AD-A268 403

AL-TR-1993-0036

ARMSTRONG LABORATORY

DEFINITIONS OF TERMS RELATING TO AIRCRAFT WINDSCREENS, CANOPIES, AND TRANSPARENCIES (U)

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MARCH 1993

FINAL REPORT FOR PERIOD OCTOBER 1990-NOVEMBER 1992

AIR FORCE MATERIEL COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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AL-TR-1993-0036

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FOR THE COMMANDER

KENNETH R. BOFF, Chief
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Armstrong Laboratory

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 1993	FINAL (October 1990-November 1992)

4. TITLE AND SUBTITLE

Definitions of Terms Relating to Aircraft Windscreens, Canopies, and Transparencies (U)

5. FUNDING NUMBERS

C - F33615-89-C-0532
PE - 62202F
PR - 7184
TA - 18
WU - 03

6. AUTHOR(S)

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Armstrong Laboratory, Crew Systems Directorate
Human Engineering Division
HQ HSC AFMC
Wright-Patterson AFB OH 45433-7022

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

AL-TR-1993-0036

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; Distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This report presents a glossary of terms relating to aircraft windscreens, canopies, and transparencies. It addresses the need to have a single reference source which provides a common vocabulary for use by designers, materials engineers, manufacturers, evaluators, maintenance personnel, and user agencies concerned with aircraft transparencies. Its intent is to facilitate and enhance communication between these disciplines by clarifying and defining terms used within the aircraft transparency industry.

14. SUBJECT TERMS

Transparencies, Windscreens, Canopies, Optics, Polycarbonate, Acrylic, Definitions

15. NUMBER OF PAGES

44

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std 239-18
298-102

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Block 16. Price Code. Enter appropriate price code *(NTIS only)*.

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Preface

This report was prepared under work unit 7184-18-03, Transparency Effects on Visual Performance, by personnel of the Visual Display Systems Branch (AL/CFHV), Human Engineering Division, Armstrong Laboratory, Wright-Patterson Air Force Base, Ohio. Funding for this effort was provided by the Wright Laboratory's Aircrew Protection Branch (WL/FIVR).

The authors would like to express their sincere thanks and appreciation to the members of the American Society for Testing and Materials F7.08 subcommittee task force on terminology for their invaluable help in ensuring the correctness and appropriateness of the terms used in this report. Special thanks goes to Mr. Harold Merkel of Compaq Computers Inc. who initiated this effort while a member of Armstrong Laboratory.

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Introduction

This report presents a glossary of terms relating to aircraft windscreens, canopies and transparencies. The need for a report of this genre was provided by subcommittee F7.08, "Aircraft Enclosures and Transparencies," of the American Society for Testing and Materials (ASTM). Meeting twice yearly, the membership of this subcommittee is made up of individuals and organizations involved in materials development, manufacturing, design and evaluation and utilization of aircraft enclosures and transparencies. At these meetings it became increasingly clear that each of these varied disciplines had a language of its own and that terms used by people working in one discipline did not convey the same meaning to people working in the other three disciplines.

This report has been prepared to address the need identified by ASTM Subcommittee F7.08. Specifically, to develop a single reference source which provides a common vocabulary for use by designers, materials engineers, manufacturers, evaluators, maintenance, and user agencies concerned with aircraft transparencies. By clarifying terms used within the aircraft transparency industry, communication between the various disciplines would be facilitated and enhanced.

The terms selected for inclusion in this report were taken from the various reference sources listed in the bibliography. Additionally, various organizations representing the various disciplines working within the transparency industry were solicited to provide additional terms. The final list of terms were subjected to scrutiny by a task force of 18 individuals whose task was to ensure (1) that each term was correctly defined and (2) each term merited inclusion in the report.

Definitions

A

aberration – Failure of the rays from a point source to form a perfect or single point image after passing through an optical system. This manifests itself as formation of multiple images or formation of single imperfectly defined images.

abrasion shield/coating – A thin sheet of glass, plastic, or other transparent surface finishing material applied to the inside or outside face of a transparency to resist abrasion.

absorption – The amount of light that is neither reflected nor transmitted but is retained within the object.

achromatic – Lacking in hue and saturation. Achromatic colors vary only in brightness from black to white (colorless).

acrylic – Thermoplastic or thermoset material produced by a polymerization of the monomeric derivatives of acrylic acid; supplied in forms of cast sheets, rods, bars, tubes, crystals, granules, or powder; may be transparent, opaque or a variety of colors. Also known as an acrylate, a methacrylate base, or polymethyl methacrylate (PMMA).

acrylic, cross-linked – A thermoset plastic sheet of cast acrylic used to make stretched acrylic.

acrylic, stretched – A polymethyl methacrylate plastic sheet that has been heated and stretched either in two perpendicular directions (biaxial) or in all directions (multiaxial) in the plane of the sheet. This improves crack propagation and craze resistance by realigning the molecules.

acuity, visual – The smallest detail that the eye is capable of resolving at a specified distance. Expressed by visual angle in minutes of arc.

ADBIRT – Advance Design Bird Impact Resistant Transparency. See *BIRT*.

adherend – An object bonded by an adhesive.

ambient light – Light surrounding all sides (existing lighting conditions of the environment).

amorphous – Without crystalline molecular structure.

analyzer – A polarizing element that can be rotated about its axis to control the amount of transmission of incident plane polarized light, or to determine the plane of polarization of the incident light.

angle, critical (Θ_c) – The angle of incidence at which the angle of refraction is 90°for the interface of two optical media. At angles of incidence greater than Θ_c, total internal reflection occurs.

angle of deviation – The angle through which a ray of light is bent by reflection or refraction. It is expressed in minutes of arc, degrees or milliradians.

angle of incidence – The angle between the incident ray of light and a line normal to the surface of the transparency.

angle of installation – See *installed angle.*

angle of reflection – The angle between the reflected ray and a normal to the surface.

angle of refraction – The angle made by the refracted part of a light ray with a line perpendicular to the surface of the refracting medium through the point of incidence of the refracted ray.

angle of view – The angle subtended by the total field of view at the observer's eye position.

angstrom – A unit of measurement of wavelength of light equal to 10^{-8} cm. Abbreviated A.

angular deviation – The angular displacement of a light ray from its original path as it passes through a transparent material. It is expressed in units of angular measurement (degree, minutes of arc, milliradians).

angular deviation device – A device that measures the angular deviation of a collimated beam of light, in azimuth and elevation, as it passes through a transparency.

angular displacement – The angular separation of the secondary image from the primary image as measured from the design eye position of a transparency. See *multiple imaging separation.*

annealing – The controlled heating and cooling of a material according to a prescribed schedule to minimize residual stresses.

annealing schedule – The relationship between time and temperature at which a material is exposed to assure proper annealing.

anti-icing – A method of preventing or removing ice accumulation.

antireflective coating – A thin film applied to a transparency surface to reduce its reflectance.

antistatic agents – Agents which minimize static electricity build-up in transparencies. Such agents are of three basic types: (1) Metallic devices which come into contact with the transparencies conducting the static charge to earth. The surface of the material is not modified by these devices, therefore subsequent static charge can accumulate during handling; (2) Chemical additives which, when mixed with the compound during processing give a reasonable degree of static protection to the finished products; (3) Transparent metallic films which are grounded to the airframe.

arch – A freestanding structure which supports the transparency.

azimuth – The horizontal coordinate in a system of spherical coordinates, measured in a horizontal plane as an angular rotation about a fixed vertical axis.

