TABLE OF CONTENTS

FOREWORD 1

PUBLICATION 1

REFERENCE STANDARDS 2

GLAZING CLASSIFICATIONS 3
- Type I
- Type II
- Type III

LIGHT TRANSMISSION 3
- Photosynthetically Active Radiation
- Total Solar Radiation
- Haze and Luminous Transmittance
- Near Infrared Transmission
- Medium/Far Infrared Radiation

ASTM E-424-71 3

ENERGY 5
- U-Value

STRENGTH 5
- Hail Resistance
- Tear Resistance
- Wind Load

LONGEVITY 6
- Type I
  - Strength
  - Solar Light Transmission
- Type II
  - Current Text
  - Load
  - Glazing System Design & Safety
- Type III
  - Strength
  - Solar/Par Transmission

COMBUSTIBILITY 8

MISCELLANEOUS 9

CHEMICAL AND MATERIAL COMPATIBILITY 9

National Greenhouse Manufacturers Association 1986 (2004)

GLAZING STANDARD GUIDELINES & VOLUNTARY STANDARD TEST METHODS

FOREWORD

The NGMA, having received comment from grower and residential purchasers of glazing materials regarding the vagueness, confusion and lack of standard test method citation in the public advertising of glazing performance, has promulgated the Glazing Standard. It covers recommended test methods form heat transfer, light transmission, longevity, and resistance to hail, tearing, wind load and combustibility.

The use and results reporting of the recommended test method shall be voluntary on the part of glazing manufacturers, greenhouse manufacturers or glazing resellers. Some manufacturers may prefer one test method over another. A few tests are mandatory depending on the industry and application. The voluntary NGMA Standard is published with the official recommendation of NGMA in order that Architects, engineers, greenhouse manufacturers, consumers and growers may request glazing performance measurements based on this standard and that glazing manufacturers voluntarily comply with those requests.

Nothing contained herein shall be construed as a mandatory requirement (i.e., as a basis for NGMA membership) and no comments or statements herein shall be construed to imply that only one type, shapes, form or material content of glazing is preferred over another nor that any brand names associated with NGMA membership are preferred over other member's brands or nonmembers brands

PUBLICATION

This standard is the property of and published by the national Greenhouse Manufacturers Association, a nonprofit group dedicated to the continued growth of controlled environment horticulture in the U.S.A... This standard may be amended from time to time and the dates of all revisions shall be identified at the end of this Paragraph – April 1990 (April 2004)

REFERENCE STANDARDS (In this Publication)

