SAE Aerospace
An SAE International Group

AEROSPACE RECOMMENDED PRACTICE

SAE ARP924 REV. A

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Superseding ARP924

Specification and Inspection of Glass for Integrally Lighted Aerospace Instruments

1. SCOPE:

1.1 Scope:

This SAE Aerospace Recommended Practice (ARP) covers the requirements for the types of glass to be utilized in the fabrication of cover glasses and lighting wedges used in aerospace instruments. It defines the maximum extent of physical defects and recommends standard methods of inspection and evaluation. Definitions of terminology used in this document are covered in 2.2.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 U.S. Government Publications: Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-G-174	Glass, Optical (INACTIVE FOR NEW DESIGN)
MIL-C-675	Coating of Glass Optical Elements (Anti-Reflection)
MIL-PRF-13830	Optical Components for Fire Control Instruments; General Specification Governing the Manufacture, Assembly, and Inspection of

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2.1.2 ASTM Publications: Available from ASTM, 100 Barr Harbor, West Conshohocken, PA 19428-2959.

ASTM C 1036 Standard Specification for Flat Glass

2.2 Definitions:

BACK COATING: Coating material which is deposited on the side opposite that which is being coated in the evaporated coating process, generally resulting in an objectionable appearing film or haze.

BEAUTY DEFECTS: Beauty defects are those imperfections of components and elements of an optical system which do not affect the optical characteristics. They are undesirable but may be accepted if they do not cause a significant degradation of image quality or environmental stability.

CHIPS: Chips are areas from which glass has broken away from the surface, edge, or bevel of an optical element.

COATING HOLES (VOIDS): Areas void of coating arising from dust, dirt, lint, or improperly cleaned surfaces beneath the film.

COLOR SHIFT: A change in the dominant wavelength or the color purity of light which has been reflected from or has passed through the glass.

DIGS: Digs are breaks or the polished surface of a round, oval, square, etc. shape including pits, holes, and surface-broken bubbles.

DISTORTION: Inhomogeneities in the glass or irregularities in the surface of the element causing displacement of images.

FIRE POLISH: A specular reflective finish that is produced by flame or molding or an equivalent surface that may be produced by mechanical means.

INCLUSION: Foreign matter trapped within the glass substrate or trapped on the surface by a coating.

INTEGRALLY LIGHTED INSTRUMENT: An instrument where the lighting system is designed such that the light sources are contained within the instrument enclosure, thus not relying on any outside source of illumination; the instrument may employ reflected or transilluminated light.

REFRACTIVE INDEX: When a light ray is refracted at the surface of separation between air and glass, the ratio of the sine of the angle of incidence in the air to the sine of the angle of refraction in the glass is equal to the refractive index of the glass.

2.2 (Continued):

SCRATCHES: Furrows or grooves in the surface of the glass caused by the removal of glass, usually made by coarse grit, fragments of glass, sharp tools, etc. rubbed over the surface.

SEEDS: Small bubbles of air or gaseous inclusions entrapped within the glass.

SHORT FINISH: Gray appearance of a polished glass surface resulting from this operation not being carried to the point where all traces of the previous grinding or smoothing operation are removed.

SLEEK: A scratch having boundaries which appear polished.

SPATTER: A term used to denote the condition resulting when large particles of coating material condense on the glass surface, and adhere there, in evaporated coating processes.

STAIN: A stain is a discoloration of the glass surface, caused by the deposit of foreign matter on the surface or changes produced on the surface of the glass by chemical action of some substance with the glass.

STRIAE (CORDS): Striae are apparent streaks or veins in the glass which are the result of minor variations in the index of refraction within the body of the glass.

WAVE: Surface irregularity causing objects viewed through the glass to appear wavy or rippled.

3. RECOMMENDATIONS:

3.1 Cover Glass:

3.1.1 Glass Substrate: The types of glass used for a cover glass are soda lime or borosilicate such as optical crown glass, polished plate glass, and clear sheet glass. A further definition of the above is covered in ASTM C 1036 (flat glass). When optical crown glass is selected, a six digit number should be used to specify the glass: the first three numbers pertain to the index of refraction and the last three digits pertain to the Abbe Constant (dispersion value) - one example is type 523-586. The control of the characteristics should be ±0.005 for the index of refraction and ±1.0 for the dispersion value. The chemical and physical properties of the glass need not be supplied unless required. The range of index of refraction of a cover glass when used with an anti-reflective coating should be between 1.47 and 1.55 and should be specified on the glass drawing. For cover glasses, uncoated, of a maximum thickness of 1/4 in, the minimum transmission of any wavelength between 400 and 700 nm should be 87%. The selection of the cover glass, with respect to cost, should be governed by the following consideration: optical crown glass will be more expensive because plate and sheet glass are available in standard thicknesses. ASTM C 1036 outlines the standard thicknesses available. Normal plate or sheet glass are preferred when platinizing is a requirement.