B

band distortion – A wavy or rippling effect seen in a concentrated area of a transparency.

barium sulphate plate – A Lambertian reflector that scatters incident light in a perfectly diffusing pattern. In the measurement of haze, it is used to determine the illumination impinging on the surface of a transparency.

biaxial stretching – See *stretching, acrylic, stretched.*

binocular – Pertaining to vision with both eyes.

binocular alignment device – A device that measures the degree of binocular disparity introduced by a transparency by comparing relative differences in image location as seen by each of the two eyes.

binocular deviation – The angular difference in deviation of two parallel incident rays.

binocular field – The field of vision of the two eyes acting together.

bird impact resistant transparency (BIRT) – A transparency that is designed to withstand a bird strike while the aircraft is flying at a specified speed.

bird strike – The impact of a bird on an aircraft or aircraft transparency.

birefringence – The separation of a light beam as it penetrates a doubly refracting material, into two diverging beams commonly known as ordinary and extraordinary beams. In transparencies, this may appear as rainbowing, or the apparent random dispersion of light into its component colors.

blister – An imperfection; a relatively large bubble or gaseous inclusion. See *defects, minor optical.*

bolt hole crack – A crack in the transparency at or near the bolt hole (normally cannot be detected by ordinary visual inspection).

bondline – Common surface of adjacent laminae joined by a bonding process.

boresight – To align the sighting device on an aircraft (Head-Up- Display, gunsight) to be coincident with the bore of a weapon or a detection device (gun, rocket, missile, radar, video camera, flir).

bow frame – See *arch.*

bow tie – Diffraction streaking. See *streaking.*

break pattern – A characteristic of glass which causes it to break into pieces of variable size and sharpness as temper and the amount of stress at fracture is varied.

brightness – (1) A subjective assessment of the amount of light that appears to be emitted by a body. (2) Quantitative term more correctly referred to as luminance or luminous intensity.

buffing – The process by which the surface of a material is brought to a high polish, usually through the use of a buffing compound applied by a rotating cloth wheel.

bulk modulus (modulus of compression) – The ratio of hydrostatic pressure to the change in volume per unit volume.

bull's-eye – A localized depression or bulge in a transparency surface creating a lens like defect which produces optical distortion.

bus bar – One of a set of electrical conductors used to transmit power to the edge of the heated area of a transparency.

butt line – A series of longitudinal vertical planes that are used to locate a point to the left or right of the center of a fuselage. The center line (axis of symmetry) is 0.

C

canopy – (1) The transparency of the aircraft which provides vision primarily to the side and overhead areas. (2) A single transparency that encloses the entire aircraft cockpit.

case depth – The compressive layer thickness of thermally tempered or chemically strengthened glass.

casehardened – A process of hardening a substance so that the surface layer or case is made substantially harder than the interior or core. Also, a term sometimes used for tempered glass.

cast – (1) To form a plastic mass into a specific shape by setting in a mold; (2) To form a plastic film or sheet by pouring liquid resin onto a moving belt or by polymerizing between glass plates.

casting – The finished product of a casting operation producing a definite shape.

catalyst – A substance that accelerates the cure of a resin system without generally being affected chemically.

central tension – The magnitude of tension within glass resulting from thermally tempering or chemical strengthening.

chemical tempering – An ion exchange process which puts larger ions into the outer surface of glass, putting the outer surfaces into compression and the interior of the glass in tension. This process is capable of producing a higher degree of surface compression than the practical limits of thermal tempering.

chip pulling – Tendency of an interlayer or seal to shrink as a result of cold exposure and pull chips from the surface of glass, either by shear or tension or both. Primarily found in glass/PVB laminations.

chromatic – Of or relating to color; perceived as having a hue; not white, gray, or black.

CIP (Cast-in-place) – A term used to identify a type of interlayer material that is poured between the transparent face sheets of a fabricated part and cured as a component part of the assembly.

clamshell – Intralaminar cracking found in materials.

clearview – A window that is opened to provide a clear view when the front windshields are iced over or obliterated due to birdstrike. The pilot uses this window to land the aircraft.

coating, abrasion resistant – A protective coating to minimize surface damage. See *hardcoat, coating, protective.*

coating, anti-reflective – A thin film applied to a transparency surface to reduce its reflectance.

coating, E-C – An electrically conductive thin film deposited on a transparent material; used on windscreens as the heating element and to dissipate static charge.

coating, high-reflecting – A broad class of single or multilayer coatings that are applied to a surface for the purpose of increasing its reflectance over a specified range of wavelengths. Single films of aluminum or silver are common; but multilayers of at least two dielectrics are used when low absorption is required.

coating, P-static – Thin conductive coating used to bleed off static electrical charge buildup on a transparency. (Also called antistatic coating).

coating, protective – Films that are applied to a coated or uncoated optical surface primarily for protecting the surface from mechanical abrasion, chemical corrosion, or both.

coefficient of expansion – The fractional change in the length or volume of a body per degree of temperature change. See *thermal expansion.*

cohesion – The state in which the particles of a single substance (such as an adhesive or adherend) are held together by chemical forces.

cold box – A chamber used to test parts for low temperature stability and heat uniformity.

cold dispatch – The ability of a windshield system to meet the certification requirements at a specified temperature without artificial heating. The capability may also be specified at a reduced speed as an emergency procedure.

cold flow – Creep at room (ambient) or lower temperatures.

collimate – To render light rays parallel.

collimation – The process of aligning the optical axis of optical systems to the reference mechanical axes or surfaces of an instrument; or the adjustment of two or more optical axes with respect to each other. The process of making light rays parallel.

collimator – An optical device which renders diverging or converging rays parallel. It may be used to simulate a distant target, or to align the optical axes of instruments.

color – The sensation produced by light of different wavelengths throughout the visible spectrum.

composite windshield – A windshield composed of layers of plastic and glass or of different plastics, which are bonded together.

concave – A term denoting a surface curved inward, as the inside of a sphere or circle.

conductivity, electrical – The reciprocal of electrical resistance.

conductivity, thermal – Time-rate of heat transfer through a unit volume at a unit difference in temperature.

contrast – The ratio or other numerical representation of the difference in photometric brightness between two stimuli fields or surfaces.

convergence – The bending of light rays toward a single point.

convex – A surface curved outward, as the exterior of a sphere or circle.

copolymer – A polymeric system comprised of two or more different monomeric units.

core ply – The primary structural ply of a transparency.

coupon – A sample of material used for testing.

crack propagation resistance – A measure of the work, other than that resulting in permanent deformation, which is absorbed per unit nominal area of crack extension, determined at the time when a creeping natural crack leaps forward. This property is sometimes called *fracture toughness.* See *K-value, toughness.*

crazing – A series of small defects which appear as fissures or fine cracks on or under the surface of but not extending entirely through the material. In plastics, true crazing is the condition just prior to crack formation, and is an area of low density which manifests a difference in refractive index.

creep – The slow deformation of a material under stress.

crew shield – See *spall shield.*

critical optical area – Area of a windscreen or canopy that requires a high degree of optical quality, as defined by drawings or specifications. It is used for gunsight, taxi, takeoff and landing. See *primary optical area.*

crosslinking – The formation of a three-dimensional network of chemical bonds, usually covalent, between polymer molecules. When extensive, as in thermosetting resins, crosslinking makes one infusible, insoluble, supermolecule of all the chains.

crown glass – A hard, easily polished, highly transparent optical glass with high refraction and low dispersion.

crystal – A state of molecular structure in some resins which denotes stereo-regularity and compactness of the molecular chains forming the polymer.

cure – The achievement of certain physical properties of a material by chemical reactions; usually accomplished by the action of heat, radiation, catalysts, or a combination thereof with or without pressure.