ASTM C-158	Method for Flexure Testing of Glass (Determination of Modulus of Rupture).
ASTM C-236	Test method for steady-state thermal performance of building assemblies by means of a guarded hot box.
ASTM D-256	Test method for impact resistance of plastics and electrical insulating materials.
ASTM D-265	Test for Impact using Gardner Impact Method.
ASTM D-568	Test method for rate of burning and /or extent of burning of Flexible plastics in a vertical position.
ASTM D-635-74	Test method for rate of burning and/or extent of burning of self supporting plastics in a horizontal position.
ASTM D-638	Test for Plastics – Tensile Strength, Elongation, and Tensile Modulus.
ASTM D-696	Test method for Coefficient of linear thermal expansion of plastics.
ASTM D-79	Test methods for flexural properties of un-reinforced and reinforced plastics and electrical insulation materials.
ASTM D-882	Test method for tensile properties of thin Plastics sheeting.
ASTM D-1003	Test method for haze and luminous Transmittance of transparent plastics.
ASTM D 1709-03	Test Method for Impact resistance of Polyethylene film by the free falling dart method.
ASTM D-256A	Test method for Impact resistance of thermoplastics recording IZOD impact values.
ASTM D-1922-03	Test method by propagation of resistance of Plastic film and thin sheeting by pendulum method.
ASTM D-1925	Test for yellowness index of plastics.
ASTM D-1929	Test method for ignition properties of plastics.
ASTM D-2843	Test method for density of smoke from the burning or decomposition of plastics.
ASTM D-3763	Test method for high speed punctures properties of plastics using load and displacement sensors.
ASTM D-4364-02	EMMAQUA practice for performing accelerated outdoor weathering of plastics using concentrated natural sunlight.
ASTM E-84	Test method to determine Smoke density and Flame spread ratings Similar to UL-723, ANSI No. 2.5, NFPA No 255 and UBC 42-1
ASTM E-72	Method for conducting strength of panels for building construction.
ASTM E-167	Recommended practice for Goniophotometry of object and materials.
ASTM E-330	Test Methods for structural performance of exterior windows, curtain walls and doors by uniform static air pressure difference.
ASTM E-424-71	Test Method for Solar Energy Transmittance and Reflectance (Terrestrial) of Sheet Materials.
ASTM E-822-92	(2003) Practice for determining resistance of solar collector cover to hail impact with propelled ice balls.
ASTM E-831	Test Method for linear thermal expansion of solid materials by Thermo chemical Analysis.
ASTM E-903-82	Test method for solar absorptance, reflectance and transmittance of materials using integrate spheres.
ASTM E-971-88	Standard Practice for calculation of Photometric transmittance and reflectance of materials to solar radiation.
ASTM E-972-88	Standard Test Method for Solar Photometric transmittance of sheet materials using sunlight.
ASTM E-1084-86	Standard Test Method for Solar Transmittance (Terrestrial) of sheet materials using sunlight.
ASTM E-1175-87	Test method for determining solar or phototrophic reflectance and absorptance of materials using a large diameter integrating sphere.
ASTM E-1886-02	Standard Test method for performance of Exterior Windows, Curtain Walls, and Storm shutters Impacted by Missile/s and exposed to Cyclic Pressure Differentials.
ASTM E-1996-03	Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors and Storm Shutters Impacted by Windborne Debris in Hurricanes.
ASTM G-26	Recommended practice for operating light exposure apparatus (xenon-arc type) with and without water for exposure of non-metallic materials.
UL94	Test for Flammability of Plastic Materials for Parts in devices and appliances.

CLASSIFICATIONS & LIGHT TRANSMISSION

GLAZING CLASSIFICATIONS

Because various glazing materials have radically different response to environmental conditions such as solar irradiance, wind, snow, and hail; and are by virtue of composition and manufacturing parameters quite different in physical properties, NGMA has elected to describe three different categories of glazing:

Type I Thin films, generally ranging from 2-8 mills (.002"-.008") normally double layer, air inflated Polyethylene, EVA (ethylene vinyl acetate), polyvinyl chloride (PVC), polyvinyl fluoride and polyester films fall into this category.

Type II "Flexible plastics such as fiberglass reinforced plastic (Thermoset Polyester (FRP), acrylic, polycarbonate, polypropylene, PVC, and PETG panels and the "ladder profile"("Multiwall") type structured materials such as polycarbonate, acrylics, Polypropylene, PETG and laminar composites of both (any)." This includes the following:

Flexible Thermoplastics

- o Multiwall Acrylic Sheet
- o Monolithic Acrylic Sheet
- o Corrugated Acrylic Sheet
- o Double & Multiwall Polycarbonate Sheet
- o Monolithic Polycarbonate Sheet
- o Corrugated Multiwall Polycarbonate Sheet
- o Corrugated Monolithic Polycarbonate Sheet
- o Monolithic PETG Co-Polymer (Glycol modified Polyester Terephthalate)
- o Multiwall Polypropylene Sheet
- o Monolithic PVC Sheet

Flexible Thermoset Polyester Plastic Sheet (Glass Reinforced FRP)

- o Monolithic fiberglass sheet
- o Corrugated fiberglass sheet

Composites

- o Combinations of Glazing plastics laminated to each other
- o Combinations of Glazing plastics laminated to Glass

TYPE III Rigid Materials – Glass: Float Glass, annealed, chemically strengthened, tempered and laminated forms of float, annealed, chemically strengthened, tempered, and rolled patterned glass

LIGHT TRANSMISSION

PHOTOSYNTHETICALLY ACTIVE RADIATION

Applicable to Types I and II and III, Photosynthetically Active Radiation (PAR) is the visible portion of the (light) spectrum from 400-700 nanometers and is regarded by many horticulturists as being critical for plant growth and development

Comparative analysis of glazing materials' light transmitting properties must take into consideration the number of layers of glazing involved for all three types. Single layer glazing generally will have somewhat higher solar transmission than multiple layer glazing.

