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TABLE OF CONTENTS

	<u>Page</u>
PROJECT GOALS.	1
INTRODUCTION	3
TECHNICAL DISCUSSION	4
Task 1 - Information Search	4
Task 2 - Accelerated UV Exposure of Glazing and Housing Materials.	4
Task 5 - Evaluation of UV Protective Coatings and Films . .	6
A. UV Absorbing Films	7
B. Acrylic Coatings	7
Task 7 - AR Coatings.	9
FUTURE WORK.	10

PROJECT GOALS

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 will be made and materials selected. These polymers will then be exposed to accelerated weathering in the Weather-Ometer, and loss of optical, tensile, and other physical properties measured. Critical mechanical, thermal and environmental resistance properties will be examined on polymers having good weather resistance.

The state of development of surface etching processes and solar anti-reflective coatings to reduce surface reflectivity and to increase percent solar transmission of plastics will be investigated. Methods will be investigated for applying anti-reflective coatings to plastics for large-volume production.

Durable coatings and films for UV protection of plastic glazings will be evaluated. Cost studies will be made of collector glazing and housing materials as well as the comparative cost effectiveness of surface etching versus anti-reflective coatings and of UV protective coatings versus building the stabilizer into the polymer molecule.

The overall program is divided into nine 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 IR-And/Or Anti-Reflective Coatings for Reducing Reflectivity.

Task 8 - Investigate Means for Applying IR And/Or AR Coatings in Large-Volume Production.

Task 9 - Cost Effectiveness.

INTRODUCTION

There are four broad areas of technology that are being considered in this program: (1) UV-resistant glazing and housing materials; (2) UV protective coatings; (3) surface etching processes; and (4) anti-reflective coatings.

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; eventually they may even crumble away entirely.

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.

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 or physical properties.
- d. Property retention over a wide use/temperature range, from -40 to 300°F .
- 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.

TECHNICAL DISCUSSION

Task 1 - Information Search

This was essentially completed during the early phase of the program. However, it is, nevertheless, a never-ending task because there are always new coatings coming on the market as well as new glazings, e.g., Ardel from Union Carbide. Thus, we will continually be on the lookout for new materials to introduce into the program.

Task 2 - Accelerated and Outdoor Exposure of Glazing and Housing Materials

A. Glazing Materials

Twenty plastic glazing materials are under accelerated weathering exposure in the Weather-Ometer and natural outdoor exposure (at a 45° angle) on the roof at Hazardville, CT. These materials are divided into four classes (Table 1) - fluorocarbons, thermoplastic polyester, thermoset polyester and a miscellaneous group (composed of polycarbonates, cellulose acetate butyrate, acrylic, polyvinyl chloride and crosslinked ethylene/vinyl acetate copolymer). These materials were chosen on the basis of our experience and the desire to include a wide variety of potentially useful polymer chemical classes.

Samples are under exposure for four, eight and twelve months. At the end of each time period the glazings are 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 is shown in Table 2⁽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.

Table 3 indicates the loss in solar transmission after four months exposure in the Weather-Ometer. Table 4 reveals similar data for outdoor exposure at Hazardville, CT (45° angle) after 4 and 12 months. Table 5 compares percent transmission retained after 4 months in the Weather-Ometer and after 4 and 12 months exterior exposure.

Fluorocarbons evidence little change even after 12 months outdoors. The same is true of both the thermoset and thermoplastic polyesters although Mylar has begun to degrade in the Weather-Ometer after four months. In the miscellaneous group only the plasticized polyvinyl chloride (PVC) reinforced with polyester scrim evidences optical degradation in both the Weather-Ometer and outdoors.

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. In Table 6 all of the glazing materials are ranked by optical index after eight months exposure outdoors at Hazardville, CT.

(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).

Incipient failure is also indicated by clouding or spotting. Table 7 reveals the visual changes occurring in all 20 of the glazing materials after four months outdoor and Weather-Ometer exposure. The fluorocarbons (Top 5) are unchanged. However, several of the polyesters, Mylar-Llumar are undergoing clouding in the Weather-Ometer, but not outdoors. This is undoubtedly due to the known hydrolysis effect of moisture (water spray in the Weather-Ometer) on the ester group. The yellowing of Lexan and CAB (cellulose acetate butyrate) is the first sign of UV oxidation. The yellowing of the PVC/scrin 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.

Although optical properties are the prime prerequisite of any glazing, it is also important that there be adequate retention of tensile properties during weathering. Table 8 reveals the tensile strength, modulus and ultimate elongation of the glazing materials after four months of outdoor exposure. Three fluorocarbons have lost tensile strength - Tedlar 400XRB160SE, Halar 500 and Kynar 450 - but only Kynar 450 has also decreased in elongation.