D

daylight opening – All of the transparent area of the finished part.

definition – The sharpness of imagery produced by an optical system.

degree of polymerization (DP) – The number of structural units, or "mers," in the polymer molecule in a particular sample. The value is obtained from the molecular weight of the polymer divided by that of the mer. If average molecular weight is used, then the value is the average DP. In most polymers the DP must reach several thousand if worthwhile physical properties are to be achieved.

delamination – The separation of the layers in a laminate into its constituent parts, due to the failure of the adhesive or resin binder, caused by moisture ingress, mechanical and/or thermal stress, and chemical UV degradation of the adhesive layer.

delamination, edge – Separation of the layers of a material at the edge of a laminate.

delamination, internal – Separation of the layers of material in a laminate other than at the edge.

deletion (isolation) lines – Scribed or etched lines which divide the EC coating into separate areas for heating control.

density, optical – Logarithm to the base 10 of the reciprocal of diffuse transmittance.

design eye – Reference point in aircraft design from which all anthropometric design considerations are taken (the designed location of the pilot's eye).

deviation – The deflection of a ray of light passing through a transparent medium caused by non-parallism of opposite surfaces. Measured in angular milliradians, prisms, or in prism diopters. It is a function of the angle of incidence at each thickness of material and the index of refraction of the material. See *angular deviation.*

di-butyl sebacate (DBS) – A liquid plasticizer for polyvinyl butyral which converts it to an interlayer.

dichroic glass – A glass which will transmit some colors and reflect others, or which will display certain colors when viewed from one angle and different colors when viewed from a different angle.

dichroic materials – Materials which exhibit dichroism.

dicing – The violent breakage of full thermally tempered or chemically tempered glass or glass ceramic which produces particles with no dimension greater than the thickness of the material. Particle size is dependent on the degree of temper and stress at fracture.

dielectric strength – The maximum electrical gradient a dielectric material can withstand without failing; expressed in volts per thickness.

diffraction – The bending of light waves around an obstacle.

diffraction streaking – See *streaking.*

diffusion – A scattering of light by reflection, diffraction, or transmission. Diffuse reflection results when light strikes an irregular surface such as a frosted window or the surface of a frosted or coated light bulb. When light is diffused, no definite image is formed.

diffusivity, thermal – The measurement of heat flowing through a unit area of a substance per unit of time, divided by the product of the specific heat, density and temperature gradient in the material.

dig – Deep, short scratches on the surface of glass. See *scratches.*

disparity – See *binocular disparity.*

dispersion – The process by which rays of light of different wavelength are deviated angularly by different amounts as, for example, with prisms and diffraction gratings. The term dispersion is also applied to other phenomena which cause the index of refraction and other optical properties of a medium to vary with wavelength.

displacement – (1) In passing through a window with parallel surfaces, light rays are bent and displaced. The displacement is zero for 0 angle of incidence, and increases as the angle of incidence, thickness, or index of refraction are increased. The displacement is linear and usually measured in millimeters or fractional inches. It does not increase with distance and the effect on pilot vision probably is not significant. (2) The image offset caused by refraction of light as it passes through a transparency. See *lateral displacement.*

displacement grade – A measure of optical distortion made from photographs of grid-board images taken through aircraft transparencies. The measure is typically made directly on a photographic print and measures the maximum displacement of a distorted line (horizontal and vertical) with respect to its undistorted orientation. The measure does not take into account the total displacement of the distorted line from its undistorted image, nor does it consider the length or angular width of the distorted line. In some cases the horizontal and vertical worst cases from defined areas are geometrically added to produce a factor of severity which is used for specification limits.

distortion – The rate of change of deviation resulting from non parallel surfaces in a transparent part. Expressed as the angular bending of the light ray per unit of length of the part, for example, milliradians per centimeter. May also be expressed as the slope of the angle of localized grid line bending, for example, 1 in 5.

distortion, radial – A change in magnification from the center of the field to any other point in the field, measured in a radial direction to the center of the field. "Barrel distortion" results when the magnification decreases with field angle; "pincushion distortion" results when the magnification increases with field angle.

divergence – The bending of light rays away from each other.

double image – (1) Two images of an object resulting from severe localized distortion. (2) The perception of two images from a single object due to excessive binocular disparity.

drape forming – Method of forming a thermoplastic sheet in which the sheet is clamped into a movable frame, heated and draped over high points of a male mold.

dry seal – A pressure or weather seal which is molded and cured; may be a component of the transparency or the support structure.

ductility – The extent to which a solid material can be deformed by elongation without fracture.

E

EC coating – See *coating, E-C.*

ECM – (1) "Electronic countermeasure(s)." (2) "Electronic countermeasure mission."

edge attachment – The means of fastening the edges of a transparency to the aircraft structure. Also includes expansion joints and any other connection between the transparency and the aircraft structure.

elastic deformation – Deformation of an object under load which disappears when the load is removed or relaxed.

elastic limit – The largest unit stress that can be developed without a permanent set remaining after the load is removed.

elasticity – The ability of a material to return to its original size or shape after having been stretched, compressed or otherwise deformed. If the strain is proportional to the applied stress, the material is said to exhibit Hookean or ideal elasticity.

electrochromic – A material property which results in a change of color when electrically excited.

elevation – An angle in the vertical plane.

elongation – The fractional increase in a material's length due to stress in tension or to thermal expansion.

emissivity – The capacity of a body to emit radiation.

emittance, spectral – A term which usually refers to radiant emittance as a function of wavelength.

EMP – Electro Magnetic Pulse. High intensity, short duration, electromagnetic field which can couple into electrical systems and induce high voltage and current transients.

enclosure – The complete assembly, including transparency, edge attachments, frames, fairings, side beams, seals, etc.

enclosure, transparent – Any aircraft windscreen, canopy or window.

environmental stress cracking (ESC) – The susceptibility of a material to crack or craze under influence of environmental exposure and mechanical stress.

EOP – Edge of part.

ev – Electron volt; a unit of electrostatic energy. It is not a measure of potential difference.

eyebrow – A small transparency usually directly above and slightly forward of the pilot's head but aft of the windscreen.