For comparing potential plant growth, NGMA recommends that glazing manufacturers test and report the PAR data derived from the following test procedure/s.

"Light Transmission is measured over the spectrum from 300-2500 nanometers, which includes the PAR range. The Procedure provides a method to determine the weighted average transmission over this range. Testing and reporting should be performed according to the procedures specified in ASTM E-424-71 and/or any of the appropriate procedures listed below;(ASTM E-1175-87 "Standard Test method for determining Solar or phototrophic Reflectance of materials Using a large Diameter Integrating Sphere." Testing should be performed at incidence angles of 0", 45" and 60").

NGMA recommends ASTM 424-74 and one or any of the procedures listed below appropriate for the material substrate (ASTM E-1175 measurements) for comparison of new materials in Type I, Type II or Type III. Light Transmission values of aged materials will vary widely based on exposure conditions. {see LONGEVITY sections}"

TOTAL SOLAR RADIATION
Solar irradiance applicable to Types I, II, and III includes the entire energy spectrum created by the sun. It includes the major energy carrier in the near infrared waveband and is useful in calculating total energy gain in a greenhouse so that heating and cooling requirements can be calculated. ASTM E-903 provides this data and ASTM E-891 the calculating procedure.

HAZE AND LUMINOUS TRANSMITTANCE
Haze, the percentage of transmitted light that deviates from the incident beam by forward scattering and luminous transmittance, the ratio of transmitted light to incident light may be pertinent to a grower's overall evaluation of a glazing system. The procedures of ASTM D-1003 should be used to determine these values applicable to Type I and II. The procedures of ASTM E-903 should be used to determine the values applicable to Type III.

NEAR INFRARED TRANSMISSION
Near Infrared energy is the thermal solar radiation, which adds to the heating of the greenhouse. The infrared transmission from 700-2500mm is measured by procedures specified in ASTM E-903.

MEDIUM/FAR INFRARED RADIATION
Far infrared energy is the energy, which is reproduced by the (Thermal) mass inside a greenhouse. Transmission of far infrared energy through a greenhouse covering affects the heat retention capability of a greenhouse. 5 to 20 microns is the range of importance and 7 to 14 microns is the most critical area of that range as measured by procedures specified in ASTM E-903 modified.

ASTM E-424-71
Standard Test Methods for Solar Energy Transmittance and Reflectance (Terrestrial) of Sheet Materials American Society for Testing and Materials, 1916 Race St, Philadelphia PA 19103-1187, June 1971

PROCEDURES

- ASTM 903-82 – Standard test method for Solar Absorptance, Reflectance, and Transmittance of Materials using Integrating Spheres
- ASTM E-1084-86 – Standard Test Method for solar Transmittance (Terrestrial) of sheet materials using sunlight
- ASTM E-971-88 – Standard practice for calculation of Photometric transmittance and reflectance of materials to solar radiation
- ASTM E-972-88 – Standard Test Method for Solar photometric transmittance of sheet materials using sunlight.
- ASTM E-1175-87 – Standard Test Method for Determining Solar Photopic Reflectance, Transmittance or absorptance of materials using a Large diameter integrating sphere
- ASTM E-1003 Standard Test Method for measuring Haze, Luminous & Transmittance of Transparent Plastics

LIGHT TRANSMISSION (REVIEW)