All of the polyesters under exposure show significant (tensile and elongation) degradation, especially Mylar. In the group of thermoset polyesters only Sunlite II has degraded by chain scission, while the increase in tensile indicates that Glasteel is crosslinking.

In the miscellaneous group Lexan, CAB and Plexiglass V-811 (acrylic) are beginning to degrade. However, it is well known that acrylics are activated by wavelengths lower than 290nm, i.e., wavelengths not found in the sun's spectrum at the earth's surface. Some of these shorter wavelengths are found in the carbon arc Weather-Ometer. Therefore, acrylic and other selected glazing materials will also be exposed in the RS-4 sunlamp to recheck the validity of the Weather-Ometer. Another check on the Weather-Ometer is the outdoor exposure at Hazardville, CT.

B. Housing Materials

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

- Wood composites (1&2)⁽¹⁾
- Fiberglass reinforced polyester (3&4)
- Peroxide crosslinked, filled HDPE (5&6)
- Thermosets (7&8)
- Glass or talc filled thermoplastics (9&10)
- Thermoplastic Foams (11&12)
- PVC compounds (13&14)

(1) The numbers refer to specific materials in Table 9.

Changes in tensile strength, modulus and ultimate elongation are shown in Table 10 and the percent tensile strength and elongation retained in Table 11. 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 (Masonite and Pan-L-Board) is not as significant as are the visual changes, e.g., swelling or delamination.

After four months Weather-Ometer exposure Masonite Super Dorlux loses about half its tensile strength but retains its elongation; the opposite is true of Pan-L-Board where the strength triples and elongation is down to 1/3 of the original.

Neither of the fiberglass reinforced polyesters (#3 and 4), Tables 10 and 11) nor the two thermosets (#7 and 8) 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.

Both polyvinyl chloride formulations are crosslinking as indicated by their increase in tensile strength. Such crosslinking is a "plus" initially but could lead to embrittlement if carried too far.

Visual changes in the housing materials after four months in the Weather-Ometer are revealed in Table 12. 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.

Task 5 - UV Protective Films and Coatings

Polymers that are weather-resistant are high in price. 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. Coating With UV Absorbers

Base on UV stable polymer

2. Commercial Films Containing UV Absorbers

Tedlar 100BG30UT (polyvinyl fluoride)
Korad 201R (acrylic)

3. Film with UV Absorbing Characteristics

Tedlar 20 (400SG20TR)
Halar 500 (Ethylene/Chlorotrifluoroethylene)

4. Stabilize The Substrate

A. Films

Tedlar 20 (Tedlar 400SG20TR) (Polyvinyl fluoride, duPont) and Halar 500 (Ethylene chlorotrifluoroethylene, Allied Chemical) were chosen as films which absorb strongly in the UV and are reputed to be UV stable. In addition, three commercial films containing UV absorbers, two fluorocarbon types, (Tedlar 400XRB-160SE from duPont) and an acrylic (Korad 201R, from XCEL Corp.) were investigated. All four of these films were laminated by a variety of techniques to the following four glazing substrates:

- Tedlar 400XRB160SE (polyvinyl fluoride)
- Plexiglass V-811 (acrylic homopolymer)
- crosslinked Ethylene/Vinyl Acetate Copolymer
- Llumar (thermoplastic polyester)

Tedlar 100BG30UT 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 include heat, Lupersol 101 peroxide [2,5-Dimethyl-2,5-di(t-butyl peroxy)hexane from Lucidol], GESS4179 silicone adhesive, duPont 68070 adhesive and Dow Corning Z6030 (methacryloxy-propyl trimethoxysilane) interspersed between the films. Efficiency of adhesion is rated in Table 13 for each of these systems on a scale of F (failure), M (moderate adhesion) and S (strong adhesion).

Judging bond strength as is, i.e., on a dry basis, is only the first step. In actual use a laminate will have to withstand wide variations in moisture. Therefore, to accelerate bond degradation promising laminates were immersed in water for one week and bond strength re-evaluated (Table 14). Those laminates showing the best adhesion are now under exposure in the Weather-Ometer (Table 15).

The integrated solar transmission of the laminates ranges from 85 to 89% (Table 16).

In the same table appears the solar transmission of each of the individual materials. In every case solar transmission of the laminates is either below the individual film transmission or at the value of the film with the lowest transmission. This decrease in transmission could be caused by optical mismatch or by the adhesive.

B. 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 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.

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 acrylic coatings were considered primarily.

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 coatings to more than twelve years of outdoor weathering without any visible evidence of deterioration⁽¹⁾. Experiments at Springborn Laboratories with acrylic coatings show promising performance.