F

fatigue – The failure of a material under repeated stress. See *environmental stress cracking.*

faying surface – The surface of an object in contact with a bonding agent.

field of view – In general, the maximum cone or fan of rays passed through an aperture and measured at a given vertex. In an instrument, field of view is synonymous with true field.

field of vision – The total three dimensional space within which objects can be seen by moving the eyes and the head.

fish eye – A bubble on the formed surface of transparent or translucent plastic materials, appearing as a small globular mass.

float glass – Glass which has had the surfaces formed by floating in a continuous ribbon on the surface of a bath of molten tin in a controlled atmosphere. This form of glass has largely replaced plate glass.

fuselage station – A series of vertical planes that are used to locate a point along the fore-aft direction of an airframe.

G

glare – The dazzling sensation of relatively bright light that interferes with optimal vision. The sensation produced by brightness within the visual field that is sufficiently greater than the luminance to which the eyes are adapted so that it will cause annoyance, discomfort, or loss in visibility.

glare, reflected – Glare resulting from specular reflections off of polished or glossy surfaces in the field of view.

glass – An amorphous inorganic product of fusion, usually transparent or translucent, consisting ordinarily of a solution of silicates that has cooled to a rigid condition without crystallizing.

glass, optical – A glass, whose composition, melting, heat treatment, and other processing is carefully controlled during manufacturing to satisfy optical specifications such as index of refraction, dispersion, transmittance, spectral transmittance, freedom from birefringence, permanence, etc., based on the application for which it is to be used.

glass transition temperature (Tg) – The temperature region in which the amorphous polymer changes from a glassy solid to a soft rubbery material. The measured value of the glass transition temperature depends to some extent on the method of testing.

glazing – Act of furnishing or fitting with a glass or a plastic transparency.

glint – A bright, reflected flash or beam of light.

gridboard – An optical evaluation tool used to detect the presence of distortion in windscreens. It is usually a vertical rectangular backboard with horizontal and vertical intersecting lines with maximum contrast between the lines and background.

grid line slope – An optical evaluation method of determining the slope of a deviated grid line to that of a non-deviated grid line. The degree of deviation is indicated by a ratio, *e.g.*, 1:2, 1:8 or 1:16. (The visual optical quality improves as the ratio gets smaller.)

H

hair line crack – A fine crack having no apparent width.

halation – The scattering of light by the transparency into the viewer's line of sight, reducing the perceived contrast of external objects. See *haze*.

hard coat – A surface coating that is intended to make the transparency more durable under adverse conditions.

haze – Ratio of the scattered light to the total light that comes through the transparency.

haze index – The ratio of corrected veiling luminance created by the transparency to the illumination impingent on its surface.

haze meter – A device used to measure haze.

haze ratio – The ratio of the haze index to the transmission coefficient (measured at installed angle). A number indicating relative clarity of a transparent part.

heat-deflection point (heat distortion) – The temperature at which a standard test bar (ASTM D 648) deflects 0.010 inches under a stated load of either 66 or 264 psi.

heat treat – The process of subjecting a material to controlled conditions of heating and cooling to develop specific properties in the material such as strength, thermal shock resistance, etc.

high polymer – A large molecule which is usually but not always comprised of repeat units of the low-molecular-weight species. Arbitrarily designated as having a molecular weight greater than 10,000.

hoop – An edge attachment which conforms to the station loft line profile of the fuselage. See *rail*.

I

illuminance – The internationally accepted photometric term for the intensive property of the luminous flux passing through a cross section of a beam, or falling on an illuminated surface. Units: lumens per square foot (foot- candle) or lumens per square meter (lux).

impact resistance – Resistance of a material, laminate, or coating to breakage, deformation, or other damage when subjected to sharp blows or shock loading. It is indicated by the energy expended by a standard pendulum-type or falling weight impact machine in breaking a standard specimen in one blow.

impact strength – (1) The ability of a material to withstand shock loading. (2) The force necessary to fracture a given test specimen in a specified manner.

incident light – A ray of light which falls upon or strikes the surface of a transparency.

inclusions – Extraneous or foreign material within the body of the glass or plastic of the transparency.

index of refraction – (1) A number applied to transparent substances which denotes the relation between the angle of incidence and the angle of refraction when light passes from one medium to another. (2) In physical terms, the ratio of the velocity of light in a vacuum to the velocity of light in the material under consideration.

infinity, optical – A term used to denote a distance sufficiently great so that light rays emitted from a body at that distance are for all practical purposes, parallel.

infrared (IR) – The electromagnetic radiation beyond the red end of the visible spectrum. The wavelengths range from .786 microns to 1 millimeter. Referred to as *IR radiation.*

installed angle – The part attitude as installed in the aircraft. Defined by the angle from a horizontal line to the vertical plane of the part, and the angle of sweep back from a horizontal line normal to the center line of the aircraft.

interferometer – An instrument employing the interference of light waves for purposes of measurement; such as determining the accuracy of optical surfaces by means of Newton's rings, and the measurement of optical paths, and linear and angular displacements.

interlayer – A transparent flexible material used as a thermally compensating layer and adhesive between separate plies of a transparency. In a laminated transparency, each interlayer is considered a separate ply. The interlayer may add to the toughness, ductility and impact resistance of composite glazings. See *CIP, Di-Butyl Sebacate (DBS), PVB.*

internal reflections – Reflections of light or bright objects inside the crew station that enter the pilot's eyes by way of the inside surface of the transparency.

izod impact test – A test designed to determine the relative resistance of a plastic material to a shock loading. It may or may not involve the notching of a specimen, which is then placed in the jaws of the machine and struck with a weighted pendulum. See *impact strength.*

J

K

K-Factors – A measure of the toughness or crack propagation resistance of material. Originally applied to acrylic but being evaluated for application to polycarbonate.

K-Value – The ratio of power dissipated at either the hot spot or control point to the average of the entire heated area for electrically conductive coatings. $K_A = \frac{average\ power}{power\ at\ control\ spot}$ $K_H = \frac{power\ to\ hot\ spot}{power\ at\ control\ spot}$ $K_M = \frac{average\ power}{power\ at\ hot\ spot}$

L

laminar shear strength – The shear strength parallel to the laminar plane of a composite. Also, in stretched acrylic, the shear strength parallel to the principle surfaces.

laminar tensile strength – Flatwise tensile strength perpendicular to the laminar planes.

laminate – The process of bonding two or more plies of transparent plastic or glass with or without an adhesive. The transparent laminates used as glazing materials consist of two or more sheets of transparent plastic or glass bonded with or without an adhesive. The reinforced laminates used for edge attachment consist of one or more layers of reinforcing materials such as glass cloth or synthetic fabric cloth impregnated with a laminating resin. When the resin is cured, the resulting laminate may have better properties than either component material. In some instances the laminating resin, if cured in contact with the glazing material, may act as an adhesive between the glazing material and the reinforced laminate. Reinforced laminates are sometimes referred to as *impregnates*.

laminated – A term used to denote a product that consists of two or more layers of material.

lapping – The finish-grinding or polishing operation on a rough surface by the use of abrasive grains usually contained in a liquid carrier or medium.

lateral displacement – The shift or movement of a light ray from its original path as it passes through a transparent material while maintaining parallelism between the original and final paths. The change in location of an image due to this change in path.

lensing – A magnification or minification of visual images which may vary in extent from one portion of the transparency to another. The inherent positive or negative dioptric power found in a curved finished transparency (i.e., windscreen, canopy).