Visible Light Radiation	Solar Radiation
ASTM D-1003	ASTM E424-71
Light Transmission	Direct Solar Transmission %ST
Light Reflection	Solar Reflection %SR
Light Absorption	Solar Absorption %SA
	Total Solar Transmission % STt
	Total Solar Reflection % SRt
	Shading Coefficient SC

** This adds in a big way: ASTM E424-71 as a Reference Standard – primary or alternate as acceptable testing criteria.

ENERGY

"U VALUE"

Applicable to Types I, II, and III (glazing): where U=Rt equals the sum of the R Values. This is the overall rate of heat or Energy Transfer; the lower the absolute value, the more resistance to heat transfer, "R-Value" is reciprocal (=1/U) and is commonly used in consumer advertising where the "R-Value is the resistance to heat transfer. The higher the "R-Value of a glazing material the more resistant it is to heat transfer.

National Greenhouse Manufacturers Association recommends that U values be calculated and reported for all glazing materials. Summer and winter values are to be reported, with shading coefficient to be included in summer value. Shading coefficients can be calculated using the ASHRAE formula.

NOTE: Air infiltration is a significant factor in heat loss, but is not a part of ASHRAE U-Value calculation procedures. Total glazing systems may vary widely in air infiltration and growers are cautioned to include air infiltration heat loss in their overall assessment of energy loss (gain).

STRENGTH

HAIL RESISTANCE

Type I

A.) NGMA recommends ASTM D-1709-03 Standard test methods for Impact resistance of Plastic Films by the free falling dart method, Using Method A

Type II & Type III

A.) NGMA recommends ASTM E-822-92 (2003) Standard Practice for determining Resistance of Solar Collector Covers to Hail by impact with propelled ice balls. Nine values will be reported using three sizes of 1", 1 1/2" and 2" at three speeds of 50, 60, and 70 mph.).

B.) NGMA recognizes as voluntary: ASTM E-1996-03 Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors and Storm Shutters Impacted by Windborne Debris in Hurricanes as also demonstrating the impact value of Type II & Type III materials for large and small missile impact including hail.

C.) NGMA recognizes as voluntary: ASTM E-1886.02 Standard test method for performance of Exterior Windows, Curtain Walls, and Storm Shutters Impacted by Missile(s) and exposed to Cyclic Pressure Differentials as also demonstrating impact and deflection capabilities of Type II & III materials under cyclic wind pressure.

TEAR RESISTANCE

Type I

A.) NGMA recommends ASTM D-1922-03 Standard Test Method for Propagation of Tear resistance of Plastics Film Sheeting by Pendulum Method.

WIND LOAD

Wind load resistance is usually more a function of structural integrity than glazing strength. Growers are urged to refer to the NGMA Standard for Greenhouse Structures, appropriate building codes, manufactures literature and the unique aspects (mechanical properties) of the glazing material holding – film (or glazing system –hard cover)

LONGEVITY (TYPE I, II, & III THE BASICS)

The usable life of glazing (skinning) materials is defined as the number of months or years that a material will function effectively in a commercial growing application. To function effectively, it must retain some portion of its essential properties (mechanical, physical, thermal and electrical) of strength and inherent light transmission (that part owing to internal chemical change as opposed to that owing to external factors such as accumulated dust. dirt and the effects of corrosive atmospheres (internal & external).

In some materials, the decrease in light transmission, not loss of physical strength determines the useful life of the glazing material.

Type I materials; (NGMA recommends outdoor weathering test for) Type I should be tested with actual outdoor weathering. DSET Laboratories facilities, Atlas Weathering Service Group, at their headquarters in Arizona is the (an) NGMA approved test center for actual outdoor weathering.

ASTM D-4364-02 Standard Practice for performing Outdoor Accelerated Weathering tests of Plastics Using Concentrated Sunlight – "is applicable to a range of plastics materials including, but not limited to plastic films, sheets, laminates and extruded and molded product in a variety of selected sizes."

The claiming of specific useful life of a glazing shall be based on a well defined actual outdoor exposure or by correlation between results of an accelerated weathering procedure and actual outdoor weathering. The only currently acceptable accelerated weathering test for Type I & Type II materials is ASTM D-4364 EMMAQUA.