Both solvent-based and latex acrylic coatings are being examined. 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.

In Table 17 the wide variety of coatings under study are shown with information on type of coating, manufacturer, presence of UV absorbers and the manufacturer's opinion on expected weathering life, suggested method of application and effect of prolonged water exposure.

The coating procedure involved sections of glazing dipped into the coating and dried both at room temperature and at 100°C. We first checked to be certain the coating did not attack the glazing, and secondly that the coating had good bond strength both as is (dry) and after one week's water immersion for those samples having good adhesion dry.

After one week's immersion in room temperature water the color clarity and bond strength were noted. Of over 22 coatings only five had sufficient adhesion to the EVA to test wet and after immersion only one (EB9388 - Experimental Urethane Latex from Valspar Corp.) still had a strong bond (Table 18).

The story is quite different for the acrylic coatings on Plexiglass V8-11 (polymethylmethacrylate homopolymer). Most coatings gave good bonds dry and many were still good after water immersion (Table 19).

To improve adhesion several coatings were applied to uncrosslinked EVA and the sheet cured in a press. Bond strength was improved but coating quality was poor. Other acrylic coatings will be examined for improved bond strength; primers will be used if necessary.

(1) Rohm & Haas, "Thermoplastic Acrylics-Exposure Series 57YY" Memo 5101243: May 14, 1969; Quoted by Permission.

C. Surface Etching

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.

Previously a wide variety of potential chemical etchants were examined on four transparent plastics: peroxide crosslinked ethylene/vinyl acetate copolymer (Elvax 150 from duPont), polymethylmethacrylate (Rohm & Haas' Plexiglass V-811), thermoplastic polyester (Llumar - a UV absorber impregnated material from Martin Processing, Inc., Martinsville, Va.), and polyvinyl fluoride (Tedlar 400XRB160SE from duPont). These four were chosen because they are four widely varying chemical structures - polyolefin, acrylic, thermoplastic polyester and a fluorocarbon - with potential as glazings. Gloss, as a possible indication of decreased reflection was measured and found to be decreased. However, in no case was transmission improved.

More recently the etching conditions in Table 20 were investigated on Llumar Plexiglass V-811 and Tedlar 400XRB160SE. Acetophenone has been reported by Honeywell to increase reflection of Tedlar. With all three glazings solar transmission was decreased rather than increased.

Task 7 - AR Coatings

The use of AR coatings has long been in use on glass to reduce reflection loss and increase transmission. Such coatings are now being investigated on plastics.

Sheets of the following were coated by Evaporated Coatings, Huntington Valley, PA, 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 Plexiglass V-811 (acrylic)

Table 22 presents the direct transmission at 550nm and Table 23 the direct transmission over the range of 400nm to 700nm. The same picture is shown by both sets of data. In all cases, except one - multilayer crosslinked EVA, there is an increase in percent transmission on the coated sheets. Solar integrated transmission will be measured for these materials and if results are still promising samples will be subjected to accelerated weathering.

These and two other materials (Lexan and Sunlite Premium II) will be AR coated by three other companies - ITW (Illinois Tool Works), AO (American Optical) and OCLI (Optical Coatings Lab).

FUTURE WORK

Weather-Ometer exposure will be completed and EMMAQUA Arizona outdoor exposure initiated. Soiling studies will be carried out on the samples exposed for one year outdoors at Hazardville, CT. A wide range of properties will be evaluated on promising, i.e., the more weather stable, glazing materials.

UV stabilizer systems will be blended into the optimum acrylic coatings, coated onto the most weather stable glazings and the composite will be exposed in the Weather-Ometer. Evaluation of etching processes and AR coatings will continue.

TABLE 1
GLAZING MATERIALS

	<u>Chemical Structure</u>	<u>Manufacturer</u>	<u>Sample Thickness Mils</u>
<u>Fluorocarbons</u>			
1. Tedlar 400XRB160SE	Polyvinyl Fluoride	duPont	4
2. PFA 9705	Perfluoro Alkoxy	duPont	2
3. Halar 500	Ethylene/Chlorotri- fluoroethylene	Allied	2
4. Kynar 450	Polyvinylidene Fluoride	Pennwalt	5
5. FEP 100A	Perfluorethylene Propylene	duPont	1
<u>Thermoplastic Polyesters</u>			
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
<u>Thermoset Polyesters</u>			
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
<u>Miscellaneous</u>			
14. Lexan	Polycarbonate	G.E.	40
15. Tuffak CM-2	Abrasion Resistant Polycarbonate	Rohm & Haas	40
16. Tenite 479	Cellulose Acetate Butyrate (CAB)	Tennessee Eastman	35
17. Plexiglas V811	Polymethyl Methacrylate	Rohm & Haas	40
18. Geon 103EP Scrim Reinforced	Polyvinyl Chloride	Monsanto	20
19. EVA 150	Peroxide Crosslinked Ethylene/Vinyl Acetate Copolymer	Uncrosslinked EVA 150 is from duPont	20
20. Flexigard 7410	Polyester/acrylic Laminate	3M	8