light array – A matrix of equally spaced lights used for photographic evaluation of multiple imaging.

light box – A rear illuminated box that is used to hold target patterns for photographic evaluation of transparencies.

light, collimated – A light bundle in which the rays emanating from any single point in the object are parallel to one another. Light from an infinitely distant real source, or apparent source, such as collimator reticle, is collimated light.

light, polarized – A light beam whose electric vectors vibrate along the same direction, that is in a single plane containing the line of propagation, is said to be "plane polarized" (often called linearly polarized). If each electric vector can be broken into two perpendicular components that have equal amplitudes and that differ in phase by 1/4 wavelength, the light is said to be "circularly polarized." Circular polarization is obtained whenever the phase difference between the two perpendicular components is any odd, integral number of quarter wavelengths. If the electric vectors are resolvable into two perpendicular components of unlike amplitudes and differing in phase by values other than 1, 1/4, 1/2, 3/4, etc., wavelengths, the light beam is said to be "elliptically polarized."

line of sight (LOS) – Straight line of vision connecting the observer's eye with the observed object. Line of vision; optical axis of a telescope or other observation instrument.

linear displacement – See *lateral displacement.*

lint – The collective term for small quantities of dirt, dust, hair and fuzz, dispersed within a laminate.

luminance – The internationally accepted photometric term for the intensive property of an emitting, transilluminated, or reflecting surface (formerly called brightness). The luminous flux emitted, transmitted or reflected per solid angle per unit projected area of the surface. Units: foot-lambert, millilambert, or candle per square metre (nit).

luminous transmittance – The ratio of transmitted to incident light. See *transmittance.*

M

magnification – The increase in apparent size obtained by viewing through a lens or other optical device.

major defects – Gross distortion, chips, cracks, crazing, deep scratches, or any defect which may significantly impair visibility through the windscreen.

mark off – Surface distortions on a transparency caused during heat forming when irregularities in a form are transformed to the part being formed.

mark, scuff – Surface imperfections produced by the transfer of mold surface defects to the component during molding and forming operations.

masking – The process of protecting a transparent surface by the application of a strippable coating or by the application of heavy kraft paper or plastic film with a pressure sensitive adhesive that is not harmful to the plastic.

mechanical properties – The properties having to do with structural performance.

melt index – The amount, in grams, of a thermoplastic resin which can be forced through an orifice of defined diameter when subjected to a given force at a given temperature for a given time in minutes.

memory – A characteristic of a finished plastic part to return to its original shape once stress has been relieved beyond the forming temperature (stretched acrylic is a good example of a material with a strong memory).

methyl methacrylate – A colorless, volatile liquid derived from acetone cyanohydrin, methanol and dilute sulphuric acid and used in the production of acrylic resins.

milkiness – A condition of pronounced cloudiness in glass or plastic, usually a quality control problem.

minification – The apparent reduction of an object by a lens or other optical device.

minor defects – Imperfections such as light scratches, inclusions, bubbles, or blemishes.

modified – Containing ingredients such as fillers, pigments or other additives, that help to vary the physical properties of a plastic material. An example is oil-modified resin.

modulus of elasticity – Stress/strain ratio in a plastic material that is elastically deformed.

modulus of rupture (MOR) – The fictitious tensile or compressive stress, S, in the extreme fiber of a beam computed by the flexure equation S = Mc/I, where M is the bending moment that causes rupture, c is the distance from the neutral axis to the extreme fiber, and I is the moment of inertia of the cross-section area about the neutral axis. MOR is considered the primary measure of glass strength.

modulus of toughness – (For ductile material such as acrylic.) The area under the stress-strain curve up to the point of rupture.

Mohs' value – A measure of hardness based on a scale, established in 1822 by Frederick Mohs, giving a relative ranking of minerals in the order in which one will scratch another.

moisture-vapor transmission – The rate at which water vapor permeates through a plastic film or wall at a specified temperature and relative humidity.

mold forming – A process for forming hot glass or plastic into or over a mold with air or hydraulic pressure or by its own weight.

mold release – See *parting agent.*

mold seam – A line formed at the point of contact of the mold halves. The prominence of the line depends on the accuracy with which the mating mold halves are matched.

molding shrinkage (mold shrinkage, shrinkage, contraction) – The difference in dimensions, (measured at normal room temperature and expressed in in/in) between a molding and the mold cavity.

monochromatic – Having or consisting of one color.

monocular – Pertaining to or affecting one eye.

monocular field – Field of vision with one eye alone.

monolith – A transparency consisting of one ply of "as-received" sheet, plastic or glass.

monomer – A relatively simple molecular structure that is repeated many times in a polymer. See *polymer.*

monomeric cement – Monomer used as an adhesive; it polymerizes (thickens and hardens) under the influence of heat, light and/or catalyst in the joint.

MOR Bar – Modulus of rupture bar. Generally used to test glass strength in bending, since tensile tests are erratic.

MTBF – Mean time between failure.

MTBRR – Mean time between removal or replacement.

mud cake cracking – Surface cracking which shows a typical pattern of mud which has dried and cracked.

multiaxial stretching – See *stretching.*

multiple images – Images of external lights that result from multiple reflections off the internal surfaces of the transparency. Referred to as *ghost images.*

multiple imaging ratio – The ratio of the apparent luminance of the secondary image to the apparent luminance of the primary image. See *angular displacement.*

multiple imaging separation – The angular separation of primary and secondary multiple images as measured from the design eye position.

N

N, n – A symbol used to indicate index of refraction. It is usually used with a subscript to indicate the wavelength of light, e.g., N_D or n_D indicates the index of refraction for sodium light of 5893 angstrom wavelength. The red and green-blue lines given by the hydrogen tube coincide with the Fraunhofer lines $C(N_C)$ and $F(N_F)$ respectively.

Newton's rings – A series of rings or bands resulting from the interference of reflected beams of monochromatic light from two adjacent polished surfaces that are separated by a thin film of air.

nonoptical area – Area of a transparency with no fixed optical specification requirements. See *optical free zone.*

normal – An imaginary line forming right angles with a surface or other lines. It is used as a basis for determining angles of incidence, reflection and refraction. Sometimes called the *perpendicular.*

notch sensitivity – Term used in connection with the mechanical properties of a material to describe the extent to which the presence of a surface irregularity such as a notch, crack or scratch will increase the tendency to fracture. Low notch sensitivity is associated with ductile materials, high notch sensitivity with brittle materials.