3.1.1 (Continued):

The glass shall be essentially free of color such that a standard white target shall appear unchanged in color when viewed through the thickness of the glass. Section 3 contains the inspection procedure.

3.1.2 Physical Defects: Physical defects are as follows:

a. External:

chips - edge
scratches - long in nature
digs - generally round in nature
distortion - impairs normal viewing
short finish - incomplete polishing
wave - surface appears wavy or rippled

b. Internal:

bubbles, seeds - considered as digs
fracture - unacceptable
striae (cords) - unacceptable if in the plane of viewing
inclusion - considered as a dig

The acceptance of chips in a cover glass should be specified relating to design requirements. Edge chips that do not encroach on the exposed aperture should be allowable, providing the chip does not interfere with the sealing of the cover glass in the bezel. Edge chips should be stoned, sandblasted, or beveled out. In order to specify an instrument cover glass, the magnitude of acceptable scratches and digs must be defined. It is recommended that the following limits apply when using the surface quality standards for optical elements: medium scratch; number 20 dig or inclusion or coating spatter; number 40 pinhole or coating voids as specified in MIL-PRF-13830. The following glass surface quality conditions shall govern the acceptance of a cover glass:

1. A medium scratch is one which cannot be detected through the glass at perpendicular incidence, using adequate background lighting, at a distance of greater than 11 ft. The combined length of medium scratches shall not exceed one-quarter the diameter of the glass.

2. When a medium scratch is present, the maximum combined length of acceptable scratches shall not exceed three-quarters the diameter of the glass.

3. When a medium scratch is not present, the maximum combined length of acceptable scratches shall not exceed twice the diameter of the glass.

3.1.2 (Continued):

4. The dig number is the actual diameter of the defect specified in units of 1/100 mm: a number 20 dig represents a 0.0079 in diameter defect. In the case of irregular shaped digs the mean diameter will be utilized. The permissible number of maximum size digs or voids shall be one per each 20 mm of diameter: the sum of all dig diameters shall not exceed twice the diameter of the maximum size specified per 20 mm diameter.

The physical defect limits apply to each surface of the glass and successively to each coated surface. In computing maximum length scratches in other than circular glass, the mean measurement of the part shall be used in lieu of the diameter. The free aperture of the instrument should be specified on the print and a more liberal tolerance allowed for any area beyond the free aperture. The procedure to inspect the glass for defects shall be accomplished as outlined in Section 3.

In order to apply an anti-reflective coating to a glass substrate, a non-coated border must be permitted to accommodate a jig or fixture. It is recommended that a minimum of 0.040 in be permitted and more if possible (as measured from the edge of the glass). Imperfections attributable to the anti-reflection coatings are as follows: spatter, pinholes or voids, and back coating. MIL-C-675 may be referenced for the requirements of anti-reflection coatings.

An example of the notes appearing on a cover glass drawing is as follows:

1. Optical crown glass type 523-586 grade C per MIL-G-174 (INACTIVE FOR NEW DESIGN)
2. Glass quality q^3-Glazing select in accordance with ASTM C 1036 on front and back surfaces
3. The glass shall be coated with an anti-reflection coating in accordance with MIL-C-675; the coating shall cover the front and back surfaces excluding a border of 0.060 + 0.0/- 0.060
4. The edges of the glass shall have a fine ground finish

3.2 Lighting Wedge:

3.2.1 Glass Substrate: The types of glass used for a lighting wedge are optical crown, clear sheet, and polished plate. The polished plate glass is available in different grades as specified in ASTM C 1036. The designer should be aware that the specification of other than optical crown or q^2-Mirror grade glass for wedge lighting purposes could cause an undesirable color shift. The glass shall be essentially free of color such that a standard white target shall appear unchanged in color when viewed through the thickness of the glass (reference Section 3). A lighting wedge fabricated with normal (green) plate glass would cause a definite color shift to the reflected light illuminating display. The range of index of refraction of a lighting wedge when used with an anti-reflection coating should be between 1.47 and 1.55 and should be specified on the wedge drawing. For lighting wedges, uncoated, of a maximum thickness of 1/4 in, the minimum transmission of any wavelength between 400 and 700 nm should be 90%.