TABLE 2
Degradation of Polyethylene Exposed to
 15,000 Langleys in Arizona, 1960

<u>Month</u>	<u>Carbonyl Formed, %</u>	<u>Elongation Retained, %</u>	<u>Est. UV ^a Exposure</u>
January	0.019	100	345
February	0.025	100	435
March	0.029	100	615
April	0.036	91	795
May	0.055	79	945
June	0.120	43	1020
July	0.130	19	1035
August	0.102	25	1020
September	0.070	43	975
October	0.036	88	690
November	0.020	100	435
December	0.017	96	285

^aTotal langleys in the region of 2900-3150°A, obtained by multiplying 15,000 langleys by the fraction of energy in this region.

TABLE 3
INTEGRATED SOLAR OPTICAL TRANSMISSION⁽¹⁾
AFTER FOUR MONTHS EXPOSURE IN THE
WEATHER-OMETER

<u>Material</u>	<u>Original</u>	<u>% Transmission After 4 Months</u>
<u>Fluorocarbons</u>		
Tedlar 400XRB160SE	92	89
P.F.A.	94	95
Halar 500	93	93
Kynar 450	93	92
F.E.P. 100-A	96	95
<u>Thermoplastic Polyesters</u>		
Mylar	84	74.9
Nat. Metallizing 45-95-1	88	86
Nat. Metallizing 45-95-2	85	85
Llumar	86	86
Ardel	70	69
<u>Thermoset Polyesters</u>		
Filon 558	87	83
Sunlite Premium II	87	85
Glassteel 500	83	85
<u>Miscellaneous</u>		
Lexan	86	84
Tuffak CM-2	85	84
C.A.B.	91	88
Plexiglass V-811	90	90
Polyvinyl Chloride/scrim	88	81
Flexigard 7410	86.3	88

(1) Integrated over the range 350nm to 2100nm.

TABLE 4

INTEGRATED SOLAR⁽¹⁾ OPTICAL TRANSMISSION AFTER
4 MONTHS AND 12 MONTHS EXTERIOR EXPOSURE
AT HAZARDVILLE, CONNECTICUT

Glazing Material	Solar Transmission Original	% Solar Trans. After Exposure	
		4 Months	12 Months
<u>Fluorocarbons</u>			
Tedlar 400XRB160SE	92	89	88
P.F.A.	94	95	93
Halar 500	93	92	89
Kynar 450	93	91	90
F.E.P. 100A	96	95	91
<u>Thermoplastic Polyesters</u>			
Mylar	84	84	81
Nat. Metallizing 45-95-1	88	85	85
Nat. Metallizing 45-95-2	85	86	85
Llumar	86	86	84
Ardel	70	71	72
<u>Thermoset Polyesters</u>			
Filon 558	87	85	84
Sunlite Premium II	87	86	82
Glassteel 500	83	83	100
<u>Miscellaneous</u>			
Lexan	86	86	82
Tuffak CM-2	85	86	84
Tenite CAB	91	88	86
Plexiglass V-811	90	90	89
PVC Scrim	88	82	77
Flexigard	88	89	86

(1) Air Mass 2

TABLE 5

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

Material	Original	% Solar Transmission Retained		
		Weather-Ometer	Outdoors	
		4 Mos.	4 Mos.	12 Mos.
<u>Fluorocarbons</u>				
Tedlar 400XRB160SE	92	97	97	96
P.F.A.	94	100	100	99
Halar 500	93	100	99	96
Kynar 450	93	99	98	97
F.E.P. 100-A	96	99	99	95
<u>Thermoplastic Polyesters</u>				
Mylar	84	89	100	89
Nat. Metallizing 45-95-1	88	98	97	97
Nat. Metallizing 45-95-2	85	100	100	100
Llumar	86	100	100	98
Ardel	70	99	100	100
<u>Thermoset Polyesters</u>				
Filon 558	87	95	98	97
Sunlite Premium II	87	98	99	94
Glassteel 500	83	100	100	100
<u>Miscellaneous</u>				
Lexan	86	98	100	95
Tuffak CM-2	85	99	100	99
C.A.B.	91	97	97	95
Plexiglass V-811	90	100	100	99
Polyester Scrim Reinforced PVC	88	92	93	88
Flexigard 7410	88	100	100	98
Crosslinked EVA ⁽²⁾	89	(2)	98	(2)

(1) Integrated over the range 350nm to 2400nm.