O

ohms per square – An extensive coefficient of proportionality between electric field and surface current in a thin film coating. It is a surface property independent of the size or thickness of the film.

opaque – Not transparent or translucent; impervious to visible light, i.e., has zero luminous transmittance. A substance which is impervious to light applied to transparent or translucent substances. To make impervious to light.

open seed – A blister leaving a hole in the glass surface. See *blister.*

optical density – Logarithm to the base 10 of the reciprocal of transmittance.

optical flat window – A transparent window in which both front and back surfaces are parallel to each other within a specified tolerance.

optical free zone – Area of a transparency where there are no optical specifications. See *nonoptical area.*

optical properties – Those properties of a transparent material which pertain to the effect the medium has upon light, such as index of refraction, dispersion, homogeneity, and freedom from defects.

optical system – A combination of optical components arranged so as to perform one or more optical functions.

optics – The branch of physical science which is concerned with the nature and properties of electromagnetic radiation and with visual phenomena.

orange peel – Granular or dimpled appearance (having the apparent texture of an orange peel) of a transparency surface due to improper manufacturing.

orientation – The alignment of the crystalline structure in polymeric materials so as to produce a highly uniform structure. This can be accomplished, for example, by cold drawing or stretching in fabrication.

overcoat – A layer of material applied to a transparent part to protect it from physical or chemical damage during shipment or storage. See *masking.*

P

parallax – An apparent movement of an object against its background due to a change in position of the observer's eye or due to viewing an object first with one eye, and then with the other.

parting agent – A substance, e.g., wax, silicone oil, used to coat a mold cavity to prevent the molded piece from sticking to it and thus facilitating its removal from the mold.

parting line – Seam on a molding or casting where the two halves of a mold meet in closing. See *mold seam.*

permeability – (1) The passage or diffusion of a vapor, liquid or solid through a barrier without physically or chemically affecting it. (2) The rate of such passage.

photoelasticity – A technique for measuring the stresses and strains in a transparent material by observing the change in the double refraction of the material when it is subjected to stress.

photometer – An instrument for measuring electromagnetic radiation in the visible range.

photopic – Vision under illumination sufficient to permit the discrimination of colors. Sometimes called daylight vision.

physical optics – The branch of science which treats light as a wave phenomenon wherein light propagation is studied by means of wave fronts rather than rays.

physical properties – The properties inherent to the material such as refractive index, thermal coefficient of expansion, dielectric strength, etc.

Pilkington process – A process for making flat glass in which molten glass is drawn continously from a tank, and then passed between rolls to form a continuous sheet of prescribed thickness.

pits – Small indentations in the transparency surface.

plane – A surface which has no curvature; a perfectly flat surface.

plastic – Any of numerous organic synthetic or processed materials that are either thermoplastic or thermosetting polymers of high molecular weight and that can be molded, cast, extruded, drawn, or laminated into objects, films, filaments, or sheets.

plastic deformation – A permanent change in the size or shape of an object under stress, without fracture; opposed to elastic deformation.

plasticity – A property of a material that permits permanent and continuous deformation without rupture, upon the application of a force that exceeds the yield value of the material.

plasticize – To soften a material and make it plastic or moldable either by adding a plasticizer or by using heat.

plasticizer – Chemical agents added to plastic compositions to improve flow and processability and to reduce brittleness. This is achieved by lowering the glass transition temperature.

plate glass – Flat glass that is formed by a rolling process, and then ground and polished on both sides, with surfaces essentially plane and parallel.

plies – One of several layers that are laminated together.

polarimeter – A polariscope equipped with a half-shade device and an angular scale generally attached to the analyzer. It is used to measure the amount of rotation of the plane of polarization by materials placed within it.

polariscope – A combination of a polarizer and an analyzer used to detect birefringence or rotation in the plane of polarization of materials placed between them.

polarization – The splitting of a beam of light into two components, each vibrating in its own plane.

polarizer – An optical device for splitting a beam of light into its two orthogonal electromagnetic components, each vibrating in its own plane.

polarizing filter – A filter that polarizes the light passing through it.

polishing – The process of putting a highly finished surface on a glass or plastic surface, by rubbing it with a finely milled abrasive, such as rouge, cerium oxide, or a similar material.

polycarbonate – Tough transparent thermoplastic, characterized by high impact strength and high softening temperature, used in the construction of aircraft transparencies. Bisphenol A polycarbonate is the type currently considered for structural aircraft glazing.

polycarbonate resins – Polymers derived from the direct reaction between aromatic and aliphatic dihydroxy compounds with phosgene or by the ester exhange reaction with appropriate phosgene derived precursors. Structural units are linked by carbonate groups.

polymer – A large molecule of high molecular weight, formed by the reaction of simple molecules (mers or monomers), either by "addition" polymerization or by polycondensation (condensation polymer). (When two or more different monomers are involved, the product is called a copolymer). A polymer can usually be represented by a chain of repeating structural units, known as "mers."

polymerization – A chemical reaction in which the high-molecular- weight molecules are formed from monomers.. When two or more different monomers are involved, then the process is called copolymerization or heteropolymerization.

polymethyl methacrylate – A thermoplastic polymer synthesized from methyl methacrylate. It is a transparent solid with exceptional optical properties and good resistance to UV radiation and water. It is obtainable in the form of sheets, granules, solutions and emulsions. Polymethyl methacrylate is a material that is extensively used for aircraft domes, lighting fixtures, decorative articles, etc.; it is also used in optical instruments and in surgical appliances.

polysiloxanes – Polymers that contain the Si-O linkage. Usually synthesized by the polycondensation of silanols.

polysulfides – Polymers containing sulfur and carbon linkages. An example of this type of polymer is Thiokol rubber, which is synthesized from organic dihalides and sodium polysulfide.

polysulfone – A polymer containing a sulfone linkage. These thermoplastic materials exhibit exceptional high temperature and low creep properties, have high arc resistance, are self-extinguishing and may be molded and extruded.

polyurethane resins – A family of resins produced by reacting disocyanates with glycols to form polymers. These groups, under the influence of heat or certain catalysts, will react with each other, or with water, glycols, etc., to form a tough durable material used in transparent enclosures as interlayers or face plies.

polyvinyl butyral (PVB) – A thermoplastic material derived from a polyvinyl ester in which some or all of the acid groups have been replaced by hydroxyl groups and some or all of these hydroxyl groups have been replaced by butyral groups by reaction with butyraldehyde. It is a colorless, flexible, tough solid and is used primarily in interlayers for laminated transparent material.

portable photometer – Small field portable instrument for measuring luminances.

position, installed – The angular p· ·ion of a windscreen as it would be found in an aircraft.

postforming – The forming, bending or shaping of thermoset laminates that have been heated to make them flexible before the final thermosetting reaction has occurred. Upon cooling, the formed laminate retains the contours and shape of the mold over which it has been formed.

press bending – Forming hot glass or plastic between two contoured molds. Mainly for single curvature or shallow draw.

pressure forming – A thermoforming process wherein pressure is used to push the sheet to be formed against the mold surface as opposed to using a vacuum to suck the sheet flat against the mold.

press polish – A finish for thermoplastic sheet stock produced by contact under heat and pressure with a very smooth, hard material which gives the plastic a high sheen or optical finish.

primary image – The image formed by rays from an object (usually a light source) transmitted through the transparency without being reflected. See *multiple imaging.*

primer – A coating applied to a surface to improve the performance of the adhesive bond.

primary/optical area – An area of the windshield which is defined as most critical for flight vision and which is subject to the most demanding optical quality control.

proportional limit – The greatest stress a material can withstand without deviating from the law of proportionality (Hooke's Law).

P-Static (Precipitation Static) – Electrical charge built up on the outer surface of the windshield due to the impingement of charged particles. Also called *triboelectric charging.*

Q

quality, optical – Surface defects, scratch and dig rating, sphericity and related quantities are usually used to define quality of an optical element or system.

quality, surface – A means of specifying allowable flaws by comparison to reference standards of quality.