The same testing procedure used for determining the strength and light transmitting properties of a given material should be used to determine the strength of the weathered material.

Test comparison for strength shall not be made between material types. Strength values are only valid for the overall evaluation of a glazing material for a given application.

TYPE I

STRENGTH:

For Flexible Films, the strength shall be considered inadequate when the elongation to Break has decreased to 50% of the original value. The recommended test method is ASTM D-882,

METHOD A.

SOLAR/LIGHT TRANSMISSION:

Solar/Par values to controls and weather samples shall be measured by ASTM E-903 and shall be compared to determine the loss for a given period of time (example: 1yr, 3 years, 10 years)

TYPE II (Strength of TYPE II Materials)

CURRENT TEXT
The strength and control of weathered samples shall be measured by any (one or more) of the following procedures. The sample thickness shall be (1/8") (or performed in the same thickness for intended use) for the appropriate tests, and where applicable, the side that is exposed during the weathering is the side put under tension (or impacted using an appropriate test procedure)

1.) Tensile Strength, Elongation, Tensile Modulus ASTM D-638
2.) Flexural Strength ASTM D-790
3.) Flexural Modulus ASTM D-790
4.) Impact Resistance ASTM D-265 Gardner Impact
5.) Hail Resistance ASTM E-822
6.) Impact Resistance ASTM D-3029 Method
7.) Deflection temperature under flexural load ASTM 648
8.) Specific Gravity ASTM D-792
9.) Coefficient of Thermal Expansion ASTM-696

NOTE: We can also include new ASTM's for High Impact –IE Dade County & Hurricane.

NOTES: Type II Materials
Wind, Dead, Live Loading & Design

1.) Wind, dead, live load resistance being the design function of the structural integrity of a greenhouse substructure, each Type II glazing plastic material has unique properties (tested in accordance with the procedures listed) which must meet local building code for load and for flammability. The NGMA recommends a thorough review of all glazing manufacturer's literature and warranties to include but not be limited to the following:

A.) LOAD

Review thickness, width, and length considerations for flat and/or cold curved glazing pertaining to the material of choice. Glazing manufacturer printed literature, engineering tables, and copies of actual testing results should be applicable for both positive and negative loads for all structures.

Sheet installation is expressed in terms of width, gauge, & length for glazing bar and purlin distance recommendations. Since some Type II materials require fastening to accommodate negative requirements loading consult glazing materials manufacturer guidelines for fastener type, dimension, and composition.

Since Type II materials are used on opened roof and vented structure applications, negative loading conditions must be considered.

- **Point fastening materials**- selection & method of installation/attachment for flat and cold curved greenhouses must be considered. Negative load failure occurs when part of or entire sheet/s is forced (detached) from the structure. The fasteners must be of sufficient area (diameter) of contact, number and placement to prevent this type of failure.
- **Materials compatibility** – Wet sealants & dry gaskets and sealing tapes which come into contact with the glazing product must be compatible with the composition of the glazing. Incompatible materials lead to stress failure under load and weathering.

- Pre and post installation guidelines, sheet preparation and cleaning instructions for one and two sided UV protective glazing materials should be noted and expressly followed.

B.) GLAZING SYSTEM DESIGN & SAFETY:

- Since Type II glazing materials deflect to some degree under load:

- Edge bite and expansion clearance provided by glazing systems are primary design criteria's. Glazing material manufacturers should indicate by written or graphic illustration glazing system design requirements and recommendations for their product

  - Two side glazed
  - Four side glazed
  - Edge bite and clearance
  - Expansion/contraction coefficient
  - Point fastening materials
  - Loading tables for gauge, width & length and combinations thereof.

TYPE III

STRENGTH:
For glass the strength shall be considered inadequate only upon actual breakage. Glass manufacturers shall test the flexure strength according to ASTM C-158, and report it for each type of glass produced.