(2) Data not yet available.

TABLE 6

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 400XRB160SE	Fluorocarbon (UV Stabilized)	81
6.	Plexiglass V-811	Acrylic	80
7.	CAB	Cellulose Esther	78
8.	Flexigard	Polyester/Acrylic Laminate	76
9.	Nat. Metallizing 45-95-1	Thermoplastic Poly- ester (UV Stabilized)	75
10.	Filon 558	Tedlar Coated FRP	73
11.	Nat. Metallizing 45-95-2	Thermoplastic Poly- ester (UV Stabilized)	72
12.	Llumar	Thermoplastic Poly- ester (UV Stabilized)	72
13.	Tuffak CM-2	Polycarbonate	71
14.	Lexan	Polycarbonate	71
15.	Sunlite Premium II	Thermoset Polyester	71
16.	Glassteel 500	Thermoset Polyester	70
17.	Mylar	Thermoplastic Polyester	68
18.	PVC Scrim Reinforced	Polyvinyl (polyester scrim) Chloride (UV Stabilized)	68
19.	Ardel	Polyether	50

(1) Product of % transmission after elapsed time and original transmission. Plexiglass original transmission is 96% x 8 month % transmission retained of 90% = 86.

TABLE 7

Qualitative Color Changes on Glazings
After Four Months Exposure

Glazing Materials	Original Color	Color Changes After 4 Months Exterior Exposure	Color Changes After 4 Months Weather-Ometer
<u>Fluorocarbons</u>			
- Tedlar 400XRB160SE	Clear	None	None, few spots
- P.F.A.	Clear	None	None
- Halar 500	Clear, slight distortion	None	None
- Kynar 450	Clear	None	None
- F.E.P. 100-A	Clear	None	None
<u>Thermoplastic Polyesters</u>			
- Mylar	Cloudy	None	Severe clouding
- Nat. Metallizing 45-95-1	Clear	None	Slight clouding
- Nat. Metallizing 45-95-2	Clear	None	Very slight clouding
- Llummar	Clear	None	White spots
- Ardel	Amber tint	None	None, a few spots
<u>Thermoset Polyesters</u>			
- Filon 558	Cloudy, fibers visible	None	None
- Sunlite Premium II	Cloudy, fibers	None	None
- Glassteel 500	Cloudy, fibers visible	None	None
<u>Miscellaneous</u>			
- Lexan	Clear	None	Yellowing, spots on surface
- Tuffak CM-2	Clear	None	Spotting
- C.A.B.	Clear	Slight yellowing	Slight yellowing
- Plexiglass V-811	Clear	None	None
- Polyvinyl Chloride/ Scrim	Clear, slight distortion	Slight yellowing	Yellowing
- Crosslinked EVA	Clear	(1)	(1)
- Flexigard 7410	Clear	None	None

(1) Data not yet available.

TABLE 8
Tensile Properties of Glazings 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
<u>Fluorocarbons</u>						
- 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
<u>Thermoplastic Polyesters</u>						
- 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	3.43	5.83	48	37
- Llumar	29,936	22,927	5.02	3.48	53	32
- Ardel 100	(1)	-	-	-	-	-
<u>Thermoset Polyesters</u>						
- 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 (1)	6,630	9,149	5.10	4.22	1.0	4.5
<u>Miscellaneous</u>						
- Lexan	7,401	7,064	1.66	2.07	42	13
- Tuffak CM-2	(1)	-	-	-	-	-
- CAB	5,190	3,375	0.92	0.89	29	40
- 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)	(1)	-	-	-	-	-
- EVA 150	(1)	-	-	-	-	-

(1) Data not yet available.

TABLE 9

Housing Materials
Exposed in the Weather-Ometer

1. Super Dorlux Masonite particle board, 0.125"; Masonite Corporation.
2. Pan-L-Board, 0.100"; Mead Corporation.
3. FRP Sheet (glass fiber reinforced polyester), 0.125"; Polyply, Inc
4. Polyester S660, 0.140"; Fiberite Corporation.
5. Carbon black filled peroxide crosslinked high/density polyethylene; 0.125"; Springborn Laboratories formulation.
6. Burgess KE clay-filled, peroxide crosslinked high density polyethylene; 0.125"; Springborn formulation.
7. Melamine-M2037 (melamine/formaldehyde copolymer), 0.125"; Fiberite Corporation.
8. Filled phenolic (phenol/formaldehyde copolymer FM 4005), 0.125"; Fiberite Corporation.
9. Dylark 250 (styrene/maleic acid copolymer - glass filled), 0.125"; Arco Chemical Company.
10. Forty percent talc-filled polypropylene; 0.125"; Hercules Corporation.
11. Polypropylene structural foam - 30 percent fiberglass; 0.150"; Vantage Products Corporation.
12. Cellular polyvinyl chloride, 0.125"; B. F. Goodrich.
13. Exterior grade PVC pipe compound 7084 (polyvinyl chloride); 0.125"; B. F. Goodrich Company.
14. IBID "11" but using 85857 compound, 0.125"; B. F. Goodrich.

