75
6	13	14	12	8	16	73	81
7	9	8	15	40	69	79	81
8	58	63	67	68	67	70	71
9	4	2	2	2	3	24	66
10	0	0	0	0	0	6	66
11	1	1	1	1	1	13	62
12	4	5	4	5	17	23	66
13	4	3	4	3	4	20	50
14	42	42	43	43	47	60	70
15	15	45	64	69	71	73	74
16	0	0	0	0	0	1	60
17	0	0	0	0	0	7	71
18	0	0	0	0	45	53	54
19	1	10	22	45	63	73	78
20	5	20	39	62	75	85	87
21	0	2	5	8	12	46	81
22	0	0	0	0	1	25	82

Page two

TABLE 74 - Continued

UV TRANSMISSION SPECTRUM OF ACRYLIC/UV ABSORBER SYSTEMS

	Wavelength						
Acrylic Coating No.	290	300	320	340	360	380	400
23	0	0	0	0	0	3	60
24	0	2	6	9	15	46	74
25	1	8	19	31	44	70	82
26	1	5	17	31	44	73	77
27	0	0	0	16	58	78	82
28	0	0	0	0	0	27	83
29	0	0	0	5	61	71	75
30	2	0	2	65	75	78	78
31	0	0	0	80	88	89	89
32	0	0	0	0	1	25	80
33	0	0	0	71	81	82	83
34	0	0	0	71	84	85	86
35	0	0	0	0	0	8	82
36	0	0	0	0	0	31	83
37	0	0	0	28	73	81	82
38	0	0	0	0	0	8	12
39	0	0	0	0	0	5	10
40	0	0	0	0	0	5	10
41	0	0	0	0	0	7	12
42	0	0	0	0	0	7	13
43	0	0	0	0	0	8	18
44	0	0	0	0	0	14	16
45	0	0	0	0	0	7	17

TABLE 75

COATED GLAZINGS SENT TO DSET FOR EMMAQUA EXPOSURE

Glazing Material	Coating	U.V. Absorber	Concentration
X-ℓ EVA/Scrim(1)	None	-	-
X-ℓ EVA/Scrim	Valspar EB9389(4)	-	-
X-ℓ EVA/Scrim	Valspar EB9389	Cyasorb 5411(8)	2%
X-ℓ EVA/Scrim	Neocryl A-601(5)	-	-
X-ℓ EVA/Scrim	Neocryl A-601	Cyasorb 8411(9)	2%
X-ℓ EVA/Scrim	Neocryl A-601	Cyasorb 531	2%
X-ℓ EVA/Scrim	Neocryl A-601	Sanduvor VSU (10)	2%
Lexan(2)	None	-	-
Lexan	Arolon 557-D-70(6)	-	-
Lexan	Arolon 557-D-70	Sanduvor VSU(11)	2%
Lexan	Arolon 557-D-70	Tinuvin 328	1%
Lexan	Arolon 557-D-70	Tinuvin 328	2%
Lexan	Arolon 557-D-70	Tinuvin 328	5%
Lexan	Arolon 557-D-70	Tinuvin 328(12)	.75%
		Irganox 1010	.1 %
		DSTDPO (12)	.25%
Lexan	Rohm & Haas B-84(7)	-	-
Lexan	Rohm & Haas B-84	Tinuvin 328	2%
Lexan	Rohm & Haas B-84	Cyasorb 5411	2%
Lexan	Rohm & Haas B-84	Sanduvor VSU	2%
Plexiglas V-811(3)	None	-	-
Plexiglas V-811	Arolon 557-D-70	-	-
Plexiglas V-811	Arolon 557-D-70	Tinuvin 328	2%
Plexiglas V-811	Rohm & Haas B-84	Cyasorb 5411	2%
Plexiglas V-811	Rohm & Haas B-84	Tinuvin 328	2%
Plexiglas V-811	Rohm & Haas B-84	-	-
Plexiglas V-811	Rohm & Haas B-84	Sanduvor VSU	2%