R

rail – The horizontal edge attachment of a transparency. See *sill.*

rainbowing – Colored patterns in a transparency produced by the photoelastic molecular nature of the material and stress gradients in the transparency. Certain angles and light polarizations in relation to some windscreen designs may produce localized bands of color in the transparency which can be distracting.

RCS – Radar cross-section; The display of a returned radar signal from reflective surfaces which is referred to as the signature of the target.

reflections – See *internal reflections.*

refraction – A change in the angle of propagation of a wave that occurs when it passes from one transparent medium to another.

refractive index – See *index of refraction; Snell's Law.*

residual stress – Stress locked in a transparency at the time of manufacture.

resin – Any of a class of solid or semisolid organic products of natural or synthetic origin, that are generally of high molecular weight. Resin usually refers to the essential ingredients before final processing and fabrication. Most resins are polymers.

resistance, bird – The requirement imposed on a windscreen to withstand bird impact while the aircraft is flying at a specified speed.

resistivity – The ability of a material to resist passage of electrical current either through its bulk or on its surface. The unit of volume resistivity is the ohm-cm., or surface resistivity, the ohm.

resolution – The ability of a lens or optical system to form separate images of two objects close together. The ability to optically resolve fine detail.

RH – Relative humidity. The ratio of the amount of water vapor actually present in the air to the greatest amount possible at the same temperature.

Rockwell Hardness – A common method of testing a plastics material for resistance to indentation in which a diamond or steel ball, under pressure, is used to pierce the test specimen. The load used is expressed in kilograms and a 10-kilogram weight is first applied and the degree of penetration noted. The so-called major load (60 to 150 kilograms) is next applied and a second reading obtained. The hardness is then calculated as the difference between the two loads and expressed with nine different prefix letters to denote the type of penetrator used and the weight applied as the major load.

RTV – Room temperature vulcanate. RTV rubber can be a form of silicone rubber which vulcanizes at room temperature or any temperature curing elastomer.

S

sag forming – A process by which a material is clamped only at its perimeter and formed by heating in an oven until it sags by its own weight to a predetermined depth.

salt abrasion – A method of abrading transparent material using extra-fine salt flakes which simulates high speed flight through frozen rain, snow, and light hail.

sandwich heating – A method of heating a thermoplastic sheet prior to forming which consists of heating both sides of the sheet simultaneously.

scratch – Any marking or tearing of the surface. A sharp, penetrating surface defect in glass or plastic caused by an abrasive material.

secondary image – The image resulting from internal reflection of external lights from the surfaces of a transparency. See *multiple imaging.*

semi-tempered – A term used to define tempered glass which has been tempered to approximately 1/2 the maximum strength possible for thick glass.

shatter resistance – See *crack propagation resistance, K-value, toughness.*

shear modulus – The ratio of unit shear stress to unit shear strain up to the proportional limit.

sheet (thermoplastics) – A flat length of a fused thermoplastic resin .010 inches or greater in thickness.

shimmer – The distracting visual effect of a multitude of high frequency interruptions of expected images. It can be produced by moving the eyes/head when viewing objects through a transparency.

shore hardness – A procedure for determining the indentation hardness of a material by means of a durometer. Shore designation is given to tests made with a specified durometer instrument.

sill – The horizontal edge attachment of a transparency. Referred to as *rail.*

sizing – The process of applying a material to a surface to fill pores and thus reduce the absorption of the subsequently applied adhesive or coating or to otherwise modify the surface. Also the surface treatment applied to glass fibers used in reinforced plastics. The material used is often called size.

skim – A term used to denote streaks of dense seeds with accompanying small bubbles.

sleek – An imperfection; a fine scratchlike mark having smooth boundaries, usually produced by a foreign particle in the polishing operation. See *scratches.*

slip forming – A method of forming three-dimensional parts in which thinning out is reduced by allowing the excess plastic sheeting to slip through the clamping rings while the sheet is being stretched during forming.

slip plane – Component that is built into the edge area of some aircraft laminates to act as a stress relief in low temperature exposure to prevent cold chips in glass.

slope, grid line – An optics evaluation method of determining the slope of a deviated grid line to that of a non-deviated grid line. A ratio is the index of degree of distortion, e.g., 1:2, 1:8, or 1:16. Also called slope reading.

snap-back forming – A method of forming based on the memory of transparent plastic sheets to return to their flat sheet form when hot.

Snell's Law – Snell's Law, often called the law of refraction, describes the relation between the angle of incidence and the angle of refraction of a light ray passing between media with different indices of refraction:

$$\frac{\sin \Theta_i}{\sin \Theta_r} = \frac{n'}{n}$$

where Θ_i is the angle of incidence, Θ_r is the angle of refraction, n' is the index of refraction of the medium containing the refracted ray, and n is the index of refraction of the medium containing the incident ray.

soda-lime glass – A glass containing a substantial proportion of lime, usually associated with soda and silica.

softening range – The range of temperature in which a plastic changes from a rigid to a soft state. Actual values will depend on the test method. Sometimes erroneously referred to as softening point.

spall – A small particle flaking off of a glass or plastic sheet. A spall from the inside surface of a windscreen as a result of high velocity impact could be harmful to the pilot.

spall shield – A thin piece of plastic or glass bonded to the structural ply with an interlayer, with the intention being that the interlayer will contain the broken structural ply fragments in case of fracturing, thereby protecting the crew. See *crew shield.*

star fracture – A minute radial craze usually originating from an inclusion, bubble or other microscopic defect. It can be detected as bright pinpoint reflection in oblique light.

stop drill – The process of drilling holes at the extremities of cracks to stop the propagation of the crack.

strain – Change in length per unit of original length, caused by stress on the body due to temperature changes.

streaking – The pattern observed on a windscreen produced by diffraction of a light source by many small parallel lines or scratches. Also, called *bow tie* or *arcing.*

stress – (1) Tension or compression caused by the strengthening process, incomplete annealing, temperature differences, inhomogeneity, or by forces imposed upon the object from without. (2) The force per unit area of a body that tends to produce a deformation.

stress crack – External or internal crack in a plastic caused by tensile, or shear forces. The development of such cracks is frequently accelerated by the environment to which the plastic is exposed. The stresses that cause cracking may be present internally, externally or a combination of both. Appearance of a network of fine cracks is often called *crazing*.

stress, internal – The tension, compression, or shear stresses within an optical element usually caused by cooling, incomplete annealing, or chemical strengthening.

stretched acrylic – Acrylic sheet that has been heated and then stretched 60% to 80% either biaxially or multiaxially to improve its craze resistance and reduce notch sensitivity.

stretch forming – A sheet-forming technique in which the heated thermoplastic sheet or metal is stretched over a mold and subsequently cooled.

stretching – Stretching a heated plastic sheet either in two perpendicular directions (biaxial) or in all directions (multiaxial) in the plane of the sheet to improve the physical properties by orientation of the molecules.

stria – (1) A defect in optical materials consisting of a sharply defined streak of transparent material having a slightly different index of refraction than the body of the material. (2) A cord of low intensity generally of interest only in optical glass and plastic.

substrate – Basic surface on which a material adheres.

surface haze – That portion of haze (light scatter) caused or induced by properties or degradation of the surfaces of transparent parts.