TABLE 10

Tensile Properties of Housing Materials
After Four Months Exposure in the
Weather-Ometer

<u>Material</u>	Tensile Strength psi		Modulus psi x 10 ⁻⁵		Ult. Elongation %	
	<u>Original</u>	<u>After 4 Months</u>	<u>Original</u>	<u>After 4 Months</u>	<u>Original</u>	<u>After 4 Months</u>
1. Super Dorlux Masonite	4150	1910	9.1	3.71	<1	0.9
2. Pan-L-Board	1570	4670	1.3	5.64	5.5	1.7
3. FRP Sheet	10260	11550	14.1	21.0	2	1.8
4. S-660 Polyester	3710	4010	18.9	30.7	<1	0.1
5. Carbon-Filled Crosslinked HDPE	3525	2410	1.52	2.56	259	227
6. Clay-Filled Crosslinked HDPE	2520	275	1.51	2.10	248	17
7. Melamine M6024	3560	4050	14.9	15.3	<1	0.4
8. Filled Phenolic	6050	6590	18.9	21.2	<1	0.4
9. Dylark 250	4110	2080	3.2	3.63	<1	0.7
10. Talc-Filled Polypropylene	4090	3975	7.60	7.18	8	3
11. Glass-Filled Polypropylene Foam	1440	1200	1.0	0.93	7.5	2.0
12. Cellular PVC	1680	1990	1.1	1.21	46	20.0
13. Geon 7084 PVC	4800	6820	4.6	5.22	46.5	8.0
14. Geon 85857 PVC	4770	6430	4.0	3.94	5.5	2.0

TABLE 11

Tensile Property Retention of Housing
Materials After Four Months Aging in
the Weather-Ometer

<u>Material</u>	<u>% Tensile Strength Retained</u>	<u>% Ultimate Elongation Retained</u>
1. Super Dorlux Masonite	46%	90%
2. Pan-L-Board	297%	31%
3. FRP Sheet	113%	90%
4. S-660 Polyester	108%	(1)
5. Carbon-Filled Crosslinked HDPE		
6. Clay-Filled Crosslinked HDPE		
7. Melamine M6204	114%	(1)
8. Filled Phenolic FM 4005	109%	(1)
10. Talc-Filled Polypropylene		
11. 30% Glass-Filled Polypropylene Foam	83%	27%
12. GEON PVC Cellular Sheet	118%	43%
13. GEON 7084 PVC	142%	17%
14. GEON 85857 PVC	135%	35%

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

TABLE 12

Visual Changes on Housing Materials After
Four Months Exposure in the Weather-Ometer

Housing Material	Original Color	After 4 Months Exposure in Weather-Ometer	Other Changes
1. Super Dorlux	Brown	Chalky White	Slight delamination. White can be scraped off.
2. Pan-L-Board	Brown	Completely white, front and back	Moderate delamination
3. FRP Sheet (glass fiber reinforced polyester)	Shiny Black	Dark gray	None
4. Polyester S-660	Shiny Black	Dull Black	None
5. Carbon black filled crosslinked HDPE	Black	Black	None
6. Burgess KE clay-filled crosslinked HDPE	White	Off White	None
7. Melamine M2037	Shiny Black	Dull Black	None
8. Filled Phenolic FM 4005	Shiny Black	Dull Black with patches of gray	Gray patches scrap easily
9. Dylark 250	Yellow	Dark yellow-tan	None
10. 40% Talc-filled Polypropylene	Gray	White	Surface can be scraped off
11. Polypropylene Structural foam 30% glass filled	Gray	Grayish-green, some white patches	Bubbles in edges. Crumbles easily
12. Cellular PVC	White	Dark Brown	None
13. GEON 7084	White	Light tan	None
14. GEON 85857	White	Light tan	None

TABLE 13
BONDING⁽¹⁾ OF LAMINATES

Substrates	(2) Korad 201R	Tedlar (2) 100BG3OUT	(2) Halar 500	(2) Tedlar 400SG20TR
Tedlar 400XRB160SE	Heat N Peroxide S GE (3) F DC F DP S	N N N N S	N F F F F	N N N N N
Plexiglass Acrylic V-811	Heat S Peroxide S GE S DC S DP S	N S M F S	N F F F M	N S S F M
Crosslinked EVA	Heat F Peroxide S GE S DC S DP S	M M S S S	N M F F F	F M F F S
Llumar Polyester	Heat N Peroxide S GE F DC M DP S	N F F F S	N F F F S	N F F F F

(1) F - Failure

M - Moderate

S - Strong Adhesion

N - Not Attempted

(2) Protective top cover.