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(1) Peroxide crosslinked ethylene/vinyl acetate copolymer compression molded with Craneglas material
(2) GE Lexan polycarbonate, no UV stabilizer
(3) Rohm and Haas Plexiglas V-811, polymethyl methacrylate
(4) Valspar's EB-9389 experimental latex acrylic coating
(5) Polyvinyl chemicals Neocryl A-601 latex acrylic coating
(6) Spencer Kellogg Arolon 557-D-70 solvent based acrylic coating (IPA)
(7) Rohm and Haas Acryloid B-84 solvent based acrylic coating (butanol/toluene)
(8) American Cyanamid Co., Cyasorb UV 5411
(9) American Cyanamid Co., Cyasorb UV 5411
(10) Sandoz Color and Chemical ,Sanduvor VSU
(11) Ciba-Geigy, Tinuvin 328
(12) Ciba-Geigy, Tinuvin 328
Ciba-Geigy, Irganox 1010
DSTDPO

TABLE 76

EFFECT OF EMMAQUA EXPOSURE ON EVA/SCRIM
PERCENT TRANSMISSION

S.L. No.	Glazing	Acrylic Coating	UV Absorber	% Conc.	% Tansmission		
					Original	4 Months	6 Months
13024-1	EVA/Scrim	Neocryl A-601	-	-	82	82	80
13024-2	EVA/Scrim	Valspar EB-9389	-	-	88	86	84
13024-3	EVA/Scrim	Valspar EB-9389	Cyasorb UV-5411	2	88	86	85
13024-4	EVA/Scrim	Neocryl A-601	Sanduvor VSU	2	84	83	82
13024-5	EVA/Scrim	Neocryl A-601	Cyasorb UV-5411	2	83	87	83
13024-6	EVA/Scrim	Valspar EB-9389	Permyl B-100	0.05	86	88	86
13024-7	EVA/Scrim	Neocryl A-601	Tinuvin 328	2	84	87	84
13024-8	EVA/Scrim	Neocryl A-601	Cyasorb UV-531	2	85	82	81
13024-9	Lexan	Arolon 557-D-70	Tinuvin 328	1	87	83	81
13024-10	Lexan	Arolon 557-D-70	Tinuvin 328 DSTDP DSTDP Irganox 1010	0.75 0.25 0.10	86	84	83
13024-11	Lexan	Arolon 557-D-70	Cyasorb UV-5411	2	86	84	84
13024-12	Lexan	Acyrloid B-84	Tinuvin 328	2	87	87	87
13024-13	Lexan	Acryloid B-84	-	-	87	87	86
13024-14	Lexan	Acryloid B-84	Cyasorb UV-5411	2	88	83	81
13024-15	Lexan	Arolon 557-D-70	Tinuvin 328 Goodrite 3114 Naugard P	0.35 0.35 0.30	86	90	86
13024-16	Lexan	Arolon 557-D-70	Tinuvin 328	5	87	89	87
13024-17	Lexan	Arolon 557-D-70	-	-	88	88	86
13024-18	Plexiglas V-811	Acryloid B-84	Tinuvin 328	2	86	89	86
13024-19	Plexiglas V-811	Arolon 557-D-70	-	-	88	86	85
13024-20	Plexiglas V-811	Arolon 557-D-70	Tinuvin 328	2	86	87	86
13024-21	Plexiglas V-811	Acryloid B-84	Sanduvor VSU	2	84	85	85
13024-22	Plexiglas V-811	Acryloid B-84	Cyasorb UV-5411	2	86	85	85
13024-23	Plexiglas V-811	Acryloid B-84	-	-	88	85	83
13024-24	Plexiglas V-811	Arolon 557-D-70	Cyasorb UV-2126	2	85	84	84