T

temper – (1) The degree of residual stress in glass measured polarimetrically or by polariscopic comparison with a standard such as one or more strain disks. (2) Term sometimes employed in referring to tempered glass.

thermal conductivity – Ability of a material to conduct heat; quantity of heat that passes through a unit cube of a substance in a unit of time when the difference in temperature between the two faces is one degree.

thermal expansion (coefficient of) – The fractional change in length (sometimes volume specified) of a material for a unit change in temperature.

thermal stress cracking (TSC) – The cracking or crazing of a material caused by exposure to elevated temperatures.

thermal tempering – A process of heating glass to near its softening points and rapidly cooling it under rigorous control to achieve its increased strength tempered characteristics. Thermally tempered glass can range from "annealed" to "full," with semi-tempered glass being approximately midway between the two.

thermoforming – Any process of forming thermoplastic sheet into a desired contour of shape that consists of heating the sheet and contracting it with mold surface, or other means of creating the required shape. Once the plastic cools, it retains this contour.

thermoplastic – (1) Capable of being repeatedly softened by heat and hardened by cooling with little change in properties. (2) A material having a linear macromolecular structure that will repeatedly soften when heated and harden when cooled. A plastic that is thermoplastic in behavior. Typical of the thermoplastics family are the styrene polymers and copolymers, acrylics, cellulosics, polyethylenes, nylons, polycarbonates, some urethanes and a variety of fluorocarbon materials.

thermosetting – The property of a material to change into a substantially unfusible or insoluble product when cured either by application of heat or by chemical means. A cured thermosetting material cannot be remelted without destroying its characteristics.

tin float – A process in which the molten glass is floated on molten metal at a sufficient temperature to heat polish while the opposite side is flame polished. See *float glass*.

torsional shear – Shear yield strength of adhesive bonds determined by applying torsional shear loads.

toughness – A measure of a material's ability to absorb energy before fracture (a strong feature of polycarbonate material).

translucent – Transmitting and diffusing light so that objects beyond cannot be seen clearly.

transmission – (1) The process by which incident flux leaves a surface or medium on a side other than the incident side. (2) The ratio of the amount of radiant energy leaving the last surface of an optical system to the amount of radiant energy incident on the first surface.

transmissivity – The ratio of the intensity of light emerging from a transparency to the intensity of the light incident upon it. Also referred to as *luminous transmittance.*

transmittance, diffuse – The transmittance measured with diffusely incident flux. Also, the ratio of diffusely transmitted flux leaving a surface or medium to the total incident flux.

transmittance, internal – The ratio of the flux incident on the second surface of a medium to that transmitted by the first.

transmittance, luminous – The ratio of the luminous flux transmitted by an object to the incident luminous flux. See *transmittance.*

transmittance, radiant – The ratio of the radiant flux transmitted by an object to the incident radiant flux (the rate of flow of any radiation).

transmittance, spectral – Transmittance for a specific wavelength of incident light.

transparency – An optically clear structure which is a component of the windscreen or canopy assembly.

triboelectricity – A charge of electricity generated by friction.

U

ultraviolet (UV) – Rays of radiant energy immediately beyond the violet end of the visible spectrum, between 100 and 390 nanometers, which are deleterious to the human eye.

ultraviolet-absorbing material – A transparent material in which the spectral transmittance at any wavelength in the 290-330 nanometers wavelength band does not exceed five percent when measured on a specimen 0.250 inch thick.

uniaxial stretching – A process used in the manufacture of certain films that also makes them birefringent by virtue of the molecular orientation after stretching in one direction only.

uniform density – In a transparency, the property of attenuating visible light consistently throughout the part.

UV stabilizer (ultraviolet) – Any chemical compound which, when mixed with a thermoplastic material, protects the polymer by removing the energy absorbed by the polymer before degradation can occur.

V

vacuum forming – Method of sheet forming in which the plastic sheet is heated and drawn down by a vacuum usually into a mold. In a general sense, it is sometimes used to refer to all sheet-forming techniques, involving the use of vacuum and stationary molds.

veiling glare – Glare produced by light distributed over the visual field so as to cause reduced contrast and therefore reduced visibility. Sometimes called *veiling luminance.*

vents – (1) A hole, slot or groove in a mold provided to allow air and gas to escape during the molding operation. (2) Small fractures in glass or plastics.

virtual image – If a bundle of rays having a given divergence has no real or physical point of intersection of the rays, then the point from which the rays appear to proceed is called the virtual image. The distance of the virtual image is inversely proportional to the divergence of the rays. Since there is no physical intersection of rays there is no real image that can be focused on a screen. The image of any real object produced by a negative lens or convex mirror is always virtual. The image produced by a positive lens of an object located within its focal length is also virtual.

visco elastic – Having both viscous (liquid like flow) and elastic properties.

visible spectrum – The portion of the electromagnetic spectrum to which the retina is sensitive and by which we see. Extends from about 380 to about 760 nanometers in wavelength.

vision, binocular – The simultaneous use of both eyes in the process of vision.

visual angle – The angle subtended by an object on the retina.

visual field of regard – The total space within which objects can be seen by moving the eye, with the head stationary. See *field of vision.*

visual range – The distance where the contrast between object and background of the sky becomes imperceptible owing to aerial light.

volume haze – (1) The portion of haze caused or induced by properties or degradation of the material bounded by the two exterior surfaces of transparent parts. (2) The portion of haze not due to surface effects.

volume resistivity (specific insulation resistance) – The electrical resistance between opposite faces of a 1 cm cube of insulating material. It is measured under prescribed conditions using a direct current potential after a specified time of electrification. It is commonly expressed in ohm- centimeters. The recommended test is ASTM D257.

V_{50} **protection ballistic limit** – The velocity at which a specified projectile has a 50% chance of penetrating an armor panel.

W

warm forming – A process of forming a pane from stretched acrylic at a temperature low enough to prevent relaxation toward its original unstretched form.

warp – Large out-of-plane surface irregularity.

waterline – Intersection of the body exterior profile and a horizontal plane, often used as synonymous with water level, thus WL 0 is the lowest point of the body and all subsequent slicing planes are parallel to the prime longitudinal axis or other horizontal reference.

waviness – A wave-like unevenness or out-of-plane area in the surface of a plastic.

weathering – Deterioration of a material's surface during exposure to atmospheric conditions.

wedginess – Departure of the surfaces of a transparency from parallelism resulting in a prism or wedge effect. Usually expressed in minutes or seconds of arc, or in interference fringes per inch.

wet seal – A weather or pressure seal which is applied uncured to a surface at installation or to a joint after installation.

windshield – The transparency on the aircraft used for forward vision in taking off, flying, and landing; usually made of laminated glass or plastic, also known as a windscreen.

X,Y,Z

Young's modulus of elasticity – The ratio of tensile stress to strain within the elastic limit of a solid body.

yield value (yield strength) – The lowest stress at which a material undergoes plastic deformation. Below this stress, the material is elastic; above it, viscous.

zone, critical – Designated area of a windscreen used for gunsight, taxi, takeoff and landing. See *critical optical area.*

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