(3) See Table 14 for material explanation.

TABLE 14
COMPOSITE 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
Plexiglass V-811 ⁽⁴⁾	Tedlar 20	Lupersol 101	M	F (Hazy)
Plexiglass V-811	Tedlar UT	Lupersol 101	M	M
Plexiglass V-811	Tedlar UT	DP	S	S
Plexiglass V-811	Korad 201R	Lupersol 101	S	S
Plexiglass V-811	Korad 201R	Heat Only	S	S
Plexiglass V-811	Korad 201R	DC	S	S
Plexiglass V-811	Korad 201R	DP	S	S
Plexiglass 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 15
GLAZING LAMINATES ON EXPOSURE
IN THE WEATHER-OMETER

<u>Top Film</u>	<u>Substrate</u>	<u>Adhesive</u>
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) Plexiglass 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-Dl(t-butylperoxy) Hexane.
 (7) Korad 201R - Multistage Acrylic Copolymer.
 (8) Tedlar 100BG30UT - Polyvinyl Fluoride (1 Mil, adhesive bondable, UV stabilized).
 (9) Llumar - Polyester.

TABLE 16
INTEGRATED SOLAR TRANSMISSION
FOR LAMINATES

<u>Substrate</u>		<u>Protective Top Film</u>		<u>Adhesive</u>	<u>% Solar Trans. of Laminate</u>
<u>Type</u>	<u>% Solar Trans.</u>	<u>Type</u>	<u>% Solar Trans.</u>		
1. Korad 201R	91	Tedlar 400XRB160SE	92	Lupersol 101	89
2. Korad 201R	91	Plexiglass V-811	90	Heat	87
3. Korad 201R	91	X-L EVA	91	DuPont 68070	87
4. Korad 201R	91	Llumar	86	DuPont 68070	86
5. Halar 500	93	X-L EVA	91	Lupersol 101	89
6. Halar 500	93	Llumar	86	DuPont 68070	85
7. Tedlar 100BG3OUT	92	Plexiglass V-811	90	DuPont 68070	88
8. Tedlar 160BG3OUT	92	X-L EVA	91	DuPont 68070	87
9. Tedlar 100BG3OUT	92	Llumar	86	DuPont 68070	86
10. Tedlar 400XRB 160SE	92	Plexiglass V-811	90	DuPont 68070	88
11. Tedlar 400XRB 160SE	92	X-L EVA	91	Lupersol 101	88

TABLE 17A
COATINGS EXAMINED

Coating	Manufacturer	UV Absorbers	Solar Expected Lifetime	Suggested Method of Application	Prolonged H ₂ O Exposure Effects
Arolon 557-D-70 - Solvent Based Acrylic	Spencer Kellogg	None	Not long (~1 Yr.)	Dip or Spray and Bake	If baked, it is very resistant
Joncryl 74F - Water Based Acrylic/Styrene " 101 - Water Based Acrylic/Styrene " 61 - Solvent Based Acrylic/Styrene M 50 - Water Based Acrylic/Styrene M 130 - Water Based Acrylic/Styrene Perma-cote 62 - Solvent Based Acrylic/Styrene	Johnson Wax	None	~1 Year ~1 Year ~1 Year ~1 Year ~1 Year ~1 Year	Dip or Spray and Bake	May tend to blush
Hycar 2600x91 Acrylic Latex " 138 Acrylic Latex " 172 Acrylic Latex " 256 Acrylic Latex	B.F. Goodrich Chemicals	None Suggests Irganox 1024 & Tinuvin 328 (0.25-0.50% WT.)	No facts on this	Dipping and Baking	Less Resistant These two are more resistant
Neocryl A-622 Acrylic Latex	Polyvinyl Chemicals	None, Suggests Cyasorb VU24	Not Long (~1 Yr.)	Spray	500 Hr. Q.U.V. W. Ometer = No Effect
LB9388 (Experimental) Urethane Latex EB9389 (Experimental) Buacrylate/Methyl Methacrylate, Acrylic Latex EB9391 (Experimental) Buacrylate/Methyl Methacrylate, Acrylic Latex	Valspar Corp.	None Suggests Cyasorb UV24	3-4 Years	9388 May not surface wet	Water spot problems
3730 - Self Reactive Styrene/Acrylic Latex 2345 - Vinyl/Acrylic Copolymer Latex 2813 - Self Reactive Vinyl/Acrylic Terpolymer Latex 4280 - Self Reactive Acrylic Latex (w/ Minor portion of acrylonitrile)	National Starch and Chemicals Co.	None	Pigmented 9 Yrs. Unpigmented = ?	Any	Some blushing
Mistacote 600-F-900 Acrylic Latex	MR Plastics	Has UV Screeners	3-5 Years		Resistant
229S49442 - Black Transparent W.B./Lac. Solvent Based Acrylic S49444 - Transparent Black Lac., Solvent Based Acrylic SV2898 - Thinner	Red Spot Paint	All have UV absorbers	No facts on life-time	Any	They have a tendency to spot
347-63-5S - Solvent Based Acrylic T-512 - Thinner	Service Coatings	Has Tinuvin 328 and 1076	~1 Yr. (not considered a permanent outdoor coating)		
Rhoplex WL81 - Acrylic Latex Methyl Methacrylate Acryloid B-84 - Solvent Based Acrylic Coating	Rohm and Haas	None, Suggests 2% Tinuvin	Coatings not	Bake	Resistant Resistant