TABLE 77

PERCENT DIRECT TRANSMISSION OVER THE RANGE 400-700 nm AFTER AR COATING BOTH SIDES OF A PLASTIC SHEET

Material	AR Coated	Coated at Normal Incidence		Coated at 45°	
		Single(1) Layer	Multi Layer	Single Layer	Multi Layer
EVA	No	75.5	75.5	66.5	66.5
EVA	Yes	77.5	30.1	67.3	14.9
Llumar	No	83.8	83.8	79.0	79.0
Llumar	Yes	93.4	90.6	90.2	86.4
Plexiglass V811	No	89.1	89.1	82.6	82.6
Plexiglass V811	Yes	92.3	95.2	86.7	90.0
Tedlar	No	60.9	60.9	46.3	46.3
Tedlar	Yes	66.1	61.6	47.3	47.9

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(1) Magnesium fluoride

TABLE 78

PERCENT DIRECT TRANSMISSION AT 550 nm AFTER AR COATING BOTH SIDES OF A PLASTIC SHEET

Material	AR Coated	Coated at Normal Incidence		Coated at 45°	
		Single Layer(5)	Multi Layer	Single Layer	Multi Layer
EVA(1)	No	63	63	67	67
EVA	Yes	79	30	68	15
Llumar(2)	No	77	77	82	82
Llumar	Yes	97	94	94	87
Plexiglass V811(3)	No	89	89	82	82
Plexiglass V811	Yes	93	96	87	90
Tedlar(4)	No	61	61	46	46
Tedlar	Yes	67	63	47	48

(1) Peroxide crosslinked ethylene/vinyl acetate copolymer (20 Mil).

(2) UV stabilized thermoplastic polyester (5 Mil).

(3) Acrylic homopolymer (40 Mil).

(4) Tedlar 400XRB160SE.

(5) Single layer uses magnesium fluoride.

TABLE 79

ETCHING OF PEROXIDE CROSSLINKED EVA(1)

Etching Bath(3)	Time (Min.)	Gloss	Observations
Toluene		(2)	Excessive solvent swell.
Toluene (60°C)	6	(2)	Loss of structural integrity (fell apart).
10% KOH, 1% Triton X100 (Soap), 89% Isopropyl Alcohol	6	95%	No development of haze.
85% H_2SO_4 (AQ)	2	74.5%	"Water Spots".
79% H_2SO_4 (AQ) 1.2% $K_2Cr_2O_7$	6	72.5%	Some haze.
Heptane	2	51%	Haze and Mod. surface swell.
Acetone	2	91%	Slight surface swell.
$C\,Cl_4$	1	10%	Much solvent swell and haze
29% NaOH (AQ)	6	88%	No development of haze.
10% NaOH (AQ)	2	91%	No development of haze.
30% N,N-DiMe Formamide, 30% N,N-DiEt Acetamide, 40% Ethylene Glycol	6	108%	Moderate "Water Spotting".
66% H_2SO_4 (AQ) 22% H_3PO_4 (AQ) 7% $K_2Cr_2O_4$	6	101%	Hazy "Water Spotting".
1,1,1-TRI Cl Ethane	6	39%	Hazy surface w/swell.

(1) Ethylene/vinyl acetate copolymer (EVA), Gloss is 112.5%

(2) Cannot obtain gloss from un-flat sample.

(3) In all tables etching baths are at toom temperature, unless specified otherwise.

TABLE 80

ETCHING OF ACRYLIC - PLEXIGLAS V-811 (1)

Etching Bath	Time (min.)	Gloss I (2)	Observations (3)	Gloss II (2)
Acetone	6	93.5%	Very slight haze	111.5%
Isopropanol	6	106.5%	Streaky haze	113%
Toluene	6	73%	Slight haze	108%
Et Acetate	6	107%	Very slight haze	113%
Gl. Acetic Acid	6	68.5%	Slight streaks of haze	113%
29% NaOH (AQ)	6	54%	Weaving haze pattern	112%
85% H_2SO_4 (AQ)	1	15.5%	Chalky opaque surface	Surface decomposition
79% H_2SO_4 (AQ) 1% $K_2Cr_2O_4$	6	16.0%	Chalky opaque surface	Surface decomposition
89% Isopropanol 10% KoH 1% Triton X100 (Soap)	6	87%	Slight haze w/"water-spot" streaking	113%
1,1,1-Tri Chloro Ethane	1	94%	Feathers (4) Apparent	114%
30% N,N-DiMe Formamide, 30% N,N-DiEt Acetamide, 40% Ethylene Glycol	6		Faint surface scratches and feathers (4)	113%

(1) 123% Gloss for unetched acrylic

(2) Gloss I & II represent gloss reading taken before and after surface cleaning with silicone tissue paper.