SOLAR/PAR TRANSMISSION
Loss of solar and PAR values in glass is anticipated to be of so little change as to not require testing of weathered samples.

COMBUSTIBILITY

FLAMMABILITY TYPE I:

- NGMA recommends that Flammability shall be measured and reported in accord with ASTM D-568
- ASTM D-568 supports a sample vertically. A flame is allowed to burn until it either extinguishes itself or burns past a gage mark (100mm) on the bar. If the sample does not burn past the 100mm gauge mark, time and extent of burning are reported. If it burns past the gauge mark, an average burn rate, in centimeters per minute, is reported.

FLAMMABILITY TYPE II

PRIMARY Standard ASTM D-635-74

- NGMA recommends that Flammability for Type II materials shall be reported in accord with ASTM D-635-74.
- Uniform Building Code Standard 26-7 "Method for Determining Classification of Approved Light Transmitting Plastics." This method is based on ASTM D-635-74 Standard test method for rate of Burning and/or extent of burning of Plastics in a Horizontal Position

  - Abar of material to be tested is supported horizontally at one end. The free end is exposed to a specified gas flame for 30 seconds. The elapsed time and burn length are measured and reported if the specimen does not burn more than 100mm. An average burning is reported for a material if it burns past the 100mm mark from the ignited end.

- Classification requirements per UBC Standard 26-7, Sec 26.706.5

  - CC-1: Plastic Materials which have a burning extent of 1 inch (25mm) or less when tested in nominal .060-inch (1.5mm) thickness (or in the thickness intended for use) by this test
  - CC-2: Plastic Materials which have a burning rate of 2.5 inches per minute (64mm/min) or less when tested in Nominal .060 thickness (or in the thickness intended for use) by this test.

- NGMA recommends that materials be tested in the thickness intended for use by this Standard.

ADDITIONAL FLAMMABILITY STANDARDS

- NGMA recognizes that glazing material manufactures conduct additional tests for varied applications and may or may not apply to applications in the industry. They are mentioned in this standard to educate and to further define material capability and to enable comparison if required. Certain plastics glazing materials may be reported in accordance with these standards.

    - o ASTM E-84 S*tandard Test Method for Surface Burning Characteristics of Building Materials* both as to equipment and test procedure. This procedure is similar to UL-723, ANSI No 2.5, NFPA No 255 and UBC 42-1.

- Two values are reported using this test method: Flame Spread & Smoke density

NFPA Class	UBC Class	Flame Spread
A	I	0-25
B	II	26-75
C	III	76-200

** Smoke (density) Developed: 0-450 all classes

- o ASTM D-2843 - Applicable to Types I & II – This test measures the loss of light transmission through smoke produced from a burning plastic.
- o ASTM D-1929 – Applicable to Types I & II – This test measures both flash ignition and self ignition.
- o UL 94 – Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.

MISCELLANEOUS

ASTM D-696: Coefficient of Expansion of Type I and Type II materials should be measured and reported using this standard.
ASTM E-831: Coefficient of Expansion of Type III materials can be reported using this standard.

CHEMICAL AND MATERIAL COMPATIBILITY

NGMA recommends that each manufacturer of a product that comes into contact with glazing materials be prepared to advise the user of any potential problem or other incompatibility with a specific type of glazing material. Likewise, a glazing manufacturer should warn potential customers of any known products that are incompatible with their glazing.

These would be products that would be used in a greenhouse (Structure) and would come into contact with the glazing. This would include but not be limited to the following.

- Anti- fogging agents
- Plasticizers used in glazing system gaskets, fasteners, shade cloths, thermal blankets, etc.
- Sealants and caulking compounds
- Wood preservatives
- Shading compounds
- Shading fabrics
- Washing compounds
- Repair tapes
- Pesticides, by chemical class of compound
- The carrier (solvent) for any of the above products

When a grower uses new materials he is urged to ask the manufacturer about the compatibility of it with other materials of contact in the greenhouse.

OTHER PUBLICATION AVAILABLE FROM NGMA

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