TABLE 17B
COATINGS EXAMINED

Coating	UV Absorber	Expected Solar Lifetime	Suggested Mode of Application	Prolonged H ₂ O Exposure Effects
ED25164 - Celanese Solvent/Coating			Spray/Bake	
Spraylat	None	Not Long		
Airflex 6500 - Air Products, Ethylene/Vinyl Chloride Terpolymer end capped w/Amide Airflex 6514 - Air Products, Ethylene/Vinyl Chloride Terpolymer end capped w/Amide	None Suggests 5% Hexamethyl Phosphoric triamide, 5% Diphenyl Phthalate, 5% 2,4-Dihydroxy Benzophenone	No faults on outdoor lifetime		Resistant

TABLE 18

Effect of Water Immersion on Bond Strength
of Coatings on EVA

Coating	Application Drying Temp (C°)	Before Immersion	While Still Wet	After Drying	Bond ⁽¹⁾ Before Immersion	Bond While Still Wet	Bond After Drying
Joncryl 74F ⁽²⁾	Room Temp	Clear	White, few bubbles	Clear	M	F	F
Hycar ⁽³⁾ 2600 x 91	100°C	Clear	White	Clear	M	F	M-F
	Room Temp	Clear	White	Clear	M	F	F
Hycar ⁽³⁾ 2600 x 138	100°C	Clear	Clear	Clear	S	F	F
	Room Temp	Clear	Clear	Clear	S	F	F
EB9388 ⁽⁴⁾	100°C	Clear, few cracks	Clear, cracks few bubbles	Clear, surface all crack	S	S	S
2813 ⁽⁵⁾	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

(2) Acrylic/styrene copolymer latex

(3) Acrylic Latex

(4) Urethane latex

(5) Vinyl/acrylic latex

TABLE 19

Effect of Water Immersion on Bond Strength
of Coatings on Plexiglass V-811*

Coating	Application Drying Temp (C°)	Before Immersion	While Still Wet	After Drying	Bond Before Immersion	Bond While Still Wet	Bond After Drying
Aroclon 557-D-70	Room Temp	Clear with bubbles	White	White	S	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 19 -(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 20
ETCHING CONDITIONS

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

TABLE 21
Percent Solar Transmission
After Etching

Glazing Material	Original Transmission	Transmission After Etching	Etching Solution
Plexiglass V-811	90	88	1,1,1-Tri Chloro Ethane
Llumar	86	85	Ethyl Acetate
Tedlar 400XRB160SE	92	88	Acetophenone

TABLE 22

Percent Direct Transmission at 550nm After
AR Coating Both Sides of a Plastic Sheet

<u>Material</u>	<u>AR Coated</u>	<u>Coated at Nor- mal Incidence</u>		<u>Coated at 45°</u>	
		<u>Single⁽⁵⁾ Layer</u>	<u>Multi Layer</u>	<u>Single Layer</u>	<u>Multi Layer</u>
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 23

Percent Direct Transmission Over the Range
400-700nm After AR Coating Both Sides of a Plastic Sheet

<u>Material</u>	<u>AR Coated</u>	<u>Coated at Nor- mal Incidence</u>		<u>Coated at 45°</u>	
		<u>Single Layer</u>	<u>Multi Layer</u>	<u>Single Layer</u>	<u>Multi Layer</u>
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