(3) These observations are for the uncleaned samples. All surfaces cleared up w/cleaning.

(4) Internal solvent hazed fissures possibly propagated from surface imperfections, by the solvent.

TABLE 81

ETCHING OF 5 MIL LLUMAR - POLYESTER (1)

Etching Bath	Time (Min.)	Gloss	Observations
Methanol	6	118.5%	Some surface scratches
1,2-DiChloro-Ethylene	6	119%	Light mid-line "water spots"
Isopropanol	2	102.5%	Slight haze
10% KoH 1% Triton X1000 (Soap) 89% Isopropanol	6	117%	A few small "water spots"
Et Acetate	6	118.5%	Clear sample
29% NaOH (AQ)	6	118.5%	A few small "water spots"
85% H_2SO_4 (AQ)	6	99%	Scratched surface w/a few "water spots"
1.2% $K_2Cr_2O_7$ 79% H_2SO_4 (AQ)	6	118%	Clear sample
Gl. Acetic Acid	6	118.5%	Clear sample
1,1,1-Tri Cl Ethane	6	115%	Clear sample
30% N,N-DiMe Formamide, 30% N,N-DiEt-Acetamide, 40% Ethylene Glycol	6	119%	Clear sample

(1) Original Gloss of 119%

TABLE 82

ETCHING OF TEDLAR XRB160SE(1)

Etching Bath	Time (Min.)	Gloss(2)	Observations
Acetophenone (100%)	1	24%	Only slight solvent curl
Acetophenone (100%)	2	24%	Difficult to flaten
Acetophenone (100%)	3	24%	Gloss % dependent on position in meter
Acetophenone (100%)	10	19%	Blotchy and crumpled sample
Acetophenone	0	52%	Silky/smooth surface (not shiny)

(1) Polyvinyl fluoride, 4 mil film

(2) Original gloss is 52%

TABLE 83

OPTICAL PROPERTIES OF ETCHED MATERIALS

Plastic	Etching	75° Gloss %	Transmission(4) %	Reflectance
EVA(1)	Before After	112.5 37	88 84	6 6
Acrylic V-811(2)	Before After	123 112	93 93	8 6
Llumar(3)	Before After	118 118	83 83	9 8

(1) EVA - etched in cold toluene for 6 minutes. Unreliable reading because solvent swell curled the sample too much to allow it to lay flat.

(2) Acrylic (V-811) - etched in 29% NaOH for 6 minutes.

(3) Llumar Polyester - etched in 29% NaOH for 6 minutes.

(4) Integrated over range of 350-800 nm. (see Footnote 4 , Table 6)

TABLE 84

ETCHING CONDITIONS

Glazing Materials	Etching Solution	Time Minutes	Temp. °C
Plexiglas V-811	1,1,1-Tri Chloroethane	1	23
Llumar	Ethyl Acetate	6	60
Tedlar 400XRB160SE	Acetophenone	0.5	60

TABLE 85

PERCENT TRANSMISSION AFTER ETCHING

Glazing Material	Original[1] Transmission %	Transmission After Etching %	% Transmission Retained	Etching Solution
Plexiglas V-811	96	90.2	94.0	1,1,1-Tri Chloro Ethane
Llumar	92	84.9	92.2	Ethyl Acetate
Tedlar 400XRB160SE	90	82.5	91.7	Acetophenone

(1) See Footnote 4, Table 83)

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